SATYENDRA NATH BOSE NATIONAL CENTRE FOR BASIC SCIENCES

Newsletter

Vol. 11, Issue 1 (2021)

Editorial

We are very happy to publish the online issue of the Newsletter, covering various activities during the first half of the present year 2021. Indeed it is quite reassuring that we have been able to maintain our activities during the prevailing pandemic and we deeply appreciate the great efforts made by all the contributors for sharing their interesting articles and inputs. We hope that the readers will take some delight in going through the S. N. Bose Centre's academic activities highlighted in the Newsletter. We sincerely believe we shall be able to continue with our endeavour in the coming days and look forward to making many more significant contributions in the field of basic sciences. We wish you all the best! Stay safe and healthy.

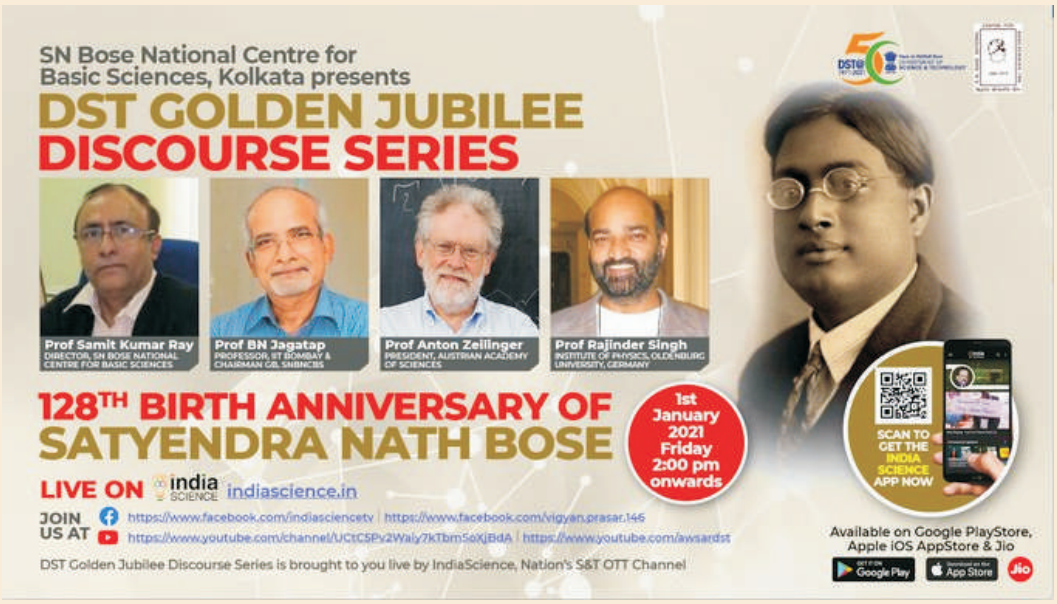
Professor Satyendra Nath Bose

News and Events (Academic)

COLLOQUIUM / NAMED LECTURES

Celebration of 128th Birth Anniversary of S. N. Bose and 25th S. N. Bose Memorial Lecture

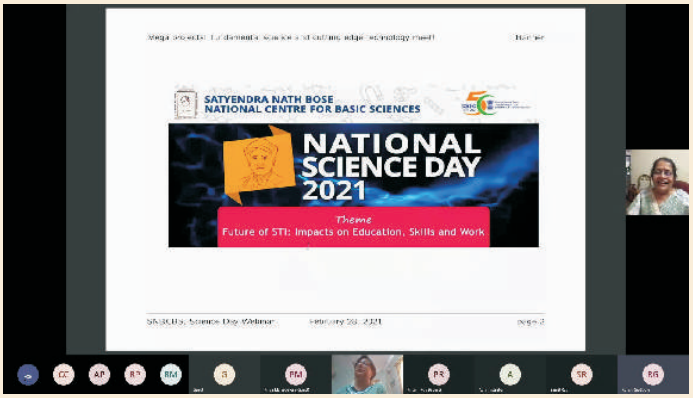
A series of lectures by eminent scientists was arranged to celebrate the 128th Birth Anniversary of S. N. Bose as well as to celebrate the Golden Jubilee of Department of Science and Technology, Govt. of India.



