Summary Report

About Department/Center/School: DEPARTMENT OF PHYSICS, IIT KHARAGPUR was established in 1951. The department has modern facilities like STM, MBE, Raman, XPS, XRAY, Lasers, etc and provides consultancy services to industries and other institutes. The department is deeply engaged in frontier areas of theoretical and experimental physics and technologies of new materials and optical fibres. The department runs a large number of sponsored projects on these areas.

1. Academic Programs (Range of Degrees and Disciplines):

i) Integrated M.Sc. (5 yrs) in Physics
ii) 2yr M.Sc. in Physics (Joint M.Sc.-Ph.D programme),
iii) M.Tech(Solid State Technology),
iv) Ph.D. Programme.

2. **Major 4-5 Thrust Areas of Research:**

Condensed Matter Physics, Optics & Photonics, Astrophysics, High Energy Physics, Complex Systems.

3. Curriculum and Courses & Teaching Environment

Items	**Ratio/ Number**	**Items**	**Number/%**
Teacher-student Ratio	1:59 (including 1st year UG)	Average No. of students motivated (%) to opt of careers Eng/ Tech. Sectors UG/PG/PhD	**30%**
No. of Faculty members as on today	26 and 1 joint faculty	Average No. of students motivated (%) to opt of careers in Science sectors UG/PG/PhD	**70%**
Average No. of Tutorial Assistants	60	No. of teaching labs	**09**
No. of UG/DD students	230/0	Average No. of students per experiments in core courses	**02**
No. of PG students/PhD students	15/83	No. of Students' workshops/``Tinkering'' Labs	**Nil**
Average no. of tutors with more than 100 students	Nil	No. of new courses introduced	**08**
Average Students placements (%) (UG/DD/PG)	75%	No. of New program introduced	**2 (Joint M.Sc-Ph.D & Joint M.Tch Ph.D)**
No of major curriculum review in both UG & PG level	3	Undergraduate Vs PhD strength expressed as Percentage	**37%**
No of UG lab (teaching labs) developed/set-ups	6	No of PG/research labs developed/new set up	**5**
No of E class rooms	Nil	No. of lab classes per week	**26**

Average No. of Course done per student for B. Tech/DD/M. Tech/Ph.D	4-Theory 2-labs per semester	No. of core/elective/seminar/projects subjects taken for B. Tech, DD, and M. Tech respectively	As per Curriculum

4. Research and Development & its Environment

Items	Number	Items	Number	Items	No.
Total No. of Publications in Journals (2008-13)	**500**	Average no. of citation per paper	**04**	No of large interdisciplinary research projects	**04**
Total No. of Publications in Conference & Symposium	**317**	Average Journal publication per year	**100**	Number of Int. conf./workshop attended by students	**39**
Total No of Books & e-books published	**05**	h-Index of the department since 2008/overall h-index in Scopus	**19**	No. of PDF hired in the Institute	**02**
Total No of Edited Conference Proceedings/book chapters	**04**	Number of papers with citation more that the average no. of citation of the Journals	**93**	No. of international Students as PhDs/PDFs	**00**
Total No. of Technology Developed/transferred	**Nil**	No. of recognitions & Awards, fellows etc to faculty/students (provide break up if necessary)	**02**	No. of International visiting researchers/ adjunct faculty stayed for at least a week	**12**
Total No. of Patents Filed/Obtained	**03**	Average Retention(%) of Young faculty for at least 10 years	**80%**	No. of short courses/workshops /conf. organized with international participations	**14**
Total No. of Copyright Filed/Obtained	**Nil**	No. of Sponsored research Project /fund(lakh) generated from non-internal source	**38/1428** **Lakhs**	Average No. of PhD granted per year	**10.3**
No. of Publications per Faculty/Masters/PhD students	**20/020/9**	No. of Consultancy /fund (lakh) generated from non-internal source	**06/33.38 lakhs**	Average No. of PhD Granted per year per faculty	**2.5**
No. of Publications per Faculty/Masters/PhD students in Top Ten Journals as Identified by the department	**12/01/05**	No of Internal and external Collaborations research papers/research projects/PhD students	**210/8/10**	Patent granted per faculty	**0.1**
Average No. of Citation per faculty per year	**19**	No of M. Tech students motivated into pursuing PhD/PhD graduates motivated to pursue career in Academics(abroad or IIT etc)	**40/23**	Number of articles in collaborations with Ten countries*	**52**
Ranking of the department		Ranking of the department in		No of articles of	**682**

in terms of average citations per paper within the Institute		terms of total number of Journal publications within the Institute/publications per faculty		the dept. contributing towards h-index of the Institute since 2008	

