Ph.D Brochure
Department of Physics

Year 2024

- Introduction
- High Energy Physics and Astrophysics
- Optics, Photonics, Spectroscopy and Laser-Plasma Physics
- Theoretical Condensed Matter Physics (Quantum/Classical)
- Experimental Condensed Matter Physics
- Quantum Information and Quantum Technologies: Theory
- Eligibility Criterion and Application Procedure

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Introduction

Thank you for your interest in the Ph.D program in Physics at IIT Hyderabad! We hope that you will carefully review the information provided here to help you find out about the exciting opportunities we offer to pursue doctoral research in some of the most current and dynamic areas of physics and how you can apply.

The Indian Institute of Technology, Hyderabad (IITH) was established in 2008, and is now functioning from its permanent campus in Kandi village of Telangana State. The Department of Physics at IIT Hyderabad is a rapidly growing department, presently we have 23 permanent faculty members, a number which we actively seek to increase, more than 75 Ph.D. students and a large number of MSc. and B.Tech (in Engineering Physics) students. The department has several groups pursuing research in diverse areas of physics. Presently their efforts are concentrated mainly in the the following fields:

- High Energy Physics and Astrophysics
- Optics, Photonics, Spectroscopy and Laser-Plasma Physics
- Computational Condensed Matter Physics (Quantum/Classical)
- Experimental Condensed Matter Physics
- Quantum Information and Quantum Technologies: Theory

Ph.D Curriculum: The IITH Physics Department is dedicated to providing the Ph.D students with both a broad background and in-depth training in their area of specialized research. Once admitted to the Ph.D program, the student has to earn 12 credits to complete his or her coursework requirements for a PhD. We offer intensive training in the fundamental topics of Physics through the core courses to prepare our Ph.D students for the challenges that lie ahead in their academic journey. The range of core courses offered include Classical Physics and Quantum Physics. In addition to the core courses, specialized elective courses are offered to the Ph.D students in their respective areas of research. Following the coursework, the Ph.D program is focused on full-time research. Students will work closely with their supervisors, and also interact with other members of their group, and also other groups. Further information on the elective courses offered and research of the various groups are provided in the following pages of this brochure. PhD students come into contact with an array of faculty and other members of the Physics community through journal clubs, public lectures and weekly seminar series (organized by research areas). Students will also have an opportunity to travel abroad for an international conference to present research papers.

Ph.D Qualification Process: Please check out the page detailing the eligibility criterion and details of application procedure if you are interested in pursuing a Ph.D at IITH Physics Department.

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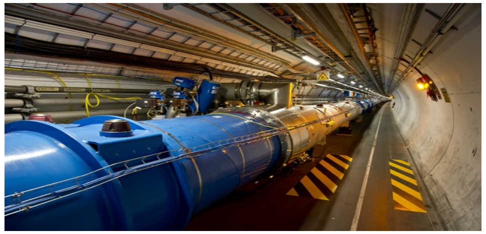
High Energy Physics and Astrophysics

At the **HEP** group, we are looking for motivated Ph.D students to join us on a range of exciting projects. High Energy Physics is poised on the verge of a revolution with the LHC soon to attain peak energy and luminosity and a whole new generation of cosmological and gravitational experiments coming up. This means we are certain to cross over into unexplored territory beyond the standard model of particles and the standard model of cosmology, into supersymmetry, dark matter, dark energy, astrophysical cosmology, astrostatistics, hidden sectors and extra dimensions.

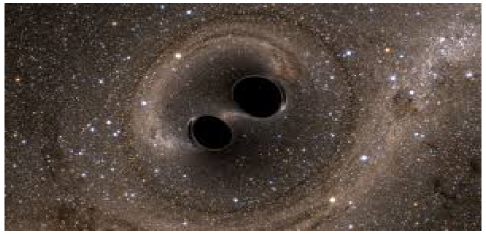
At our group, there is scope to do research in the formal aspects of theory (Quantum Chromodynamics, String Theory), phenomenology targeting the latest collider searches (beyond the standard model, neutrinos, dark matter, Higgs), and also experimental research based on the the Compact Muon Solenoid (CMS) experiment at the CERN Large Hadron Collider & the Belle-2 experiment in Japan (on topics such as flavour physics, Higgs physics, search for new particles associated with physics beyond the standard model such as Dark Matter candidates). The HEP group is also a part of leading international experiments and collaborations worldwide with faculty members working as part of the CMS collaboration at CERN, Switzerland; the NOvA Neutrino collaboration at Fermilab, USA; and the Belle collaboration at KEK, JAPAN.

