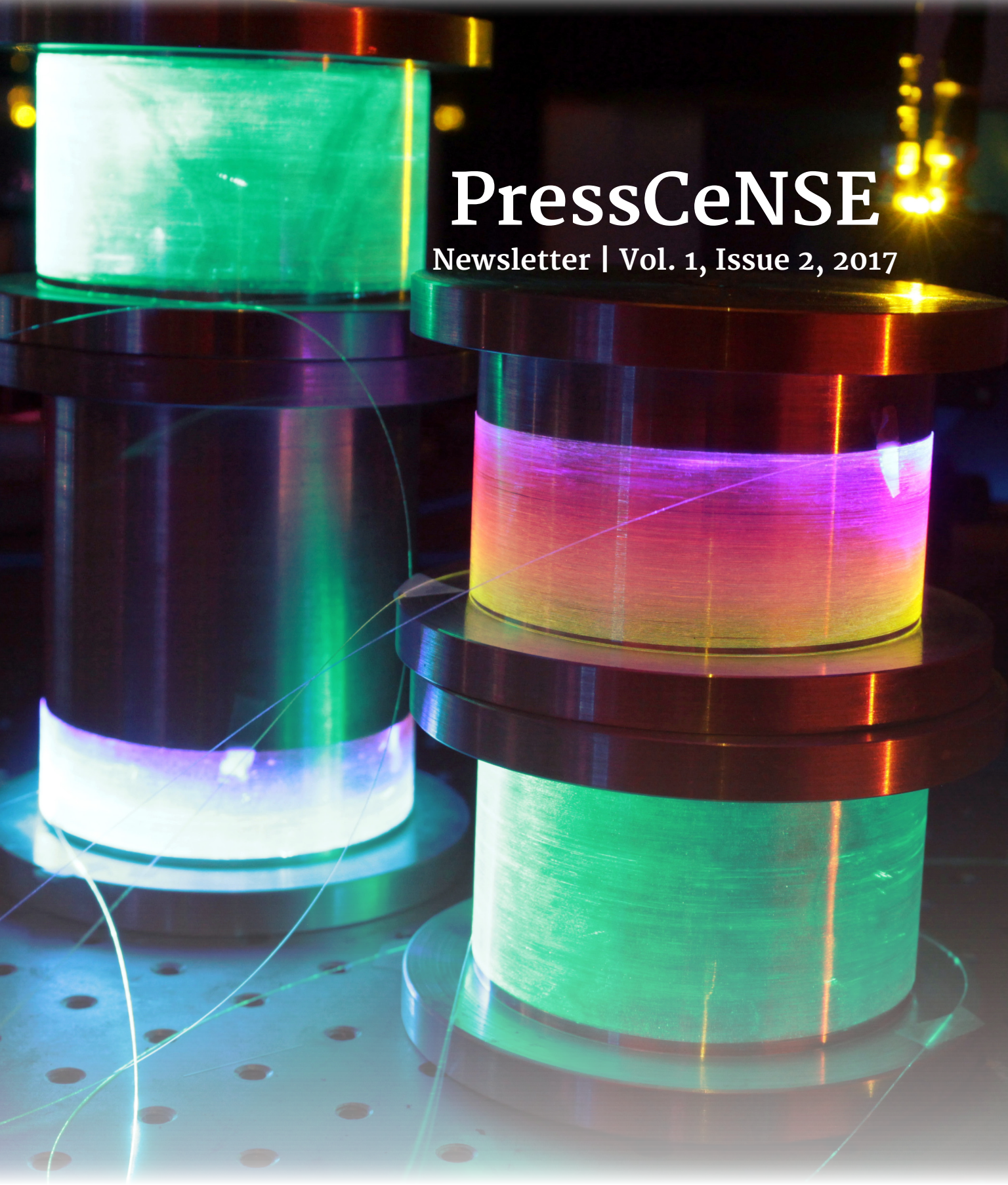

PressCeNSE

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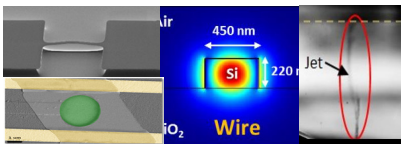
Centre for Nano Science and Engineering (CeNSE)

Indian Institute of Science

CONTENTS

What's new in research at CeNSE 

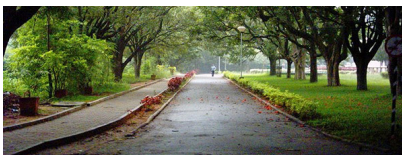
3

Visit by HRD Minister Javadekar 
9

Impressions from International Conferences 
11

Words from Graduating Students 
13

NSNST 2017 
15

An Ode to IISc 
16

CeNSE Open Day 2017 
17

Cover photo: "Raman Rainbow" by Arun S

What's new in research at CeNSE

MEMS/MOEMS LAB

Prof. Rudra Pratap

Residual stress in MEMS structures is a common occurrence and is usually undesirable especially when it is compressive. Presence of compressive residual stress beyond a critical value leads to the buckling of suspended fixed-fixed MEMS beams. While theoretical studies on the vibrational behaviour of these buckled structures exist in the literature, very few experimental investigations on such micromechanical structures have been reported. Recently, we have been trying to explore various ways of exploiting the dynamic characteristics of fixed-fixed buckled beams. So far our efforts have been to measure the natural frequencies of these released structures one of which is shown in Figure 1. These structures are fabricated from amorphous silicon carbide thin films deposited by PECVD. Laser Doppler vibrometry has been used for dynamic characterization of these structures under atmospheric conditions. Figure 2 shows a non-dimensional plot of frequency against axial load for the first four modes of vibration. For the measured data, the average values along with the standard deviation are plotted for each beam. Measured values are seen to match well with the estimated values computed from exact analytical formulations. The most important observation from these measurements is that the odd (1st and 3rd) mode frequencies vary with the axial load, whereas the even (2nd and 4th) mode frequencies remain unaffected. Based on these observations we propose to exploit them for potential sensing applications where the transduction mechanism involves change in the residual stress in the beam. An example of such mechanism is the case where, the beam is coated with an adsorbent material which swells due to absorption of the target analyte and induces compressive stress in the process. This will result in an application of chemical sensing. In such applications, the ability to control sensitivity will make the technique more versatile. In Figure 2 sensitivities for odd modes are shown as dotted lines. These findings will enable device designs with desirable sensitivity. The invariance of even modes can be used for applications where there is a need for stable resonance against stress causing parameters, e.g., temperature change.

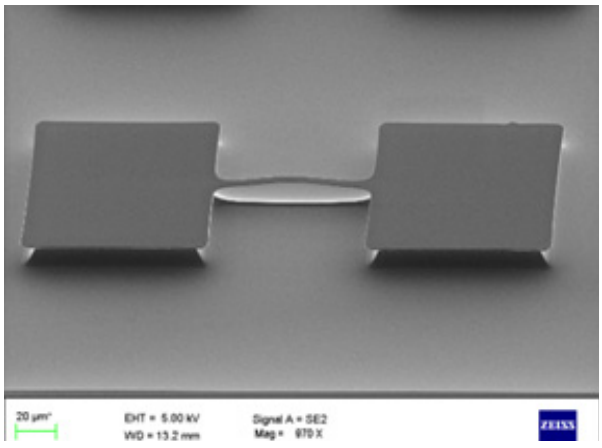


Figure 1: The SEM image of a buckled SiC beam

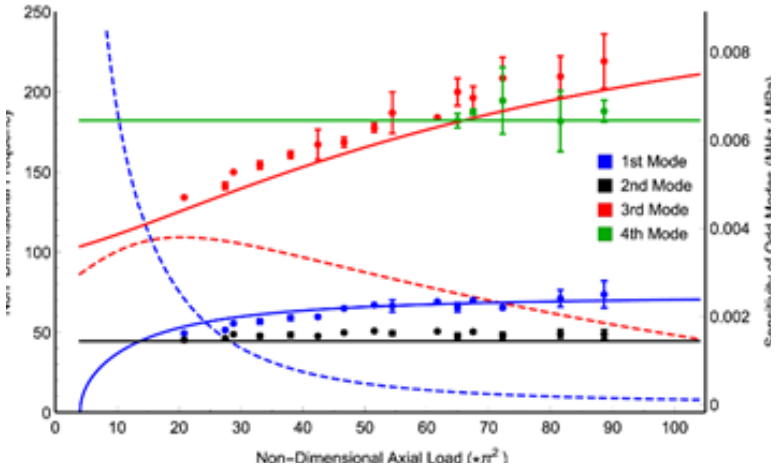


Figure 2: Non-Dimensional plot of estimated (solid-lines) and measured (points) frequency along with sensitivity of odd mode (1st and 3rd) frequencies (dashed-lines) against axial load