5.External Stakeholder Engagement and others

Items	Number	Amount Lakh
No. of PhD/Master students' thesis funded by Industries	Nil	Nil
Total number of Industry sponsored projects and its income (Lakh)	1.0	2.0
No. of Curriculum Development Initiative for Industries	Nil	Nil
No of Technology transfer/adopted by Industry/Labs		
No. of Nationally relevant research projects	15	600
No of Policy inputs/consultancies provided	03	
No. of Research grant and seed money from internal savings of the Institute per young faculty of the department and its total fund	02	100
No. of Community Relevant projects	Nil	Nil

6.Vision for the Future (in brief):

a. Departments/centers/schools should spell out its Mission and Vision Statements, (b) Plans for future to achieve the projected goals and (c) measures adopted towards above.

Mission: The mission of the department is to expand the knowledge in physics and closely related science and its conveyance to the students in a healthy learning environment.

Vision: The department wishes to be recognized for the distinction of its faculty, their research they and the excellent education they impart to the students. High priority will be given to the education of students from other disciplines by creating innovative curricula to match their appetite. The students will have the best instructions through the finest educational technology available and a stimulating environment in their classes.

The department made a pledge to produce physics research at the forefront of science during its inception and it is time to redeem the pledge. Physics has always been a beacon for curious minds and new ideas and we wish to emphasize and pursue a leading role in that direction.

7. External peer review of the Dept./centre/schools (in brief):

(a) Date of the peer review: ***12.03.2013***

a. Name of the Experts involved and their affiliations in short:

1. ***Prof. G.K. Mehta, Ex-Director, IUAC, New Delhi***
2. ***Prof. J.K. Bhattacharya, Director, HRI, Allahabad***
3. ***Prof. Amitava Raychaudhuri, Palit Professor, Univ. of Kolkata.***
4. ***Prof. Y.N. Mahapatra, Distinguished Professor, IIT Kanpur***

(b) Measures adopted/action taken at the department level to address the recommendations of the peer review report:

i. *Reduction of 5 credits in the final (4th Semester) of 2 yr. M.Sc. programme*
ii. *Change of Department name (Department of Physics instead of Physics & Meteorology)*
iii. *Further review of curriculum in progress*

8. **Strengths, Weaknesses, Opportunities & Threats (SWOT) Analysis of the Department**

STRENGTHS

• **The quality of students and faculty**:

We have excellent PG and UG students and a broad physics programme.

• **The quality of research and teaching**:

Steadily increasing - highlighted by the review committee in March, 2013. Our UG students get selected to PhD programmes in top places in the world and go to highly rated places for summer project.

• **Interdisciplinary research**:

We have collaborations with several other departments and Institutes in diverse areas.

WEAKNESSES

• **Student teacher ratio**:

The number of students has increased manifold over the years and the faculty strength in Physics has in fact reduced.

• **Research funding and support:**

In comparison to national labs our funding is less. To attract very bright faculty we need to improve both. Lack of space and technical support (e.g., a good workshop) for advanced laboratories, absence of a system of teaching assistants, absence of proper career guidance programme are other major weaknesses. Bringing research scholars' remunerations and benefits at par with other National institutes should help.

OPPORTUNITIES

• For the students, we open the world before them.

The level of teaching and constant contact/exchange with best places in the world, provide excellent opportunities for the student to launch their career.

• **Platform for interdisciplinary research:**

Immense opportunity to act as a conduit for such work on campus as well as in this region. Opportunities exist for us to work as a nucleus for joint basic & applied research centre in the eastern India. We are uniquely placed in this regard with strong engineering and basic research support on campus.

