The International Symposium on Modern Optics and Its Applications (ISMOA) is a meeting held by the Indonesian Optical Society (InOS). The 10th ISMOA is organized in collaboration with the Physics of Magnetism and Photonics Research Group of ITB. This scientific forum is aimed at communicating new research discoveries and developments on Modern Optics among the active research scientists and engineers, as well as to expose those results to young scientists and students in the ASEAN countries.

The symposia have been held successfully for nine times, since 2001. It has so far been the only international scientific event of its kind organized in Indonesia. The venue of these events was at Bandung Institute of Technology (Institut Teknologi Bandung, ITB), which is the oldest and most prestigious arts, science and engineering university in Indonesia. As the capital city of West Java province, Bandung is famous for its cultural tradition and beautiful mountainous surrounding.

The meetings have always been highlighted by more than a dozen invited distinguished speakers of international reputation, including Fellows of international associations, and endorsed by the Optical Society of America (OSA) as well as the Abdus Salam International Center for Theoretical Physics (ICTP).
Foreword from President of the Indonesian Optical Society

On behalf of the Organizing Committee as well as the Indonesian Optical Society (InOS) or Himpunan Optika Indonesia (HOI), in Indonesian, I sincerely welcome you to the 10th International Symposium on Modern Optics and Its Applications (ISMOA), and thank you for your continued support and contribution to this event.

It is a happy coincidence that this biannual meeting is taking place in this special Year of Light as declared and promulgated by UNESCO. It has given us an additional impetus to take this opportunity for the dissemination of the important roles of light and optics in our daily lives, especially the modern conveniences and facilities for personal as well as social activities largely enjoyed by all walks of people. For that purpose, public lectures and exposition of optical phenomena and their applications are also held in conjunction with this meeting.

Meanwhile we notice with pleasure the large variety of topics on important advances in the field to be presented in this symposium. This will keep us abreast with the important progresses of modern optics and its applications, providing the opportunity to interesting and useful discussions during the meeting as well as stimulate the research interest of the young scientists and students. It is important to note the increased number of speakers and poster presenters from this region, particularly the Indonesian participants who have completed their Ph.D. education or doing their postdoctoral researches abroad. Among them many are directly or indirectly motivated or facilitated through the fruitful interaction with our invited scientist in the previous ISMOA which testifies to the benefits of this symposium. Meanwhile the increased participations of researchers from our neighbouring countries are also providing us with the conviction of continued organization of this event for the further development of research cooperation.

Finally, I would like to convey our grateful appreciation to Institut Teknologi Bandung, the Abdus Salam International Centre for Theoretical Physics (ICTP), Italy, The Optical Society of America (OSA), USA and Office of Naval Research Global (ONRG), USA for their support for this event.

Alexander A. Iskandar
Welcoming Address by the Rector of Institut Teknologi Bandung

It is a great pleasure for me to witness the consecutive implementation of the 10th International Symposium on Modern Optics and Its Applications (ISMOA), and to deliver this welcoming address to this scientific forum for the second time. First of all, I would like to extend on behalf of Institut Teknologi Bandung, our warm welcome to ITB to all the participants of this meeting. I would also like to express our sincere appreciation to all speakers, especially the invited distinguished speakers, for your important contributions to this event.

I understand that optics as one of the oldest branches of physics and sciences has evolved continuously to serve the growing needs of the scientific and technological communities, as well as the human welfare in general. Its recent advances have even played the central roles in the discoveries of a large variety of new phenomena, supporting the development of novel applications, covering photonic science and technology for applications in high speed and high capacity optical communication and information processing (ICT), nano optics, plasmonics and nano biophotonics for scientific as well as bio-medical applications. In keeping with these developments, we are very happy to be the host of this symposium, which we believe will not only stimulate the studies and researches of this broad subject, but also pave the way for fruitful international scientific networking and research collaborations. I hope that this gathering will also help to facilitate cross cultural exchanges and to foster mutual understanding.

Finally I wish you an enjoyable and successful meeting and a pleasant stay in Bandung.

Bandung, July 2015

Prof.Dr.Ir. Kadarsah Suryadi, DEA
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International Endorsements

Optics and Photonics Society of Singapore
**General Information**

**Period and Venues of activities**

- **10 August 2015**: Tutorial Workshop and Introduction to Poster Presentations
  - New Seminar Room
  - Physics Building, Institut Teknologi Bandung
- **11-12 August 2015**: Symposium
  - West Aula, Institut Teknologi Bandung
- **13 August 2015**: Excursion

**Official Language**

- English

**On-site Registration**

- **Monday, 10 August 2015, 07.30 – 08.20**, New Seminar Room, Physics Building
- **Tuesday, 11 August 2015, 08.00 – 08.30**, West Aula, Institut Teknologi Bandung

**Submission of manuscript for publication**

Selected papers presented in the Symposium will be submitted to the Journal of Nonlinear Optical Physics and Materials for publications. Manuscripts should be submitted to the secretariat by 1 November 2015.

**Social Events**

- **Welcoming Reception**
  - **10 August 2015, 17.30 – 19.00**, Physics Building
- **Symposium Banquet hosted by the Indonesian Optical Society (by invitation)**
  - **11 August 2015, 18.30 – 21.00**, West Aula, Institut Teknologi Bandung

**Information for Presentation**

All presentation will be delivered in plenary session. Speakers are requested to upload their presentation before the session. Speakers are requested to come to the presentation room 10 minutes before the start of the appropriate session and notify the chairperson of their presence.

Time allocated (including question and answers) to each speaker is
- 30 minutes for each invited paper
- 15 minutes for each contributed paper

**Information for Poster Presentation**

The Introduction to Poster Presentation with a 2 slides – 2 minute oral summary of your research with the format: introduction, results, and conclusions, will be held in a
special session on Monday (10 August 2015). Poster presentation will be held on the first day of the symposium (Tuesday, 11 August 2015).

**Excursion to Mount Tangkuban Perahu Crater and Grasia Spa Hot Spring**

- Thursday, 13 August 2015
- Depart from ITB main gate at 08.00
- The ISMOA 2015 Organizing Committee will provide buses for this excursion, however entrance fee to each location and lunch are at own expenses.
- Participants who are interested to join this excursion should register at the Organizer’s desk at the latest by 12.00 noon on Wednesday, 12 August 2015.
Tutorials on
Modern Optics and Its Applications
Monday, 10 August 2015

Venue : New Seminar Room, Physics Building, Institut Teknologi Bandung

07.30 – 08.20 Registration
08.20 – 08.30 Opening Ceremony of Tutorial Courses on Modern Optics and Its Applications
Opening Address by the Dean of the Faculty of Mathematics and Natural Sciences, ITB

08.30 – 09.20 Tutorial Lecture Session 1: *Introduction to Quantitative Phase Imaging (QPI)*
*YongKeun PARK* (Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea)

09.20 – 10.10 Tutorial Lecture Session 2: *Introduction to Quantitative Phase Imaging (QPI)*
*YongKeun PARK* (Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea)

10.10 – 10.30 Coffee Break

10.30 – 11.20 Tutorial Lecture Session 3: *Plasmonic metasurfaces*
*Olivier J.F. MARTIN* (Nanophotonics and Metrology Laboratory, Swiss Federal Institute of Technology Lausanne (EPFL), Lausanne, Switzerland)

11.20 – 12.10 Tutorial Lecture Session 4: *Plasmonic metasurfaces*
*Olivier J.F. MARTIN* (Nanophotonics and Metrology Laboratory, Swiss Federal Institute of Technology Lausanne (EPFL), Lausanne, Switzerland)

12.10 – 13.00 Lunch

13.00 – 13.50 Tutorial Lecture Session 5: *Frontiers of Guided Wave Nonlinear Optics*
*Benjamin J. EGGLETON* (Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), Institute of Photonics and Optical Science (IPOS), School of Physics, The University of Sydney, Australia)

13.50 – 14.40 Tutorial Lecture Session 6: *Frontiers of Guided Wave Nonlinear Optics*
*Benjamin J. EGGLETON* (Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), Institute of Photonics and Optical Science (IPOS), School of Physics, The University of Sydney, Australia)
14.40 – 15.00     Coffee Break
15.00 – 17.00     Oral Introduction to Poster Session (40 posters @ 2 min – 2 slides)
17.30             Welcoming Reception
Abstracts of Tutorial Lectures on Modern Optics and Its Applications
Introduction to Quantitative Phase Imaging (QPI)

YongKeun Park
Department of Physics, Korea Advanced Institute of Science and Technology
Daejeon 305-701, Republic of Korea

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In this course, we will introduce the basic principles and applications of QPI. In the first part of the course – Methods – we will cover the main approaches to QPI, including phase-shifting, off-axis, common-path, and white-light methods, together with their figures of merit. A practical guide to designing and implementing instrumentations for QPI, along with image processing techniques will be presented. The second part of the course – Applications – will review recent advances in the biomedical applications of QPI. We will cover basic applications published in the recent literature on cell structure, dynamics and light scattering, as well as clinical applications such as blood testing and tissue diagnosis.
Plasmonic metasurfaces

Olivier J.F. Martin
Nanophotonics and Metrology Laboratory, Swiss Federal Institute of Technology
Lausanne (EPFL), CH-1015 Lausanne, Switzerland

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About fifteen years ago, David Smith introduced the concept of a metamaterial: an artificial material, which electromagnetic properties are determined by the artificial “atoms” it is composed of. These artificial “atoms” consist of micro- or nano-structures that are designed to support electromagnetic resonances, thus producing a metamaterial that exhibits an electromagnetic response that does not occur naturally, such as for example negative refraction [1]. Unfortunately, fabricating three-dimension (3D) metamaterials that operate at optical frequencies is very difficult, since it requires artificial “atoms” nanostructures with dimensions in the sub-100 nm range, which must then be stacked together to build a 3D structure.

On the other hand, it is possible to organize such nanostructures on a surface and produce one layer of metamaterial: a so-called metasurface. Such metasurfaces can also exhibit very interesting properties and can be used to replace specific bulky optical elements, or even design completely new optical functionalities. In this short course, I will show how plasmonic nanostructures – which support extremely strong optical resonances – can be used as artificial “atoms” to build metasurface for different applications [2].

After reviewing the basic principles of plasmonics, I will describe the different optical modes that can be supported by such plasmonic nanostructures and show how their combination can lead to unusual optical resonances, such as Fano resonances. I will describe some fabrication techniques that can be used to produce these nanostructures at different lengthscales. Finally, I will draw parallels between grating and plasmonic metasurfaces and show how the latter can be designed to control the flow of light.

Reference
This tutorial will review recent research and applications in the field of nonlinear guided wave optics with emphasis on both fundamentals and emerging applications. Starting from a strong foundation in the principles of nonlinear optics, we will review recent progress in emerging nonlinear optical platforms with an emphasis on the different materials, including silicon, chalcogenide, III-V semiconductors, photonic crystal fibres, nanophotonic circuits and others. We will establish key figures of merit for these different material systems and a general framework for nonlinear guided wave optics with emphasis on the applications in emerging areas of science and technology. We will then review recent progress and breakthroughs in the following areas: All-optical processing, Ultra-fast optical communications, Slow light, highly nonlinear and emerging waveguides, Ultrafast measurement and pulse characterization, Frequency combs and optical clock, Optical parametric amplifiers and oscillators, Generation and applications of optical super-continuum, Nonlinear localization effects and solitons, Nonlinear optics for quantum information.
10\textsuperscript{th} International Symposium on Modern Optics and Its Applications
Tuesday, 11 August 2015

Venue: West Aula, Institut Teknologi Bandung

08.00 – 08.30 Registration
08.30 – 08.50 Opening Ceremony of 10th International Symposium on Modern Optics and Its Applications
Opening Address by the Rector of Institut Teknologi Bandung

1st session Chairperson: Benjamin J. EGGLETON

09.00 – 09.30 Invited Paper-1: Manipulating Rays Through Transformations
Martin McCALL (Department of Physics, Imperial College London, UK)

09.30 – 10.00 Invited Paper-2: Perfect absorption in near-dielectric gratings
Martijn de STERKE, Björn STURMBERG, Lindsay BOTTEN, Kokou DOSSOU, Chris POUTON, and Ross McPHEDRAN
(CUDOS and IPOS, School of Physics, University of Sydney, Sydney Australia)

10.00 – 10.30 Coffee Break

2nd session Chairperson: Martin McCALL

10.30 – 11.00 Invited Paper-3: Stimulated Brillouin scattering in Photonic Integrated Circuits
Benjamin J. EGGLETON (Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), Institute of Photonics and Optical Science (IPOS), School of Physics, The University of Sydney, Australia)

11.00 – 11.30 Invited Paper-4: Optically probing symmetry breaking in the Skyrmionic insulator Cu2OSeO3
R.B. VERSTEEG, S. SCHÄFER, I. VERGARA-KAUSEL, M. GRÜNINGER, A. AQEEL, T.T.M. PALSTRA, Paul H.M. van LOOSDRECHT (II. Physikalisches Institut, University of Cologne, Germany)

11.30 – 12.00 Invited Paper-5: Review on Spectrochemical Analysis Using Laser-Induced Plasma at Low Pressure and TEA CO2 Laser-Induced Metal-Assisted Gas Plasma at 1 atm
Kiichiro KAGAWA (Fukui Science Education Academy, Fukui, Japan)

12.00 – 13.00 Lunch Break

3th session Chairperson: Christoph BUBECK

A. BRÄUER, A. BRÜCKNER, F. WIPPERMANN, A. OBERDÖRSTER (Fraunhofer Institute IOF, Jena, Germany)

13.30 – 14.00 Invited Paper-7: Subwavelength light focusing and imaging
Jung-Hoon PARK, Chunhyun PARK, Yong-Hoon CHO and YongKeun PARK (Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea)

4th session Chairperson: Paul H. M. van LOOSDRECHT

14.00 – 14.15 Contributed Paper-1: Photoinduced Spin Dynamics and Ultra-Large Faraday Rotation in CH$_3$NH$_3$PbI$_3$ Perovskite Thin Films
David GIOVANNI, Hong MA, Julianto CHUA, Michael GRÄTZEL, Ramamoorthy RAMESH, Subodh MHAISALKAR, Nripan MATHEWS and Tze Chien SUM (Nanyang Technological University, Singapore)

14.15 – 14.30 Contributed Paper-2: Optical fiber bonded 1D nanobeam laser as a portable index sensor
Indra KARNADI, Putu E. PRAMUDITA, Jehyeon SON, Chang-Min LEE, Hoon JANG, Bumki MIN, and Yong-Hee LEE (Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea)

14.30 – 14.45 Contributed Paper-3: The G-centre photoluminescence from carbon implanted high energy proton irradiated SOI
D. D. BERHANUDDIN, J. SAMPE, P. S. MENON, M. A. LOURENÇO, R. M. GWILLIAM, S. SHAARI, and K. P. HOMEWOOD (Institute of Microengineering and Nanoelectronics, Universiti Kebangsaan Malaysia, Malaysia)

M. MULDARISNUR and F. MARLOW (Max-Planck-Institut fur Kohlenforschung, Germany)
15.00 – 15.15  Contributed Paper-5: Infrared Laser of Photodynamic Therapy using Exogenous Gold Nanoparticles for Cancer Cells Inactivation
Retna APSARI, Naili SAIDA TIN, SUHARININGSIH (Department of Physics, Airlangga University, Surabaya, Indonesia)

15.15 – 15.30  Contributed Paper-6: Slotted Patch Antenna on LiNbO3 Optical Modulator for Free Space Radio-Wave and Optical Fiber Up-Links
Y.N. WIJAYANTO, P. DAUD, H. MURATA, A. KANNO, D. MAHMUDIN, N. YAMAMOTO, and Y. OKAMURA (National Institute of Information and Communications Technology, Japan)

15.30 – 17.00  Coffee Break

15.00 – 17.00  Poster session

18.30 – 21.00  Symposium Banquet (by invitation only)
Wednesday, 12 August 2015

5th session  Chairperson : Martijn de STERKE

08.30 – 09.00  Invited Paper-8: Time-reversed nonlinear optical mixing processes
               Xianfeng CHEN, Yuanlin ZHENG, and Wenjie WAN (Key Laboratory for Laser Plasma (Ministry of Education), IFSA Collaborative Innovation Center, Shanghai Jiao Tong University, Shanghai, China)

09.00 – 09.30  Invited Paper-9: Second harmonic generation in multi-resonant plasmonic nanostructures
               Olivier J.F. MARTIN (Nanophotonics and Metrology Laboratory, Swiss Federal Institute of Technology Lausanne (EPFL), Lausanne, Switzerland)

09.30 – 10.00  Invited Paper-10: Sub-Wavelength Field Distribution and Photo-Rectification in Metamaterials
                Teruya ISHIHARA (Tohoku University, Department of Physics, Sendai, Japan)

10.00 – 10.30  Coffee Break

6th session  Chairperson : YongKuen PARK

10.30 – 11.00  Invited Paper-11: Directional nano-antennae for surface plasmon polaritons and light
                Jasper KNOESTER (Zernike Institute for Advanced Materials, University of Groningen, Groningen, The Netherlands)

11.00 – 11.30  Invited Paper-12: Scattering characteristics of metal and dielectric optical nanoantennas
                Ho-Seok EE, Eun-Khwang LEE, Jung-Hwan SONG, Jinhyung KIM, Min-Kyo SEO (Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea)

11.30 – 11.45  Group Photo

11.45 – 13.00  Lunch

7th session  Chairperson : Oliver J.F. MARTIN

Kazuaki SAKODA and Hiroyuki TAKEDA (National Institute for Materials Science, Photonic Materials Unit, Tsukuba, Ibaraki, Japan)

Fitri FITRILAWATI, Norman SYAKIR, Ellen BACKUS, Zhaoyang LIU, Xinliang FENG, Klaus MÜLLEN, Christoph BUBECK (Max Planck Institute for Polymer Research, Mainz, Germany)

14.00 – 14.30 Invited Paper-15: TBA
Yiping CUI (Southeast University, Nanjing, China)

8th session Chairperson: Min-Kyo SEO

14.30 – 14.45 Contributed Paper-7: Normal, degenerated, and anomalous-dispersion-like Cerenkov sum-frequency generation in one nonlinear medium
Ning AN and Xianfeng CHEN (Shanghai Institute of Laser Plasma, Shanghai, China)

S. W. HARUN, A. A. LATIFF, A. HALDER, M. C. PAUL, S. DAS, S. K BHADRA and H. AHMAD (Photonics Research Centre, Department of Physics, University of Malaya, Malaysia)

15.00 – 15.15 Contributed Paper-11: Hybrid plasmonic-photonic modes for light emission enhancement
Aimi ABASS and Bjorn MAES (Institute of Nanotechnology, Karlsruhe Institute of Technology, Karlsruhe, Germany)
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<td>15.15 – 15.30</td>
<td>Contributed Paper-12: Surface Plasmon Resonance Sensor using Functionalized Alkanethiols Monolayer for Illegal Compound Detection SUHERMAN, Kinichi MORITA and Toshikazu KAWAGUCHI (Department of Chemistry, Universitas Gadjah Mada, Yogyakarta, Indonesia)</td>
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<td>15.30 – 16.00</td>
<td>Closing Ceremony</td>
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<td>16.00 – 16.30</td>
<td>Coffee Break</td>
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<td>Indonesian Optical Society Congress</td>
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Extended Abstracts

10th International Symposium on Modern Optics and Its Applications

Tuesday, 11 August 2015
Manipulating Rays Through Transformations

Martin McCall
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Transformation Optics is the new branch of optics that deals with how in principle any morphing of space, and indeed spacetime, can be replicated in an appropriately designed inhomogeneous electromagnetic medium. The most celebrated example is of course the electromagnetic cloak, in which a region of space is effectively excised from view so that any object within the region is rendered invisible to an external observer [1]. Such cloaks have been the focus of much recent research, both experimental and theoretical, as researchers seek to implement a design strategy that is apparently only limited by technology, not through physical principle.

