

A fluorescence microscopy image showing several cells with blue nuclei and green/red cytoplasm, overlaid with a white grid. The title 'PHOTONICS NEWS' is centered in white serif font.

# PHOTONICS NEWS

February 2014 | Volume 16

International School of Photonics

# International School of Photonics

A center for Research and Higher Education in Photonics



**Prof. V. P. N. Nampoori**  
Chief Editor

\*\*\* Editors \*\*\*

Arun  
Anand  
Pradeep  
Sr. Anju

\*\*\* Cover Design \*\*\*

Anand  
Pradeep

\*\*\* Publisher \*\*\*

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*We are glad to bring to you the 2014 edition of Photonics News. At the outset let us congratulate the ISRO and its scientists in their quantum leap in space explorations by successful Mangalyan mission. There are some new components added to the current issue. Details of works being carried out by scientists in other laboratories in the area of photonics apart from the various groups in International School of Photonics are included in this issue. We hope to expand the scope of Photonics News in future by incorporating research articles also. This issue contains research articles by Reji Philip's group from Raman Research Institute, Bangalore; Jinesh Mathew; Ranjan Singh and Kailasnath. An article by Prof. Girijavallabhan describes one of the major latest applications of Raman effect in the field of sensor application.*

*I would like to bring to your notice on a new chapter added to the field of Engineering and Technology called frugal initiatives or frugal engineering. A research journal on Frugal Engineering is brought out by Springer Verlag. Frugal Engineering refers to the development of technologies with minimum cost both in monetary aspects and in the environmental interventions. This new face of technology stems out from the fact that sustenance of a technology is based on three components namely economic, social and environmental aspects. In many of the initiatives the first component alone is given priority by pushing the other two into the back benches. This will create imbalances in society as well as in nature. Nature will respond to this through the depletion of natural resources and nature's reaction through what we call natural calamities. India's Mangalyan is an example of frugal engineering with minimum monetary inputs and very high success outputs. While many of the similar expeditions by other countries were failure in the initial couple of times especially in escaping from the earth's gravitational pull India overcame all the obstacles in a single mission. We also congratulate ISRO for the development of India's own cryogenic engine for launching space vehicles. Without any formal training there are individuals who invent devices which are useful to society with minimum expenses. Trained technologists and engineers can also provide inputs to frugal engineering and thereby getting a chance to serve the society.*

*We wish all the readers of Photonics News a happy and prosperous 2014 and wish success in all of your ventures.*

Thanks to all the students, faculty and alumni, who had taken time and effort to contribute articles. Special thanks to Mr. Arindam Sarkar for providing photographs of various events. We are grateful to the Director, for giving us the opportunity to bring out Photonics News 2014 and for agreeing to increase the volume of the newsletter. - Editorial committee





### DIRECTOR'S MESSAGE

I am happy to see that the Photonics News is being brought out in a new shape and style during this year. The dynamic editorial board headed by Prof. V.P.N. Nampoori should be congratulated for this new makeover. The team of editors have relentlessly worked with dedication for bringing out this publication in an elegant manner. Hats off to the students and scientists including our alumni who have contributed for enriching the content of this Photonics News. Hope this publication will enable us to showcase our strength and work coherently along with our alumni for taking the School to international heights. Let the spirit shown behind the publication converge all like minded people towards celebrating 2015 as the International Year of Light announced by UNESCO in a grand scale.

**Prof. P. Radhakrishnan**

### COVER STORIES

#### Multimodal Bio-imaging

p06

*Multimodal imaging is defined as the “next generation of clinical imaging platforms”, where two or more imaging techniques such as CT, MRI, PET, Mass spectroscopy, EEG, X-ray, Optical, THz are combined to tap their unique strengths. These multiple imaging modalities require designing of novel nanoscale materials that can simultaneously deliver contrast and imaging agents. Learn about how rare earth doped nanophosphors are exploited in NIR/MRI imaging.*

#### Nano Raman Probe

p08

*The use of Raman spectroscopy for high resolution optical imaging is severely limited by the inherent weakness of the Raman effect. The Canadian scientists demonstrates a giant resonant Raman effect from J-aggregated dye molecules stuffed in a single walled carbon nanotubes. The elimination of undesired fluorescence background and protection against photobleaching along with enhanced emission of Raman effect by multifold allows the realization of multispectral Raman imaging.*

#### Bio Organic Light Emitting diode

p28

*Everyone has at least a superficial knowledge of what is Deoxyribonucleic acid, which carries the core genetic blueprint for every living organism. It is interesting that DNA could be used for photonic and optoelectronic application. It is reported to have good semiconducting properties with a resistivity of 1 MΩ/cm, which is equivalent to that of a good semiconductor. Find page 28, to learn more about how DNA could be exploited in light emitting diodes.*

### FEATURES

#### Carbon based Optical Diode

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*Dr. Reji Philip, RRI Bangalore*

#### Optical sensor for patient's breathing pattern

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*Dr. Jinesh Mathew, Heriot-Watt University*

#### Nonlinear plasmonics and metamaterials

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*Prof. Martti Kauranen, TUT, Finland*

#### Insider's Investigations

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*The latest developments and research achievements at the International School of Photonics*

#### Potential dangers of mobile phone towers

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*Mr. Vijesh*

#### Glimpse of life @ ISP

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*Photo gallery*

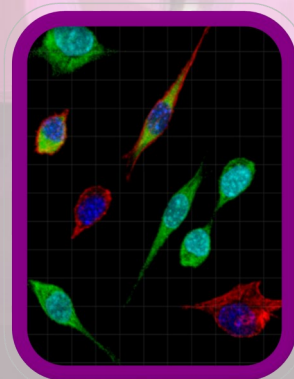
#### Endeavors of Student Chapters

p34

*The activities of ISP-SPIE and ISP-OSA*

### COVER PAGE

An edited image of fibroblast cells coated with GdF<sub>3</sub>:Nd<sup>3+</sup> nanoparticles through multiphoton microscope. The original image can be found in page 7.



## New Doctorates from ISP

We are happy to announce that two of our PhD students have reached the milestone of successfully defending their thesis this year.

**Dr. Sreelekha G** for her dissertation titled “Photonics based applications of substituted polyphenylenevinylene in solutions and free standing films”. Sreelekha’s research work is supervised by Prof. C. P. Girijavallabhan. She joined our PhD program in 2007 and has published five papers in international journals and has attended many conferences.



**Dr. Sreelekha**

**Dr. Roseleena Thomas** for her dissertation titled “Synthesis and characterization of Telluriumoxide glasses for photonics applications”. Roseleena joined the PhD program in 2009 and was supervised by Dr. Sheenu Thomas. She holds credit to four papers in international journals and presented papers in many conferences.



**Dr. Roseleena**

Please join us in congratulating them on this major achievement!

## Awards 2013

The presentation of these awards are made at Annual Photonics Workshop 2014. All the awards consist of a cash prize, merit certificate and memento. A Best Researcher award will be instituted from this year to honor a researcher from this School who publishes research papers in journals with top total impact factor during every year.



**Ms. Divya**

**Ms. Divya Sasi** (*Best Researcher award 2013*) This award is endowed by Prof. Radhakrishnan, present Director of ISP to honor the best research paper from the school every year.

**Ms. Anjitha** (*Photonics Society of India award 2013*) who stood first in M. Tech (Optoelectronics and Laser Technology) course. The award is established by the founder Director, Prof. C. P. Girijavallabhan. She also receives *Satish John Memorial award* for best project award in M. Tech course for the current year.



**Ms. Anjitha**

**Mr. Ravi Nandan** (*C V Raman award 2013*) for the best project from Integrated M. Sc (Photonics) course. This award is endowed by Prof. V. P. N. Nampoori, Emeritus Professor at ISP. He was also a record topper in overall CPGA in M. Sc course.



**Mr. Ravi Nandan**

**Ms. Mary Ida Meloday** (*Nalanda Endowment award 2013*) who topped in the first semester Integrated M. Sc (Photonics) course. This award is instituted by Prof. N. G. Devaki, Professor at the department of Hindi, CUSAT.



**Ms. Mary Ida**





# Annual Photonics Workshop 2013

*On the red letter day for ISP, as it celebrates its existence since its incipience in 1995, it is an usual custom to convene 'Annual Photonics Workshop' (APW). The focal theme of last year's workshop was 'Industrial and Medical Applications of Photonics'.*

The inaugural function was held at C V Raman auditorium at ISP on 27<sup>th</sup> February. The meeting was presided over by the Director, Dr. M. Kailasnath and he welcomed the gathering. Honorable Vice Chancellor of the University Dr. Ramachandran Thekkedath inaugurated the workshop. On this occasion he released the annual newsletter of the school 'Photonics News'. The Editor-in-Chief, Prof. V. P. N. Nampoori briefed the contents. During the inaugural ceremony the toppers of the M. Sc Photonics course and M. Tech Optoelectronics and Laser Technology course were rewarded with mementos, certificates and cash awards. Prof. C. P. Girijavallabhan, the founder director of ISP felicitated the function.

About 70 young scientists, researchers and teachers from all over India participated in this two day workshop. The participants were proffered illuminating lectures on the applications of photonic tools by experts from industries. Dr. B. Aneesh Kumar, the Manager of Color Research Group of Akzonobel, Bangalore gave a talk on new trends and application in color technology. Dr. K. R. Suresh Nair, the Managing Di-

rector of Innobreeze Technologies, Cochin had a chat with the participants about how photonics can be tapped for better lifestyle.

On February 28<sup>th</sup>, the 18<sup>th</sup> birthday of International School of Photonics as well as the National Science Day, Emeritus Prof. V. P. N. Nampoori gave a lecture on the history of Higgs Bosons. Dr. Biju Raju of Renjini Eye Hospital at Ernakulam explained how lasers are used in eye surgery. The interesting videos of the surgery initiated long discussion with the participants. Dr. K. Rakesh Kumar Singh from IIST, Thiruvananthapuram, Dr. Nibu George of Baseliious College, Mr. Fazluddeen, from Honeywell Technology Solutions and Dr. P. T. Ajith Kumar of Light Logics Holography and Optics Pvt. Ltd. were the other speakers. Poster sessions, lab visits, industrial stalls were among the other attractions. A video on Sreenivasa Ramanujan was displayed for the audience commemorating the great mathematical legacy. The workshop concluded with a valedictory session chaired by the Director while the coordinator Ms. V. C. Priyamvada thanked the participants and the organizing committee.

# technology focus

## Multifunctional Nanophosphors for Bioimaging

Recent progress in nanoscience has allowed a greater availability of enhanced sensitive analytic techniques in bioimaging which has become an extremely demanding area in biophotonics. Multimodal imaging has attracted increasing attentions, because different molecular imaging methods provide different spatial resolution, imaging depth, and areas of application. For example, X-ray computed tomography (CT) imaging gives more anatomic detail in living animals than other *in vivo* imaging tools. Fluorescence imaging provides a sole tool for visualizing living biosamples from cell to animal. However they are limited by resolution and poor imaging depth. By combining fluorescence imaging and CT imaging, the ability to accurately track biological behaviour in specified sites *in vivo* could be achieved. Similarly, non-optical imaging, such as MRI can be used to image deep in to the tissue that is not currently possible with optical imaging. Therefore, it is required to develop multifunctional materials for multi-modality molecular imaging.

In biological imaging and photodynamic therapy, light is targeted to a specific tissue location either directly or indirectly. In the case of direct light based imaging and therapy, high energy photons in the X-Ray, gamma ray, etc. regions may produce harmful effects to the biological tissue whereas modalities which use lower-energy wavelengths are much more desirable. The indirect method based on infrared (IR) light offers several advantages such as low energy IR excitation, low scattering and absorption by tissues, local delivery, and low tissue damage. However, there are significant shortcomings with these current imaging agents: viz. photobleaching in organic dyes and

luminescence blinking in QDs, toxicity of QDs and radioactive materials, autofluorescence with UV excited dyes and QDs, low information density, and overall the high technology cost.