Photonics Research Lab

Prof. Shankar Kumar Selvaraja

Integrated photonics is an excellent platform for sensing application. It provides exemplary advantages of being compact, scalable, highly sensitive and selective to realise on-chip fluid and gas sensing. All optical sensing techniques require maximum light-matter interaction. In an on-chip optical sensing, the interaction of the analyte with the evanescent field of the waveguide results in a change in the spectral response of the sensing device. Since the sensitivity relies on the light-analyte interaction cross-section, it is essential to increase it to achieve maximum sensitivity. A potential candidate to increase the interaction cross-section is a slot waveguide. Unlike in traditional planar waveguides, for a slot waveguide, the light is confined in a 100 nm gap of low-index medium flanked by high-refractive index rails. One of the challenges in using such a waveguide system is excitation of the fundamental slot mode. Due to the large difference in the mode shape and propagation constant, coupling light into a slot waveguide is extremely challenging and thus, significantly limits the device performance.

To address the coupling challenge, we have designed and demonstrated a novel coupling scheme. The proposed scheme has a high-coupling efficiency (99%) and highly tolerant to volume fabrication (<3%). Furthermore, one can also tune the coupling device to compensate for fabrication imperfections. To demonstrate the scheme, the proposed coupler with test device was fabricated at National Nanofabrication Center (NNfC), CeNSE. Optical and Thermo-Optic measurements were performed to validate and verify the excitation of fundamental slot mode. The proposed coupling scheme is protected through an Indian Patent application.

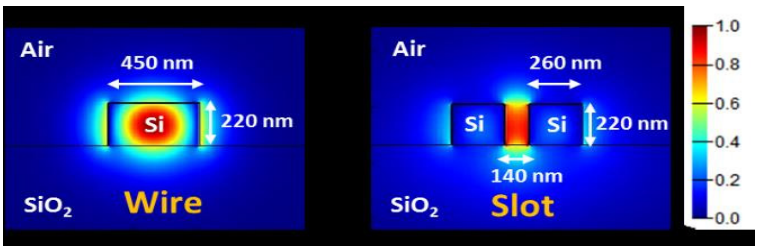


Figure 1: Simulated Electric field of the propagating fundamental mode in a Wire and Slot waveguide

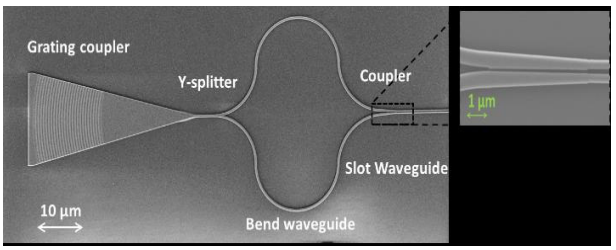


Figure 2: Scanning Electron Microscope image of a fabricated circuit with grating coupler and slot mode coupler

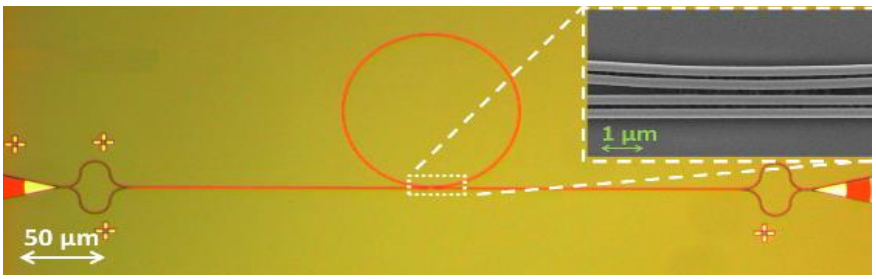


Figure 3: Optical microscope image of a slotted ring resonator with input and output coupler. The inset shows the SEM image of the ring-bus coupling

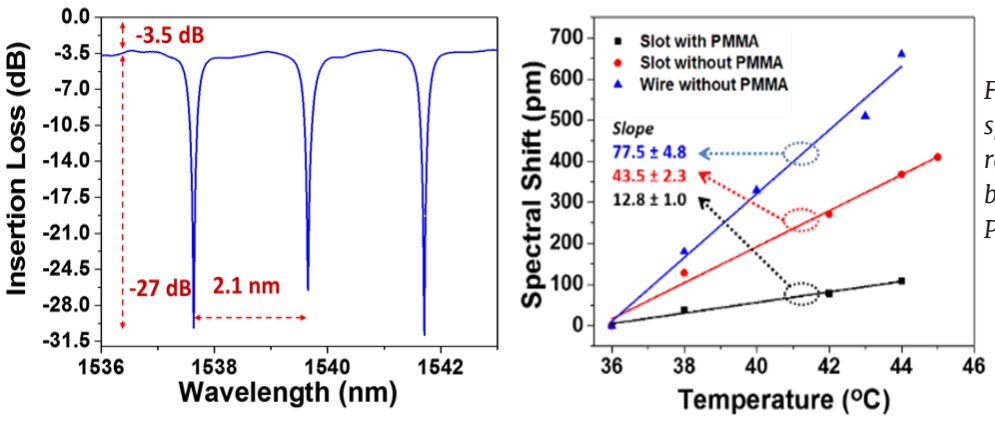


Figure 4: (left) Transmission spectral response of a slotted ring resonator and (right) athermal behaviour of the slotted-ring with PMMA coating.

Micro and Nano Sensors Lab

Prof. Akshay Naik

Nanoelectromechanical systems (NEMS) based on two dimensional (2D) materials are ideal for sensing applications. Two dimensional materials like molybdenum disulphide (MoS2) being atomically thin are extremely sensitive to external stimuli. The bottleneck with such resonators is their low quality factor (Q) typically around 100 at room temperature. Our lab has recently demonstrated the ability to manipulate the vibrations of a drum of nanometre scale thickness – a million times smaller than that of human hair. We utilize degenerate parametric amplification to amplify the motion and enhance the signal and quality factor. This is achieved by employing a pump to modulate the spring constant of the resonator at twice the resonant frequency. We observe drastic improvement in the quality factor and a gain of 10 dB is obtained in the mechanical response of MoS2 based resonators. An enhanced quality factor improves various parameters such as force sensitivity, displacement and mass resolution. This demonstration of amplification at room temperature is important for exploiting these devices for sensing applications.

