Recent Research Interest @ Saurabh Basu's Group

My group at Physics, IITG comprises of research in diverse topics and phenomena in electronic systems. The emphasis is mostly on topological phenomena occurring in a variety of models that are both of theoretical and experimental interests. One of the key interest is the exploration of topology in non-equilibrium conditions. For example, we are interested in Floquet topological aspects of different tight-binding models that demonstrate rich topological features and robust edge states. In presence of driving, the topological phase gets richer with the emergence of newer edge modes that are shifted from zero energy, albeit remain resilient to local perturbations.

Additionally, we investigate the effects of disorder and inhomogeneities, revealing emergence of Anderson localization and phases with interesting fractal properties. In particular, we find multifractal states to populate our spectrum which are discerned by the fractal and Hausdroff dimensions. These fractal states are usually indicative of a mobility edge present in the system, and a mixture of extended and localized phases. A multi-parameter scaling theory is often used to locate the critical points separating the localized and extended phases accurately. Our works have established methods for computing topological invariants in out-of-equilibrium contexts and utilized multi-modal driving to compare with the static counterpart.

Currently, we are also looking at the non-Hermitian aspects of the periodically driven models, focusing on the fate of the skin effect and constructing a non-Bloch theory and construction of the generalized Brillouin zone to recover bulk-edge correspondence in driven systems. Besides, we look at a variety of non-Hermitian Hamiltonian and try to find their electronic circuit analogues which will aid in unravelling the phenomena of topology and localization in physics labs. The circuit analogues are facilitated by an uncanny similarity between the Laplacian and the Hamiltonian, both of which possess the same form at resonance conditions.

Another aspect of our research deals with higher order topology which has emerged as a variation of the traditional (first order) topological systems, and have edge modes typically occurring in less than the spatial dimensions by two (instead of one as in first-order insulators). This poses a challenge in defining the topological invariant, as most of the conventional quantities fail to characterize these insulators. The symmetry analyses of these systems along with studying topological transitions (sometimes even re-entrant transitions, for example, first-order → second-order → first-order) etc form a significant part of the research. Again, disorder plays a crucial role, whose effects on various phase transitions need to ascertained.

Further, we also investigate topological phases in interacting systems. For example, how the presence of electron-electron and electron-phonon interactions induce plausible occurrence of topological phase transitions induced by these interactions in multiband systems (especially the one flat-bands that promote strong electronic interactions), such as alpha-T3 and Kagome lattices. Our study may be applicable to exploring correlation-driven exotic topological phases in novel quantum materials.

We also have expertise in dealing with skyrmions and magnons in magnetically ordered materials. Notionally similar topological phases arise in magnetic systems as well, whose properties can be precisely tuned via controlling the magnon band topology. Berry curvature, Chern number and the quantized Hall conductivity with no modification in their nomenclature, albeit conceptually carrying distinct implications.

The group also specializes in building devices based on graphene and its variants that should have significant impact on the study of spintronics. Particularly, we are focussing on analytically studying the (both spin and charge) persistent currents in a ring geometry. Also we study spin filtering phenomenon within a Rashba-coupled alpha-T3 annular disk to analyze its spin polarization charateristics to assess its utility as a spin-filter or a spin-diode. Additionally, we aim to explore the magnetoconductance effect in an alpha-T3 Corbino disk which has been conceptualized as quantum Hall pump.