Essentially, all of these limitations can be eliminated with IR based trivalent rare earth (RE) ions doped nanophosphor technology. Optical imaging allows for high resolution of very small localized cells, even single cells, and provides clear visualization of the cells in relationship to their surrounding tissues. Because cells are able to internalize RE phosphors, it would even be possible for *in vivo* tracking. On the other hand, non-optical imaging, such as MRI can be

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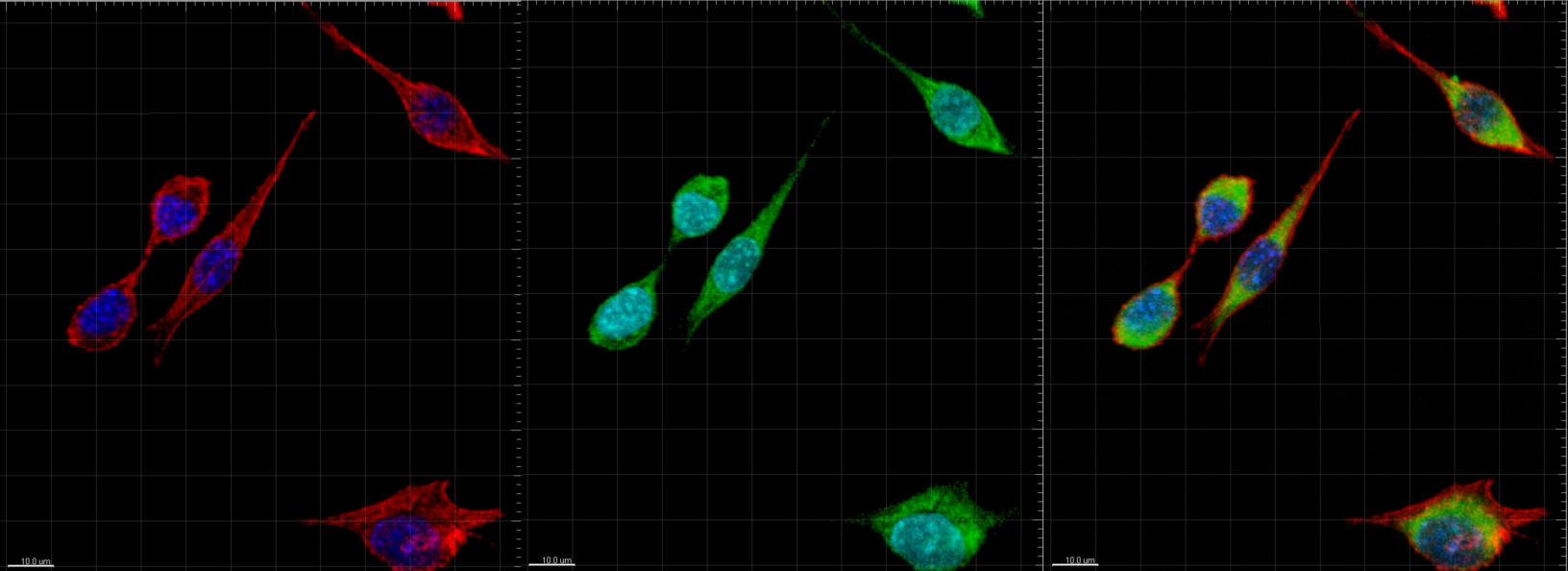
Exploiting optical and magnetic properties of rare earth doped nano-phosphors such as Nd<sup>3+</sup> doped GdF<sub>3</sub> in multimodal biomedical imaging

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used to image deeper in tissue that is not currently possible with optical imaging. It too can resolve down to the single cell level. Therefore, an ideal biomarker can be used for both forms of imaging simultaneously. Recently, Eu and Yb, Er doped GdVO<sub>4</sub> luminomagnetic nanoparticles were studied as a candidate for biomedical imaging under UV excitation. Similarly, rare earth doped NaGdF<sub>4</sub>, Fe<sub>3</sub>O<sub>4</sub>/SiO<sub>2</sub>/α-NaYF<sub>4</sub>: Yb,Er has been suggested as a potential bimodal imaging phosphor by several researchers.

The University of Texas at San Antonio (UTSA) has been actively involved in the synthesis, magnetic and optical properties, and multimodal imaging studies of rare earth doped upconversion nano-





***Multiphoton microscope images of fibroblast cells with PMAO coated  $GdF_3:Nd^{3+}$  nanoparticles***

phosphors like  $Nd^{3+}$  doped  $GdF_3$  (luminomagnetic nanophosphors). Bimodal imaging with these nanoparticles is achieved by the strong NIR fluorescence properties of the rare earth dopant  $Nd^{3+}$  as well as the magnetic properties of the  $Gd^{3+}$  in the nanocrystalline host. Most magnetic contrast agents currently used in clinical medicine consist of  $Gd^{3+}$ -based organic chelates that are administered orally or intravenously and excreted mainly through the kidneys. Because of its toxicity, lone hydrated  $Gd^{3+}$  ions are separated by chelation to reduce potential toxic effects. However, even for Gd based chelates, the metal ions may be released during metabolic process, and the subsequent toxicity can lead to serious health issues. These issues can be circumvented by using Gd-based nanophosphors where the Gd ions are firmly attached to the rigid crystalline matrix.

It is well known that most biological tissues have a lower attenuation in the NIR region than in the UV-VIS region. The absorption spectrum of the pig skin shows lowest attenuation is observed in the 700-1100 nm region. The penetration depth of 1064 nm light makes this a highly favourable emission wavelength for deeper tissue imaging, and the  $GdF_3:Nd^{3+}$  nanoparticles are particularly well suited to this due to their strong 1064 nm emission. Following the detailed optical and magnetic characterization of the  $GdF_3:Nd^{3+}$  nanophosphors, they were then implemented as contrast agents for NIR excited imaging in tissues and as contrast agents in MRI. Furthermore, the cell viability and cytotoxicity of these nanophosphors was also explored at various concentrations.

UTSA recently imaged the tissue by placing

the  $GdF_3:Nd^{3+}$  nanoparticles under varying thickness of pig skin, ranging from a 0.67 to 5 mm. Emission spectra were collected through each thickness and it can be seen that the 1064 nm emission is easily discernible even at the greatest tissue thickness of 5 mm. To investigate the suitability of these nanoparticles for bioimaging applications, fibroblast cells (L929) were incubated with the PMAO coated phosphors for 24 hours, stained, and imaged with a multiphoton / confocal microscope. Optical slices of the cells were obtained by exciting the DAPI at 358 nm, the Alexa Fluor at 647 nm. The nanoparticles were excited at 488 nm and their emission at 532 nm was used to create the nanoparticle channel in the multiphoton microscopy since the current detectors do not respond to 1064 nm. Nearly all of the nanoparticles have been internalized by the fibroblasts within 24 hours. The nanoparticles were found to be well dispersed within the cytoplasm and the nuclei when the images were taken, and there was no significant clustering of the nanoparticles nor deformation of the cells due to the nanoparticles. In summary, nanophosphors that exhibit both excellent optical and magnetic properties are to be utilized as a multimodal agent in biomedical applications such as imaging, targeted drug delivery, and photodynamic therapy.



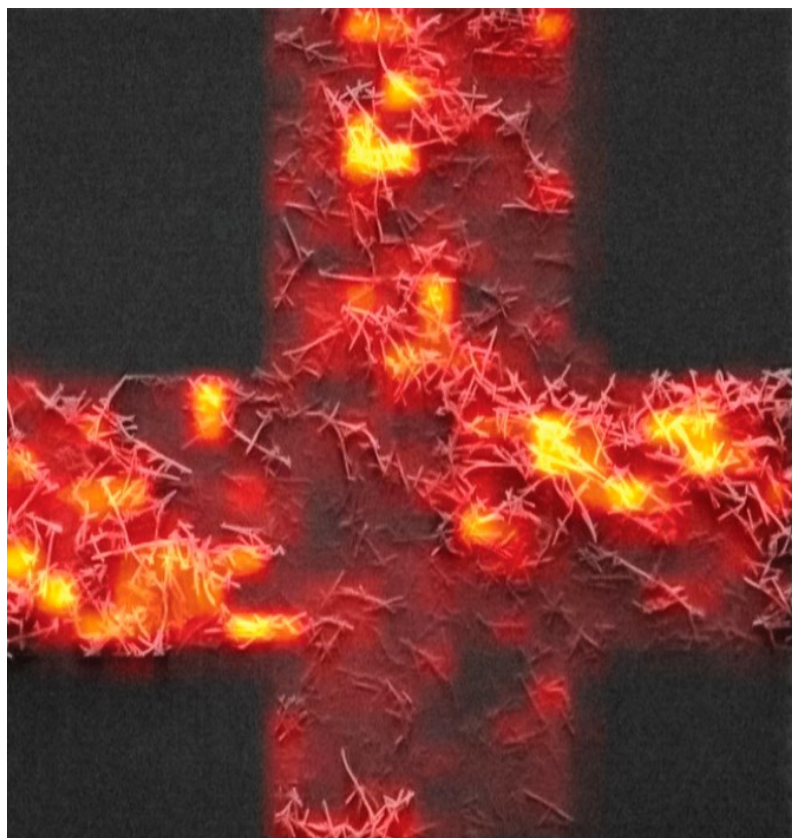
**Dr. Kailasnath**

*Dr. Kailasnath (kailas@cusat.ac.in) is assistant professor at ISP and he is on leave to pursue his post doctoral studies at University of Texas at San Antonio.*

## Novel Nano Raman Probe

**R**aman Spectroscopy has many times sprung surprises during its 85 year long history. It received a new shot of life when lasers were introduced in the field of Raman studies in the early sixties of the last century. Apart from making Raman Spectroscopy a standard analytical tool, all kinds of new nonlinear Raman effects were discovered and studied in great details by this new approach. Even though Raman process is a weak effect, the use of tunable lasers made possible the study of resonance Raman Effect with a million fold increase in the intensity of Raman lines. This was a great help in trace analysis where certain chemical species had to be identified with ppb sensitivity. Surface Enhanced Raman Effect was another process whereby the Raman lines from molecular species adsorbed on treated metal surfaces could be recorded with very high intensities. Raman imaging and Raman probes developed in recent years were of great value in biomedical studies. Now the new tools provided by Nanotechnology are making their impact in the field of Raman Spectroscopy as well.

Dye molecules have been used as probes to study the molecular processes especially in living cells and tissues. By noting their fluorescent signature it is possible to detect their presence thereby providing the details of their migration and interactions. Now scientists at University of Montreal in Canada have created tiny molecular tags made of dye molecules inserted into carbon nanotubes. This technique is very useful in developing high resolution imaging techniques based on

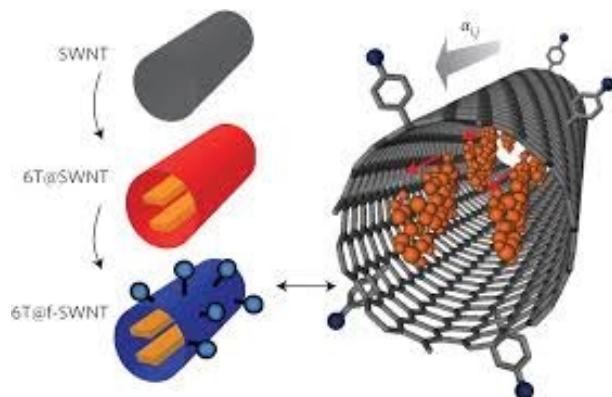


***Giant Raman signals from nanoprobe - Raman hotspots Courtesy: University of Montreal / Nature Photonics***

It has been found that such tags not only suppress the fluorescence signals from the dye molecules, but also boost the weak Raman signals a million times. This novel approach promises the development of new medical diagnostic techniques and treatments and has the potential to yield new detection techniques such as anti-counterfeiting measures.

Raman imaging from biological samples is beset with problems. Since generally Raman signals are extremely weak, one way to increase their strengths is to increase the intensity of the exciting laser radiation. This invariably leads to the damage of the sample and might even vaporize the target. Strong background fluorescent emission is another serious problem which has to be eliminated for successful Raman imaging. The team led by Richard





***Dye stuffed Carbon nanotubes Courtesy: University of Montreal / Nature Photonics***

Martel at University of Montreal made use the special properties of carbon nanotubes to eliminate these drawbacks. The carbon nanotubes are hollow tubes with wall thickness of just one atom. The dye molecules are stuffed into these nanotubes and the result is that this process substantially modifies the emission properties of the dye molecules. In such nano-tags the undesired fluorescence from the dye is effectively turned off and the weak Raman emissions are enhanced a million fold. These tags which are essentially dye filled carbon nanotubes of 500 nm length and 1 nm in diameter, can be inserted into any target such as tissues and cells and they act as tiny nanoprobe when the detectors are tuned to the specific Raman emission lines.

