Rakshit Jain

CONTACT INFORMATION

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RESEARCH INTERESTS

Experimental solid state physics and Photonics

EDUCATION

Indian Institute of Technology Bombay, Mumbai, India *July 2014 – Present*

Final Year (Bachelor of Technology in Engineering Physics with honors), Department of Physics

- **Major CGPA:** 9.30/10 (Detailed List of Courses)
- **Minor Degree:** Department of Electrical Engineering

PUBLICATIONS AND PREPRINTS

- **Jain R.**, Poonia V.S, Ganguly S. *Sensitive Magnetic Compass in presence of decohering nuclear environment* . (in preparation to be submitted for publication in *Physical Review E.*)

KEY RESEARCH WORK

Quantum Sensing Lab, University of Basel, Department of Physics

Fully Tunable Fano Resonances in strain driven NV center in Diamond

Guide: Prof. Patrick Maletinsky *Summer 2017*

In this study, we proposed an experimental scheme to observe Fano resonances on a single spin-1 system in a closed-loop "∇" configuration, enabled by coherent driving with strain and microwave fields. The key innovation was to mimic a continuum of spin states by controlling the level splittings of the NV system while maintaining a three-photon-like resonance with the driving fields. We theoretically established the dependence of the Fano asymmetry factor of the resonance with the phase difference between strain driving and magnetic fields. Currently, the group is in the process of realizing the scheme experimentally in diamond cantilevers

Side Project: Using Dynamical Decoupling pulses to probe the depth of NV centers

Guide: Prof. Patrick Maletinsky and *Dr. James Wood* *Summer 2017*

For quantum sensing with single NV spins, the distance between the sample and NV center is an important parameter for determining the sensitivities and spatial resolution. One way to determine this distance is to sense surface spins (mostly protons) and determine the depth by fitting a known function[1]. In this project, firstly I built a single spin confocal setup from scratch and obtained counts from a single NV center. Then I implemented a CPMG pulse in order to probe the nearby spins. We could detect signal from C-13 spin by aligning the field and measuring the refocusing frequency from the precision of nearby spins. The group is now implementing the DD pulses on diamond nanopillars to determine the NV depth for future quantum sensing experiments.

Photonics And Quantum Enabled Sensing Technology Lab, Indian Institute of Technology Bombay

Sensing Radical Pair by single defect centers in Diamond

Guide: Prof. Kasturi Saha, with Vishvendra Singh Poonia *May 2017 -*

Probing the spin dynamics of radical pair system is essential for understanding the avian compass. In this work, we propose sensing of spin transitions of electron spins of radical pair using diamond NV center probe by appropriately controlling the dynamics of radical pair and single spin in diamond. The spin of the NV center is driven by both dipolar and electric field[2] components of the chemical reaction of the radical pair. Both of these interactions cause different phase gains in the spin state of the NV center. The dipolar couplings lead to an AC phase gain due to spin state transitions that would correspond to time the molecule actually remains coherent in presence of environmental dephasing. On the other hand, the electric fields only correspond to the recombination time scales. Thus by suitably controlling the NV center's spin, we developed a scheme to probe both of these phase gains. In this scheme, electron spin in NV could act as an

[1] https://journals.aps.org/prb/abstract/10.1103/PhysRevB.93.045425
[2] https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.118.200402

effective sensor of dephasing time of the Radical pair. This work is under preparation for publication.

Hybrid Gyroscope based on NV centers and a BAW gyroscope
Guide: Prof. Kasturi Saha; Research and Development Project *July 2017 -*
I worked on investigating how a MEMS BAW gyroscope can be coupled with a NV center in diamond to ensure stability and sensitivity. We proposed coupling the NV with the degenerate modes of a disc via AC strain and detecting gyroscopic action by sensing excitation of these modes via coriolis transfer. The sensing mechanism depends on the magnetically forbidden transitions of the NV center and hence would be robust against magnetic noise as well as dipolar couplings with other NVs. We realized that the sensitivities are limited by thermal noise of the disc in the case of ensemble detection and deviation from non-linearity due to strong coupling. Also, we could establish that the NV spins coupled to the MEMS gyroscope could make it robust against any non-monotonous drifts in the Q factors. In future, we would be looking for improving the stability of a MEMS gyroscope to other deviations like capacitance drifts using the scheme we proposed.