A particle detector laboratory is under development and there will be opportunity to work on particle physics detectors and reconstruction of particle with particle detectors. The institute also hosts an Advanced Darksky Observatory (ADO) with a 0.5-meter Robotic optical telescope.

Specialized elective courses are offered by the



The Large Hadron Collider



Collapse of Black Hole Binary

NOvA Experiment

Advanced Darksky Observatory at IITH

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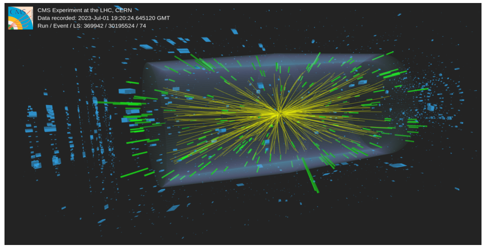
High Energy Physics and Astrophysics

group faculty to prepare students for research in high energy. Such electives include Quantum Field Theory, General Relativity, Particle Physics, Cosmology, Group Theory, Computational Particle Physics.

Following the course work, the Ph.D program is focused on full-time research. Students will work closely with their supervisors, and also interact with other members of the HEP group, participating fully in the life of the group including HEP Journal Clubs, Remote Seminar Series, HEP gym, GIAN courses, Workshops and Conferences (e.g. FFCP'18).

To find out more details please, visit the IITH HEP group web-page:
https://physics.iith.ac.in/research-areas/hep.html
and that of the Astrophysics group:
https://physics.iith.ac.in/research-areas/ac.html.
The web-pages also contain the research profiles of individual faculty members.



Particles collisions at the CMS experiment at the LHC

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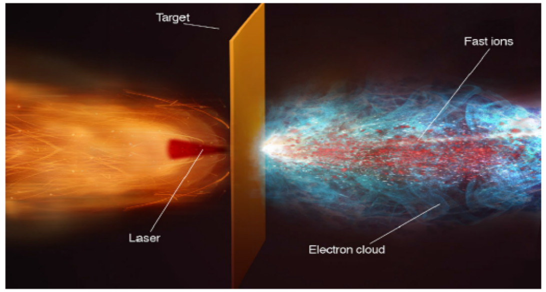
Optics, Photonics, Spectroscopy and Laser-Plasma Physics

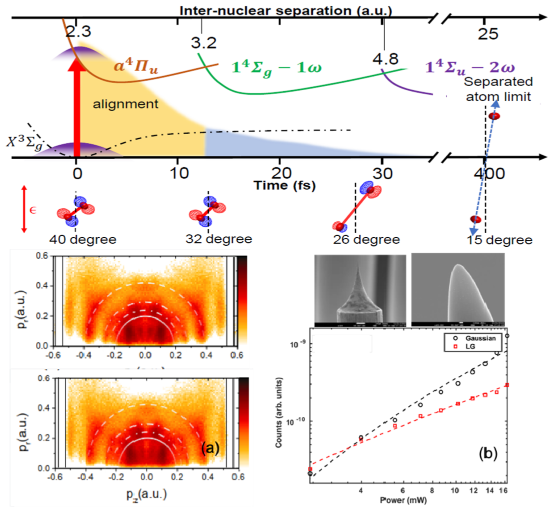
We are looking for strongly motivated students with a keen interest to learn and develop exciting experiments and theoretical understanding. Our group is dedicated to achieving excellence in research and innovation, driving forward areas of research, which have a positive impact on society. The interaction of laser pulses with matter is opening up new frontiers in physics, which is enabled by advances in ultrashort pulse laser technology, which have enabled new regimes ranging from probing electronic structure of atoms and molecules, transient spectroscopy towards the development of tabletop accelerator technology, astrophysical plasma modelling & fusion power.

