Northern Optics & Photonics 2018
12-14 September 2018

Lund University, Lund, Sweden

PhotonicSweden
The Swedish Technology Platform in Optics and Photonics

SOS Svenska OptikSällskapet
Swedish Optical Society
the Swedish Branch of the European Optical Society

Lund University

LLC
Lund Laser Centre

CONFERENCE PROCEEDINGS

Northern Optics & Photonics 2018
12-14 September 2018

Lund University, Lund, Sweden

CONFERENCE PROCEEDINGS

PHOTONICSWEDEN
C/O ACREO SWEDISH ICT AB
BOX 1070
164 25 KISTA
SWEDEN

INFO@PHOTONICSWEDEN.ORG
PHOTONICSWEDEN.ORG

ISBN 978-91-639-6488-6

CONTENT

CONTENT

POSTER PRESENTATIONS

POSTER PRESENTATIONS

Plenary Presentations

Interdisciplinary laser spectroscopy – Applications to environment, ecology, agriculture, food safety and medicine

S. Svanberg[1,2]

[1]*Department of Physics, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden*
Email: sune.svanberg@fysik.lth.se
Telephone: +46760502126
[2]*Center of Optical and Electromagnetic Research, South China Academy of Advanced Optoelectronics, South China Normal University, University City Campus, Guangzhou 510006, China*

Keywords: laser spectroscopy, environmental monitoring, biophotonics, ecology, food safety,

Abstract

Lasers have brought about a revolution in spectroscopy with great impact both in the field of basic sciences as well as in applications. The realm of laser spectroscopy reaches from interaction with single photons to petawatt laser beams, from X-rays to terahertz, from CW to attoseconds. Spectroscopy using laser sources has had major impact in the energy, environmental as well as the medical sectors. The author will give a small historical account of his own travel through laser spectroscopy during a 45 year period. The focus will be on recent development in applied spectroscopy with a clear focus on practical implementation. Examples from applications related to the environment, agriculture, food safety and medicine will be given. The talk emphasizes the value of cross-disciplinary work to help solving important societal issues.

Some reviews on applied laser spectroscopy by the author:

1. S. Svanberg, Laser Spectroscopy Applied in Energy, Environmental and Medical Research, Appl. Phys. **B46**, 271 (1988)
2. S. Svanberg, Fluorescence Spectroscopy and Imaging of Lidar Targets, Chapter 7 in T. Fujii and T. Fukuchi (Eds) *Laser Remote Sensing* (CRC Press, Boca Raton 2005) pp 433-467
3. S. Svanberg, Laser Based Diagnostics - from Cultural Heritage to Human Health, Appl. Phys. **B 92**, 351 (2008)
4. M. Brydegaard and S. Svanberg, Multispectral Imaging in Development, Europhysics News **42/5**, 4-5 (2011)
5. S. Svanberg, LIDAR, Invited book chapter for F. Träger, Ed., Springer *Handbook of Lasers and Optics*, 2nd Edition (Springer, 2012), pp 1146
6. S. Svanberg, Gas in Scattering Media Absorption Spectroscopy – from Basic Studies to Biomedical Applications, Lasers and Photonics Reviews **7**, 779 (2013)
7. S. Svanberg, Laser Spectroscopy in Medical Applications, Chapter 10 in *Lasers for Medical Applications: Diagnostics, therapy and surgery*, Ed. H. Jelinkova (Woodhead Publishing, Cambridge 2013) pp. 286-324

Benefiting from a Small Country: The Potential of Laser Research and Laser Industry in Lithuania

Algis Piskarskas, Vilnius University, Lithuania

Lithuania has became known as a country promoting laser science and industry since in the late eighties the scientific potential accumulated at academic institutions was converted into inovative femtosecond tunable lasers and ultrafast matter-diagnostic OPA spectrometers that soon came on demand in world markets. One of the mostly cited and recognised inventions from Lithuania is OPCPA ultrafast technology, enabling to boost laser light to extreme intensities and recently to produce compact lasers of multiterawatt power at local companies.

During recent years lithuanian laser industry has been growing exceptionally fast, around 20% per year. Most screens of smartphones are cut from glass using ultrafast lasers produced by lithuanian companies. Laser industry there consists of around 40 laser companies employing more than 900 people with the total annual revenue exceeding 120 mln €. These lasers are on demand by 90 out of 100 best universities in the world and are exported to over 70 countries.

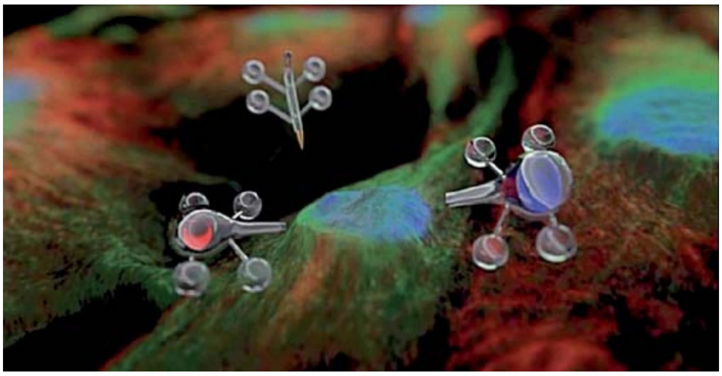
The main stimulus which led to a successful breakthrough of lithuanian lasers to the world market – that is the strong links between research, education and industry.

In the talk, an overview of the main trends of laser research and description of coopetative research infrastructure will be presented, as well as participation in Laserlab-Europe and ELI projects.

Light Robotics: light-driven and –actuated micro-robotics for biophotonics at the cellular level

Jesper Glückstad
DTU Fotonik, Dept. Photonics Engineering, Techn. Univ. Denmark
Ørsted Plads 343, DK-2800 Kgs. Lyngby, Denmark
Jesper.gluckstad@fotonik.dtu.dk
www.PPO.dk www.OptoRobotix.com www.GPCphotonics.com

After years of working on light-driven and –actuated micro manipulation [1-14], we can see that a confluence of developments is now ripe for the emergence of a new area that can contribute to biophotonics at the cellular level – *Light Robotics* – which combines advances in microscopic 3D-printing, 3D light sculpting and advanced light-matter interaction and actuation. Last Summer we published a comprehensive Elsevier book volume [15] covering the fundamental aspects needed for Light Robotics including optical trapping systems, microfabrication and microassembly as well as underlying theoretical principles and experimental illustrations for optimizing optical forces and torques. The new book is presenting various novel functionalities that are enabled by these 3D designed light-driven micro-robots (or micro-drones) in addition to various nano-biophotonics applications demonstrating the unique use of biophysical tools based on light robotic concepts. We have endeavored to make this new discipline accessible to a broad audience from advanced undergraduates and graduate students to practioners and researchers not only in nano-biophotonics and micro- and nanotechnology but also to other areas in optics, mechanical engineering, control and instrumentation engineering and related fields.



Light Robotics performed in a microbiologic environment

1) Glückstad, J., "Sorting particles with light", Nature Materials 3, 9 (2004).
2) Rodrigo, P. , Gammelgaard, L., Bøggild, P., P.-Nielsen, I., Glückstad, J., Opt. Express 13, 6899 (2005)
3) Glückstad, J. & Palima, D., "Generalized Phase Contrast", Springer Series in Optical Sciences, 315 pages (2009).
4) Papagiakoumou, E., Anselmi, F., Begue, A., Sars, V., Glückstad, J., Isacoff, E., Emiliani, V., Nature Methods 7, 848 (2010).
5) Tauro, S., Bañas, A., Palima, D., Glückstad, J., Opt. Express 18, 18217 (2010)
6) Glückstad, J., "Sculpting the object", Nature Photonics 5, 7 (2011)
7) Palima, D., Bañas, A., Vizsnyiczai, G., Kelemen, L., Ormos, P., Glückstad, J.,"Wave-guided Optical Waveguides", Opt. Express 20, 2004 (2012).
8) Palima, D., & Glückstad, J.,"Gearing up for optical micro-robotics: synthetic microstructures actuated by optical trapping and optical manipulation", Lasers & Phot. Reviews 17, 478 (2013).
9) Wu, C., Palima, D, Novitsky, A; Ding, W; Gao, D; Shukovsky, S; and Glückstad, J.,"Engineering light-matter interaction for emerging optical manipulation applications", Nanophotonics 3, 181 (2014).
10) Villangca, M., Bañas, A., Palima, D., and Glückstad, J.,"Dynamic diffraction-limited light-coupling of 3D-maneuvered wave-guided optical waveguides," Opt. Express 22, 17880 (2014).
11) Villangca, M., Bañas, A., Palima, D., Glückstad, J., "Generalized phase contrast-enhanced diffractive coupling to light-driven microtools" Opt. Eng. 54, 111308 (2015).
12) Villangca, M., Casey, D., Glückstad, J.,"Optically-controlled platforms for single- and sub-cellular transfection and surgery," Biophysical Reviews 7, 379 (2015).
13) Villangca, M., Palima, D., Bañas, A., Glückstad, J., "Light-driven micro-tool equipped with a syringe function," Light: Science & Applications, Nature Publ. Group, 5 (9) e16148 (2016).
14) Bañas and J. Glückstad, "Holo-GPC: Holographic Generalized Phase Contract," Opt. Comm., 392, 190-195 (2017).
15) Glückstad, J. & Palima, D., "Light Robotics: structure-mediated nanobiophotonics", Elsevier Science, 482 pp (2017).

Oral Presentations

Complete control over reflected fields with plasmonic metasurfaces

Sergey I. Bozhevolnyi
Center for Nano Optics, University of Southern Denmark
email: seib@mci.sdu.dk
Telephone: +45 6550 7341

Keywords: Metamaterials, metasurfaces, surface plasmons

Abstract

In recent years, optical metasurfaces, i.e., optically thin planar arrays of resonant subwavelength elements arranged in a periodic or aperiodic manner have attracted progressively increasing attention due to their planar profiles and thus ease of fabrication, while enabling an unprecedented control over optical fields by modifying boundary conditions for impinging optical waves. Lately, integration of multiple diversified functionalities into a single metasurface has come to the fore as a quickly developing research area with fascinating possibilities for realization of very dense integration and miniaturization in photonics that requires dealing with formidable challenges, especially for operation in the visible [1]. In this talk, I overview our latest achievements in this area using gap-plasmon based phase-gradient metasurfaces operation in reflection geometry [2]. In particular, plasmonic metasurfaces for single-shot spectropolarimetry [3] are presented followed by other examples of multifunctional metasurfaces, for example, those performing the (linear) polarization splitting of a normally incident light with subsequent focusing these orthogonal polarizations into two separate focal spots [4]. The considered multifunctional metasurfaces can enable further advances in the field of photonics integration.

References:
1. F. Ding, A. Pors, and S. I. Bozhevolnyi, "Gradient metasurfaces: a review of fundamentals and applications," Rep. Prog. Phys. **81**, 026401, 2017.
2. A. Pors, O. Albrektsen, I. P. Radko, S. I. Bozhevolnyi, "Gap plasmon-based metasurfaces for total control of reflected light," Sci. Rep. **3**, 2155 (2013).
3. F. Ding, A. Pors, Y. Chen, V. A. Zenin, and S. I. Bozhevolnyi, "Beam-size-invariant spectropolarimeters using gap-plasmon metasurfaces," ACS Photon. **4**, 943, 2017.
4. S. Boroviks, R. A. Deshpande, N. A. Mortensen, and S. I. Bozhevolnyi, "Multifunctional metamirror: polarization splitting and focusing," ACS Photon. **5**, 1648, 2018.

Compressive sensing Raman spectroscopy for stand-off detection of explosives and precursors

Matilda Ågren[1], Markus Nordberg[1], Mattias Svanqvist[1], Martin Glimtoft[1], Henric Östmark[1]
[1]Department of Security of Explosives, FOI Swedish Defence Research Agency, SE-14725 Tumba, Sweden
email: matilda.agren@foi.se
Telephone: +46 8 555 040 72

Keywords: imaging Raman, digital micromirror device, DMD, explosives, compressive sensing, stand-off, trace detection, coded aperture

Abstract

A hyperspectral version of the single-pixel camera have been implemented with a digital micromirror device (DMD) for the detection of explosives particles with stand-off imaging Raman spectroscopy. Results show a stable reconstruction of the hyperspectral data cube and possibility to spatially separate substances with close lying Raman peaks.

It has previously been shown that imaging Raman spectroscopy based on a tunable filter setup is applicable for detecting single explosives particles at stand-off distances[1,2]. However, due to the sequential imaging at different wavelengths, large amounts of light is lost in the measurement, often leading to an effective transmission below 1 %. In combination with the inherit disadvantages of Raman, such as low signal strength due to the low Raman cross section, and competing signal from fluorescence and background material, this can result in long measurement times.

It is highly desired to increase the sensitivity and the measurement speed. To improve light throughput we are currently investigating possibilities to use DMDs to replace the tunable filter in the setup. Changing to DMDs in the setup adds significant flexibility to the system and gives new possibilities.

Much research has been performed on compressive sensing during the last decade[3,4,5]. In our research it is developed by applying the technique to explosives particle detection through implementing a hyperspectral version of the single-pixel camera. The system used is based on a 2nd harmonics Nd:YAG laser for sample excitation, collection optics, DMD, and a spectrometer with ICCD camera for signal gating and detection.

---

[1] Östmark, H., et. al, "Stand-off detection of explosives particles by multispectral imaging Raman spectroscopy," Appl. Opt. 50, 5592-5599 (2011)
[2] Glimtoft, M., et. al., "Towards eye-safe standoff Raman imaging systems", Proc. SPIE 9072, 907210-1 (2014)
[3] Duarte, M.F., et al., "Single-Pixel Imaging via Compressive Sampling," IEEE Signal Processing Magazine 25, 83-91 March (2008)
[4] Cull, E. C., et al., "Standoff Raman spectroscopy system for remote chemical detection," Proc. SPIE 5994, 59940H-5 (2009)
[5] Arce, G. R., et. al., "Compressive Coded Aperture Spectral Imaging," IEEE Sign. Proc. Mag. 31, 106-115 (2014)

Initial results shows a stable hyperspectral image reconstruction, even for low signals in the presence of interfering background signal[6]. To spatially separate substances with close lying Raman peaks have also shown possible[7] and the modularity of the system facilitates combination of imaging Raman with non-spatially resolved fluorescence suppression techniques, such as Kerr gating.

[6] Glimtoft, M., et. al., "Digital micromirror devices in Raman trace detection of explosives" Proc. SPIE 9823, 982312-1 (2016)

[7] Svanqvist, M., et. al., "Stand-off detection of explosives and precursors using compressive sensing Raman spectroscopy", Proc. SPIE 9824, 98240C-1

Scheimpflug Lidar for flame thermometry

E. Malmqvist[1], J.Borggren[1,2], M. Aldén[1], J.Bood[1]
[1] Div. of Combustion Physics, Dep. of Physics, Lund University, Sweden
[2] Norsk Elektro Optikk Lund AB, Maskinvägen 1, Lund, Sweden
email: elin.malmqvist@forbrf.lth.se
Telephone: +46736402622

Keywords: Lidar, laser radar, thermometry

Abstract

Scheimpflug Lidar (laser radar) is a laser-based remote sensing technique which can provide range resolved measurement in the backward direction. The range resolution is attained by imaging a laser beam, transmitted from the Lidar system, along a detector. Sharp imaging is achieved by placing the laser beam, the collection optics and the detector according to the geometric rule called the Scheimpflug principle. One of the great advantages of Scheimpflug Lidar compare to conventional Lidar, which is often based on pulsed lasers and time-of-flight detection, is that it readily can be implemented with small continuous-wave diode laser. The fact that the technique use imaging instead of time-of-flight detection to achieve range resolution is also an advantage when using fluorescence based techniques since the fluorescence life times of the species will not degrade the range scale.

In this work, Scheimpflug Lidar has been used to perform stand-off, spatially resolved flame thermometry in the backward direction. Two different thermometric techniques have been combined with Scheimpflug Lidar; Rayleigh scattering and two-line atomic fluorescence (TLAF). Rayleigh scattering thermometry has been performed in a McKenna flame resulting in one-dimensional (1-D) temperature profiles recorded at a distance of ~2 m. TLAF thermometry, in which the population of two different energy states of an atom are probed, has been carried using both a line-array detector and a two-dimensional (2-D) array detector, resulting in both 1-D and 2-D temperature profiles.

Bidirectional Flame Lasing

*Pengji Ding[1, *], Maria Ruchkina[1], Marcus Aldén[1] and Joakim Bood[1]*

[1]Div. of Combustion Physics, Department of Physics, Lund University, Box 118, SE-221 00 Lund, Sweden
email: pengji.ding@forbrf.lth.se
Telephone: +46767111375

Keywords: Femtosecond; Two-photon excitation; Lasing effect; CH_4/O_2 flame

Abstract
Lasing refers to the generation of highly directional laser-like emission remotely pumped by laser pulses in a medium such as ambient air or a flame. It has been intensively investigated because of its potentials to revolutionize the field of remote sensing. Earlier studies were carried out in flames, where lasing effect has been observed in various radicals, for example H, O, N etc., through two-photon resonant excitation. This scheme was later applied to generate lasing of O and N in ambient air, which can be dramatically improved by predissociation of the air constituents. However, the underlying physical mechanism of two-photon-excited lasing effect is still unsettled although it has been studied for more than one decade. Currently there are three different proposals: (1) Amplified Spontaneous Emission (ASE), in which case population inversion is responsible for optical gain; (2) Superfluorescence (SF), where a macroscopic dipole occurs in the population inverted medium; (3) Both hyper-Raman scattering and four-wave mixing are involved in the generation of lasing emission. Here, we experimentally studied 656 nm lasing emission of atomic hydrogen via two-photon resonant excitation by focusing 125-fs laser pulses of 205-nm wavelength in a methane/oxygen welding flame (see Fig. 1), where hydrogen atoms are naturally present. Lasing occurs in both forward and backward directions, and the forward signal strength is almost one order of magnitude stronger than the backward one. It has been found that the durations of lasing pulses are around 20 ps, and decreases with increasing pump laser energies. Furthermore, the delay of the lasing pulse with respect to the pump pulse decreases with increasing pump energies. These results show high similarities with the behaviors of SF, suggesting that the femtosecond two-photon-excited lasing emission of atomic hydrogen might be SF.

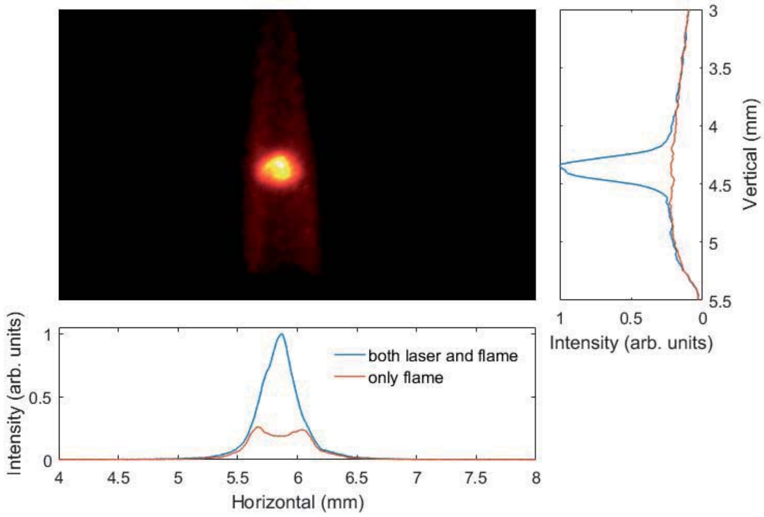


Fig. 1 *Image of backward emission captured by a CCD camera. The orange lines in the profile curves corresponds to chemiluminescence from the flame.*

Micro-Focusing of Broadband High-Order Harmonic Radiation for Pump-Probe Experiments

Piotr Rudawski[1], Hampus Wikmark[1], Fabian Brunner[1,2], Hélène Coudert-Alteirac[1], Hugo Dacasa[3], Emma Kueny[1], Jan Lahl[1], Sylvain Maclot[1], Jasper Peschel[1], Philippe Zeitoun[3], Anne L'Huillier[1], and Per Johnsson[1]

[1]Lund University, Box 118, Lund, 22100, Sweden
[2]ETH Zürich, Auguste-Piccard-Hof 1, 8093 Zurich, Switzerland
[3] Laboratoire d'Optique Applique, ENSTA ParisTech, École Polytechnique, Chemin de la Hunière, 91761 Palaiseau CEDEX, France
Email: piotr.rudawski@fysik.lth.se
Telephone: +46 462227547

Keywords: high-order harmonic generation; ultrafast nonlinear optics; extreme ultraviolet; XUV focusing; wavefront sensing; attosecond pulses; pump-probe experiments

Abstract

In the high-order harmonic generation (HHG) process, an intense laser field is used to create attosecond pulse train with photon energies up to hundreds of eV. At the High Intensity XUV beamline, high energy infrared (IR) pulses are loosely focused in a noble gas to generate high-energy extreme ultraviolet (XUV) attosecond pulse trains. The XUV radiation can be refocused to high enough intensities to induce nonlinear interaction with atoms and molecules [1].

In order to reach such high intensities on target, corresponding to more than 10^{12} W/cm^2, we perform micro-focusing of the XUV beam using a double toroidal mirror in a Wolter configuration. To optimize the focusing setup, the size and shape of the XUV focal spot was measured on a scintillating crystal, as well as calculated by back propagation of wavefronts measured using an XUV wavefront sensor. Using the measured wavefronts, we isolated the astigmatic components of the beam and minimized them using the Wolter setup or a deformable mirror (DM) for the IR beam. After the optimization process, the XUV focal spot was estimated to be 3.6 x 4.0 µm full width at half maximum [2].

To take advantage of the high intensities obtained at the beamline, we present a setup which combines split-delay-unit [3] with a Mach-Zehnder-type of an interferometer for simultaneous XUV-XUV-IR measurements. The setup, together with double-sided velocity map imaging spectrometer [4], enables time-dependent investigation of a range of phenomena in atoms and molecules by recording simultaneously the 3D momentum distribution of electrons and ions.

References

[1] B. Manschwetus et al, Phys. Rev. A 93, 061402 (2016)
[2] H. Coudert-Alteirac et al, Appl. Sci. 7, 1159 (2017)
[3] F. Campi et al, Rev. Sci. Instrum. 87 (2016)
[4] L. Rading et al, Manuscript submitted

Inorganic thin film solar cells – efficient, tunable and long term stable

Charlotte Platzer-Björkman[1]
[1]*Solid State Electronics, Dep Engineering Sciences, Uppsala University*
email: charlotte.platzer@angstrom.uu.se
Telephone: +46184713120

Keywords: photovoltaics, building integration, tandem cells

Abstract

The two dominating commercial thin film solar cell technologies CdTe and CIGS ($Cu(In,Ga)Se_2$) have reached lab scale record efficiencies above 22% and large area module efficiencies above 18% [1]. Together with demonstrated long term stability, this makes these technologies suitable for large scale electricity generation. Current research and development of thin film solar cells is focused on applications where the unique properties of the materials can enable new applications or improved performance. One example is building integrated photovoltaics, where aesthetics, light weight, variation in transparency and flexibility can allow facades and roofs to produce significant amounts of electric energy without compromising appearance. Another example is the possibility to increase efficiency of silicon or thin film modules by making tandem structures. For this, efficient devices based on wide band gap materials with transparent contacts are needed. Tuning of composition and alloying with different elements can be used for CIGS to make a suitable tandem top cell. Another option is Cu_2ZnSnS_4 (CZTS), based on only earth-abundant elements, where alloying can also give suitable band gap ranges. An advantage for both CIGS and CZTS is that toxic elements such as Cd and Pb are not needed for high performance. In this presentation, current state-of-the-art of CIGS and CZTS thin film solar cells is given with focus on building integration and tandem top cells.

1. Green, M.A., et al., *Solar cell efficiency tables (version 51).* Progress in Photovoltaics, 2018. **26**(1): p. 3-12.

Scheimpflug lidar for biological targets

Mikkel Brydegaard[1,2,3], Samuel Jansson[1,2], Elin Malmqvist[1,2], Xun Wang[4], Zheng Duan[4], Shiming Zhu[4], Guangyu Zhao[1,4], Sune Svanberg[1,4], Joakim Bood[1]*

[1]Lund Laser Centre, Dept. of Physics, Lund University, Sölvegatan 14, Lund 22346, Sweden
[2]Centre for Animal Movement Research, Dept. of Biology, Lund University, Sölvegatan 34, Lund 22346, Sweden
[3]Norsk Elektro Optikk AS, Prost Stabels vei 22, 2019 Skedsmokorset, Norway
[4]Center for Optical and Electromagnetic Research, South China Normal University, Guangzhou 510006, China

* Mikkel.Brydegaard@fysik.lth.se

Keywords: Scheimpflug, lidar, biophotonics.

Abstract
During recent years we developed a new low-cost and compact laser radar method referred to as Scheimpflug lidar[1]. The technique utilizes modern high-power continuous laser diodes and CMOS detector arrays and greatly reduce instrument size and complexity in respect to previous time-of-flight approaches using solid state laser and cascade detectors. Scheimpflug lidars employ large aperture but infinite focal depth and display extraordinary capability of resolving sparse structures and organisms in the environment with unprecedented details in time and space[2]. In particular we have applied the method for biological targets ranging from aquatic algae and micro-organisms[3], airborne insects[4] and vertebrates[5] and vegetation structure[6]. We have employed the method in various field campaigns and can report great efficiency and organism counts of hundreds of thousands in a matter of days. We have pursued target classification using size calibration, modulation spectroscopy, dual-band reflectance and polarization methods and also hyperspectral fluorescence spectroscopy. Here, we give a brief review of our recent progress.

[1] M. Brydegaard, E. Malmqvist, S. Jansson, J. Larsson, S. Török, and G. Zhao, "The Scheimpflug Lidar Method," *SPIE Lidar Remote Sensing for Environmental Monitoring,* vol. **10406**, 2017.

[2] M. Brydegaard, A. Gebru, and S. Svanberg, "Super resolution laser radar with blinking atmospheric particles – application to interacting flying insects.," *Prog. Electromagn. Res.,* vol. **147**, pp. 141-151, 2014.