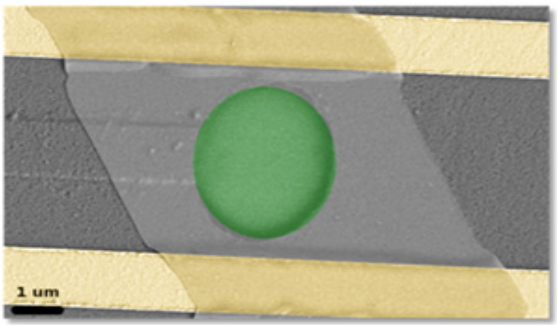


Figure 1: False colored scanning electron micrograph of MoS2 drum resonator

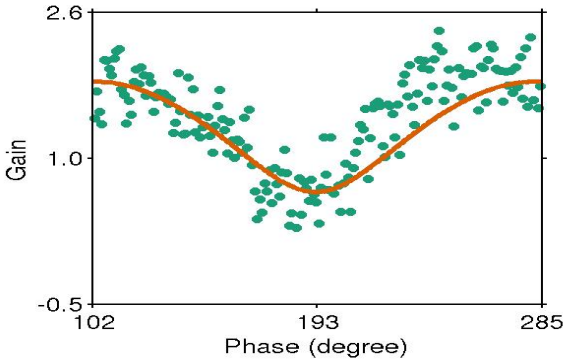


Figure 2: Variation of gain with phase

Heterojunction Lab

Prof. Sushobhan Avasthi

There is widespread interest in integrating III-V materials on silicon. Unfortunately, there is a large disparity between the interatomic spacing of Silicon(Si) and that of Gallium Arsenide(GaAs), which is technologically one of the most important III-V semiconductors today. This "lattice mismatch" leads to a very high density of defects in the GaAs when grown on Si. While it has a large mismatch with Si, GaAs is lattice matched to Germanium(Ge) (only ~1% mismatch). So, high-quality GaAs active layers can be integrated on Si if a buffer layer of crystalline Ge is introduced between GaAs and Si. This approach is challenging because Ge is not lattice matched to silicon (~4% mismatch), and Ge films grown on Si are typically very defective. Some Ge-on-Si growth techniques have been reported but they typically use complicated stacks grown using MBE, which may not be practical for commercial CMOS fabrication. Recently, the Heterojunction Lab successfully demonstrated a one-step method to grow epitaxial Ge (100) on Si (100) wafers using liquid-phase epitaxy (LPE). LPE involves melting amorphous Ge films followed by subsequent cooling. As the Ge melt precipitates on top of silicon, it gets oriented with the underlying Si lattice. This is advantageous because such an approach can be scaled to large areas which translates to high throughput and lower cost, unlike the techniques that are currently known. The remarkable feat was achieved by carefully preparing the growth surface, maintaining purity of the gases & precise temperature control.

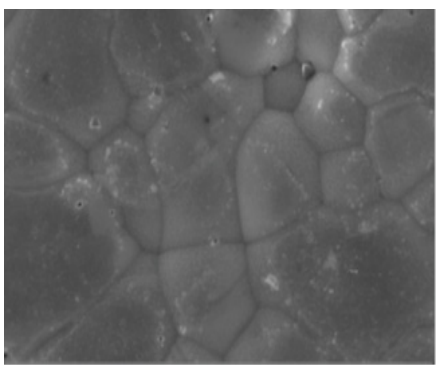


Figure : SEM of recrystallized Ge on Si (100) wafers

Microfluidics Lab

Prof. Prosenjit Sen

Generation of monodisperse micro-droplets is of significant interest for many applications including lab-on-chip, aerosol formation, micro/nanoparticle creation etc. Electro-hydrodynamic jetting (electrospraying), a well-known technique for polar and conductive liquids uses high voltages in the order of several kV and requires bulky setup for continuous fluid supply. Here we report a new jetting phenomenon that is capable of generation and transfer of sub-picoliter droplets. The device configuration is similar to coplanar electrowetting on dielectric (EWOD), with the water droplet sitting in the gap between a pair of electrodes. A 6µm SU8 serves as the dielectric, isolating the droplet from the electrodes. High speed imaging at 6000 fps was used to capture the jetting phenomena. When 460Vac (50kHz) was applied to the coplanar electrodes the droplet spread due to Dielectrophoresis(DEP). When DC bias was applied to the top-plate, placed 3mm above the DEP substrate, a jet was observed implying the micro-droplets were charged. The proposed technique is suitable for integration with EWOD platforms with minimal design modifications. Changing the DC bias on the top-plate allows control over generation and trapping. To measure size, the micro-droplets were collected on oil covered substrate which prevented evaporation and coalescence (Figure 3). 240 droplets were randomly selected and measured manually over imaged area of 0.48×0.34mm2. We observed that the mean droplet size increased from 5µm to 7.1µm with increasing top-plate bias voltage. A minimum relative standard deviation (RSD) of 0.24 means a reasonably good monodispersity. Droplet velocity in the jet also increased linearly with increasing DC field, providing a method to control the impact dynamics on the top-plate which is important for applications like printing, pattern transfer, etc.

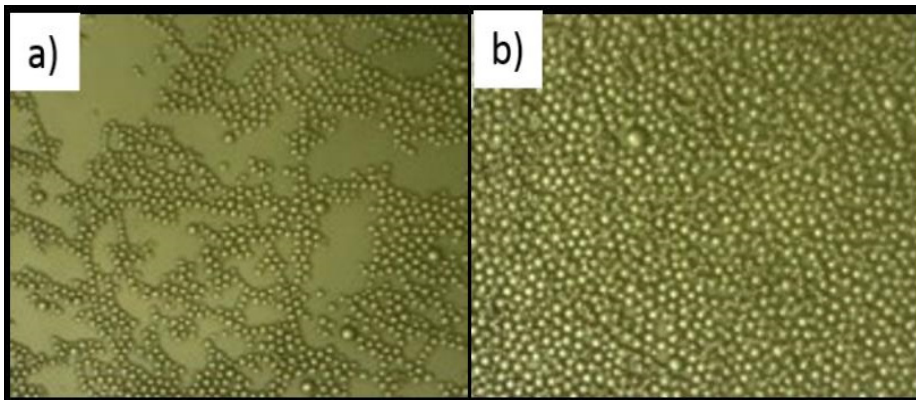


Figure 1: Water droplets captured on oil coated top plate by varying the DC volatges a) -250V b)-1kV

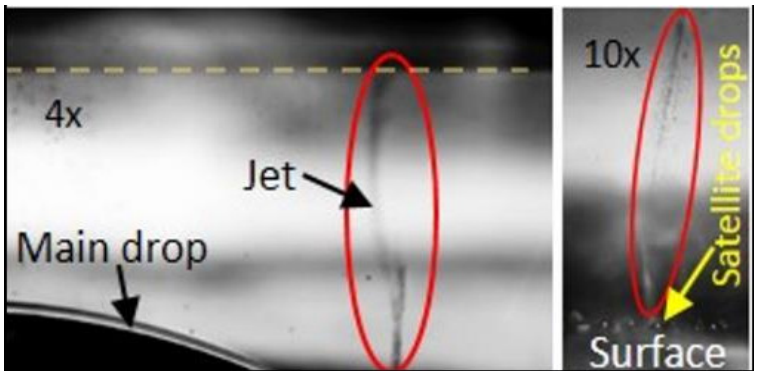


Figure 2: Jetting phenomena captured at 4x and 10x

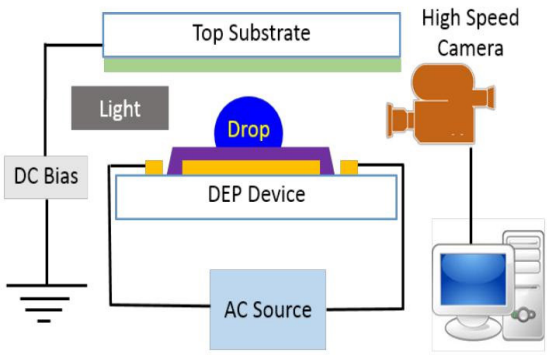


Figure 3: Schematic of the experimental setup

Deep UV Optoelectronics

Prof. Digbijoy N. Nath, Prof. R. Muralidharan and Prof. Srinivasan Raghavan

Deep UV (DUV) photodetectors (PD) operating in the solar blind regime of the electromagnetic spectrum (230-290 nm) find a wide range of strategic, astronomy-related as well as commercial applications including flame and bio-medical sensors, emitter calibration and machine inspection. III-nitrides offer several advantages over conventional Si-based UV-detectors, photomultiplier tubes (PMT) and Multiple Channel Plate (MCP) owing to their superior material and electrical properties such as tunable direct wide band gap, radiation-resistance and intrinsic solar blind nature. This eliminates the need for filters and operational complexities and thereby enables light-weight and compact DUV detectors at room temperature with higher quantum efficiencies.