Quantum Biology and Biomimetics Group, Indian Institute of Technology Bombay
Sensitivity and Coherence in a Realistic Radical Pair model
Guide: Vishvendra Singh Poonia and Prof. Swaroop Ganguly; Junior Thesis
The radical pair model is the most accepted hypothesis to explain the navigational capability of certain migratory birds. I worked on identifying whether the spin dynamics of the radical pair exploits coherence in its functioning. Firstly, by modifying the existing techniques, I found an effective way to simulate dynamics of a realistic radical pair model which involves very large Hilbert space. Moreover, in this case the system closely resembles to singlet-triplet spin dynamics in the Double Quantum Dots(DQD). Since, decoherence in DQDs is rather well understood[3], we were able to correlate results. We concluded from our studies that the compass can still function in a parameter regime where in spite of fast decoherence due to nuclear environment, sensitives are still significant.
We plan to submit this work for publication in Physical Review E.

Hybrid Optoelectronics Lab, Indian Institute of Technology Bombay
Scanning PL and PC studies on Perovskites
Guide: Prof. Dinesh Kabra ; Senior Thesis *August 2017 -*
Inorganic-Organic hybrid perovskites are emerging materials for solar cell and light emitting sources. They are marked by their distinguishing properties of low cost and relatively easier processing making them leading candidates for next generation solar cell and light emitting applications. In the phase one of this project, I worked on probing the transport of carriers on a device by spatial excitation using a laser and scanning piezo stage. By scanning over the interfaces we were able to extract the diffusion length of hole and electron carriers using a lock-in detection.
I am currently working on extracting the phase delay from these measurements as it related to the diffusion parameters and one can extract both recombination times and mobility for both the carriers from such a measurement.

Achievements and Awards

- Received DAAD WISE Scholarship for 10 weeks internship in Germany. (Declined)
- Received Purdue Undergraduate Summer Experience(PURE) Scholarship for 8 weeks Summer Internship at Purdue.(Declined)
- Received **AP grade** for **exceptional performance** in 3 courses done at IITB - Introduction to Condensed Matter Physics, Introduction to Renewable Technologies and Electronic Devices and Circuits
- Awarded Hostel Technical Color for enhancement of Technical activities and culture of the Hostel.
- Selected for National Mathematics and Physics Olympiads on the basis of performance at state level in high school
- All India Rank 746 in JEE Advanced among 121,000 overall participants for entrance to the IITs
- Awarded with Medhawi Vidyarthi Protsahan Scholarship for being among the top candidates in Higher School Certificate Exam

[3] https://journals.aps.org/prb/pdf/10.1103/PhysRevB.72.125337

Other Research Projects

Photodetectors based on a few layer ReS_2 devices
Guide: Prof. Saurabh Lodha ; Indian Institute of Technology Bombay *August 2016- Dec 2016*
I worked on measurements of few layer ReS_2 based photodetector devices. By using a optical chopper we were able to measure response time of the order of few ms. I also reviewed optical properties of several devices based on various 2D materials.

miRNA regulation of Gene expression.
Guide: Prof. Amitabha Nandi ; *Indian Institute of Technology Bombay* *Summer 2016*
I modeled gene regulation in the gene expression network by forming a complex between miRNA and mRNA. I analytically calculated fano-factors and various moments involved in gene regulation by analyzing master equation of the set of reactions. I also simulated the reaction kinetics using Gillespie algorithm to analyze steady state behaviour.

Prototype Spark Chamber for detecting Cosmic rays.
Guide: Prof. Pradeep Sarin, *Indian Institute of Technology Bombay* *Winter 2015*
In this winter project, we made a prototype spark chamber for detection of cosmic rays from PCB copper plates placed in helium chamber. We designed etched PCB plates in order to reduce corona. Report can be found here

Key Course Seminars/ Term Papers

Electromagnetically Induced Transparency *PH 440: Atomic and Molecular Physics*
Instructor: Prof. Gopal Dixit, Course Seminar, IITB
Presented coherent population trapping and effect of strongly coupled laser field to induce transparency to a probe field. [Slides]