[3] G. Zhao, M. Ljungholm, E. Malmqvist, G. Bianco, L.-A. Hansson, S. Svanberg, and M. Brydegaard, "Inelastic Hyperspectral Lidar for Profiling Aquatic Ecosystems," *Laser & Photonics Reviews,* vol. **10**, pp. 807–813, 2016.

[4] S. Zhu, E. Malmqvist, W. Li, S. Jansson, Y. Li, Z. Duan, K. Svanberg, H. Feng, Z. Song, G. Zhao, M. Brydegaard, and S. Svanberg, "Insect abundance over Chinese rice fields in relation to environmental parameters, studied with a polarization-sensitive CW near-IR lidar system," *Applied Physics B,* vol. **123**, 2017.

[5] E. Malmqvist, S. Jansson, S. Zhu, W. Li, K. Svanberg, S. Svanberg, J. Rydell, Z. Song, J. Bood, M. Brydegaard, and S. Åkesson, "The bat-bird-bug battle: daily flight activity of insects and their predators over a rice field revealed by high resolution Scheimpflug Lidar " *Royal Society Open Science,* 2018.

[6] X. Wang, Z. Duan, M. Brydegaard, S. Svanberg, and G. Zhao, "Range-resolved area imaging of vegetation fluorescence using laser-based drone technology," 2018.

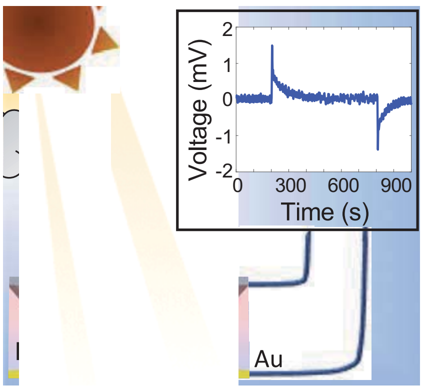
Hybrid plasmonic and pyroelectric harvesting of light fluctuations

Mina Shiran Chaharsoughi[1], Daniel Tordera[1], Andrea Grimoldi[1], Isak Engquist[1], Magnus Berggren[1], Simone Fabiano[1], Magnus P. Jonsson[1]
[1]Linköping University
email: mina.shiran@liu.se
Telephone: 0700850882

Keywords: Plasmonic heating, gold nanodisks, pyroelectric copolymer, solar energy harvesting

Abstract

State-of-the-art solar energy harvesting systems based on photovoltaic technology require constant illumination for optimal operation. However, weather conditions and solar illumination tend to fluctuate. Here, a device is presented that extracts electrical energy from such light fluctuations. The concept combines light-induced heating of gold nanodisks (acting as plasmonic optical nanoantennas), and an organic pyroelectric copolymer film (poly(vinylidenefluoride-co-trifluoroethylene), P(VDF-TrFE)) that converts temperature changes into electrical signals. This hybrid device can repeatedly generate current pulses, not only upon the onset of illumination (13 μA m^{-2} by sunlight), but also when illumination is blocked. Detailed characterization highlights the key role of the polarization state of the copolymer, while the copolymer thickness has minor influence on performance. The results are fully consistent with plasmon-assisted pyroelectric effects, as corroborated by combined optical and thermal simulations that match the experimental results. Owing to the tunability of plasmonic resonances, the presented concept is compatible with harvesting near infrared light while concurrently maintaining visible transparency.



Reference:
Hybrid plasmonic and pyroelectric harvesting of light fluctuations
M.Shiran Chaharsoughi, D.Tordera, A. Grimoldi, I. Engquist, M. Berggren, S. Fabiano, and M.P. Jonsson
Advanced Optical Materials 2018, doi.org/10.1002/adom.201701051

Light Extraction Enhancement in GaN-based LEDs by Structured TiO_2 Nanoparticles-based Optical Coatings

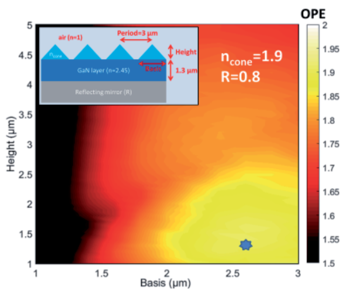
Dennis Visser[1,*], Yohan Désières[1,2], Ding Yuan Chen[1], Casper Schippers[1] and Srinivasan Anand[1]

[1]*Department of Applied Physics, KTH Royal Institute of Technology,*
Electrum 229, SE- 164 40 Kista, Sweden
[2]*University Grenoble Alpes, CEA, LETI, MINATEC Campus, F-38054 Grenoble, France*
[*]*Email: dvisser@kth.se*
[*]*Telephone: +4687904351*

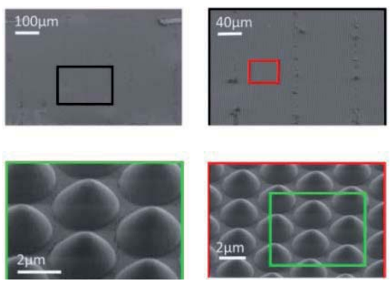
Structured metal oxide-based optical coatings are interesting alternatives for light extraction enhancement (LEE) in GaN-based light emitting diodes (LEDs). For these LEDs, the most commonly used method for LEE is to structure the GaN surface by etching.[1,2] For example, periodic, quasi-periodic and random patterning of the LED surface, are well studied and optical power enhancement (OPE) >2 has been reported.[3,4] Alternatively, an add-on layer with an appropriate material and surface structure on the LEDs can provide comparable OPE. Such an add-on layer is also beneficial for LED technologies such as micro-LEDs hybridized on CMOS substrates and thin film InGaN/GaN LEDs for which surface patterning by etching is difficult to control.

In this work, we investigate microcone arrays composed of titanium dioxide (TiO_2) nanoparticles (NPs) as add-on layers for OPE in blue emitting (440 nm) GaN-based LEDs without encapsulation. TiO_2 NPs are transparent in the visible spectrum and have a refractive index comparable to GaN. They can also be packed together to form specific high-index structures. Additionally, the geometrical size (~50 nm) of the TiO_2 NPs can also contribute to light extraction by optical scattering effects.

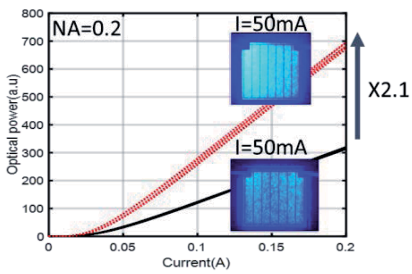
Colloidal TiO_2 NPs-based microcone arrays were fabricated on functioning GaN-based LEDs (with surface contact lines) and on Si, glass and GaN planar surfaces using a low pressure (~ 0.1 bar) and low temperature (≤100 °C) embossing process, developed in-house. Scanning electron microscopy (SEM) results show the surfaces homogenously covered by the embossed microcone array; the period was 3 µm, and the microcone height and base diameter were ~1.35 µm and ~2.6 µm, respectively. Detailed reflectivity measurements were performed on compacted TiO_2 NPs films (on Si) to determine the effective refractive index. The group indices were evaluated from the wavelength positions of the oscillation maxima of the Fabry-Perot fringes and fitted using a Bruggeman model. From these results, a fill factor of ~0.58 and an effective refractive index of ~1.9 (at a wavelength of 440 nm) for the TiO_2 NPs layer were determined. For this refractive index value, ray tracing simulations of the LED structure show OPEs >1.8 for microcone heights in the range of ~1.3-3.5 µm and base widths in the range of ~2-3 µm. Electro-optics measurements were performed on the LEDs to determine the influence of the embossed TiO_2 NPs microcone arrays on the OPE. An OPE as high as ~2.1 was obtained for the embossed LEDs, which is amongst the highest values reported in literature.



Ray tracing simulations for TiO_2 microcone array structures (without encapsulation) on a vertical thin film GaN-based LED.



Embossed TiO_2 NPs microcone array structures on a pre-fabricated LED.



Measured optical power vs drive current of the LEDs before/after embossing of the TiO_2 NPs microcone array structures.

References

[1] M. R. Krames et al., J. Display Technol., **3**, 160 (2007).
[2] A. David et al., Appl. Phys. Lett., **105**, 231111 (2014).
[3] E. Matioli and C. Weisbuch, J. Phys. D-Appl. Phys., **43**, 354005 (2010).
[4] S. Jiang et al., Nature. Sci. Rep., **6**, 21573 (2016).

Optical whispering gallery mode microsphere resonators

J. Alnis, A. Atvars, I. Brice, R. Viter
Institute of Atomic Physics and spectroscopy of the University of Latvia
email: janis.alnis@lu.lv
Telephone: +371 27463408

Keywords: Whispering gallery mode resonators, biosensors, tunable diode lasers

Optical whispering gallery mode resonators (WGMR) typically have round shape and keep circulating light wave inside thanks to a total internal reflection. WGM resonators allow to significantly increase the effective path length of the light allowing to make sensors, for example, to detect molecules attaching to the surface [1].

We are melting SiO_2 microsphere resonators from a telecom fiber SMF-28 with an oxy-hydrogen torch or with a CO_2 laser. For the excitation we use a VCSEL laser at 760 nm and an ECDL at 780 nm and achieve optical Q factors at the 10^8 range. For biosensing applications we are developing chemical methods for WGMR coating [2] with ZnO.

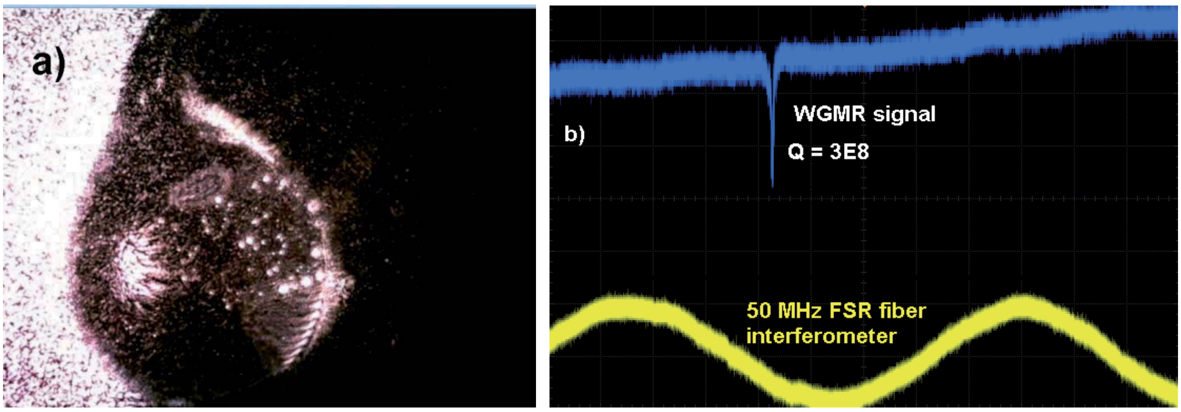


Fig . 1. a) 0.5 mm diameter SiO_2 microsphere with prism coupling of the light.
On the right lower side periodic circle structure is visible by excitation of a higher transversal order WGM mode.
b) A resonance with Q=3E8 and 50 MHz interferometer waves for the laser scan calibration.

We thank for support ERAF project Nr.1.1.1.1/16/A/259: “Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb”.

1. F. Vollmer, S. Arnold, Nature Methods 5, 591–596 (2008).
2. I. Brice, A. Pirktina, A. Ubele, K. Grundsteins, A. Atvars, R. Viter, J. Alnis, Development of optical WGM resonators for biosensors, Proc. of SPIE, 105920B-1 (2017).

Recent advances in secure quantum communication based on energy-time entanglement

Guilherme B. Xavier[1]
[1]*Institutionen för Systemteknik, Linköpings Universitet, 581 83 Linköping, Sweden*
email: guilherme.b.xavier@liu.se

Keywords: Quantum communications, Bell tests, optical interferometry, optical fibers

Abstract

Fundamental tests of local realism, the so-called Bell tests, have been performed extensively over the past decades on a wide spectrum of physical systems. On a more practical aspect, they are a major component in the field of secure quantum communications [1]. In this sense, Bell tests based on energy-time entanglement are particularly relevant due to their suitability to long-distance transmission over optical fibers [2]. A long-standing loophole, due to the post-selection procedure in the standard adopted energy-time scheme [2] has been recently addressed with the geometrically modified "Hug" configuration [3]. Here we will review recent experiments where the Hug configuration was used to perform a Bell inequality violation over optical fibers in the laboratory and over deployed optical networks [4,5]. We will discuss the impacts of these results to enable secure quantum communications over the optical communication infrastructure. Finally, new results where a fully automated Bell test, based on the Hug configuration, which successfully took part in the worldwide experiment known as The BIG Bell Test, will be presented [6].

References

[1] A. K. Ekert, Phys. Rev. Lett. **67**, 661 (1991).
[2] J. D. Franson, Phys. Rev. Lett. **62**, 2205 (1989).
[3] A. Cabello et al, Phys. Rev. Lett. **102**, 040401 (2009).
[4] A. Cuevas et al, Nat. Commun. **4**, 2871 (2013).
[5] G. Carvacho et al, Phys. Rev. Lett. **115,** 030503 (2015).
[6] C. Abellán et al (The Big Bell Test collaboration), Nature **557**, 212 (2018).

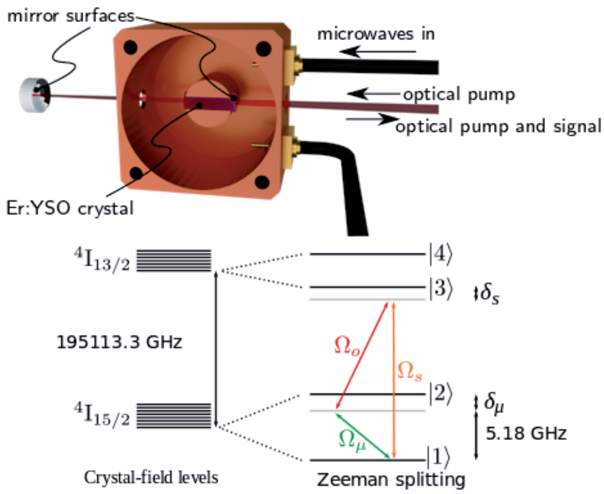
Cavity enhanced microwave to optical signal conversion in Er^{3+}:YSO

Sebastian P. Horvath[1,†] Xavier Fernandez-Gonzalvo[1], Yu-Hui Chen[1], and Jevon J. Longdell[1]
[1]The Dodd-Walls Center for Photonic and Quantum Technologies, Department of Physics, University of Otago, 730 Cumberland Street, Dunedin, New Zealand
email: sebastian.horvath@fysik.lth.se

Keywords: optical-to-microwave, Er^{3+}:YSO, Raman-heterodyne spectroscopy

Abstract

The ability to efficiently convert quantum states encoded at microwave frequencies to the optical domain would substantially enhance the versatility of superconducting qubits as a platform for quantum information processing. In particular, in order to avoid being swamped by thermal noise, systems employing microwave encoded quantum states must operate at milli-Kelvin temperatures, and as a result the scale over which such quantum states can be distributed is limited to the size of a dilution refrigerator. The ability to efficiently transfer microwave quantum states to the optical domain would enable use of existing fiber and free-space optical technology, as well as opening up prospects for hybrid quantum systems, harnessing optical technologies, such as photon storage with coherence times of hours.
Here we employ a Raman-heterodyne spectroscopy based technique in erbium doped yttrium-orthosilicate (Er^{3+}:YSO) yielding an upconverted signal in the optical-telecommunications frequency band. We demonstrate an improvement of nearly four orders of magnitude compared to past Raman-heterodyne schemes by using resonant enhancement of both the optical pump beam as well as the microwave input signal.
We achieved a maximum frequency upconversion efficiency of 1.26×10^{-5} using an optimal microwave power at 4 K; however, at lower microwave powers this efficiency dropped considerably. By modeling the atom-cavity system we found that this could be attributed to reabsorption of upconverted photons by other atoms in the sample, an effect that was reduced at higher input powers due to holeburning in the upconversion frequency band. Using our model, we project that at 50 mK, as well as with improvements in optical impedance matching, our current system could achieve an efficiency of 14% in the low microwave power limit.



Top: the upconversion apparatus. A Fabry-Perot resonator formed between a mirror coated end of an Er^{3+}:YSO crystal and an external mirror. The microwave resonator is a loop gap design. Bottom: Energy level diagram of the even isotope of Er^{3+}:YSO. The transitions used to realize the upconversion device are indicated in green, orange, and red.

References:

Xavier Fernandez-Gonzalvo, Sebastian P. Horvath, Yu-Hui Chen, and Jevon J. Longdell *arXiv:1712.07735* (2017).

† Current Address: Department of Physics, Lund University, P.O. Box 118, SE-22100 Lund, Sweden

750 nm direct emitting MECSELs and VECSELs towards isotope separation applications for nuclear medicine

Kostiantyn Nechay, Hermann Kahle, Jussi-Pekka Penttinen, Antti Tukiainen, Sanna Ranta, Mircea Guina [1]

[1] Optoelectronics Research Centre, Laboratory of Photonics, Tampere University of Technology
Korkeakoulunkatu 3, FI-33720 Tampere, Finland

email: kostiantyn.nechay@tut.fi
Telephone: +358413698179

Keywords: VECSELs, semiconductor lasers, molecular beam epitaxy, nuclear medicine

Abstract

A vertical-external-cavity surface emitting lasers (VECSEL) is a versatile laser type, which can deliver high-power, high-quality beam in an extremely broad wavelength range, from UV to mid-IR. VECSELs have been proven as eligible and reliable light sources meeting the strict requirements of applications in the atomic and molecular (AMO) physics. A recently invented method of magnetically activated and guided isotope separation (MAGIS) is a key solution for resolving the worldwide long-term radioisotope shortage in nuclear medicine. For each of the about 150 isotopes the MAGIS method can separate, it relies on one certain laser light source. We present 750 nm VECSEL that can be used for producing Technetium-99m radioisotope, which is considered to be the most common radioisotope and used in tens of millions diagnostic procedures annually. Moreover, hemoglobin and water have low absorption centered at 750 nm, hence number of applications in biophotonics, dermatology and photodynamic therapy can benefit from the VECSELs in this wavelength range.
We demonstrate two different VECSEL's semiconductor gain architectures delivering record output powers of direct emission. The demonstrated VECSELs cover 740-790 nm wavelength range thus narrowing spectral gap in the challenging 700-800 nm wavelength region.

$KTiOPO_4$ Metasurface for Terahertz Wave Manipulation

Jingyi Tian[1,2], Fredrik Laurell[1], Valdas Pasiskevicius[1], Min Qiu[2], and Hoon Jang[1,]*
[1]Laser Physics, Department of Applied Physics, KTH, Sweden
[2]College of Optical Science and Engineering, Zhejiang University, China
*hj@laserphysics.kth.se
Telephone: 0760685908

Keywords: All-dielectric metasurface, Terahertz, ferroelectrics

Abstract

In the recent decades, terahertz (THz) parametric oscillators (TPO) using ferroelectric crystals have facilitated tunable THz sources at room-temperature [1, 2], where the strong THz absorption near the phonon resonances was alleviated by operating the devices close to the ferroelectric surface for an immediate outcoupling of THz waves. However, despite the efforts to improve the inefficient THz outcoupling by utilizing the normal incidence in a shaped crystal or by placing silicon prisms on the ferroelectric surfaces, the large impedance mismatch to the free space remained a challenge for an efficient outcoupling of THz radiation. Besides, the transmitted THz waves in far-field had to be further processed by other optical elements such as lens or waveplates for the practical applications of the THz sources. In contrast to THz transmission based on the simple Fresnel equations, interference between multipolar resonances in micro-structures allows us to take advantage of large refractive index to fully manipulate the amplitude, phase and polarization of THz waves in the far-field. If the ferroelectric surface can be structured in such a way that one can engineer the transmitted THz field via simultaneous excitation of electric and magnetic resonances, it will lead to a monolithic integration of a THz source with various functionalities such as THz focusing, steering and switching.

In this work, we experimentally demonstrate all-dielectric multipolar resonances in a ferroelectric metasurface that consists of $KTiOPO_4$ (KTP) micro-blocks in a square array. The KTP metasurface is fabricated on a polymethylpentene (TPx) substrate that is transparent in the THz frequency range. Taking advantage of the structural simplicity and relatively large dimensions of the grooves, we employ precision diamond-saw dicing for fast fabrication of the structures. Each KTP micro-block has dimensions of $370\times370\times130$ μm^3 with the fixed gap size of 100 µm to the neighboring KTP block.

The fabricated KTP metasurface is characterized using THz time-domain spectroscopy, where the suppressed transmission at magnetic and electric dipole resonances are identified near the wavelength of 800 µm and 900 µm, respectively. Their relative spectral positions can be tailored by varying the aspect ratio of each KTP block, which enables the control of THz transmission through a ferroelectric surface [3]. This result will lead to a compact THz device that combines THz generation and manipulation in one ferroelectric platform.

References

[1] T. A. Ortega, H. M. Pask, D. J. Spence, A. J. Lee, "Stimulated polariton scattering in an intracavity $RbTiOPO_4$ crystal generating frequency-tunable THz output, "Opt. express, **24**, 10254 (2016).
[2] W. Wang, Z. Cong, X. Chen, X. Zhang, Z. Qin, G. Tang, N. Li, C. Wang, Q. Lu, "Terahertz parametric oscillator based on $KTiOPO_4$ crystal" Opt. lett. **39**, 3706 (2014).
[3] J. Tian, Y. Yang, M. Qiu, F. Laurell, V. Pasiskevicius and H. Jang, "All-dielectric $KTiOPO_4$ metasurfaces based on multipolar resonances in the terahertz region," Optics Express, **25,** 24068-24080 (2017).

Improving Medical Imaging by Reducing the Speed of Light by 4 Orders of Magnitude

Alexander Bengtsson[1], Meng Li[1], Mengqiao Di[1], Lars Rippe[1], Andreas Walther[1], Sebastian Horvath[1], Chunyan Shi[1], Qian Li[1], Adam Kinos[1], Magnus Cinthio[2], Tobias Erlöv[2], Stefan Kröll[1]
[1]Department of Physics, Lund University, 221 00 Lund, Sweden
[2]Department of Biomedical Engineering, Lund University, 221 00 Lund, Sweden
email: alexander.bengtsson@fysik.lth.se

Keywords: Medical Imaging, Slow Light, Rare-Earth-Ion-Doped Crystals

Abstract
Ultrasound optical tomography (UOT) is a non-invasive medical imaging technique aiming at taking high contrast and high resolution images deep inside the human body. Both laser pulses and ultrasound pulses are sent into the tissue. Tissue scatters light strongly, and a small part of the laser light will pass through the ultrasound pulse and be frequency shifted by ± the ultrasound frequency. By monitoring the intensity of the frequency shifted light leaving the tissue, information about the optical absorption properties at the location of the ultrasound pulse can be obtained. Images with optical contrast and ultrasound resolution can thus be constructed by moving the position of the ultrasound. UOT could potentially be used for imaging of deep-lying cancer tumors, or for imaging of the oxygenation level at the frontal part of the heart, a feat not possible with any currently available medical imaging technique. It is however extremely challenging to filter out the frequency shifted light, which is orders of magnitude weaker compared with the carrier, and only shifted in frequency by about 2 MHz. In this presentation we discuss how to filter out the frequency shifted UOT signal by tailoring a *narrowband transmission window* in the absorption profile of rare-earth-ions doped into inorganic crystals. Such a filter provides attenuation of the carrier light due to the absorption by the ions *outside the transmission window*, while almost completely transmitting the frequency-shifted UOT signal. Additionally, the light *inside the transmission window* is slowed down by about 4 orders of magnitude compared with the carrier because of strong dispersion within the transmission window. This allows for additional attenuation using time gating. We present our recent UOT measurements in tissue phantoms (see Fig. 1) using the same type of slow light filters as in Ref. [1], which we compare with simulations from Ref. [2]. We also discuss potential filter materials within the tissue optical window, along with simulations that indicate that a filter wavelength of about 700 nm would be superior in terms of resolution for imaging of oxygenation level at large imaging depths.

Fig. 1. Scattering tissue phantom

[1] H. Zhang, M. Sabooni, L. Rippe, C. Kim, S. Kröll, L.V. Wang, P.R. Hemmer. ”Slow light for deep tissue imaging with ultrasound modulation”. App. Phys. Lett. 100, 131102 (2012).

[2] A. Walther, L. Rippe, L.V. Wang, S. Andersson-Engels, and S. Kröll. “Analysis of the potential for non-invasive imaging of oxygenation at heart depth, using ultrasound optical tomography (UOT) or photo-acoustic tomography (PAT)”, Biomed. Opt. Express 8, 4523 (2017).

Monte Carlo simulations of multispectral snapshot image data for skin microcirculation estimation

Maria Ewerlöf[1], Marcus Larsson[1], E. Göran Salerud[1]
[1]Department of Biomedical Engineering, Linköping University, Sweden
email: maria.ewerlof@liu.se
Telephone: 013286763

Keywords: Biomedical optics, multispectral imaging, Monte Carlo simulations, diffuse reflectance spectroscopy, skin blood saturation, microcirculation.

Abstract

A functional skin microcirculation is essential for the body, but might be impaired by, for example, a wound or a pathological condition. Estimating blood tissue fraction and saturation makes it possible to get information on how well-nurtured the tissue is. It is important in many diagnostic and therapeutic clinical solutions, including wound healing and therapeutic treatment follow-up.

To optically capture the physiological processes in human skin tissue, we use a XIMEA xiSpec camera (MQ022HG-IM-SM4X4-VIS, XIMEA®, Germany) with high framerate. The camera has a CMOS detector with 16 wavelength-specific Fabry-Perot filters in the range 470-630 nm overlaid in a mosaic pattern. The spectral bands are known, and substantially overlapping. The xiSpec camera can capture 170 multi-spectral cubes per second with an image format of 512x272 pixels, which allows for high temporal and spatial resolution.

The multispectral cubes are analyzed using inverse Monte Carlo simulation, where the detector spectral bands and the emission spectrum of the white light source are accounted for. Simulations are performed for a two-layered tissue model with different combinations of optical parameters (epidermal thickness, hemoglobin concentration, oxygen saturation, melanin concentration and spectrally dependent reduced-scattering coefficient). By finding a simulated spectrum that matches a measured spectrum, we can estimate blood tissue fraction and saturation of imaged skin tissue.