• **Joint curriculum with other departments**:

Such proposals have already been submitted

THREATS

Geographical isolation and lack of other opportunities often act as a deterrent for students and faculty to come here. Increase in the number of students without large-scale increase in infrastructure is another point of concern. In addition**, in a globalised environment, comparison with top places in the world is mandatory and unless we consider a holistic approach to bring recruitment, research, teaching and other facilities at par** with them, we may fall behind further**.**

9. Additional Information, if any

***Note: Ten countries: US, UK, Germany, Japan, Canada, France, Italy, Australia, Singapore, South Korea (optional :China may be replaced with anyone if department wants)**

Important Highlights

Research Profile: Department of Physics, April 2014

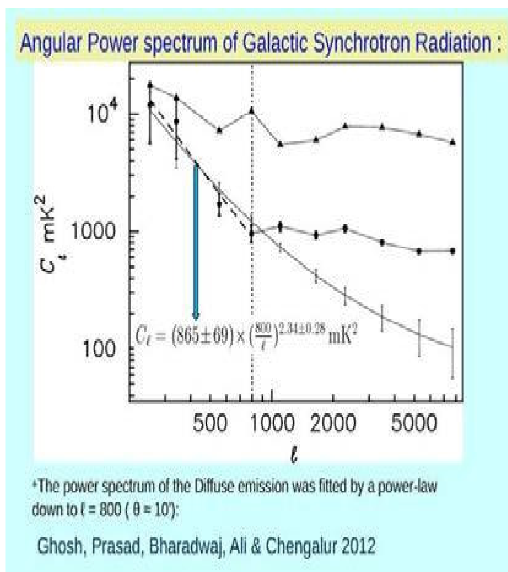
Preamble

Excellence and sustained efforts in research and teaching in the Department of Physics has brought recognition through increasing collaboration, quality publication and sponsored projects as well as very bright students over the years. In spite of having emphasis on new basic science, the Department fosters harnessing the basic sciences for technological development across the boundaries and disciplines in tune with the common goal of the Institute.

There has been strong evolution in core fields in this decade, and that has maintained the vitality and strengths so that today the department is recognized for condensed matter physics, cosmology, astrophysics, nonlinear dynamics, nuclear physics, atomic and molecular physics and photonics. The teaching programmes in the department are also highly successful in mixing applications with basic sciences.

Astro-Physics and Cosmology:

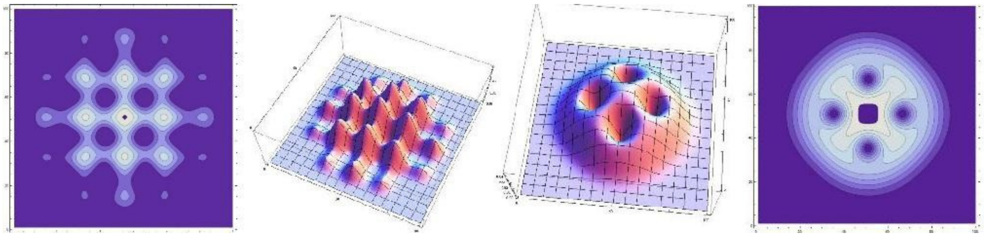
Research is currently focused on using redshifted 21 -cm radiation from neutral Hydrogen to probe the Universe. This is perceived to be one of the most important future probes of cosmology. This provides the capability to study the Universe over a very large redshift range from z~30 when the first luminous objects were formed, through z ~ 15 - 6 when the Universe was reionized to z =0 the present Universe. Theoretical and semi-numerical model predictions are being pursued along with carrying out observations in this field. Foreground removal is possibly the largest challenge which has to be overcome in this field. GMRT observations at 610 and 150 MHZ have been carried out to quantify and characterize the foregrounds for detecting the redshifted 21-cm signal. The diffuse Galactic synchrotron radiation at 150 MHz and sub-degree angular scales has been detected (see Figure), and among other things the current work is focused on strategies for foreground removal and signal detection.



Atomic & Molecular Physics:

Interaction between ultra-cold atoms and light with angular momentum has been studied, completely quantum mechanically, for the first time in literature. New physics has been studied on the procedure of transfer of angular momentum from light to electron in atoms. Application as candidate of quantum entanglement has been studied. Accuracy of fundamental constants, such as fine-structure, nuclear parameters (hyperfine, parity non-conserving weak charge, anapole moment), frequency standard used for GPS systems have been studied with very high precession using correlation exhausting relativistic ab initio many body methods

Dynamics of condensed atomic gas: vortex structures:



BioPhysics:

The research being pursued allows manipulation and study of bio-molecules at single-molecule level using techniques like Optical tweezers, smFRET, AFM. How biological macro- molecules fold (and unfold) is a question of immense importance in both the physical sciences and life sciences. By conducting many sequential measurements the distributions and fluctuation of molecular properties can be characterized, transient intermediates can be revealed. Free-energy landscape formalism provide the fundamental conceptual framework for understanding of the biophysics of folding: in principle, the microscopic rates, diffusion constant and pathways for folding can be predicted quantitatively given the landscape profile. The group is keen to learn new techniques to explore more in the field of Biophysics to improve our understanding of living world.