The Canadian Scientists used a fairly simple method to prepare the nanoprobe. Using nitric acid the carbon tubules were cleaned and their ends were opened up. The dye molecules then dissolved in a suitable solvent was mixed with carbon nanotubules and the solution was heated for few hours. Under these conditions the dye molecules fill the tiny nanotubules and they align themselves along the tube axis. Each of the tubules will now contain around 500 dye molecules. The next step is to attach the nanoprobe to the samples to be studied. They can be chemically tied on to any object like bacteria or cells or proteins. These substances then become some sort of Raman tagged materials. According to Dr. Martel, attaching nano probes to a sample is like printing a barcode on an object, allowing it to be identified even if it is not Ra-

man active or visible. Rest of the procedures is exactly like normal Raman Spectroscopy where a laser beam is used as an exciting source and the scattered light is analyzed with a spectrometer. The difference, however is that there will be a huge increase in the intensity of the Raman signals. Suppression of the fluorescent emission from the dye molecules which normally interferes with the Raman signals is an additional bonus.

When the incident photon is absorbed by the dye molecules, its excitation energy is passed on to the nanotubes before the molecule has the opportunity to emit a photon by de-excitation leading to fluorescence emission. The involvement of carbon nanotubes thus suppress the fluorescence from the dye molecules which would otherwise overwhelm and wash out the Raman signals. With the dye stuffed nanotubes the Raman signals are so bright that they completely dominate the spectrum and these are a million times stronger than the Raman signals from other surrounding molecules, when the fluorescence signal is thus suppressed.

The nanotubes also protect the dye from the environment and especially prevent the photo bleaching by the laser beam. Even though fluorescent dyes have been routinely used for tagging, fluorescence signal is not a great bar code compared with Raman signals as many more complex signals which are sensitive to environment can be generated with dyes in Raman nanoprobe. These innovative Raman nanoprobe are very versatile as they come in handy for multispectral analysis in applications ranging from protein detection to biomedical imaging. For example they can be added to banknote ink so that it becomes possible to help the authorities to eliminate the problem of counterfeiting.



**Prof. Girijavallabhan**

[Resource: Nature Photonics 8, 72 \(2014\)](#)

*Author: Dr. C P Girijavallabhan, Emeritus Professor at ISP (email: vallabhan@cusat.ac.in)*

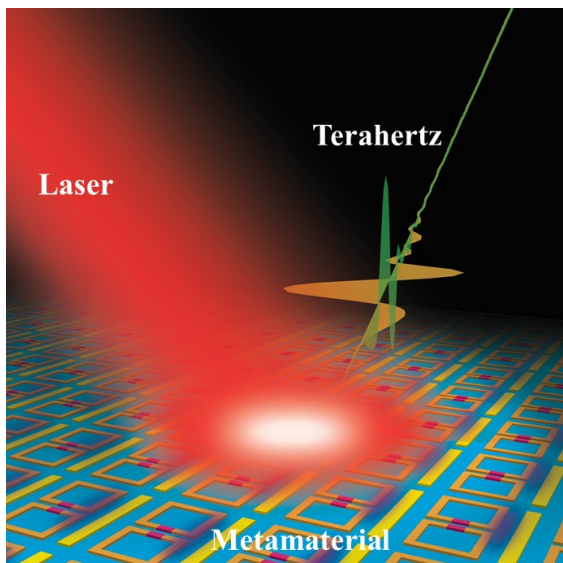
# Slowing down light with Metamaterials

Light with its different colors has fascinated the human mind since the inception of mankind. Manipulating light and its propagation has been a topic of interest for the researchers and this has led to a new branch in science called as Metamaterials. As the name suggests these are materials which are not present in nature by itself, but those which are artificially engineered and hence called as 'Meta-Materials'. They can manipulate EM wave to provide peculiar properties like Negative Index of Refraction, Super-Lensing, Invisibility cloaking etc. which are otherwise not possible. The fundamental building blocks of Metamaterials are called as 'Meta-molecules'. These are sub wavelength sized unit cells called Split Ring Resonator (SRR) which determines the frequency of operation of the metamaterial.

Based on the coupling of SRR with the incident light the elements of meta-molecule can be called as a bright atom or a dark atom. These are basically two SRR's having different spatial orientation with respect to incident polarization direction, in which the bright atom inductively couples the incident energy into the dark atom. The near field coupling between

the meta-molecule resonators is exploited to create a resonant transparency window that mimics the quantum phenomena of electromagnetically induced transparency (EIT). The researchers at Los Alamos, Oklahoma State University, and Tianjin University jointly have designed Metamaterials that consist of two identical SRRs and one cut wire made up of aluminum, with silicon filling the "splits" in the SRRs. Each unit cell behaves like an active molecule. Such 10400 unit cells have been arranged on a 10 mm x 10 mm sapphire substrate. It is the destructive interference between the non-radiative inductive-capacitive (LC) resonance of SRRs and the radiative dipole resonance of the cut wires that results in a classical analog of EIT.

When a terahertz beam is shined perpendicular to the face of the metamaterial chip, the material is strongly transparent at its lowest group velocity. By concurrently shining a femtosecond near-infrared laser pulse at a slight angle to this surface, the LC resonance property of the SRRs changes due to the generation of carriers in Sipads, and the electromagnetically induced resonant transparency begins to diminish. As the laser power is increased, the transparency peak slowly fades and disappears completely, and light propagates through the metamaterial as if it were an ordinary medium. The main benefit is that if you can slow down light in an active mode. An EIT effect also ensures a very strong light-matter interaction resulting in enhanced optical nonlinearities that would play a major role in the progress of on-chip, all-optical signal processing and quantum computation.



*A laser beam exciting the silicon islands in metamaterial, increasing the group velocity of terahertz wave*

*Resource: [Nature Communications 3, 1151 \(2012\)](#)*

*Author: Dr. Ranjan Singh*

*(RANJANS@ntu.edu.sg) is an assistant professor at Nanyang Technological University, Singapore. He completed his post graduate from International School of Photonics.*



**Dr. Ranjan**



# research highlights

## An all-carbon solid-state Optical Diode

Photonic devices are poised to replace today's Si-based electronics technology which suffers from lack of speed and power dissipation issues that limit their performance. The success of photonic devices relies heavily on the application of new optical materials and the miniaturization of existing device design. Materials, in general, show reciprocal light transmission, i.e., light transmission remains essentially the same in opposite propagation directions. An optical diode is an optical element that exhibits unidirectional transmission of light, similar to the unidirectional current flow in an electronic  $p$ - $n$  junction diode. Such an optical diode possessing non-reciprocal light transmission is fundamental to any photonic logic circuit for optical signal processing and signal isolation.

Recently, optical diode action has been achieved in Si using expensive and complex fabrication techniques. Even though CMOS compatible devices can thus be fabricated, the ever-increasing demand for denser, faster, and power-efficient devices has driven a continuous effort to miniaturize Si technology to such an extent that it has almost reached fundamental limits. On the other hand, nanostructured

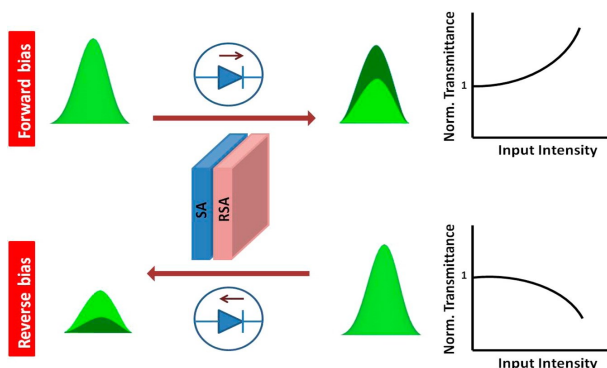
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... the reverse saturable absorption of C<sub>60</sub> and the saturable absorption of graphene can be combined to obtain the modest reciprocity factors of a solid-state all-carbon optical diode.

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carbons are posited to offer an alternative to Si and lead to further miniaturization of photonic and electronic devices that support high speeds. While present-day carbon nanotechnology is well set to carry forward the scaling in size, a concomitant scaling in speed ne-

cessitates the need for all-carbon photonic devices. Yet, carbon-based photonic technologies ostensibly lag their electronic congeners in development.



*Optical diode action in graphene/C<sub>60</sub> structure*

In this context, we recently reported the first realization of a miniature all-carbon solid-state optical diode which is based on axially asymmetric nonlinear absorption in a graphene/C<sub>60</sub> sandwich structure. Optical nonreciprocity is achieved using a simple configuration of a thin saturable absorber, SA (graphene) and a thin reverse saturable absorber, RSA (C<sub>60</sub>) arranged in tandem. Graphene and C<sub>60</sub> are different allotropic forms of carbon, and while energy levels of graphene exhibit a continuous Dirac-cone like structure near the K-point, C<sub>60</sub> possesses ro-vibrationally broadened discrete singlet and triplet electronic levels. Such contrasting electronic structures of graphene and C<sub>60</sub> result in characteristically different nonlinear absorption behavior. In this work we successfully demonstrated that these fundamental differences in nonlinearity of carbon allotropes can be elegantly engineered to introduce a jump discontinuity in transmission along the direction of beam propagation, to achieve optical non-reciprocity.

As shown in Figure 1, in the *forward bias* light first passes through the SA followed by RSA, whereas in the *reverse bias* light propagates in the reverse order. For a sample thickness of  $\sim 10$  nm, we have demonstrated a moderate nonreciprocity factor (ratio of forward to backward transmission) of 6.2 dB and 4.9 dB with few-layer graphene/ $C_{60}$  and bilayer graphene/ $C_{60}$  respectively. This all-optical diode action is polarization independent and has no phase-matching constraints. The non-reciprocity factor of this device can be tuned by varying the number of graphene layers and the concentration or thickness of the  $C_{60}$  coating. This ultra-compact graphene/ $C_{60}$  based optical diode is versatile with an inherently large bandwidth, chemical and thermal stability, and is suitable for cost-effective large-scale integration with existing fabrication technologies such as R2R manufacturing onto flexible polymer substrates.

This work was done jointly by researchers from the Sri Sathya Sai Institute of Higher Learning (SSSIHL), Prasanthi Nilayam; Raman Research Institute, Bangalore; and Clemson University, South Carolina, USA.

*Resource: Nano Letters 13, 5771, 2013*

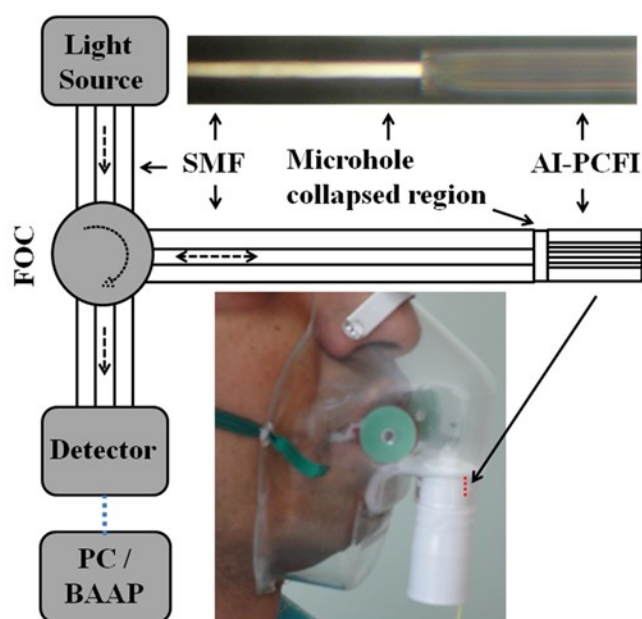
*Author: Dr. Reji Philip (reji@rri.res.in) is an associate professor at Raman Research Institute, Bangalore since 2005. He is also an alumnus of Cochin University of Science and Technology.*



Dr. Reji

## A miniature Optical Breath Sensor

A photonic-crystal fibre interferometer (PCFI) that can function as an optical breath sensor and is safe to use inside a magnetic resonance imaging scanner could prove to be a useful alternative to electronic sensors in hospitals. The face-mask device works by optically sensing the change in air humidity when the patient exhales. A short length ( $\sim 1$  mm) photonic crystal fibre inside the mask is filled with agarose, whose refractive index is highly sensitive to humidity. This sensitivity causes changes in the optical path length inside a fibre interferometer and thus a rise or fall in the output signal, thereby providing a real-time indicator of the patient's breathing pattern.



« Schematic diagram of a fiber optic breath sensor system, (upper) microscope image of an AI-PCFI and (lower) a photograph of the mask placed on the volunteer's face showing the position of the sensor inside the mask (dotted line). (FOC- Fiber optic circulator, SMF-Single mode fiber, AI-PCFI-Agarose infiltrated-photonic crystal fiber interferometer, PC/BAAP-Personal computer/Breath analysis application program; dotted arrows represent the light path).