These deep-UV photodetectors can be realised using thin films (~500 nm thick) of Aluminium Gallium Nitride (AlxGa1-xN), with x > 0.45. Due to the lack of economically viable native substrates, the growth (deposition) of these films relies on relatively cheap substrates such as sapphire, silicon carbide and silicon. Sapphire is the most preferred substrate for deep-UV optoelectronics owing to its wide band gap and hence, transparency to DUV radiations. Due to deposition on non-native substrates, these films notoriously possess a high density (~108-1010 cm-2) of atomic-scale defects called dislocations which are detrimental for performance of optoelectronic devices. Controlling these defects is extremely important and has been one of the major bottlenecks in commercialization of DUV optoelectronic devices. A high-performance DUV photodetector is expected to possess a high spectral responsivity (A/W), low background noise (dark current) and a high selectivity (DUV to visible rejection ratio).

In this work, lateral photodetectors with interdigitated metal-semiconductor-metal (MSM) geometry were fabricated on AlGaN thin-films grown on sapphire using Metal Organic Chemical Vapor Deposition (MOCVD) housed at National Nanofabrication Centre (NNfC), CeNSE. Detectors with a very high spectral responsivity of 1.5 A/W (at 5 V applied bias) have been demonstrated, which is highest amongst detectors operating at this wavelength. The high responsivity values are attributed to an internal gain mechanism owing to which these PD exhibited external quantum efficiencies well-exceeding 100%.

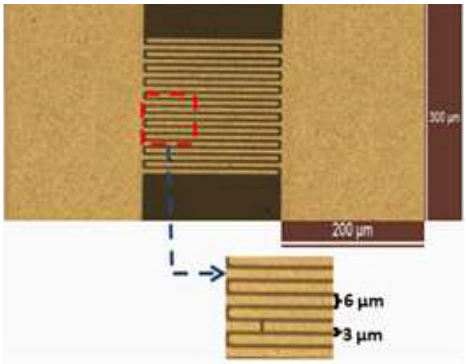


Figure 1: Optical micrograph of the fabricated MSM photodetector

The device performance parameters viz. detector gain and dark current were found to have a significant dependence on the crystalline quality in these AlGaN thin-films, especially the dislocation density. By improving the dislocation density in the AlGaN thin films by 100-times, a billion-fold reduction in dark current from mA (10-3 A) to pA (10-12) could be obtained.

Reference: S. Rathkanthiwar et. al, "Gain mechanism and carrier transport in high responsivity AlGaN-based solar blind metal semiconductor metal photodetectors", J. Appl. Phys. 121, 164502 (2017)

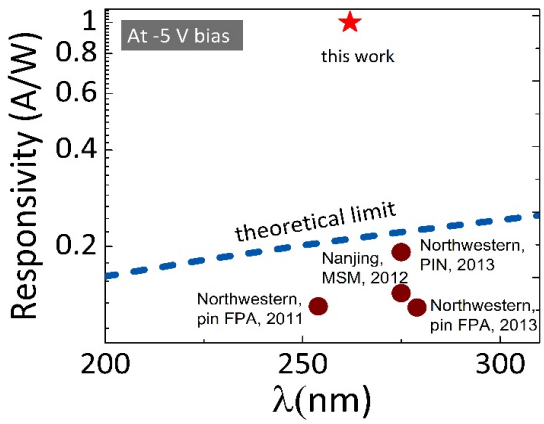


Figure 2: Comparative overview of spectral responsivity value for this work with those reported in literature

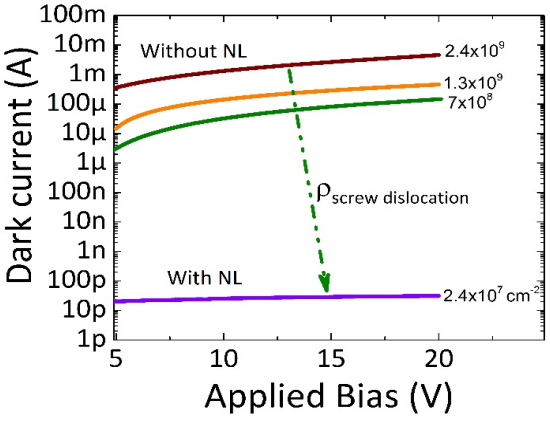


Figure 3: Billion-fold dark current reduction through crystal quality optimisation

Nonlinear Photonics and High Power Lasers Group

Prof. V.R. Supradeepa

Raman fiber lasers offer wavelength diversity as the Raman gain is available at any arbitrary wavelength within the transmission spectrum of silica optical fiber. Besides, they also enable power scaling, which is otherwise not possible with conventional rare-earth doped fiber laser sources at 1.5 µm. Conventionally, Raman fiber laser consists of a high power Ytterbium (Yb) fiber laser as a pump source and a cascaded Raman conversion module which performs wavelength conversion to the required output wavelength through a series of Raman Stokes shifts. In such systems, the input pump wavelength and the output laser wavelengths are decided by the fixed wavelength fiber gratings used in the module. Therefore, they inherently lack wavelength flexibility even though Raman gain is available at arbitrary wavelengths.

Here we report on a continuously tunable, high power, cascaded Raman fiber laser from 1440 nm to 1520 nm having a cascaded Raman conversion module which is color blind to the input pump wavelength. Such a cascaded Raman conversion module does not contain any wavelength selective fiber Bragg gratings therefore; it naturally provides wavelength flexibility, where, by just varying the input pump wavelength, the corresponding output wavelength varies accordingly. We use a high power, continuously tunable Yb doped fiber laser from 1060 to 1100 nm as a pump source. In addition to wavelength tuning, our cascaded Raman conversion module provides power scaling by terminating the cascading of Raman conversion process which is not present in earlier reports. We have achieved more than 30 W over a continuous tuning range of 60 nm from 1450 to 1510 nm and more than 20 W over a continuous tuning range of 80 nm from 1440 to 1520 nm. The powers achieved so far have been the highest for tunable cascaded Raman fiber lasers at the wavelengths mentioned above.

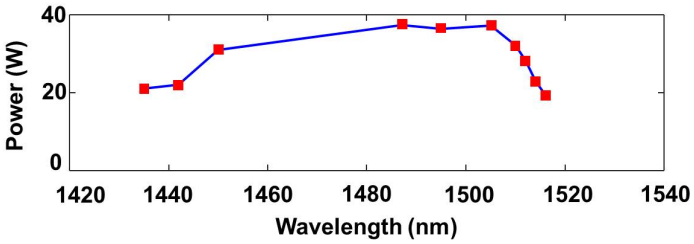


Figure 1: Output power vs wavelength

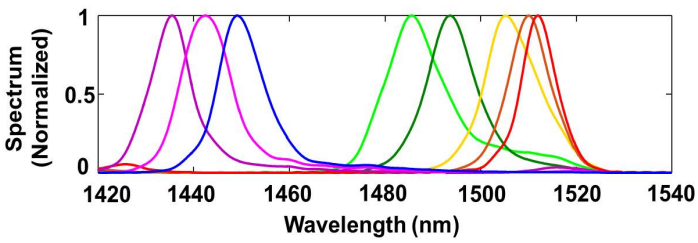


Figure 2: Wavelength tuning spectrum

Optics, Nanostructures and Quantum Fluids Lab

Prof. Ambarish Ghosh

Micron sized robotic systems designed for medical applications have been fabricated and experimented with for a decade now. However, moving them inside real tissues and organs is a huge challenge for the microrobotics community. We are making path-breaking progress in this regard. Recent work done in our lab shows how magnetic nano-swimmers move inside cells. This technique can map the spatial heterogeneity at micron scale in a crowded media. Our lab is also making progress towards trying to target cancer cells embedded in a tissue-like environment. The main challenge in trying to move propellers in dense tissue-like environment is the highly charged nature of the tissue accompanied with increased viscosity and heterogeneity at a scale of few hundred nanometers. As collagen fibres in tissue serve as a selective barrier for pathogens and beneficial agents alike, propellers have a hard time navigating this harsh environment. We are looking into novel methods to circumvent this barrier by chemical and physical methods alike. There are a few promising leads in this regards.