Spatial and temporal variations of the parameters are investigated by continuously imaging tissue before, during and after an occlusion of the arm, arterial (variation in saturation) or venous (variation in blood tissue fraction) respectively. Selected image regions are analyzed and compared to a well-documented, probe-based technique (PF6000 Enhanced Perfusion and Oxygen Saturation monitor, Perimed AB, Sweden) used as a reference.

The results clearly show that our camera-based technique is capable of capturing the dynamic microcirculatory changes in oxygenation and blood tissue fraction during occlusion provocations.

High-resolution laser spectroscopy in orthopedics

P. Chen[1], W.S. Li[2], H.Y. Lin[2], Y. Li[2], H. Zhang[2], D.L. Chen[3], W. He[1], S. Svanberg[2,4], and K. Svanberg[2,4]

[1]First Clinical School of Chinese Medicine, Guangzhou University of Chinese Medicine, 12, Jichang Road, Baiyun Area, Guangzhou 510405, China
[2]Center of Optical and Electromagnetic Research, South China Academy of Advanced Optoelectronics, South China Normal University, University City Campus, Guangzhou 510006, China
[3]1st Affiliated Hospital, Guangzhou University of Chinese Medicine, 12, Jichang Road, Baiyun Area, Guangzhou 510405, China
[4]Lund Laser Center, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden
Emails: katarina.svanberg@med.lu.se; sune.svanberg@fysik.lth.se
Telephones: +46707315470; +46760502126

Keywords: biophotonics, diode laser spectroscopy, GASMAS, orthopedics

Abstract
During the recent decades biophotonics has expanded into one of the dominating areas of photonic applications (see, e.g. [1]). One specialized area in biophotonics concerns the *in-situ* monitoring of free gas in the human body, e.g. in the lungs, the middle ear and the sinus cavities, related to the diagnosis of respiratory distress syndrome in newborns, middle-ear and sinus inflammations, respectively. We have pursued work in these areas in Lund and Guangzhou using the gas in scattering media absorption spectroscopy (GASMAS) technique, as recently reviewed in [2]. We have now extended GASMAS applications to the area of orthopedics in work concerning femoral head status, connected to the very common question of the need for total hip replacement [3]. Also knee joint problems due to arthrosis frequently requires artificial joint intervention [4]. We have shown, in studies in-vitro on bone samples extracted in connection with replacement operations, that femoral head decay is accompanied with the development of free-gas pores detectable by GASMAS [3], while such pores are absent in the arthrosis patients, where the degeneration is of different origin [4]. GASMAS is also very effective in food monitoring, where a recent example is the study of freshness of hen eggs, and the progress in hatching in fertilized eggs [5].

1. J. Popp, V.V. Tuchin, A. Chiou, and S.H. Heinemann (eds), *Handbook of Biophotonics*: Volumes I-III (Wiley, 2011).
2. K. Svanberg and S. Svanberg, Monitoring of Free Gas In-Situ for Medical Diagnostics using Laser Spectroscopic Techniques, in *Frontiers in Biophotonics for Translational Medicine*, U.S. Dimish and M. Olivo (eds) (Springer, Singapore 2015) 307-321.
3. H.Y. Lin, W.S. Li, H. Zhang, P. Chen, D.L. Chen, W. He, S. Svanberg, and K. Svanberg, J. Biophotonics, DOI 10.1002/jbio.201600229 (2016).
4. P. Chen, W.S. Li, H.Y. Lin, D.L. Chen, Y. Li, K. Svanberg, and S. Svanberg, Assessment of Free Gas in the Tibial Condyle Bone of the Human Knee by Diode Laser Spectroscopy with Possible Application to Arthrosis Diagnostics, Submitted (2018).

5. W.S. Li, H.Y. Lin, H. Zhang, K. Svanberg and S. Svanberg, J. Biophotonics Doi 10.1002/jbio.201700154 (2017).

Molecular glasses as a promising class of materials for photonic applications

M. Rutkis
Institute of Solid State Physics, University of Latvia, Riga, Latvia,
martins.rutkis@cfi.lu.lv
Telephone: +371 29234521

Keywords: (Verdana, 11 pts, italic, left adjusted)

Abstract

Over the last two decades increased interest in the development of organic photonics and optoelectronics is driven by demand for new cost effective high performance materials which are easy to process. Most of attention is focused on such application areas as photovoltaic, lighting and optical data processing. The key process in manufacturing organic photonic device for above mentioned applications is preparation of uniform thin films. In general there are two methods to prepare such films – thermal vacuum vapor deposition and solution based methods like spin coating. For the first one high equipment and processing cost is characteristic. Solution based thin film production processes are less demanding therefore became more and more popular among researchers in field of organic optoelectronics and photonics. Nowadays polymers and polymer composites are most intensively employed in attempts to create devices via solution based technology. Among them there has also been increasing interest in so called "organic molecular glasses" as photonic thin film materials[1,2]. Compared to polymeric systems, organic molecular glasses do not need complicated chemical synthesis or purification processes and has a well-defined structure.

Within last decade our attention is paid to develop organic materials for nonlinear optical (NLO) and organic electroluminescent (EL) applications. During our research it came to our attention that the presence of triphenylmethyl and triphenylsilyl substitutes noticeably enhances amorphous phase formation of low molecular weight molecules[3]. Exploiting this molecular motif large amount of glass forming structures with different active chromophores, are synthesized at RTU.

With scope of above mentioned applications thermal, optical, electrical and electrooptical properties of these compounds are intensively investigated at ISSP UL. In this contribution we would like to present our investigation results and discus possible structure property relations within this new class of low molecular glasses.

References

1. P. Strohriegl, J. V. Grazulevicius. Adv. Mater., 14, 1439 (2002).
2. S.-H. Jang and A. K.-Y. Jen. Chem. Asian J., 4, 20–31 (2009)
3. K. Traskovskis, I. Mihailovs, A. Tokmakovs, A.Jurgis, V. Kokars, M. Rutkis. J. Mater. Chem., 22 11268-11276 (2012).

Probing collective nonlinear optical effects in plasmonic oligomers with cylindrical vector beams

Godofredo Bautista[1], Christoph Dreser[2,3], Xiaorun Zang[1], Dieter P. Kern[2,3], Martti Kauranen[1] and Monika Fleischer[2,3]
[1]Laboratory of Photonics, Tampere University of Technology, Korkeakoulunkatu 3, 33720 Tampere, Finland
[2]Institute for Applied Physics, University of Tübingen, Auf der Morgenstelle 10, 72076 Tübingen, Germany
[3]Center for Light-Matter-Interaction, Sensors and Analytics LISA$^+$, University of Tübingen, Auf der Morgenstelle 15, 72076 Tübingen, Germany
email: godofredo.bautista@tut.fi
Telephone: +358 40 1981011

Keywords: nonlinear microscopy, second-harmonic generation, cylindrical vector beams, plasmonics

Abstract

Plasmonic oligomers, which consist of novel assemblies of metal nanostructures, provide new ways to tailor nonlinear optical effects, such as second-harmonic generation (SHG), through collective resonance effects. Traditional approaches to study collective SHG effects in such nanostructures, however, have relied on experimental conditions that use either plane wave or focused beam excitation with homogenous, e.g., linear, states of polarization.

Here, we probe collective SHG effects in plasmonic oligomers using SHG microscopy with focused cylindrical vector beams (i.e., radial and azimuthal polarizations) [1]. We also utilized rotationally symmetric radial and azimuthal, arrangements of gold nanorods with varying number of rods that were prepared using electron beam lithography. The constituent nanorods were designed so that their longitudinal plasmon resonance falls near the fundamental excitation wavelength used in the nonlinear experiments. We observed that the efficiency of SHG from the oligomers is strongly influenced by the input beam polarization and interparticle coupling. These experimental results agree well with our surface-SHG calculations based on the boundary element method. The work describes a new way to study coupling effects in arrangements of nanostructures and to manipulate the efficiency of nonlinear optical effects at the nanoscale.

Reference

[1] G. Bautista, C. Dreser, X. Zang, D. P. Kern, M. Kauranen, and M. Fleischer, "Collective Effects in Second-Harmonic Generation from Plasmonic Oligomers," Nano Lett., 18 (4), 2571–2580 (2018)

Purcell Enhancement of Rare-earth ions Doped in Nano-crystals

Mohammed Alqedra, *Lars Rippe, Stefan Kröll and Andreas Walther*
Department of Physics, Lund University, P.O. Box 118, SE-22100 Lund, Sweden
Email: mohammed.alqedra@fysik.lth.se
Telephone: +46 46 222 8370

Keywords: (Rare-earth ions, Purcell Enhancement, Fiber Cavity, Quantum Computing, Quantum Optics)

Abstract

Crystals doped with rare-earth ions (REIs) have attracted a lot of interest over the last few years due to their interesting coherence and optical properties, and their potential for quantum information processing applications.
In free atoms, the 4f-4f transitions are electric dipole forbidden. When doped into dielectric crystals, the non-centrosymmetric crystal field breaks the symmetry of REIs wavefunctions, as a result, the 4f-4f transitions becomes weakly allowed (oscillator strength: $10^{-9} - 10^{-6}$). The optical transitions also become inhomogeneously broadened, making it possible to address individual ions by targeting different frequencies. Each state will have a permanent electric dipole moment, which can be used to trigger ion-ion interactions. The exceptionally long coherence times of the hyperfine levels and the possibility to couple them via optical transitions provide a suitable choice of an addressable and controllable qubit state.
However, the long excited state lifetimes, and thus the low emission rates, makes it difficult to readout the state of the qubit, which is a crucial criterion for quantum computing applications.
In this presentation we will describe our continuing work on realizing Purcell enhancement for single Nd ion as a readout scheme. This can be done by placing REIs doped nano-crystals inside a high finesse fiber micro-cavity with small mode volume $\sim\lambda^3$ [1]. The qubit transition can be enhanced by tuning the cavity so it is on resonance with the transition frequency. If the ion-cavity interaction is strong enough, the state of a single ion could have a back action on the cavity. Depending on the state of a single ion, the cavity resonance will be shifted away from the cavity linewidth, creating a quantum switch.
This work was started by investigating the coherence and optical properties of Nd ions, which has the highest oscillator strength compared to other REIs. An inhomogeneous linewidth of 5 GHz was measured at liquid helium temperature for the $4I_{9/2} - 4F_{3/2}$ transition. The lifetime T_1 and the coherence time T_2 of the optical excited state was measured at 1T magnetic field and was found to be 308 μs and 5.7 μs, respectively. This means that a Purcell factor >110 ($2T_1/T_2$) is needed in order to have a Fourier limited emitted photons.

References:
1. D Hunger *et al* 2010 *New J. Phys.* 12 065038

Progress in III-V/Si photonic integration technology

Mircea Guina
Tampere University of Technology, Tampere, Finland
email: mircea.guina@tut.fi
Telephone: +358408490004

Keywords: III-V/Si hybrid photonic integration, monolithic integration

Abstract

The use of light-based technology in a form resembling the scalability, functionality, and compactness of electronic integrated circuits, has been an intensive area of development for the last decade. The research area dealing with photonic integrated circuits (PICs) has progressed at a fast pace owing in particular to vigorous advances in developing the Si-based passive optical technology platform. While these developments have traditionally been powered by the needs for solving the high-speed communication and power consumption bottlenecks, for example in telecomm and data center applications, there is an increasing trend to deploy PIC solutions in higher value applications, such as automotive, life-science, and sensing. The expanding area of applications requires addressing new wavelength regions, for example transitioning from 1.55 μm telecom window to mid-IR region, which has higher relevance for sensing. Major advances are also needed in developing more flexible and simpler solutions for integration of III-V light sources and other optoelectronics components on Si-photonics platform to ensure increased scalability and functionality of the PICs.

The presentation reviews the recent advances in developing III-V optoelectronics for integration with Si-based photonic chips. In particular, we address the need for developing mid-IR GaSb-based light sources for integrated sensors, and new device architecture for decreasing the complexity of hybrid integration. We also introduce a new approaches for monolithic integration making use of Si/SiGe/Ge technology platform, which is also gaining momentum in microelectronics.

Photonic crystal fiber characterization using streak camera

Vygandas Jarutis[1] , Julius Vengelis[1], Valdas Sirutkaitis[1] ,
Marius Franckevičius[2] and Vidmantas Gulbinas[2]
1 Laser Research Center, Faculty of Physics, Vilnius University, Sauletekio av. 10, LT-10223 Vilnius, Lithuania
2 Center for Physical Sciences and Technology, Sauletekio av. 3, LT-10257 Vilnius, Lithuania
email: vygandas.jarutis@ff.vu.lt
Telephone: +370 5 2366005

Keywords: photonic crystal fiber, streak camera

Abstract

Photonic crystal fibers (PCFs) currently became important part of many optical experiments and have found many applications [1–5]. Here we present experimental measurements of PCF by the means of streak camera, which reveals interesting peculiarities of light propagation in our PCF. It seems that for single mode PCF in addition to fundamental modes there are additional modes which can propagate along the fiber with relatively small loses (fig 1). Numerical calculations indicates that those additional modes can be attributed to the cladding of the fiber.

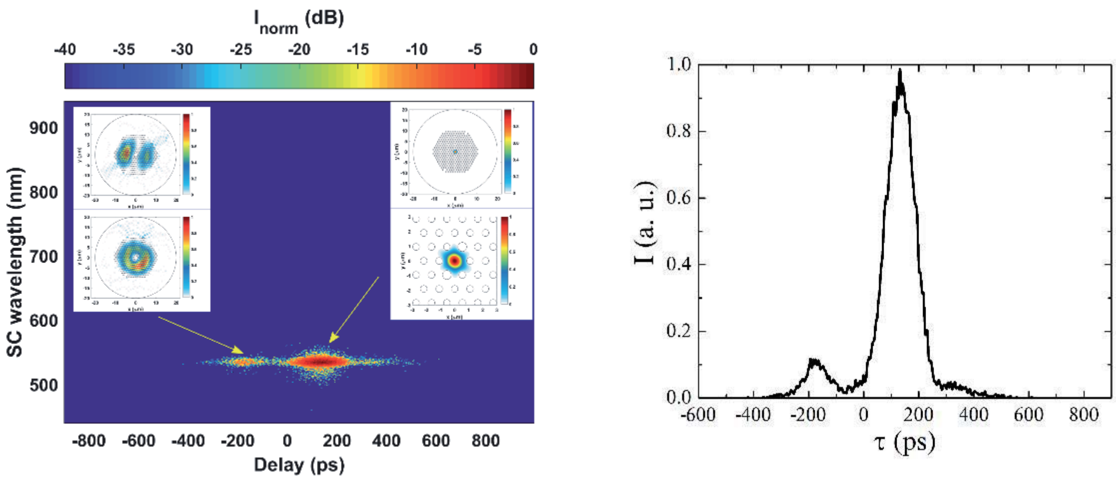


Fig. 1 Left: spectrogram of streak camera. Insets – numerically calculated profiles of PCF modes. Right: Relative intensity of the pulse from PCF.

References
[1] S.Diddams and J.C.Diels, J. Opt. Soc. Am. B 13," 1120 (1996)
[2] L.G.Cohen and C.Lin, Appl. Opt. 16, 3136 (1977)
[3] B.Costa, D.Mazzoni, M.Puleo, and E.Vezzoni, IEEE J. Quantum Electron. 18, 1497 (1982)
[4] G.Genty, H.Ludvigsen, M.Kaivola, and K.P. Hansen, Opt. Express 12, 929 (2004)
[5] J.Vengelis , V.Jarutis , and V.Sirutkaitis, Optics Letters, Vol. 42, No. 9 (2017)

All-organic waveguide Mach-Zehnder interferometric device for communication and sensing applications

Edgars Nitiss, Arturs Bundulis, Andrejs Tokmakovs, Janis Busenbergs, Martins Rutkis
Institute of Solid State Physics, University of Latvia, Kengaraga 8, LV-1083
email: edgars.nitiss@cfi.lu.lv

Keywords: organic materials, waveguides, nonlinear optics, sensors

Abstract

In the last couple of decades a tremendous growth in the use and development of waveguide photonics in the measurement technology and informatics can be noticed. This has been motivated mainly by the requirements in miniaturization of devices as well as in reduction of their costs and energy consumption. In this presentation we demonstrate our achievements in creation of all-organic waveguide devices. We have recently developed a waveguide electro-optical modulator capable of operating in the visible spectral range as well as a waveguide organic vapor sensor. Both devices have been made using direct-write optical lithography and their operation parameters have been investigated. The operation of both devices has been enabled by a novel nonlinear optical material that allows precise tuning of material refractive index, is sensitive to environmental conditions, as well as exhibits second order optical nonlinearity. In this presentation we will discuss the principles of the development of previously mentioned elements as well as strategies for device testing.

Robust, Low-Threshold, Cascade-Free Mirrorless Optical Parametric Oscillator

Andrius Zukauskas[1], Riaan Stuart Coetzee[1], Carlota Canalias[1] and Valdas Pasiskevicius[1]
[1] Department of Applied Physics, Royal Institute of Technology, Roslagstullsbacken 21, 10691 Stockholm, Sweden
email: az@laserphysics.kth.se
Telephone: 0700535327

Keywords: Nonlinear Optics, MOPO, PPRKTP

Abstract

Mirrorless optical parametric oscillators (MOPO) represent a class of parametric devices based on three-wave mixing arranged in a counter-propagating geometry. Such arrangement of interacting waves provides unique properties, such as: highly efficient single-pass operation, inherently narrow bandwidth of the backward wave, and low sensitivity to thermal and angular detuning. Essentially this makes MOPO attractive for a broad range of nonlinear optical applications, including LIDARs and sources of nonclassical light. Despite all these attractive features, so far the utilization of MOPO has been limited to a few demonstrations. This is due to the fact that the only feasible way to compensate for a large phase mismatch in counter-propagating geometry is by employing quasi-phase matching (QPM) with sub-micrometer periodicities. Such QPM structures are notoriously difficult to achieve, and so far were reliably demonstrated only in Rb-doped $KTiOPO_4$ (RKTP) crystals. Following the convention for the signal and idler wavelengths $\omega_s \geq \omega_i$, the waves in counter-propagating geometry of nonlinear interaction can be arranged so that either the signal or the idler wave is generated in the backward direction, relative to the pump direction. In the latter case phase-matching can be achieved with a longer QPM period, however, MOPO is then prone to cascaded counter-propagating processes, which may be detrimental for some applications. While the former case requires shorter QPM periods, it essentially allows cascade-free MOPO operation. In this work we demonstrate to the best of our knowledge for the first time a low-threshold, cascade-free MOPO device based on periodically poled RKTP (PPRKTP) crystal with the period of 509 nm.

The PPRKTP crystals used in this work were produced by employing the coercive field engineering technique. A periodic ion-exchange pattern with the period of 509 nm was created on the c^- faces of the crystals, followed by electric field poling using planar electrodes. The resulting domain structures represent high-quality QPM gratings with excellent uniformity in a volume of 7 × 3 × 1 mm^3, reflected by an effective nonlinearity of 7.5 pm/V. Pumped by a Q-switched, injection-seeded, Nd:YAG, master-oscillator-power amplifier system operating at 1064 nm, a representative PPRKTP sample generated counter-propagating signal centered at 1856 nm and co-propagating idler at 2495.5 nm. The operation threshold was achieved at intensity of 83 $MWcm^{-2}$ – a value similar to the ones obtainable in co-propagating OPOs based on PPRKTP. Pumped at maximum energy of 6.48 mJ, the MOPO achieved total conversion efficiency of 53%. The measured spectra of signal and idler waves are shown to be narrowband with linewidths in range of 0.5 nm. In this contribution we further discuss the details and prospects of MOPO devices based on sub-μm QPM structures in RKTP.

Anisotropic light scattering in transparent wood

E. Vasileva[1], A. Baitenov[1], I. Sychugov[1], M. Yan[1], H. Chen[2], Y. Li[2], L. Berglund[2], S. Popov[1]
[1]*Department of Applied Physics, SCI School, KTH-Royal Institute of Technology, Stockholm, 16440*
[2]*Wallenberg Wood Science Center, Department of Fiber and Polymer Technology, KTH - Royal Institute of Technology, Stockholm, 10044*
email: vasileva@kth.se
Telephone: 0737652022

Keywords: transparent wood, semi-ordered structure, anisotropic light scattering

Abstract
Transparent wood has been a subject of undergoing intense study in several disciplines such as material science [1, 2], energy saving technology [3] and photonics [4, 5]. As the name implies, the material is produced from a natural wood via several steps of chemical treatment which makes material to transmit light with preserved wood structure [6]. Indeed, TW is a composite material consisting of wood template infiltrated with a polymer of proper refractive index. In particular, wood has a hierarchical structure with the feature sizes scaling within the range of few nanometers up to hundreds of micrometers [7]. This internal naturally formed semi-ordered structure of wood is responsible for its highly anisotropic optical properties. Namely, scattering in wood is produced on the interfaces of the media with different indices of refraction: air-filled voids formed during the manufacturing process, wood chemical components of slightly different refractive index with/and polymer infiltrated [8]. It is not straight forward to characterize such material and it was typically done with the haze characterization. However, the method assumes uniform scattered light distribution, which is not always the case for TW samples. In our work we discuss and characterize the parameters of light scattering within TW structure similar to traditional haze definition in terms of image content. We have shown the correlation of the experimental results with the theoretical model based on the scattering probability distribution.

1. Berglund, L.A. and I. Burgert, *Bioinspired Wood Nanotechnology for Functional Materials.* Advanced Materials: 2018. **30**(19).
2. Gan, W., et al., *Transparent magnetic wood composites based on immobilizing Fe3O4 nanoparticles into a delignified wood template.* Journal of Materials Science, 2017. **52**(6): p. 3321-3329.
3. Zhu, M., et al., *Transparent and haze wood composites for highly efficient broadband light management in solar cells.* Nano Energy, 2016. **26**: p. 332-339.
4. Vasileva, E., et al., *Lasing from Organic Dye Molecules Embedded in Transparent Wood.* Advanced Optical Materials, 2017. **5**(10).
5. Li, Y., et al., *Luminescent Transparent Wood.* Advanced Optical Materials, 2017. **5**(1).
6. Li, Y., et al., *Towards centimeter thick transparent wood through interface manipulation.* Journal of Materials Chemistry A, 2018. **6**(3): p. 1094-1101.
7. Borrega, M., et al., *Composition and structure of balsa (Ochroma pyramidale) wood.* Wood Science and Technology, 2015. **49**(2): p. 403-420.
8. Li, Y., et al., *Optically Transparent Wood from a Nanoporous Cellulosic Template: Combining Functional and Structural Performance.* Biomacromolecules, 2016. **17**(4): p. 1358-1364.

Recent progress in compact fiber-based mid-IR lasers and applications

Irina T. Sorokina[1,2]
[1]*Department of Physics, NTNU, N-7491 Trondheim, Norway*
[2]*Atla Lasers AS, Richard Birkelands vei 2b, N-7491 Trondheim, Norway*
email: Irina.Sorokina@ntnu.no
Telephone: +47-91897909

Keywords: lasers, fiber lasers, solid-state lasers, mid-infrared lasers, material processing, sensing

Abstract

Recent progress in ultrafast science and technology was marked by passing by the fiber-based lasers of two barriers: 11) operation wavelength has overcome the 2 microns mark, which has been the longest operation wavelength of a fiber laser for decades and ii) the spectral bandwidth has overcome the limit set by the rare-earth ions typically used as dopants of fiber lasers. To generate supercontinuum one would normally use a combination of a femtosecond laser and a nonlinear fiber, such as e.g. a photonic crystal fiber.

In the last few years it became possible to generate femtosecond pulses in the mid-IR spectral range above 2 and even 3 microns directly from the laser, avoiding nonlinear conversion steps, as well as mid-IR supercontinua directly from the compact MOPA type fiber lasers. These sources are characterized by ultrashort pulse duration down to few optical cycles, Watt level output power, tens of nanojoules pulse energy, and up to GHz repetition rate. Important aspect of the new technology is the tunability of the laser output, which makes such laser technology a real breakthrough of large industrial and economic significance. The emission wavelength of the femtosecond laser is electronically selectable in the wide spectral range, roughly from 2 to 3 um. If demanded by application, the laser can be configured as a coherent supercontinuum light source with spectrum reaching wavelengths well beyond 3 um. Alternatively, one can convert the 2 – 3 um frequency comb towards 3 – 6 micron frequency combs using periodically patterned nonlinear crystals such as OPGaAs or OPGaP. The shortest pulses that we could recently generate around 4 microns reach only three optical cycles in duration.

The built-in tunability of femtosecond pulses, high quality frequency combs as well as the ability to produce supercontinua directly from the laser are making this novel mid-IR laser technology particularly attractive for industrial applications demanding either high quality processing or ultrahigh sensitivity measurements. The application areas include, but are not limited to microelectronics, photovoltaics, THz generation, confocal nonlinear microscopy and neurosurgery, as well as environmental, oil and gas sensing.

Mid-IR supercontinuum generation and cascaded soliton self-compression in $\chi^{(2)}$-modulated $KTiOPO_4$

Anne-Lise Viotti[1,], Robert Lindberg[1], Andrius Zukauskas[1], Rimantas Budriunas[2,3], Dainius Kucinskas[2,3], Tomas Stanislauskas[3], Fredrik Laurell[1], and Valdas Pasiskevicius[1]*
[1]Dept. of Applied Physics, Royal Institute of Technology, Stockholm, Sweden.
[2]Vilnius University Laser Research Center, Vilnius, Lithuania.
[3]Light Conversion Ltd., Vilnius, Lithuania.
Email: alviotti@kth.se Phone: +46701667466

Keywords: Nonlinear Optics, Supercontinuum generation, ferroelectric materials.

Abstract
The generation of octave-spanning mid-infrared supercontinuum spectra is interesting for several applications, in particular for seeding of optical parametric amplifiers. Such broad spectra can be generated by cascading interactions in second-order nonlinear materials [1]. Structured ferroelectrics such as periodically poled $KTiOPO_4$ (KTP) and periodically poled $LiNbO_3$ are especially appealing for tailoring the magnitude and sign of the cascaded $\chi^{(2)}$ effective Kerr nonlinearities over the full transparency range of the material. Due to cascading, the effective Kerr coefficient can be substantially larger than the native Kerr coefficient. In this contribution, we present a theoretical model and experimental demonstration of near-and mid-infrared supercontinuum generation in periodically poled Rubidium-doped KTP (PPRKTP) using 128 fs pump pulses with moderate pump intensity, centered at 1.52 µm. Additionally, a model describing the experiment and based on a single equation for nonlinear propagation of a total broadband field envelope in a dispersive structured medium is presented [2]. Specifically, the model was used to design a periodic RKTP structure for the broadest supercontinuum generation and simultaneous soliton self-compression. Experimental results, as seen in Fig.1, are in excellent agreement with the simulations and show octave-spanning supercontinuum as well as pulse self-compression down to 18.6 fs.