*Author: Dr. Jinesh Mathew (jineshtmathew@hotmail.com) completed his PhD from Dublin Institute of Technology, Ireland. He is an alumnus of ISP since 2006.*



Dr. Jinesh



# Development of minimally-invasive Blood Glucose monitoring system

**D**iabetes mellitus, commonly known as diabetes, is one of the foremost metabolic disorders affecting the health of over 380 million people. It is one of the leading causes for death and disability around the globe. Diabetes is a condition caused by the variations in blood glucose level above (Hyperglycemia) or below (Hypoglycemia) the normal range (80-120mg/dl) resulting in blood toxicity. Hyperglycemia can occur when body is not producing the hormone insulin (Type1/ Insulin dependent) or the body is unable to produce enough insulin and/or has become insensitive to the insulin that it is producing (Type 2/ Insulin independent). Hormone insulin plays a crucial role in metabolism of blood glucose and maintaining its level. Typical complications of diabetes include increased risks of heart diseases, kidney failure, blindness, and even amputations which can be fatal. However, even with these serious complications, diabetes can be diagnosed and controlled by stringent personal monitoring of blood glucose level. With millions of people testing their blood glucose levels, glucose is so far the most popular analyte to be sensed and holds a major share of biosensor industry.

Over the years different methods have been proposed to monitor the blood glucose level. Electrochemical sensors are amongst the most widely developed technology for blood glucose monitoring. These sensors are invasive in nature and have biocompatibility issues which restrict them from being used for continuous blood glucose monitoring and frequent monitoring as required by Type1 and extreme cases of Type2 patients. Also, the electrochemical sensors are not stable enough to be included with insulin pump in a closed loop.

With recent advancement in photonics, optical biosensors have been used for various applications in biomedical industry which include the study of absorbing or weakly absorbing fluids (like blood). Optical methods require very less sample volume (< 1µl)

and are also capable of remote probing. The project aims to investigate the use of fibre optics together with spectroscopy and associated techniques to device a novel, patient friendly minimally-invasive blood glucose sensor which can be used for continuous and intermittent monitoring. Fibre optics has been widely used for network communications and sensing applications.

Advantages included are high bandwidth, high sensitivity, immunity to electromagnetic interference, tolerance to harsh environment and electrical isolation. Optical fibre can act both as a sensing element and a medium to carry information in real time. Multiple sensors can also be realized in same fibre. Research will involve theoretical modelling of fibre parameters, its design and development of sensing element. The experimental part will also include the characterisation and testing of sensor. Further the possibility of technique being used for multi-analyte detection will also be investigated.



Mr. Vivek

*Author: Mr. Vivek Viswambaran (v.viswambharan@rgu.ac.uk) is pursuing his doctoral studies at Robert Gordon University, Scotland. He is an alumnus of ISP since 2012.*

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# Nonlinear Plasmonics and Metamaterials

The optical properties of metal nanoparticles are dominated by their plasmon resonances. Such resonances lead to strong local fields, which are important for enhancing nonlinear effects. In the following, we summarize the results of the Nonlinear Optics group at Tampere University of Technology (TUT) on second-harmonic generation (SHG) from metal nanoparticles.

SHG requires non-centrosymmetric structures and is also otherwise sensitive to the symmetry of the sample structure. Our samples consist of arrays of lithographically fabricated gold nanoparticles. Their SHG response is measured at normal incidence using a femtosecond laser with 1060 nm wavelength. We have shown that SHG is indeed extremely sensitive to symmetry-breaking defects of the samples, which can also be interpreted in terms of multipolar contributions to the nonlinear response. Significant improvements in sample quality, however, have allowed the dipole limit to be reached, opening the possibility for engineering the nonlinear properties. We have subsequently shown how subtle details of the arrays can strongly affect SHG through diffractive coupling between the particles. Furthermore, by combining SHG-active particles with SHG-passive particles, we have enhanced the SHG response through lattice interactions between the two types of particles. It has become evident that for further optimization of the nonlinear responses of nanostructures, we need to first understand the responses of individual particles. This also presents new opportunities, because the focal fields can be tailored for the desired coupling with the modes of the particles.

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*Author: Martti Kauranen (martti.kauranen@tut.fi) is Head of the Nonlinear Optics group and Professor of Physics at the Tampere University of Technology since 1999. Also, he is presently the Dean of the Faculty of Natural Sciences at TUT.*



Prof. Martti

## Coherent backscattering and random lasing

The study of optical disordered media has been an area of intense research in the recent years. Interesting properties are shown by homogenous and periodic systems when disorder is introduced into the system. One such example is a random laser where lasing is observed when some disorder like, fine powders or particles are introduced into a homogenous gain medium. In the case of conventional lasers, lasing action occurs within a well-built resonator cavity which can support specific lasing modes based on its physical dimension. Unlike this, the random lasers rely on scattering which takes place randomly from the particles that induce disorder. The multiple scattering that takes place between the particles in the gain medi-

um can provide the necessary optical gain required for stimulated emission. There can be two mechanisms that lead to random lasing, they are, resonant feedback and non-resonant feedback. In the case of resonant feedback a photon after set of scattering events returns to its initial scatterer thus forming a closed loop which can be considered as a cavity whereas for non-resonant feedback the multiple scattering of light in the gain medium alone can provide the required optical gain for the lasing action.

For the current study the disorder system consisted of Zinc Oxide nanoparticles of 500nm average size suspended in diethylene glycol medium where

# insider's investigations

## Optimization of betanin pigments for dye-sensitized solar cell

Since Grätzel developed dye-sensitized solar cell (DSC), a new type of solar cells, in 1991, they have attracted considerable attention as environmental friendliness and low-cost alternatives to conventional inorganic photovoltaic devices. A DSSC consists of a redox electrolyte sandwiched between a working electrode and a counter electrode. To date this field has been dominated by solid state junction devices which is now being challenged by the emergence of third generation of cells based on the nanocrystalline oxide and conducting polymer films. Betalains are a class of natural vegetal pigments with various co-pigments such as the betalamic acid, indicaxanthin, betanidin, which modify their light absorption properties. They are also capable to form complex metal ions, possessing the requisite functional group ( $-\text{COOH}$ ) to bind to ZnO. Although the betalain dyes fulfil the criteria mentioned above, they have not been suitably studied as dye sensitizers. The betalain pigments comprise of betacyanin, betanin (I) and betanidin (II), with maximum absorbance in green region, and the betaxanthins in blue region. We focus our attention on DSSC using betanin extracts from red beets as light-absorbing material with a variety of working electrodes. Furthermore the effect of electrolyte with different ion composition has also been studied. Cell efficiency of 2.99% and overall photon to current conversion efficiencies (IPCE) 20% were achieved using ZnO nanoparticle electrode with iodide based electrolyte in acetonitrile solution.



*aparna.subash@gmail.com*

**Ms. Aparna**

ZnO nanoparticles acts as the scattering centers. As a pre requisite condition for the resonant random lasing action, the confinement of light, also known as localization of light should occur. The degree of localization can be identified by observing the coherent backscattered light. The backscattering cone  $\theta$  has an explicit relation with the mean free path  $l$ , which gives an idea about the particle density.

$$\theta = 0.7\lambda/2\pi l$$

After confirming the localization of light within the medium, Rhodamine 6G dye was added into the system which acted as the gain medium. Frequency doubled (532nm) pulsed (7ns) Nd:YAG laser was used to excite the system. Initially at low power ordinary fluorescence occurred and then as the power was increased first threshold occurred which was identified

by significant narrowing of emission spectrum and when the power was further increased second threshold occurred adding discrete peaks to the emission spectrum which are the quasi-states of random lasing. Once these random lasing media are immobilized on a platform they can have unique emission pattern and can find its applications in preventing banknote forging, identifying friendly/enemy vehicle in military, temperature sensing in hostile environments, tumor diagnostics in medical field, narrow spectrum coherent sources, nanomachine communication etc.



*arunisyourfriend@gmail.com*

**Mr. Arun**



## Kuramoto Oscillators on a ring

Kuramoto's mathematical model for coupled oscillators represents a wide variety of real systems, from biology to engineering, in which the coordination of several individuals is relevant. Kuramoto showed that for any system of weakly coupled nearly identical limit cycle oscillators, the long term dynamics are given by phase equations of the form

$$\dot{\theta}_i = \omega_i + \frac{K}{N} \sum_{j=1}^N \sin(\theta_j - \theta_i), \quad i = 1, \dots, N$$

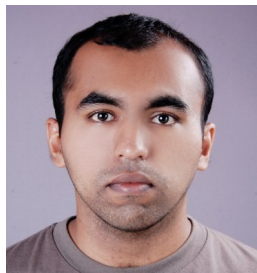
Here we consider  $N$  identical oscillators bidirectionally coupled on a ring structure. For such a system governing equations are given by

$$\dot{\theta}_j = K(\sin(\theta_l - \theta_j) + \sin(\theta_r - \theta_j))$$

where  $\theta_l$  and  $\theta_r$  are nearest neighbors of the  $j^{\text{th}}$  oscillator. To quantify the collective dynamics of the system a macroscopic quantity is used called the order parameter. It is defined as

$$r e^{i\Psi} = \frac{1}{N} \sum_{j=1}^N e^{i\theta_j}$$

Here  $r(t)$  is a measure of phase coherence and  $\Psi(t)$  is the average phase. When  $r=1$  all the oscillators are synchronized and the system acts like a giant oscillator. Synchronization property reduces as  $r$  decreases. We investigate the stability of synchronized and unsynchronized states when parameters of the system are altered. For bidirectionally coupled Kuramoto oscillators on the ring,  $r=1$  is always a stable steady state. But the stability of the state with  $r=0$  depends on the number of oscillators on the ring. It acquires stability only when  $N>4$ . In this case at any point of time the phase difference between a pair of adjacent oscillators will be  $2\pi/N$ . Depending on the initial condition, here  $r$  may go to 0 or 1.



Mr. Bejoy

bejoyrosily@gmail.com

## FQY using dual beam thermal lens technique

The dual beam thermal lens technique is an effective method for the measurement of absolute fluorescence quantum yield (FQY) of dye solutions since no standard reference sample is used. This method is very convenient and useful, especially at higher concentrations nearing fluorescence quenching. The concentration-dependent quantum yield of Methylene Blue (MB) in distilled water was studied using this technique. The FQY was measured and observed that the reduction in the quantum yield is due to the non-radiative relaxation of the absorbed energy. The localized heating of sample leads to change in temperature dependent refractive index, which causes a probe beam to diverge. The quantum efficiency can be calculated from the thermal lens signal.



Ms. Bini

binivibin@gmail.com

The FQY closely depends on the environment of the fluorescing molecule, internal non-radiative conversion ( $S_1 \rightarrow S_0$ ), intersystem crossing ( $S_1 \rightarrow T_1$ ), excited singlet state absorption, aggregation of dye molecules etc. These are strongly dependent on excitation source, solvent characteristics and the concentration of the dye solution. In the present case a significant reduction in fluorescence quantum yield can be expected due to dimerization at higher concentrations.

The absorption spectrum of MB resides around 660nm. The FQY is decreased as the concentration is increased. This reveals that non-radiative processes become significant at higher concentrations and results in enhanced thermal lensing. The rapid decrease in FQY at higher concentrations can be due to the formation of dimers and aggregates which have zero or very small fluorescence quantum yield. The role of triplet state absorption is also to be considered as an important factor.

## Photoluminescence studies of $\text{TiO}_2$ - $\text{CeO}_2$ nanocomposites

Rare earth when doped with semiconductors figures in various applications such as in optical storage, medical diagnostics, optoelectronics, nano-sensors etc. The width and intensity of the fluorescence bands are affected by the crystal structure. The fluorescence emission can be tuned by suitable doping of rare earth metals, which could be utilized in various applications. Their photoluminescence can be used to study the active doping sites. In a recent work, we doped Cerium dioxide ( $\text{CeO}_2$ ) in titanium dioxide ( $\text{TiO}_2$ ) using the sol gel process followed by their photoluminescent studies using fluorimeter. The doped sample was luminescent in near ultraviolet and green region. The luminescent properties were also compared with Laser induced Fluorescence, using high power lasers. Fluorescence quenching was observed as the doping composition varies and also, within the same composition as the concentration decreases, accompanying corresponding wavelength shift. This can be attributed to the changes in the crystal lattice of  $\text{TiO}_2$  when  $\text{CeO}_2$  is introduced to its vicinity. As the amount of  $\text{TiO}_2$  increases more  $\text{Ce}^{3+}$  ions are released leading to increased fluorescence.