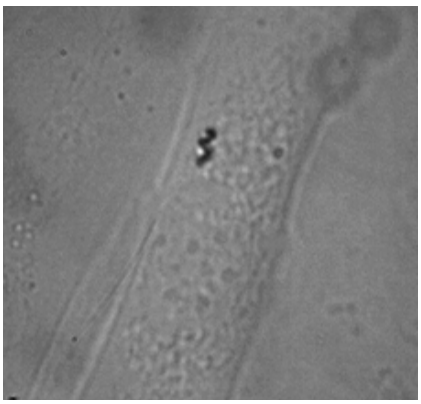


Figure: Propeller inside a cell being manoeuvred by an externally applied magnetic field

Visit By HRD Minister Javadekar

It was a moment of pride for all of us at CeNSE when Honbl. Union Minister of Human Resource and Development, Shri Prakash Javadekar visited our centre on July 1, 2017. He was welcomed by Prof. Anurag Kumar, Director, IISc., Prof. Navakant Bhat, Chairperson, CeNSE and other faculty members.

Union Minister Shri Prakash Javadekar being welcomed by Prof Anurag Kumar, Director, IISc. and Prof. Navakant Bhat, Chairperson, CeNSE

The faculty members introduced Shri Javadekar to the state-of-the art fabrication facilities at the National Nano Fabrication Centre (NNfC). The research students and faculty members also set up several demonstrations to showcase some of the active research work being conducted at the centre as well as couple of start-ups that have incubated from the centre. Following this, faculty members shared with him the interdisciplinary research work being carried out across varying domains the Centre.

Faculty members giving Shri Javadekar a tour of the National Nano Fabrication Centre (NNfC)

The Minister shared his vision of a developed, prosperous India which could be achieved through innovation in science and technology. He mentioned that he reveres IISc as a temple for science, technology and innovation and was overwhelmed with the interaction he had with the students and faculty members at the Centre. He was amazed to witness the cultural and scientific diversity within the CeNSE family and expressed his gratitude towards the faculty members who have dedicated themselves to research in India despite other prospects abroad and the family members of the students for motivating them to pursue a career in research.

Interaction with the faculty members and research students at CeNSE

The main highlight of Shri Javadekar's visit was his interaction with the students and research staff at the centre. The minister was enthralled to know about the innovative projects CeNSE students were working on, some of which included drug-delivery in the blood-stream using nano-robots, portable and affordable lab-on-a-chip devices, GaN-based power transistors for miniaturized AC to DC convertors, ultraviolet (UV) photodetectors for UV-astronomy and UV-LEDs for point-of-use water purification. The interaction with students reflected the zeal of the "Make in India" initiative and highlighted how these research projects can help meet real world challenges.

Shri Javadekar emphasized the importance of passion and sustained scientific efforts to leap-frog as a world leader in technology, science and innovation and also iterated the importance of research-industry collaboration to achieve this goal.

He very rightly mentioned that if the legacies of Nalanda and Takshashila had continued, India would have been leading the world in terms of education. It was a proud moment for all of us when Shri Javadekar shared that his interaction with student researchers at the centre has given him the much-needed confidence that institutes such as Indian Institute of Science have the power to transform India into a world leader in science and technology yet again.

He shared with the audience that the Government of India is working towards setting up 20 world-class research institutes on the lines of the IISc in the next two decades and assured that there would be no dearth of projects or funding for research and innovation and no bright minded student would have to look for opportunities outside India. He also mentioned how the Goods and Services Tax (GST) would improve government treasury and would ensure that more funds are available for health, education, research and innovation.

The event culminated with the presentation of a souvenir fabricated at NNfC, CeNSE which had the CeNSE logo as well as Shri Javadekar's photo and name etched on a Silicon wafer.

Prof. Anurag Kumar presenting the souvenir fabricated at NNfC, CeNSE

Impressions From International Conferences

Conferences are a great way to get acquainted with and to explore the forefront of research being conducted in a particular field. They not only provide us with new perspectives and ideas, but also allow us to make new contacts and forge new collaborations. However a lot more can come out of conferences. Top conferences don't just offer tutorials, lectures, posters and networking opportunities; they also offer new experiences - of foods, festivals, sights, scenes and a whole lot of cultural immersion. Indeed, many conferences are organized with this in mind: in places that are tourist destinations in their own right or are close to tourist destinations.

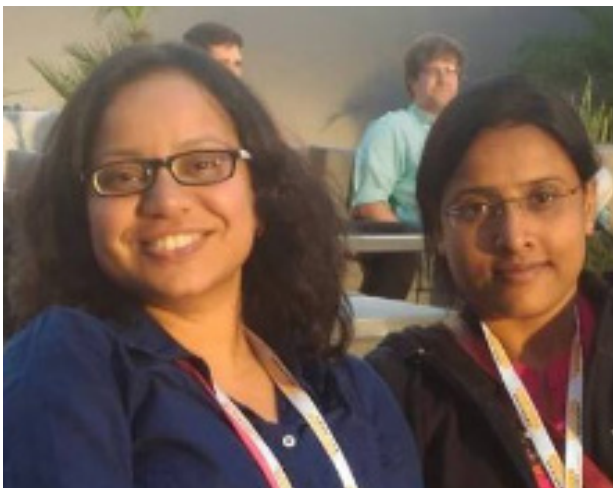
Many students from CeNSE have attended and presented at multiple international conferences in the past few months. Here we have compiled some accounts of the 'first-time' experiences during these conferences.

Pramod, Khushboo, and Arun attended the 2017 Spring Meeting of Materials Research Society in Phoenix, AZ, USA. Saloni attended the Photovoltaics Specialist Conference (PVSC) in Washington DC, USA. Arun and Balaswamy attended CLEO-Europe conference in Munich in June 2017.

Pramod

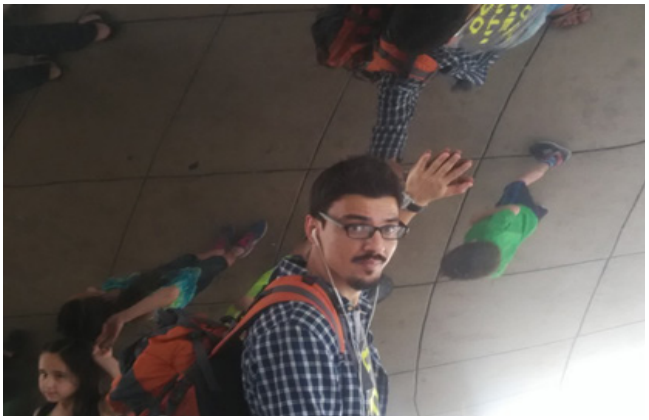
Typically when a grad student attends a conference it will either be to present a poster, deliver a talk or to attend different symposia, which makes my experience during the 2017 Spring Meeting of the Materials Research Society (MRS) unusual. I was a symposium assistant during the conference and I was responsible for ensuring that the projectors and display systems were working, a laser pointer was in place and the speakers were all present. The last session of one of the symposia on the last day of the conference saw a decently strong attendance. When the clock struck two, the first talk was supposed to start – and the first speaker was present and ready to begin. Now, typically, a session chair introduces the speakers before they take the stage but the session chairs were nowhere to be seen! After a short delay and much commotion involving the conference organizers, I, being the only person 'in-charge', was asked to chair the session. What ensued was a smooth session with many a mis-pronounced middle-eastern name.