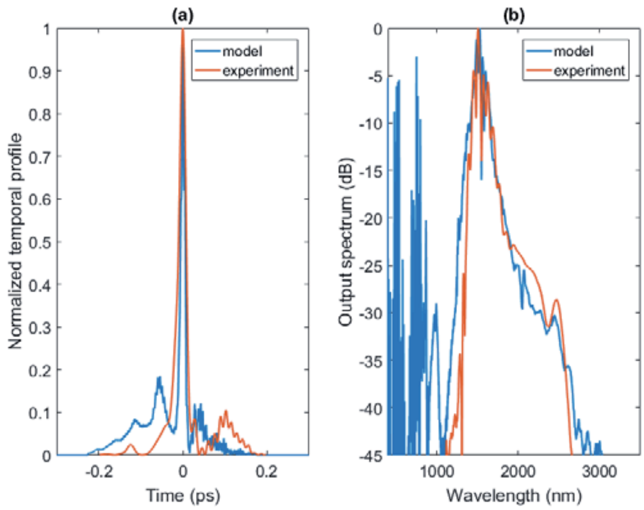


Fig.1. Comparison of (a) output temporal profiles and (b) output supercontinuum spectra for both the numerical model and the experimental results

References
[1] M. Seidel, et al., Sci. Rep. **7**, 1410 (2017).
[2] M. Bache, et al., Phys. Rev. A **82**, 063806 (2010).

Spinwave harmonic comb generation by ultrafast laser pulses with a high repetition rate in thin magnetic films

Ademir Aleman, Shreyas Muralidhar, Ahmad Awad, Dag Hanstorp & Johan Åkerman
Dept. of Physics, University of Gothenburg, SE 412 96, Gothenburg, Sweden
email: ademir.aleman@physics.gu.se
Telephone: +46 031 786 9140

Keywords: spinwave, magnonics, Brillouin, ultrafast, magnetism, nanostructure.

The discovery of ultrafast demagnetization by ultrashort laser pulses in 1996[1], triggered interest in optical manipulation and detection of the magnetization at nanometer scale as a rout for the development of new technologies. It is by focusing an ultrashort laser pulse on a thin magnetic sample possible to either write a magnetic domain or launch a propagative spinwave (SW) [2].

Typically, SWs are injected in nanostructures by electrical current, RF antennas or laser pulses. Optical characterization of SWs has been primarily based on either Magneto-Optical Kerr Effect (MOKE) [3] or Brillouin Light Scattering (BLS) [4]. So far, all optical studies on ultrafast demagnetization have been carried out using MOKE microscopy. The main advantage of instead using BLS in such experiments is the direct access to the frequency domain information, which provides a deeper insight to the phenomenon under investigation.

Here we proposed a new method to fully optically create, manipulate and characterize SWs in magnetic structures at the nanoscale. We report the excitation of SWs in a thin film magnetic sample by means of a high repetition femtosecond laser. The new technique offers strong advantages over other methods, with its sensitivity to all spin waves excited in the thin film. The laser spot on the sample forms a sub-micron magnon source with specific and narrow equally spaced frequencies which directly depend on the laser characteristics irrespective of the sample magnetization and the applied external field. The SW comb generated by this method propagates several microns away from the laser spot. We show that this technique may be used to locally enhance SW's which frequencies resonate with a harmonic of the repetition rate of the excitation laser. By using a BLS microscope, we could frequency and spatially resolve the phenomena down to sub-micron and sub-GHz resolution.

Acknowledgements
Funding from the Knut & Alice Wallenberg foundation is greatly acknowledged.

References
[1]E. Beaurepaire, J.-C. Merle, A. Daunois, and J.-Y. Bigot, Phys. Rev. Lett. 76, 4250 (1996)
[2]C. D. Stanciu, F. Hansteen, A. V. Kimel, A. Kirilyuk, A. Tsukamoto, A. Itoh, and T. Rasing, Phys. Rev. Lett. 99, 047601 (2007).
[3]J. Hohlfeld, E. Matthias, R. Knorren, and K. H. Bennemann, Phys. Rev. Lett. 78, 4861 (1997)
[4] T. Sebastian, K. Schultheiss, B. Obry, B. Hillebrands and H. Schultheiss, Front. Phys., Vol. 3, id.35 (2015)

Optical properties of block copolymer based self-assembled hyperbolic metamaterials.

Morten KILDEMO*,

Department of Physics; Norwegian University of Science and Technology; 7491 Trondheim; Norway

Xuan WANG, Ashod ARADIAN and Virginie PONSINET,

CNRS, University of Bordeaux, CRPP UMR5031, 33600 Pessac, France ; CEA, CNRS, LIONS NIMBE UMR 3685, 91191 Gif sur Yvette Cedex, France ;

Abstract

Nanophotonics explores the possibility of modulating light propagation with very small amount of matter using nanoscale phenomena. The occurrence of plasmons at metal/dielectrics interfaces, is one of the interesting phenomena that has led to active research efforts towards the fabrication of nanostructured metal-dielectric materials and surfaces. We here discuss the experimentally extracted uniaxial optical properties of self-assembled periodic lamellar assemblies composed of nanometric domains of pure polymer and domains of composite of polymer loaded with a high density of gold nanoparticles. Spectroscopic Mueller Matrix Ellipsometry with appropriate modelling, is highly suitable to extract optical properties of such nanophotonic structures [1-4]. We show here that for large gold loading, the lamellar stacks present a frequency domain, in which the ordinary and extraordinary components of the dielectric function are of opposite signs [5]. This peculiar property, called "hyperbolic", allows for the propagation of large magnitude wavevectors, carrying details finer than half the wavelength, otherwise corresponding to evanescent non-propagative waves in a usual dielectric.

References:

1. J. P. Banon, T. Nesset, T. Brakstad, Z. Ghadyani, M. Kildemo & I. Simonsen. Critical dimension metrology of metasurfaces based on angle resolved spectroscopic Mueller Matrix scatterometry. *Opt. Lett.* 42(13) 2631-2634 (2017).
2. M. Kildemo, J.-P. Banon, A. Baron, B. B. Svendsen, T. Brakstad & I. Simonsen. Optical response of gold hemispheroidal lattices on transparent substrates. Appl. Surf. Sci. **421** (2017) 593.
3. Aas, L.M.S., et al., *Optical properties of biaxial nanopatterned gold plasmonic nanowired grid polarizer.* Optics Express, **21** (2013) 30918.
4. T. Brakstad, M. Kildemo, Z. Ghadyani & I. Simonsen. Dispersion of polarization coupling, localized and collective plasmon modes in a metallic photonic crystal mapped by Mueller Matrix Ellipsometry. *Opt Express* **23** (2015) 22800.
5. X. Wang, K. Ehrhardt, C. Tallet, M. Warenghem, A. Baron, A. Aradian, M. Kildemo & V. Ponsinet. Hyperbolic-by-design self-assembled metamaterial based on block copolymers lamellar phases. *Optics & Laser Technology* **88**, 85-95, (2017).

*) Email: Morten.Kildemo@ntnu.no;

Self-assembling nanomaterial structures as a platform technology for micro-LEDs

Lars Samuelson
Solid State Physics/NanoLund, Lund University and Glo AB, Lund.
Email: lars.samuelson@ftf.lth.se

Directly Blue, Green and Red-emitting ultra-small light-emitting diodes (LEDs) are strong candidates for coming generations of high-resolution screen, be that for the more standard smart-phones, for virtual reality (VR) or augmented reality (AR) systems, for heads-up display technologies and even for smart, human-centric lighting. By selective area nucleation of nanowires, we are able to form nanowire seeds that are absolutely dislocation free, also when formed on a highly defective GaN seed-layer. Two approaches are then taken: (i) one where first an n-type core of dislocation-free GaN nanowire is formed, on to which a radial pn-junction is grown, and (ii) one where we first form a perfect pyramid of InGaN which is later transformed into a dislocation-free and relaxed InGaN platelet, on top of which green- and red-emitting quantum wells can be formed. I will in this talk present and discuss recent progress in our unique nanowire-based materials technologies providing such RGB micro-LEDs, enabling pixel-sizes down to the 10µm range.

References:

B. Monemar et al., “Nanowire-Based Visible Light Emitters, Present Status and Outlook”, Chapter 7 in Semiconductors and Semimetals 94, 227-271 (2016).

L. Samuelson et al., “Gallium nitride nano-sized LEDs”, SPIE newsroom, 10.1117/2.1201603.006385 (2016).

Z. Bi et al., “Hing In-content InGaN nano-pyramids Tuning crystal homogeneity by optimized nucleation of GaN seeds”, J of Applied Physics 123, 2, 025102 (2018)

Epitaxial growth of GaAs Nanowires on Silicon substrate for photovoltaic applications

Elizaveta Lebedkina, Dmitrii Viazmitinov, Stela Canulescu, and Elizaveta Semenova
DTU Fotonik, Technical University of Denmark, 2800 Kongens Lyngby, Denmark
email: lile@fotonik.dtu.dk
Telephone: +4545256388

Keywords: (Nanowires, GaAs, silicon, epitaxy, MOVPE)

Abstract

Direct bandgap III-V semiconductor nanowires (NWs) grown directly on silicon are very promising materials for optoelectronic and photovoltaic applications [1]. It is well known that it is impossible to grow a monocrystalline planar film of Gallium Arsenide (GaAs) or Indium phosphide (InP) on silicon (Si) without structural defects. However, in case of nanowires these materials can be directly grown on Si with high crystalline quality due to their small footprints and the resulting low stress on the NW/Si interface. Recently it was demonstrated that III-V NW on top of a single junction Si solar cell can greatly improve the power conversion efficiency (PCE) [2]. A PCE of 28,15% can be theoretically obtained in such a GaInP NW/Si tandem solar cell, even considering the possible surface and bulk defects in III-V semiconductors [3].
Here we present selective area non-catalytic metalorganic vapour phase epitaxy (MOVPE) of GaAs NWs on Si (111) substrates. We investigate the influence of growth parameters on GaAs NWs grown through the openings in a Si_3N_4 mask with a diameter of 200nm and altering pitch. Optimization of the mask etching process improved the yield of vertical standing NWs, which can be seen by comparing fig.1a with 1b. In order to improve the optical properties of a GaAs NW array we investigated different approaches of surface passivation of GaAs NWs. Figure 1c illustrates a 7 times increase of photoluminescence signal from GaAs NWs after surface passivation with GaP monolayer in-situ the MOVPE chamber.

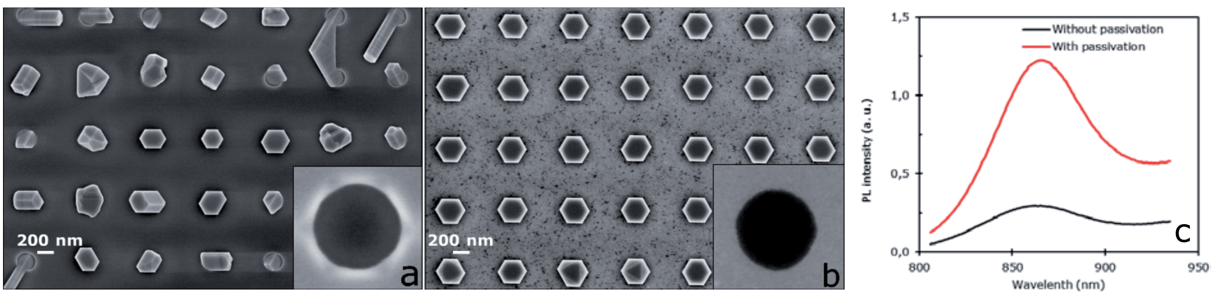


Fig.1. Top view SEM image of GaAs NWs grown on a mask with overetching into the Si substrate – (a) and without overetching - (b). Insets show Si_3N_4 mask opening before growth. (c) Photoluminescence of GaAs nanowires with and without surface passivation.

[1]Zhang, Y., et al. (2015). Journal of Physics D: Applied Physics, 48(46).
[2] Trojnar, et al. (2016). IEEE Journal of Photovoltaics, 6(6), 1494–1501.
[3] Wang, Y., et al. (2015). Nanoscale Research Letters, 10(1), 0–4.

Tunable Diffractive Optical Elements

S. Valyukh[1], A. Rybalochka[2]
[1]Thin Film Physics, IFM, Linköping University, SE-58183 Linköping, Sweden
[2]Lashkaryov Institute of Semiconductor Physics of NASU, Kyiv, Ukraine
email: sergiy.valyukh@liu.se
Telephone: +4613281742

Keywords: diffractive optical elements, liquid crystal, beam steering, augmented reality, lighting

Abstract

Effective and compact non-mechanical active optical elements for control of direction of light propagation are highly required for many applications in optics and photonics. Combination of diffractive optics with liquid crystals offers more degrees of freedom in the optical design and allows new possibilities for hybrid optoelectronic systems with optimized performance, compactness and tunability. There are lenses with variable focal distance, dynamic diffraction gratings, tunable prisms, etc. Among the attractive features of such optical elements are low driving voltage, low energy consumption, relatively low cost, and small sizes. We investigated formation of a desired liquid crystal director distribution by the use of inhomogeneous alignment, i.e. non-uniform the pre-tilt angle and anchor energy. Such an approach enables one to control the optical element by a uniform electric field when only two continues electrodes are needed. Physical limitations and potential abilities of liquid crystal diffractive optical elements will be considered. A reflective spectrally selective lens based on cholesteric liquid crystal, a projection optical system in form of a lens array for an augmented reality display built into a contact lens, and a beam steerer for lighting will be discussed as examples of practical applications.

UTOFIA: Underwater Time-of-Flight Camera for 3D and range extension

Karl Henrik Haugholt[1], Petter Risholm[1], Igor Abrasimov[2], Jonathan Alexander[2], Chris Softley[2], Chris Yates[2], Jostein Thorstensen[1], Jens T Thielemann[1]

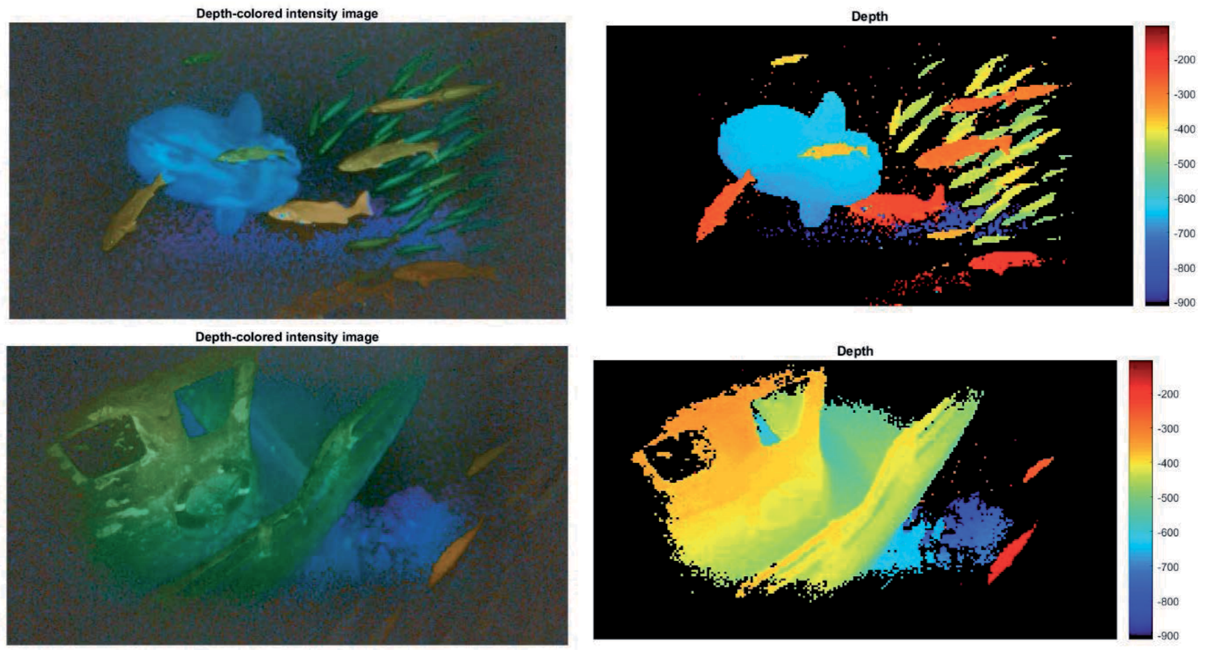
[1]SINTEF Digital, Forskningsveien 1, 0373 Oslo, Norway
[2]Odos Imaging Limited, Scottish Microelectronics Centre, Alexander Crum Brown Road, EH9 3FF, Edinburgh, United Kingdom
email: khe@sintef.no

Telephone: +47 93003539

Keywords: Underwater Imaging, Lidar, Time-of-Flight, Range Gating

Abstract

We present a compact (7 litres), light-weight underwater range gated camera that provides 3D data in real time (>10Hz) and provides extended visibility range in turbid waters. The principle of underwater range gating as well as the system itself is presented, together with recent results of from field trials towards sea bottom inspection and fish monitoring.



Example images with UTOFIA in Nordsoen Oceanarium in Hirtshals. Right images are depth images where depth, from 2 – 9 meters, is colour coded. Depth code is shown in the bars to the right. In the left images depth information is coded in to the regular image to enhance visualization. UTOFIA can capture 3D of objects several meters in extension. Upper images show fishes and lower images a ship wreck.

UTOFIA System Two; subsea camera unit (lower left), topside power, umbilical cable and PC.

Design tool for Time-Of-Flight and Structured-Light based 3D cameras

Gregory Bouquet[1], Jostein Thorstensen[1], Kari Anne Hestnes Bakke[1], and Petter Risholm[1]
[1]SINTEF Digital, Forskningsveien 1, 0373 Oslo, Norway
email:gregory.bouquet@sintef.no
Telephone: 004798230482

Keywords: Three-dimensional image acquisition; Instrumentation; Time-Of-Flight imaging; Structured-Light imaging

Abstract

Active illumination 3D imaging is a set of techniques where distance images are generated through the use of a camera and an illumination source. We can divide this field into two groups of techniques, namely Structured Light (SL), where the distance information is recovered through triangulation, and Time of Flight (TOF) techniques, where the distance information is recovered through the measurement of travel time for a light pulse [1].
Over the last decade, both of these groups have seen an impressive evolution. From a technical point of view, Structured Light techniques have been pushed forward by rapid development in computer performance for distance calculations [2], development of digital projectors (notably Digital Micromirror Device projectors) and high frame-rate, high resolution digital cameras. Time of Flight techniques have been pushed forward through the increasing availability of pulsed illumination sources (notably LEDs with nanosecond pulse duration) and rapid shutter camera chips [3–4].
In this paper, we present a theoretical design tool that allows prediction of 3D imaging precision based on error propagation of shot noise (signal and background) and dark noise (readout noise) inherent in the measurements. Theoretical expressions are developed for both TOF and SL imaging systems. The expressions contain only physically measurable parameters and no fitting parameters. We perform 3D measurements with both TOF and SL imaging systems, showing excellent agreement between theoretical and measured distance precision. The theoretical framework can be a powerful 3D imaging design tool, as it allows for prediction of 3D measurement precision already in the design phase.

References
[1] L. Pérez, Í. Rodríguez, N. Rodríguez, R. Usamentiaga, and D. F. García, Sensors (Basel) 16(3), E335 (2016).
[2] Ø. Skotheim, H. Schumann-Olsen, J. Thorstensen, A. N. Kim, M. Lacolle, K. Haugholt, and T. Bakke, in Proc. SPIE 9393, Three-Dimensional Image Processing, Measurement (3DIPM), and Applications (2015), p. 93930A.
[3] S. J. Kim, S. W. Han, B. Kang, K. Lee, J. D. K. Kim, and C. Y. Kim, "A three-dimensional time-of-flight CMOS image sensor with pinned-photodiode pixel structure," IEEE Electron Device Lett. 31, 1272–1274 (2010).

[4] D. Monnin, A. L. Schneider, F. Christnacher, and Y. Lutz, in 3D Data Processing, Visualization, and Transmission, Third International Symposium on (2006), pp. 938–945.

Single-photon counting 3D Geiger-mode laser radar imaging

Lars Sjöqvist, Markus Henriksson, Per Jonsson
Dept. of Electro-Optical Systems, Swedish Defence Research Agency-FOI
P.O. Box 1165, 581 11 Linköping, Sweden
email: larsjo@foi.se
Telephone: +46709277458

Keywords: Single-photon counting, laser radar, 3D imaging, Geiger-mode, APD

Abstract
Single-photon three-dimensional (3D) laser radar imaging shows interesting features for applications such as e.g. remote object classification and recognition, detection of partly concealed objects, terrain mapping and support to autonomous vehicle navigation. Using a Geiger-mode (Gm) Avalanche Photo Diode (APD) array detector 3D data can be generated with high range resolution and allowing multiple detections with high frame rate. The single-photon sensitivity implies that relatively low laser pulse energy is required. In this work recent activities at FOI using a single-photon Gm-APD laser radar 3D imaging sensor is presented [1,2].

The 3D laser radar utilises a 128×32 Gm-APD InGaAs array detector operating at 90 kHz frame rate and synchronised to a 1542 nm pulsed laser mounted in a bi-static arrangement. The instantaneous angular field of view was 0.5 or 0.25 mrad using a lens with 100 mm focal length in combination with a ×2 extender. An optical interference filter, 15 nm bandwidth, is positioned between the detector and the optics to reduce signals from the background. The sensor was mounted on a rotation stage to provide panoramic acquisition.

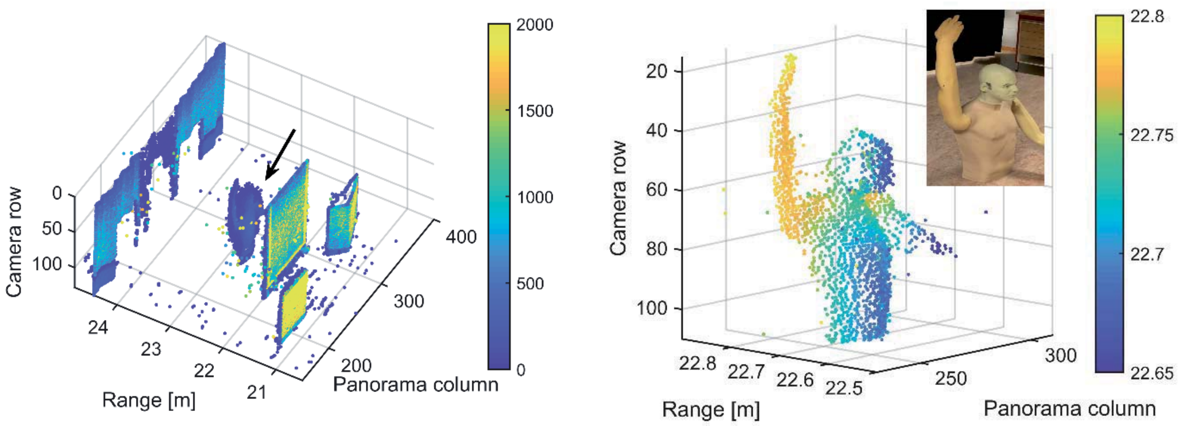


Figure Example of an indoor scene with screens, a mannequin (arrow) and semi-transparent canvas (left). An extracted mannequin hidden behind a semi-transparent canvas (right).

Indoor and outdoor scenes up to 340 m range have been studied to evaluate the sensor performance. The figure shows an example from indoor experiments studying penetration capabilities and range resolution and accuracy. Examples from panoramic outdoor experiments will be presented.

1. P. Jonsson et al., "Experimental evaluation of penetration capabilities of a Geiger-mode APD array laser radar system," Proc. SPIE 10434, 1043405 (2017)
2. M. Henriksson et al., "Photon counting panoramic 3D imaging using a Geiger mode avalanche photodiode array", Submitted to Opt. Engin. (2018)

Previous and current activities within underwater optics and analysis of liquids at Norsk Elektro Optikk

Jon Kristian Hagene[1]
[1]*Norsk Elektro Optikk AS, Norway*
email: jonkr@neo.no
Telephone: +47 900 50 258

Keywords: Underwater optics, laser camera, liquid analysis

Abstract

At the time when Norsk Elektro Optikk (NEO) was founded in 1985 the business plan included consulting services for the offshore oil and gas industry as well as products for optical underwater inspection and communication. High power blue/green lasers were used for testing transmission in water both in a water reservoir in municipal water treatment plant as well as in the sea. A dramatic drop in the oil price shortly after the incorporation of NEO lead to change of plans, underwater optics was put on hold for several years.

However, underwater optics came back and NEO developed an underwater external pipeline inspection system in cooperation with the Norwegian oil company Statoil. This was a system based on line scan cameras depicting pipelines from the outside and line by line. The system improved image quality in particular with regards to backscatter compared to traditional video systems.

This cooperation with Statoil should lead to two new development projects for internal inspection of natural gas pipelines. The first project was focused on internal imaging of natural gas pipelines and was based on line scan cameras and laser illumination. Imagery probably never seen from the inside of natural gas pipelines in operation was the result. The technical success of the first in-line system, lead to a request to measure dimensions and depths of cavities. A second in-line system based on combined 3D profiling and imaging was developed and this system was an alternative to traditional inspection tools.

A new wave in the underwater optics field started with the Norwegian Defense Research Establishment (FFI) lacking optical imaging tools suitable for use on their autonomous underwater vehicle (AUV) Hugin. A very lean joint development project between FFI and NEO resulted in an image mosaicking LED based camera system for use on AUVs. This system has a practical range (altitude) from around 4 to 8 meters in coastal waters. A next step in optical tools for AUVs was a "laser camera" targeting longer ranges (AUV altitudes). A system based on a high output green laser, a laser fan and an area sensor combined with real time signal processing produces a combination of a 3D profile and gray level images of the seabed. The project has met many challenges with regards to testing of the system to demonstrate its potential.

Currently two projects are ongoing involving spectroscopic analysis of liquids for process control and emissions monitoring with potential for other applications. Techniques used are ATR spectroscopy and fluorescence spectroscopy.