Our group has opportunities in aspects of experimental and theoretical investigation such as:

- ultrafast dynamics of atoms and molecules,
- ultrafast nonlinear optics and time-resolved/ optical pump-terahertz probe spectroscopy,
- table top X-ray source,
- ultrashort electron source,
- exciton dissociation dynamics at a donor/ acceptor interface in an organic photovoltaic system,
- astrophysical, fusion, & intense laser plasmas,
- table top ion accelerators - Medical applications (ion cancer therapy).
- Photonics, nonlinear optics, Fiber optics, lasers and sensors
- Plasmonics, Nanophotonics, Infrared imaging, Terahertz devices, Metamaterials



Plasma and Laser interaction



Atomic and Molecular Dynamics

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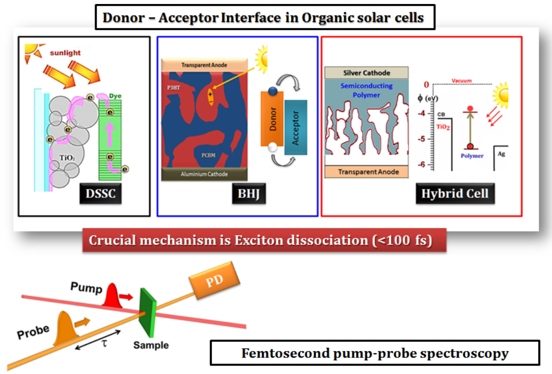
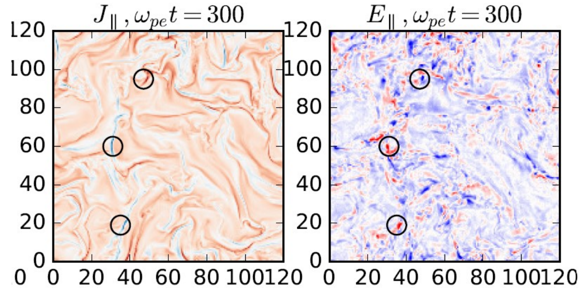
Optics, Photonics, Spectroscopy and Laser-Plasma Physics

The group has active collaborations in various central laser, FEL and synchrotron facilities in the UK, US and Europe; NIMS Tsukuba, Tohoku and Osaka University in Japan. To find out more details please visit the group webpage listed on https://physics.iith.ac.in/research-areas/optics.html which also provides links to profiles of individual faculty members.

Specialized elective courses are offered to prepare students for research in Atomic, Molecular and Plasma Physics. Such electives include Lasers and Photonics, Plasma Physics, advanced courses in Atomic and Molecular Physics. Following the course work, the Ph.D program is focused on full-time research. Students will work closely with their supervisors for designing experiments, and also interact with other members of the group. They can also pursue theoretical/numerical research. Students will have the opportunity to travel abroad for international conferences to present research papers and also to perform experiments at international facilities.



Photophysics



Plasma Turbulence

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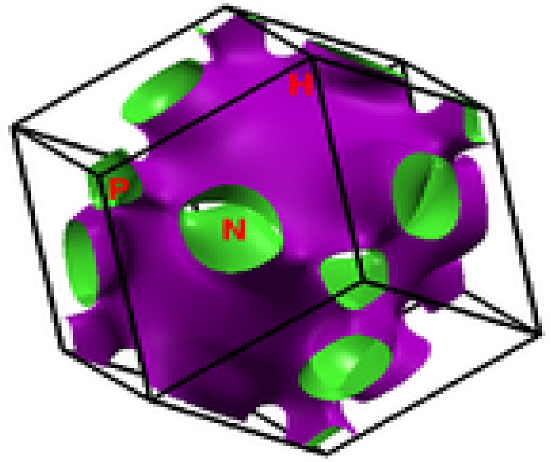
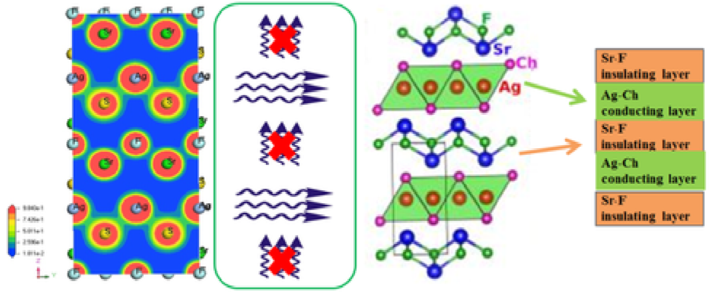
Theoretical Condensed Matter Physics