The 25th S. N. Bose Memorial Lecture was held through virtual platform on 1st January, 2021. The Speaker was Prof. Anton Zeilinger, Institute for Quantum Optics and Quantum Information, Vienna and President, Austrian Academy of Sciences, Austria. Prof. Zeilinger spoke on the topic *"From Einstein and Bose to quantum teleportation and beyond"*.

Celebration of National Science Day 2021

The Centre has celebrated The National Science Day 2021 held through virtual platform on 28th February, 2021 on the theme of "Future of STI - Impacts on education, skills and work". The Speaker was Prof. Rohini Godbole, Indian Institute of Science, Bengaluru, who spoke on the topic "*Mega projects: fundamental physics and cutting edge technology meet*".

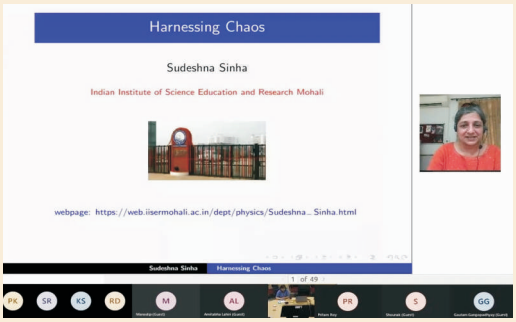


15th C. K. Majumdar Memorial Lecture

The 15th C. K. Majumdar Memorial Lecture was held through virtual platform on 15.02.2021. Prof. John Michael Kosterlitz (Nobel Laureate, 2016), Professor of Physics, Department of Physics, Brown University delivered the lecture on "*Topological defects and phase transitions*".

Bose Colloquium

1. Prof.. Sudeshna Sinha, Indian Institute of Science Education and Research, Mohali, India, delivered a lecture on 08.01.2021 on the topic "*Harnessing chaos*".



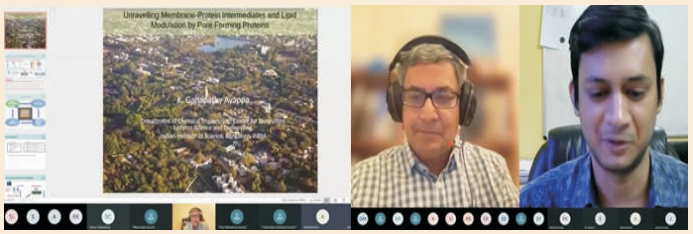
2. Prof. Abhishek Dhar, International Centre for Theoretical Sciences, Bengaluru, delivered a lecture on 12.03.2021 on the topic *"Blast in the one-dimensional cold gas: From Newton to Euler and Navier-Stokes-Fourier"*.

3. Prof. B. N. Jagatap, Indian Institute of Technology, Bombay, and Chairman, Governing Body of S. N. Bose Centre, delivered a lecture on 15.03.2021 on the topic *"Seeking convergence of science, education and society in new India"*.

Institute Colloquium

1. Dr. Bidisha Sinha, Associate Professor, Indian Institute of Science Education and Research, Kolkata, delivered a lecture on 05.03.2021 on the topic *"Spatio-temporal regulation of membrane fluctuations and mechanics in cells"*.

2. Prof. K. Ganpathy Ayappa, Indian Institute of Sciences, Bengaluru, delivered a lecture on 30.04.2021 on the topic "*Lipid modulation by pore forming toxins*".