In 2011, the author and his co-workers made a significant breakthrough in the field of Transformation Optics by extending the idea of using spatial transformations to cloak objects in space, to using space-time transformations to cloak events in time [2]. Despite some initial skepticism, the so-called spacetime cloak was rapidly realized experimentally [3].

But having scaled these two mountains, cloaking in both space and time, where do we really stand in Transformation Optics? Are the original assertions that the transformation optics algorithm is exact correct? Does Transformation Optics really provide a means of effectively curving space without the large mass densities associated with gravitational distortion? What are the prospects for using ideas from Transformation Optics in other fields such as acoustics, thermal physics and quantum physics?

In this talk I will give a critical overview of the subject of Transformation Optics, tracing its history, attempting answers to the above questions, and pointing towards future prospects.

References
Perfect absorption in near-dielectric gratings

Martijn de Sterke\textsuperscript{1}, Björn Sturmberg\textsuperscript{1}, Lindsay Botten\textsuperscript{2,3}, Kokou Dossou\textsuperscript{2}, Chris Poulton\textsuperscript{2}, and Ross McPhedran\textsuperscript{1}

\textsuperscript{1} CUDOS and IPOS, School of Physics, University of Sydney 2006, Sydney Australia
\textsuperscript{2} CUDOS, School of Mathematical and Physical Sciences, University of Technology Sydney, Sydney 2007, Australia
\textsuperscript{3} National Computational Infrastructure, Australian National University, Canberra 2601, Australia

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The achievement of perfect absorption, especially in thin structures for which the thickness \(d \ll \lambda\), where \(\lambda\) is the wavelength, is interesting in its own right and is also important for optimizing solar cells. Such thin layers are relevant, for example, when dealing with “earth-abundant” materials. These tend to exhibit strong absorption, but have poor electronic properties, leading to rapid electron-hole recombination. The absorbing layer therefore needs to be very thin (tens of nanometers) to ensure that the charge carriers can reach the electrical contacts.

It is well-known \cite{1} that perfect absorption can be achieved in the symmetric geometry in Fig 1a in which light is incident from both sides. Perfect absorption requires that \(r + \delta = 0\), where \(r\) is the Fresnel coefficient off the surface and \(\delta = e^{2\pi n d/\lambda}\), where \(n \equiv n' + i n''\) is the layer’s (complex) refractive index. For thin layers this reduces to \(n = (i\lambda/(\pi d))^{1/2}\) \cite{1,2}. While such geometries are polarization-independent, and the required refractive index scales favourably with the thickness, the requirement that \(n' = n''\) is difficult to satisfy. In addition, for light incident from one side the maximum absorption drops to 50%.

The geometry in Fig. 1(b) has the same characteristics, but requires light to be incident from one side to achieve perfect absorption. Nonetheless, the awkward requirement that \(n' = n''\) remains. An improvement can be achieved when the uniform structure is replaced by a volume grating (see Fig 1(c)) \cite{3,4}. In such structures light is coupled into waveguide modes by the periodicity which acts as a grating coupler. Perfect absorption can be achieved in these structures, though the results depend on polarization.
shows the absorption versus $n'$ and $n''$ for a layer of thickness $d/\lambda = 1/150$ for the geometry in Fig 1c, for TE polarization. Other parameters are given in the figure caption. Note that perfect absorption can be achieved with the required refractive index now close to the real axis—the figure now shows two perfect absorption at two refractive indices, close to the first and second Wood anomalies where the first and second diffracted orders in the grating become propagating. Importantly, the perfect absorption is achieved for refractive indices close to the real axis; for example, near the first Wood anomaly the required refractive index is $n = 4.06 + 0.47i$, corresponding to a dielectric medium with moderate losses. The required refractive index can be adjusted by changing the grating parameters.

![Figure 2](image)

**Figure 2.** Absorption versus $n'$ and $n''$ for a grating consisting of a medium of refractive index $n' + in''$ and air, each with 50% fill fraction, a thickness $d/\lambda = 1/150$ and a period $A/\lambda = 14/15 \approx 0.93$ and normally incident TE-polarized light.

In conclusion, we have shown that perfect absorption can be achieved in weakly absorbing media with a grating. Such structures are amenable to fabrication and experiments to confirm the modeling results are currently underway.

**References**

Stimulated Brillouin scattering in Photonic Integrated Circuits

Benjamin Eggleton
Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), School of Physics, University of Sydney, NSW Australia
egg@physics.usyd.edu.au

On-chip Stimulated Brillouin scattering (SBS) is at the focus of current because of its potential for integration of a variety of important photonic functionalities. In general, however, short length scales remain a challenge for on-chip nonlinear optics. Here, we demonstrate a concept for selectively enhancing and inhibiting nonlinear interactions on a chip by exploiting the frequency dependence of the optical density-of-states near the edge of a photonic-bandgap. We use this concept to enhance and inhibit on-chip SBS.

The nonlinear optical process known as Stimulated Brillouin scattering (SBS) describes the coherent three wave interaction between an optical pump wave and a red-shifted optical Stokes wave through the intermediary of an acoustic wave. SBS has proven to be extremely useful for a number of photonic applications but is also considered a nuisance in some systems such as long optical fiber communication links and in high power lasers.

On-chip nonlinear optics is a thriving research field, which creates opportunities for manipulating light in small-footprint integrated devices. In the recent years there has been a remarkable surge of interest in harnessing SBS on the nanoscale [1]. The first demonstration [2] of on-chip SBS was based on a chalcogenide photonic chip. This was enabled by a large material nonlinearity as well as strong confinement of the optical and the acoustic mode [2]. This demonstration has opened the door for the photonic integration of a variety of SBS based applications such as tunable optical delay [7] and filters [8], lasers [3,9], frequency comb sources [10] and microwave photonic signal processing [11,12].

In general, on-chip nonlinear optics is challenging due to the short length scales. Nonlinear interactions can be enhanced by exploiting materials with large nonlinearity in combination with high-Q resonators or slow-light structures. This, however, often results in simultaneous enhancement of competing nonlinear processes, which limit the efficiency and can cause signal distortion. Recently, we showed that the frequency dependence of the optical density-of-states near the edge of a photonic bandgap can be exploited to selectively enhance or inhibit nonlinear interactions on a chip [13]. We demonstrated this concept for SBS using a narrow-band one-dimensional photonic bandgap structure: a Bragg grating.

Figure 1a) shows the concept of enhancing and inhibiting SBS by tuning the pump such that the frequency of the Stokes wave coincides with the edge of the stopband or the centre of the stopband, respectively. Fig. 1b) and 1c) show experimental results. In Fig. 1b) the pump wave with power below the SBS threshold PSBS is tuned to the edge of a multiwavelength grating with stopbands spaced by the Brillouin frequency shift. When pump, first and second order Stokes wave coincide with the edges of the stopbands,
nonlinear interactions are enhanced and a frequency comb is generated with 8 components. Figure 1c) shows the case of for the optical pump wave above the SBS threshold $P_{\text{SBS}}$. Here, SBS is inhibited when the Stokes frequency coincides with the stopband.

Figure 1. a) Concept of enhancement and suppression of SBS and illustration of the 6.8cm long chalcogenide rib waveguide (4µm × 850nm) with a Bragg grating. b) Tuning the pump wavelength ($P_{\text{pump}} = 0.5W < P_{\text{SBS}} = 0.6W$) to the edge of a multi-wavelength grating shows an enhancement of the SBS cascading as pump and Stokes waves are simultaneously aligned with the grating edges. c) Scanning the wavelength of the pump laser relative to the grating with the pump power ($P_{\text{pump}} = 0.8W$) above the SBS threshold $P_{\text{SBS}}$. There is no more SBS generated when the Stokes wave frequency is aligned with the stopband.

References


Optically probing symmetry breaking in the Skyrmionic insulator Cu₂OSeO₃

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The cubic insulator Cu₂OSeO₃ has recently gained considerable scientific interest owing to the presence of a Skyrmion lattice phase. The Skyrmion phase is a magnetic topologically protected state, which manifests itself as a hexagonal lattice of spin vortices, and originates from a combination of different magnetic interactions. Together with their topologically protected nature, the nanometer size scale of Skyrmions may potentially allow them to be harnessed as bits in racetrack memory devices. The ability to achieve all-optical control of Skyrmions would add yet another degree of flexibility to Skyrmion-based devices. This, however, requires intimate knowledge of the optical and magneto-optical properties of these materials, but to date, research in this realm has been limited.

Here, we present an optical and magneto-optical spectroscopy study of the Skyrmion material Cu₂OSeO₃, which shows the presence of an appreciable optical activity arising from the lack of inversion symmetry in the crystal structure as well as a remarkably large magneto-optic response characterized by a giant Verdet constant. In addition to this, our data show an important structure-magnetism coupling which leads to the presence of a magneto-optical rotation which is even in the applied magnetic field, as well as the presence of a fluctuation regime in the vicinity of the paramagnetic-chiral order phase transition [1]. From the obtained optical data we also constructed the H-T phase diagram of Cu₂OSeO₃, which is found to be in good agreement with the literature [2]. In addition to gaining insight into the nature of the magnetic phases and the optical properties of the material, our observations open an exciting new avenue on the quest for optical manipulation of Skyrmionic matter.

References
Review on Spectrochemical Analysis Using Laser-Induced Plasma at Low Pressure and TEA CO2 Laser-Induced Metal-Assisted Gas Plasma at 1 atm

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Laser-induced plasma spectroscopy has widely adopted as modern technique for practical and rapid multi-elemental analysis. This analytical technique can be categorized into two, “target plasma” method and “gas plasma” method. The target plasma method can be separated into two streams, high pressure plasma method, which is done at 1 atm and well known as Laser-Induced Breakdown Spectroscopy (LIBS) and low pressures plasma method. Based on many experimental results we have clarified that in the low pressure atoms are excited by the shock wave, and we have called this method as Laser-Induced Shock Wave Plasm Spectroscopy (LISPS)\(^1\). Some of its applications are high sensitive analysis in solid samples and in film attached on the substrate. On the other hand, when TEA CO\(_2\) laser with a pulse energy of several hundred mJ is focused on metal surface, a different plasma phenomenon appears due to the unique characteristics of the laser, which has a low frequency (long wavelength) of 10.6 \(\mu\)m and long pulse duration(200ns)\(^2\). Namely, strong “gas plasma” is produced, while the metal itself is never ablated. This phenomenon never occurs in the case of standard LIBS technique. TEA CO\(_2\) laser induced- gas plasma has many favorable characteristics, namely enough high temperature (~6000K) but with not so high plasma density, good special uniformity in plasma density and very high heat capacity. One of its applications is direct analysis of milk powder and pharmaceutical powder\(^3\). Furthermore, we have demonstrated that a lot of He metastable atoms are produced in He gas plasma. The validity of the excitation process through He metastable atoms is evident by the specific characteristics of the analytical emission, namely the strong intensity with low background, narrow spectral width and long lifetime. Noble applications of “selective detection of H” in metal samples will be introduced\(^4\).

References

Acknowledgements
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Ultra-Thin Multi-Aperture Camera Modules with Megapixel Resolution for Mobile Applications

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Summary

The slim design of portable electronic devices (e.g. smartphones) causes a constant need for miniaturized camera systems. This trend pushes the shrinking of opto-electronic, electronic and optical components. While opto- and micro-electronics have made tremendous progress, the technology for the miniaturization of optics still struggles to keep up. The demand for a higher image resolution and large aperture of the lens (both driven by shrinking pixel size) conflict with the need for a short focal length and a simple, compact design. These conditions impose high demands on the fabrication technology, especially when considering that it has to meet one-hundreds of a percent relative accuracy. Wafer-level optics (WLO) fabrication for camera lenses is a promising candidate, enabling high-volume production with low cost. However, the resolution that is currently available with WLO-technology is limited due to material and process control issues. We realized a 720p resolution module by an alternative lens design using a multi aperture scheme which captures different portions of the field of view (FOV) within separated optical channels.

1. Introduction

At present, the applications of embedded digital camera modules are spread widely with about 3 billion shipments in 2014. The reasons for that market success are the instant availability of optical information and the possibility of miniaturization. This is a driving force especially for mobile consumer electronic (CE) devices whose increasingly slim designs push the micro-electronic and optics technologies. Besides the high-volume consumer market other fields of camera applications like automotive, security and medical imaging exhibit high growth rates.

From the product design point of view it is a vision to realize even slimmer camera modules in order to fit into CE-devices and to further decrease the optics fabrication and integration costs by means of parallelization. Both features are promised by multi-aperture (or array) cameras where each optical channel can be miniaturized as long as multiple channels are used in order to keep the resolution of the camera high.

2. Basic layout of multiaperture cameras

A fundamental architectural feature of the multi aperture camera (“electronic cluster eye”) is the segmentation of the field of view (FOV) – or in other words the fact that different optical channels of a lenslet array have different viewing directions (Figure 1). The FOVs of adjacent optical channels overlap by half of their FOV size interleaving their sampling grids on the object plane to increase the sampling density by a linear factor of two – a
technique called braiding. This enables a 50\% reduction of the focal length and likewise the total track length while maintaining the resolution of a larger optical system [1]. Each optical channel creates a partial image of its respective part of the FOV as if it was a stand-alone camera with tilted angle of incidence. All partial images are recombined by image processing in order to yield the final image of the full FOV. It is the segmentation of the FOV which makes it possible to achieve a good resolution with a rather simple optical setup (only few components) in each channel because the size of the FOV per optical channel is relatively small. This enables an easier fabrication e.g. using wafer-level optics technology leading to higher yield and lower costs. Additionally, the multi-aperture architecture enables features like software refocusing, all-in-focus and 3D/depth imaging in close range just like light field cameras do [2].

Furthermore, the principle of the electronic cluster eye is in theory scalable towards arbitrarily high resolution as long as the fabrication processes are matured enough to realize the resulting array optics.

3. Fabrication

A diamond machining process was developed by a company using a combination of diamond milling and fly cutting for the creation of the single masters for microlens segment arrays. The requirements for the creation of two arrays, each with 15x9 different freeform surfaces with optical quality and high fill factor, were not state of the art. The process is challenging due to the complexity in the array: dense arrangement of cells, steep jumps at cell edges, high shape accuracy required for a tiny cell width of 514µm and a maximum depth of 160µm. The structures were copied twice into a soft, transparent...
polymer and subsequently printed on a glass wafer. The advantage of a soft tool is the ability for an easy demolding during the step & repeat imprinting.

4. Characterization & Results
Additional to the characterization of the individual optical surfaces of the microlens arrays, we determined the resolution of the camera modules using measurements of the modulation transfer function (MTF).

Measured and simulated data is in good agreement giving a cutoff spatial frequency of about 300 cycles per millimeter (MTF at about 10%). We found the contrast at lower and mid spatial frequencies to be reduced relative to the simulated curve which is probably due to diffuse stray light and defocus induced by the shape errors of the surfaces of the lenslets. The already mentioned actions to achieve a lower surface profile deviation will reduce this difference.

5. Conclusion and outlook
We demonstrate a digital array camera module with 720p resolution and a total track length (TTL) of less than 2mm realized by wafer-level technology. The ultra-thin computational imaging module achieves a reduction of the TTL of 50% compared to conventional single aperture setups (of same f-number, resolution and pixel pitch) by applying a segmentation of the field of view according to the principle of the electronic cluster eye. The resulting small field of view per optical channel leads to a less complex optical design - or in other words a good MTF performance can be achieved by only two optical surfaces (a single lens element) per channel. This reduces the effort for the manufacturing and assembly so that e.g. wafer-level optics technology is applicable. The described way of mastering refractive freeform microlens segment arrays (RFFA) using diamond machining and step & repeat imprint lithography processes was for the first time...
successfully applied to realize demonstrators with up to 300 cycles/mm optical resolution in the image plane.

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References
Subwavelength light focusing and imaging via wavefront shaping and measurement in complex media

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We demonstrate that multiple scattering can be controlled via wavefront shaping in order to obtain a sub-diffraction limited focus at an arbitrary position and the full-field dynamic sub-wavelength imaging. Due to the random structure of the highly scattering media there are no restrictions on the physical position of the focus giving the system a high degree of freedom. We also present that the full-field dynamic sub-wavelength imaging can be obtained by transferring the optical near-field into propagating far-field components by multiple light scattering from disordered nanoparticles, which was previously demonstrated in microwave regime. By transferring the optical near-field into propagating far-field components by multiple light scattering from disordered nanoparticles, which we call “scattering super-lens”, we achieve sub-wavelength light focusing by far-field wavefront control (Fig. 1) or imaging from a single-shot measurement of a speckle field (Fig. 2). This new concept can be regarded as aperture-less scan-free near-field nanoscopy. Two-dimensional imaging can also be readily obtained by scanning the near-field focus or employing the concept of the transmission matrix. This technique can also be utilized for reflection-type optical tomography of biological tissue based on optical coherence tomography or digital phase conjugation technique for suppressing multiple light scattering.

Figure 1. Schematic of sub-diffraction limited focusing using scattering super-lens. Modified from Ref. [2].

References


Photoinduced spin dynamics and ultra-large Faraday rotation in CH$_3$NH$_3$PbI$_3$ perovskite thin films

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Abstract: We present the first study of ultrafast spin dynamics in CH$_3$NH$_3$PbI$_3$ thin film. Photoinduced ~90% $J$-polarized electrons and ultra-large Faraday rotation of 10°/μm are observed. Potentially, these perovskites are excellent candidates for spintronics applications.

CH$_3$NH$_3$PbI$_3$ has recently emerged as highly potential material for solar cell with efficiencies up to 20% [1]. Density functional theory studies not only showed that its band structure is strongly modulated by spin-orbit coupling (SOC) [2], but also predicted the presence of a Rashba-type splitting [3]. These discoveries denote a novel semiconductor system with highly promising characteristics for spin-based applications. Detailed studies on elucidating the spin dynamics are therefore urgently needed to assess its suitability for spin-based applications.

Previously it has been shown that CH$_3$NH$_3$PbI$_3$ has a direct bandgap at R-point (~1.6 eV) with $J = \frac{1}{2}$ ($L = 1$) conduction band (CB) and $J = \frac{1}{2}$ ($L = 0$) valence band (VB) – fig. 1(a) [2-4]. From this band-structure, we envisage that 100% $J$-polarized carriers at band edge can be photogenerated using circular polarization. By degenerate circular pump-probe, we investigate the photoexcited $J$-polarized carrier dynamics in solution processed 70 nm-thick CH$_3$NH$_3$PbI$_3$ film. Circularly polarized pump defines the $J$-orientation of the carriers in the sample, while each probe circular polarization will trace the different $m_j$ states (referred as “$J$-states”), which enable us to elucidate the dynamics of the electron/hole angular momentum flip and also model these dynamics with a simple two-level system [5]. Here, we model the population kinetics of the electrons (holes) in a given $|J, m_j\rangle$-state in CB (VB) can be described by the following rate equation – fig. 1(b):

$$\frac{d}{dt} f_{r,h}^{J=1/2, m_j=\pm 1/2} = A \left( \frac{1 \pm |p|}{2} \right) e^{-|\tau|} - \frac{f_{r,h}^{J=1/2, m_j=\pm 1/2}}{\tau_{r,h}} - \frac{f_{r,h}^{J=1/2, m_j=\pm 1/2}}{\tau_{e,h}}$$  \hspace{1cm} (1)

where $f$ denotes the occupation factor, $\tau_{r,h}$ is the $J$-relaxation or ‘$J$-flip’ time, while $e$ and $h$ are index for electron and hole respectively, $\tau_0$ is the excitation pulse width, and $p = 1$. By this model, the experimental observation is well-fitted and yields to $J$-flip time ~0.4 ps and ~1.2 ps for holes, while ~4 ps and ~7 ps for electrons at 293 K and 77 K respectively. Due to its weak dependence of temperature, we assign electron $J$-flip to Elliot-Yafet mechanism by defects and grain boundaries scattering.
Figure 1. (a) Energy bands of CH$_3$NH$_3$PbI$_3$ at R-point. (b) Model of band-edge $J$-states dynamics of CH$_3$NH$_3$PbI$_3$. Figure (c) and (d) are normalized degenerate circular pump-probe signal with 19 μJ/cm$^2$ (750 nm) $\sigma^+$ pump, and $\sigma^+$ probe (blue), $\sigma^-$ probe (red) and their total (magenta), at 293 K and 77 K respectively. (e) TRFR study on CH$_3$NH$_3$PbI$_3$. (d) Maximum rotation as function of temperature. Fig. (a) is adapted with permission from ref [2]. Copyright (2014) American Chemical Society.

