Manoranjan Kumar

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Guidance of Students/Post-Docs/Scientists

a) Ph.D. Students

1. Debasmita Maiti; Frustrated Magnetic Ladders : A DMRG Study; Awarded
2. Monalisa Singh Roy; Edge Modes in 1D Chains of Correlated Electrons and Their Junctions; Thesis submitted
3. Sudip Kumar Saha; Thermodynamics of Low-Dimensional Interacting Quantum Systems: A Hybrid Exact Diagonalization and Density Matrix Renormalization Group Study; Under progress
4. Sk Saniur Rahaman; Quantum Phases in Quasi-One Dimensional Frustrated Spin Systems; Under progress; M Sanjay Kumar (Co-supervisor)
5. Koushik Mandal; Theoretical investigation of the properties of correlated fermionic systems in low dimension; Under progress; Ranjan Chaudhury (Supervisor)
6. Sudipta Pattanayak; Ordering kinetics, steady state and phase transition in active particle systems: Role of noise and boundary; Awarded; M Sanjay Kumar (Co-supervisor)
7. Somashree Ghosal; Hubbard model on Quasi one and two dimensional lattices; Under progress
8. Monalisa Chatterjee; Topological aspect of Frustrated low dimensional Spin Systems; Under progress
9. Jyotirmoy Sau; Topology in Strongly Correlated Systems; Under progress
10. Manodip Routh; Effect of temperature on exotic quantum phases of strongly correlated system; Under progress

b) Post-Docs

1. Joy Prakash Das; Effect of impurity in strongly correlated 1D systems

c) External Project Students / Summer Training

1. Saurav Kantha; Machine learning methods for detection of phase transitions in spin systems

Teaching

1. Spring semester; Advanced Condensed Matter Physics II; PhD; 7 students; with 1 (Prof. Tanushri Saha Dasgupta,) co-teacher

Publications

a) In journals

1. Monalisa Singh Roy, **Manoranjan Kumar**, Jay D. Sau and Sumanta Tewari, *Fermion parity gap and exponential ground state degeneracy of the one-dimensional Fermi gas with intrinsic attractive interaction*, Physical Review B, 102, 125135, 2020
2. Monalisa Singh Roy, **Manoranjan Kumar**, and Sourin Das, *Tunneling density of states in a Y junction of Tomonaga-Luttinger liquid wires: A density matrix renormalization group study*, Physical Review B, 102, 035130, 2020

3. Vinod K Gangwar, Shiv Kumar, Mahima Singh, Labanya Ghosh, Yufeng Zhang, Prashant Shahi, Matthias Muntwiler, Swapnil Patil, Kenya Shimada, Yoshiya Uwatoko, Jyotirmoy Sau, **Manoranjan Kumar** and Sandip Chatterjee, *Pressure induced superconducting state in ideal topological insulator* $BiSbTe_3$, Physica Scripta, 96, 055802, 2021
4. Sudip Kumar Saha, Hrishit Banerjee and **Manoranjan Kumar**, *Topological transitions to Weyl states in bulk* Bi_2Se_3*: Effect of hydrostatic pressure and doping*, Journal of Applied Physics 129, 085103, 2021
5. Sudip Kumar Saha, **Manoranjan Kumar** and Zoltán G.Soos, *Bond-bond correlations, gap relations and thermodynamics of spin-1/2 chains with spin-Peierls transitions and bond-order-wave phases*, Journal of Magnetism and Magnetic Materials, 519, 167472, 2021
6. Dayasindhu Dey, Sambunath Das, **Manoranjan Kumar**, and S. Ramasesha, *Magnetization plateaus of spin-1/2 system on a 5/7 skewed ladder*, Physical review B, 101, 195110, 2020
7. Sudipta Pattanayak, Jay Prakash Singh, **Manoranjan Kumar**, and Shradha Mishra, *Speed inhomogeneity accelerates information transfer in polar flock*, Physical Review E, 101, 052602, 2020
8. Shaon Sahoo, Dayasindhu Dey, Sudip Kumar Saha and **Manoranjan Kumar**, *Haldane and dimer phases in a frustrated spin chain: an exact groundstate and associated topological phase transition*, Journal of Physics: Condensed Matter, 32, 335601, 2020

Talks / Seminars Delivered in reputed conference / institutions

1. Young Investigators Meet on Quantum Condensed Matter Theory-2020; Dec 15, 2020; National Institute of Science Education and Research (Online mode), Bhubaneswar; 15-18 December, 2020

Administrative duties

1. Member of computer center working committee
2. Member of library purchase committee
3. Member of VASP
4. Jest coordinator from S. N. Bose National Centre for Basic Sciences, Kolkata

Extramural Projects (DST, CSIR, DAE, UNDP, etc.)