Why thermal and gas cameras are so cool
System engineering to user focused solutions

Jonas Sandsten
FLIR Systems Inc.
email: jonas.sandsten@flir.se
Telephone: +46 73 436 26 04

Keywords: Thermal cameras, Gas cameras, Systems Engineering, Long Wave Infrared Radiation (LWIR), Noise Equivalent Concentration Length (NECL), thermal Advanced Driving Assistance System (ADAS)

Abstract

Handheld cameras are everywhere today. Many use them for fun and some utilize them in very many other important human activities. We will present a collage of fascinating applications for thermal and gas cameras. Many have heard stories about people who were lost and then found with thermal cameras from a helicopter or drone. “Man over board!”, is another situation when a thermal signature helps rescue a person. Visualization of hazardous gas guides the gas plant operators to increased situational awareness and therefore the risk for potential disaster is minimized. Solar cells that gets overheated can easily be spotted from a drone equipped with thermal cameras and power line isolators are routinely inspected for abnormal heating with flying cameras. Very quickly we have started to accept autonomous driving systems and they need a multitude of sensors and software to be able to respond swiftly in an extreme variety of situations. The thermal advanced driving assistance system is one of the components needed to make the car autonomous. Later in the collage of applications we will show the thermal anatomy of butterflies freely flying around in the tropical air.

The collage motivates why systems engineering always should strive to have a holistic view and a focus on the solutions for the users in all these applications and many others. We will also touch on the importance of having product owners thinking of the best for the customer and adopt this to real product development. As an example, we will use a gas camera development process and show highlights from the system engineering process leading to an awarded product that customers highly appreciate.

Higher order multipoles in metamaterial homogenization

Christopher A. Dirdal[1], Hans Olaf Hågenvik[2], Haakon Aamot Haave[2], Johannes Skaar[3]
[1]Microsystems and Nanotechnology (MiNaLab), SINTEF Digital
[2]Department of Electronic Systems, NTNU – Norwegian University of Science and Technology.
[3]Department of Technology Systems, University of Oslo
email: christopher.dirdal@sintef.no
Telephone: +47 930 25 739

Keywords: Electromagnetic metamaterials, composite materials, homogenization theory, permittivity, permeability, Maxwell Equations.

Abstract

The rise in diversity and complexity of realizable metamaterial structures have spurred renewed interest into homogenization theories. These are theories that allow for the formulation of *effective* macroscopic Maxwell's equations in structured media from the *exact* microscopic ones, and thereby allow for effective plane wave solutions in materials with complex structures, where dimensions are well below the wavelength.

In contrast to homogenization of conventional media, spatial dispersion is generally significant and higher order multipoles must be considered when describing metamaterials [1]. The magnetic response can be interpreted to be a second order spatially dispersive effect [1-3]. Also, the electric quadrupole and parts of electric octupole and magnetic quadrupole are second order effects, and may be of the same order of magnitude as the magnetic dipole term [1]. However, the presence of higher order multipoles may introduce the need for so-called additional boundary conditions [4-6]. In the general case of weakly spatially dispersive media, it is not clear how to find the additional boundary conditions and associated Fresnel equations for obtaining the transmission and reflection coefficients, which is of particular relevance to designing metasurfaces.

References:

1. Dirdal, C.A., et al., *Higher order terms and locality in metamaterial homogenization.* arXiv:1701.01708, 2017.
2. Landau, L.D., Lifshitz, E.M., and Pitaevskii. L.P., *Electrodynamics of continuous media*. Vol. 8. 2013: elsevier.
3. Silveirinha, M.G., *Metamaterial homogenization approach with application to the characterization of microstructured composites with negative parameters.* Physical Review B, 2007. **75**(11): p. 115104.
4. Agranovich, V.M. and Ginzburg, V.L., *Spatial Dispersion in Crystal Optics*, in *Crystal Optics with Spatial Dispersion, and Excitons*. 1984, Springer. p. 136-270.
5. de Lange, O. and R. Raab, *Electromagnetic boundary conditions in multipole theory.* Journal of Mathematical Physics, 2013. **54**(9): p. 093513.
6. Yaghjian, A. and M. Silveirinha, *Additional boundary condition for electric quadrupolar continua derived from Maxwell's differential equations.* Radio Science, 2016. **51**(8): p. 1312-1321.

Development of industrial Scheimpflug lidar systems

Can T. Xu[1,2], Jesper Borggren[1,2], Magnus Birch[1,2], and Mikkel Brydegaard[1,2,3]
[1]NEOLund AB, Maskinvägen 1, 227 30 Lund, Sweden
[2]Norsk Elektro Optikk AS, Prost Stabels vei 22, 2019 Skedsmokorset, Norway
[3]Lund Laser Centre, Dept. of Physics, Lund University, Sölvegatan 14, 223 46 Lund, Sweden
email: can.xu@neolund.se
Telephone: +46 723 85 18 14

Keywords: lidar, gas sensing, emission sensing, atmospheric sensing, technology development

Abstract

The first Scheimpflug lidar concepts were proposed, developed and demonstrated already in 2013 by Norsk Elektro Optikk AS (NEO). The novel lidar concept allows for significant reduction in size and cost of the system as compared to conventional high-power pulsed systems. For atmospheric monitoring, NEO has during the last 5 years validated its use for, e.g., aerosol monitoring, aerial fauna monitoring, gas sensing and profiling of industrial processes. Today, the NEO industrial activities of Scheimpflug lidar are primarily pursued through the subsidiary NEOLund AB in Lund. NEOLund works closely with the researchers at Lund University and is responsible to integrate the knowledge, NEO intellectual properties, technologies, and research activities of the Lund University lidar group, to implement the crucial and necessary engineering steps to industrialize our lidar systems based on the Scheimpflug concept. Here, we present the NEOLID-S5 atmospheric LIDAR system which, compared to the early research prototypes comprises of complete overhauls of all assemblies, development of new smart control software, laser safety features as well as optimization algorithms.

Title: *Key quality parameters in hyperspectral cameras*

Abstract:
Every Industrial hyperspectral detector on the market can distinguish between an apple and a tomato due to their different spectral signatures, and the typically large number of pixels available on each object. Will this still be the case if the apple and the tomato were only a few pixels large?

In this presentation we will discuss which quality parameters are important and the impact of the different parameters on the processing results. We will also demonstrate that scientific grade data quality is actually needed to get reliable and repeatable processing results.

This submission would probably fit best in the following session: Optical Systems and Applications

Best regards
Trond Løke
CTO - HySpex Division
Norsk Elektro Optikk AS
Prost Stabels vei 22
2019 Skedsmokorset
Phone: +47 67974700 Direct/Mobil: +47 91575342
Skype: trondneo
Web: www.hyspex.no email: trond@neo.no

Poster Presentations

Diagnostics Tool for Cancer Tissues Using Terahertz Spectroscopy Imaging

Leena Al-Ghuraibawi
University of Essex, School of Computer Science and Electronic Engineering, Wivenhoe Park, Essex, CO4 3SQ, United Kingdom
Email: lffalg@essex.ac.uk
Telephone: +447778 189028

Keywords: *Terahertz, imaging spectroscopy, enhanced detector, terahertz photonic devices*

Abstract

The terahertz field science and technology expanded rapidly to touch many areas from basic science to the real applications [1] due to the unique characteristics of this radiation. Terahertz radiation has a very low photon energy, non-ionizing and thus it does consider a sophisticated radiation for biological tissues [2].

By Using a terahertz spectroscopy system for medical imaging applications will lead to enhance the ability for early diagnosis of a diseases. Two kinds of general approach in this research project. The early stage of the research project will include studying the characteristics of tooth decay, the second part, we will propose to use samples of mouth cancer tissue. The early stage of the research project which requires extracted tooth samples. The measurements will be conducted by using a terahertz time domain spectroscopy system which includes a nanowire designed detector and then compare the terahertz spectra results with the conventional imaging system like x-ray imaging. The first part of the measurements will completely be considered as an ex-vivo system.

The extracted tooth will be used in this study as a sample to be tested by using a specific wavelength of laser then acquiring the data with a specific enhanced detector. The tooth will be divided in a number of slides, the thickness of the tooth slide will depend on the terahertz setup dimensions. The analysis to reveal the underlying characteristics of the observed information from the extracted teeth is required for the practical use of the terhertz spectroscopy setup. This will be used as a supporting information for detection the mouth cancer as a second approach.

Later, we will propose to conduct the study as an in-vivo system based on the outcomes of terahertz photonic devices.

References

[1] SS Dhillon, MS Vitiello, EH Linfield, AG Davies, Matthias C Hoffmann, John Booske, Claudio Paoloni, M Gensch, Peter Weightman, GP Williams, et al. The 2017 terahertz science and technology roadmap. *Journal of Physics D: Applied Physics*, 50(4):043001, 2017.

[2] Yiwen Sun, Ming Yiu Sy, Yi-Xiang J Wang, Anil T Ahuja, Yuan-Ting Zhang, and Emma Pickwell-MacPherson. A promising diagnostic method: Terahertz pulsed imaging and spectroscopy. *World journal of radiology*, 3(3):55, 2011.

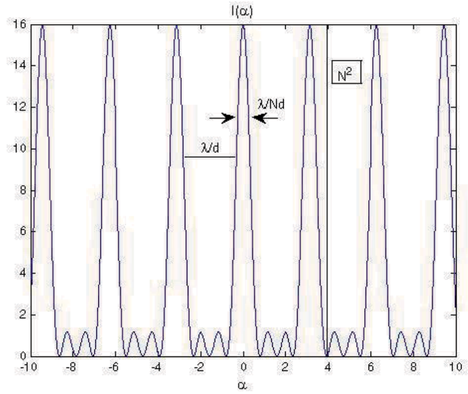
Integrated Optics Based on Nonlinear Optical Diffraction Grating

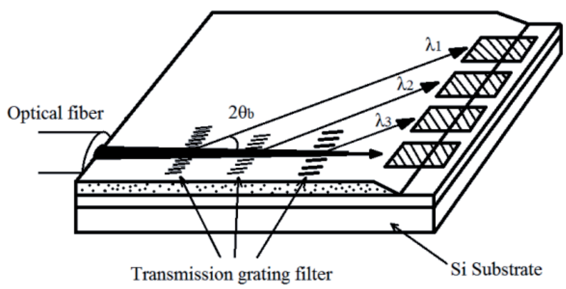
A. C. Amaro de Faria Jr[1,2]
[1]*Institute for Advanced Studies – IEAv, S. J. Campos, SP, 12220-000, Brazil*
[2]*Technological University of Parana - UTFPR, Guarapuava, PR, 85053-525, Brazil*
email: atoni.carlos@gmail.com
Telephone: 55 123947-5540

Keywords: Photonics, Integrated Optics, Optical Fiber Sensors.

Abstract

We designed a sensor based on an optical diffraction grating characterized by a set of slits that one extend regularly through a planar network. An nonlinear incident optical beam is diffracted in each slit producing a scattered optical beam whose relative optical intensity can be controlled by the diffraction grating dimensions and the angle of incidence of the optical beam. The result is an optical beam that produces a precisely localized interference pattern on a particular bulkhead in the device itself. The relative light intensity of the scattered beam is given by $I(\alpha) = I_1(\alpha)\sin^2(N\Delta/2)/\sin^2(\Delta/2)$, with $\alpha=\sin\theta$, θ the angle of direction of the incident optical beam, N is the number of slits, Δ the lag between corresponding points of the two slits and $I_1(\alpha)$ is the intensity of the beam scattered through a slit. We can modulate the signal of the diffracted beam by regulating the dimensions of Δ and N. For $|\Delta| << 1$ and $N >> 1$, for example, we obtain a distribution function of the relative optical intensity of the scattered beam, figure below left. These illumination points may be suitably coupled to a waveguide or to a network of waveguides which will conduct the modulated optical beam from the diffraction point considered. The network has a periodic structure along the plane of the waveguide. The guided modes of the propagating beam are collinearly coupled by the network. The optical beam can reach on the diffraction grating through a waveguide that produces distinct wavelengths by collimating and focusing on a set of photodiodes. The photodiode array may be located appropriately at the points of maximum or minimum optical intensity according to the angular spacing that can be properly regulated: $\Delta\theta = d/\lambda$ where d is the spacing between the slits, as shown in figure below right. These photodiodes can compose an integrated circuit to process the optical signals. Among many applications of this device is the processing and transmission of optical signals to modulation of scattered optical intensity and control of the optical signal from the design of the diffraction grating.





Quantum Control and Processing of Optical Signals

A. C. Amaro de Faria Jr[1,2]
[1]*Institute for Advanced Studies – IEAv, S. J. Campos, SP, 12220-000, Brazil*
[2]*Technological University of Parana - UTFPR, Guarapuava, PR, 85053-525, Brazil*
email: atoni.carlos@gmail.com
Telephone: 55 123947-5540

Keywords: Quantum Optics; Nonlinear Optics; Optical modelling; Optical fiber control; Optical Processing.

Abstract

We present the development of the implementation of quantum control and the processing of optical signals through the scattering of light in optical structures. We describe the method by which the scattering process can be implemented and present the design of a device capable of viable such application from the scattering intensity of the optical signal. The system's implementation mechanism is capable of processing nonlinear optical effects and quantum noise from the propagation of light through an optical structure. The mechanism can innovate applications to optical fiber sensors and signal processing. Quantum control and the processing of optical signals can be conveniently implemented from a description of non-linear optics.

The medium through which the electromagnetic wave propagates responds in various ways to the electromagnetic field. This response depends on how the atoms and molecules are arranged spatially composing the constituent medium and how the interaction or scattering of the electromagnetic wave through the medium will occur. In other words the way the medium responds to the electromagnetic excitation is contained in the medium polarization due to the propagation of the electromagnetic wave. It is in this context that some recent analyzes have discovered some solutions from the nonlinear response of the optical material to the propagation of the electromagnetic wave which may lead to an approach of some quantum effects from a nonlinear treatment of electromagnetism in the propagation medium.

The propagation of optical pulses through waveguides such as optical fibers and optical structures can give rise to nonlinear optical effects and quantum effects. The appropriate modelling of these effects can be used for the development of optical control devices and sensors to the optical fiber whose resolution can be regulated properly. In addition, the method allows the selection of propagation modes by selecting the desired modes by knowing the Band Gap of the waveguide or the photonic crystal.

The development of optical fiber sensors and optical processors with the purpose of optical control is based on the propagation of optical pulses through waveguides as optical fibers and photonic crystals. The propagation of the pulses through these suitable optical structures can generate nonlinear and quantum effects as Raman and Brillouin scatterings. We have analytically modeling these effects from the nonlinear optics equations on dielectric media describing the propagation of these optical pulses by developing a model that can be implemented computationally for the processing and propagation of these optical signals.

Spherical whispering gallery mode resonators covered by ZnO nanolayer

Aigars Atvars[1], Roman Viter[1], Igor Iatsunslyi[2], Inga Brice[1], Karlis Grundsteins[1], Andra Pirktina[1] and Janis Alnis[1]
[1]Quantum Optics Laboratory, Institute of Atomic Physics and Spectroscopy, University of Latvia, Raina Blv. 19, Riga, LV-1586, Latvia
[2]NanoBioMedical Centre, Adam Mickiewicz University, 85 Umultowska str., 61-614, Poznan, Poland
email: Aigars.Atvars@lu.lv
Telephone: +37125986724

Keywords: whispering gallery mode resonator, atomic layer deposition, ZnO

Abstract
Whispering gallery mode (WGM) resonators are solid-state cavities made in a curved form, such as ball, disk or toroid, that create conditions for the light to travel around the perimeter of the structure by experiencing a total internal reflection. A light can be introduced in the resonator by prism or optical fiber. Such resonators can be used as optical frequency filters or biosensors [1] as they have specific optical resonances that shift if the change is experienced in the refraction index of the resonator or media, or the size of the resonator.
The current study explores effects observed in spherical WGM resonators when they are covered by ZnO nanolayers (Fig. 1a). Resonators were made from 125 μm SMF-28 single mode optical fiber by using a hydrogen flame. Resonators of diameters ~ 0.5 mm were obtained. Atomic layer deposition technique was used to cover resonators with ZnO nanolayers of 5, 10, 20 and 100 nm thickness. Results show that the sharpest resonances (in the region of 780 nm) are seen when 20 nm ZnO nanolayer is used (Fig. 1b). It was observed that resonators covered with ZnO, unlike uncovered resonators, are not electrically attracted to the surface of prisms, which is an advantage for finding the best prism-resonator coupling distance.

Figure 1. Resonator covered by 20 nm ZnO nanolayer. (a) a photo of the resonator and a coupling light, (b) irregular resonances observed (blue line).

Acknowledgements: The research of Riga group was financed by ERDF project No. 1.1.1.1/16/A/259.

[1] Brice, I., Pirktina, A., Ubele, A., Grundsteins, K., Atvars, A., Viter, R., & Alnis, J. (2017). Development of optical WGM resonators for biosensors. Proceedings of SPIE, Vol. 10592, 2017, Article number 105920B.

Event modeling for light scattering in nonhomogeneous semi-ordered materials

A. Baitenov, E. Vasileva, M. Yan, I. Sychugov, Y. Li, H. Chen, L. Berglund, S. Popov
KTH, Stockholm, Sweden
email: baitenov@kth.se
Telephone: +46769487009

Keywords: Simulations, Computational physics, Light scattering, Nonhomogeneous materials, Mie theory

Abstract

There exist multiple models developed in order to study light scattering in different homogeneous and periodic media. Lately, more work on nonhomogeneous, fibrous materials is being done. Asymmetric, semi- or quasi- periodic structure is one of the important features of that type of materials. That kind of structures are encountered in biological tissues, transparent paper and wood, as well as in systems where scattering elements are suspended in liquid. We present a model based on the probability distributions calculated using Mie theory for 2D case for simulating the light scattering by nonhomogeneous semi-ordered materials like transparent wood. Such materials include scattering elements of different scales in semi-periodic fashion requiring inclusion of the size distribution and positional distribution of scattering elements. Results of the simulation for transparent wood are presented with distribution parameters corresponding to balsa wood template. Produced results are compared with experimental results and analyzed.

3D imaging of hydroxyl radicals in a gliding arc discharge in single shot

Yupan Bao[1], Karolina Dorozynska[1], Panagiota Stamatoglou[1], Chengdong Kong[1], Jianfeng Zhou[1], Sebastian Pfaff[1], Johan Zetterberg[1], Mattias Richter[1], Marcus Aldén[1], Elias Kristensson[1], Andreas Ehn[1]
[1]Lund University, Sweden
email: yupan.bao@forbrf.lth.se
Telephone: 0735047870

Keywords: 3D image, gliding arc discharge, Planar Laser-induced fluorescence

Abstract

Instantaneous three-dimensional (3D) representation of hydroxyl radicals (OH) in the vicinity of a gliding arc discharge is here presented. As a non-equilibrium plasma with relatively high electron-temperature and density, gliding arc discharge has been widely utilized in various plasma chemical processing applications [1]. The gliding arc plasma is initiated and sustained between two diverging electrodes by an alternating current power source (35 kHz). A gas flow between the electrodes cause the gliding arc plasma to extend into a diffuse glow type gliding arc discharge. The 3D data is reconstructed by four planar laser-induced fluorescence (PLIF) images of OH that were acquired with a technique called Frequency Recognition Algorithm for Multiple Exposures (FRAME). In 3D FRAME, instantaneity of the data sampling is achieved by capturing four PLIF images, which are induced by laser sheets originated from the same laser pulse, within one acquisition. Being spatially tagged with different spatial modulation frequencies, the four images can be identified and separated in the post processing with the FRAME algorithm [2]. An example of the instantaneously acquired 3D image of the OH distribution around the gliding arc is shown in Figure 1 where the structure of the gliding arc discharge channel is revealed. The FRAME concept, as well as the gliding arc, is investigated in different conditions and configurations.

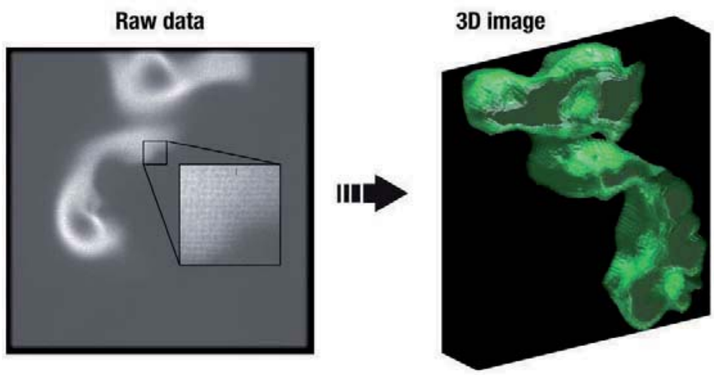


Figure 1. Raw data together with the corresponding 3D image of the OH distribution around the gliding arc, captured instantaneously using FRAME.

[1] Fridman, Alexander, et al. "Gliding arc gas discharge." Progress in Energy and Combustion Science 25.2 (1999): 211-231.
[2] Kristensson, Elias, et al. "Instantaneous 3D imaging of flame species using coded laser illumination." *Proceedings of the Combustion Institute* 36.3 (2017): 4585-4591.

The Optimization of Pulse Compression for Compact High Energy Femtosecond Fiber Laser with CVBG Compressor

T. Bartulevicius[1,2], L. Veselis[1,2], K. Madeikis[1,2], A. Michailovas[1,2], and N. Rusteika[1,2]
1. Ekspla Ltd, Savanoriu ave. 237, LT-02300 Vilnius, Lithuania
2. Center for Physical Sciences and Technology, Savanoriu ave. 231, LT-02300, Vilnius, Lithuania
email: t.bartulevicius@ekspla.com
Telephone: +37062851953

Keywords: Ultrafast laser, ytterbium fiber laser, pulse compression, volume gratings.

High energy ultrashort pulse fiber chirped pulse amplification (FCPA) systems are increasingly attractive for applied science and technology applications. FCPA systems, which use traditional diffraction grating stretchers and compressors, are quite bulky due to large physical size required for stretching and compression of laser pulses of hundreds of picoseconds in duration. To overcome this practical limitation, this task can be performed in ultrafast fiber laser configuration using chirped fiber Bragg grating (CFBG) as pulse stretcher and chirped volume Bragg grating (CVBG) as pulse compressor as it was proposed in [1]. However, in this demonstrated system, compressed pulses were not transform-limited and had residual non-compressed pedestal due to the lack of management of higher order dispersion in the system.

In this work, we presented compact FCPA system consisting of CVBG compressor and CFBG stretcher that was manufactured with matched chromatic dispersion profile to achieve high fidelity compression of femtosecond pulses [2]. Additionally dispersion of the FCPA system was fine-tuned by means of controlling temperature patch along CFBG stretcher instead of cutting back of the fiber while minimizing the recompressed pulse duration. In this contribution, we demonstrate a compact high-energy fiber laser producing up to 10 μJ energy (26 MW peak power) and ~350 fs duration pulses. High fidelity femtosecond pulses were achieved by tuning second and third order dispersion by implementing nonlinear thermal gradient along the CFBG stretcher. This FCPA configuration opens path to truly compact, robust and environmentally stable high energy fiber laser sources which could be used for efficient parametric wavelength conversion, various imaging applications requiring moderate average power and as a seed source in high power high energy femtosecond CPA laser systems. Detailed information about numerical calculations for optimization of ultrashort pulse compression and high energy FCPA system will be presented at the conference.

References

[1] S. Frankinas, A. Michailovas, N. Rusteika, V. Smirnov, R.Vasilyeu, A.L. Glebov, "Efficient Ultrafast Fiber Laser Using Chirped Fiber Bragg Grating And Chirped Volume Bragg Grating Stretcher/Compressor Configuration," Proc. of SPIE **9730** 973017-1-6 (2016).
[2] T. Bartulevicius, S. Frankinas, A. Michailovas, R. Vasilyeu, V. Smirnov, F. Trepanier, and N. Rusteika, "Compact fiber CPA system based on a CFBG stretcher and CVBG compressor with matched dispersion profile," Opt. Express **25**, 19856-19862 (2017).

COMBINED LASER-INDUCED INCANDESCENCE AND ELASTIC LIGHT SCATTERING FOR THE STUDY OF THE INFLUENCE OF METALS ON SOOT FORMATION

J. Simonsson, N.-E. Olofsson, A. Hosseinnia, H. Bladh, P.-E. Bengtsson

Division of Combustion Physics, Department of Physics,
Lund University, Lund, Sweden

email: per-erik.bengtsson@forbrf.lth.se
Telephone: +46 46-222 3109

Keywords: laser-induced incandescence, elastic light scattering, extinction, soot, potassium chloride, coherent anti-Stokes Raman spectroscopy

Abstract

An experimental investigation has been performed where the influence of metal salts on soot formation has been studied. By combining two-dimensional laser-induced incandescence (LII) and elastic light scattering (ELS), two-dimensional information could be obtained on soot properties in the flames. For these studies, seven metal salts (NaCl, MgCl2, AlCl3, KCl, CaCl2, FeCl3 and ZnCl2) were dissolved in water and aspirated into a premixed ethylene/air flame. At lower flame heights, in the soot inception region, the LII signal (representing soot volume fraction) was marginally affected by all additives, whereas the ELS signal strongly decreased with increasing additive concentration for the alkali salts. At higher heights, in the soot growth region, the soot volume fractions were lowered for the addition of potassium, calcium and sodium chloride, in order of significance. Some of the salts (MgCl2, AlCl3 and FeCl3) resulted in negligible influence on LII signals and slightly higher ELS signals throughout the flames, and we relate these signals to salt particles propagating through the flame. Main focus in our study was on the addition of potassium chloride for which several parameters were investigated. For example, soot primary particle sizes were evaluated using combined LII and ELS, showing decreasing particle sizes for increasing concentrations of potassium, in reasonable agreement with particle sizes evaluated using transmission electron microscopy. Also, CARS thermometry showed slightly higher flame temperature, ~ 30 K, for the potassium-seeded flame compared to the reference flame.