Time-resolved Faraday rotation (TRFR) without magnetic field was also performed to examine the photoinduced magnetization in the CH$_3$NH$_3$PbI$_3$ film – fig. 1(e). The sign inversion of the signals for opposite circular polarizations of the pump beam and null signal from the linear pump excitation help validate that the magnetization observed originates from the photoinduced carrier $J$-polarization, further supported by the bi-exponential lifetime fitting. Moreover, our remarkable finding is the giant photoinduced Faraday rotation signal emerging from such thin films, which is equivalent to 10º/μm (at 200 K). Such strong coupling with light highlights the potential for this material for spintronics applications such as spin-switches. Furthermore, the versatility for this perovskite material class promises wider applications. This work has been published in ref [5].

References
Optical fiber bonded 1D nanobeam laser as a portable index sensor

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In this work, we present a portable index sensor, which is based on an InGaAsP 1D nanobeam laser bonded on an optical fiber. Unlike conventional photonic crystal (PC) lasers based sensor [1-2], in this configuration there is no bulky optical setup required since the pumping and detection processes can be done simultaneously through the fiber. In addition, due to its compact size and portability this device can be employed for remote and bio-sensing applications. Fig (1) shows the schematic of the experimental setup. The nanobeam laser is optically pumped using 980 nm InGaAs laser diode. To transmit the emitted light from the nanobeam laser to an optical spectrum analyzer (OSA), a 2x2 directional coupler (980nm/1550nm WDM) is used.

![Fig 1. Optical setup for sensing experiment](image)

To demonstrate our portable index sensor design, we put the device inside water-ethanol solutions of different concentrations. For the spectral measurement, the resolution bandwidth of the spectrometer is set to 70 pm. From the wavelength shift that is observed by the OSA, we can estimate the sensitivity of our device to be ~150 nm/RIU. Further optimization of the 1D nanobeam design can boost the sensitivity even more.
References

The G-centre photoluminescence from carbon implanted high energy proton irradiated SOI

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The G-centre as an emissive point defect gained a lot of attention recently due to its sharp zero phonon luminescence peak at a wavelength of 1.28 μm (0.97 eV) with the evidence of lasing occurred in the structure [1]. The emission of the G centre is attributed to the carbon substitutional–carbon interstitial (C$_s$C$_i$) complex which interacts with silicon interstitials during the damage event. The G centre emission at 1280 nm is in the spectral range which is vital in long-haul fiber-optic networks and is ideally suited to silicon intra-chip and inter-chip low-power data interconnects. A new method fully compatible with CMOS (Complementary Metal Oxide Semiconductor) technology to efficiently produce the lasing G-centre has been recently reported [2,3]. It combines the implantation of carbon, subsequent heat treatment followed by high energy proton implantation on bulk silicon substrates to form C$_s$C$_i$ complexes and Si interstitials. The luminescence intensity of the G-centre emission varies with the implant conditions such as the carbon and proton doses. The next critical step is to transfer this new technology to the silicon-on-insulator (SOI) platform to provide the optical confinement as the result of a very large refractive index contrast between the Si and SiO$_2$ for future amplifier and laser structures. Furthermore, SOI wafers are now the main material used in CMOS Silicon technology because of their attractive quality of improving the device performance for the same device dimensions as in bulk Si substrates. Therefore, the transfer of light technology from bulk to SOI platform is crucial for future integration of electronics and photonics industry.

We report efficient generation of the lasing di-carbon G-centre on silicon-on-insulator (SOI) substrates utilizing a new technique that is fully compatible with standard silicon ultra-large-scale integration (ULSI) technology. Photoluminescence measurements were carried out to investigate the point defect mediated luminescence of the G centre with a wavelength of 1280 nm in bulk Si and SOI samples. Prior to the photoluminescence measurements, the samples were implanted with high doses of carbon and irradiated with high energy protons to activate the self-interstitials that are crucial in the formation of the centre. The result shows a prominent, sharp luminescence at the carbon related, G centre at 80 K which is highly comparable with the results on bulk silicon samples.
References


Angle-resolved transmission spectroscopy of opal films

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We investigated the angular behavior of light transmission through opal films over a broad range of wavelengths and angles. The opal films were prepared using the capillary deposition method (CDM) [1]. The observation of many well-defined diffraction peaks indicates that the CDM results in opal films with high quality. Peaks overlapping at normal incidence split when samples are rotated. The angular shift of these peaks was found to satisfy the kinematical diffraction theory very well. Furthermore, the variation of intensity with incident angle can be interpreted in terms of a simplified dynamical diffraction theory [2]. Moreover, the presence of two differently oriented domains in CDM-made opal films is essential in discussing the measured spectra. These domains can be assigned to parallel microscopic stripes of ABC and ACB type fcc structures.

Figure 1. Opal orientation for angle-resolved spectroscopy (ARS) measurement (a) case V, (b) case H. The shaded regions show parts of the samples where measurements were performed. The angle $\theta_{\text{ext}} = 0$ is normal incidence.
Figure 2. ARS map with the calculated lines for different families of diffraction planes for, (a) case V, and (b) case H.

References
Infrared laser of photodynamic therapy using exogenous gold nanoparticles for cancer cells inactivation

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The aim of this research is to determine the effect of infrared diode laser energy dose exposure using 808 nm wave length to MCF-7 human breast cancer cells in vitro with and without the addition of the photosensitizer, a photodynamic therapy phenomenon. The wide of laser beam used was 0.4491 cm² with an intensity of 0.4491 W/cm². Photodynamic therapy (PDT) is a treatment for inactivating MCF-7 cancer cells using photosensitizer as light-activated cancer cytotoxicity. Exogenous photosensitizer used in this research was gold nanoparticles (GNPs) taken from a mixture between Chloroaufic acid (1.17mM) and Sodium thiosulfate (3mM). The concentration of photosensitizer obtained from the toxicity test in the amount of 25μl per sample. The distance exposure between diode laser and sample was 2 cm. The radiated energy dose were 161,301 J/cm², 184,344 J/cm², and 207,387 J/cm². The expected death of MCF-7 cancer cells from this phenomenon is apoptosis. Apoptosis is a programmed cancer cells death by vanishing the ability to replicate itself. The percentage of cells death was 7.80% without photosensitizer gold nanoparticles. At 161,301 J/cm² energy dose, the percentage of cells death before being given photosensitizer was 44.89% and 61.70% of percentage after being given by photosensitizer. In terms of 184,344 J/cm² energy dose, the percentage of cells death before being given photosensitizer was 50.00 %, and 81.81 % after being given photosensitizer. At 207,387 J/cm² energy dose, it was found 72.20 % before being given photosensitizer and 78.26% after being given photosensitizer. The radiation of infrared laser with the addition of photosensitizer gold nanoparticles resulted the highest percentage of cancer cells death in the amount of 31.81%. Based on the finding of this research, it was found that the energy dose of 184,344 J/cm² infrared laser resulted the highest death of cell apoptosis. Based on these results, it was concluded that the infrared laser exposure with exogenous photosensitizer of gold nanoparticles can inactivate cancer cells and can be used as a candidate for cancer therapy.

Keywords: apoptosis, cancer cell, gold nanoparticles, laser diode, MCF-7, photochemical, photo physical
References


Slotted patch antenna on LiNbO$_3$ optical modulator for free space radio-wave and optical fiber up-links

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Free space radio and optical fiber technologies are widely used for several applications in communication, imaging, sensing, and so on [1,2]. Up-link methods for the technologies are required, they can be composed of radio-wave antennas and optical modulators. The radio-wave antennas and optical modulators can be arranged discretely each other [3,4]. In this paper, we propose a slotted patch antenna on an optical modulator for hybrid uplinks to free space radio and optical fiber networks.

Fig. 1 shows the structure of the proposed device. A slotted patch antenna is fabricated on a LiNbO$_3$ optical crystal stacked to a MCL-FX2 low-k dielectric substrate. The patch antenna length is set at a half wavelength for the designed radio-wave for effective radiation to the free space. A narrow slot in micrometer order is located on the center of the patch antenna. An optical waveguide located close to the slot for effective optical modulation. The reverse side of the substrate is covered with a ground electrode.

Figure 1. Structure of the proposed device in whole (3D) and cross sectional views.

When the radio-wave is coupled to a feeding of the slotted patch antenna, the resonant standing-wave radio-wave current is induced on the patch antenna surface along $x$-axis. Therefore, the radio-wave can be irradiated to the free space with linear polarization for radio-wave up-links. Simultaneously, due to the continuity of the current flow along the slot, displacement current and strong electric field are induced across the slot. When light is coupled to the optical waveguide, optical modulation by the radio-wave can be
obtained through electro-optic effects. Therefore, the modulated light can be propagated to optical fibers as up-link methods. Based on the operational principle, the proposed device can be operated for free space radio and optical fiber up-links.

The proposed device was designed for 15GHz operational frequency. Microwave characteristics of the proposed device were analyzed using electromagnetic analysis software. The calculated return losses are shown in Fig. 2. We can see that the operational frequency of the proposed device is slightly shifted the patch antenna with no slot structure. It might be due to capacitance effects of the slot on the patch antenna. Microwave electric field distribution on the LiNbO$_3$ crystal surface is shown in Fig. 2. The strong electric field across the slot can be used for optical modulation. Characteristics of optical modulation were also calculated by considering interaction between microwave and optical electric fields. The calculated modulation index is shown in Fig. 3. We can see that optical modulation in 1550nm optical wavelength can be obtained using the proposed device.

![Return Losses and E_z Distributions](image1)

**Figure 2.** Calculated return losses and $E_z$ distributions.

![Modulation Index](image2)

**Figure 3:** Calculated modulation index.

The slotted patch antenna on an optical modulator for hybrid uplinks to free space radio and optical fiber networks. Analysis of the proposed device characteristics for 15GHz operational radio-wave frequency and 1550nm operational optical wavelength were done and reported. Now, we are designed array structure for improving antenna gain and modulation index furthermore.

**References**


Time-reversed nonlinear optical mixing processes

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Time-reversal symmetry is ubiquitous in physics; it allows a physical process to reverse in a backward direction of time. Recently, it has been theoretically and experimentally demonstrated that a time-reversed process of laser emission, or coherent perfect absorber, can enable total absorption of coherent light fields inside an optical cavity of loss by time-reversing the original gain medium. Nonlinearity, however, can often destroy such symmetry in nonlinear optics, making it difficult to study time-reversal symmetry with nonlinear optical wave mixings. Here we demonstrate time-reversed wave mixings for optical second harmonic generation (SHG) and optical parametric amplification (OPA) by exploring this well-known but underappreciated symmetry, characterize their nonlinear properties as opposite to their time-reversal counterparts, and reveal the nontrivial dynamics of phase varying in time-reversed nonlinear wave-mixing schemes. This allows us to observe the annihilation of coherent beams. Our study offers new avenues for flexible control in nonlinear optics and has potential applications in efficient wavelength conversion, all-optical computing, etc.

References
Nonlinear optics is a fascinating topic of modern optics, which has been made possible by the developments of ultrafast lasers. Nonlinear optical phenomena usually resort to specific bulk crystals with a strong nonlinear susceptibility.

In this talk, I will explore another way of realizing nonlinear optical effects, using plasmonic nanostructures. Such nanostructures do not exhibit a strong bulk nonlinear susceptibility; yet, they can be used to produce nonlinear effects, such as second harmonic generation. In those metallic structures, the second harmonic originates from the surface of the metal and is strongly enhanced by the significant optical near-field excited at their surface by the plasmon resonance.

After reviewing the mechanisms that lead to second harmonic generation in plasmonic nanostructures, I will focus on multi-resonant plasmonic antennas and show how optical resonances at the fundamental and second harmonic frequencies can boost the nonlinear response of such an antenna. I will then show that more complex nanostructures that support Fano resonances can also provide further enhancement channels for second harmonic generation.

Since second harmonic generation produces photons with twice the frequency from the original excitation, the experimental study of this effect requires plasmonic materials that exhibit resonances in the short wavelength part of the visible spectrum, thus putting constraints on the possible materials that can be used; in particular, gold – the metal of choice for plasmonics – is not so well suited for nonlinear effects. To address this experimental challenge, we have developed new fabrication techniques for the realization of plasmonic nanostructures in aluminum and silver.
Sub-Wavelength Field Distribution and Photo-Rectification in Metamaterials

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In free space, the smallest light field distribution is characterized by its wavelength. So in order to utilize light for lithography, higher frequency light with shorter wavelength have been used for smaller structures. Near a metal surface, however, the feature size can be much smaller due to the short wavelength of surface plasmon polariton. We had demonstrated that by using a silver mask with periodic slits, it is possible to fabricate 50 nm line-and-space structures with 436 nm [1] as is shown in Fig.1. Recently by combining metal film with dielectric structure, we showed that more complex structures can be prepared [2]. In any cases, electromagnetic simulation is useful to design the optimized structures.

![AFM image of resist pattern prepared by Surface Plasmon Resonant Interference Nanolithography Technique (SPRINT)](image)

Figure 1. AFM image of resist pattern prepared by Surface Plasmon Resonant Interference Nanolithography Technique (SPRINT) [1]

The microscopic electric field distribution may provide DC electric field due to optical rectification if an inversion symmetry is broken. Figure 2 shows photo-induced voltage as a function of wavelength for symmetric and asymmetric structures. The symmetric structure gives photo-induced voltage which is anti-symmetric function of incident angle, while an asymmetric structure exhibits finite voltage even at the normal incidence [2].

Square array of holes in a metal film gives similar effect. Furthermore, for oblique incidence, transverse voltage perpendicular to the incident plane is observed for circularly polarized light [3]. The sign of voltage depends on the direction of circular polarization.
Figure 2. Angle dependence of photo-induced voltage for symmetric and asymmetric grating structures [2]

Metamaterial does not have to have periodic sub-wavelength structure. One example is nano-porous gold (NPG). It is obtained by etching a thin foil of Au-Ag 50:50 alloy with nitric acid, which results in interconnected pores in a gold film. It shows similar longitudinal and transverse photo-induced voltage [5].

References
Directional nano-antennae for surface plasmon polaritons and light

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The development of nanophotonics hinges on the control of optical energy flow at the nanometer length scale. Metal nanoparticles (MNPs) and interfaces between metals and dielectrics offer great potential for this development, as the plasmon excitations in metal objects are confined excitations that, moreover, interact strongly with light. For instance, Surface Plasmon Polaritons (SPPs) that exist at metal-dielectric interfaces are electromagnetic waves that can be confined well below the diffraction limit and can propagate over distances of several tens of microns.

In this presentation, I will address two proposals for systems existing of MNPs for directional excitation of waves in the optical regime, both using arrays of MNPs as primary ingredients. Each MNP is modelled as an electrical dipole. Dipoles interact with each other through retarded dipole-dipole interactions described by the Green’s function that is appropriate for the overall geometry. The first system is a directional antenna for SPPs over a metal/dielectric interface. We show that c.w. optical excitation of an asymmetric dimer of MNPs may launch a directional wave of SPPs on the interface, i.e. the SPP propagates in one direction and not in the other [1]. The effect can be traced back to the elliptical polarization of the main hybrized eigenmodes of the system. Using longer chains of MNPs is expected to increase the focus of the directional antenna.

As second example, I will introduce an antenna existing of an array of MNPs that are excited by the evanescent wave incident on the system via a strong dielectric contrast interface. We have shown that this yields an antenna for optical radiation whose directionality (in polar as well as azimuthal angles with respect to the normal to the interface) is well-defined and can be controlled by the excitation conditions [2]. The phenomena observed are well-understood using the concepts of image dipoles and phased arrays.

References
Scattering characteristics of metal and dielectric optical nanoantennas

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Optical resonances of metallic or dielectric nanoantennas enable to effectively convert free-propagating electromagnetic waves to localized electromagnetic fields and vice versa.[1, 2] Plasmonic resonances of metal nanoantennas extremely modify the local density of optical states beyond the optical diffraction limit and thus facilitate highly-efficient light-emitting.[3] nonlinear signal conversion,[4] photovoltaics,[5] and optical trapping.[6] The leaky-mode resonances, or termed Mie resonances, allow dielectric nanoantennas to have a compact size even less than the wavelength scale. The dielectric nanoantennas exhibiting low optical losses and supporting both electric and magnetic resonances provide an alternative to their metallic counterparts.[7, 8] To extend the utility of metal and dielectric nanoantennas in further applications, e.g. metasurfaces and metamaterials [9], it is required to understand and engineer their scattering characteristics.

At first, we characterize resonant plasmonic antenna radiations of a single-crystalline Ag nanowire over a wide spectral range from visible to near infrared regions.[10] The single-crystalline Ag nanowire with an atomically smooth surface establishes high-quality Fabry-Perot (FP) resonances of surface plasmon polaritons (SPPs). The scattering properties at the Fresnel and Fraunhofer regions are measured by dark-field optical microscope and direct far-field scanning set-up, respectively. The angle- and spectrum-resolved far-field scattering measurements successfully identify the FP resonances and mode matching conditions of the antenna radiation. We also reveal the mutual relation between the SPP dispersion at the near-field and the antenna radiation at the far-field.

Secondly, we perform a systematical study on strong light scattering properties of high-refractive-index dielectric nanoantennas. Scattering spectra of the transverse-electric (TE) and transverse-magnetic (TM) leaky-mode resonances supported by a single Si nanoblock are measured by dark-field microscopy and analyzed by the finite-difference time-domain method and modal dispersion model.[11] In particular, the lowest-order TM_{01} mode overcomes the optical diffraction limit and its resonant wavelength can be tuned over the whole visible wavelength range depending on the length of the Si nanoblock. The wide tuning of the TM_{01} leaky-mode resonance allows spectral overlap with other leaky-mode resonances and results a large scattering cross section approaching the theoretical single-channel scattering limit. Strong resonant scattering of the Si nanoblock generates vivid structural color from blue to green, yellow, and red. We also demonstrate carbonaceous dielectric nanorod antennas by the electron beam-induced deposition (EBID) method.[12] Compared to conventional top-down fabrication techniques, the EBID method is easier to fabricate complex three-dimensional metallic or
dielectric nanostructures on any desired substrates including atomic force microscope tips and even free-standing geometries. The EBID carbonaceous nanorod antennas also show resonant light scattering properties and tunable structural color generation over the whole visible spectrum.