Khushboo



Right from landing in San Franscisco, traveling abroad to attend the 2017 MRS Spring Meeting was a great experience. I was surprised by how sparsely populated the city of Phoenix was – with mostly empty roads and very few people. I was however surprised by the buskers on the streets, something that we don't really find here in India. I liked the culture of downtown Phoenix Ambassadors – who helped us find our way around the city. The conference venue was impressive and I could interact with students from other countries, where I discovered how similar we are in how we work. It was also interesting to meet Indians studying abroad. What was difficult for me to adapt to was the Food. While it was generally hard to find vegetarian food, the whole idea of fast food is also very different compared to what we have here, which was the main reason why I was very happy to land at home in India two weeks later! I carried back with me many memories, sights from the Grand Canyon and a wealth of good experience, perspective and insight.

Arun



Having lived in Germany and having attended international conferences before, traveling abroad to attend a conference was not as new as it was to deliver my talk. Thanks to all the butterflies in my stomach which lasted all the way till the last session on the last day of the conference when I was scheduled to speak, I feel I might not have enjoyed the visit to its potential. Visiting US at a time when it was full was activism and getting to see a part of it in Chicago on Tax Day was rather interesting. I loved the stay at the Phoenix Hostel, which was full of interesting people and the management who were friendly and made me feel welcome. I, however, was left craving for Indian food after two weeks of staying abroad. At the end, what matters while engaging in such travels is that one must gain something in terms of knowledge and life experience, which I did!

Saloni

Attending PVSC 2017 in Washington D.C. was a great experience as it exposed me to the work going on internationally in my field (growth of epitaxial Germanium films). During the poster session, I got the opportunity to meet researchers from all over the world with shared research interests; Prof. Ignacio Rey-stolle Prado from Spain working on III-V semiconductors, Dr. Nikhil Jain from Alta Devices working on germanium for next generation devices, Dr. Ruitao Wen from MIT are few to mention. I was fortunate to get the Graduate Student Award where I was responsible for running the session smoothly. It gave me a chance to meet the researchers and get introduced to them during and after their talks. I also visited the iconic white house and the magnificent Washington monument. D.C. is full of old vintage houses which reminded me of the European stone-based architecture. I also got to visit the Air and Space museum which had a real spacecraft preserved from the first moon landing, among other scaled models of airplanes. I also saw the first flying balloons constructed by the Wright brothers. All in all, PVSC was a productive and also a fun experience.

Velpula Balaswamy (left) and Arun (right)

CLEO is a widely known and well-attended conference in the Photonics community and this was the first conference abroad for both of us. The conference was huge in terms of the topics covered and a number of sessions were running parallel. The conference venue itself was spread over a large area, but thanks to the CLEO mobile app, with which we could pre plan and schedule the sessions to attend.

CLEO-Europe is famous for the 'Laser Show' that is organized every time during the conference, where all leading photonics industries across the globe displayed their latest products and they also provide some very nice goodies to the people who come to their stalls .

Prof. Supradeepa also attended the conference along with us and we spent an evening with his grad school supervisor & colleagues. Other than the conference, Munich is an amazing place with a pleasant climate and fantastic food. Since the conference was organized at the right time in summer, went on a brief Euro-trip as well.

Words From Graduating Students

This year, seven M.Tech students defended their theses and eleven PhD students submitted their theses, out of which five were students who worked jointly with advisors from other departments. CeNSE celebrated the graduation of the outgoing batch on the 4th of July. Mementos and memorabilia were distributed to the students. PhD students and their advisors shared anecdotes and impressions about the time they spent working at CeNSE.

Left – The Chairperson addressing the gathering. Right – Prof. Srinivasan Raghavan awarding a memento to parents of Adithya Manjunath

This year is also memorable because the first M.Tech batch from CeNSE had their convocation ceremony on 5th July 2017. We asked Shreyash Hadke from the first M.Tech batch of CeNSE (2016) and Sam Sarkar from the current outgoing batch to recollect their experiences during their time at CeNSE.

Shreyash

To say that my overall experience at CeNSE was overwhelming would be an understatement. The two years that I spent in CeNSE as a Masters student have been the most academically rewarding ones so far – and many of the "technically smart" things that I now say have had their roots somewhere in the numerous discussions with the students and faculty in CeNSE, and in the innumerable coursework assignments. These things are probably true for all IISc students in general, but CeNSE sets itself apart, as it always does with everything – be it with the prominent curved facade of the CeNSE building, or by the subtle gestures of welcoming the incoming Masters and PhD students with a wooden pen carved with their names!

With a welcome like that, one surely felt being a part of the CeNSE family. The next few weeks strengthened that bond even further, with events such as the CeNSE Freshers day and the CeNSE sports day, in the latter of which you could see professors you had previously only seen on Google Scholar, racing against one another playing lemon spoon. The first few weeks were too good to be true, and as it turned out later, they were indeed a calm before the storm – a storm of differential equations, Gibbs free energy, electrodynamics, Schrodinger, and force and moment balances. That storm eventually led to pleasant summertime though, with the diverse but relevant coursework now helping me in my PhD research work.

Professors love experiments. Being the first batch of Masters students at CeNSE, there used to be an inside joke that we're being experimented upon. I guess I can speak for all of the Masters students when I say that we didn't mind being experimented upon, especially looking at the efforts that all the experimentalists took to make sure that the experiment goes well. It almost seemed as if they knew better what we wanted from our Masters, than we knew ourselves. The first year flew by with coursework, and the second year brought with itself the experience that I most fondly associate CeNSE with – the Masters thesis! I was a part of Vasu's and Sushobhan's research groups, and my research work was a part of the SERIIUS project, that involved a few more professors from other departments. It was quite an experience to give presentations to a group where sometimes Professors outnumbered students! Discussions with Vasu, Sushobhan, and Manish Jain were always intellectually rewarding, sometimes so much so, that you'd feel thermodynamically, electronically, and DFT-cally enlightened, respectively. Mix that with RP's frequent and often-necessary motivational talks, and you have a recipe for success.

Academic adventures apart, CeNSE was (and I am sure still is) a place where even the non-nerdy ones could just hang out. The cafeteria samosas, multiple open terraces and balconies, and the badminton court take care of that. To conclude (as academics always do) CeNSE helped me grow as a person and as a researcher, and choosing CeNSE for my Masters education is a decision that I would always look back fondly upon

Sam

Will I be able to cope with the rigourous coursework? Will I make a fool of myself in the labs? Will they realize their selection mistake and withdraw my admission offer (impostor syndrome!)? My head was buzzing with myriad such questions as I walked past the CeNSE entrance two years ago. I had been working in the industry since I completed my undergraduate degree quite a while ago. I was afraid I would be out of touch with academics. I was happy to realize that my fears were unfounded. With empathetic professors, I was able to ease into my class room routine. Regular assignments, quizzes and tests ensured that I had to stay on top of the coursework. This system (as opposed to one big hairy exam at the end of semester) was a boon because it reduced the pressure on students. If you do poorly in one test, you have more chances. I enjoyed attending many talks at different departments even though they weren't necessarily related to my research and coursework. When it came to electives, I was able to pick courses pertaining to my interests. I felt that the number of mandatory core courses was too high. It would have been great to be able to trade a few of those core courses with some other interesting courses. The research opportunity that the master's students get is splendid. My adviser allowed me to pave my own way and supported me throughout. His inputs were insightful. The only thing I didn't like was that some items took a long time to procure. Time is extremely valuable and anything we can do to reduce the wait time will be good for the students.

I recall the time when I had just started here. Someone from Prof Ambarish Ghosh's group had to teach me how to use the optical microscope and the digital Vernier Callipers. I was so green behind the ears! As I graduate now, I feel so good about the fact that I can routinely do AFM, e-beam Lithography and what not. All thanks to the CeNSE faculty and staff members.