Spin Hall effect *EP503: Advanced Magnetic Materials*
Instructor: Prof. Avinash Mahajan, Course Seminar, IITB
Presented Spin Hall effect and its detection by optical and electrical means. [Slides]

Integer Quantum Hall effect *PH308: Introduction to Condensed Matter Physics*
Instructor: Prof. P.P. Singh, Term paper, IITB *Autumn 2015-16*
We studied landau levels formation due to presence of an magnetic field which leads to quantized hall voltage. [Report]

Random Number Generation and Sampling *Microprocessor Lab*
Instructor: Prof. Pradeep Sarin, Course Projects, IITB *Spring 2014-15*
Generated a true random signal by utilising diode noise and then sampled it using a microprocessor to make an interface with a computer. We then used it as random number to perform stochastic Gillespie algorithm. [Report]

Modelling of Migration Dynamics *PH542 Non-Linear Dynamics*
Instructor: Prof. Amitabha Nandi, Course Seminar, IITB *Autumn 2014-15*
Used coupled logistic equation to show the effects of migration over population dynamics. [Slides]

Key Talks and Seminars

Scanning Photocurrent Measurements *Senior Thesis Talk*
Department of Physics, Indian Institute of Technology Bombay *November 2017*
Gave a 20 minute talk on the scanning photocurrent technique and results on my work as part of my Bachelors' Thesis.

Fano Resonances with strain driven NV centers *Group Talk*
Quantum Sensing Lab, University of Basel *July 2017*
Gave a 30 minute talk on the scheme to observe tunable Fano resonances in strain driven NV centers as a part of my summer internship at Basel.

Decohernece in Avian Magnetoreception *Junior Thesis' Talk*
Department of Physics, Indian Institute of Technology Bombay *November 2016*
Gave a 20 minute talk on my work on Decoherence in Avian Magnetoreception as a part of my Junior Thesis.

Key Coursework

Physics
Advanced Magnetic Materials, Applied Solid State Physics, Photonics, Quantum Information and Computing, Electromagnetic Theory, Quantum Mechanics I and II, Introduction to Condensed Matter physics

Electrical Engineering and Energy
Electronic Devices, Analog Circuits, Digital Systems, Signal and Systems, Introduction to Renewable Technologies

Technical Skills

Programming	Mathematica, C/C++, Python, Matlab, HTML/CSS,LaTeX
Software Packages	COMSOL, T-CAD, Origin, Inkscape, Illustrator
Science Software	Python packages: QuTip, NumPy, SciPy and Matplotlib

Extra-Curricular Activities

Positions of Responsibility

- **Teaching Assistant** *PH108: Electricity and Magnetism* *May 2016 - June 2016*
  I served as a teaching assistant for freshman course of Electricity and Magnetism . My duties included solving and explaining tutorial problems to over 50 students. It also included answer sheets evaluation and invigilation during exams.
- **Manager, Tinkerers Laboratory** *April 2016 - January 2017*
  In my junior year I worked as a manager of makers lab inside my institute. My duties included ensuring the funding and inventory maintenance of the lab.
- **Hostel technical Secretary** April 2015 - March 2016
  I served as a technical secretary of hostel. My duties included maintaining Hostel Tech Room, organizing various events and representation in various technical general championships. I was awarded Hostel technical color for enhancing technical culture of the hostel.

Technical Activities

- **General Championships**: I participated in various general championships during my second and third year. In these competitions, we made a hydro foam which is a robot that could work on all terrains and a Tesla coil from mosquito racket.
- **Hostel Technical Events** - I organized various hostel events during my tenure as technical secretary of the Hostel. Various events included intra-hostel logic competitions, dissembling various electronics around like DLP projector, transformers and analyzing how they work.

Sports

- I completed Advanced Training Course in Tennis organized by Tennis Club of IIT Bombay
- I completed a basic swimming course at LCH Fitness, Indore in my first year summers.

References

Prof. Patrick Maletinsky (Summer Internship Guide)
Email : patrick.maletinsky@unibas.ch
Associate Professor of Experimental Physics
Georg-H.-Endress Professorship
Department of Physics, University of Basel

Prof. Kasturi Saha (Research Project Guide)
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Assistant Professor,
Department of Electrical Engineering, Indian Institute of Technology Bombay

Prof. Dinesh Kabra (Senior Thesis Guide)
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