References
Dirac Cones in Photonic Crystal Slabs

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Dirac cone can be materialized on the \( \Gamma \) point (Brillouin-zone center) of periodic photonic crystals and metamaterials by accidental degeneracy, as was shown by Huang et al.\(^1\). Then, Mei et al. discussed the formation of Dirac cones, Berry phase, and mapping into the Dirac Hamiltonian for phononic and photonic crystals by the \( \mathbf{k} \cdot \mathbf{p} \) perturbation theory.\(^2\) Because the Dirac point in the Brillouin-zone center is equivalent to a zero effective refractive index,\(^1\) it has much potential for various applications such as scatter-free waveguides\(^3\) and lenses of arbitrary shapes.\(^4\)

On the other hand, we showed by tight-binding approximation and group theory that Dirac cones can also be created by accidental degeneracy in the Brillouin-zone center of metamaterials, which are characterized by well-defined electromagnetic resonant states localized in their unit structures.\(^5,6\) We proved the presence of isotropic Dirac cones with auxiliary quadratic dispersion surfaces in square-, triangular-, and simple-cubic-lattice metamaterials [Fig. 1(a)] and the presence of the double Dirac cone, or a pair of identical Dirac cones, in the triangular-lattice metamaterials [Fig. 1(b)]. We also applied the \( \mathbf{k} \cdot \mathbf{p} \) perturbation theory and group theory to this problem and showed that the structure of the first-order perturbation matrix is determined almost uniquely by the mode symmetry, and completely clarified the conditions for obtaining the Dirac cones.\(^7\) We further analysed the propagation of the Dirac cone modes in photonic crystal slabs and showed that their propagation direction can be controlled by the polarization of the incident plane wave.\(^8\)

**Figure 1.** (a) Dirac cone with an auxiliary quadratic dispersion surface (dotted lines) and (b) double Dirac cone on the \( \Gamma \) point \((\mathbf{k}=0)\) of the two-dimensional Brillouin zone materialized by accidental degeneracy of two modes with particular combinations of mode symmetries.

In this presentation, we report on both the analytical and numerical calculations of the dispersion relation of photonic crystal slabs and present the sample parameters that materialize the two-dimensional Dirac cone. We also show that the dispersion relation for
low-Q Dirac cone modes considerably deviates from the linear dependence [Fig. 2(b)] whereas the dispersion relation is linear for high-Q Dirac cone modes [Fig. 2(a)]. The deformed dispersion relation [Fig. 2(b)] apparently gives a superluminal propagation \( v_g > c \) of light waves. These features (deformed dispersion and superluminal propagation) look similar to light propagation in anomalous dispersion media, which was extensively studied in 1980s. In fact, the apparent superluminal propagation is an artifact that was brought about by an insufficient treatment of the dispersion curves in which only the real part of the eigen frequency is taken into consideration. Indeed we have to properly consider the decrease of the electromagnetic energy during the propagation due to absorption and diffraction for the anomalous dispersion media and the photonic crystal slabs, respectively. We will present analytical results according to this prescription in the talk.

**Figure 2.** The dispersion relation of the Dirac cone and an auxiliary quadratic mode in the vicinity of the \( \Gamma \) point of the square-lattice photonic crystal slab. \( a \): lattice constant, \( t \): thickness, \( R \): radius of air holes. (a) \( t/a = 1.0 \), (b) \( t/a = 0.8 \).

**References**


Ultrathin Films of Graphene Oxide - Critical Assessment of Photoreduction Strategies

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Approaches to graphene-based electronic materials and devices frequently use graphene oxide (GO), combined with a suitable reduction process to remove the oxygen-containing groups. Photoreduction of GO films can generate suitable structures of reduced graphene oxide (RGO) by means of irradiation masks or laser direct writing techniques [1,2]. However, the photoreduction mechanisms are not fully resolved yet as the distinction between photothermal and photochemical reaction pathways still needs fundamental clarification.

We have prepared ultrathin films of GO by spin-coating from aqueous solutions, irradiated them with monochromatic light obtained from a high-pressure mercury arc combined with narrow band filters, and a femtosecond laser system at 800 nm. We used UV-Vis-NIR absorption spectroscopy to characterize conversion and reaction rate of the photoreduction quantitatively. The kind of photoreaction is analyzed by the characteristic influence of the light intensity on the reaction yield. Photothermal reactions show a threshold behavior, i.e., a minimum sample heating is required. Photochemical reactions can occur via single- or multiple photon absorption. We verify pure photochemical photoreduction of GO by single-photon-absorption at UV and even visible light irradiation wavelengths, and two-photon induced photoreduction with high-intensity laser pulses at 800 nm. We observe onsets of reduction of GO at significantly lower temperatures and photon quantum energies as reported earlier. Our work has critical implications on stability issues of RGO devices which will be discussed.

References
Normal, degenerated, and anomalous-dispersion-like Cerenkov sum-frequency generation in one nonlinear medium

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Nonlinear Cerenkov radiation (NCR), emerges in nonlinear optics when intense laser injecting into nonlinear media and gives rise to coherent harmonic generation in the Cerenkov angle, \( \cos \theta = \nu/\nu' \) where \( \nu' \) and \( \nu \) denote the phase velocity of nonlinear polarization wave and harmonic wave, respectively. In this letter, we reveal a variety of NCR patterns that occurs in a single photonic crystal under different dispersion circumstances. By varying the wavelengths of two collinear incident waves, we observe a series of consecutively evolving \( \chi^{(2)} \) up-conversion processes which manifest themselves as normal, degenerated and anomalous-dispersion-like NCR type sum-frequency generation (SFG).

**Figure 1.** (a) - (c) Illustrations of the typical patterns with the wavelength of incidence F2 at 1250nm, 1340nm and 1450nm, respectively. (e) - (f) Schematics of the phase-match conditions of the Cerenkov sum-frequency generation in normal dispersion stage, degenerated stage, and anomalous dispersion stage, respectively. (g) Experimental pattern of the two sets of multiple conical harmonic generations.

In addition, multi-conical SFG has also been observed, which results from two types of scattering-assistant phase-matching geometries. Under anomalous dispersion, the two sets of multiple conical harmonic generations are resulted from the sum-frequency by the scattering phase-matching processes of each incidence.
Tunable ultra-narrow linewidth in passively Q-switched erbium-doped fiber laser

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An ultra-narrow linewidth laser is proposed and successfully demonstrated by employing an ultra-narrow tunable bandpass filter (TBF) and the linewidth frequency obtained is 17.5 kHz. The ultra-narrow linewidth of the passively Q-switched erbium doped fiber laser is realized by using a single wall carbon nanotube (SWCNT) saturable absorber (SA). The stable ultra-narrow linewidth of Q-switched pulses can operate with a tunable range from 1525 to 1561 nm, covering a wavelength range of 36 nm. The average 3 dB bandwidth for each output spectrum is approximately 0.017 nm. The Q-switched states at different lasing wavelengths are observed and recorded at fixed pump power of 82.4 mW. The highest repetition rate is 37.98 kHz at the wavelength of 1545 nm with the smallest pulse width of 1.15 μs and the pulse energy is close to 0.18 nJ.

References
Electromagnetically-induced transparency in optical fibers

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Electromagnetically induced transparency (EIT) is a quantum interference phenomenon in which the absorption of a medium can be highly reduced within a frequency band of transparency window [1]. In EIT system, a three level atomic system is considered where there are two fields, namely a strong control pump field and a weak signal field, interact with the medium. The pump coherent field changes the refractive index of the medium through which the weak signal field propagates and this leads to low absorption of the signal field. In addition, within the transparency window, a dispersion of the medium varies rapidly and it induces significantly reduced group velocity which leads to slow light [2].

EIT in the bulk medium has been demonstrated which leads to a reduced group velocity of c/250 [1]. EIT and its slow light in cavity and waveguides have been also investigated [3-5]. EIT medium was proposed at the interface between two materials for an all-optical control of surface polaritons [4]. EIT inside the core of cylindrical waveguide with metal or metamaterial cladding has been considered for possible plasmonic devices applications [5]. These authors considered slow light for TM surface modes that occur in cylindrical waveguides with reduced loss using metamaterial cladding.

In this work, we focus on the effect of cylindrical confinement on the properties of EIT and the slow light due to spatial inhomogeneous pump coherent field and transverse spatial confinement of the resonant three-level atomic system in the optical fiber. The guided modes are treated in the weakly guiding approximation which renders the analysis into manageable form. The transparency window and permittivity profile of the core due to the strong pump field in the EIT scheme is calculated. For a specific permittivity profile of the core due to EIT, the propagation constant of the weak signal field and spatial shape of fundamental guided mode are calculated by solving the vector wave equation using the finite difference method [6]. It is found that the transparency window and slow light field can be controlled via the optical fiber parameters. The reduced group velocity of slow light in this configuration is useful for many technological applications such as optical memories, effective control of single photon fields, optical buffer and delay line.
References
Holmium-doped fiber laser pumped with dual wavelength thulium ytterbium co-doped fiber laser

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Holmium and thulium doped fiber lasers provide an efficient method of generating high average power in the 1.8 – 2.2 μm spectral region [1-2]. Thulium doped fiber lasers (TDFLs) typically operate efficiently at wavelength around 1950 nm region and they are not able to efficiently access longer wavelengths due to the diminishing emission cross-section of thulium in silica. In this paper, a room temperature all-fiber dual-wavelength holmium doped fiber laser operating in 2 μm region is demonstrated for the first time using a newly developed a holmium-doped fiber (HDF) as a gain medium.

The proposed fiber laser is constructed using a simple half-opened linear cavity, which is formed by the broadband mirror and an output coupler reflector. A 3 m long HDF is used as the gain medium. The HDF is pumped by a dual wavelength Thulium-Ytterbium co-doped fiber laser (TYDFL) operating at 1991 and 1999 nm with a signal to noise ratio of more than 34 dB (Fig. 2). The TYDFL is obtained using a 15 m homemade Thulium Ytterbium co-doped fiber (TYDF), which is pumped by a 980 nm multimode laser diode (LD) via a multimode combiner (MMC). The output coupler reflector is formed by the 4% Fresnel reflection from the perpendicular cleaved fiber end. The laser output is measured by using an optical spectrum analyzer (OSA) with a resolution of 0.02 nm and an optical power meter (OPM).

As the pump photons at 1991 and 1999 nm are absorbed by the Holmium ions, it excites the ions from ground state 5I8 to 5I7. As the ion relaxes to ground state, it generates photons at longer wavelengths of 2075 and 2083 nm, which oscillate in the linear cavity to generate dual-wavelength laser. The output spectrum of the proposed laser as recorded by an OSA is shown in Fig. 3 when the TYDFL output power is fixed at 320 mW. As seen in the figure, a dual-wavelength output lines are obtained at 2075 and 2083 nm with a signal to noise ratio of more than 17 dB. The 3 dB bandwidth of both lasers is measured to be less than 0.2 nm. The power difference between the two peaks is less than 1 dB. Dual-wavelength laser operating in this spectral region have applications in LIDAR, remote sensing and biomedical applications [3].
Figure 1. Experimental setup

Figure 2. Output spectrum of the TYDFL pump

Figure 3. Output spectrum of the HDF laser

References
Hybrid plasmonic-photonic modes for light emission enhancement

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Distinct modes of electromagnetic waves which overlap spectrally and spatially can couple with each other to form hybridized resonances. These hybrid modes inherit and mix characteristics of the interacting bare resonances. Periodic arrays of metallic nanoantennas support an interesting class of such hybrid modes, in particular those that arise from the coupling between Localized Surface Plasmon Resonances (LSPR)s in individual nanoantennas with diffracted or guided modes. These hybrid plasmonic-photonic modes can be tailored to have a long propagation length well suited to modify the emission from spatially extended sources in the periodicity plane, while preserving sub-wavelength confinement and strong near-field enhancement.

Here, we show how a hybrid plasmonic-photonic mode’s radiative loss, dispersion, linewidth, and field extension can be tuned by controlling the coupling strength via the geometry of the structure. We present variable angle light extinction experimental spectra for five arrays with different nanorod width and explain our results with numerical simulations. We provide a plane wave model that interprets the near- and far-fields of these eigenmodes, describing the intricate behavior of confinement and radiative loss versus in-plane momentum.

We further proceed to demonstrate active spectral and directional control of quantum dot light emission enhancement via hybrid plasmonic-photonic modes. The tuning was achieved by covering the array with a thermotropic Liquid Crystal (LC), which changes from a birefringent (Figure 1a) to an isotropic state (Figure 1b) above the critical temperature. In turn, this modifies the resonance conditions of the coupled system. The photoluminescence enhancement dispersion measured in the birefringent and isotropic state is shown in Figure 1c and 1d respectively. The narrow linewidth (< 6 nm) and angular spread (<1.5 degrees) of this resonance allow us to tune the emission with unprecedented wavelength and angular specificity. Numerical simulations reveal that the tuning mechanism depends on the modal field profile, more specifically on the orientation of the dominant mode polarization in the LC layer with respect to the LC axis.
Figure 1. Schematic representation of the sample. (a) At room-temperature (23°C) the liquid crystal is ordered, making the medium overlying the plasmonic antennas birefringent. (b) At higher temperatures (> 58 °C) the liquid crystal is disordered, yielding an isotropic refractive index in the same medium. Measured variable angle photoluminescence enhancement spectra at (c) 24°C and (d) 60°C. The black dashed lines in all the plots represent the dispersion of the fundamental TM waveguide mode in the absence of the aluminum nanodisk array.

References
* Equal contribution
Surface plasmon resonance sensor using functionalized alkanethiols monolayer for illegal compound detection

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Surface plasmon resonance (SPR) sensor receives great interests because of its sensitivity as an optical transducer. SPR-based biosensors are most commonly used for proteins analysis in the life sciences, drug discovery and food industry. For this purpose, the biosensor chip is equipped with immobilized biochemical recognition element. For immobilization of biochemical recognition elements on the sensor surface, the self-assembly monolayer (SAM) of organosulfur has been extensively studied. Structural characteristic of monolayer is an important issue for further application of SAM-based molecular electronics. This study focuses on the relation between structure of alkanethiols SAM of different chain length and its sensitivity of the detection. The surface structure is characterized by electrochemical methods, FTIR and STM.

The target compound in this research is clenbuterol as illegal compound. Clenbuterol is a member of the β-adrenergic agonist family, which is mainly used for bronchodilators agent and asthma treatment. Farmers used this illegal compound to increase their profit gain due to optimum production of lean meat.

SPR experiments were performed using a SPR 670 (NIPPON Laser and Electronics-Japan) equipped with a flow injection system for immunoanalysis. Figure 1 shows the STM image of the sensor surfaces. First, different chain length of alkanethiols were flowed over the Au chip surface. Au surface was covered with succinimide terminated alkanethiols monolayer by self-assembly. And then, clenbuterol (in PBS solution) was injected to the surface. Succinimide group was replaced with clenbuterol (antigen) by amide coupling reaction. In order to put off unreacted succinimide groups, ethanolamine was injected as blocking agent. Sensor chip was used for detection of β-agonist immediately after fabrication.

For the detection of clenbuterol, indirect competitive inhibition method was used. The pre-mixture process of the antibody solution (PBS solution clenbuterol antibody) and a clenbuterol standard solution was optimized. Then, free antibody in the pre-mixture solution will bind to the clenbuterol (antigen) immobilized on the sensor surface. So, in this indirect competitive inhibition method, the heavyweight of antibody will interact to
sensor surface instead of lightweight antigen. By this process, we expect the significant responses from the SPR measurement with rapid detection time.

By using different chain length of alkanethiols compound as monolayer structures for the sensor surface fabrication, it was found that shorter chain-length of alkanethiol reveals higher sensitivity in the detection process. For multiple analyses, surface regenerations are required by 0.1 M NaOH injection. By this method, clenbuterol can be detected within 1000 s per one sample in total.

![Gold surface](image1)

**Figure 1.** STM images of the sensor surface from different alkyl chain length of DSP thiol (left image) and DSU (right image) thiols.

**References**


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Poster Presentations
PP-01  Growth and nonlinear optical properties of BaMgF$_4$ single crystal
Zhuo WANG, Yuanlin ZHENG, Anhua WU, Yuqi ZOU, JunXU and Xianfeng CHEN (Department of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai, China)

PP-02  Characteristics of Synthesized Graphene Oxide and Its Optical Properties
Norman SYAKIR, Annisa APRILIA, Syafiul ANAM, Rhesti NURLINA, FITRILAWATI (Department of Physics, University of Padjadjaran, Sumedang, Indonesia)

PP-03  Multiple users entanglement distribution with PPLN
Tong XIANG, Qichao SUN, Mengying ZHAN and Xianfeng CHEN (State Key Laboratory on Advanced Optical Communication Systems and Networks, Department of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai, China)

PP-04  Co-sensitizers for Dye-Sensitized Solar Cells (DSSCs)
Preeyapat PROMPAN, Taweesak SUDYOADSUK, Kittiya WONGKHAN and Rukkiat JITCHATI (Organometallic Catalytic Center (OCC), Department of Chemistry, Faculty of Science, Ubon Ratchathani University, Thailand)

PP-05  Investigation on the Effect of Dye Adsorption Processes for Dye-Sensitized Solar Cell (DSSC)
H. SANTOSO, V. ZHARVAN, R. DANIYATI, N. ICHZAN AS, G. YUDHOYONO, ENDARKO (Department of Physics, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia)

PP-06  A novel charged iridium polymer for polymer light emitting diode
Natsiri WONGSANG, Praweena WONGKAEW, Kittiya WONGKHAN, Somboon SAHASITHIWAT and Rukkiat JITCHATI (Organometallic Catalytic Center (OCC), Department of Chemistry, Faculty of Science, Ubon Ratchathani University, Thailand)

PP-07  Thermally Stable Encapsulation Material Based on Green and Red Lanthanide Phosphor for White Light Emitting Diodes
Wedianti SHUALDI, Nik Mohd Azmi Nik Abd AZIZ, Nurul Huda YUSOFF, Nor Adhila MUHAMMAD, Khairuldin Mohd ISHA (Energy Materials Section, Advanced Materials Research Center
(AMREC), Standards and Industrial Research Institute Malaysia (SIRIM) Berhad, Kedah, Malaysia)

PP-08 Analysis of Optical Gain in Nd$^{3+}$ Doped Glass Medium using FDTD Method
O. F. Tri-MARYANA, R. HIDAYAT (Physics of Magnetism and Photonics Group, Physics Department, Institut Teknologi Bandung)

PP-09 Excitation Mechanisms of the 1mJ Picosecond Laser Induced Plasma Emission in Low Pressure Ambient Helium Gas and the Improved Performances of Spectrochemical Analysis
Nasrullah IDRIS, May-On TJIA, Koo Hendrik KURNIAWAN, Kiichiro KAGAWA (Department of Physics, Syiah Kuala University, Aceh, Indonesia)

PP-10 Direct Evidence of the Role of He Triplet Metastable Excited State in Excitation Process of Laser-Induced He Gas Plasma
Hery SUYANTO, Rinda HEDWIG, Zener Sukra LIE, Koo Hendrik KURNIAWAN, May-On TJIA, Kiichiro KAGAWA (Department of Physics, Udayana University, Denpasar, Indonesia)

PP-11 Rapid Determination of Anthocyanin in Cacao (Theobroma Cacao L) Leaves Using Digital Image Processing for Finest Cacao Clone Selection
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PP-12 Non-adiabatic Microfiber Sensor for COD Investigation
Su Sin CHONG, Abdul Aziz Bin ABDUL RAMAN, Sulaiman W. HARUN, Hamzah AROF (Department of Chemical Engineering, University of Malaya, Kuala Lumpur, Malaysia)

PP-13 A specific gravity sensor for crude oils based on polymer optical fiber using a ratiometric measurement method
E. RIZKY, S. FIRMANSYAH, SEKARTEDJO, A. M. HATTA (Department of Engineering Physics, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia)
PP-14 Relative Humidity Sensor Using A PMMA Microfiber Coated With ZnO Nanostructure
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PP-15 Humidity sensor based on Microfiber Resonator with Reduced Graphene Oxide
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PP-16 The use of SMS fiber structure for current measurement
I. NOVITASARI, R. N. HIDAYATI, SEKARTEDJO, A. M. HATTA (Department of Engineering Physics, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia)

PP-17 High energy pulse in passively Q-switched using MWCNT/PVA as a saturable absorber
S.N.M. HASSAN and H. AHMAD (Photonics Research Center, Department of Physics, University of Malaya, Kuala Lumpur, Malaysia)