Research in the Thoretical Condensed Matter Physics group can be divided into three subgroups. The first subgroup focuses on materials, which includes a diverse variety of topics such as basic electronic structure, phase transitions, magnetism, superconductivity, optical properties, transport properties. The second subgroup focuses on the study of complex systems like disordered systems, soft-matter, non-equilibrium statistical mechanics, biophysics, and many more. The third subgroup focuses broadly on quantum statistical mechanics that includes non-equilibrium dynamics, quantum chaos, quantum phase transitions, topological phases, Floquet phases, localization-delocalizatio transition in disordered systems, quantum annealing etc.

This field of research is highly connected to different applications, like graphene, graphene-like materials, bio-mimetic materials, cancer metastasis, which are high in demand now. In addition, one can find a huge range of applications such as detector systems, energy storage, superconducting materials etc.



Fermi Surface of $LaRu_4P_{12}$



Charge flow in a layered structure of $SrAgChF$

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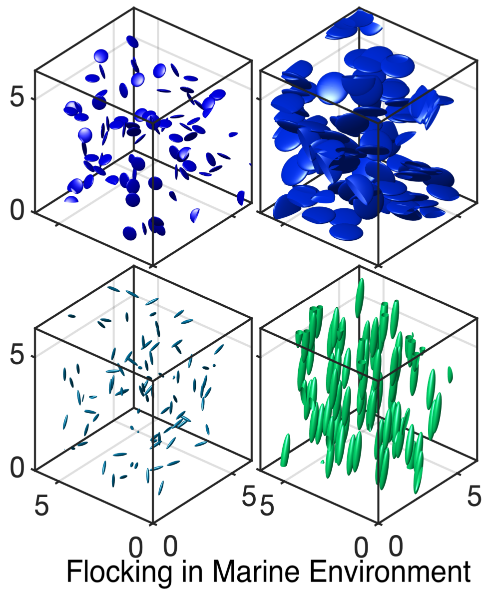
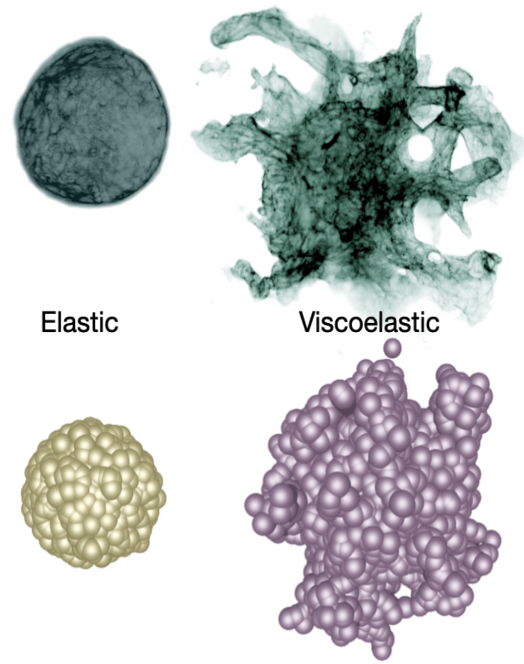
Theoretical Condensed Matter Physics





Tissue growth in viscoelastic matrix

Our group at IITH is actively involved in exploring various material properties using first-principle calculations to design high potential materials for different applications and develop models to understand complex systems such as viscoelastic flows, and biophysical systems. For more details visit http://physics.iith.ac.in/index.html. We welcome applications from students who are strongly motivated to work with us on innovative problems in Condensed Matter Physics.