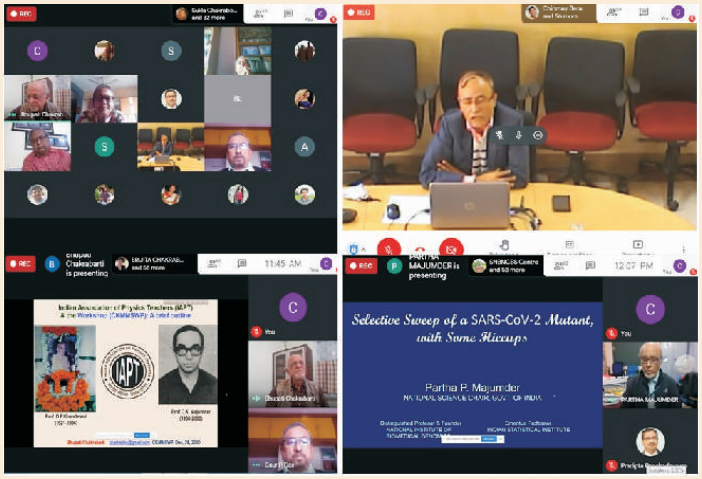


3. Prof. Sumit Mazumder, Physics Department, University of Arizona at Tucson, delivered a lecture on 06.05.2021 on the topic *"Spin ladders to nowhere"*.

CONFERENCES / WORKSHOPS / LECTURES

C. K. Majumdar Memorial Wokshop

The C. K. Memorial Workshop in physics was held at the Cenre during 28th December to 4th January, 2021.



Departmental Seminar

Dr. Debanjan Bose, Ramanujan Fellow, Department of Astrophysics and Cosmology, delivered a lecture on 19.03.2021 on the topic "*Probing high energy universe with gamma-rays and neutrinos*".

Scientific stories

The Origin of Neutrino Oscillations

Amitabha Lahiri

Neutrinos are mysterious particles. They are copiously produced in nuclear reactions in stars, they interact very weakly with everything else trillions of them pass through every human being every second without anyone noticing; a neutrino's spin always points in the opposite direction of its motion, and until a few years ago, neutrinos were believed to be exactly massless.

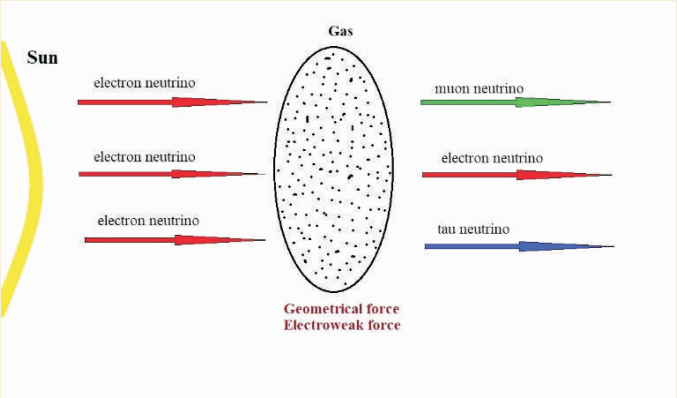
Neutrino oscillations changed this view. There are three types, or 'flavors', of neutrinos in the universe the electron, muon and tau neutrino. The Sun's energy comes from fusion reactions which also produce neutrinos, but only of the electron type. Models of the Sun relate the rate of neutrino production to luminosity, but experiments found only one third of the neutrinos (Nobel Prize 2002). The solution of this puzzle is that neutrino flavor states are superpositions of three neutrino states of definite mass, which evolve at different rates. This leads to a 'mixing' or 'oscillation' of the flavor states over the distance they travel. If the detecting instrument recognises only the electron neutrino, it appears as if only one third of all neutrinos have arrived.

The Super-Kamiokande and Sudbury experiments established beyond doubt that neutrinos do oscillate (Nobel Prize 2015). It is generally believed that this implies a breakdown, or at least an extension, of the Standard Model, because neutrinos must have non-zero and unequal masses in order to oscillate. There are different models of neutrino mass, each with its own difficulties. The question of how the neutrino gets its mass is still an open one.