Towards ultraviolet and blue microcavity lasers

Michael A. Bergmann, Filip Hjort, Ehsan Hashemi, David Adolph, Martin Stattin, Tommy Ive, Jörgen Bengtsson, Johan Gustavsson and Åsa Haglund
Photonics Laboratory, Department of Microtechnology and Nanoscience, Chalmers University of Technology
email: michael.bergmann@chalmers.se
Telephone: 0317721888

Keywords: ultraviolet, blue, microcavity laser, DBR, electrochemical etching

Abstract

The development of III-nitride-based (Al,Ga,In(N)) microcavity lasers is a challenging task. Significant progress in recent years has resulted in realizations of electrically pumped devices with optical output power in the mW-range and with threshold current densities below 20 kA/cm^2. However, to become practical, the lifetime and power conversion efficiency of these devices must be improved. Among the challenges are achieving transverse optical mode confinement, high-reflectivity mirrors and control over the resonator length.

We will highlight our theoretical work on transverse optical mode confinement, emphasising the overwhelming risk of ending up with an optically anti-guided cavity, and its consequences such as very high optical losses that easily could double the threshold gain for lasing. We will show some anti-guided cavities with reasonable threshold gain and built-in modal discrimination. However, all anti-guided cavities are very sensitive to temperature effects and small structural changes in the cavity caused by fabrication imperfections.

We have explored electrically conductive distributed Bragg reflectors (DBRs) in both AlN/GaN and ZnO/GaN. The AlN/GaN DBRs were grown with different strain-compensating interlayers, and the DBR without interlayers had the lowest vertical resistivity with a specific series resistance of 0.044 $\Omega\,\mathrm{cm}^2$ for eight DBR-pairs. In the ZnO/GaN DBR, the measured resistance was dominated by lateral and contact contributions, setting a lower measurable limit of $\sim 10^{-4}\,\Omega\,\mathrm{cm}^2$ for three DBR-pairs. Numerical simulations show the importance of having in-plane strained layers in the ZnO/GaN DBR, since that leads to cancellation of the spontaneous and piezoelectric polarization. This results in a dramatically reduced vertical resistance, potentially three orders of magnitude lower than what could be measured.

An alternative to an epitaxially grown DBR is a dielectric DBR, which offers high reflectivity over a broader wavelength range, relaxing the requirements on resonator length control. To deposit a dielectric DBR on the bottom side of the cavity, the sample must first be bonded to a carrier wafer before the substrate can be removed. We used thermocompression gold-gold bonding to successfully bond the laser structure to a Si carrier wafer. The subsequent substrate removal is a challenging process due to the chemical inertness of the III-nitride-based materials. A doping-dependent electrochemical etch technique was used, which allows for the selective removal of a sacrificial (n-doped) layer between the cavity and the substrate. This resulted in nm-precise cavity lift-off with a low root-mean-square surface roughness down to 0.3 nm. Thus, the process is suitable for the fabrication of high-quality optical devices such as microcavity lasers. In addition, the technique offers a new alternative to create III-nitride-based optical resonators, mechanical resonators, thin film LEDs and transistors.

Laser-based measurements of quantitative species concentrations in gas phase

Christian Brackmann, Haisol Kim, Jim Larsson, Joakim Bood and Marcus Aldén
Division of Combustion Physics, Lund University
email: christian.brackmann@forbrf.lth.se
Telephone: 0462224962

Keywords: laser diagnostics, Raman spectroscopy, laser-induced fluorescence, gas phase, combustion

Abstract

Laser-based methods have for long time been utilized for non-invasive diagnostics of combustion processes and flow velocities, temperatures, concentrations of chemical species and particles can all be measured with excellent spatial and temporal resolution. However, quantitative measurements of species concentrations still represent a significant challenge but are nevertheless crucial for development and validation of computational models. Such models for simulations are effective tools for optimization to obtain efficient combustion with minimized levels of pollutant emissions. Raman spectroscopy and Laser-induced fluorescence (LIF) are commonly employed methods for measurement of chemical species that both present challenges to achieve true quantitative concentrations. Raman spectroscopy, based on instantaneous inelastic scattering of laser photons, permits simultaneous measurement of multiple species, but low signals limit detection sensitivity and make the method sensitive to backgrounds and interferences. For LIF, detection sensitivity can be very high but the fluorescence yield is dependent on intermolecular collisions in turn governed by colliding partner molecule, pressure and temperature.

This work presents method development to handle these limitations and examples of combustion studies with quantitative species concentrations measurements. The improved Raman spectroscopy setup is based on a high-power Nd:YAG laser of kHz repetition rate, arranged in multiple-passage configurations (cf. Fig. 1a) combined with sensitive detection and filtering. Quantitative LIF measurements have been achieved using excitation with picosecond laser pulses and time-resolved detection to determine fluorescence quantum yield *in situ* and thereby also the concentration of the probed species. A measured fluorescence decay curve for the hydroxyl (OH) radical, a key species in combustion, is shown in Fig. 1b.

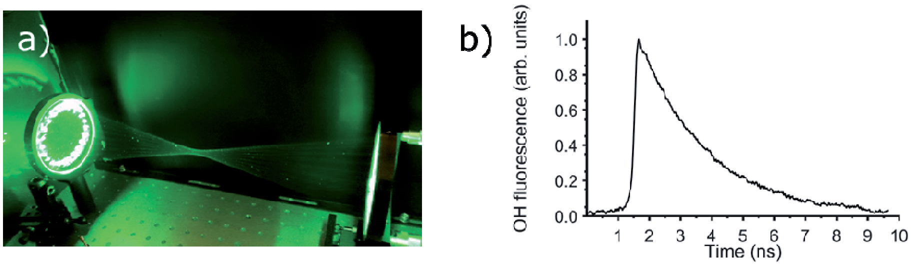


Figure 1. a) Raman spectroscopy setup with multiple passage arrangement of the laser beam. B) Decay curve for laser-induced fluorescence of the OH radical.

Ridge waveguides in $LiNbO_3$ for efficient nonlinear optical conversion

Cristine Calil Kores[1], Hoda Kianirad[1], Carlota Canalias[1], Fredrik Laurell[1]
[1]Dept. of Applied Physics, KTH–Royal Inst. of Technology, Roslagstullsbacken 21,10691 Stockholm, Sweden
email: cck@kth.se
Telephone: 073 765 2263

Keywords: Lithium niobate, waveguides, nonlinear optics.

Abstract

Lithium niobate ($LiNbO_3$) has proven a reliable platform for nonlinear optics, because of large coefficients of its χ^2 tensor which can be explored in periodically-poled crystals for processes such as second-harmonic generation, optical rectification, Pockels effect, sum- and difference-frequency mixing, and optical parametric amplification.

Nonlinear optical conversion in waveguides scales quadratically with the interaction length, while the scaling is linear in a bulk crystal driven by a focused Gaussian beam. However, the challenges of producing low-loss waveguides with preserved χ^2 and high mode confinement still have to be overcome [1] in order to produce efficient devices.

We report the development of ridge waveguides in z-cut $LiNbO_3$, through a 3-step process (fig. 1): proton exchange for the fabrication of a planar waveguide, annealing for restoring the d_{33} coefficient, and finally dicing with a circular diamond blade for the fabrication of ridge waveguides. We optically characterize the waveguides in terms of the refractive index profile, d_{33} coefficient and imaging of the single transverse mode at 633 nm.

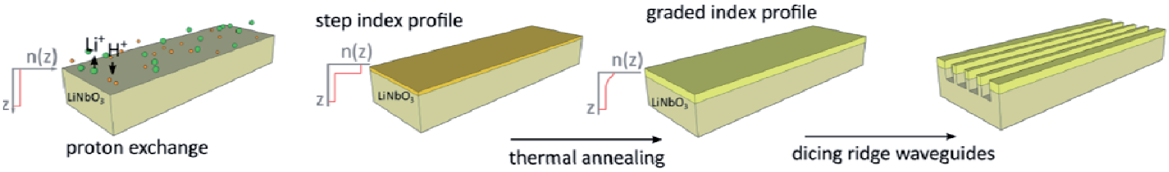


Fig 1. Fabrication steps of the annealed proton exchanged ridge waveguides in $LiNbO_3$

[1] Bazzan, M. and Sada, C., "Optical waveguides in Lithium niobate: recent developments and applications", Appl. Phys. Rev. 2, 040603 (2015)

RAMAN SPECTROSCOPY ON SOOT PRODUCED FROM A MINI-CAST SOOT GENERATOR: IMPACT ON STRUCTURE FROM HEATING IN AIR AND NITROGEN UP TO 900 °C

Kim Cuong Le[1*], Sandra Török[1], Thomas Pino[2], Per-Erik Bengtsson[1]

[1]*Division of Combustion Physics, Department of Physics, Lund University, Lund, Sweden*
[2]*Institut des Sciences Moléculaires d'Orsay, Univ. Paris-Sud, Université Paris-Saclay, Orsay, France*

email: thi_kim.cuong_le@forbrf.lth.se
Telephone: +46 46-222 93 60

Keywords: Raman spectroscopy, soot, laser-induced fluorescence, mini-CAST

Abstract

Soot is formed from incomplete combustion and can when freshly emitted to the atmosphere show a variety in its characteristic properties: size, morphology, internal structure, optical properties. The characteristic properties of soot depend on various parameters in the combustion process such as the fuel and type of combustion process as well as on the time and temperature history. In this work a mini-CAST soot generator was used to produce soot within a range of sizes and optical properties, and the produced soot was sampled at heated in an inert atmosphere up to 900 °C. Optical studies were performed on the soot samples during this heat treatment to study how the internal bonding structure of soot is affected in order to gain knowledge about maturation in soot formation processes. Raman spectroscopy was used to probe the structural changes through intensity changes in the observed Raman lines. Also, laser-induced fluorescence was used as a diagnostic tool to study the evanescence of the organic fraction (containing polycyclic aromatic hydrocarbons (PAHs)) of the soot during heating. This study is also extended into high-resolution transmission electron microscopy (HRTEM) images of heated soot. The outcomes are very promising to unveil soot structures including soot cores and organic fractions, and we observe an increased graphitization with increasing heating temperatures.

Illumination Pattern Estimation for Multiple Exposures Extraction in a Snapshot Imaging Technique

Karolina D. Dorozynska and Elias Kristensson
Department of Combustion Physics, Lund University, 223 63 Lund, Sweden.
email: karolina.dorozynska@forbrf.lth.se
Telephone: 0046703590295

Keywords: Phase, Multispectral Imaging, Snapshot, Structured Illumination.

Abstract

We present an improvement to the snapshot imaging technique, FRAME (Frequency Recognition Algorithm for Multiple Exposures), where the phase information is included in the illumination pattern estimation for image extraction. This can potentially improve the image storage capacity and resolution.

FRAME uses structured illumination in order to record multiple exposures of various different sample information in a snapshot. FRAME currently only considers the spatial frequency of the illumination pattern, and its orientation, when extracting different exposures in the Fourier Domain. By ignoring the phase of the illumination pattern, FRAME may suffer from inaccuracies in the image reconstruction as well as the incorporation of unnecessary cross-talk. An accurate estimation of the illumination pattern can therefore lead to more robust image extraction in the FRAME algorithm where there is potential to increase the image storing capacity and spatial resolution.

Figure 1. (a) A simulated example of a sample (here a photographer) being imaged using a modulated illumination pattern, with a non-constant phase. (b) A constant frequency modulation pattern with zero phase used to demodulate the simulated image. (c) An arbitrary phase intensity distribution for simulation purposes. (d) A modulation pattern which is described by the phase given in (a) and the frequency and angle given in (b).

Figure 1(a) shows a simulation example of a captured FRAME image with one illumination source. In order to demodulate this image, reference matrices describing the spatial frequency and rotation are used. Figure 1(b) illustrates the illumination pattern where the spatial frequency and angle are described and the phase is set to zero. By setting the phase in the captured image to an arbitrary constant value and using an illumination pattern with no phase contribution means that the latter is not being correctly described. Figure 1(c) describes a phase intensity profile, which in conjunction with the spatial frequency and angle information given in figure 1(b), correctly describes the illumination pattern used in figure 1(a). This full description of the illumination pattern is given by figure 1(d).

If the illumination pattern can be fully described with the inclusion of the phase description then the phase could be used as an additional parameter in the encoding stage. This could result in image artifacts being reduced or removed and increased image storing density, which in turn can be used to obtain more temporal, spatial (resolution and volumetric) or spectral information about the sample(s).

Investigation on Raman scattering and stray light suppression in spectroscopy using periodic shadowing

Miaoxin Gong[1], Haisol Kim[1], Jim Larsson[1], Christian Brackmann[1], Elias Kristensson[1], Andreas Ehn[1], Marcus Aldén[1]
[1]Affiliation 1 Division of Combustion Physics, Lund University
email: miaoxin.gong.7113@student.lu.se
Telephone: +46736865204

Keywords: Raman spectroscopy, stray light suppression, periodic shadowing, molecular physics

Abstract

Stray light is known as a strong interference in spectroscopic measurements which causes spectral distortion and leads to inaccurate measurement data. A general solution to this problem is a method named periodic shadowing (PS). The fundamental idea of PS is mainly based on lock-in amplification where photons that enter the spectrometer through the entrance slit are tagged with a predefined pattern. The stray light does not maintain this pre-defined pattern during its passage through the spectrograph and will, in contrast to the signal photons, appear as a wavelength-dependent intensity offset at the detector. This distinction allows the signal photons to be identified and separated from the stray light, both in one- and two-dimensional measurements, using a post-processing routine.

As an often-used laser-diagnostic method, Raman spectroscopy suffers significantly from stray light that is caused by the intense elastic Rayleigh and Mie scattering as well as reflections. Especially in the low-wavenumber Raman shift region, where rotational transitions are located, the spectral lines are severely affected by stray light.

This current investigation utilizes a high-repetition-rate laser system to maximize average laser power but still provides the ability to suppress continuous background signals with gated detectors. Periodic Shadowing is tested in this experimental configuration to minimize the effect of stray light in Raman spectroscopy measurements.

Electron acceleration and x-ray emission from interacting wakefields

I. Gallardo González[1], H. Ekerfelt[1], J. Björklund Svensson[1], G. Gatti[2], A. Gonoskov[3,4,5], D. Guenot[1], M. Hansson[1], M. Marklund[3], J. A. Pérez-Hernández[2], C. Salgado[2], E. Wallin[3], G. Zeraouli[2] and O. Lundh[1]*
[1]Department of Physics, Lund University, PO Box 118, SE-22100 Lund, Sweden
[2]Centro de Láseres Pulsados (CLPU), Parque Científico, E-37185 Villamayor, Salamanca, Spain
[3]Department of Physics, Chalmers University of Technology, SE-41296 Göteborg, Sweden
[4]Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod 603950, Russia
[5]University of Nizhny Novgorod, Nizhny Novgorod 603950, Russia
email: isabel.gallardo@fysik.lth.se
Telephone: 0462227597

Keywords: laser wakefield acceleration, betatron radiation, interacting wakefields

Abstract

The small-angle interaction of two plasma waves, generated by laser wakefield acceleration [1], is experimentally studied. A 150 TW laser, with a pulse duration of 27 fs FWHM, is split in two halves and focused in a gas mixture of helium and nitrogen. Each individual laser pulse forms a plasma and generates a plasma wave, which traps and accelerates electrons to relativistic energies by laser wakefield acceleration. The transverse oscillations of the accelerated electrons, induced by the acceleration process, also produces X-ray radiation [2]. The interaction of the two plasma waves is modified by either delaying one of the laser pulses with respect to the other or by shifting the collision point of the wakefields. The properties of the emitted electron beams and the X-ray radiation are studied for different interaction conditions.

[1] T. Tajima and J.M. Dawson, "Laser electron accelerator", Phys. Rev. Lett. **43**, 4 267-270 (1979)

[2] S. Corde, K. Ta Phuoc, G. Lambert, R. Fitour, V. Malka, A. Rousse, A. Beck and E. Lefebvre, "Femtosecond x rays from laser-plasma accelerators", Rev. Mod. Phys. **85**, 1 (2013)

Modeling of Electrically Triggered Tunable Magnetic Metamaterial Hat for Multifunctional Control in MRI applications

Dr. Hassan Ali[1,2,3,4], Professor Dr. Xiangwei Zhao[1], Professor Dr. Remo Proietti Zaccaria[2], Professor Dr. Erik Forsberg[3], Professor Dr. Muhammad Kamran[4]

[1]School of Biological Science & Medical Engineering, South East University, Nanjing, China, [2]The Ningbo Institute of Industrial Technology (CNITECH), Ningbo, China, [3]Center of Optical & Electromagnetic Research, Zhejiang University, Hangzhou, China, [4]University of Engineering & Technology (UET), Department of Electrical Engineering, Lahore, Pakistan
Corresponding Author e-mail: drali@zju.edu.cn
Cell Phone #: 00923233261974

Keywords: Hybrid materials, Magnetic negative permeability materials, Tunable hybridized magnetic metamaterial hat (THMMH).

Acquisition of images without surgical interposition into human body was possible due to magnetic resonance imaging {MRI} mechanism. We introduced noteworthy properties of specific combination of copper surface coils as tunable hybridized magnetic metamaterial hat {THMMH}. In THMMH, some of surface coils slots, which were loaded with capacitor elements and parallel merger of discrete edge ports as externally applied sinusoidal steady state current source {I_S}. We highlighted the significance of I_S , as it could made the design tunable, and reconfigurable without any requirement of its re-designing / re-fabrication. Efficiency comparison between THMMH and previously reported work {un-tunable hybridized magnetic metamaterial hat , HMMH} was analyzed. We concluded that THMMH exhibited better magnetic field {*B*-field} and SNR into region of interest {ROI} at rat's brain, as well as shown strong resonance in comparison to previously reported work on rat's brain imaging for 7-T MRI. In addition, THMMH excited two Eigen modes simultaneously, which exploited its properties as hybridized magnetic material. Furthermore, relative negative permeability, μ_r= -3.5+j20.2 for THMMH as case-I and μ_r= -5.5+j36.3 for un-tunable HMMH as case-II was achieved at 300 MHz for 7-T MRI and for comparison purpose.

Rotational CARS Thermometry and Concentration Measurements in Ethylene-Nitrogen Mixtures

Ali Hosseinnia[1], Maud Rotger[2], Cyril Richard[3], Vincent Boudon[3], Joakim Bood[1], Per-Erik Bengtsson[1]

[1.] Combustion Physics, Department of Physics, Lund University, Sweden

[2.] University of Reims Champagne Ardenne, Moulin de la Housse, France

[3.] Laboratoire Interdisciplinaire Carnot de Bourgogne, France

email: ali.hosseinnia@forbrf.lth.se

Telephone: +46703625224

Keywords: (Rotational CARS, Thermometry, Ethylene, Fourier analysis)

Abstract

Rotational CARS has during the last decades been an indispensable diagnostic tool for thermometry and concentration measurements in combustion relevant processes. So far, the majority of diatomic and triatomic species involved in combustion have been probed and studied using rotational CARS. However, less attention has been paid to hydrocarbon fuel molecules. Nevertheless, among commonly used hydrocarbons in combustion, the potential of using rotational CARS of acetylene (C_2H_2), and ethane (C_2H_6) for thermometry and relative concentration measurements have been demonstrated successfully. Ethylene (C_2H_4), gives a relatively high rotational CARS signal which is comparable with the nitrogen signal. Moreover, it is vastly used in laminar flame studies, and especially in sooting flames as the most common reference fuel. Although the pure rotational CARS spectrum of ethylene, as an asymmetric-top molecule, at room temperature has been studied and discussed to some extent, its possible applications in combustion diagnostics have not been fully explored yet.

In this work we have investigated the potential of thermometry and relative concentration measurements in mixtures of ethylene and nitrogen, using pure rotational CARS. Experimental data have been recorded at eight temperatures between 300 K and 900 K and for ethylene concentrations from 20 to 100 %.

The data confirms that the spectra of nitrogen and ethylene are largely superimposed. Moreover, high temperature sensitivity is clearly evident in the ethylene spectra, which is of interest for combustion diagnostics. For spectral fitting, a theoretical model which fairly can predict rotational CARS spectra of pure ethylene at different temperatures has been provided by Raballand et al.[1]. Although the model can calculate the energy eigenvalues quite precise, the line intensities do not fully resemble the experimental data. Part of this discrepancy may be due to lack of knowledge in collisional line broadening parameters of ethylene. This model is being improved by comparing with the carefully recorded experimental data. As an alternative method, the potential of employing Fourier analysis, which has been developed in our recent work for ethane/nitrogen thermometry[2], is being investigated. At last, in more practical experiments, measurements will be done in an ethylene diffusion flame to demonstrate the developing methods.

References

[1] W. Raballand, M. Rotger, V. Boudon, M. Loëte, "Spectroscopy of X2Y4 (D2h) molecules: tensorial formalism adapted to the O (3)# D2h chain, Hamiltonian and transition moment operators. " J. Mol. Spectrosc. 217. (2003); 239-248

[2] A. Hosseinnia, E. Nordström, H. Fatehi, J. Bood, P-E. Bengtsson, "Rotational CARS thermometry and concentration measurements in ethane-nitrogen mixtures using Fourier analysis". J Raman Spectrosc. (2018); DOI: 10.1002/jrs.5339

Optical photoswitching of symmetric dimethyldihydropyrene derivatives

Renata Karpicz[1], Irena Kulszewicz-Bajer[2]
[1]Center for Physical Sciences and Technology, Sauletekio ave. 3, LT-10257 Vilnius, Lithuania
[2]Warsaw University of Technology, ul. Noakowskiego 3, 00-664 Warszaw, Poland
email: renata.karpicz@ftmc.lt
Telephone: +370 5 261 9656

Keywords: dimethyldihydropyrene, photochromism, spectroscopic properties

Abstract

Molecular switches can be commonly applied to control different functions and properties of materials which can be used in organic electronics (as for example in new memory elements based on single molecule) or in biology to manipulate the biological systems. Photochromism of dimethyldihydropyrene derivatives is a reversible transformation under UV and visible light irradiation between two, open-ring hexatriene and closed-ring cyclohexadiene, isomers with different spectroscopic properties. Usually, the optical-active derivatives of diarylethene were fluorescent in the open-ring state and non-fluorescent in the closed-ring form.
New dimethyldihydropyrene derivatives were synthesized, and their optical properties as well as excited state dynamics were investigated in the solutions. We focus on the emissive properties of dimethyldihydropyrene derivatives with the possibility to switch them between fluorescent and non-fluorescent states. During the first 100-300 ps after excitation under visible light the closed-ring cyclohexadiene isomer were opened. Reverse transformation took place through intermediate stage during several picoseconds.

Single Ion Detection of Cerium for use as a Quantum State Probe

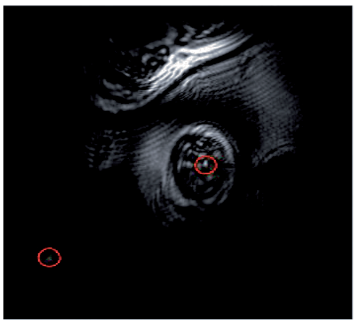
Vassily Kornienko[1], Adam Kinos[1], Stefan Kröll[1], Ivan Scheblykin[2]
[1]Division of Atomic Physics, Lund University
[2]Division of Chemical Physics, Lund University
Email: nat13vko@student.lu.se
Telephone: 0709657495

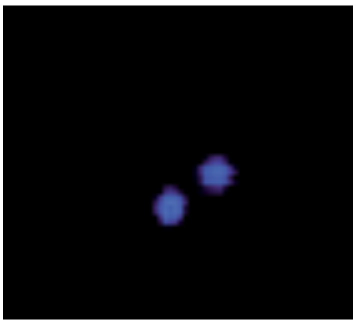
Keywords: (Quantum Computing, Rare earth ion crystals, Single Ion Detection)

Quantum computers not only have the potential to exponentially speed up the computation of difficult problems, but also allow for large quantum mechanical simulations that are not possible with today's classical computers. One approach to building quantum computer hardware is to use rare-earth ions doped into crystals. These act as a frozen gas of atoms that are spatially close enough to Stark shift the energy levels of neigbouring ions. This, along with the exceptionally long coherence times of their 4f-4f optical transitions, allows us to experimentally perform high fidelity single qubit operations (Phys. Rev. A **77**, 022307 (2008)). As of now, a large ensemble, in the order of 10^9 atoms, has been used as the qubit. This ensemble approach scales extremely poorly, in fact by a factor of $0.03^{(N-1)}$ where N is the number of entangled qubits. In order to solve this scalability problem, one approach is to use single instances as the qubit, where one could reach chains which are on average 1000 atoms long, at a 1% doping concentration (S.Bengtsson MSc, Dept. Of Physics, Lund, 2012).

When applying this single instance protocol, it is important to be able to gather enough photons from a single ion to be able to perform high fidelity readout of the quantum states. The allowed 4f-5d transition in cerium is ideal for this use. It has been argued that high fidelity readout of the qubit state is possible simply by looking at the fluorescence of the cerium ion (Journal of Luminescence. 170, 102 (2016) and Phys. Rev. A **92,** 022319 (2015))

In order to apply this protocol, it must be possible interact and gather the fluorescence from a single cerium ion. A stable UV laser system and a confocal microscopy setup suitable for this purpose has been developed in Lund (Rev. of Sci. Instr. **87**, 033701 (2016)). As of now, single ion detection has evaded the system. The hypothesized reason is that fluorescence from ions behind the confocal setup focus contribute to a noise floor that is higher than the fluorescence from a single ion. The solution for this is to use microcrystals instead of bulk material. A new setup has been made where we have images of microcrystals on a substrate (Figure to the left) along with an image of single microcrystal fluorescence taken with a normal Nikon camera (Figure to the right). Single ion detection experiments are now under way!





Control of plasmonic nanostructures for high performance applications

A. Kumar[1, 2], R. P. Singh[2], T. Mohanty[3] and A. Taneja[1]

[1]Department of Chemistry, Dr. B. R. Ambedkar University, Agra, India

[2]Physical Research Laboratory, Navrangpura, Ahmedabad, India

[3]School of Physical Sciences, Jawaharlal Nehru University, New Delhi, India

Interaction of light with plasmonic nanoparticles whose wavelength is of the order of interacting light wavelength, have new physics and applications in electronics, optics and optoelectronics. When the light of wavelength corresponding to the surface plasmon resonance absorption propagates through a nonlinear medium metal nanoparticles strongly absorb visible light due to their surface plasmon resonance in which the conducting electrons undergo a collective excitation induced by electric field of visible light. This enhances the local electric field near and on the surface of metal nanoparticles. The enhancement of local electric field within the metal nanoparticles, leads to the formation of an electromagnetic wave. This wave induces a huge field on the particle surface strongly polarizing the atoms of the molecules adsorbed. As the electrons of the atoms vibrate around their center of mass, the induced dipole moment oscillates at the wave frequency. This will affect the density, velocity and plasmonic oscillations of the electronic clouds of each nanoparticle which will improve self-focusing property of the light propagating through a nonlinear media. Self-focusing can be tuned by controlling size and shape of nanostructures that can play a significant role in medical purposes, LEDs, lasers, sensor, solar cell, photovoltaic and other optical applications. The Ag@Au nanoparticles are used so that the plasmon resonance corresponding to excitation wavelength can be systematically tuned by varying the thickness of the Au-shell. This can help in increased stability and trapping capability of plasmonic nanoparticles that will boost the development of numerous applications in science and technology.