PP-18 Switchable Wavelength Thulium Doped Fiber Laser at 1900nm by Using AWG
A. MUHAMAD, M. F. ISMAIL, M. Z. ZULKIFLI, H. AHMAD (Photonics Research Centre, University of Malaya, Kuala Lumpur, Malaysia)

PP-19 Generation of Coherent Vector Soliton Mode-locked Thulium-doped Fiber Ring Laser
A.A. LATIFF, H. SHAMSUDIN, Z. C. TIU, S.W. HARUN, H. AHMAD (Photonics Research Centre, University of Malaya, Kuala Lumpur, Malaysia)

PP-20 Implementation of SOI-Based Rib Waveguide for High Speed On-Chip Optical Interconnect (OI) in Circuit Level
Siti Sarah Binti Md SALLAH, P. Susthitha MENON, Sawal Hamid Md ALI, Md. Shabiul ISLAM (Faculty of Engineering and Build
Environment, Institute of Microengineering and Nanoelectronics(IMEN), Universiti Kebangsaan Malaysia (UKM), Selangor, Malaysia

PP-21 Nonlinear Study on Two Mode Fiber
S.N.A. SAKEH, H. AHMAD, M.Z. ZULKIFLI (Photonics Research Center, University of Malaya, Kuala Lumpur, Malaysia)

PP-22 Spiral Structured Growth of ZnO on Plastic Optical Fiber towards Light Side Coupling
H. RAFIS, S. MANJUNATH, Hoorieh FALLAH, S.W. HARUN, Waleed S. MOHAMMED, G. Louis HONYAK, Joydeep DUTTA (Photonics Research Centre, University of Malaya, Kuala Lumpur, Malaysia)

PP-23 Performance of Optical Crosstalk for AWG Demultiplexer Designed with Large and Small Cross Section of Rib Waveguide Structure on SOI
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PP-24 Controllable pulse width via different lengths of PMF in a Sagnac loop passively mode-locked fiber laser
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PP-33 Nonlinear Bond Model of Second and Third Harmonic Generation in Body and Face Centered Cubic Crystal Structures
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A. AZWAR, A. SOEHIANIE, A.A. ISKANDAR and M.O. TJIA (Physics of Magnetism and Photonics Research Group, Institut Teknologi Bandung, Bandung, Indonesia)

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R.N.S. SURYADHARMA, A.A. ISKANDAR, M.O. TJIA (Physics of Magnetism and Photonics Research Group, Institut Teknologi Bandung, Bandung, Indonesia)

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Adisetyo PANDUWIRAWAN and Alexander A. ISKANDAR (Physics of Magnetism and Photonics Research Group, Institut Teknologi Bandung, Bandung, Indonesia)

PP-40  Study of optical coupling between two silver nanorods using mechanical model

Fransiska R. WIDIASARI and A.A. ISKANDAR (Physics of Magnetism and Photonics Research Group, Institut Teknologi Bandung, Bandung, Indonesia)
Extended Abstracts

10th International Symposium on Modern Optics and Its Applications

Poster Presentations
Growth and nonlinear optical properties of BaMgF$_4$ single crystal

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The BaMgF$_4$ single crystal is grown by the temperature gradient technique. The raw materials were BaF$_2$(99.99%) and MgF$_2$(99.99%). One a-cut BaMgF$_4$ single crystal was used as a seed. 0.5 wt% PbF$_2$(99.99%) was used as oxygen scavenger. The typical dimensions of the as-grown BaMgF$_4$ single crystal are diameter 75mm with the height 50mm. The short cut-off wavelength of BaMgF$_4$ single crystal was determined to be 130nm which is consistent with the previously reported result. The measured second order nonlinear optical coefficients are one order of magnitude larger than the previous values reported in the 1970s and consistent with our recent theoretical calculation. Second harmonic generation from 1064nm to 532nm and 800nm to 400nm femtosecond laser in the single domain BaMgF$_4$ crystal were realized by birefringent phase matching. The measured nonlinear refractive indices are one order of magnitude larger than the values of conventional nonlinear optical crystals, such as BBO and LBO. The possible applications of BaMgF$_4$ single crystal in fabricating all solid-state lasers in VUV region are also discussed.

References

Characteristics of synthesized graphene oxide and its optical properties

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Graphene oxide receives a lot of attention due to its promising properties for electronic devices [1]. Graphene can be prepared from the graphene oxide (GO) combining with a reduction process for removing oxygen containing groups [2]. We report a progress on synthesis of graphene oxide using a modified Hummers method [3], its thin film preparation, and photoreduction treatment using existing equipment in our laboratory.

Graphene oxide (GO) was synthesis from graphite powder that treating with mixture of sodium nitrate (NaNO₃), potassium permanganate (KMnO₄), sulfuric acids (H₂SO₄). The mixture was stirred, and then peroxyde acids (H₂O₂) as added into the mixture. The mixture was filtered and rinsed with chloric acids (HCl) and water for many times to get a pure GO pasta. The GO pasta was dried under vacuum and then dispersed in water. Further in order to change GO flakes to become more thinner as GO sheets, the dispersed GO was exfoliated by sonicating under ambient temperature and followed by centrifugation. The dispersed GO in water and its surface morphology is shown in Figure 1.

![Image](attachment:figure1.png)

**Figure 1.** The synthesized dispersed GO (a), and its surface morphology (b)

In order to compare our synthesized GO with the commercial one, we used a commercial GO synthesized by Graphenea [4], we measured their optical spectra for varied concentration and Energy Dispersive Spectroscopy (EDS). We obtained that both samples have a similar spectra. The results will be further discussed in order to justify our synthesized GO.
We also prepared ultrathin films of GO on a fused silica substrate by spin-coating from aqueous solutions. The optical spectra of obtained GO film was also compare with the commercial one. We found a similar feature as spectra of the synthesized GO thin film as the commercial one.

In order to remove oxygen-containing groups, the GO film was irradiated with ultraviolet light from mercury lamp combined with the UG11 filter. We used UV-Vis-NIR absorption spectroscopy to characterize a removing of oxygen contain due to photoreduction process. The quantitative analysis of the obtained spectra will be discussed.

References
Multiple users entanglement distribution with PPLN

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Generating entangled photon pairs over a broad wavelength range through 5%MgO-doped PPLN makes it possible to distribute entangled photon to multiple users. Due to the 30 nm bandwidth of difference-frequency spontaneous parametric down conversion (SPDC) in type-I quasi-phase-matching (o-light input), we realize wavelength-flexible polarization entangled photon pairs around the communication band in high quality. The source is continus laser at 778nm. SPDC photon pairs are all around 1556nm. Then different wavelength photon is selected into dense wavelength-division multiplexing channels to structure an optical network. The certain wavelength’s information transfers to the certain receiver, what’s more, every one is able to share the information with any other receivers like the classic net. This entangled photon source is significant of quantum entanglement distribution, building a more convenient and efficient quantum optical network.

References

Co-sensitizers for dye-sensitized solar cells (DSSCs)

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The dye-sensitised solar cell (DSSC) has been proposed as a low-cost and high-efficiency alternative to conventional photovoltaic cells in 1991 [1]. At present, efficiencies of more than 11% can be obtained for DSSCs using electrolytes based on volatile organic solvents [2]. One of the most important components of DSSC is the photosensitizer which absorbs light from the sun and transfers an electron from its excited state to the conduction band of TiO$_2$. The most common sensitizers are Ru(II) complexes such as N$_3$ and N$_{719}$. However, a limitation of these materials is absence of strong absorption in the red region of the visible spectrum. Co-sensitization is an effective approach where in a combination of two or more dyes adsorbed together on TiO$_2$ surface, extending the light harvesting ability and enhance large molar extinction coefficient in near infrared region to enhance the performance of DSSCs [3]. Herein, we report that the photovoltaic performance of the co-sensitizer form ruthenium complexes. The molecular structures of sensitizers are shown in Fig. 1.

![Figure 1](image_url)

**Figure 1.** The synthesized dispersed GO (a), and its surface morphology (b)

The UV-vis absorption spectra of N$_{719}$, P$_2$, YN$_{07}$, N$_{719}$+P$_2$ and N$_{719}$+YN$_{07}$ are shown in the fig. 2 (left). There are two absorption bands which are observed in the 300–800 nm region; the one at 450 nm is attributed to the $\pi-\pi^*$ transition of ligand and the other one at 500-600 nm shows a lower-energy MLCT band. We found that the absorption spectra of co-sensitization at 380 and 540 nm shows much higher extinction coefficients than those from the pure N$_{719}$, P$_2$ and YN$_{07}$. 


Figure 2. UV-Vis absorption in EtOH (left) and I-V curve (right) of N719, P2, YN07, N719+P2 and N719+YN07.

The photovoltaic parameters of DSSCs were investigated with pure and co-dyes under standard AM 1.5 sun light using liquid electrolyte I/I$_3^-$. The I-V curves is shown in Fig. 2 (right) and are summarized in Table 1. The results show the power conversion efficiency of N719+P2 and N719+YN07 at 2.37% and 1.59% respectively (compared with N719, P2 and YN07 about 5.17%, 1.42% and 0.46%, respectively).

Table 1. The characterized data and photovoltaic parameters of devices from complex N719, P2, YN07, N719+P2 and N719+YN07

<table>
<thead>
<tr>
<th>Complexes</th>
<th>$J_{sc}$ (mA cm$^{-2}$)</th>
<th>$V_{oc}$ (mV)</th>
<th>FF</th>
<th>$\eta$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>3.82</td>
<td>0.52</td>
<td>0.72</td>
<td>1.42</td>
</tr>
<tr>
<td>YN07</td>
<td>1.41</td>
<td>0.48</td>
<td>0.68</td>
<td>0.46</td>
</tr>
<tr>
<td>N719+P2</td>
<td>4.08</td>
<td>0.56</td>
<td>0.73</td>
<td>2.37</td>
</tr>
<tr>
<td>N719+YN07</td>
<td>5.84</td>
<td>0.53</td>
<td>0.74</td>
<td>1.59</td>
</tr>
<tr>
<td>N719</td>
<td>12.02</td>
<td>0.60</td>
<td>0.71</td>
<td>5.17</td>
</tr>
</tbody>
</table>

Acknowledgement
The authors would like to thank Ubon Ratchathani University for the financial support.

References
Investigation on the effect of dye adsorption processes for dye-sensitized solar cell (DSSC)

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Dye Sensitized Solar Cell (DSSC) which is able to convert light into electrical energy has been successfully fabricated and characterized. The TiO\textsubscript{2} layer with thickness of 10 \textmu{}m was doctor-bladed on ITO (Indium Tin Oxide) glass as an active working electrode and was then sandwiched with a counter electrode which was prepared with 8B pencil powder onto the ITO glass. A DSSC with $2 \times 1.5$ cm\textsuperscript{2}, KI as electrolyte and N749 as dye sensitizer was prepared for this study. Influences of the dye adsorption time between ultrasonication method (Cole Parmer 8891, 42 KHz) and conventional dipping method (without ultrasonication) were investigated. The DSSC performances were measured for various dye adsorption times for both adsorption processes. The measurement results are showed in terms of the I-V curves presented in Figure 1.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure1.png}
\caption{I-V Characteristics of the DSSC}
\end{figure}

It can be deduced from Figure 1 that the ultrasonication method is better than conventional dipping method regarding to the reduction of the dye adsorption time toward the best performance of the cell. Specifically, $V_{oc} = 326$ mV, $J_{sc} = 0.16$ mAcm\textsuperscript{-2}, fill factor = 0.46 and efficiency = 0.025\%, which are achieved using ultrasonification method under
xenon-light intensity with dye absorption time of 20 seconds. Where as the same performance of the DSSC cell prepared with conventional dipping method requires and adsorption time of 12 hours ($V_{oc} = 357$ mV, $J_{sc} = 0.14$ mAcm$^{-2}$, fill factor = 0.42 and efficiency = 0.021

References


A novel charged iridium polymer for polymer light emitting diode

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Organic light-emitting diodes (OLEDs) have become an alternative to conventional inorganic technology due to improved efficiency and stability [1]. Alternatively OLED using polymeric emitters referred as polymer light-emitting diodes (PLEDs) are very attractive because the devices usually processed from solution, such as spin-coating or screen or ink-jet printing [2]. PLEDs of iridium(III) complexes have been increasingly attractive in recent year [3] because of a high internal quantum efficiency which could be achieved and shown high efficiency with different colors. Here, we report the synthesis of the charged iridium(III) complex in the polymers by varying the content of iridium(III) complex unit shown in Figure 1 which were used in PLED devices.

![Figure 1. Structure of target polymers](image)

The synthesis and characterization of these polymers was prepared following our previously reported [4]. The absorption spectra show in Figure 2(a) that observed in two regions. At short wavelength below 400 nm were assigned to the \(\pi-\pi^*\) transition from fluorene unit and ligands. The weaker absorption tails that appeared above 425 nm were due to the MLCT. The PL spectra is showed in Figure 2(b). The emission peak at 443 nm was assigned from poly(fluorene) backbone and the emission peak at 470 nm was assigned the iridium complex unit.
Figure 2. (a) UV–visible absorption spectra and (b) PL spectra of polymers in dichloromethane solutions.

The polymers were used in PLEDs with the device structure of ITO/PEDOT:PSS/polymers/TPBi/BPhen/LiF/Al. The results show the CIE coordinates and their emission color pictures of PLEDs as presented in Figure 3. We found that the low content of iridium(III) units emit the blue color from poly(fluorene) main chain. Whereas with the increasing content of iridium(III) units, the device were tuning to the white light PLED from both poly(fluorene) and iridium complex units.

Figure 3. CIE coordinates and picture of emission colour for PLED devices with configuration of ITO/PEDOT:PSS/Iridium polymers/TPBi/BPhen/LiF/Al.

References
Thermally stable encapsulation material based on green and red lanthanide phosphor for white light emitting diodes

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This study reported thermal stability of hybrid sol-gel encapsulation materials doped with lanthanides complexes for generating white light. Red and green lanthanide phosphor, Eu(tta)₃phen and Tb(4DBBA)₃TPPO were incorporated into VTES:TEOS hybrid sol-gel and dispensed into 360 nm to 390 nm UV LED packages. Thermal properties of developed encapsulation material were analysed by TGA. A thermal aging test up to 96 hours was done to check the stability of developed encapsulation material towards UV LED junction temperature of 120°C and the luminescence properties changes was observed using photoluminescence measurement. To check the encapsulation material stability on forward voltage, the operation voltage has been increased from 3.0V to 4.0V. The photometric measurement were recorded using integrating sphere for the properties of Colour Rendering Index (CRI), colour temperature and Commission Internationale de L’Eclairage (CIE) colour coordinates. Based on the results, the encapsulation material developed in this work is shown to produce white colour with CIE colour coordinate of (0.32, 0.35), CRI up to 75 and colour temperature around 6000K.
Figure 1. Commission Internationale de l’Eclairage (CIE) color coordinates of the white LEDs based on Green and Red Lanthanide Phosphor

References
Analysis of optical gain in Nd$^{3+}$ doped glass medium using FDTD method

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The development of rare-earths doped glass-based materials in laser application is still attracted many attentions for various applications, such as in optical communications and high power lasers for manufacturing. It is necessary, for designing the laser structure, to perform a numerical calculation or simulation of optical gain of the gain medium. For that purpose, the commonly employed simulation method is by numerically solving a set of ordinary differential equations representing the population rate equations and spatial intensity distribution. [1,2] By using this method, the results for one dimensional case can be easily obtained. However, it is not for the complex structures in two- and three-dimensional cases, such as channel waveguides and micro-ring. Therefore, we have tried to develop a simulation based Finite-Difference Time-Domain (FDTD) method. However, FDTD is usually applied for a transparent non-amplifying medium. The gain factor is related to the imaginary part of permittivity, which is introduced in the FDTD algorithm. This approach is then applied to calculate optical gain for Nd$^{3+}$ doped glass in one-dimensional case with variations in Nd$^{3+}$ ion concentration, medium length, and pump power. The calculation results using this FDTD method shows an agreement with the results from the first method. Although the implementation of this method is time consuming, this method may be useful for calculating two- and three-dimensional complex structures with high optical gain medium, such as quantum dots. At this stage, the present results may be useful as a reference for designing the Nd$^{3+}$ doped glass laser medium.

**Keywords:** rare earth glass laser, Nd$^{3+}$ doped glass, optical gain, FDTD

**Acknowledgment**
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**References**
Excitation mechanisms of the 1mJ picosecond laser induced plasma emission in low pressure ambient helium gas and the improved performances of spectrochemical analysis

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This experiment is conducted to study the excitation mechanism of plasma emission induced by very low energy (1 mJ) picoseconds Nd-YAG laser in low pressure He ambient gas. For this study, the measurement is carried out by spatially resolved imaging technique and time resolved measurement of the emission intensities of copper sample. The experiment shows the excitation mechanisms responsible for the emission in both the primary and the secondary plasmas are basically the same as observed in LIBS employing nanosecond laser at higher output energy (10-150 mJ). However, the shock wave excitation process is found to last considerably shorter in this case. Consequently, the atomic emission detected with a gate delay of 2 μs is attributed to the delayed excitation by the Penning like energy transfer process from the He metastable excited state. As a result, the delayed detection of the analyte atoms emission offers favorable spectra for spectrochemical analysis in He ambient gas. The application of this technique to spectrochemical analysis of a number of samples displayed excellent spectral qualities illustrated by a typical result shown below. These results are also obtained with minimal destructive effect indicated by the tiny dimension of created craters of merely about 10 diameter and only around 10 nm deep. It is especially noteworthy that the excellent emission spectrum of deuterium, D detected from D doped titanium sample is free of spectral interference effect due to the undesirable ubiquitous water molecules and yielding an impressive detection limit of about 10 \(^{-12}\). This experiment also shows a potential application to a high resolution depth profiling of impurity distribution in the tested sample.
Figure 1. The emission spectrum of D I 656.1 nm taken from titanium doped with 1,000 ppm of D. The ps laser energy is fixed at 1 mJ and the ambient He pressure is kept constant at 4 kPa.

References
Direct evidence of the role of He triplet metastable excited state in excitation process of laser-induced He gas plasma

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A time resolved spectroscopic study is performed on He plasma emission in a special orthogonal double pulse experiment employing a ns laser for the He plasma generation and a ps laser for target ablation. The schematic setup for the experiment is given below. The study is focused on the most dominant He I 587.6 nm (triplet) and He I 667.8 nm (singlet) emission lines potentially responsible for the previously proposed He assisted excitation mechanism. The result reveals the clearly more dominant and remarkably longer lasting He I 587.6 nm emission is shown in the following figure. This is in good agreement with the delayed excitation of the ablated analyte atoms, which is verified by detecting the emission with the correspondingly delayed target irradiation after He gas plasma generation in the double pulse experiment.

**Keywords:** He gas plasma, Laser-Induced Breakdown Spectroscopy (LIBS), He I 587.6 nm, He I 667.8 nm, Triplet and singlet He metastable excited state

**References**


Figure 1. Experimental set-up

Figure 2. Time profile of He I 587.6 nm emission signal recorded by the oscilloscope (a) from He gas plasma induced by the ns YAG laser alone. (b) detected by operating both YAG lasers with the zinc target ablated 3 μs after the ns laser irradiation.
Rapid determination of anthocyanin in cacao (Theobroma Cacao L) leaves using digital image processing for finest cacao clone selection

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Java Edel is a superior clone and regarded as one of the finest cacao in the world. Despite its economic value, Java Edel is endangered due to the land reduction. This opens new challenge to find the clones that will provide high economic and biological potentials. Previously, the selection criterion of superior clone is based on the content of pigments, especially anthocyanin (Sari, 2012). This paper describes a new development on digital image processing for determination of anthocyanin pigments in the young leaf of cacao in order to screen the finest character of Java Edel.