Condense Matter Physics:

The semiconductor physics research group is actively involved in physics of heterostructures & low dimensional semcionductors for next generation electronic and photonic devices. Demonstrated mid infrared Ge quantum dot photodetectors at room temperature using intersubband transitions in the valence band. Self assembled Ge nanocrystals grown by MBE have shown to exhibit luminescence in the visible region due to the quantum confinemnet of carriers making silicon based semiconductors attractive as light emitters. One dimensional nanostructures of Si and group II-VI semiconductors are being studied for their applications in optoelectronic, photovoltaic and nanoelectronic devices.

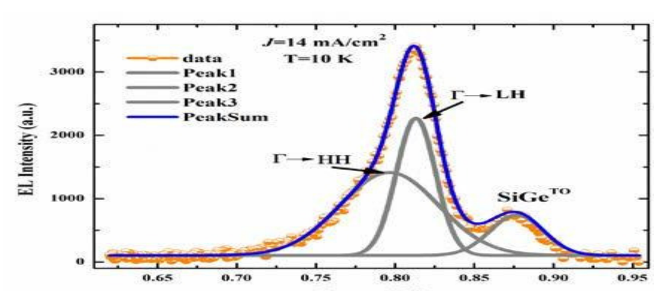


Fig. Direct bandgap electroluminescence from strained Ge grown o virtual SiGe substrate using molecular beam epitaxy

The experimental condensed group is working in the area of Strongly Correlated Systems, Nanostructured magnetic materials, Magnetic thin films and multilayers, Dilute magnetic semiconductors, Superconductivity, Spintronics, Multiferroics, CMR, GMR materials, Magnetic Metallic Glasses, Highly Spin Polarized Magnetic oxides and Magnetic Huesler alloys for Magnetoelectronics, Magnetocaloric materials etc. The group has developed a low temperature high magnetic facility 9 Tesla Superconducting Magnet System with CFMVTI cryostat down to

1.6 K. The facility is routinely used to measure (a) Electrical transport, Magneto-transport, Hall Voltage etc. (b) To measure Linear and Non-linear complex Ac magnetic susceptibility, I-V, C-V, magneto-impedance, magneto-capacitance etc. measurements down to 1.6 K (c) To measure Thermoelectric power in the temperature range of 5 – 300 K in presence of magnetic field in the range of 0 - ± 8 T. (d) Measurement of all chemically synthesized nanosized magnetic oxides, spintronic oxides using the newly installed CFMVTI interfaced with GPIB-USB PC (automation) with all measuring equipments using LABVIEW (version 8.5) software.

One group is engaged in studying magnetic materials in combination with the semiconductors for spintronic applications. The group has made THREE significant contribution in this field of research. (i) They have developed a characterization technique, namely, cantilever beam magnetometer (CBM) which is capable to measure magnetization, magneto-crystalline anisotropy and magnetostriction of magnetic materials in any form of thin film, bulk, nanoparticles and ribbon. The in-situ CBM can also measure the mechanical stress as a function of film thickness during the growth. (ii) We have demonstrated that a heterostructure of ferromagnetic film on semiconductor behaves like a diode as well as giant magnetoresistive element below room temperature. To achieve the same above room temperature, further investigation is going on. And (iii) we have extensively studied the transition metal doped Ge, ZnO & SnO_2 based diluted magnetic semiconductor (DMS) and evolution of impurity phases such as ferrites and Sn-doped Fe_2O_3.