But there is an alternative mechanism for neutrino oscillations that does not require neutrinos to be massive. Professor Amitabha Lahiri of SNBNCBS showed in a paper with his student Subhasish Chakrabarty that the geometry of space-time can cause neutrino oscillations even if neutrinos are massless. Einstein's theory of general relativity says that gravitation is the manifestation of space-time curvature. Neutrinos, electrons, protons and other particles which are in the category of fermions show a certain peculiarity when they move in presence of gravity space-time induces a quantum force in

addition to gravity between every two fermions. This force can depend on the spin of the particles, which causes massless neutrinos to appear massive when they pass through matter, for example the Sun's corona or the Earth's atmosphere. Something similar happens for electroweak interactions, and together with the geometrically induced mass it is enough to cause oscillation of neutrinos.

DOI: *10.1140/epjc/s10052-019-7209-2*



On-Demand Magnonic Nanochannels - A Novel Approach Towards Wave-Based Computing

Anjan Barman

Conventional electronics is composed of logic circuits having a large number of transistors interconnected by metallic wires. The data carried by electric charges suffers undesirable Joule heating, limiting its integration density. Spintronics offer to harness electron spins. Their collective precession, the so-called spin-waves or magnons, can carry information encoded in its amplitude, phase, wavelength and frequency without any physical motion of particles, eliminating unwanted energy waste and promising wave-based computing. Efficient performance of wave-based computing demands parallel processing, i.e. transfer of magnons with encoded information through parallel channels. To this end Anjan Barman and coworkers have developed electrically reconfigured parallel magnonic nanochannels using the principles of voltage controlled magnetic anisotropy. Spin-waves were efficiently transferred through these nanochannels and measured optically by Brillouin light scattering technique. The strong magnon-magnon coupling between the adjacent nanochannels opened up magnonic bandgap, which could be switched 'ON' and 'OFF' and its magnitude altered by a meagre voltage of few volts. In future these nanochannels can be engineered further to transfer specific bands of frequencies through designed parallel channels towards development of on-chip multiplexing devices.

Reference

S. Choudhury et al., Science Advances **6**, eaba5457 (2020)

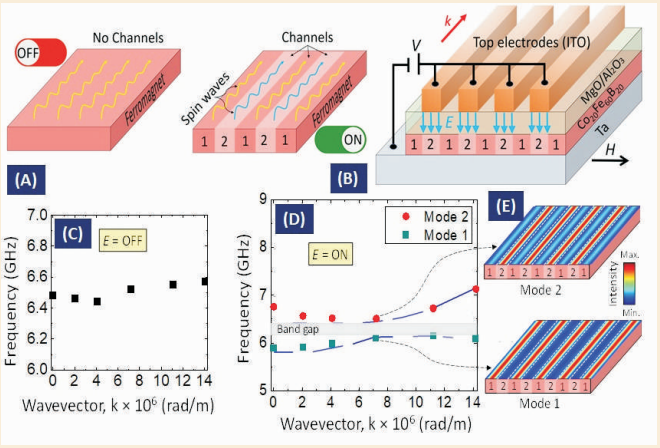


Figure: A. Schematic illustration shows the concept of spin wave nanochannels. B. Schematic illustration shows the device structure and formation of nanochannels. Spin-wave frequencies versus wavevector when electric field, *E* is OFF (C) and ON (D). E. Heatmap plots show the spatial distribution of spin-wave intensity for spin-wave mode 2 and mode 1 at wavevector $k = 7.1 \times 10^6$ rad/m.