NSNST 2017

The National Symposium on Nano Science and Technology (NSNST): A Report

The Indian Nanoelectronics Users Program (INUP) was launched in 2008, with funding from the Ministry of Electronics and Information Technology (MeitY), to make the sophisticated facilities of the Centre of Excellence for Nanoelectronics (CEN, the precursor to the present-day CeNSE) to academic researchers from around the country. Because of the unique way in which the program is administered – with funding provided directly to CeNSE, so that participants do not themselves have to seek funding – INUP has been a very successful and much-sought-after program, with thousands of researchers trained and hundreds of projects conducted with substantial output in terms of theses, publications and patents.

This success prompted MeitY and CeNSE to consider developing a program inspired by the INUP, but designed for R&D personnel in companies – new or established, entrepreneurs, and "freelancers". Such a program would "open up" the state-of-the-art infrastructure of CeNSE to ambitious technologists around the country who wish also to benefit from the start-up ecosystem of Bengaluru.

The National Symposium on Nano Science and Technology (NSNST) was organised with the motivation of bringing such non-academics to CeNSE and to prompt and enable them to make CeNSE as part of "their own laboratory". To ensure that this would happen, INUP@CeNSE partnered with India Semiconductor and Electronics Association (IESA), which has a national footprint in electronics and nanotechnology. Unlike a typical Symposium, in addition to lectures and lab tours, NSNST would include "Cluster Meetings" among participants on four different themes: Health and Wellness, Agriculture and Water, Energy, and Sensors. Ideas, possible projects, and entrepreneurial ventures in these broad domains would be discussed so that solutions to problems in these domains may begin to emerge.

The three-day Symposium began on Sunday, July 2, 2017, with well-attended Tutorial sessions on Photovoltaics, Biosensors, Photonics, MEMS conducted by members of CeNSE faculty. The Symposium was inaugurated on Monday, July 3, formally by Shri Priyank Kharge, Honourable Minister for IT, BT, and Tourism, Govt. of Karnataka. In his remarks, Shri Kharge referred to the pro-active measures being taken by the state Govt. to encourage and assist entrepreneurship in technology, both in metro Bengaluru and in Tier-2 cities. He noted that the Govt. had enunciated a start-up policy and that it was also funding Technology Business Incubators (TBI) in various domains all around the state. (Funding for TBI in Nanotechnology at CeNSE has been approved.) The Plenary Talk of the Symposium was given by Dr. R.K. Sharma, Director, Solid State Physics Laboratory, DRDO, New Delhi. Technical lectures were also delivered by Dr. Kaushik Vaidya and Dr. Suraj Rengarajan of Applied Materials, Dr. Amitava Pramanik of Unilever, and Prof. Navakanta Bhat, Chairperson, CeNSE.

Many participants put up posters that described their current project, their research results, or products they had in mind. But, it was the Cluster Meetings that turned out to be the "surprise" and the "find" of the Symposium. Two such meetings – on Health and Wellness, moderated by Prof. Navakanta Bhat, and on Agriculture and Water, moderated by Prof. Rudra Pratap, CeNSE – were held on July 3. Two others – on Energy, moderated by Prof. Sushobhan Avasthi, CeNSE, and on Sensors, moderated by Prof. M.M. Nayak and Dr. Vijay Mishra, CeNSE – were held on July 4. Each lasted about two hours and was by attended by at least 35 enthusiastic participants brimming with ideas, dreams, questions, even answers. The meetings offered opportunity for participants to make brief presentations on their ideas or plans, to seek advice, to share difficulties. Some shared their start-up experience with the would-be entrepreneurs and offered tips. Having taken a tour of the laboratories at CeNSE, they could begin to give shape to their ideas and to consider how to collaborate with CeNSE. When, at the end of the Cluster Meetings, participants were asked how many were ready to incubate a start-up at the TBI to come up at CeNSE, many hands went up! It was most pleasing and gratifying to find so many of them spend two full days to listen to one another and explore possibilities together. The prospects are indeed bright that projects and start-ups in collaboration with CeNSE will soon begin to emerge, seeding at CeNSE an "INUP analogue" for entrepreneurs and industry.

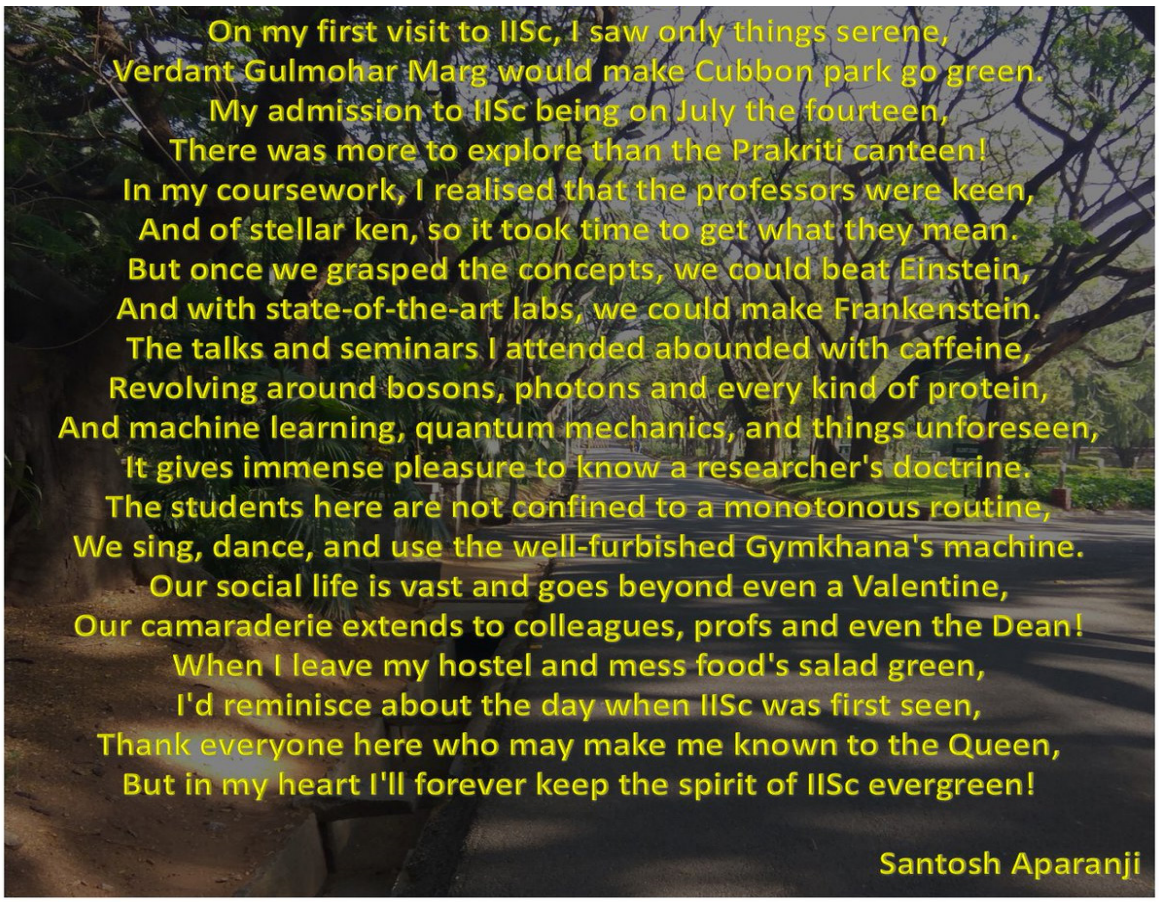
The Valedictory of NSNST was delivered by Shri Gaurav Gupta, Principal Secretary, IT & BT, GoK, who outlined the initiatives of the Govt. to further build the ecosystem in the state so that it becomes home to 20,000 start-ups soon, zooming past the current total of about 7000. All this augurs well for NSNST@CeNSE in the years to come!