1. Exploring Quantum and Thermal fluctuations in Frustrated Magnets at Low Temperature; SERB, DST, GOI; PI

Conference / Symposia / Schools organized

1. 3rd annual conference of quantum condensed matter; Sep 7, 2020; S. N. Bose National Centre for Basic Sciences; 5 days

Scientific collaborations with other national / international institutions (based on joint publications)

1. Zoltán G. Soos, Department of Chemistry, Princeton University, Princeton, New Jersey 08544, USA; International
2. Sujit Sarkar, Poornaprajna Institute of Scientific Research, 4 Sadashivanagar, Bangalore 560080, India; National
3. S. Ramasesha, Solid State and Structural Chemistry Unit, Indian Institute of Science, Bangalore 560012, India; National
4. Jay D. Sau, Condensed Matter Theory Center, Joint Quantum Institute, University of Maryland, College Park, Maryland 20742, USA; International
5. Sumanta Tewari, Department of Physics and Astronomy, Clemson University, Clemson, South Carolina 29634, USA; International
6. Sandip Chatterjee, Department of Physics, Indian Institute of Technology (BHU), Varanasi 221005, India; National
7. Shradha Mishra, Department of Physics, Indian Institute of Technology (BHU), Varanasi 221005, India; National

8. Sanjay Singh, Department of Physics, Indian Institute of Technology (BHU), Varanasi 221005, India; National

Areas of Research

Quantum condensed matter theory, Non-equilibrium phenomena in classical and quantum systems, Development of numerical techniques in quantun many-body systems, Topology in low dimensional quantum systems

Our group has been involved in study of exotic phases and quantum phase transitions in strongly correlated low dimensional frustrated systems, e.g., spin liquids, dimers, vector chiral phases, multipolar phases etc. The study of many body systems has been a frontier area of research in quantum condensed matter physics, and it has been a challenge to solve the Hamiltonian of these systems accurately. The widely available numerical methods such as quantum Monte Carlo methods often fail due to sign-problems in presence of frustration in spin systems or fermionic systems away from half filling. Whereas, exact diagonalization (ED) can access ground state or a few excited states only for small systems. To solve large sizes of correlated systems we use the density matrix renormalization group (DMRG) method, a state of art method, based on the systematic truncation of irrelevant degrees of freedom in the system. This method is well suited to obtain low energy excitations of large system size in low dimensions and these low energy spectrums can be utilized to get low temperature thermodynamics accurately. Our group has been actively involved in developing the DMRG algorithm for various complex systems and also studying the quantum phase transition and low-temperature properties of strongly correlated systems.

Recent research output from our group are the following:

1. We have recently applied this method to shed light on the temperature dependence of structural dimerization (spin-Peierls systems) and electronic dimerization in bond-order-wave (BOW) phase in strongly correlated spin models.

2. The anomalous enhancement of tunneling density of states (TDOS) in the Y-junction system has been interesting for decades, but there was no direct study of TDOS in these systems. We studied the TDOS and explored the criteria for enhancement. Our studies also predict that the enhancement of the TDOS is restricted only in the neighborhood of the junction of the system.

3. Our group also studied one dimensional attractive Fermi gas in presence of Zeeman field and spin-orbit coupling to explore the topological state. We show that no robust Majorana modes exist in the system even at low filling.

4. A pressure induced transition from an insulating to a Weyl semi-metal state in Bi_2Se_3 due to band inversion is predicted by our group and we also studied the effect of rare earth element doping on this transition.

Plan of Future Work Including Project

1. Our goal is to study the effect of the thermal fluctuation on the exotic phases like vector chiral, dimer and spin nematic phase (two magnon condensation state). The study of vector chiral will help us to understand the mechanism of improper kind of multiferroic material. The applications of this study can be easily done in designing magnetic switches and sensor. In these systems the mechanism of flow of spin current and thermal fluctuations in these systems are beyond the current understanding, therefore this study is very crucial for designing any future quantum devices based on the vector chiral phase. The magnon condensation in spin system is one of the most recent developments in the present context and this system promises magnon based superconductors and we hope these studies will give a boost to the conceptual foundation of future applications of these systems. The valence bond states are claimed to work as one of the qubits system in quantum computers. In the strong dimer limit, the ground state of the system behaves as the product of the multiple dimers. Our study will help in understanding the robustness of the qubits and some of these concepts may be helpful in designing the quantum computers. Moreover these studies are important from the fundamental understanding of concepts in condensed matter and quantum mechanics.