Ms. Divya

email: divyasasi7@gmail.com

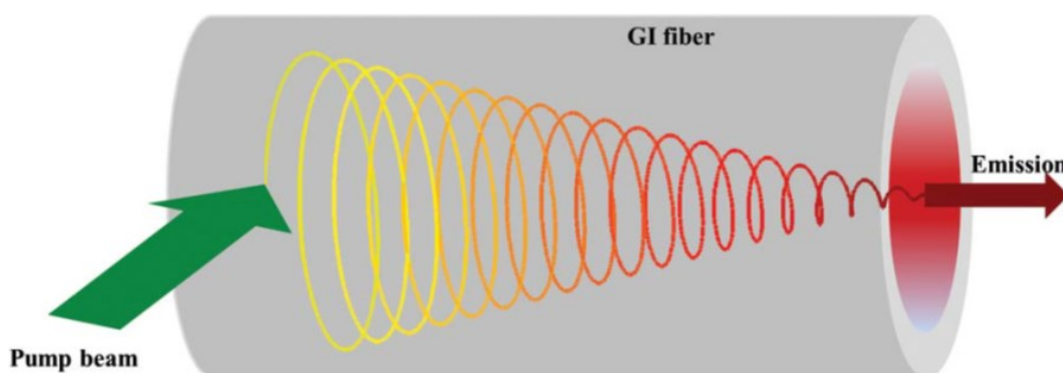
## Laser emission from the whispering gallery modes of a GI fiber

Organic dye doped polymers have been widely used as gain media in optical amplifiers and solid-state dye lasers due to the large absorption and induced emission cross sections of dye molecules. Laser dye doped polymer optical fibers are highly efficient for lasing action with narrow pulse width and wide tunable range. Whispering gallery microcavities have been widely used in very low threshold lasers, narrowband filtering, add-drop filters, biosensing applications, etc., due to their small size and very high Q factor. They have several geometries like microsphere, microring, microdisk, etc. These microcavities confine optical fields into an interior region close to the surface of the resonator by resonant recirculation due to the total internal reflection at the boundary. In a study investigated at ISP, whispering gallery mode (WGM) laser emission has been observed from Rhodamine B doped polymer optical graded index (GI) fiber by transverse pumping with a frequency doubled Q-switched Nd:YAG laser. The propagation and confinement of these modes were also observed. A variation in the free spectral range from 0.29 to 1.24 nm is obtained along the length due to the confinement of WGMs in the GI fiber.



Mr. Linslal

email: linslal@gmail.com



*Confinement and propagation of whispering gallery spirals (modes) in a GI fiber when excited with a pump beam.*



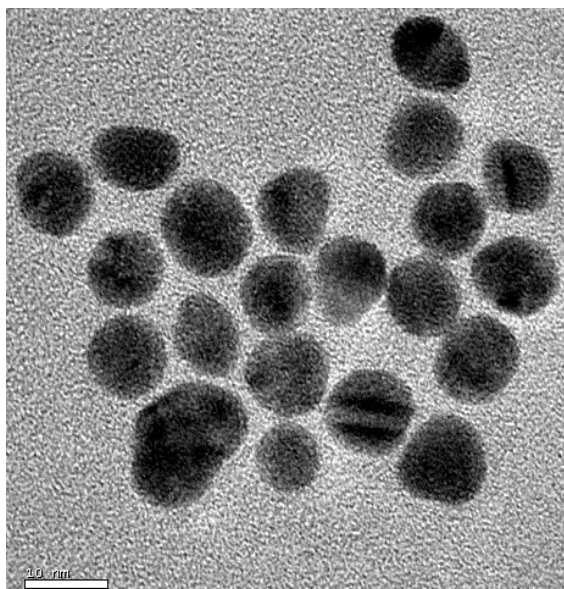
Sr. Anju

email:  
srrosmmin2009@gmail.com

## Nonlinear optics of plasmonic nanoparticles

Nonlinear optics is one of the mature research fields relevant to fundamentals and applications of light matter interaction. Several nonlinear optical processes such as second harmonic generation (SHG), two-photon resonances, four-wave mixing etc, have played critical role in realizing various optical devices. Plasmonic metals such gold and silver exhibit inherent non-linear optical behavior. The nonlinear optical property of plasmonic nanostructures can be varied, modulated and eventually controlled by optimizing geometric features such as size, shape and arrangement of the nanostructures. One such plasmonic geometry that has captured attention in recent times is the plasmonic nanoparticles. Third-order optical nonlinear absorption in gold nanoparticles studied by the Z-scan technique with nanosecond laser radiation of 532-nm wavelength shows, nonlinearity varies with concentration of gold nanoparticles within the range of our investigations which in turn may depends on the particle size. The nonlinear absorption and the RSA behaviour in metal nanoparticles were

usually believed due to free carrier absorption (excited state absorption). Optical limiters are eventually those systems which transmit light at low input fluence or intensities, but become opaque at high inputs. Optical power limiting is effected through the nonlinear optical processes of the sample.



*A TEM image of gold nanoparticles. The scale shown is 10 nm. The image depicts a dispersed spherical nanoparticles of sizes less than 10nm.*



Mr. Jaison

email: jaison.peter@gmail.com

## Laser emission from dye doped polymer films

Light amplification and spectral narrowing are studied in various systems both in the liquid and solid forms, where the spectral linewidth is reduced to a value less than 10 nm. Spectral narrowing in most of the systems is explained in terms of amplified spontaneous emission (ASE), where the spontaneously emitted light is amplified by the gain medium as it propagates along the path of the maximum optical gain. Reflections from the internal surfaces can increase the path length or allow multiple passes inside the gain medium which in turn build up the ASE at a faster rate. At ISP labs, we use a rhodamine 6G dye doped polymer film without any external cavity. Since the pumped polymer film was a free-standing one, the lateral faces of the film acted as mirrors, thus giving rise to a Fabry-Perot type optical cavity in which the cavity length corresponds to the film thickness. The emission and the number of resonant modes depend strongly on the quantum yield and film thickness. The obtained mode spacing agrees well with the theoretical value. The Q-value of the microlasers was found to be  $> 1500$ , which results in narrow laser emission lines with a width of about 0.35 nm.



## Inverse opal photonic crystal of chalcogenide glass for IR applications

Photonic crystals are special structures having spatial architectures (1D, 2D and/or 3D) with a periodically changing complex dielectric function at scales comparable to wavelengths of light in demanded frequency range. Therefore, the periodical distribution of complex dielectric function leads to appearance of distinct regions in the dispersion spectrum, where photons are either allowed or forbidden to propagate, i.e., formation of photonic bandgap (PBG). The PBG structures possess some interesting optical phenomena such as strong localization of photons, theoretically lossless sharp bending of light direction, suppression or enhancement of light emission. Due to the absence of optical modes in the gap, spontaneous emission is suppressed for photons with corresponding frequencies in the forbidden region. Therefore by tuning the photonic band gap to overlap with the electronic band edge, the electron-hole recombination process can be controlled in a PBG material, leading to enhanced efficiency and reduced noise in the operation of semiconductor lasers and other solid state devices.

Chalcogenide glasses (Chg) are good host for Rare Earths (RE) which have fluorescence emission in IR region due to their high IR transparency and low phonon energy. Consequently, RE doped Chg have been of growing interest because of their significant application as IR laser active medium. Therefore constructing such materials with PBG overlapped with the electronic band edge will yield a highly efficient laser.

As a first step towards this objective a colloidal silica crystal photonic films with periodicity in the visible wavelength region have been prepared. Chg solution is filled in the voids of the colloidal crystal lattice and is dried out. Inverse opals of Chg can be prepared by etching out the beads.



**Ms. Indu**

*email: indusebastian@gmail.com*

## Random lasing in dye doped polymers

Random lasers are the sources of stimulated emission without a cavity, in which the feedback is provided by highly disordered gain medium, and not by optical cavities as in regular lasers. We demonstrate coherent back scattering and random lasing from an active random media of Rhodamine 6G doped polymer fiber particles on different sizes. The feedback for lasing originates mainly from backscattering of particles. The particle-size dependence of transport mean free path, which was deduced from Coherent Backscattering (CBS) measurements. Here, the lasing threshold depends strongly on the size distribution, dye concentration and intensity of excitation in the ensemble.



**Mr. Lijith**

*email: lijithagn@gmail.com*

An active random medium can be obtained by introducing disorder in a laser material, for instance, by grinding a Rhodamine 6G doped polymer optical fiber. We investigated such fibers by varying the different concentration of dyes and size of the particles. The intensity of the scattered light is then measured as the function of the angle (radian) from which mean free path ( $l$ ) were deduced. It was found that the mean free path decreases with increases in both dye concentration and sizes of the samples.

The sample in the cuvette was transversely pumped at 532 nm with a frequency doubled Q-switched Nd: YAG laser (Spectra Physics) with 8 ns pulses at 10 Hz repetition rate. The lasing with a spectral narrowing occurs above particular threshold intensity ( $\approx 6.5\text{mJ}$ ). The samples are far out of the Anderson localization regime (i.e.  $kl \approx 1$ , where  $k=2\pi/\lambda$ ). Therefore, lasing due to the non resonant feedback occurs in the diffusive regime.

## Filamentation characteristics of tightly focused femtosecond pulses in atmosphere

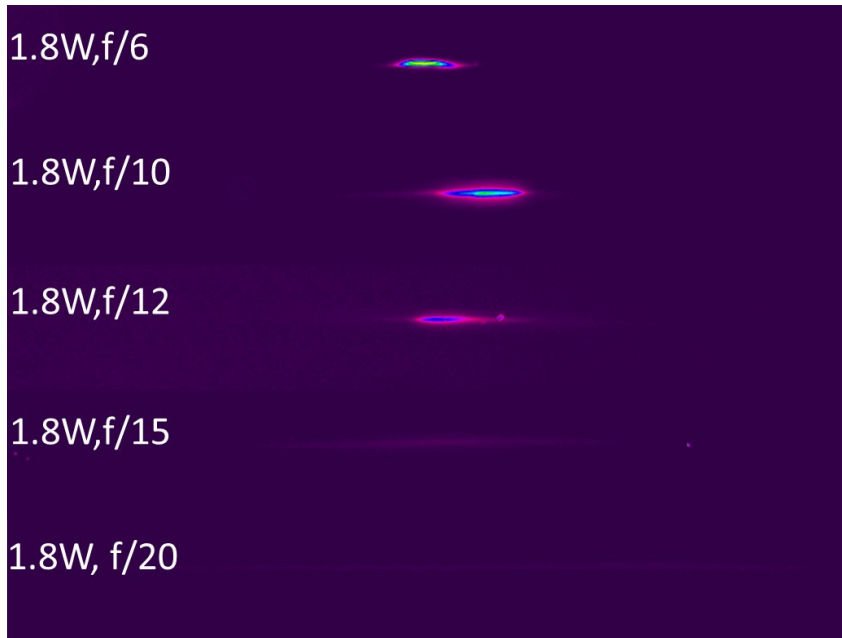
The investigation of the filamentation in air under different focusing geometries is of special interest due to the numerous potential application of it in different fields. The complete characterisation of the filaments was performed under  $f/10$  ( $NA=0.05$ ),  $f/15(0.033)$  and  $f/20(0.025)$  respectively. Filaments were observed to propagate longer distances over few tens of Rayleigh length ( $Z_R$ ) of the focused pulses in vacuum.

For a given Numerical Aperture (NA) and polarization of pulses, the length and intensity of self emission increased with increasing input power. For smaller NA, filamentation occurred before the geometrical focus while the intensity at the geometrical focus was low. In such cases filament length is distance between transformed self focus and geometrical focus of the filament. For higher NA, the filament was more localized near the geometrical focus. The length of the filament was observed to be longer for (linearly polarised) LP pulses. In general the filament was observed to propagate over  $2-5 Z_R$ . However, the width was observed to spread over  $2-40$  times the spot size of the laser beam at focus in vacuum. The width of the fila-

ment also increases with increased input power for any given NA. But the intensity of self-emission is observed to be higher with (circularly polarised) CP pulses compared to LP pulses. Comparison of filament length as a function of power for different NA's confirm that with higher NA length was almost saturated for all input powers but in lower NA length is increased with increase in power.

The filament width was measured to be  $\sim 40-200 \mu\text{m}$ . with NA of  $0.025$ ,  $0.033$  and with these NA the multiple filaments were not observed. As the NA was increased to  $0.05$  the width increased to  $250-440 \mu\text{m}$ . This indicates the presence of multiple filaments at higher NA (tighter focusing geometries) as observed by the self-emission. The filament width measured is used to estimate the intensity within the single filament following the methodology proposed by Shengqi et. al. From the transverse line profiles along a fixed  $Z$  the width of the self-emission  $d_{sf}$  is measured which in turn was used to estimate the width of the plasma filament  $d_{laser}$  (laser beam diameter). The intensity for  $12.2 P_{Cr}$ , LP under NA  $0.05$  is calculated to be  $3.8 \times 10^{12} \text{ W/cm}^2$ . However the appearance of multiple

filaments makes these measurements more challenging.