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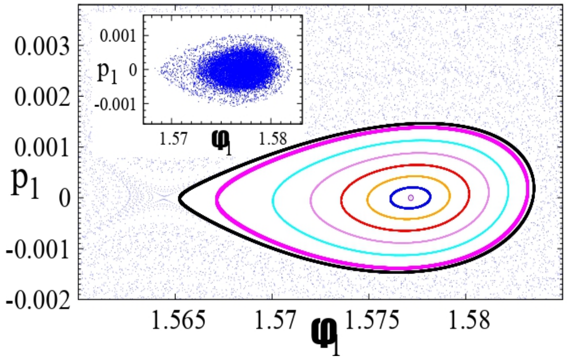
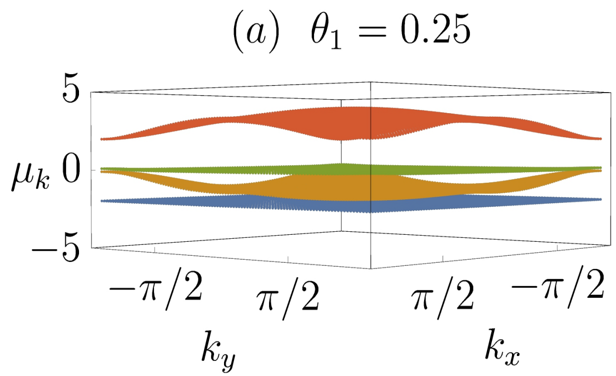
Theoretical Condensed Matter Physics

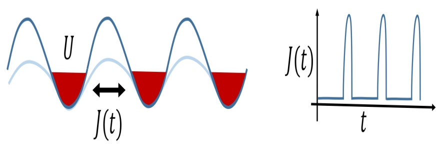


Many-body chaos



Floquet flat band

In the third subgroup, we focus on the interdisciplinary topics of condensed matter and statistical physics that include non-equilibrium dynamics, quantum chaos, quantum phase transitions, topological systems, Floquet phases, localization-delocalization transition in disordered systems, quantum annealing etc. We are also interested in working in quantum simulations for spin systems in both equilibrium and non-equilibrium scenarios. The mentioned research direction is an active area of research worldwide, not only for their interesting fundamental physics, but also their applicability in building quantum computers and quantum simulators. The students will have scope here to learn both analytical and numerical techniques, and to apply those for realistic systems. We welcome interested and motivated students in our group. To learn more, please visit the webpage of IIT Hyderabad physics.



Bosonic josephson junctions

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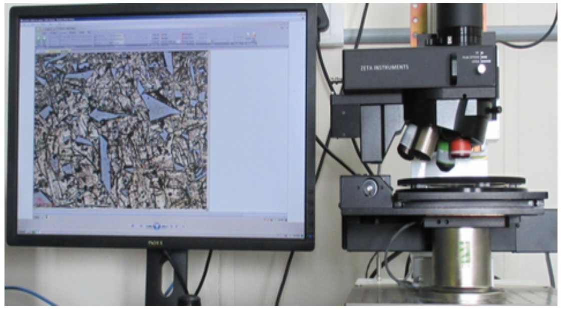
Experimental Condensed Matter Physics

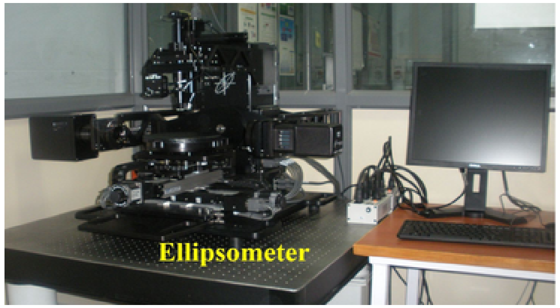
Understanding the fundamental physical concepts behind various materials, in particular, technological devices such as spin-electronics, semiconductor devices and nanoelectronics have been of great interest in recent past due to their strong potential for practical applications. On top of that today's technology demands smaller, faster and reliable devices. It is a challenge to understand the ultrafast time scale (10^{-9} s to 10^{-18} s) prevalent in these nanoscale systems brought about by processes involving fundamental interactions between electron, spin, phonon and their corresponding correlation length and time scales.