Prof. Navakanta Bhat, Chairperson, CeNSE, presented a special memento fabricated in the CeNSE Clean Room to Honourable Shri Priyank Kharge, who inaugurated the Symposium

The Valedictory Address of the Symposium was delivered by Shri Gaurav Gupta, Principal Secretary, IT and BT, Govt. of Karnataka

An Ode To IISc

Santosh Aparanji, a student researcher at CeNSE won a prize in the Write-up competition organized by Student's Council, IISc



CeNSE Open Day 2017

Indian Institute of Science opens its doors every year to general public to mark the confluence of two important events; the birth anniversary of the institute's founder Sir Jamsetji Nusserwanji Tata (March 3) and National Science Day (February 28) which is celebrated to commemorate the discovery of Raman Effect by Sir C.V. Raman, the first director of the Institute.

The celebration is termed as Open Day and the day not only acts as a platform to provide the visitors a flavour of the world-class research that is carried out at the institute but also gives them an opportunity to interact with the student researchers, thus serving as a source of motivation to the budding young minds.

Each department within the institute displays a range of demos, live experiments and exhibits, unveiling the interesting scientific and technological research work carried out by the student researchers there and every year, thousands of enthusiastic visitors from across all age groups and all professional domains participate in this one-of-a-kind scientific event.

Open Day 2017 was celebrated on March 4 and students and faculty at Centre for Nano Science and Engineering (CeNSE) came together to conceive and build scientific demos that expounded the principles of various research directions they are involved in. The demos included fun activities that helped bring out the joy of exploration and science.

The visitors at CeNSE were first introduced to the world of nano-scale wherein they experienced a journey through the hierarchy of dimensions starting from a meter to an angstrom (which is 10 billion times smaller than a meter). This was brought across not only by showcasing the nano scale research conducted at the centre but also through citing structures in nature that span these dimensions. The visitors were amazed to know that research at CeNSE is carried out at dimensions 1 lakh times smaller than the average thickness of human hair.

Meter – Nanometer demonstration

After an introduction to the world of nanoscale, the visitors walked through a range of fascinating demonstrations set up by researchers at the centre wherein they experienced how research at such small dimensions can be used to realise a plethora of interesting applications. These demonstrations truly reflected the essence of CeNSE which essentially lies in the amalgamation of research encompassing different fields ranging from material sciences to electronics, chemistry to neuroscience, and biology to photonics. Some of these demos included car racing utilising solar energy, water bouncing (like a ball!) on a super hydrophobic surface and measuring one's strength using piezoelectric crystals.

One of the demos that caught the maximum attention was the thermal imager that utilised heat from one's body to capture the image. Whoever dropped by the demo got an image clicked and also received a copy over e-mail!

Kids enjoying solar-powered car race

Getting clicked through the thermal imager

Every year, Open Day provides the visitors an opportunity to take a window tour around the 25,000 sq. ft. state-of-the-art cleanroom (National Nano Fabrication Centre, NNfC) housed at CeNSE. This Open Day, over 10,000 enthusiasts got to visit NNfC and view the world class fabrication facilities. They were amazed to see how fabrication at such small scales is routinely done in NNfC and it was a moment of proud for us when a lot of young students shared with us how this visit inspired them and they expressed their desire to join this Centre as researchers. Of them, 50 visitors won the chance to wear the cleanroom gown, go inside the cleanroom and explore these facilities closely. These winners were decided by a Science and Technology Quiz conducted by the CeNSE students over multiple sessions through the day and it saw a lot of participation from visitors from across varied age groups and professional domains.

Visitors being given a tour of the CeNSE cleanroom

The highest scorer in each session won an entry into the cleanroom whereas the other good performers were awarded with a special memento fabricated in the CeNSE cleanroom. The memento, which had the logos of both IISc. and CeNSE etched onto a Silicon wafer and a thin layer of gold deposited over it, was much appreciated by everyone.

The visitors thoroughly enjoyed the exhibits and demonstrations and were enthralled to see the research work being conducted at our Centre. The day culminated with some cheerful photo sessions with the CeNSE family rejoicing a successful event.

Visitors participating in the Open Day Quiz

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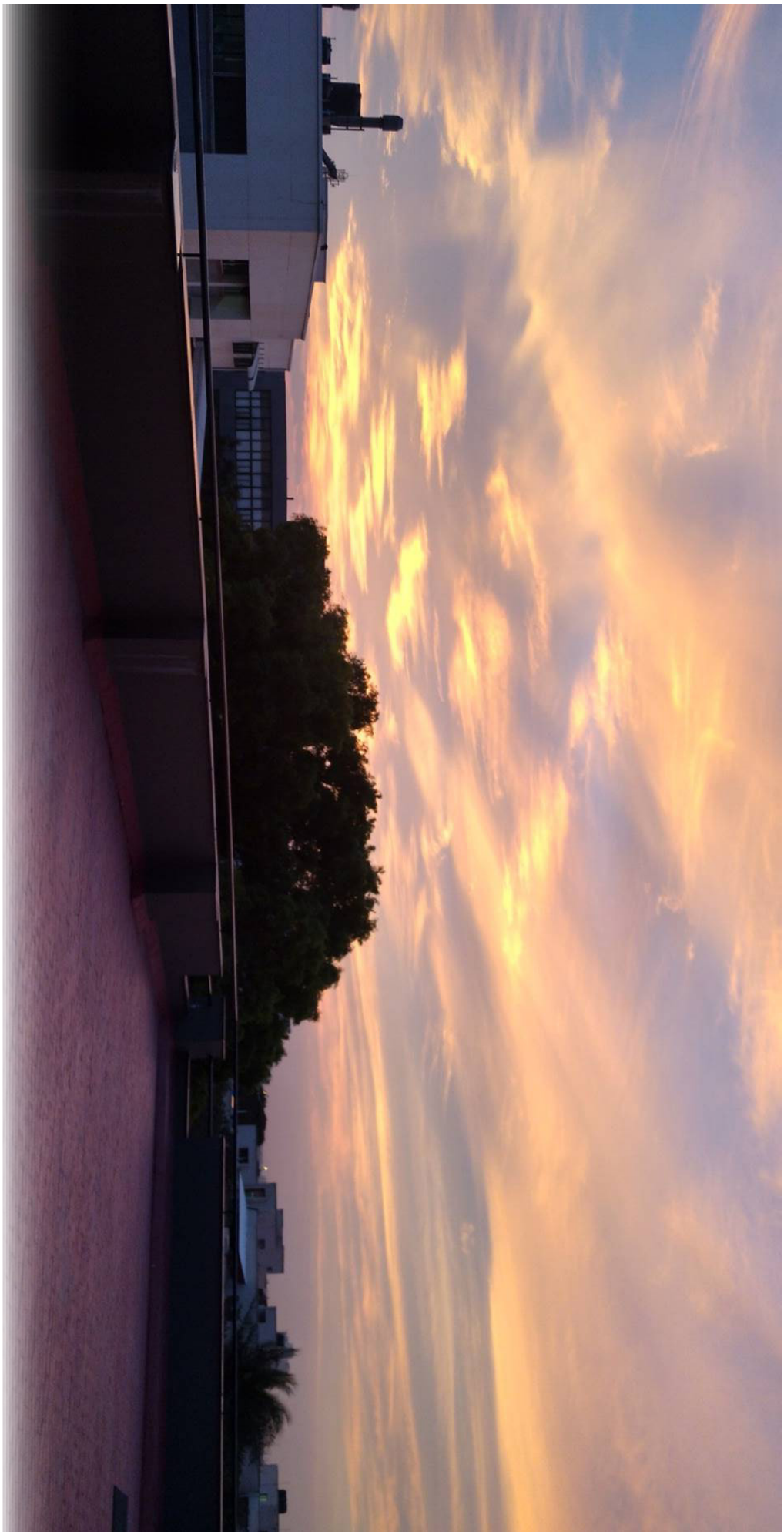

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