Mars: the Red Planet Revisited

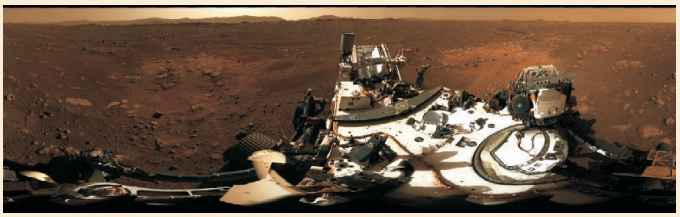
Ramkrishna Das

Even a couple of decades earlier, it was beyond imagination that planets around any other star than the Sun, could exist at all! However, the scenario changed after the first confirmation of an extra solar planet (51 Pegasi) around a Sun-like star, in 1995, by Michel Mayor and Didier Queloz. Since then the subject has become quite exciting and scientists have discovered more than seven thousand planets orbiting around other stars. Few of them are similar to our earth, though they are staying at a long distance.

But, what about life? Is there life on other worlds? Is it possible to survive on the other planets in our solar system? To answer all these questions scientists are searching the solar system for signs of life and the potency of other solar system objects to harbor life. And thus, scientists have been interested in Mars, due to its proximity and similarities to the Earth.

Scientific studies show that billions of years ago, Mars had the three critical ingredients for life: an abundance of the chemical building blocks (especially, carbon and hydrogen), liquid water on its surface and an energy source to power the chemical reactions that make life possible. Though, the Martian surface is inhospitable today, the possibility of life existing deep beneath its surface hasn't been ruled out.

After several attempts, the US Mariner 4 (1965) became the first spacecraft to reach close to Mars, and took close up pictures of the impact-cratered Martian surface during it's flyby. Since then, more than twenty successful missions have explored the red plant's atmosphere and surface, including the Mars Orbital Mission sent by the Indian Space Research Organization, in 2014. The latest Mars-bound mission is NASA's Perseverance rover, which has landed on the Martian surface on February 18, 2021. It is a small, car-sized, nuclear-powered, one ton, six wheeled Mars rover. It has landed successfully in the Jezero Crater, where, about 3.5 billion years ago there was a lake filled with water and flowing rivers. It is an ideal place to search for the residues of microbial life, test new technologies, and lay the groundwork for human exploration in near future.



First 360-degree panoramic view around the landing site, taken by NASA's Perseverance Mars rover. The picture was generated by joining 142 individual images taken on the third Martian day of the mission (Feb. 21, 2021). (Courtesy to Credits: NASA/JPL-Caltech/MSSS/ASU)

What made the latest mission more important and exciting is that it has a drone helicopter aboard, called Ingenuity, which will perform experimental flight test to become the first aircraft to fly on another planet. It is a very challenging task as the Martian atmosphere is very thin (~99% less dense than the Earth's atmosphere) to achieve sufficient lift. Further, the operators sitting on the Earth will not be able to see the helicopter and control its movement with a joystick instantly.

The rover will characterize the planet's geology and past climate, measure the atmospheric and weather properties, and be the first mission to collect Martian rock and soil, which will be picked up and brought to the Earth by a future mission. It will perform an experiment to check if oxygen could be generated out of the Martian atmosphere. The success of these experiments will pave the way for human exploration to the Red Planet. The key objectives of the mission is to investigate whether microbial life existed on Mars billions of years ago, which would be an extraordinary discovery to tell that the life is a natural feature of the universe, not just a unique aspect of the planet Earth!

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1. Martinez G. M., Newman C. N., De Vicente-Retortillo A. et al., The Modern Near-Surface Martian Climate: A Review of In-situ Meteorological Data from Viking to Curiosity. Space Science Reviews, 212, 295 (2017).

2. Ramkrishna Das, Elemental abundances in novae. Journal of Astrophysics & Astronomy, 42, 13 (2021).

Sensing versus Adaptation in Bacterial Chemotaxis

Sakuntala Chatterjee

Many organisms in nature respond to the chemical signal received from their environment by showing bodily motion. If it is a chemical which they are attracted to, for example, nutrient, or some other attractant, the organisms show a tendency to migrate towards the region where the chemical concentration is high. On the other hand, if it is a toxic chemical or some other repellant, they move towards region where this chemical is present in low concentration. Such directed motion of an organism guided by chemical signal received from its environment is known as chemotaxis.