The experimental condensed matter physics group at IITH conducts vibrant research in frontier areas of physics such as spintronics, magnonics, magnetic materials, advanced functional materials and microelectromechanical systems (MEMS). We thus offer a diverse range of cutting-edge topics for students to work on. Research laboratories are equipped with state of the art experimental facilities, thereby providing direct hands-on experience. Faculty members in this group have strong national and international collaborations, which provide many opportunities for students to visit and interact during the course of their research. Students can select a research field based on their interests and subject to the availability of vacancies with respective faculty members.

Courses for PhD scholars are designed in such a way that the students can attain very good understanding about their research field. The Physics department aims at strengthening the core physics course along with specialized elective courses.

Some of the elective courses aimed at Ph.D students interested in working our group, include experimental techniques, advanced functional





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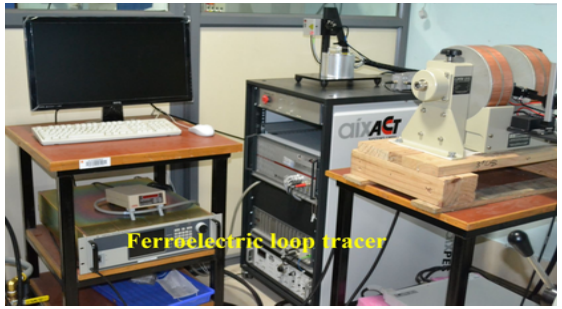
materials, application of magnetic materials, microfabrication techniques, semiconductor device physics, spintronics and many more.



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Quantum Information Theory and Quantum Technologies

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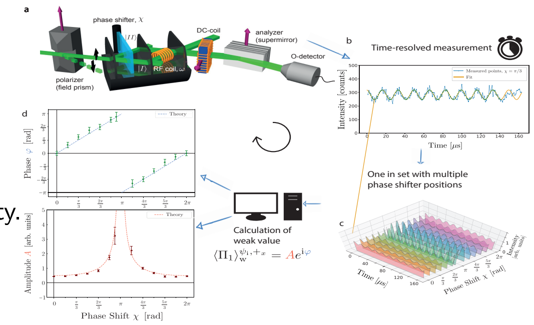
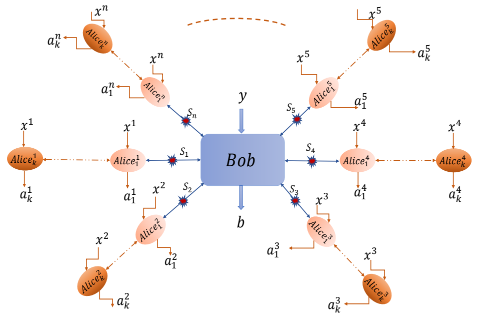
We are looking for highly motivated students to pursue their research on various aspects of quantum information theory and quantum technologies. Research in this direction is carried out in two subgroups. A) Quantum Foundations to Quantum Technologies: Quantum theory is astonishing. Despite its enormous success as a physical theory, there is still no consensus among physicists about what this theory is saying about the nature of reality. This is one of the many motivations for pursuing research on quantum foundations. Another is the development of quantum technologies, such as quantum computation, quantum cryptography, quantum metrology by exploiting its peculiar features. A better understanding of the theory facilitates the identification and development of these new technologies and also further the harnessing of the power of non-classicality. There may also be some special non-classical features that exist in nature providing advantage in some information processing task even if quantum theory is replaced by another physical theory in future.

In this subgroup, the students will have the scope and freedom of working in various interrelated research topics. The broad areas (not limited to) are the following; i) Quantum Foundations (nonlocality, contextuality, macrorealism, ψ-ontic and ψ-epistemic interpretation of quantum states) ii) Device-independent certification protocols (Random number generation, self-testing state, measurement and instruments based on prepar measure or entanglement based scenario) iii) Quantum information processing (Communication Complexity, Quantum channels, Quantum Thermodynamics) iv) device-independent quantum cryptography (Theoretical analysis of the security of the key distribution, Error correction) iv) Quantum Network (Nonlocality in open and closed netwroks and applications in certification protocols) v) Quantum metrology and sensing (Standard parameter estimation technique, Quantum clock). To find out more details please visit the IITH Quantum Information Theory group webpage http://physics.iith.ac.in/QIT_Physics/. Students may also propose their topics of interest under the above mentioned theme. We remain open for new ideas and opinions.