Some Salient achievements:

(a) Observation of Grifiths phase singularity, exchange Bias effect and surface spin glass ordering, suppression of charge and Antiferromagnetic ordering and appearance of ferromagnetism, large Magnetocaloric effect (b) Emergence of Ferromagnetism in Nanoparticles of Antiferromagnetic $Sm_{0.5}Ca_{0.5}MnO_3$ and $Nd_{0.4}Sr_{0.6}MnO_3$ etc. manganites. (c) Evidence of electronic phase arrest and glassy ferromagnetic behavior in $(Nd_{0.4}Gd_{0.3})Sr_{0.3}MnO_3$ manganite nanoparticles, Spin glass and memory effect in antiferromagnetic manganites Nanoparticles (d) Observation of FM-metallic state in nanoparticles of FM-insulating NSMO system, size-induced ferromagnetism, critical behavior, magnetic relaxation dynamics, aging, memory effect and enhanced magnetoresistance in nanoparticles, tunable charge ordering and exchange bias effect on size modulation, enhancement of room temperature carrier induced ferromagnetism of Fe-doped ZnO epitaxial thin films with Al co-doping.

The theoretical condensed matter group is engaged in understanding the electronic properties of novel materials. We are interested in the correlated electronic & Bosonic systems with and without disorder. These are systems with multiple, competing degrees of freedom where correlation plays a major role rendering an electron at the border of particle and wave. Such systems exhibit exotic, often degenerate, ground and excited states which are studied intensely for their use in memory devices, spintronic applications as well as future materials for quantum computing.

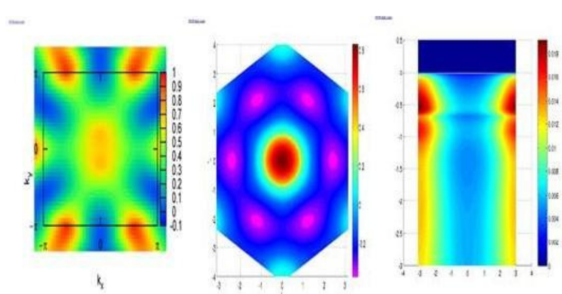


Fig. Theoretical Fermi surface maps of some correlated systems

Another experimental group is engaged in studying solid state properties and to synthesize novel compounds using highly energetic ion beams. On one hand, the ions capable of inducing fusion evaporation reaction are used to study local magnetic properties of solids and magnetic moment fluctuations therein, while, on the other hand, swift heavy ions are used to synthesize and characterize nano-scale compounds of metals, semiconductors, insulators and composites thereof. Accelerator facilities at Inter University Accelerator Centre, New Delhi and at Tata Institute of Fundamental Research are being actively utilized for these studies. At larger length scales, i.e., in bulk, the group's research activities include the exploration of quantum critical behavior in simple metallic alloys, and studies of Griffiths phase compounds. The group has alloy and thin film preparation facilities, and an X-ray Photoelectron Spectrometer (XPS) as major characterization equipment. A picture of the XPS machine is shown below.

Organic electronics research has attracted both scientific and economic interest during the last two decades or so, triggered by a rapid increase in its development. Flexibility, lower cost, easy processability are some attractive features of organic material based devices. Understanding the basic mechanism of transport in these materials lend comprehensive investigations and newer propositions.

Organic light emitting diodes (OLEDs), Organics Field Effect Transistors (OFETs), Organic Solar Cells (OSCs), Organic Non-Volatile Memories (ONVMs) are few examples of successful endeavors. With newer materials, different device structures, and different processing routes have drive the development further in a dynamic way and at the great-leap in coming years with more breakthroughs in both research and technological areas.

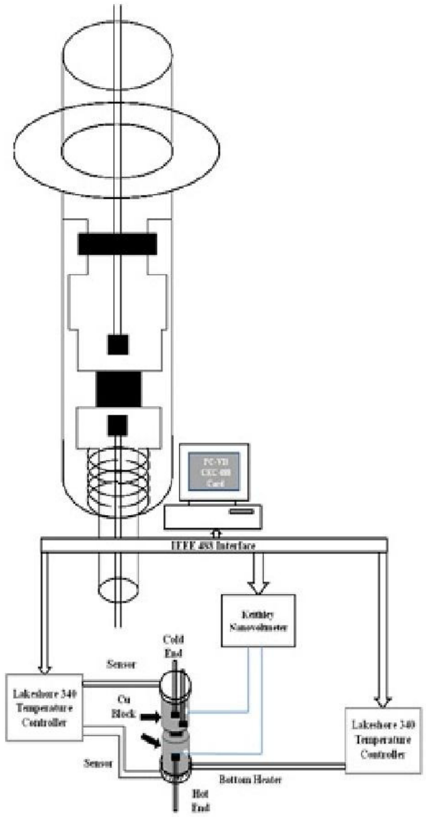
The group of organic electronics of the Physics department is involved in the following activities

- To investigate the role of interfaces between organic and inorganic contacts using Ohmic and Schottky type.
- To study the size effects in enhancing the carrier transport and transfer by measuring the electrical transport (conductivity and mobility) properties.
- To identify the defect levels responsible for the carrier quenching using photoluminescence and capacitive techniques.
- To incorporate tandem structures and their variants to enhance the properties.