[1] A. Kumar and T. Mohanty, J. Phys. Chem. C 118, 7130 (2014).

[2] P. P. Patra, R. Chikkaraddy, R. P. N. Tripathi, A. Dasgupta and G. V. Pavan Kumar, Nat. Commun., 5, 4357 (2014).

Remote imaging photoplethysmography device for palm microcirculation assessment

Edgars Kviesis-Kipge, Uldis Rubīns
Institute of Atomic Physics and Spectroscopy, University of Latvia, LV 1050 Riga, Latvia.
email: cobba@inbox.lv

Keywords: Photoplethysmography imaging.

Abstract

Photoplethysmography (PPG) is a non-invasive method for studies of the blood volume pulsations by detection and analysis of the backscattered optical radiation from tissue. Blood transport dynamics can be monitored with simple PPG contact sensors at different body sites – earlobe, fingertip, forearm, etc.
Photoplethysmography imaging (PPGI) is a non-invasive technique for detection of blood flow pulsations in skin using backscattered optical radiation [1]. The optical radiation after the penetration into skin is partially absorbed by tissue and it is modulated by blood pulsations due to cardiac activity. Backscattered radiation can be detected by video camera as weak light pulsations and can be visualized by video processing algorithm [1,2]. Non-contact photoplethysmography imaging is method with ability to get the PPG signal, without touching the observed body location.
In recent years we have developed custom made 1-channel the compact remote photoplethysmography imaging prototype device for monitoring of blood volume pulsations from human palm using near infrared range (760nm) LED's [3].
Our PPGI device consists of twelve circularly oriented near-infrared LED sources (760nm), *Ximea* video camera with *Edmund Optics* lens and on-board electronics.
We present new results from the updated version of our PPGI prototype device. This version of the device introduces a significant improvement due to the improved range of LED brightness adjustment and LED thermal stability, which results in more accurate measurement results.

ACKNOWLEDGEMENTS
This work has been supported by European Regional Development Fund project "Development of prototype devices for non-invasive skin assessment", under grant agreement No.1.1.1.2/16/I/001, No. 1.1.1.2/VIAA/1/16/070.

References
[1] Zheng, J., Hu, S., Echiadis, A. S., Azorin-Peris, V., Shi, P. and Chouliaras, V. A remote approach to measure blood perfusion from the human face. Proc. SPIE v.7169, 716917 (2009).
[2] Rubins, U., Upmalis, V., Rubenis, O., Jakovels, D. and Spigulis, J. Real-time photoplethysmography imaging system. Proc IFMBE, Vol 34, pp. 183-186 (2011).
[3] E. Kviesis-Kipge, U. Rubīns. Portable remote photoplethysmography device for monitoring of blood volume changes with high temporal resolution. IEEE **DOI:** 10.1109/BEC.2016.7743727 (2016).

Optical diagnostics for lung function monitoring on preterm infants – studies on a 3-D tissue phanom

Jim Larsson[1], Dennis Leander[2], Peilang Liao[2], Emilie Krite Svanberg[3], Märta Lewander Xu[2], Johannes Swartling[2], Sara Bergsten[2], Joakim Bood[1]*

[1]Division of Combustion Physics, Lund University, Lund, Sweden
[2]GPX Medical, Maskinvägen 1, Lund, Sweden
[3]Department of Clinical Sciences, Anesthesiology and Intensive Care Medicine, Skåne University Hospital, Lund University, Lund, Sweden
[*]Corresponding author: jim.larsson@forbrf.th.se
Telephone: 046-222 81 70

Keywords: absorption spectroscopy, medical diagnostics, 3D-printed model, scattering media

Abstract

We are here presenting the development of a 3D-printed phantom based on CT-images of a preterm infant for evaluation of optical techniques. The work is part of a joint project[1] where the aim is to develop a system for non-invasive monitoring of the lung function of preterm infants based on the absorption technique GASMAS (gas in scattering media absorption spectroscopy).

The phantom is 3D-printed in nylon and only the boundaries, i.e., the walls, of the identified organs bone, skin, fat, heart and lung are printed to create volumes which can be filled with a liquid phantom. The liquid is a mixture of the highly absorbing Indian ink and highly scattering Intralipid, to provide desirable optical properties that corresponds to literature values of corresponding organs. The bone is printed solid and the lung is air-filled with a sponge material inserted.

The gas content in the lung is evaluated using two narrowband tunable-diode lasers at 760 and 820 nm to probe the absorption of oxygen and water vapor, respectively. Due to the light being multiple scattering before collected on the detector, the absorption path length is unknown and, hence, the gas concentration cannot be obtained from the Beer-Lambert law. Instead the oxygen concentration is obtained by first evaluating the concentration of water vapor by measuring the gas temperature and assuming a relative humidity of 100%. Then the absorption path length of water vapor is obtained via the Beer-Lambert law and in turn used to calculate the oxygen concentration in the lung model. This procedure to obtain an oxygen concentration is based on the assumption that the laser light at 760 and 820 nm traverse the same distance between source and detector.

Two different light delivery solutions were employed; first the laser light is focused into an optical fiber where the fiber end is a diffuser probe that is placed on the skin of the model, light is then detected by a 10 x 10 mm detector also placed on the skin. Here different measurement geometries on both the left and right lung were tested to find optimal intensity transmission and absorption depths. Absorption path lengths from 2 to 8 cm were determined for different source and detector positions. Secondly, the laser light was focused into an optical fiber with a fiber end that is diffuse. The fiber was inserted into the trachea of the lung model and the transmitted signal was registered by placing the detector, again, onto the skin of the model. Comparison with the dermal

measurements shows that inserting the optical fiber into the trachea gives a detectable absorption signal at an increased number of detector positions and an overall higher light transmission is observed.

1. *NEO-Lung, Development of neonate bedside lung monitoring sensor based on diode laser spectroscopy*. 2018-04-30; Available from: https://www.eurostars-eureka.eu/project/id/9833.

Characterization of visual and IR reflectivity for soft car targets

Mikael Lindgren, Stefan Nord
Research Institutes of Sweden AB, Measurement Science and Technology
email: Mikael.Lindgren@ri.se
Telephone: +4610 516 5713

Keywords: AD, ADAS, soft car target, reflectivity

Abstract

Advanced Driver Assistance Systems (ADAS) and Automated Driving (AD) vehicles rely heavily on optical sensors. Extensive testing of optical sensors is required and typically performed at test tracks like AstaZero. Soft surrogate targets are used for safety reasons, but the optical characteristics of surrogate targets may differ considerably from that of real vehicles. During tests the quality of the soft surrogate targets deteriorates due to repeated impacts and reassembly of the targets, and there is a need for methods to secure the quality of the soft surrogate targets over time.

RISE has conducted a project together with Volvo Cars and Veoneer to develop and validate accurate and repeatable measurement methods of the optical characteristics of 3D soft car targets. The goal is to support international standardisation (ISO) with standard methods enabling future verification and calibration of optical characteristics of active safety 3D soft car targets.

The poster presents results from optical measurements on soft car targets and real cars, performed in the project. One target was subjected to 100 rear-end collisions during which the reflectivity was measured.

Time-Gated Raman probe for Raman measurements in high temperatures

Jussi Tenhunen[1]
Hannu Lindström[1]
Kai Ojala[1]
Pekka Tanskanen[2]
Timo Fabritius[2]
email: *jussi.tenhunen@vtt.fi*
Telephone: +358207222264
[1]*VTT Technical Research Centre of Finland Ltd*
[2]*University of Oulu, Process Metallurgy Research Unit*

Keywords: High temperature, Raman probe, Time-Gated Raman, low frequency Raman, anti-Stokes, spodumene

Abstract

A TG-Raman probe for Raman measurements in high temperatures (1100 °C) is designed and manufactured in OPTI-Hai project. The goals for the design were to reach a high collection efficiency for the received Raman signal, to reach low Raman frequencies close to Rayleigh line on Stokes side of the spectrum and to reach low Raman frequencies close to Rayleigh line on Anti-Stokes side of the spectrum.

The probe is modular, so the adaptation to different processes can be realized by redesign of just the front optics and without any modifications on the most complex part of the optics – the excitation and Raman pickup optics. The probe has also anti-Stokes feature, which means that the temperature of a measurement point can be measured reliably and accurately eluding problems associated with pyrometers, which are susceptible to variations in emissivity and radiation of the oven itself reflected from the sample surface. Moreover, a built-in cooling system for the probe body is designed and built.

A spectrum of cyclohexane was measured at the room temperature using the designed hot temperature Raman probe and a commercial probe as a comparison. Results confirmed that the realized hot temperature Raman probe can reach 100 cm^{-1} distance from the Rayleigh line from both Stokes and Anti-Stokes sides of the Raman spectra whereas the commercial probe can reach 150 cm^{-1} at Stokes side and >300 cm^{-1} for Anti-Stokes.

As a conclusion, all the design goals were achieved. The realized principle can be applied for example in online chemometric on-line analysis of the roaching process of spodumene (from alpha form to beta form) allowing closed loop control of the roaching time and roaching temperature of spodumene. This is of high economical value for the lithium enrichment process. OPTI-Hai project is co-financed by Innovation Funding Agency Business Finland.

Optical Repetition Rate Stabilization of Ultrafast SESAM-Based Yb Doped All Fiber Oscillator

K. Madeikis[1,2], K. Viskontas[1], R. Danilevicius[1,2], T. Bartulevičius[1,2], L. Veselis[1,2], A. Michailovas[1,2], and N. Rusteika[1,2]
[1] Ekspla Ltd., Savanoriu ave. 237, LT-02300 Vilnius, Lithuania
[2] State research institute Center for Physical Sciences and Technology, Savanoriu 231, LT-02300 Vilnius, Lithuania
email: k.madeikis@ekspla.com
Telephone: +37062641571

Keywords: laser stabilization; fiber nonlinear optics; ultrafast lasers

Abstract

In this work we demonstrate all-fiber concept of precise repetition rate control of an ultrafast ytterbium oscillator passively mode-locked using semiconductor saturable absorber mirror (SESAM). Refractive index change in Er-doped fiber core induced by pump laser power change allowed to lock repetition rate of oscillator to external clock frequency using phase-locked loop (PLL) electronics.
Two different wavelength diodes (976 nm and 1550 nm) were tested for pumping erbium doped fiber. Setup with 976 nm pump diode showed about 10 Hz range of total repetition rate control compared with 4 Hz at 1550 nm pump. Difference in control range was caused by the increased amplification of the oscillator pulses in Er fiber pumped at 976nm wavelength. At the 12 mW pump power energy of the oscillator pulses increased about 11% for 976nm pump, meanwhile in setup with 1550 nm pump pulse energy changed only around 1%. Increase in pulse energy was accompanied in wavelength shift of the oscillator. Because different wavelength pulses were reflected at different location of CFBG, pulse round trip time and therefore a repetition rate of the oscillator was also changed. The crosstalk between repetition rate control and the output pulse energy from the oscillator is clearly undesirable effect, therefore 1550 nm pump was used for locking repetition rate of the oscillator to the external clock.
With PLL electronics enabled, timing jitter of the oscillator was measured using high bandwidth (20GHz) oscilloscope. <1 ps timing jitter was estimated, which was limited by our current measurement setup. The timing jitter measurements with signal source analyzer which should assure sub-100 fs resolution is under preparation. Results and detailed overview of the experiments will be presented at the conference.

Conversion of optical vortices into beams with polarization singularities by optical parametric amplification

Maksym Ivanov[1], Aidas Matijošius[1], Paulius Stanislovaitis[1], Titas Gertus[2] and Valerijus Smilgevičius[1]

[1] Laser Research Center, Vilnius University, Sauletekio ave. 10, Vilnius LT-10223, Lithuania

[2] Altechna R&D Ltd., Mokslininku st. 6A, Vilnius LT-08412, Lithuania

email: aidas.matijosius@ff.vu

Telephone: 037069830511

Keywords: optical vortices; radial polarization; polarization singularities; optical parametric

Abstract

Radially polarized beams were first generated in 1972 [1]. Radially and azimuthally polarized beams are two examples of a wide family of beams with polarization singularities. Yang et al. [2] has demonstrated an experimental generation of such beams by superposition of Laguerre–Gaussian modes.

In this work we propose a technique to generate radially and azimuthally polarized beams as well as higher order polarization singularities by optical parametric amplification. The basic idea of the proposed method is to obtain two optical vortices with opposite topological charges by means of the optical parametric amplification and to superimpose them by using a quarter-waveplate (Fig. 1). The pump beam carries no topological charge while the signal beam is an optical vortex. According to the law of the topological charge conservation, the idler wave will be formed with a topological charge opposite to the signal. Afterward, with a properly oriented quarter-waveplate, the combined signal-idler beam is converted to a radially or azimuthally polarized beam.

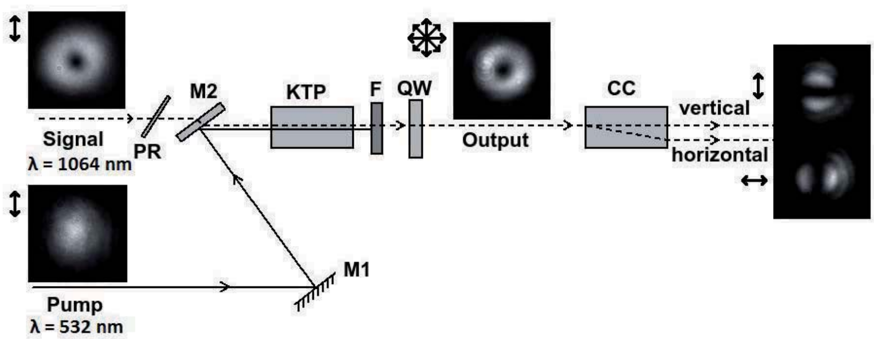


Fig. 1. The beams with polarization singularities generation experimental setup. Polarization states are given by the small arrows in the left of the images

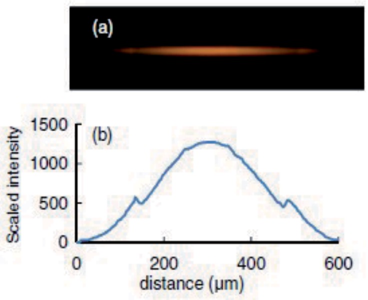
References

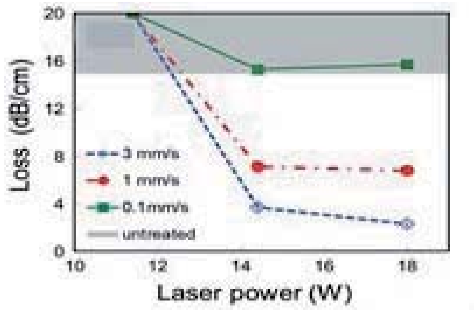
1. D. Pohl, Appl. Phys. Lett. **20**, 266 (1972).
2. C.-H. Yang et al., Sci. Rep. **6**, 31546 (2016).

Utilization of CO_2 laser beam radiation to process semiconductor core fibers

Korbinian Mühlberger, Taras Oriekhov, Fredrik Laurell, Ursula Gibson, Michael Fokine
Royal Institute of Technology, Applied Physics, Stockholm, 106 91, Sweden.

Conventional glass fibers are widely used and an established technology. A new field of research arose by introducing semiconductors as core materials to expand fiber applications to different wavelengths. Those hybrid fibers exploit the advantages of the optical and electro-optical properties of semiconductor material within the flexible fiber geometry. Manufactured with a drawing tower, their as-drawn quality is not suitable for optical purposes since the semiconductors are neither mono-crystallized nor is the local composition of compound semiconductors controlled. This can be overcome since the fiber geometry offers the unique possibility to reprocess them by irradiation of a CO_2 laser beam. It is reported that by controlling various parameters (temperature of the fiber core, size of the localized melt-zone and the velocity at which the melt-zone is shifted through the fiber) the semiconductor core can be modified. For example, it is possible to recrystallize the core to reduce optical transmission losses and inscribe grating structures for various optical applications.





Acknowledgments:
The project activities are supported by Stiftelsen for Strategisk Forskning (SSF) grant RMAI5- 0135, and the Knut and Alice Wallenberg Foundation (KAW) grant 2016.0104.

REFERENCE

[1] N. Healy, M. Fokine, Y. Franz, T. Hawkins, M. Jones, J. Ballato, A. C. Peacock, U. J. Gibson, "$C0_2$ Laser-Induced Directional Recrystallization to Produce Single Crystal Silicon-Core Optical Fibers with Low Loss," Advanced Optical Materials, 4(7), 1004-1008 (2016).

[2] D. A. Coucheron, M. Fokine, N. Patil, D. W. Breiby, O. T. Buset, N. Healy, A. C. Peacock, T. Hawkins, M. Jones, J. Ballato, U. J. Gibson, "Laser recrystallization and inscription of compositional microstructures in crystalline SiGe-core fibres," Nature Communications, 7, 13265 (2016).

Spectroscopy of optically levitated droplets.

Soumya Radhakrishnan and Dag Hanstorp
Department of Physics, University of Gothenburg, SE-41692 Sweden
email: soumya.radhakrishnan@physics.gu.se
Telephone: 0317869144

Keywords: Optical levitation, spectroscopy, FRET

Abstract

Optical manipulation was first demonstrated by Ashkin and Dziedzic[1] in 1970. In the present studies, the technique of optical levitation is employed to investigate the collision of liquid droplets. The basic experimental setup consists of i) two diode-pumped solid-state (DPSS) lasers ii) droplet dispensers iii) a spectrometer and finally, iv) a chamber to isolate the levitated droplet from the external laboratory air turbulence. Both the laser beams are vertically aligned to the levitating chamber and are focused onto the droplets by a lens with f=30 mm. One laser has an output wavelength of 660 nm and is used to levitate the droplets. The droplets do not absorb at this wavelength. The other laser has an output at 532 nm and is used to spectroscopically investigate the coalescence of two droplets.

In the first phase of the experiment, spectroscopy of a single droplet is investigated. For this, droplets are produced on-demand from the droplet dispensers placed vertically above the levitation chamber and trapped using the 660 nm laser. The levitated droplet is then illuminated with the 532 nm laser. The scattered light from the levitating droplet is imaged by a lens with f=20 mm, placed at right angles to the laser beam, onto the aperture of an optical fiber attached to a spectrometer. In this way, spectroscopic studies (Raman, fluorescence) of a single trapped droplet can be investigated.

In the second phase of the experiment, the coalescence of two droplets is investigated using spectroscopic means. Here, the two droplets are injected with different dyes in order to monitor the process of coalescence. Once a droplet containing the dye ATTO 532 is trapped using the 660 nm laser, a second droplet containing the dye ATTO 550 is injected to the trap in order to investigate the degree of coalescence of the two droplets. Both droplets are illuminated by light from the 532 nm laser. The intensity of the scattered light varies strongly during the coalescence process. The coalescence process is thus monitored by recording the time evolution of fluorescence due to Förster Resonance Energy Transfer (FRET)[2] after coalescence. In this way, the spectroscopy of the emitted light from the droplets is investigated both before and after coalescence.

The results showing the FRET effects will be presented which are obtained when two droplets containing the two different fluorescent dyes collides and coalesce. Further results on this effect and other spectroscopic studies such as the Raman effect will also be presented. The study and spectroscopy of coalescing droplets is an ongoing research project with the long-term goal to investigate environmental effects of aerosols in the atmosphere.

References
1.Ashkin, A. *Phys. Rev. Lett.* **1970,** *24***,** 156–159.
2.Förster, T. *Naturwissenschaften* **1946**, *6*, 166–175.

Structural Colors from Self-Organized InP Nanopillars

Ajith P Ravishankar, Dennis Visser and Srinivasan Anand*
Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, Electrum 229, S-164 40 Kista, Sweden
**email: aprav@kth.se*

Keywords: nanopillars, structural colors, ion sputtering, InP

Abstract

Dielectric surfaces patterned with nanostructures display interesting optical properties in transmission, reflection and absorption. Structural colors observed from these patterns depend on the nanostructure size, shape, choice of material, spatial separation between individual structures, and the surrounding media [1]. Spectral features in reflection or transmission from nanostructured media can arise from various optical phenomena like interference, scattering, absorption, optical resonances, or a combination of these. The wide choice of parameters to tune the structural color can be useful in many applications such as color filters, displays, security and sensors. There have been recent studies on semiconductor nanostructures for structural color generation, including their integration into CMOS and solar cell technologies [2, 3]. III-V semiconductor nanowire arrays have also been demonstrated to exhibit color spectra through selective absorption [4].

Here, we present the fabrication of self-organized indium phosphide (InP) nanopillars by nitrogen (N_2) ion sputtering and their optical properties. During ion-sputtering of InP, preferential sputtering of phosphorous (P) occurs leaving excess indium (In) on the surface. The In atoms diffuse on the surface and form clusters which act as local masks, leading to the formation of InP nanopillars [5]. These structures display a range of colors depending on the height and shape of the nanopillars, which are controlled by the process conditions. We analyze the reflection spectra from these pillars, including the specular and diffuse components, taking into account the effect of pillar height and shape and the presence of a metallic (indium-rich) cap. Finite difference time domain (FDTD) simulations of the reflectivity spectra together with Mie scattering theory, are used to explain the origin of the observed structural colors.

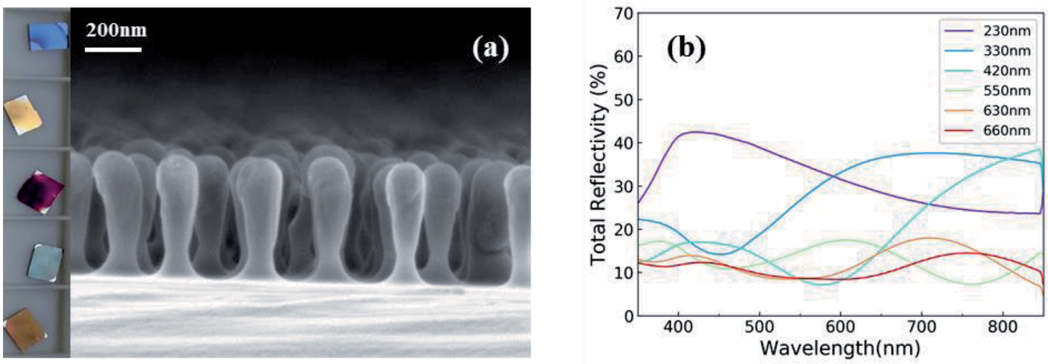


Figure: (a) Cross-sectional SEM image of the self-organized InP nanopillars obtained after ion beam etching for 2 min. The panel on the left shows a range of colors seen from the samples etched for different times. (b) Total reflectivity spectra of the InP nanopillars for different heights.

References:

[1] T. Xu, et al., *Small*, **7**, 3128 (2011).
[2] Kwanyong Seo et al., *Nano Letters*, **11**(4), 1851 (2011).
[3] V Neder et al., *Applied Physics Letters,* **111**, 073902 (2017).
[4] P. M. Wu et al., *Nano Letters,* **12** , 1990 (2012).
[5] R. Sanatinia et al., *Nanotechnology,* **26**, 415304 (2015).

Photolysis-free two photon laser induced fluorescence of H atom

*Maria Ruchkina[1, *], Pengji Ding[1], Marcus Aldén[1] and Joakim Bood[1]*

[1]*Div. of Combustion Physics, Department of Physics, Lund University, Box 118, SE-221 00 Lund, Sweden*
email: maria.ruchkina@forbrf.lth.se
Telephone: 0722696428

Keywords: LIF; TPLIF; Two-photon excitation process; Femtosecond laser pulse; H atom

Abstract

Investigation of H atoms is highly demanded in the combustion environment since they are present in every chemical reaction which involves hydrocarbons. Optical detection of H atoms is difficult because the wavelength which is needed for the excitation is in the vacuum-UV region, where air is absorbing strongly. To overcome this problem two-photon excitation methods have been developed. Following the 2-photon excitation from n=1 to n=3 state the H atom emits fluorescence at the wavelength 656 nm. The use of fs-laser pulses benefits when it comes to the detection of species which might suffer from interfering photodissociation. The experiment was conducted where no difference in TPLIF (two-photon laser induced fluorescence) line profiles received for different laser output energies was found. This clearly indicates the absence of photolytically produced hydrogen atoms. TPLIF has many advantages, this technique allows imaging of atomic species in the premixed flame environment with high temporal and spatial resolution. The present investigation was conducted in a welding torch flame of 1.5 mm diameter, precisely at the tip of the flame. The experiment revealed that the concentration of H atoms at the top of the flame is lower than at the edges of the flame. It should be mentioned that LIF signal might suffer from SE (stimulated emission). Further investigations should be conducted in order to investigate the impact of SE on the signal.

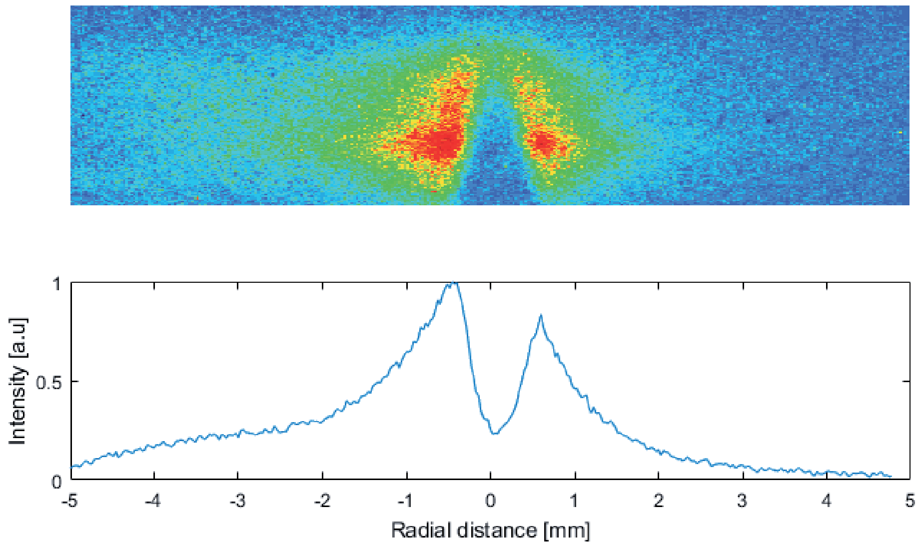


Figure 1. TPLIF image of H atom fluorescence signal on a tip of CH_4/air flame (Φ= 1.3), where the laser sheet is 7 mm height.