Ms. Sreeja

*Sreeja Sasi is a part-time senior research scholar at ISP and a assistant professor at Al Ameen College, Aluva.*

## Intensity of electromagnetic radiation from mobile phone towers:

### A case study over Cochin

Radiation continuously emitted from mobile phones, transmitting towers, Wi-Fi, TV and FM towers, microwave ovens, etc. are called Electromagnetic radiations (EMR). A cell phone that is ON but not in use is also radiating. In India, there are more than 50 crore mobile phone users and over 4 lakh cell phone towers to meet the communication demand. This growing use of wireless communication has introduced concerns about health risks from non-ionizing radiations. Various epidemiological and experimental studies have been carried out and the results have shown to have a close relation between biological effects and Electromagnetic radiation.



**Mr. Vijesh K R**

*Vijesh is a project assistant under Prof. V. P. N. Nampoori*

The effectiveness or seriousness of the issue has not been realized among the common man yet as one cannot see or smell or hear microwave and its effect on health is noted after a long period of time. Therefore, majority of the people tend to have casualness towards personal protection. The relevance for our study on cell phone radiation lies on the following reasons:

- Increase in the use of cell phones and subsequent widespread human exposure to EMR.
- Current exposure guidelines are based largely on protection from acute injury from thermal effects.
- Very little information is available about potential health effects of long-term exposure to EMR.
- Sufficient data from human studies may not be available for several years.

As a preliminary step we have conducted surveys in different parts of Cochin Corporation and mapped the radiation intensity in those areas. The measured radiation intensity is then separated into 3 different groups green, yellow and red indicating the preliminary risk levels in the hazard analysis. The result of our study is alarming. Most of the areas in Cochin Corporation have radiation intensity greater than the minimum allowable level and



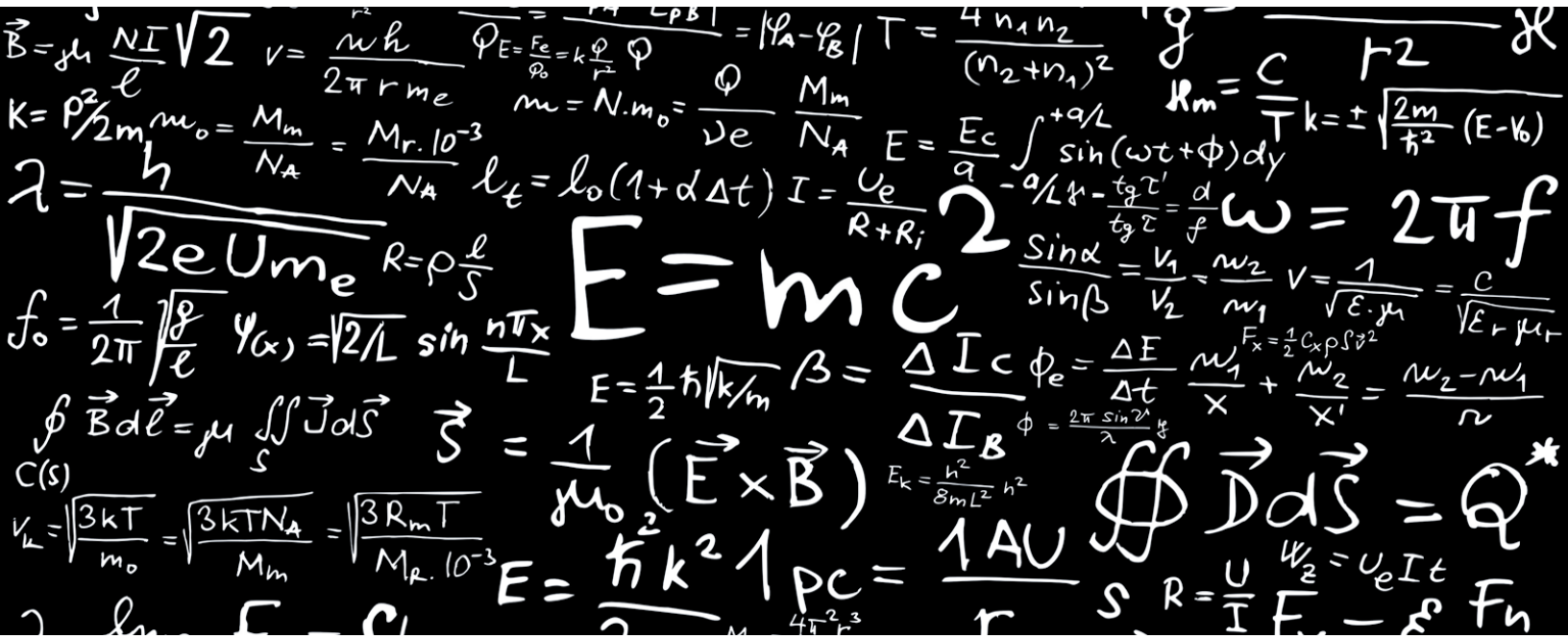
***Non-radiated (left) and Radiated (right) Bengal gram***

some of the areas are dangerously affected. Therefore there is a need for further validation, more precise prediction (verification) and analysis of the obtained results. Later an experiment setup was designed so as to understand the biological impacts of EMR on pea and bengal gram. In this two set of seeds were grown; one with exposure to mobile radiation and the other free from radiation. The germination characteristics were compared with those of controlled group. Initially, we provide 30 minutes radiation in the morning and evening and measured the growth on a daily basis. Then we compared the growth of with non-radiated seeds.

Currently, wireless communication devices are used by more than 90 percent of the Indian population. Given this large number of users, if adverse health effects are shown to be associated with cell phone use, this could potentially be a widespread public health concern. Hence stricter radiation norms must be enforced in India. So give a thought, do we really want future of our nation to be deaf or suffer from many health problems, which could have been avoided if certain precautionary steps were taken on time.



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**W**EEKLY/ Special seminars are organized possibly on every Thursdays by ISP members or guests. These seminars were sponsored by the ISP Student's Chapters of SPIE—the international society for optics and photonics, Optical Society of America and Photonics Society of India. Dr. Robert Czaplicki visited ISP during March 2013 as part of the Indo-Finnish project and delivered a lecture on second order nonlinearity from Silicon Nitride thin films. Dr. Czaplicki is an Academy Postdoctoral Researcher from Nonlinear Optics Group, Tampere University of Technology, Finland. Two of our research scholars Mr. Linesh J and Ms. Misha Hari gave their presynopsis talk on their research work. Mr. Linesh was working on design and development of fiber optic sensors while Ms. Misha was working on thermal and nonlinear optical properties of metal nano structures.



Dr. Robert Czaplicki

Preparation, properties & applications of Chalcogenide Glasses - *Mr. Musfir*

Synthesis and characterization of ZnSe nanoparticles - *Ms. Manju*

Preparation and characterization techniques for BaTiO<sub>3</sub> and CdS nanoparticles - *Mr. Nideep*

Microwave assisted polyol method, for the preparation of cdse nanoballs - *Sr. Anju*

New approach to the solutions of Maxwell's equations - *Mr. M. Rajendran*

Preparation and optical characterization of CdTe quantum dots - *Mr. Nideep*

Thermal deformation analysis of aluminium heat sink using ESPI - *Mr. Rethesh*

SHG studies in thin films of CdS and its nanocomposites - *Mr. Mathew*

Elitzur-Vaidman bomb test - *Mr. Bejoy*

Polymer optical fiber gratings - *Prof. Radhakrishnan*

Mobile phone radiation intensity and the hidden danger - *Ms. Hrudy Balachandran*

Structural analysis of chalcogenide nanoclusters - *Ms. Indu Sebastian*

Synthesis and evaluation of TiO<sub>2</sub> based DSCC - *Ms. Divya Sasi*

Chitosan coated LPG based fiber optic biosensor for detection and estimation of cholesterol - *Mr. Bobby Mathews*



# in the NEWS

**Distinguished Visitors:** This year the School was enlightened by prominent resource persons from various Universities around the world.

[Dr. Nakkeran Kaliyaperumal](#) from University of Aberdeen, Scotland visited the School during January 2014 and delivered a lecture on optical fibers and its applications.

[Prof. Prahlad Vadakkepat](#) from National University of Singapore visited ISP during December 2013, to present an interesting talk on Robotics and to introduce frugal innovations to ISPIans.

During July 2013, [Dr. Radhakrishnan Prabhu](#) presented a series of talks on optical communications. He visited our School in connection with UKIERI project. He is a lecturer at the School of Engineering at Robert Gordon University in Aberdeen.

[Prof. Martti Kauranen](#), Professor of Physics from Tampere University of Technology at Finland delivered a lecture on nonlinear properties of metallic nanoclusters.

A report of the research work (see article on page 21) done by our project assistants Mr. Vijesh KR and Ms. Hrudya Balachandran appeared in a leading Malayalam newspaper “Mathrubhumi” on January 30. The report titled in Malayalam which translates as ‘High mobile phone radiation over Cochin’.

CUSAT takes runners-up trophy in south zone inter-university youth festival held at Gulbarga University, Karnataka. Arjun C Vinod, a senior graduate student of ISP bagged first prize in photography contest.

**Newcomer:** The School welcomes Ms. Ajina Cheruvalath to PhD program. She joined in October 2013 under the guidance of Dr. Sheenu Thomas. Ajina propose to investigate certain nanomaterials for photonic applications. She has a master’s in Photonics from National Institute of Technology, Calicut.

**Placement cell:** Identifying the growing demand for technically qualified people globally in the field of Industrial Photonics and understanding the necessity to bridge academics with industrial practices, a placement cell has been formed exclusively for the students of International School of Photonics. The placement cell is expected to act as a platform for motivated students who want to start their career in Photonics industry and it can induce a healthy interaction between ISP and the industries, R&D institutes at national and international level. The team consists of a faculty advisor, Dr. Sheenu Thomas (Assistant Professor at ISP); representatives of students from each batch headed by a student coordinator, Mr. Aslam Nazar; and a parent representative. The cell is planning to conduct employability enhancement activities and on-campus placement for final year students (MSc. And M.Tech).

**Alumni News:** We are delighted to share their success stories.

[Mr. Vivek Viswabharan](#) - research student at Robert Gordon University, Scotland

[Dr. Sony George](#) - post-doctoral researcher at Gjøvik University College, Norway

**Dr. Nithyaja Balan** - assistant professor at Government College, Madappally, Kozhikode

**Mr. Shinu Gervasis** - Hindustan Aeronautics Limited, Bangalore

[Ms. Kavitha KG](#) - research student, ICFO (Institute of Photonic Sciences), Spain

**Mr. Nithin Surabh Jha** - research student, Herriot Watt University, Scotland

**Mr. Ravi Nandan** - research student, Indian Institute of Science, Bangalore

**Mr. Ajan P R** - research student, Dalhousie University, Canada

[Mr. Alok Bharthi](#) - research scholar, Weizmann Institute of Science, Israel

**Mr. Zavin A S** - research student, Indian Institute of Technology, Gandhinagar

# Development of Optical Fiber based devices for Sensing Applications (DOFISA)

## An Indo - UK Joint Research Program

**DOFISA** is an Indo – UK joint venture for research on Fiber Optic Sensing under the UGC-UKIERI (UK - India Education and Research Initiative), Thematic Partnership, funded by UKIERI.

Optical fibers are being widely used in communication network links. These fibers have been used for sensing applications as well. They have huge bandwidth and have advantages like immunity from electro-magnetic interference (EMI), electrical isolation, free from corrosion and can operate in harsh conditions. The fiber itself can be used as a sensor or can be used for carrying information to a separate sensor. These sensors are highly sensitive and they can be used for real time sensing and monitoring applications. Further, distributed sensing is possible which has the advantage of simultaneous monitoring of multiple parameters using an optical fiber.

Fiber Optic Sensing is a powerful sensing approach with wide spread use in various applications. The main aim of the collaborative project between India and UK is to design and develop a variety of novel fiber optic sensors for physical, chemical and biosensing applications, mainly based on fiber gratings. Other complementary sensing approaches, both intrinsic and extrinsic, will also be explored to demonstrate multiparameter sensing. This program also intends to share knowledge, understanding and experiences from different research groups in UK and India to develop optical fiber sensors. This would also help expose the research students to different research labs, facilities and research cultures.

Theoretical modelling and simulation of pulse propagation through optical fibers and fiber gratings can be very useful while designing fiber optic sensor. This can be helpful in selecting devices (fiber and gratings) and

optical pulse (amplitude, width, frequency) properties. It is also important to study the transmitted or reflected pulse after propagating through the optical device. This project will look into modeling and simulation of pulse propagation in fibers with and without fiber gratings.