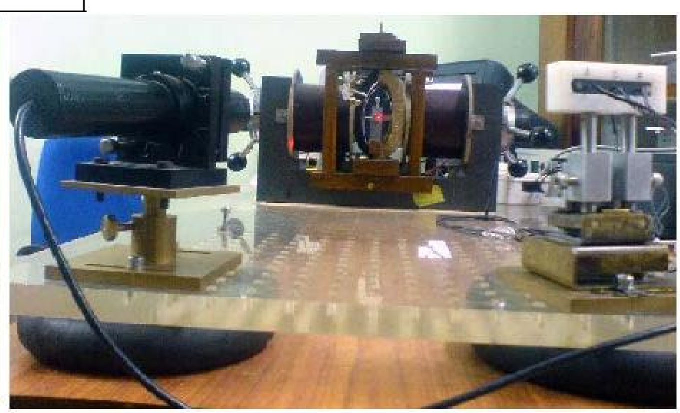
---

9 Tesla Superconducting Magnet system with VTI Cryostat down to a temperature of 1.6 K (DST sponsored Low temperature high magnetic field facility) (Courtesy: T K Nath)

Some pictures of Equipments used for Research in Magnetism and Superconductivity



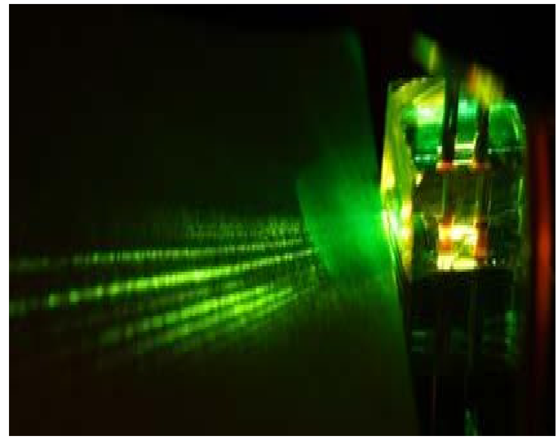
Schematic of the thermo electric power setup built on the CFMVTI
9 Tesla closed cycled refrigerator system down to 1.6 K



Home made cantilever beam magnetometer (CBM) in MTech teaching laboratory of our department.

a) Home made cantilever beam magnetometer (CBM) in Spintronics laboratory of our department
b) Home made cantilever beam magnetometer (CBM) in MTech teaching laboratory of our department. (Courtesy: A. K. Das)

Optics:



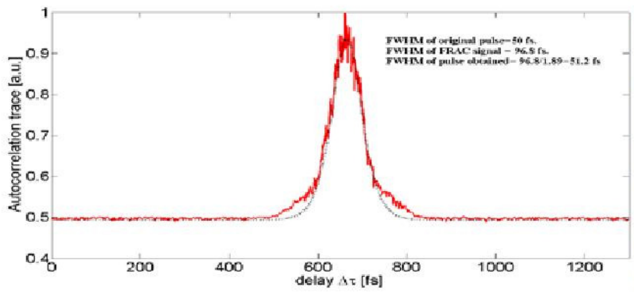
Various areas of Photonics have been exposed to provide expertise in experimental optics, light propagation in disordered systems, and several material fabrication and characterization techniques. Apart from the widely studied planar waveguiding systems, research has been carried out o n transparent glass-ceramics and photonic crystals, all with the interest towards integrated optics, such as topics concerning random lasing and experimental observation of Anderson localization of light in disordered systems. Currently, the 'Photonic Systems Laboratory' is being established at the Department of Physics, Indian Institute of Technology Kharagpur, with focus on optical and spectroscopic studies on various ordered and disordered photonic material systems.