Testing commutation relation (Performed in Atom institute, Vienna)

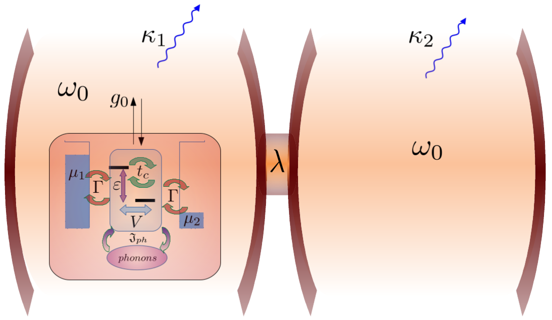


Device-independent nonlocal correlation in Star-network

Quantum Information Theory and Quantum Technologies

B) Physics of platforms for quantum technology: Advent of quantum technology requires scalable and tunable platforms where quantum effects can be controllably studied and utilized. At present some of the leading platforms in this regard are superconducting circuits, quantum dots, atoms and ions in optical traps, color centers in diamond. These platforms have shown promise for various applications like quantum sensing, quantum information processing, digital and analog quantum simulation. They are inherently noisy and dissipative because complete isolation from surrounding envrionments is not possible and often not even desired. Further, the applications require that these systems are driven out of equilibrium, for example via a time-dependent pulse or a voltage bias. Accurate theoretical modelling of the system under such conditions is crucial for many applications, like quantum sensing and quantum simulation. However, describing such driven dissipative quantum many-body systems is a major challenge. Most state-of-the-art theoretical formalisms for describing these systems are tractable and applicable only in a very restricted regime. This limits both our fundamental understanding and exploration of potential applications to a narrow regime of experimentally achievable parameters.

In this subgroup, we aim to go beyond these limitations. The broad goals of this subgroup are (i) develop analytical and numerical techniques to describe various platforms for quantum technology beyond present limitations, (ii) explore their exotic physics, both for fundamental understanding and potential applications, (iii) propose new platforms, novel working regimes and applications. This research is at the interface of condensed matter physics, statistical physics, quantum information and quantum optics. The student has the freedom to explore one or more of the above directions more deeply, while having an overall understanding of the rest. There is scope for both analytical, mathematical research (linear algebra, diagrammatic techniques) as well as research based on development and application of sophisticated numerical approaches (tensor network and sparse matrix techniques). There is also ample scope for national and international collaborations.



Coupled cavities with a voltage biased double-quantum-dot in one of them.

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Eligibility and Application Procedure

Eligibility and Application Procedure

Currently, Ph.D program at IITH takes in students either through the regular route or a special route for sponsored candidates. The eligibility criterion for the applicants to the Ph.D program is laid out in the following:

For Regular Ph.D. Candidates:

☐ M.Sc. (Physics/Applied Physics/Electronics) or an equivalent degree in engineering(M.E./M. Tech. or M.Sc.(Engg) etc.) with a valid Physics GATE score/UGC-JRF/CSIR-JRF/DST-INSPIRE Fellowship.

OR

☐ B.E./B. Tech. or equivalent engineering degree with a valid Physics GATE score.

For Sponsored Candidates:

☐ Candidates working in reputed research or industrial organizations may also apply for the **sponsored** Ph.D. program (please contact the head of the department for further details, criteria etc.) A proof of sponsorship from parent organization must be provided at the time of interview. NET qualified candidates are encouraged to apply. The eligibility criteria are similar to those for regular Ph.D candidates. Interested candidates are requested to contact the head of the department for further details. **Note**: Sponsored candidates are not eligible for stipend.

If you are interested in the activities of a particular research group or a particular faculty member at IITH Physics and you are interested in exploring the possibility of pursuing a Ph.D, **please send an email to the particular faculty**. Applications for the Ph.D program are received twice (normally in March/ April and October/November each year). Please look for PhD advertisement on our website for exact dates. One can also contact the Head of Department of Physics for further information.

MoE candidates: please check the departmental website for potential research areas.

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