Among all the species which show chemotaxis, E.coli bacteria have received maximum amount of attention from the researchers. E.coli uses its run-and-tumble motion to migrate towards the region with more nutrient. The reaction network inside the

cell has two main modules: sensing and adaptation. The nutrient molecules bind to the chemoreceptors present on the cell membrane and this input signal is processes by the sensing module of the network which results in modulation of the run-and-tumble motion of the cell. The adaptation module ensures that the intracellular variablesdo not deviate too far from their average values. For example, if some protein level becomes too high or too low, adaptation module uses negative feedback mechanism to restore the level to its average value.

One important aspect of signaling network of chemotaxis is the cooperativity or clustering tendencyof the chemoreceptors. This helps amplifying the input signal and as a result E.coli can respond to even very weak concentration gradient. Thus receptor clustering enhances the sensitivity of the cell.However, recent experiments have shown that receptor clustering also causes fluctuations in the signaling network. We have shown theoretically that there is an optimum size of the receptor clusters at which the cell shows the best chemotactic performance. To quantify performance we measure how fast the cell climbs up the concentration gradient, or how strongly the cell is able to localize in the nutrient-rich region. A good performance also means a strong ability of the cell to distinguish between nutrient-rich and nutrient-depleted regions in space. We find all these measures reach a peak at a specific size of the receptor clusters. We show this optimality is a result of a competition between sensing and adaptation modules of the network. As cluster size increases, sensing is enhanced which improves the chemotactic performance. But for large clusters, fluctuations also increase and adaptation comes into play. The signaling network is now controlled by adaptation module and sensing plays a less significant role. This brings down the performance.

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2. Shobhan Dev Mandal and Sakuntala Chatterjee. Effect of receptor clustering on chemotactic performance of E. coli: Sensing versus adaptation. Phys. Rev. E (Letters), 103:L030401, 2021.

Ph. D. Awarded / Submitted

Ph.D. degree awarded

1. **Ayan Bhattacharjee**, Thesis title: Spectral And Timing Properties of Black Holes and Neutron Stars in X-Ray Binaries Using the Two-Component Advective Flow Solution. Supervisor: Sandip K Chakrabarti

2. **Suchetana Goswami,** Thesis title: Quantum Correlations: Preservation and Applications. Supervisor: Archan S Majumdar

3. **Damayanti Bagchi**, Thesis title: Spectroscopic Studies on Hybrid-Materials of Medicinally Important Molecules for Enhanced Biological Activity. Supervisor: Samir Kumar Pal

4. **Mithun Pal**, Thesis title: Development of Quantum Cascade Laser (QCL)-Based Spectroscopic Techniques and their Applications in Trace Gas Analysis. Supervisor: Manik Pradhan

5. **Sandip Saha**, Thesis title: Characterization of Periodic Orbits in Open Nonlinear dynamical Systems. Supervisor: Gautam Gangopadhyay

6. **Kajal Kumbhakar**, Thesis title: Interactions and Dynamics of Cryoprotectants, Energy Materials and Other Complex Mixtures. Supervisor: Ranjit Biswas

7. **Samik Roy Moulik,** Thesis title: Synthesis and Study of Physical Property of Binary Oxide Nanostructures, Thin Film and Devices. Supervisor: Barnali Ghosh (Saha)

8. **Mahebub Alam**, Thesis title: Single and Double Perovskite Multiferroic Nanostructures with their Diverse Applications. Supervisor: Kalyan Mandal

9. **Poonam Kumari**, Thesis title: The Effect of Spin-Orbit Coupling on Electronic Structure and Magnetism in Low Dimensional Compounds. Supervisor: Priya Mahadevan

10. **Sudipta Pattanayak,** Thesis title: Ordering Kinetics, Steady State and Phase Transition in Active Particle Systems: Role of Noise and Boundary. Supervisor: Manoranjan Kumar & Shardha Mishra