Some research here focuses on shaping of phase singular beams and their linear and nonlinear interactions and applied optics. The research also includes generation and characterization of fractional optical vortex beams. Though the research is mainly experimental, simulations will also be performed on the generation and characterization of the phase singular beams. In addition to the generation and characterization of the phase singular beam applications of such beams in classical and quantum regime will also be investigated in detail. Imaging the phase objects based on the concepts of Fourier optics and phase contrast imaging will be the initial goal using spiral phase filters. He-Ne laser (25-LHP-991, Melles-Griot) and other opto-mechanics and optical components have been bought.

The high refractive index contrast and large nonlinear Kerr coefficient make Si an ideal candidate for nonlinear waveguides. Theoretical study is being done on the novel nonlinear optical phenomena that take place inside the Si-based nano-structured waveguides. Based on the study, different waveguide structures will be proposed that excite some fascinating nonlinear processes like mid -IR supercontinuum generation, shock-wave mediated resonance radiation, optical chaos and optical frequency comb generation. The research group mainly focuses on understanding the fundamental physical mechanism leading to these phenomena.

The experimental group is pursuing research in the field of Ultrafast science, which is a vibrant multi-dimensional and multi-disciplinary field with excellent viability for developing technology for tomorrow's world. Initially started with the development of ultrafast laser by inventing new mode-locking mechanism, the group could harness laser technology and nonlinear optics together to generate picoseconds optical pulse train. With the recent addition of femto-second laser source, it is now possible to look in to the dynamics of the physical phenomena with femtosecond time resolution. It has boosted up researchers of the group to investigate and manipulate physical phenomena in ultrafast time and energy resolution and transform it to cutting edge technology. The main focus is on the development of noncollinear optical parametric amplifier (NOPA), non-degenerate pump-probe, THz spectroscopy and magneto-optical Kerr Effect.

Part of the group is also engaged in analytical and numerical work on semiconductor based active and passive all-optical functional devices.



High Energy Physics:

The phenomenology group exclusively works in physics beyond the standard model. Indications for physics beyond the standard model come from problems related to neutrino masses, dark matter, baryon asymmetry, grand unification, etc The group have been mainly working in the neutrino mass models, but in some of these models other issues like dark matter, baryon asymmetry and so on, can also be addressed. Recently, discovery of Higgs boson has created much excitement among the particle physicists. They have worked on correlation between neutrino masses and the Higgs boson in a supersymmetric model. The group thinks on addressing these issues in other physics beyond the standard models, such as extra dimensions. In the Randall-Sundrum model, the length of the extra dimension is stabilized by a radion field which mixes with the Higgs boson. The group is working on to see the effects of the radion field on a bulk neutrino field in the extra dimensions. Apart from this, in a Type-II see-saw mechanism, smallness of neutrino masses can be addressed, only if the triplet Higgs mass is very heavy or if the mixing between triplet and doublet Higgses is very small. However, by embedding the Type-II seesaw mechanism in a supergravity setup, the small mixing between doublet and triplet Higgses can be naturally explained for a TeV scale triplet Higgs mass. In order to construct such a model, some extra symmetries need to be proposed in the model. Moreover, anomalies with respect to these additional symmetries need to be cancelled. The group have been working on these issues in a separate project.

Non-linear and complex systems:

Nanophysics is one of the most industrially and technologically relevant areas of complex systems. One of the main characteristics of the nanosystems is the mesoscopic fluctuations of their physical properties which can be well-modeled by system dependent random matrix models. A detailed understanding of these fluctuations in presence of both disorder and particle-particle interactions is still largely an open problem. The group is keen to pursue this question using correlated random matrix models.

Besides nanophysics, the group is also interested in understanding the behavior of other types of complex systems. Previously, the researchers from various areas have tried to use conventional random matrix theory to analyze the complexity in their systems. For example, the theory has been used to analyze the properties of, the cross-correlation matrix of various signals received by brain, the correlations among share prices in stock market, the random Ising model and problems in acoustics, electrodynamics etc. In almost all cases, the properties of systems were compared with stationary ensembles and the deviations were seen at certain relevant length- scales. As a result, the theory failed, and so was believed to be of limited applicability. With new results available for the more generalized random matrices that the group have been developing (capable of incorporating localized wave dynamics), these applications should be reconsidered. Success in this direction will not only throw light on a great deal of universality underlying the world of widely different complex systems, but would also help in the formulation of their physical properties.