In this study, five clones of cacao plants that have been identified previously were used as samples. The clones were DR1, DR2, DRC16 which is grouped to the finest cacao and SUL-1 (Sulawesi 1), MCC-2 which is grouped into non finest cacao clone. Red/Green index derived from young cacao leaves image as described in Sims and Gammons (2002) was used for the determination of anthocyanin content in young cacao leaves. Hunterlab Colorflex EZ was also used for non-contact spectrophotometric method to get reflectance spectra of the young leaves of cacao. Both methods were confirmed using methanol-HCL extraction as described previously (Sims and Gamon, 2002).

The results of digital image processing on R/G index showed that DR1, DR2 and DRC16 has low value of R/G index (lower than 1 as shown in figure 1) and SUL-1, MCC-2 has high R/G index (higher than 1 as shown in figure 2). This means that DR1, DR2, DRC16 has lower anthocyanin content than SUL-1 and MCC-2. Spectral data obtained from Hunterlab Colorflex EZ also confirmed that DR1, DR2, DRC16 has high reflectance at which anthocyanin absorbs at the maximum absorption band (530 nm), whereas SUL-1 and MCC-2 showed low reflectance. This also mean that DR1, DR2, DRC16 has lower anthocyanin content than SUL-1 and MCC-2. Anthocyanin Methanol-HCL extraction method also confirms that DR1, DR2 and DRC16 has lower anthocyanin content than SUL-1 and MCC-2 (DR1=0.0149±0.003µmol/ml; DR2=0.0138±0.001µmol/ml; DRC16=0.0115±0.005µmol/ml; SUL1=0.0605±0.019µmol/ml; MCC2=0.1351±0.024µmol/ml).

In the future our group would like to extend the research to seek the correlation between the phenotypical characterization based on the pigments and the genetic traits of Java Edel.
Figure 1. (a) RGB image of DRC16 clone; (b) RGB image of DR2 clone (c) RGB image of DR1 clone (d) Heatmap image of DRC16 clone; (e) Heatmap image of DR2 clone (f) Heatmap image of DR1 clone.

Figure 2. (a) RGB image of Sulawesi 1 clone; (b) RGB image of MCC-2 clone (c) Heatmap image of Sulawesi 1 clone; (d) Heatmap image of MCC-2 clone

References
Non-adiabatic microfiber sensor for COD investigation

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Abstract: A new sensing method was introduced for the first time to investigate chemical oxygen demand (COD) using a non-adiabatic microfiber sensor. It was formed by tapering the single mode fiber to generate evanescent field which is sensitive to perturbation of sensing medium. When the COD concentration increase takes effect, will induce changes in effective refractive index between the microfiber and the sensing medium where caused wavelength shifted to right.

Key words: Chemical Oxygen Demand, environmental sensing, non-adiabatic, microfiber sensor, online monitoring

Introduction: Chemical oxygen demand (COD) is one of the key indicators to characterize wastewater quality and conventionally determined by the open reflux method [1]. However, there are several limitations for this conventional wastewater quality monitoring method which include time-consuming with tedious procedures, required second chemical reagents and bulky instruments with high consumable costs [2]. It makes on-line monitoring of COD values by the abovementioned measurement methods infeasible. Therefore, there is a need to explore a new monitoring method which is rapid, accurate and simple. A non-adiabatic microfiber sensor (NAMFS) is adaptable to a wide assay of conditions, owing to its minute size, fast response, high sensitivity, and cost effectiveness. In this work, an assessment for determining COD in solution medium was developed for the first time by using a NAMFS. Different organic loadings in contaminated water induce different light propagation conditions, thus the wavelength shift were investigated.

Experimental set up: NAMFS was fabricated by tapering a short section of silica single mode fiber using flame-brushing technique. This model interferometer with the transmission spectra is given by Eq. (1) [3].

$$I = I_{\text{core}} + I_{\text{clad}} + 2\sqrt{I_{\text{core}}I_{\text{clad}}} \cos\left(2\pi n_{\text{eff}}L/\lambda\right)$$

where $I_{\text{core}}$ and $I_{\text{clad}}$ refer to the light intensity in the core mode and cladding mode, $n_{\text{eff}}$ is defined as effective index of the core and cladding modes, $L$ is the length of the interferometer region and $\lambda$ is the input wavelength. NAMFS was subsequently immersed
into COD standard solutions of 0 ppm and 800 ppm. Erbium amplified spontaneous emission was penetrated into the fiber during the sensing process to monitor its spectral response with the output end of the fiber connected to an optical spectrum analyzer (OSA model Anritsu MS9710B).

**Figure 1.** The experimental data and its best-fit curve for COD concentration 0 ppm and 800 ppm based on the value of $I_{\text{core}}=0.28$ and $I_{\text{clad}}=0.26$ respectively.

**Results and Discussion:** The changes in spectra shift of the interference peaks were subject to concentration of COD, where 0 ppm of COD was the initial sensing value to investigate the sensor response. Fig. 1 demonstrates the experimental data of the transmission spectrum for 0 ppm and 800 ppm compared with the theoretical model given by Eq. (1). The change in COD concentration from 0 to 800 ppm corresponds to a change in effective refractive index, $n_{\text{eff}}$ from 1.3337 to 1.2866. The increase in organic content of the analyte changes the $n_{\text{eff}}$ which is strongly dependent on the refractive index of the probe and the sensing medium As a result, the wavelength shifted to the right.

**Conclusion:** Chemical Oxygen Demand can be measured through non-adiabatic microfiber sensor by investigating wavelength shift. Difference level shifted in attenuation wavelength may relate to organic contain level in analyte which might cause disparity. Further research and investigation should be conducted to enhance the sensitivity and precision of the sensor to expand its potential for continuous online monitoring of COD value of wastewater.

**References**


A specific gravity sensor for crude oils based on polymer optical fiber using a ratiometric measurement method

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A specific gravity (SG) is an important parameter for analyzing the quality of crude oils. A standard method to measure the SG is by using a hidrometer method according to the ASTM D 1298-99. In this work, as an alternative to the standard method, a polymer optical fiber (POF) with removed cladding is utilized as a probe sensor using a ratiometric measurement technique to minimize the input power light source fluctuations.

A LED source is splitted into two arms by using a coupler as shown in Fig. 1. First arm, as a reference arm, consists of a POF only and it is connected to the photodiode 1 (PD-1). The second arm, a POF with the removed cladding part immersed in the SG chamber and it is connected to the PD-2. A personal computer with a data logger software of PM100 was utilized to record and process the data. The sensor has been characterized with a sensitivity of 52.278 dB/unit SG.

![Figure 1. A schematic diagram of the specific gravity measurement using POF sensor in a ratiometric measurement technique](image)

It was demonstrated the SG measurement from 5 samples of crude oils with different SG values from 0.816 to 0.905. It has a good agreement with the standard method. The effect of input light source wavelengths on the ratiometric system was also analyzed. Compared to the standard method, this measurement system offers a simple configuration, a fast measurement, a high sensitivity capability, and a low cost production.

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References
Relative humidity sensor using a PMMA microfiber coated with ZnO nanostructure

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Humidity monitoring is crucial in numerous industries like mining, chemical and biomedical plants as it may affect product quality and workers' health. It is also important in the prevention and control of corrosion in big structures such as bridges or planes [1]. Therefore relative humidity (RH) measurement has been extensively studied and a great variety of sensors, including capacitive, resistive, thermal and optical humidity sensors have been developed in the last few decades. Recently, microfiber sensors have gained a tremendous interest for various applications such as in physical, chemical or biological sensing, due to their unique geometry with low dimension and large surface-to-volume ratio and their versatility for electrical and optical detection [2]. Recently, it has been reported that ZnO nanostructure enhances the interaction of fiber guided light for humidity sensor [3]. Here, a PMMA microfiber was fabricated by direct drawing the solvated polymer. The smooth morphology of PMMA microfibers make them suitable for low loss optical wave guiding and sensing. Furthermore, PMMA optical fibers are low cost polymer fibers that are generally more physically robust and flexible than silica fibers [4]. In this paper, a PMMA microfiber coated with zinc oxide (ZnO) nanostructure is proposed and demonstrated for the monitoring of relative humidity. The ZnO nanostructure coating on the microfiber induces changes to the optical properties in response to an external stimulus.

The results showed an increase in the sensitivity of the sensor with the additional coating of ZnO nanostructure on the surface of the PMMA fiber. The working mechanism of the device is based on the observed increment in the transmission of the sensor that was carefully placed in a sealed chamber. As the relative humidity level varies from 20% to 80%, the output power of the PMLR with ZnO nanostructure coating increases linearly from -13.57 dBm to -5.13 dBm with a maximum sensitivity, linearity and resolution of 0.143 dB/%, 98% and 11.51%, respectively. This work is highly beneficial as it combines the high sensitivity obtained by using traditional silica fibers but with the ruggedness and flexibility of PMMA fibers, making them highly suitable for continuous monitoring of RH in compact areas.
References

![Image of a diagram showing the experimental setup for sensor testing.](image-url)
Humidity sensor based on microfiber resonator with reduced graphene oxide

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A simple relative humidity (RH) sensor based on a tapered single mode fiber loop resonator (MLR) is proposed and experimentally demonstrated. The refractive index of the microfiber in the MLR is modified by environmental humidity, and its wavelength changes with RH level. In this experiment reduced Graphene Oxide (rGO) is used because it has high water permeability and high sensitivity characteristics. The performance of tapered fiber has been measured with rGO and without rGO at fiber diameter of 4~6 μm. As relative humidity increases, the spectrum shifts towards longer wavelength. Experimental results show that with rGO was 0.0537 nm/%RH and without rGO (conventional MLR) was 0.0316 nm/%RH in the range of 30% - 50% relative humidity linear response has been achieved. The proposed MLR based system can be used for RH sensor and is possible to be commercialized due to its advantages such as compact in size, fast response, and low cost.

References
The use of SMS fiber structure for current measurement

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The Faraday effect on material optics is a basis for the electric current measurement using optical fibers or glass plates. The flowing current in the conductor wire near the optical fiber induces the magnetic fields, and in turn, it can affect the polarization rotation of the input light of linearly polarized in the optical fiber. A polarimetric measurement scheme can be employed to detect the current variations [1].

In this work, the Faraday effect on a singlemode-multimode-singlemode (SMS) fiber structure was investigated. A multimode interference (MMI) is a key mechanism in the SMS fiber structure. The SMS fiber structure has been exploited for many devices/sensors applications [2, 3]. Recently, Li et.al. proposed the current sensor based on ferrofluids and MMI in the SMS fiber structure [4]. In this work, as a proof of concept, the Faraday effect and MMI in the SMS fiber structure were analyzed in a simple intensity measurement technique. The variations of the DC current on the SMS fiber structure was modeled by using a modal propagation analysis [5] taking into account the field profile variations due to the Faraday effect. In the experiment, a DC current measurement was carried out by utilizing the SMS fiber structure attached to the conductor wire as shown in Fig. 1.

A simple intensity-based measurement was employed. A linearly polarized input light from a laser source 1550 nm was used in the SMS fiber structure. The intensity of output light from the SMS fiber structure was measured by using an optical power meter.

The output power of the SMS fiber structure using a multimode step index type with a length of 14.5 cm was measured experimentally for varying DC current from 0 to 15 A. It was found that the output power decreased monotonically from -31.21 to -39.54 dB, respectively. From the measurement, it can be deduced that the system has a sensitivity of 0.55 dB/A which is in a good agreement with the numerical result of 0.48 dB/A. This study is useful for the development of current monitoring system in many applications.
Figure 1. A DC current measurement set-up: the SMS fiber structure attached to the conductor wire.

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References
High energy pulse in passively Q-switched using MWCNT/PVA as a saturable absorber

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Q-switched pulse laser can be applied in various fields such as laser range finders, medical [1], material processing, environmental sensing, and long-pulse experiments [2]. This simple modulation technique of Q-factor is able to produce repetition rates in the kilohertz (kHz) region and tend to have higher pulse energies when compared to mode-locked lasers. Doping with foreign atoms is an effective method to intrinsically alter the properties of host materials and polyvinyl (PVA) is a right candidate in modifying the optical properties of carbon materials due to its higher diffusivity resulting in better uniformity in thin film formation [3] smooth as a host material. Recently, multiwall carbon nanotubes (MWCNTs), as a new family group of carbon material, have shown fascinating applications as a saturable absorber in compact fiber laser system. In this paper, we report a facile strategy to generate high pulse energies using MWCNT/PVA as a saturable absorber. The Q-switching pulse operation is obtained by sandwiching the thin film between two fiber ferrules forming a saturable absorber. By controlling the pump power, this saturable absorber is capable in generating stable pulse train with a good range of tunable repetition rate, short pulse width and produces high pulse energy. The maximum value of repetition rate, pulse width and pulse energy are 18.2 kHz, 3.36 µs and 88.4 nJ respectively. The corresponding average output power is 1.6 mW. The proposed MWCNT/PVA uses an uncomplicated fabrication process and compatible to integrate in laser cavity.

Figure 1. Configuration for passively Q-switched fiber laser using an MWCNT/PVA SA. LD: laser diode, WDM: wavelength division multiplexer, EDF: erbium-doped fiber, PDI: Polarization dependent isolator, PC: polarization controller, MWCNT/PVA: Multiwall carbon nanotube/ polyvinyl alcohol
References


Switchable wavelength thulium doped fiber laser at 1900nm by using AWG

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Switchable or tuneable wavelengths fibre laser is widely used in various applications such as optical spectroscopy and optical sensing. This type of laser is more versatile and able to replace the conservative single wavelength fibre laser. In this paper, we demonstrate a tuneable wavelength fibre laser by using an arrayed wavelength grating (AWG) with 19 channels and an optical channel selector to get a switchable single wavelength. A 2-meter thulium-doped fibre (TDF) is used as the gain medium. We use laser diodes to deliver the pump power of approximately 361mW into the gain medium via a wavelength division multiplexer to demonstrate the ability of the laser to operate steadily with selectable tuning wavelength along the tuning range, from 1874 nm to 1896 nm. A stable and narrowed laser is achieved with inter-channel wavelength spacing of approximately 0.96nm. The switchable wavelength fibre laser has good stability with the output power difference between the highest and the lowest laser peak of 3.3dB. Furthermore, the laser emission for each wavelength has a side mode suppression ratio (SMSR) of up to 58.75 dB and the SMSR difference between adjacent channels is only 3.29dB.

Figure 1. Laser emission for each switchable wavelength.

Figure 2. SMSR of the TDF tunable laser

References
Generation of coherent vector soliton mode-locked thulium-doped fiber ring laser

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Vector Soliton mode-locked fiber laser with operating wavelength of 1946.38 nm is experimentally demonstrated based on (nonlinear polarization rotation) NPR technique with incorporated a 5 m long thulium-doped fiber (TDF) as a gain medium as well as nonlinear medium. The experimental set-up of the proposed Thulium-doped fiber laser (TDFL) is illustrated in Fig. 1. The ring resonator was pumped by a 1552 nm Erbium-Ytterbium doped fiber laser (EYDFL) via 1550/2000 nm WDM. The total cavity length is around 13.9 m and the net dispersion in the cavity is operated in anomalous dispersion condition of -1.0383 ps² without any compensating components. Unidirectional operation of the ring was achieved with the use of a PDI while an in-line PC was used to fine-tune the linear birefringence of the cavity. The output of the laser is collected from the cavity via a 90:10 coupler which retains 90% of the light in the ring cavity to oscillate. The optical spectrum analyzer (OSA, Yokogawa AQ6375) with a spectral resolution of 0.05 nm is used to analyze the spectrum of the proposed TDFL whereas the oscilloscope (OSC, LeCroy W325A) is employed in conjunction with a 7 GHz bandwidth photodetector (EOT ET-5010F) to capture the output pulse train of the mode-locked emission. By controlling the polarization, the stable mode-locked emission is obtained from threshold pump power of 281 mW to 1041 mW with consistent pulse repetition rate of 14.4 MHz. The solitonic behavior is further identified with two sets of Kelly sidebands always appear coherently on the soliton spectrum as depicted in Fig. 2. At pump power of 1041 mW, maximum pulse energy and peak power are calculated as 1.21 nJ and 1.11 kW, respectively. The pulse width is estimated approximately 1.02 ps corresponded to sech² pulse profile and sideband separation.

References


**Figure 1.** Configuration of passive soliton mode-locked TDFL based on nonlinear polarization rotation effect.

**Figure 2.** Output spectrum of the soliton vector mode-locked TDFL at pump power of 1041 mW.
Implementation of SOI-based rib waveguide for high speed on-chip optical interconnect (OI) in circuit level

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The downsizing activity in Complementary Metal Oxide Semiconductor (CMOS) transistor technology has become a primary bottleneck for Electrical Interconnect (EI) in Integrated Circuits (ICs) design, especially in large chips[1]. Advances in optics have attracted researchers to explore feasibility of using optics as a key solution to overcome major limitations of conventional copper based EI mostly in high speed applications[2, 3]. In chip level, Optical Interconnect (OI) has the potential to provide larger bandwidth density and minimizing the power consumption, delay, and noise [4].

The main components of OI system are laser, modulator, waveguide and photodetector[5]. This paper focuses on modeling and analyzing the optical waveguide for OI link. A Single Mode Condition (SMC) of Silicon-On-Insulator (SOI)-based rib waveguide structure with different slab height(h), etch depth(d) and width(W) have been simulated using OptiBPM Simulator that performed under quasi-TE Solver. Fig. 1 shows a structure of SOI based rib waveguide with rectangular cross section. A correlation analysis between h, d and effective index (Neff) was investigated to identify the effect of width dimensions (W) to the rib waveguide performances. The value of Neff are strongly dependent on the value of h, d and W, where the value are in range of substrate refractive index<Neff<core refractive index to verify that it is in guided mode.

The waveguide performance in OI links like power consumption and propagation loss is recorded based on OptiSPICE simulation. In the case of high speed, we utilize 1550nm wavelength for OI simulations. In OI IC, the design of rib waveguide allows low propagation loss and strong optical confinement for practical implementations. A <0.1dBm of propagation loss is expected from OI simulations.

Figure 1. SOI based rib waveguide with rectangular cross section
References
Nonlinear study on two mode fiber

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In this paper, a nonlinear study of a multiwavelength two mode Brillouin fiber laser generating by two-mode fiber (TMF) is proposed and demonstrated experimentally. The system compromised of 500m long two mode fiber of $L_{P01}$ and $L_{P11}$ (TMF). A tunable laser source (TLS) amplified by high power erbium doped fiber amplifier (EDFA) acts as the Brillouin pump (BP) followed by a single mode fiber Bragg grating (FBG) as a reflector in the cavity with a centre of 1546.5 nm. The Brillouin scattering pump is observed in two modes of few mode fiber's $L_{P01}$ and $L_{P11}$. The setup is capable to generating maximum of 7 clearly defined Stokes lines at the highest pump power of 30.4 dBm, spanning from 1546.5 to 1547.1 nm.

**Keywords:** Two mode fiber (TMF), Brillouin fiber laser, Stimulated Brillouin scattering, $L_{P01}$ and $L_{P11}$ modes.

![Figure 1](image_url)  
**Figure 1.** Experimental setup of the proposed multiwavelength Brillouin in Two mode fiber (TMF)
Figure 2. Output spectrum of multiwavelength Brillouin TMF with different BP power.

References
Spiral structured growth of ZnO on plastic optical fiber towards light side coupling

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A spiral design structure on plastic optical fiber (POF) coated with zinc oxide (ZnO) nanorods using hydrothermal method is developed. Figure 1 shows the preparation of spiral structure on POF using clear plastic tape and the SEM image of ZnO nanorods growth structured in spiral is presented in Figure 2.