During the project, distributed sensing using optical fibers for underwater applications will be analyzed. To gain better insight into the sensing mechanism, theoretical modeling and experimental implementation will be carried out. This project will also include theoretical analysis and experimental development of sensors for distributed sensing and detection of various parameters like temperature, strain etc.

As part of the program, researchers from the participating institutions will be visiting partner organizations. Training or exposure of the research students to advanced facilities and new methods of fabrication will enhance their knowledge and understanding. Students will gain experience on different ways of design and development of fiber optic sensors and their various applications. These visits will also include research presentations at the host institutions. This would strengthen the research interactions and will generate new research ideas among the partners.

The participating institutions of this program are International School of Photonics (ISP), CUSAT and Department of Optoelectronics, University of Kerala from the Indian side and Robert Gordon University (RGU) and University of Aberdeen (UA) from UK.

The Indian team consists of Prof. P. Radhakrishnan, the Director of ISP and Prof. Mahadevan Pillai, Head of the Department of Optoelectronics at University of Kerala. The main team members from UK are Dr. Radhakrishna Prabhu, Lecturer in School of Engineering at RGU, Professor Pat Pollard, the Director of Centre for Research in Energy and Environment (CRE+E) at RGU, Dr. K. Nakkeeran from Communications & Optical



*A laser system at RGU*

Engineering research group at UA and Dr. Thanga Thevar, a lecturer at Communications & Optical Engineering research group at UA.

As proposed in the project, the UK lead, Dr. Radhakrishna Prabhu of RGU, visited the labs at ISP in July 2013. His expertise in research was shared with the students and faculty of ISP through presentations. Mr. Libish T M, a research scholar from this school, visited RGU for a fortnight to have an hands on experience on LIBS. Mr. Bobby Mathews C, a research scholar at ISP, visited the UK Partner institutions for a three month period in 2013. During his visit, research ideas were exchanged through experimental works and technical presentations. He had carried out some preliminary investigations on LIBS. He also had chances to attend various seminars and training sessions at the host institutions. Dr. K. Nakkeeran from UA visited ISP, in January 2014. Mr. Kaushal Bhavsar, Research Scholar from RGU, will be in ISP, between January and March 2014.

It is worth exchanging the expertise of the individual groups in India and UK in this research domain, which is of mutual interest for the participating groups and also for the respective countries as it has enormous potential in the present and future world. New insights gained in the area of fiber optic sensors will lead to successful development of sensors for biological applications as well. The research and development work planned to be carried out in this project will have other measurable outputs like publications in peer reviewed journals and conferences.

Successful outcomes will identify newer applications, both research and commercial, with a particular focus on bio sensing. The basic technology developed can be easily extended for the design of sensors to detect various chemical and biological species like bacteria, toxins, pollutants etc. The sensors to be developed will be useful for monitoring the quality of drinking water and foodstuffs, checking the levels of atmospheric pollutants etc. This will in turn lead to a better level of social life.

*Author: Mr. Bobby Mathews. (email: mathewsbobby@gmail.com). He is currently pursuing his doctoral studies at ISP and has been a visiting research associate at Robert Gordon University.*



# Bio Organic LED

There has been a constant push to develop new materials in device engineering so as to outshine the existing materials in performance and cost. Deoxyribonucleic acid from salmon sperm (saDNA) has been exploited as biodegradable polymeric material for photonics and electronics application. DNA, the ‘building block of life’ with its renowned double helical structure has been a subject of interest in various fields including life science, genetics, microbiology, medical science etc. Recently the “molecule of life” had made way into the field of photonics, semiconductors and display technology. Many devices such as optical waveguides, bio-organic light emitting devices, bio field emitting transistors and bio sensors are at the research table with promising results.

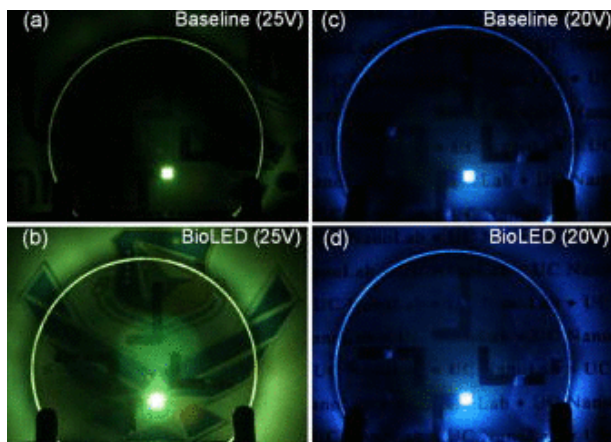


**A**lmost all organisms possess DNA in their cells. Because of large disposal of salmon waste from fishing industries, DNA from salmon testes has become a potential material for its abundance and cost effectiveness. DNA which has been of special interest to scientists and scholars since the discovery of its structure, continues to awe researchers through the emerging field of **DNA Photonics**.

DNA entered photonics through its readiness to intercalate fluorescent dyes to its major and minor grooves or in between the base pairs. This increased the fluorescence signal as the presence of DNA could resist the agglomeration of the dye molecules and thereby avoid quenching. Over a decade ago, ampli-

fied spontaneous emission and lasing action was observed from laser dyes in DNA matrix. This was also extended to organic light emitting diodes (OLEDs) where DNA could act as a host material for fluorescent emissive materials. Such LEDs have resulted in enhanced brightness and efficiency.

Based on the reports that DNA can efficiently transport electrical current as good as a semiconductor, it has been successfully incorporated into many optoelectronic devices. DNA can act as a hole transporting layer as well as electron blocking layer in various dye doped polymer light emitting diodes (PLEDs) and Quantum dot light emitting diodes (QDLEDs) based on CdSe, CdS and ZnS. The DNA lipid complex, in its solution processable solid state thin film form has shown to be effective material to block electrons (0.9eV—LUMO) while transporting holes (5.6eV—HOMO) over conventional electro optic polymers such as PMMA or PVK. This helps to design a heterostructure LED so as to tailor the recombination sites to the required emissive layers. Such



**Green and Blue BioLED incorporating DNA (b and d) in comparison with Baseline LED (a and c). Courtesy: University of Cincinnati / AIP publishing LLC**

designs have shown increased luminous efficiency.

Very recently DNA based nanofibers were used to demonstrate an all-organic non-phosphor white luminescence from coumarin and hemicyanine based dye using fluorescence resonant energy transfer. Coumarin absorbs UV light and emits blue light which is reabsorbed by hemicyanine dye to emit at different colors from blue to orange to white. The tone of white can also be adjusted from warm to cool. The role of DNA is to help orient the dye molecules spatially for efficient energy transfer while the nanofiber geometry

helps to enhance the emission intensity.

In another work, DNA was found to replace conventional epoxy EPO-TEK for better brightness and lifetime from a blue LED doped with YAG:Ce (cerium doped yttrium aluminum garnet).

DNA has proven to be an efficient optoelectronic material due to its attractive features such as renewable, inexpensive, natural, biodegradable and abundant resource. The unique material properties of DNA help it to be a promising material in electronic and photonic applications. DNA lipid complex can be deposited using various deposition techniques from simple spin coating, solvent casting, spray deposition, ink jet printing, electron spinning to sophisticated Molecular Beam Deposition (MBE) and Matrix Assisted Pulse Laser Evaporation (MAPLE). This interesting material provides high thermal conductivity, lower optical loss, acceptable thermal stability, mechanical robustness, tunable electrical resistivity, wide HOMO/LUMO bandgap which has improved device performance in terms of brightness, luminous efficiency and operating lifetime. Though research using this biomaterial is still at early stages, it has shown its impact on various applications in photonic devices. It is however important to continue to learn about how we can shape the properties of DNA to expand its applications.

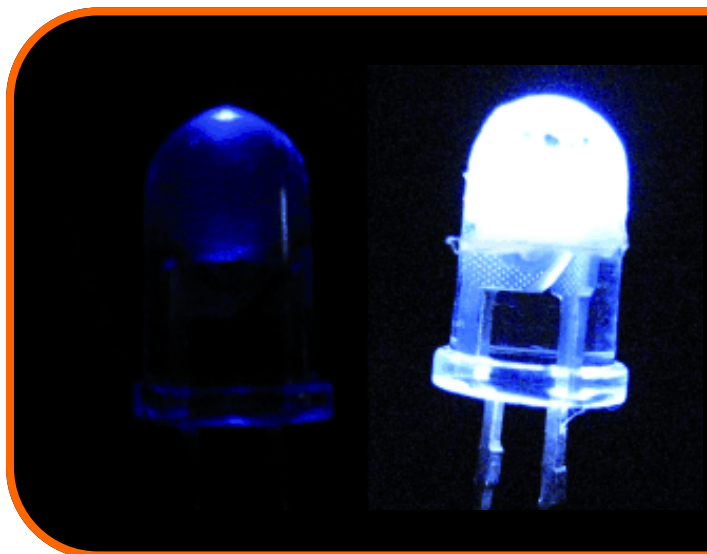
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**Mr. Pradeep**

email: [pradeep@photonics.cusat.edu](mailto:pradeep@photonics.cusat.edu)



**UV LED (400 nm) without (left) and with DNA nanofiber coating (right). Courtesy: University of Connecticut/ Angewandte Chemie**



# Nanomaterials for Multipolar Nonlinear Optics

A Finnish-Indian joint call on Nanomaterials Research



**Nonlinear Optics Group with their group leader Prof. Martti Kauranen (center, sitting) in Nonlinear Optics Laboratory at Tampere University of Technology**

**NANOMULTI** is a collaborative research assignment jointly funded by Academy of Finland and Department of Science and Technology, India. The project was designed to explore new materials with strong higher-multipolar nonlinear responses. The Indo-Finnish team presents a skill combination to make a comprehensive effort in addressing and optimizing the multipolar properties in many nanostructured materials. As the joint venture enters the final year of the 3-year project, the School summarizes some of the achievements and prospects from this collaborative research program.

**T**he Nonlinear Optics (NLO) group headed by Prof. Martti Kauranen of Optics Laboratory from Department of Physics, Tampere University of Technology (TUT) in Finland is a well-established leading research group focusing on fundamental issues regarding the nonlinear optical response of materials. The nonlinear responses are precisely characterized by unique measurement techniques and theoretical models. The main interest is in separation of surface and bulk effects to the nonlinear response and their multipolar contributions. This group forms the Finnish counterpart to our school headed by Prof. P. Radhakrishnan as Principal Investigator and Dr. Kailasnath as co-investigator in carrying out this project.



The project is aimed to make a comprehensive effort to investigate multipolar nonlinear optical responses in nanostructured materials. The main objective of this joint venture is to develop new types of nanostructured materials with high multipolar nonlinear optical responses. The project is based on the complementary expertise of - synthesis and fabrication of nanostructured optical materials from ISP and of - the experimental techniques in characterization of optical nonlinear properties, especially second harmonic generation with special emphasis on the higher multipole (magnetic- dipole and electric-quadrupole) effects from the NLO group.

The ISP team had been in active research in the area of fabrication of nanostructured materials for optical applications. The team could synthesize metal and semiconductor nanoparticles such as Ag, Au, CdS, CdSe, CdTe, ZnS, ZnO, TiO<sub>2</sub> etc. and their nanocomposites by chemical bath deposition, photochemical reaction or laser ablation. The particles are then doped in polymer matrices and fabricated using self-assembly, spin coating or tape casting techniques. An important material is the Chalcogenide glass as it possesses strong dipolar third order response and is believed that it could have strong quadrupolar second order response. The bulk chalcogenide glasses containing elements such as Selenium, Germanium, Antimony etc. are fabricated on glass substrates in nanoscale using thermal evaporation technique. The samples undergo basic characterization so as to measure its optical, molecular, structural and surface properties. These samples shall then be transferred to the NLO group through international exchange program where vigorous second order nonlinear measurements be evaluated based on single and two beam techniques that allow multipolar contributions to the nonlinearity to be separated through polarization measurements.

To make an efficient collaboration and expand the knowledge base of both teams, NANOMULTI provided an environment to promote the mobility of researchers between Finland and India. Dr. Kailasnath visited TUT during the first year to understand the measurement techniques demonstrated by the NLO group. Later two research scholars Mr. Mathew Sebastian and Mr. Pradeep Chandran from ISP visited TUT for a three month long visit in 2012 and 2013 respec-

tively. In turn, Prof. Kauranen, Dr. Robert Czaplicki and Mr. Kalle Koskinen visited ISP labs and gave lectures to educate the research scholars and grad students on second-order nonlinear optics and their characterization techniques.