11. **Anita Halder**, Thesis title: Electronic Structure of Perovskites and Related Compounds. Supervisor: Tanusri Saha Dasgupta

12. **Md Sarowar Hossain**, Thesis title: Sound Velocity and Internal Friction in Disordered Magnetic Alloys. Supervisor: Pratip Kumar Mukhopadhyay

13. **Abhishek Bagchi**, Thesis title: Development of Microactuator Systems Basrd on the Photoinduced Microactuation Effect Found in Ferromagnetic Shape Memory Alloys. Supervisor: Pratip Kumar Mukhopadhyay

14. **Soumyakanti Bose**, Thesis title: Information Theoretic Aspects of some Non-Gaussian Classical and Quantum Optical Fields. Supervisor: M Sanjay Kumar

15. **Shauri Chakrabarty**, Thesis title: Dynamics of Propagating Modes and Characterisation of Ordering in Coupled Non-equilibrium Systems. Supervisor: Sakuntala Chatterjee

16. **Pratik Tarafdar**, Thesis title: Accreting Black Hole Systems as Classical Analogue Gravity Models. Supervisor: Amitabha Lahiri & Tapas Kumar Das

17. **Subhasish Chakrabarty**, Thesis title: Field Theoretic Approach to Gravity. Supervisor: Amitabha Lahiri

Ph.D. thesis submitted

1. **Anuvab Banerjee**, Thesis title: Spectral and Timing Properties of Class Variable Source. GRS 1915+105 Using Two-Component Advective Flow Solution. Supervisor: Sandip K Chakrabarti

2. **Atanu Baksi**, Thesis title: Dynamical Aspects of Confined Media, Bulk Binary Mixtures and Other Complex Systems. Supervisor: Ranjit Biswas

3. **Juriti Rajbangshi**, Thesis title: Investigations of Multi-component Mixtures and Complex Systems with Longer-ranged Interactions. Supervisor: Ranjit Biswas

4. **Aniruddha Adhikari**, Thesis title: Studies on Therapeutic Potential of Various Nanomaterials and Ethnobotanical Ingredients in Preclinical Disease Model. Supervisor: Samir Kumar Pal

5. **Soumendra Singh**, Thesis title: Development of Spectroscopic Techniques for Potential Environmental and Biomedical Applications. Supervisor: Samir Kumar Pal

6. **Anulekha De**, Thesis title: Ultrafast Spin Dynamics in Ferromagnetic Patterned Nanostructures and Multilayers. Supervisor: Anjan Barman & Rajib Kumar Mitra

7. **Chandan Samanta**, Thesis title: Synthesis, Physical Properties and Applications of Metal Oxide Semiconductor Nanostructures and Thin Films. Supervisor: Barnali Ghosh (Saha)

8. **Monalisa Singh Roy**, Thesis title: Interactions, Correlations, and Competing Orders in Strongly Correlated One Dimensional Quantum Wires

and Quantum Gases. Supervisor: Manoranjan Kumar

9. **Debabrata Ghorai**, Thesis title: Aspects of Gauge/Gravity Duality and it's Applications. Supervisor: Sunandan Gangopadhyay & Biswajit Chakraborty

10. **Ankan Pandey**, Thesis title: Study of Dynamical Aspects of Some Class of ODEs and PDEs. Supervisor: Partha Guha

News and Events (Administrative)

Workshop on Rajbhasha

Hindi Workshop on "*Bartaman Paripreksha mey Rajbhasha Karyavayen ki Dasha & Disha*" by Shri Nirmal Kumar Dubey, Assistant Director, Rajbhasha Bibhag, Nizam Palace, Kolkata on 26.03.2021.

International Yoga Day Celebration

The Centre participated through online mode in the 7th International Day of Yoga event organized by Ministry of Ayush, Govt. of India on 21.06.2021.

A view from Indrahar Pass, Dhauladhar Range, Himalayas. Photograph by Gurudas Ghosh

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