![Figure 1. Spiral structure on POF prepared using a clear plastic tape.](image1)

![Figure 2. (a) SEM image of ZnO nanorods and (b) Microscopy image of spiral structure after synthesis.](image2)

The effect of the spiral structure was experimentally investigated using light side coupling of different wavelengths of light source as shown in Figure 3. The light sources used in this experiment are red and white LEDs operating at a wavelength of 635 nm and 580 nm, respectively. Five regions on POFs with spiral structure were specified to receive light side coupling from red and white light sources as demonstrated in Figure 4.
This development employs an excitation of these regions due to light scattering inside the ZnO nanorod coated POF, when the incident angle of the incoming light is greater than the critical angle between the surrounding and core. This allows light propagation inside the POF and light leakage from these modes, permitting two possible light coupling collection schemes which are light exits from the side and is collected either from the POF end or through a side POF probe as illustrated in Figure 5. This experimental results proves that spiral structure on POF coated with ZnO nanorods enhanced the light scattering for different ZnO growth time compared to bare fiber when light side coupling concept was applied as shown in Figure 6 (a) and (b) for red and white light sources, respectively. This concept also opens up possibilities for sensor studies requiring minimal cost and complexity.

References
Performance of optical crosstalk for AWG demultiplexer designed with large and small cross section of rib waveguide structure on SOI

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Silicon-on-insulator (SOI) has become a popular choice of material in recent years because it is widely used as a substrate for passive/active optical components for applications in modern optics communication. Our previous work [1–4] focused on the design, optimization and optical characteristics of a new double S-shaped pattern of SOI-based AWG device for different channels. In this work, we investigate the performance of optical crosstalk for SOI-based AWG devices when large and small cross sections of rib waveguides are used. It was found that AWG device with large cross section of rib waveguide structure gave better performance of optical crosstalk of -28 dB. Overall, the transmission spectrum of the AWG device fit the standard Coarse Wavelength Division Multiplexing (CWDM) wavelength grid. Figure 1 shows the designed of AWG device constructed on SOI wafer meanwhile the crosstalk is identified when neighbouring channels that carrying different wavelength was interrupt at measured channel as shown in Figure 2. The CMOS process technology was used to fabricate the AWG device.

Figure 1. Schematic layout of AWG device designed on SOI wafer.
Figure 2. Output of transmission spectrum for CWDM AWG. Indicated that how the crosstalk is determined and existing of side lobes at certain channels.

References
Controllable pulse width via different lengths of PMF in a sagnac loop passively mode-locked fiber laser

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Pulsed lasers have attracted large attention due to their significant role as light sources for various current and future optical systems. Generally, mode-locked pulse can be achieved by passive or active approaches. Passive mode-locking can be realized by incorporating a saturable absorber with suitable properties into the laser cavity. On the other hand, active mode-locking can be obtained by implementing active component such as electro-optic modulator. However, this technique contributes to the complexity of the system as well as increasing the cost. Therefore, passive mode-locking is more desirable compared to active mode-locking and more intensely investigated in the research world. In many cases, mode-locked pulse with tunable pulse width feature is interesting for applications such as telecommunication, material processing, medicine and micro fabrication. For example, in telecommunications field, pulse with tunable pulse-width manages to provide the highest tolerance to optical transmission impairments. In this work, a mode-locked fiber laser in Sagnac loop configuration with controllable pulse width is demonstrated by using different lengths of polarization maintaining fiber (PMF). Single wall carbon nanotube (SWCNT) film is used as saturable absorber to generate the mode-locked pulses. The repetition rate obtained by varying the PMF lengths ranges from 10.0 to 12.5 MHz and the pulse width measured ranges from 0.5 to 1.7 ps. The results obtained show that the pulse width of the mode-locked pulses is controllable by varying the lengths of the PMF.

Figure 1. Set up configuration for controllable pulse width via different lengths of PMF in a Sagnac loop passively mode-locked fiber laser.

Figure 2. Mode-locked output spectrum obtained by using a) 0.5m b) 1.0m and c) 2.0m PMF.

References
C+L bandwidth of multiwavelength using dual stage EDFA

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The auspicious qualities possessed by multiwavelength fiber lasers lead to their prominent use in applications within a variety of fields including telecommunications, optical fiber sensors for long haul sensing systems, and optical spectroscopy to name a few \cite{1,2}. The demand of higher capacity in telecommunication system further endorses the importance of multiwavelength laser sources. In order to realize this, an array of different methods and techniques has been adopted, for example by using nonlinear effect of four wave mixing and Brillouin scattering \cite{3}. Many articles have been published over the years, classifying various significant characteristics of multiwavelength laser such as band coverage, number of wavelengths, line spacing, height of lines, wavelength tunability, and spectrum stability. In this work, we report on the production of a wide bandwidth of multiwavelength laser (C-L band region) via a special triple loop ring cavity supported by a dual stage erbium doped fiber amplifier (EDFA). Almost 47 lines are successfully created using this laser structure, with an average constant channel spacing of 2.1 nm. In comparison to our previous report, this C-L bandwidth region displays the best performance. The effect of external parameters such as continuous wave (CW) output power of EDFA, polarization states, and the comparison between single stage, threshold lasing spectrum, and dual stage EDFA are also investigated.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Transmission_spectrum.png}
\caption{Transmission spectrum of C-L band multiwavelength with variation of pump current}
\end{figure}
References

Wideband tunable CNT-based Q-switched S-band fiber laser using tunable Fabry-Perot etalon filter

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Compact and stable Q-switched fiber lasers have found interesting usage in the fields of laser processing, environmental sensing, medicine, optical communications, reflectometry, imaging, remote sensing, fiber sensing, manufacturing, and material processing due to their ability to yield high energy pulsed lasers. A wideband tunable CNT-based Q-Switched fiber laser operating in the S-band region using a tunable Fabry-Perot etalon filter as the wavelength tuning and filtering mechanism is proposed and demonstrated. The system uses a 15 m long depressed-cladding erbium doped fiber (EDF) as the gain medium, while a thin CNT film is sandwiched between two connectors to function as the SA for the generation of the desired Q-switched pulses. The tuning range of the laser output carrying the Q-switching pulses covers a wide wavelength range of 47 nm, which spans from 1479 nm to 1526 nm. In addition, the lasing and Q-switching thresholds have a respective value of ~36 mW and ~65 mW. A repetition rate of 24.4 kHz is obtained at the maximum pump power of 100.4 mW at the wavelength of 1498 nm, together with pulse width and pulse energy of 1.2 µs and 26.1 nJ respectively.

980 nm Pump laser

Figure 1. Experimental setup of the proposed tunable Q-switched S-band fiber laser.
References
Placement of SOA and EDFA post-amplifier topologies in full spectrum CWDM system

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Placement of optical amplifiers in an optical system is crucial in improving the transmission performance by restoring the weakened signal strength over a distance. In addition, the usage of different amplifier types would significantly improve the overall system performance since the amplification region can be achieved within certain desired bands. In this paper, semiconductor optical amplifier (SOA) and erbium doped fiber amplifier (EDFA) function as post-amplifier in a full spectrum Coarse Wavelength Division Multiplexing (CWDM) system ranging from 1271 nm to 1611 nm wavelengths. Two SOAs which operate in S band and L band respectively, and a C band EDFA are used in SOA$_S$-EDFA and EDFA-SOA$_L$ topologies. In order to operate as post-amplifier, the amplifiers are placed immediately after the multiplexer to boost up the power at the beginning of the link to support 65 km transmission length. In comparison, SOA$_S$-EDFA post-amplifier produces higher gain of 46 dB compared to EDFA-SOA$_L$ post-amplifier of 37 dB. The amplified power achieved at the output of SOA$_S$-EDFA topology is 5 dB higher than that obtained using EDFA-SOA$_L$ topology. More channels with acceptable BER values at the receiver are achieved with SOA$_S$-EDFA topology. As a conclusion, SOA$_S$-EDFA post-amplifier produces better performance in the amplification of the CWDM system especially in S band and L band regions which are typically used for downstream data and voice, and video applications respectively.

References
Supercontinuum generation using few mode fiber

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We propose and demonstrate a few mode fiber for supercontinuum generation. Due to the few mode fiber having high normalized frequency parameter also called the V-number, the system is designed to generate and to detect the high power supercontinuum in the both mode. The performance of supercontinuum generation in a few mode fiber is then compared to the single mode fiber. The 0.92 ps pulses are used as a seed laser with a repetition rate of 13.36 MHz in the carbon nanotube (CNT) mode locked fiber laser. The spectral range is stretches from 1550 nm to 1700 nm has been successfully generated using a FMF.

Keywords: Few Mode Fiber (FMF), Carbon Nanotube (CNT) modelocked fiber laser, supercontinuum (SC).

![Figure 1. Supercontinuum spectrum generated in the 500 m few mode fiber compared to 500 m single mode fiber](image)

References
Multi wavelength generation employing photonic crystal fibre with mismatch zero dispersion from transmission window

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We present an experimental multi wavelength generation demonstrated by incorporating fibre Bragg gratings (FBGs) and photonic crystal fibre (PCF) with zero dispersion at 1040 nm in erbium doped fibre ring laser (EDFRL). The multi wavelength was easily generated at gain bandwidth of 20 nm either dual or triple signal idler in EDFRL set-up. The set-up achieved 38 dB of signal noise ratio which suffice to stimulate and generated multi wavelength phenomenon albeit mismatch of zero dispersion and the transmission window. It is also found that the conservation of energy is much efficient in which the idler signal separation is small to generate multi wavelengths at deviations of power 0.7 dBm using triple lasing compared 2.0 dBm of big separation. The results show that multi wavelengths light emissions were clearly observed with an average deviation of 0.01 nm and power deviation of 0.15 dBm.

1. Introduction
As reported by Liu et al, Feng et al and Awang et al which apply PCF (photonic crystal fibre) with zero dispersion at 1550 nm in oscillation cavity [1, 2]. Methods such as application through erbium doped fibre (EDF) and bismuth erbium doped fibre (Bi-EDF) and semiconductor amplifier (SOA) able to enhance transformation of energy transfer to stimulate multi wavelength phenomenon [1-4]. In our approached, we are using a PCF zero dispersion wavelength which mismatch from the transmission wavelength.

2. Experiment & Results
The experimental set-up as shown in figure 1, consists of an arrangement of EDFRL consisting of a 980 nm laser pump for the erbium doped fibre amplifier (EDFA), a circulator which has three FBGs at one of the exit doors, an optical isolator, polarisation controller and 980/1550nm WDM coupler. A set of three FBGs; FBG1, FBG2, FBG3, have a central wavelengths of 1530.47nm, 1561.42nm and 1563.95nm with reflectivity’s of 89.9%, 91.6% and 96.7% respectively which well positioned at circulator port two. While FBG 4 (peak wavelength 1532.89 nm and reflectivity of 88.4%) and FBG 5 (peak wavelength 1535.04 nm and reflectivity of 92.4 %) were used as replacement of FBG 2.
and FBG 3 for next sequence experiment. In figure 2, one of multi wavelength spectrum generated through triple idle set-up. Detail results will be described in full paper.

**Figure 1.** Experimental setup of multi wavelength generation based on EDFRL configuration.

**Figure 2.** Multi wavelength spectrum output exclusive and inclusive of PCF in the configuration of triple idler FBG 1, FBG 4 and FBG 5 respectively.

**References**

Free Spectral Range (FSR) control of a high quality factor - 1D Photonic Crystal (PhC) suspended extended cavity

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The Photonic crystal (PhC) device is a periodic structure that capable to control light passing through the medium [1]. Thus it became one of the contenders as a platform in realizing the Photonic Integrated Circuits (PIC), which can reduce the power and size requirement in the optical components. One Dimensional PhC nano-beam device can offer extra freedom for designing a more complex device especially the one which has smaller footprint. Thus, 1D PhC extended cavity became a promising candidate where the multiple resonances were excited within the band-gap. We have shown that the device can be measured repeatedly and can be reproduced giving a consistent values of Q-factor together with the optical transmission. We have also successfully demonstrated experimentally the consistency in controlling the Q-factor value ranging from 1000 to 80,000 together with good free spectral range (FSR) control between the resonances frequencies of between 30 nm to 62 nm of a long cavity based on SOI. The Q-factors for each resonance obtained for that particular extended cavity were measured in different occasion which has 5% variation in the Q-value over a period of times. We expect that the removal of Silica cladding underneath the silicon waveguide will enhance the Q-value due to better optical confinement within the waveguide. A design of a 1D PhC/PhW with extended cavity were realized in 500 nm wide PhW waveguide with a cavity length of between 1 µm to 6 µm. design were generated and simulated using Finite Difference Time Domain (FDTD) approach showing good agreement with the measured results. The patterns were transferred into the silicon substrate using a VB6 Vistec precision electron-beam lithography (EBL) machine with negative tone HSQ resist as a mask. The PhW waveguides were etched using Inductively Coupled Plasma (ICP) dry etching to remove unwanted silicon areas. Further enhancement of Q and the normalized transmission can
be achieved through the removal of silica cladding underneath the silicon core [2] for the case of 1D photonic crystal/photonic wire micro-cavity. In one occasion, at cavity length of 4.0 µm, we have successfully measured the extended wire cavity for the suspended wire as shown in Fig.2 (a). Although somewhat surprisingly, we have found that the normalized optical transmission for the resonance at P₁ is significantly low at approximately 4% as compared to the resonances at position P₂ and P₃ of approximately 30% and 50%. Those resonances were measured to have 52 nm in Free Spectral Range (FSR). The normalized transmission of the resonance varies at which we believe that the Q-factor and optical transmission is optimum for a certain cavity condition. Fig.2 (b) shows the trend of the Q-factor value between the suspended PhC/PhW extended cavities and the one with the silica cladding underneath it. For each resonance conditions, the Q-factor dropped by approximately 15%, 32% and 35% for P₁, P₂ and P₃ respectively after the removal of Silica underneath it. The difficulties in achieving high transmission and high Q for the suspended wires for this particular device is due to the abrupt change of the mode traveling from the feeder waveguide with silica cladding into the wires region where the silica has been removed. Thus it produces higher propagation losses at the interface.

Figure 2. (a) Measurement result for ultra-high Q suspended wire with extended cavity of Cₓ=4 µm (b) Comparison of the resonance Q-factor value with the suspended wire

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References
Spatial soliton in a chalcogenide-glass based nonlinear optical grating

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Chalcogenide-glass is a glass material that contain one or more chalcogenide elements such as sulfur, tellurium and selenium. InSe, SbSe, GeSbTe and AgInSbTe are few examples. Technologically, chalcogenide-glasses are used in optical fiber, lens as well as compact-disc. Recently, these materials attract many attention for its applications in nonlinear optics due to large Kerr nonlinearity, which is 1000x larger than silicon oxide (SiO$_2$) in infrared spectrum [1]. This large quantity can potentially allow the significant effects of fifth order nonlinear susceptibility to appear under a relatively low power laser.

In this report, we discuss the existence of spatial solitons in a nonlinear optical grating made of chalcogenide-glass material, as an extension of previous work reported in ref. [2]. Based on the coupled mode approximation and considering fifth order nonlinear term, the governing equation of the corresponding soliton is given as follows:

$$\hat{P}_f(b)U_{f(b)} + b_0 \left( \left| U_{f(b)} \right|^2 + 2 \left| U_{b(f)} \right|^2 \right) U_{f(b)} + c_1 U_{b(f)} + b_1 \left( \left| U_{b(f)} \right|^2 + 2 \left| U_{f(b)} \right|^2 \right) U_{b(f)} + b_2 U_{f(b)} U_{b(f)} + b_3 U_{f(b)} U_{b(f)}^2 +$$

$$d_0 \left( \left| U_{f(b)} \right|^4 + 6 \left| U_{f(b)} \right|^2 \left| U_{b(f)} \right|^2 + 3 \left| U_{b(f)} \right|^4 \right) U_{f(b)} = 0$$

where $U_f$ and $U_b$ are the envelopes of the forward and backward fields, respectively, with $\hat{P}_f = i \partial / \partial z + D \partial^2 / \partial x^2 - \eta$ and $\hat{P}_b = -i \partial / \partial z + D \partial^2 / \partial x^2 - \eta$. The symbols $b_0$ and $c_1$ are linear parameters, and $b_1$ and $b_2$ are related to the third order nonlinearity coefficient, while $d_0$ is associated with the fifth order nonlinearity coefficient. The symbol $\eta$ and $D$ denote the tuning and dispersion parameters, respectively. For the case of zero energy flow i.e. $|U_f| = |U_b|$, we found a two free parameters bright soliton with the following expression:

$$U_{f(b)} = \frac{4(\eta - \eta_0)D}{\sqrt{\cosh(2x\sqrt{(\eta - \eta_0)/D}) \sqrt{16(\eta - \eta_0)\Delta/3A_x^2D + \alpha_+^2 + \alpha_-^2}}} \exp(iKz)$$

with $A_\pm$ are the corresponding free parameters, while $\alpha_\pm \equiv \alpha_\pm(b_0, b_1, b_2)$, $K \equiv K(b_0, b_1, b_2, c_1)$, $\eta \equiv \eta(b_0, b_1, b_2, c_1)$ and $\Delta \equiv \Delta(d_0)$. We have identified the existence of an ultra sharp bright spatial soliton shown in Fig. 1.
Figure 1. Example of ultra sharp bright spatial soliton for $\alpha_{\pm} = -2$, $(\eta - \eta_0)/D = 1$, and $\Delta = 1$.

In addition to the zero energy flow case, we also discuss our preliminary results regarding the existence of non-zero energy flow i.e. $|U_f| - |U_b| \neq 0$, on the basis of dynamical system approach. It is found that the governing equation admits several interesting solitonic solutions.

References
Analytical and numerical study on two in-phase soliton pulse shift under the effect of TOD, IRS and SS

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The soliton pulses have the peculiar particle nature that has the capacity to interact with each other when placed in-phase and repel each other when placed out-of-phase [1]. The interaction of these pulses depends upon the relative spacing (q₀) and phase (ψ) imparted initially. This property of interaction results in bit error in telecommunication. It was noted that the Higher order nonlinear effects (HOE) like Third Order Dispersion (TOD), intra pulse Raman Scattering and Self-Steepening effects have the stamina in avoiding this interaction by providing pulse shifts [2,3,4]. We realize such influence of HOE on soliton interaction analytically using Darboux theory based on Lax pairs [5]. Then the interaction point is noted numerically using Split-step Fourier transform (SSFT) [6]. Finally the effect is realized in 180 Gbps telecommunication system to demonstrate the performance in terms of Q-Factor.

The Darboux transformation of the following equation (1) yields the solution in which is plotted without and with the influence HOE in fig.1(a) and (b) respectively. It is shown that without any HOE we have interaction and the interaction is restricted considering combined effect of HOE.

\[ iq_{1z} - \beta_3(z)q_{1n} - \gamma(z)|q_{1}|^2q_1 + i\beta_3(z)q_{1m} + i\chi(z)|q_{1}|^2q_1 + i\delta(z)|q_{1}|^2q_1 + i\gamma(z)q_{1} = 0 \]  

(1)

The tracing of pulse inside the fiber is numerically noted by SSFT, where the interaction of two pulse happens without HOE (seen in fig.2c) and the pulses restricts interaction with \( \beta_3 = 0.1 \) ps³/Km, \( T_R = 5fs \). The interaction of pulse for the initial pulse width of \( T_o = \sim 1ps \), Dispersion length of \( L_D = 0.13 \) Km, power of \( P_o = 5.6 \) W and initial spacing of \( q_o = 5.28is \) noted to be at 19.14 Km by SSFT which is shown in fig.2(c). The following eqn. (2) is solved using SSFT whose parameters \( \beta_2, \beta_3, T_R, \gamma, \omega_0 \) are dispersion, TOD, IRS, nonlinear coefficient and SS respectively.

\[ \frac{\partial A}{\partial z} + \frac{\alpha}{2} A + i \frac{\beta_2}{2} \frac{\partial^2 A}{\partial T^2} - \frac{\beta_3}{6} \frac{\partial^3 A}{\partial T^3} = i\gamma \left( |A|^2 A + \frac{i}{\omega_0} \frac{\partial}{\partial T} |A|^2 A - T_R \frac{\partial |A|^2}{\partial T} \right) \]

(2)

We consider a 180 Gbps, single channel, ON-OFF keyed telecommunication system implemented with fiber length of one collision period, \( L_{coll} = 38.28Km \) to note the performance in terms of Q-factor. We could show that, the Q of the system reaches zero.
perfectly at $I_p$ without the influence of HOE while the system yielded $Q$ of 64.61 under the influence of HOE at that point clearly demonstrating that HOE has restricted interaction and reducing bit error.