Recently Mr. Nideep T Karunakaran, a PhD student of ISP left for a nine-month long stay to study Cadmium Sulphide and Cadmium Telluride thin films. He also plans to carve out a thesis based on the work that would be executed there. Mr. Kalle Koskinen (a research scholar from TUT) recently visited ISP to study the fabrication of certain nanomaterials by thermal evaporation technique. Dr. Abdallah, post-doctoral researcher from TUT is also expected to visit ISP. In this final year Ms. Divya Sasi would spend three months at TUT to initiate studies on Titanium Nitride thin films.

At the Nonlinear Optics Laboratory, the samples were characterized to measure SHG signal. Single beam technique confirmed the generation of second harmonic signal in some of the thin film samples. A weakly focused and chopped infra-red laser beam was used and the resulting SHG signals were comparable with that of Silicon Nitride thin films. The Glan polarizers allowed to make measurements by varying the input and output polarization states of the laser beam. The tensorial properties of the sample were determined with the help of half-wave and quarter-wave plates. Two beam measurements using a fundamental beam of a picosecond mode-locked Nd:YAG laser are underway which shall address multipolar nonlinearity. Preliminary results showed that both CdS and Chalcogenide glasses as promising candidates for more strenuous analysis.

Through this project it is best hoped to explore research development in the field of Nonlinear Optics and strengthen ties between both the universities. It has also helped to motivate scholars through international exposure to improve the quality of their research.

*Authors: Mr. Pradeep Chandran, Mr. Nideep Karunakaran and Mr. Mathew Sebastian. (email: mathewphys@gmail.com). All the authors are pursuing their doctorate degrees at ISP and are benefited from this project.*

# Glimpse of life at ISP



At annual SPIE leadership meet



X'mas day celebrations



Workshop lab meet



Christmas celebrations





Onam celebrations



Annual Photonics Workshop 2013



Onam celebrations



At Optics Fair



## Activities of ISP Student Chapter

International School of Photonics houses two student chapters, viz. ISP-SPIE student chapter and ISP-OSA student chapter. The activities of the school are jointly funded by both the chapters.

Optics Fair is the largest student outreach program organized by the student chapters of ISP. Optics Fair 2014 was held on 7<sup>th</sup> and 8<sup>th</sup> of January 2014. Around 2000 students participated in this two-day event. The event was attended by school and college students in which they were exposed to the field of Optics and Photonics. The students of ISP exhibited experiments of wide range covering fundamentals from ray optics to fascinating phenomena in quantum optics. The chapter members were divided into four sections: Optics, Fundamental Section, Simulation Section and General Section. The event attracted students as well as teachers equally which was evident as the teachers and students competed with each other in showering questions to the ISPIans who demonstrated the experiments. The “Optics Experiment and Simulation Kit” was inaugurated during the fair.

Being one of the largest student chapters of SPIE in the world, the ISP-SPIE Student Chapter takes up the responsibility in spreading awareness about the relevance of optics and photonics career among school students throughout the state of Kerala. As a step towards this goal, the chapter organized a social outreach program known as ‘Optics To School’. To enact

this task, the chapter has constituted a production unit to design various experiments and demonstrations to be presented at the schools where the chapter team will visit. The basic principles of optics will be explained to the students through simple experiments. The event will be organized in the coming academic year starting from June.

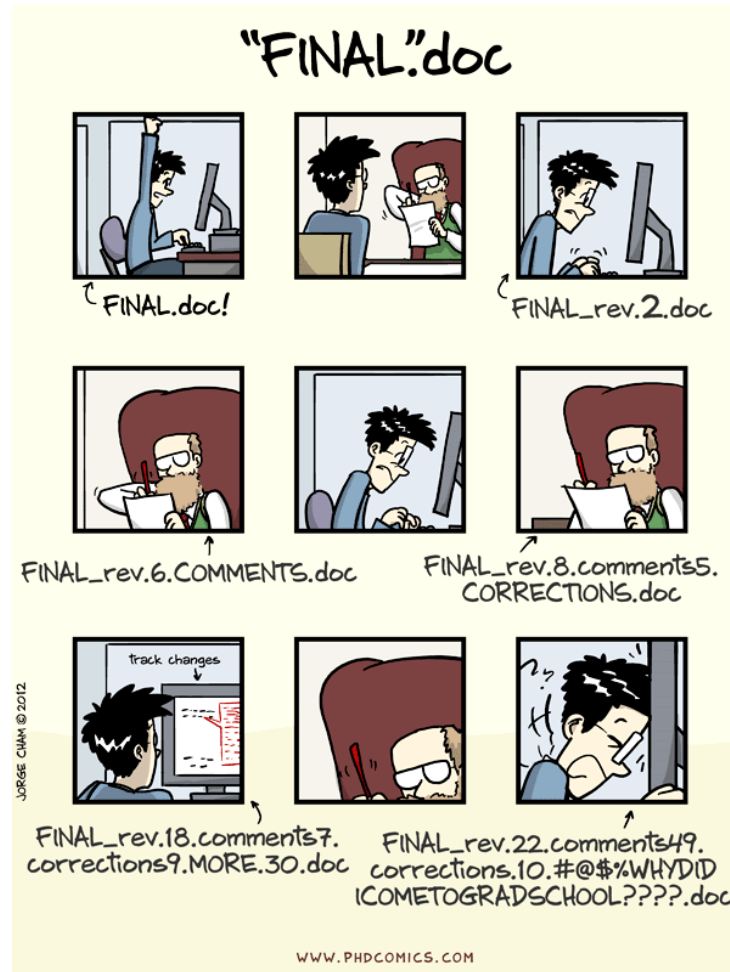
In a visiting lecturer program funded by the Chapter, Prof. Jean Luc Dumont, PhD in applied physics from Stanford University, visited the school and interacted with our students by delivering a talk on making an effective presentation. Jean-luc is a popular instructor and invited speaker worldwide. The lecture



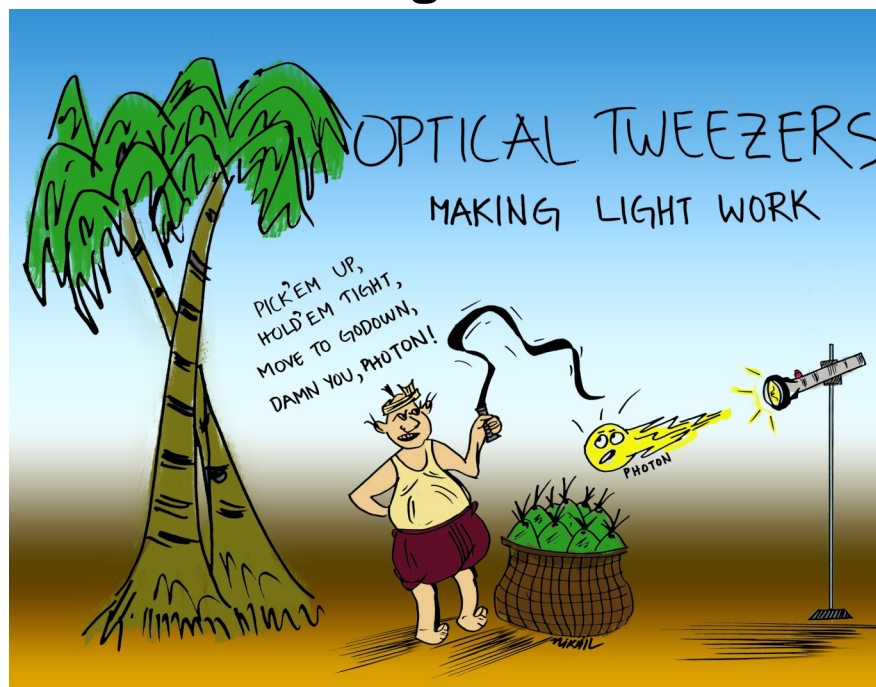
received an overwhelming response from the faculty and students of different departments within the university. The chapter is also planning to arrange another lecture by Prof. Dumont in the current academic year.



In order to ensure that learning is not only confined to classrooms, an industrial visit was organized by the student chapter. On 5<sup>th</sup> July 2013, the final year graduate students of the School visited Holmarc Opto-Mechatronics Pvt. Ltd, a leading manufacturer of Optics, Opto-mechanics, Optical instruments and motion control devices. Students had an opportunity to see and understand how theory is put into practice. The interaction with the technical experts from this industry helped students to gain an insight regarding the requirements and demands of working in an industrial environment.

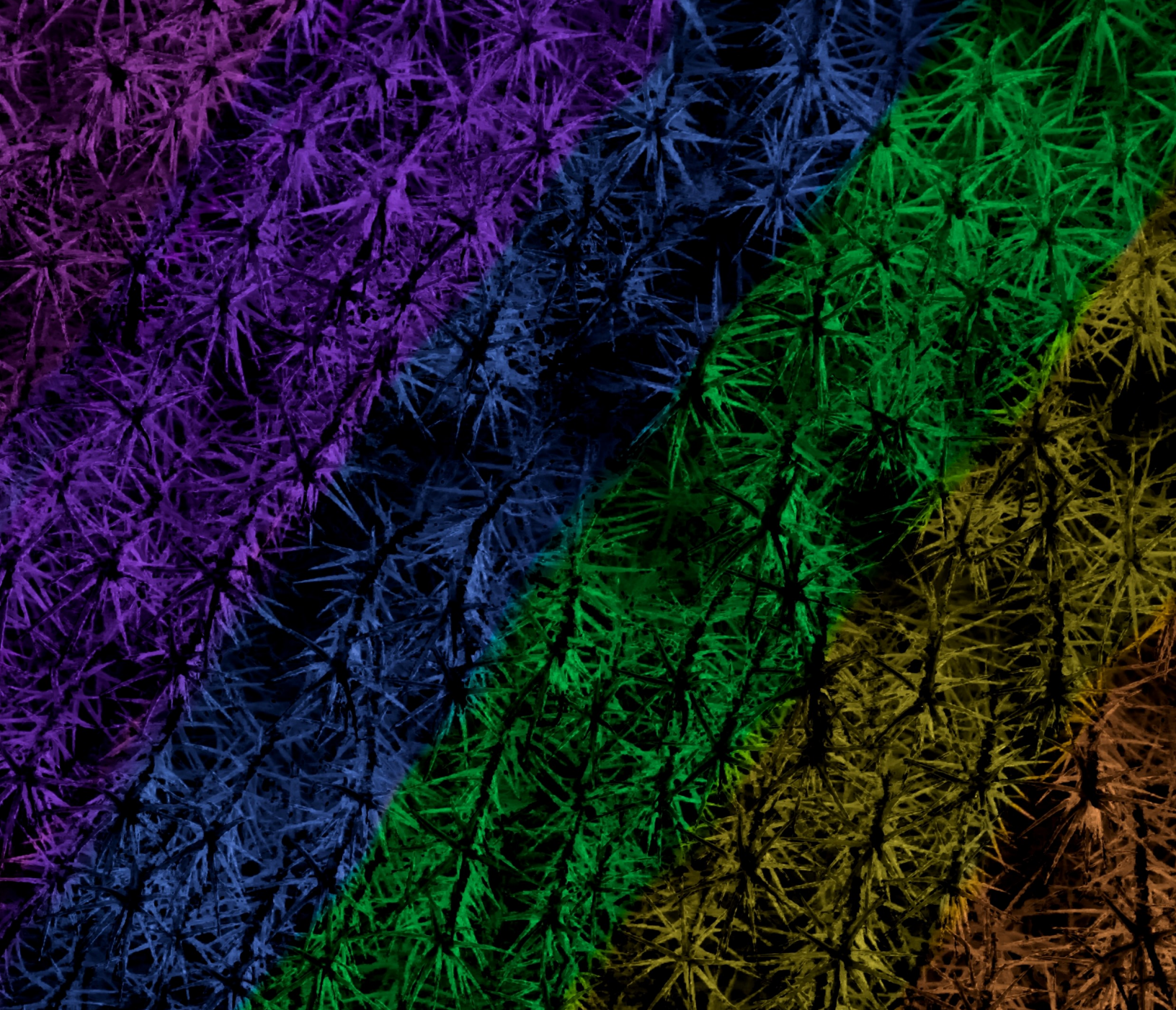


## On a lighter note



An artwork by Mr. Nikhil. He is pursuing his masters at ISP.





International School of Photonics  
Cochin University of Science and Technology  
South Kalamassery | Ernakulam | Kerala | India  
682022.

Phone. 91-0484-2575848  
Fax. 91-0484-2576714  
e-mail. [info@photonics.cusat.edu](mailto:info@photonics.cusat.edu)  
Website. [www.photonics.cusat.edu](http://www.photonics.cusat.edu)

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