Spatial coherence of light detected with nanoscatterers

K. Saastamoinen, L.-P. Leppänen, A.T. Friberg, and T. Setälä
University of Eastern Finland, Institute of Photonics, FI-80101 Joensuu, Finland
email: tero.setala@uef.fi

Keywords: Spatial coherence, electromagnetic beams, nano-optics

Abstract

The spatial coherence of partially coherent, partially polarized light beams is measured by observing the interference pattern of light scattered by a pair of nanoparticles [1,2]. The idea resembles the classic Young's double-pinhole arrangement but the apertures are replaced with dipolar nanoscatterers. The method is an important step towards the measurement of near-field spatial coherence where the conventional methods cannot be used.

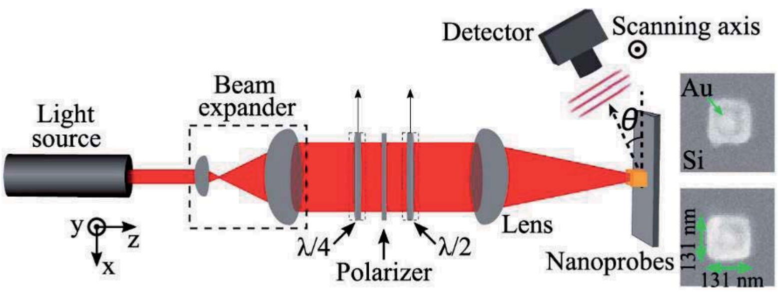


Figure 1.

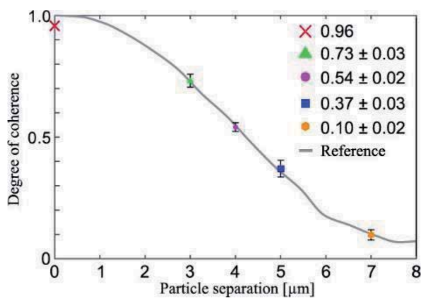


Figure 2.

The measurement setup is shown in Fig. 1. The beam preparation part consists of a multimode laser source (632.8 nm), expander, collimation optics, polarizer and waveplates. The optical elements select a desired polarization component of the electromagnetic beam and transform it to y-direction. The beam is then focused on a pair of gold nanoparticles (cubes, size ~130 nm) set on the y-axis. The dipolar particles (pairs with different separation) are deposited on a silicon surface. The far fields scattered by the particles produce intensity fringes whose visibility yields the degree of spatial coherence at the particle sites.

The colored symbols in Fig. 2 depict the degree of coherence measured with the particle pairs having the separations of 3, 4, 5, and 7 μm when the incident light is y-polarized (scalar case, no polarization sensitive elements present in the beam preparation). The zero-separation case corresponds to a (spatially fully coherent) single-mode laser and the particle separation of 3 μm. We also measured the degree of coherence with a digital micromirror device (solid line in Fig. 2). The excellent agreement between the two methods demonstrates that nanoparticle probing is a valid technique to measure the degree of spatial coherence of light beams.

[1] K. Saastamoinen, L.-P. Leppänen, I. Vartiainen, A.T. Friberg, and T. Setälä, *Optica* **5**, 67 (2018).
[2] L.-P. Leppänen, K. Saastamoinen, A.T. Friberg, and T. Setälä, *Opt. Lett.* **40**, 2898 (2015).

Advanced imaging technologies for distant assessment of in-vivo skin

Janis Spigulis, Uldis Rubins, Edgars Kviesis-Kipge, Andris Grabovskis, Aleksejs Lihacovs, Ilze Lihacova, Dmitrijs Bliznuks, Ilona Kuzmina, Ilze Oshina, Marta Lange
Biophotonics Laboratory, Institute of Atomic Physics and Spectroscopy, University of Latvia
email: janis.spigulis@lu.lv
Telephone: +371 67228249

Keywords: optical skin diagnostics and monitoring; multispectral, fluorescent and photoplethysmography imaging

Abstract

A brief overview of recently developed methods and prototype devices for remote in-vivo skin imaging [1-5] is presented. The set of new methods includes:

- Snapshot multi-spectral-line imaging for chromophore mapping in skin malformations;
- LED-based multi-spectral imaging for skin oxygenation mapping in sepsis patients;
- Combined multi-spectral and fluorescence imaging for identification of skin tumors;
- Photoplethysmography imaging for distant monitoring of local anesthesia efficiency before and during surgeries.

To validate these methods in laboratory and clinics, portable battery-powered experimental prototype devices have been designed, assembled and tested. Operational features of five such devices will be discussed, as well as the obtained preliminary results of clinical measurements by means of the developed prototypes.

[1] J.Spigulis, "Multispectral, fluorescent and photoplethysmographic imaging for remote skin assessment", *Sensors* **17**, 1165 (2017).
[2] J.Spigulis, I.Oshina, A.Berzina, A.Bykov, "Smartphone snapshot mapping of skin chromophores under triple-wavelength laser illumination", *J.Biomed.Opt.*, **22**(9), 091508 (2017).
[3] I.Oshina, J.Spigulis, U.Rubins, E.Kviesis-Kipge, K.Lauberts, "Express RGB mapping of three to five skin chromophores", *Proc. SPIE-OSA* **10413**, 104130M-1 (2017).
[4] I.Saknite, A.Grabovskis, S.Kazune, U.Rubins, Z.Marcinkevics, K.Volceka, E.Kviesis-Kipge, J.Spigulis, "Novel hybrid technology for early diagnostics of sepsis", *Proc. SPIE* **10057**, 100570F (2017).
[5] A.Lihachev, I.Lihacova, E.V.Plorina, M.Lange, A.Derjabo, J.Spigulis, "Differentiation of seborrheic keratosis from basal cell carcinoma, nevi and melanoma by RGB autofluorescence imaging", *Biomed.Opt.Express,* **9**(4),1852-1858 (2018).

Food safety monitoring by laser spectroscopic techniques

Y. Li[1], W.S. Li[1], H.Y. Lin[1], H. Zhang[1],
K. Svanberg[1,2], and S. Svanberg[1,2]

[1]Center of Optical and Electromagnetic Research, South China Academy of Advanced Optoelectronics, South China Normal University, University City Campus, Guangzhou 510006, China
[2]Lund Laser Center, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden
Emails: katarina.svanberg@med.lu.se; sune.svanberg@fysik.lth.se
Telephones: +46707315470; +46760502126

Keywords: food safety, diode laser spectroscopy, GASMAS

Abstract
Food safety aspects have attracted great international attention among consumers, not the least in China [1]. Many food products are packed in a modified atmosphere, frequently low in oxygen, to increase the shelf-life and quality of the food [2]. Measurement techniques, which are able to non-intrusively monitor the gas contents in food and food packages are clearly of considerable importance. Research along these lines started at Lund University about 10 years ago [3], and subsequent activities are partly covered in a review [4]. We use the gas in scattering media absorption spectroscopy (GASMAS) technique [4] to monitor free oxygen gas and water vapor in the head-space of packages, and inside the pores in food stuffs. Sometimes the assessment is accompanied by reflectance and fluorescence monitoring, as e.g., was the case in studies of tropical fruits [5]. Chinese milk and bread packages were studied in [6], and chicken eggs in [7,8]. The techniques are also very powerful for studying gas diffusion through package barriers, and through hatching hen egg shells, providing necessary oxygen [8].

1. D.L. Ortega, H.H. Wang, L.P. Wu, and N.J. Olynk, Modelling Heterogeneity in Consumer Preferences for Select Food Safety Attributes in China, Food Pol. **36**, 318 (2011).
2. I.J. Church and A.L. Parsons, Modified Atmosphere Packaging Technology: A Review, J. Sci. Food Agric. **67**, 143 (1995).
3. M. Lewander, Z.G. Guan, L. Persson, A. Olsson and S. Svanberg, Food Monitoring Based on Diode Laser Gas Spectroscopy, Appl. Phys. B **93**, 619 (2008)
4. S. Svanberg, Gas in Scattering Media Absorption Spectroscopy – from Basic Studies to Biomedical Applications, Lasers and Phot. Reviews **7**, 779 (2013).
5. H. Zhang, J. Huang, T.Q. Li, X.X. Wu, S. Svanberg and K. Svanberg, Studies for Tropical Fruit Ripening Using Three Different Spectroscopic Techniques, J. Biomed. Opt. **19**, 067001 (2014).
6. T.Q. Li, H.Y. Lin, H. Zhang, K. Svanberg, and S. Svanberg, Application of Tunable Diode Laser Spectroscopy in Assessment of Food Quality, Appl. Spectroscopy **71**, 929 (2017).
7. W.S. Li, H.Y. Lin, H. Zhang, K. Svanberg and S. Svanberg, Detection of Free Oxygen and Water Vapor in Fertilized and Unfertilized Eggs by Diode Laser Spectroscopy – Exploration of Diagnostics Possibilities, J. Biophotonics Doi 10.1002/jbio.201700154 (2017).

8. Y. Li, W.S. Li, L.N. Hu, K. Svanberg and S. Svanberg, Non-intrusive studies of gas contents and gas diffusion in hen eggs, to appear.

Monitoring of atmospheric atomic mercury by laser radar techniques

G.Y. Zhao[1], M. Lian[1], Z. Duan[1], S.M. Zhu[1], and S. Svanberg[1,2]

[1]Center of Optical and Electromagnetic Research, South China Academy of Advanced Optoelectronics, South China Normal University, University City Campus, Guangzhou 510006, China
[2]Department of Physics, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden
Email: sune.svanberg@fysik.lth.se
Telephone: +46760502126

Keywords: differential absorption lidar, atmospheric pollution, atomic mercury

Abstract
Mercury is a very serious neurotoxic environmental pollutant of global concern. It is now the target of the United Nation's Minamata Convention, in force since 2017 [1], and named after the mercury pollution disaster at Minamata Bay in Japan, where since the mid 1950´s almost 2000 people died from bio-accumulated mercury. China is a major producer and user of mercury, and pollution is a serious problem in China [2]. Based on Swedish experience, the SCNU Applied Laser Spectroscopy group has constructed a mobile lidar system [3] with specific capacity of atmospheric mercury monitoring using the differential absorption lidar approach [4]. The facility is now being used in different remote sensing tasks on the Chinese scene, including monitoring of mercury pollution [5,6] but also agricultural crop-growing conditions [7,8]. The Wanshan mercury mines in the Guizhou province cause extensive pollution, which was recently studied by our group [6]. Other geochemical aspects of mercury relate to geothermal energy and volcanoes [9]. Because of the high vapor pressure of mercury and its atmospheric prevalence in atomic form, it might be used in prospecting. Related, lidar may also be utilized in archeological studies of burial mercury in tombs. We have pursued a study along these lines at a major monument in Xi´an.

1. http://www.mercuryconvention.org/Portals/11/documents/Booklets/Minamata%20Convention%20on%20Mercury_booklet_English.pdf.
2. X.B. Feng, Mercury pollution in China — an overview, in: N. Pirrone and K.R. Mahaffey (eds), *Dynamics of Mercury Pollution on Regional and Global Scales*. (Springer, Boston 2005) pp. 657–678.
3. G.Y. Zhao, M. Lian, Y.Y. Li, Z. Duan, S.M. Zhu, L. Mei, and S. Svanberg, Mobile Lidar System for Environmental Monitoring, Appl. Optics **65**, 1506 (2017).
4. S. Svanberg, Differential Absorption Lidar (DIAL), in *Air Monitoring by Spectroscopic Techniques*, M. Sigrist (ed.), Wiley, N.Y. 1994, p. 85.
5. L. Mei, G.Y. Zhao and S. Svanberg, Lasers Opt. Eng. **55**, 128 (2013).
6. M. Lian, L.H. Shang, Z. Duan, G.Y. Zhao, Y.Y. Li, S.M. Zhu, G.L. Qiu, B. Meng, J. Sommar, X.B. Feng, and S. Svanberg, Lidar Mapping of Atmospheric Atomic Mercury in the Wanshan Area, China, Environmental Pollution, in press (2018).
7. G.Y. Zhao, Z. Duan, L. Ming, Y.Y. Li, R.P. Chen, J.D. Hu, S. Svanberg, and Y.L. Han, Appl. Optics **55**, 5273 (2016).

8. Z. Duan, T. Peng, S.M. Zhu, M. Lian, Y.Y. Li, W. Fu, J.B. Xiong, S. Svanberg, Q.Z. Zhao, J.D. Hu and G.Y. Zhao, Appl. Optics, in press (2018).
9. S. Svanberg, Opt. and Lasers Eng. **37**, 245 (2002).

Fast and robust creation of an arbitrary qubit state by nonadiabatic shortcut pulses in a three-level system

Hafsa Syed, *Adam Kinos, Andreas Walther, Chunyan Shi,*
Lars Rippe, Sebastian Horvath, Stefan Kröll
Department of Physics, Lund University, Sweden

Ying Yan, Lin Wan, Joel Moser
Soochow University, China

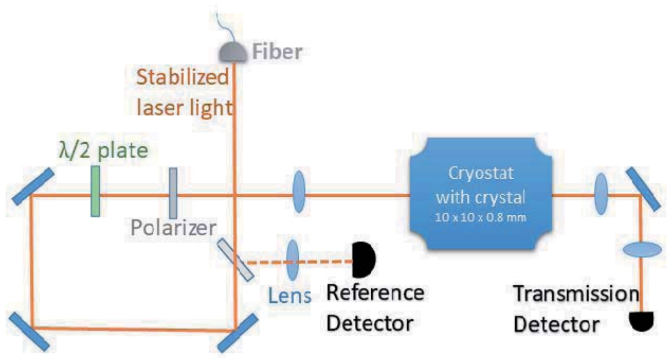
Yi-Chao Li, Xi Chen
Shanghai University, China

email: Hafsa.Syed@fysik.lth.se

Keywords: quantum computing, rare-earth ion doped crystals, shortcut pulses

Abstract

Quantum computing is a rapidly growing field with numerous candidates for the qubits used in the physical realization. In our work, we use spin states of Pr^{3+} ions doped into inorganic crystals. More specifically, our qubits consist of an ensemble of 'identical' ions differing only by a spread in resonance frequency of ~200 kHz. A challenge now is to put all these billions of ions in exactly the same superposition state although their frequencies are slightly different. Irrespective of the physical system under concern, an important step in quantum computing and quantum control is to be able to initialize qubits in a short time, with high fidelity. They also need to be robust against inevitable imperfections in the system such as frequency inhomogeneity in atomic transitions, phase errors as well as light intensity fluctuations. In 2008, arbitrary superposition rare earth qubit states were generated with four adiabatic two-color pulses[1] with a fidelity of 90%-95%. Here, we significantly improve on those results by introducing a protocol to design a single two-color resonant nonadiabatic shortcut pulse, capable of creating an arbitrary superposition qubit state that reduces the operation time by 4 times. The preliminarily estimated fidelity is 98%. These pulses are also robust against frequency detuning as high as ±300kHz, which ensures uniform control on the ensemble of qubit ions. The present approach is not limited to rare-earth doped crystals but can be generalized to any quasi three-level system.



[1] L. Rippe, et al. *Experimental quantum-state tomography of a solid-state qubit*, Phys. Rev. A **77**, 022307 (2008).

[2] Xi Chen and J. G. Muga, *Engineering of fast population transfer in three-level systems,* Phys. Rev. A **86**, 033405 (2012).

Raman Spectroscopy as a Future Tool for Process Optimization of Iron Ore Beneficiation

Sanna Uusitalo[1], Tuomas Soudunsaari[1], Juha Sumen[1], Janne Paaso[1], Jarmo Huuskonen[2]
[1]VTT Technical Research Centre, Kaitoväylä 1, 90570 Oulu, Finland
[2]Pyhäsalmi Mine Oy, Mainarintie 2, 86900 Pyhäjärvi, Finland
email: sanna.uusitalo@vtt.fi
Telephone: +358 40 848 7814

Keywords: Mineralogy, Raman, beneficiation, Iron ore

Abstract
Raman spectroscopy is a novel method for detection of minerals from quarry ores. The identification of minerals through Raman scattering is based on the vibrations of the mineral bonds, which give different minerals their own fingerprint spectra. Although the identification of minerals by Raman has been previously studied with drill core and rock samples, the utilization of Raman detection for ore slurry analysis to supplement process optimization has been missing. Optimization of beneficiation from quarry ores is dependent on the information of the mineral levels in the enriched mineral foam and the gangue slurry. The current online analysis is usually based on X-Ray fluorescence (XRF) detection, which gives information on the elements of the minerals, but not on the minerals themselves. Thus, XRF requires evaluation of possible mineral level distributions by other methods such as mineral liberation analysis (MLA). Additionally XRF has limited capability in analyzing lightweight materials such as Sulphur, which is an important element in valuable minerals, and very common elements such as iron. In this study, the suitability of Raman spectroscopy for beneficiation process analyzation and process optimization has been evaluated with detection of enriched Pyhäsalmi mine flotation ores. Three beneficiation cycles have been analyzed with an immersion probe and 785 nm Raman spectrometer Kaiser RXN2. As Figure 1 shows, the used instrumentation allowed for the recording of good quality Raman spectra, and for the identification of enriched minerals: Chalcopyrite (Copper), Sphalerite (Zinc) and Pyrite (Iron/Sulphur). The study showed that Raman spectroscopy can in future be utilized for online detection of enriched iron ore minerals from different ore slurry process phases.

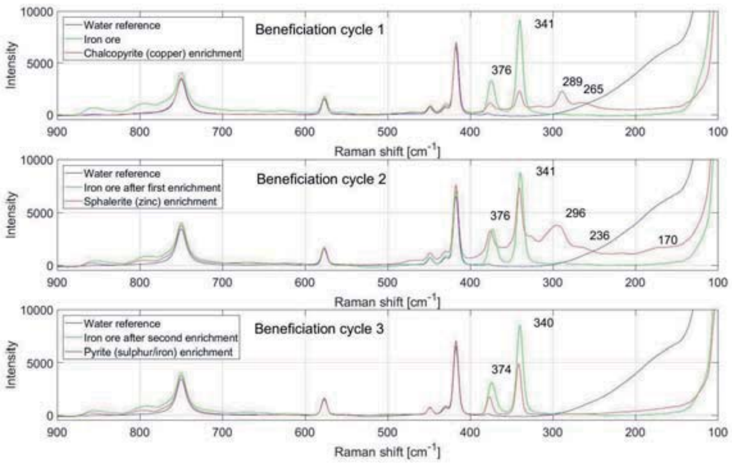


Figure 1. Raman spectra of three mine enrichment beneficiation cycles with reference to water and ore. Water spectra shows the background peaks arising from the probe window. Characteristic Raman peaks a) Chalcopyrite 289 cm^{-1} and 265 cm^{-1}, b) Sphalerite 296 cm^{-1} and 236 cm^{-1} and c) Pyrite 374 cm^{-1} and 340 cm^{-1}.

Ultrafast CPA laser system based on Yb fiber seeder and Yb:YAG amplifier

L. Veselis[1,2], T. Bartulevicius[1,2], K. Madeikis[1,2], A. Michailovas[1,2], N. Rusteika[1,2]
[1]Ekspla Ltd., Savanoriu ave. 237, LT-02300 Vilnius, Lithuania
[2]Center for Physical Sciences and Technology, Savanoriu ave. 231 LT-02300, Vilnius, Lithuania
l.veselis@ekspla.com
+37067228994

Keywords: Laser amplifiers; Ultrafast lasers; Pulse compression; Volume gratings; Fiber technology; Ytterbium.

Abstract

Chirped pulse amplification (CPA) is a key technique for obtaining high energy ultrashort pulses. Stretching of pulses is usually achieved using diffraction gratings or chirped fiber Bragg gratings (CFBG), whereas compression of pulses is conveniently achieved in diffraction grating based optical setups. However, diffraction grating based pulse compressors are bulky and require precise alignment to avoid spatial and temporal perturbations of output pulses. CPA systems based on chirped volume Bragg grating (CVBG) stretcher and compressor overcome those shortcomings. Furthermore, implementation of CFBG stretcher matched to CVBG compressor improves the system integration to a compact all fiber format.
In this work, a system featuring an all-in-fiber CPA seed source (Ekspla) and free-space amplifier based on ytterbium-doped yttrium aluminum garnet (Yb:YAG) crystal and a matched pair of CFBG stretcher (TeraXion) and CVBG compressor (IPG Photonics) has been demonstrated. The seed source generated 2.3 uJ, 200 kHz, 1030 nm laser pulses, chirped to 220 ps with CFBG stretcher. Yb:YAG crystal rod longitudinally pumped by a continuous wave high-brightness laser diode (940 nm) was used as a double pass amplifier. Seed and pump beams were overlapped on the crystal. Second pass was realized by reflecting amplified seed back to the crystal. Beam was then directed to CVBG compressor. Input and output beams were separated by polarization. The efficiency of CVBG compressor was 87%, yielding 20.8 W of output power and 104 uJ pulse energy at 200 kHz repetition rate. Optimally compressed pulse duration was 764 fs (transform-limited – 644 fs). Beam quality parameter M^2 after pulse compression was $M^2<1.2$. A more detailed overview of the system will be presented at the conference.

A 1.57 µm fiber source for atmospheric CO_2 continuous-wave differential absorption lidar

Xiong Yang[1,2], Robert Lindberg[1], Jim Larsson[3], Can Xu[4], Mikkel Brydegaard[3,4], Joakim Bood[3], Fredrik Laurell[1]
[1]Department of Applied Physics, Royal Institute of Technology (KTH), Roslagstullsbacken 21, Stockholm 10691, Sweden
[2]Centre for Optical and Electromagnetic Research (COER), State Key Laboratory of Modern Optical Instrumentation, Zhejiang University, Hangzhou 310058, China
[3]Department of Physics, Lund University, Sölvegatan 14, Lund 22346, Sweden
[4]Norsk Elektro Optikk AS, Prost Stabels vei 22, 2019 Skedsmokorset, Norway
email: xiongya@kth.se *Telephone: +46725660188*

Keywords: Seeded fiber laser, Tuneable Diode Laser Absorption Spectroscopy (TDLAS), Contineous Wave DIferrential Absorption Lidar (DIAL), Gas profiling.

Abstract
As one of the many developed techniques to map the atmospheric CO_2 concentration, DIfferential Absorption Lidar (DIAL) is of great interest, as it allows for continuous monitoring throughout the day with high resolution in space and time. Conventional time-of-flight DIAL systems are based on tunable high peak power (MW), narrow-linewidth (<pm), short pulsed lasers (ns) around 1.57 µm, usually amplified by optical parametric generation (OPG) or optical parametric oscillators (OPO). Continuous-wave DIAL (CW DIAL) is a considerably simpler solution since peak powers in the optics are low, components are compact, and the narrow line width does not conflict with short pulses. The method was introduced and demonstrated for O_2-concentration distribution measurement recently. Based on the Scheimpflug Principle, it maps the backscattered light along the beam path, from different distances, to different pixels on an array detector. To access the spectral region required for CO_2 measurements, we designed a tunable laser-amplifier source, which consists of a narrow-linewidth, CW, distributed feedback (DFB) laser as the seed and an Erbium doped fiber amplifier to scale the output power to levels that allow for long distance CW DIAL detection.

The source has a linewidth of 3 MHz, a continuous tuning range of 2 nm, covering 5 CO_2 absorption lines at 1.572 µm, and an output power of 1.3 W (limited by the available pump power). The center band is controlled by the seed diode temperature and the spectral tuning is achieved by ramping the drive current to the seed diode. The source was used for the first experimental demonstration of spatially resolved CW DIAL measurements of atmospheric CO_2-concentrations. In this measurement, the output beam from the fiber amplifier was expanded and transmitted into the atmosphere by a telescope. The back scattered light from the atmosphere was received by a Newtonian telescope and then focused onto an InGaAs detector array after a long-pass filter. By calculating the intensity ratio of received signals with on- and off- CO_2-resonance wavelengths from different pixels, the CO_2-concentration distribution along a 2000-meter return path during 12 hours was assessed. The measured concentration was around 400 ppm. Future work will focus on improving laser source, background suppression and data accuracy, as well as on longer-distance measurements in different environmental conditions.

SPONSORS

Edmund optics | worldwide

HAMAMATSU PHOTON IS OUR BUSINESS

FLIR

neoLUND Laser Technology Platform Solutions

Lund University

LLC Lund Laser Centre

THORLABS

SPONSOR OF THE PS AND SOS STUDENT AWARD 2018

1ST PRIZE

HAMAMATSU PHOTON IS OUR BUSINESS

2ND PRIZE

Edmund optics | worldwide

SPONSOR OF THE BEST POSTER AWARD

IEEE photonics society

MEDIA PARTNERS

EOS European Optical Society

ELEKTRONIK TIDNINGEN

SUPPORTED BY

Lund University

LLC Lund Laser Centre

SOS Svenska OptikSällskapet Swedish Optical Society the Swedish Branch of the European Optical Society

EXHIBITORS

acal bfi

Agilent Technologies

AZPECT part of ams TECHNOLOGIES

Cobolt a HÜBNER Group company

COHERENT

COMSOL

ECLIPSE

Edmund optics | worldwide

EKSPLA

gammadata

HAMAMATSU PHOTON IS OUR BUSINESS

KimmyPhotonics

LASER 2000

Laser Quantum A Novanta Company

LASER COMPONENTS

LIGHT CONVERSION

LightGuideOptics Group

nanor

neoLUND Laser Technology Platform Solutions

neo Norsk Elektro Optikk AS HySpex

neo Norsk Elektro Optikk AS

NKT Photonics the power of light

oplatek inspired by optics

OPTRONIC

RI.SE

SEDI-ATI fibres optiques

SiTek Electro Optics

THORLABS

von Gegerfelt Photonics