Figure 1. Two soliton characteristics using Darboux transformation (a) without HOE and (b) with HOE. Two soliton characteristics using SSFT (c) without HOE and (d) with HOE

References


Nonlinear bond model of second and third harmonic generation in body and face centered cubic crystal structures

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Surface characterization using nonlinear methods offers several advantages due to its nondestructive nature and the ability to investigate many industrial processes in real time and non vacuum condition. In the past, a comprehensive understanding up to the microscopic atomic level of the measured second harmonic generation (SHG) data -even for low simetry samples such as diamond lattices- were difficult because surfaces in their full complexity, are described by a third rank tensor with up to 27 complex and 81 complex components if using second and third harmonic generation respectively. In series of papers [1-3] Aspnes et. al. have argued consistently that azimuthal measurements of rotated Silicon samples using higher harmonics can be described by the so called bond-hyperpolarizability model. Using this model they were able to show that the experimental rotational anisotropy SHG (RASHG) data in Ref. [4] describing SHG in nonvicinal Si(111) samples can be fitted using only two complex parameters [1], namely the "up" hyperpolarizibility for the up bond and the "down" hyperpolarizibility for the three downward pointing bonds.

An important step towards the understanding of SHG in diamond and zincblende lattices was the investigation of the third rank susceptibility tensor that were obtained from the simplified bond hyperpolarizability model (SBHM) and group theory (GT) [5], were it was shown shown that one can derive from GT the SBHM tensor. The work was later extended to show that the model can fit electric field induced second harmonic (EFISH) experimental results in Metal Oxyde Semiconductor (MOS) with good accuracy [6].

In this work we present -for the first time- the calculation of the second harmonic generation (SHG) and third harmonic generation (THG) nonlinear susceptibility tensors for the p-in p-out, p-in s-out, s-in p-out, and s-in s-out polarization of a non- metallic body centered cubic (BCC) and face centered cubic (FCC) structure using the SBHM and compare it with group theory. We show that the SHG tensor will vanish inside the bulk of BCC and FCC structures but can be useful to study the nonlinear far field that are
reflected from the surface. In addition we derive the corresponding expressions for the SHG and THG far field formulas from the core assumption of SBHM that the driven anharmonic charges are oscillating only along the atomic bonds.

**Figure 1.** Bond orientation of BCC crystal structures (from the left): (001), (011), and (111)

**Figure 2.** Bond orientation of FCC crystal structures (from the left): (001), (011), and (111)

**References**

Optical response of a hybrid comprising a quantum dimer emitter strongly coupled to a metal nanoparticle

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We theoretically investigate the optical response of a nanocomposite comprising a symmetric quantum dimer coupled to a metal nanoparticle (MNP). The dimer is modeled as two coherently coupled two-level emitters. The MNP serves as a resonant mirror, giving rise to a feedback which is governed by a complex-valued parameter $G$. The latter contains all details of the interaction, material properties, and geometry of the constituents\textsuperscript{1,2}. The feedback together with the dimer’s nonlinearity results in a bistable dimer-MNP response when the applied field is in resonance with the ground-to-symmetric state transition (Fig.1). For other detunings, no bistability is found.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Field dependence of the average number of excited emitters $n$ for an isolated dimer ($G = 0$, black curve) and for a dimer coupled to an MNP ($G \neq 0$, red curve), calculated under the condition of the applied field in resonance with the ground-to-one exciton transition ($\hbar \omega = \hbar \omega_s = 3.23$ eV). Solid and dashed arrows show the direction of adiabatically sweeping the applied field magnitude $\Omega_0$ up and down. $\gamma$ denotes the population decay rate.}
\end{figure}
In the linear regime, the hybrid’s absorption spectrum exhibits a dispersive Fano-like shape [Fig 2(a) to (c)]. The spectral position and shape of the spectra depend on the detuning of the dimer’s bright one-exciton resonance relative to the plasmon transition. Upon increasing the applied field intensity, the Fano-like singularities in the absorption spectra are smeared and disappear due to the saturation of the dimer, which causes the MNP to dominate the spectrum [Fig 2(c)]. This allows tailoring the absorption spectrum of the composite by tuning the dimer-MNP resonance and the applied field intensity.

References
Going beyond the Lambertian limit of solar cells with transformation optics

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The $4n^2 / \sin(\theta_{in})$ Lambertian absorption enhancement limit under concentration has long been the golden standard relative to which all light trapping strategies are assessed [1]. Nanophotonic structures which allow one to approach or surpass this limit have been demonstrated though only successful at extremely thin active material thicknesses [2,3].

Here, we aim to develop an external light trapping scheme which provide a broadband solution to approach and potentially surpass the $4n^2 / \sin(\theta_{in})$ limit irrespective of the solar cell material and active layer thickness. Aside from giving absorption enhancement, external light trapping strategies avoid additional geometrical complications within the main solar cell structure that may disturb charge transport [4].

Similar in some ways to the external light trap in [4], the light trapping scheme we consider include an optical funnel and a substrate with a rough diffusing bottom side as depicted in Figure 1. Diffused light rays in the trapping substrate have escape probabilities that depend on the funnel exit width $w$. Achieving a large funnel entrance to exit width ratio ($P/w$) while maintaining high funneling efficiency will naturally result in a large optical path length enhancement. When considering lenses and parabolic mirrors as the light funnel, enlarging the $P/w$ ratio would typically be followed by a reduction of the acceptance angle range. In such cases, the absorption enhancement would not exceed the $4n^2 / \sin(\theta_{in})$ limit.

In the conference, we will discuss transformation optics based funneling schemes that potentially give large $P/w$ ratios while maintaining close to an omni-angle of acceptance behavior. We will discuss the feasibility of such schemes and describe the challenges in realizing them.
Figure 1. External light trap with transformation optics based funnelling structure on the top and a light trapping substrate with a rough diffuser at the bottom.

References
Single guided mode, single polarization and modal evolution in Si$_3$N$_4$ strip waveguide with highly anisotropic DAST overlay

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Single mode and single polarization waveguides are preferred in many applications, e.g. those related to sensing [1] or interference [2]. To get a single mode and single polarization waveguide, one can play e.g. with the cross-sectional geometry and inducing leakage loss using high-index materials in the vicinity e.g. the high-index substrate [3] in buffered leaky waveguides [4], or using shallow-etched rib structures for low effective index contrast [5].

In this work, we consider overlaying a highly anisotropic biaxial crystal on top of a bimodal strip waveguide and tuning the thickness of the air gap between the crystal and the waveguide to get simultaneous single guided mode and single polarization properties. In this work, we consider a Si$_3$N$_4$ [6] strip waveguide on SiO$_2$ substrate with DAST (4-dimethylamino-N-methyl-4-stilbazolium tosylate) crystal [7] overlay. A vectorial finite element leaky mode solver [8] developed earlier was used in this investigation.

The inset in Fig. 1 shows the structure under study with strip width and thickness fixed at 2 µm and 0.3 µm, respectively. We consider wavelength of 1.55 µm where the refractive index of SiO$_2$ substrate and Si$_3$N$_4$ strip are 1.45 and 1.99, respectively. The DAST crystal is oriented such that its principal axes coincide with the waveguide Cartesian axes, where the highest permittivity diagonal component is corresponding to the longitudinal axis of the waveguide, hence we get $n_{\text{clad,xx}}=1.602$, $n_{\text{clad,yy}}=1.575$, and $n_{\text{clad,zz}}=2.132$.

The figure shows the effective index of fundamental mode by varying the air gap size ($g$) from 0 to 1000 µm. Without DAST overlay ($g=\infty$), the waveguide is a bimodal waveguide supporting guided q-TE$_{00}$ and q-TE$_{10}$. Adding DAST overlay will increase the Re($n_{\text{eff}}$) following the theory given in [4]. For DAST overlay with $g$ from 0 to 5 µm, it supports guided q-TE$_{00}$ and q-TM$_{00}$. For $g>5$ µm, the q-TM$_{00}$ mode becomes leaky as its Re($n_{\text{eff}}$) passes $n_{\text{clad,xx}}$, which is the effective index of DAST for such orientation. For $g>180$ µm, the q-TE$_{00}$ also becomes leaky due to the same reason. Hence, we have a range of air gap thickness (5 µm<$g<180$ µm) which will give a single guided q-TE$_{00}$ mode. During varying $g$, we observe that the leaky modes evolve from one kind of mode label to the other and from mode with low leakage loss to high leakage loss and back to low leakage loss again due to the interaction with the DAST overlay.
Figure 1. The effective index of q-TE$_{00}$ mode denoting regime of single guided mode, single polarization as one varies the air gap size. The inset shows the structure cross-section.

References
Fano resonance in TE–polarized light scattering by a silver nanowire

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Recently a novel type of Fano resonances were found in the scattering of TE polarization wave by an infinite dielectric cylinder with a high permittivity value which can be explained as the result of interference between the internal Mie mode and the slowly-varying background. It was shown that the phenomena consist of cascaded Fano spectra of different asymmetry parameters in the calculated scattering efficiencies of the first few multipole modes. In this work, we report the result of our study on TE-polarized wave scattering by silver nanowire using the Johnson-Christy data for the permittivity of silver. The result shows that instead of the cascaded resonances found previously, only a single resonance appears in the scattering efficiency spectrum for nanowire of 20 nm radius for which the scattering efficiency is dominated by dipole mode $a_1^2$ for size parameter $\chi = (2\pi r/\lambda) < 1$. This is to be contrasted to the case of dielectric nanowire for which multipole modes are found in the scattering efficiency spectrum. The single resonance spectrum in the case of 20 nm silver nanowire is displayed below

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure.pdf}
\end{figure}

which is similar to the result reported originally by Fano for the case of atomic autoionization. It is further shown that this resonance curve can be described as the result of interference between a narrow resonance and a slowly varying background satisfying the previously proposed by Rybin \textit{et al} as a generalized Fano line-shape
\[ I = \left[ \frac{(q+\Omega)^2}{1+\Omega^2}\eta + (1 - \eta) \right] B^2 \]

where \( q \) is the Fano asymmetry parameter, \( \eta \in [0,1] \) is the portion of interacting background \( (B^2) \), \( \Omega = \frac{\omega - \omega_o}{\Gamma/2} \), \( \omega_o \) and \( \Gamma \) are the frequency and width of the narrow resonance respectively. Using this formula, the best fitted asymmetry parameters, frequencies and widths of the narrow resonances for nanowires of various radii is shown below.

It is seen from the above result, that the narrow resonance frequencies (green line) and spectral widths (red line) are independent of the nanowire radius while the associated asymmetry parameters (blue line) exhibit monotonous increase with increasing nanowire radius within the range of \( x < 1 \).

References

Possible plasmonic applications for sensing and cloaking by silver coated nanowire

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The use of plasmonic structures has been widely studied for continuous improvement of performance in various fields of application in the past decades. Among them, sensing applications have been one of the primary interest, be it for scientific or commercial purposes. Recently, the results of research in metamaterials offer an unprecedented way of manipulating light, including the cloaking concept, which can also be implemented using plasmonic structures. In this work, we show that a metal coated dielectric cylinder may also offer a simple structures for both sensing and cloaking applications. It is found that the quality of both applications depend on geometrical and physical parameters of the structure. The sensing sensitivity ($\Delta \lambda/\Delta n$) of 200 nm/RIU is achievable using silver shell as specified in Fig.1(a). Meanwhile, this structure also offers the possibility of cloaking effect expressed in terms of scattering efficiency as low as -20 dB as shown in Fig.1(b). Both results can be improved by increasing the coupling between inner and outer surface plasmons. The experimental data of silver permittivity is used for the calculation, these results may promise the physical realization for device applications.

Figure 1. Scattering efficiency (a) in dB and (b) in dimensionless unit, for refractive index of the core=4, inner radius 37.5 nm and outer radius 50nm.
References
Metallic nanosphere on a substrate for plasmonic refractive index sensing

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Metallic nanospheres have been widely used in nanoscale photonic devices due to the many attractive applications offered by plasmonic resonance effects, including especially refractive index sensing. Plasmonic resonance is strongly affected by the particle geometry, structure and surrounding environment. We present a plasmonic structure consisted of a metallic sphere embedded in a semi-infinite substrate. The effect of various substrates on the plasmonic resonance modes of a silver nanosphere for various incident light polarizations and angles will be studied to determine its refractive index sensing capability. To measure the refractive index sensing capability, we present the sensitivity and quality factor of the plasmonic resonance modes for various background refractive indices. In contrast to previous works, which are based on numerical FDTD and FEM methods, the more efficient multipole expansion method is employed in this study.

Due to symmetry breaking induced by the presence of substrate, plasmonic resonances will depend strongly on the incident light angle, polarization and also the choice of substrate material. As seen in Fig. 1a, we compare scattering efficiency for low-index dielectric substrate (glass) against silver substrate. The use of low-index dielectric substrate such as glass yields weaker plasmonic resonances compared to metallic substrate such as silver due to weaker reflection by the substrate. Furthermore, for silver substrate, we see significant effects of the light incident angle and polarization on scattering efficiency as shown in Fig. 1b. Also, for $\beta = 60^\circ$ and p-polarization, Fig. 1c shows that the $q$-factor of scattering efficiency resonance increases three-fold compared to the sphere in a homogeneous medium (from 2.4 to 7.5 at $n_{\text{back}} = 1.4$), although this is achieved at the expense of decreased of sensitivity (from 320 nm/RIU to 125.45 nm/RIU). In conclusion, these results show that this simple structure allows enhancement of plasmonic resonance modes for refractive index sensing application.
Figure 1. Scattering efficiency for various parameters: (a) varying substrate, (b) varying incidence angle and polarization and (c) background refractive index for $\beta = 60^\circ$ and $p$-polarization.

References


Study of optical coupling between two silver nanorods using mechanical model

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The effects of optical coupling between two metallic structures have attracted intensive researches due to the wide ranging phenomena, such as Fano resonance, and potential applications, such as index sensing and SERS. Most of those studies focused on the surface plasmon coupling effects. In this work we study the optical coupling between two silver nanorods at various distances, which involve contributions of surface plasmon (dark mode, D) as well as scattered waves (bright mode, B). We explore the possibility of using a simplified forced coupled oscillators model for the description of the resulted scattering cross section features. The model for single nanorod is illustrated schematically as follows

\[ \ddot{x}_d + \gamma_d \dot{x}_d + \omega_d^2 x_d + gx_b = 0 \]
\[ \ddot{x}_b + \gamma_b \dot{x}_b + \omega_b^2 x_b + gx_d = Fe^{i\omega t}, \]

where \( \omega_b, \gamma_b \) and \( \omega_d, \gamma_d \) are the resonance frequencies and damping factors of the bright and dark modes, respectively, while \( g \) denotes the coupling between the bright and the dark modes, and \( F \) is the external force. A typical scattering cross section (C_{sca}) of a single silver nanorod and its best fit by the antisymmetric normal mode of the model is shown as:

![Scattering Cross Section of a 25 nm radius Silver Nanorod](image)
The model is extended for the two nanorods at various surface to surface distances ($\ell$), by introducing additional parameters representing the asymmetric effects of $B_1$-$B_2$, $B_1$-$D_2$ and $B_2$-$D_1$ couplings. It is found that the resulted $C_{\text{sc}}$ can be reasonably fitted ($R^2 > 0.99$) by the model taking into account the appropriate parameters as shown below:

![Scattering Cross Section for two Silver Nanorods of 25 nm radius](image1)

![Scattering Cross Section for two Silver Nanorods of 25 nm radius](image2)

![Scattering Cross Section for two Silver Nanorods of 25 nm radius](image3)

As clearly seen from the above results, the contribution of dark mode becomes perceptible for $\ell < 80$ nm.

References
10th International Symposium on Modern Optics and Its Applications

Excursion
**Thursday, 13 August 2015**

**Excursion to Mount Tangkuban Perahu Crater and Grasia Spa Hot Spring**

*Note:*
- The ISMOA 2015 Organizing Committee will provide buses for this excursion, however entrance fee to each location and lunch are at own expenses.
- Participants who are interested to join this excursion should register at the Organizer’s desk at the latest by 12.00 noon on Wednesday, 12 August 2015.

07.30 – 08.00  Preparation for departure at ITB main gate

08.00 – 09.30  Journey from ITB to Mount Tangkuban Perahu

09.30 – 11.00  Sightseeing at Mount Tangkuban Perahu
   Entrance fee:
   Rp. 200,000/visitor (international)
   Rp. 20,000/visitor (local)

11.00 – 11.30  Journey from Tangkuban Perahu to Gracia Spa Hot Spring

11.30 – 13.30  Hot spring bath and lunch
   Entry fee:
   Rp. 49,500/visitor

13.30 – 15.00  Journey from Grasia Spa Hot Spring to ITB
Mount Tangkuban Perahu

Grasia Spa Hot Spring
Miscellaneous Information
Map of Institut Teknologi Bandung (ITB) and Its Vicinities
Map of Institut Teknologi Bandung (ITB) Campus

Zone A
3. Sesana Budaya Ganesa
2. Mandala Silawanggi Stadium
3. Swimming Pool

Zone B
4. Student Regiment
5. Building II (Mathematics Dept., Astronomy Dept, Center for Applied Mathematics)
6. Industrial Engineering Dept.
7. Mechanical Engineering Labs
8. Mechanical Engineering Dept.
10. Botanical Garden
11. Radio and Microwave Telecommunication Lab.
12. West Lecture Building

Zone C
14. Multipurpose Building
15. Center for Microwaves
16. North Gate
17. Sonerak Court
18. Main Library, ITB Press

Zone D
20. Building XI (School of Life Sciences and Engineering Biology Dept., Geophysics Dept., Meteorology Dept., Oceanography Dept.)
21. Lecture Theatre Building
22. TVS Lecture Building
23. Basic Physics Lab
24. High Electrical Power Lab
25. Building (Civil Engineering Lab.)

Zone E
27. T.P. Reichert Building
28. Beny Sutanto Building
29. Yusuf Pinggoni Building
30. Ahmad Bahira Building

Zone F
31. Water Resource Center
32. LAP
33. Building IV (Geology Dept., Mining Dept.)
34. Rector’s Official House
35. Canteen
37. Basic Science B Building
38. Chemistry Dept.
39. Canteen
40. Hydrology Lab.
41. East Lecture Building
42. Geology Dept.
43. Transportation System Dept.

Zone G
44. Textile Art Dept.
45. Student Union
46. Environmental Engineering Dept.
47. Building IX (Petroleum Dept.)
48. East Campus Center
49. Visitors Center
50. Art and Design Dept.
51. Canteen
52. Building I (Architecture Dept.)
53. Science and Art Gallery
54. Lecture Theater
55. East Auditorium
56. Campus Security
57. Faculty of Arts and Design

Zone H
58. Faculty of Civil Engineering and Planning
59. Visitor’s Information
60. West Auditorium
61. Civil Engineering Dept.
62. Basketball and Volleyball Courts
63. West Campus Center
64. Physics Dept.
65. Electronics and Instrumentation Lab.
66. Resources Bureau
67. Acoustics Lab.
68. Basic Science Center A Building

Zone I
69. Technology Research Center
70. ITB Cooperative
71. Tourist Research Center
72. Technology Management Dept.
73. Health Center
List of Attendees

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