

## **Thesis Abstract: Exploring Tunable Light-Matter Interaction and Topological Exciton-Polaritons using Anisotropic Two-Dimensional Materials**

Strong light-matter interaction, especially in the form of hybrid light-matter quasiparticles called exciton-polaritons, has emerged as a hotbed of condensed matter and photonics research. Realizing exciton-polaritons offers interesting possibilities like highly efficient polariton lasers, room temperature Bose-Einstein condensation, valley coherence and optical multi-stable switches. Recently, more focus has been directed toward the inherently non-Hermitian nature of exciton-polaritons. Non-Hermitian topology can lead to non-intuitive behavior in condensed matter systems, thus offering interesting possibilities in terms of applications in photonics, like robust single-mode lasing, enhanced sensing and topologically protected states.

Transition metal dichalcogenides (TMDs) are a family of semiconductors that have been shown to possess excitons with uniquely large binding energies when reduced to their monolayer form. Group VII TMDs like Rhenium disulphide ( $\text{ReS}_2$ ) possess anisotropic crystal structure, giving them a complex electronic band structure which leads to the existence of highly polarized excitons, which remain strongly bound even at the bulk limit. Anisotropic exciton-polaritons which possess polarization-dependent properties inherited from their parent excitons can thus be realized by utilizing such materials, which can lead to a plethora of interesting phenomena and applications.

To facilitate the realization of such polaritons, this thesis initially delves into an in-depth study of the excitonic properties of  $\text{ReS}_2$ . Reflectance measurements are utilized to extract the complex dielectric permittivity of the material and reveal dispersion of optical axes and the signature of two highly polarized excitons,  $X_1$  and  $X_2$ . Due to their linearly polarized dipole moment, their interaction strength with incident polarized light can be controlled by rotating the polarization. This is evident in the subsequent study, wherein a thick  $\text{ReS}_2$  layer placed on a dielectric mirror leads to the formation of exciton-polaritons whose coupling strength can be tuned from strong to weak coupling regimes using the incident light polarization. We also observe two polarized polariton bands which correspond to the prominent exciton species and their Rydberg excitations.

Furthermore, when few-layer  $\text{ReS}_2$  is embedded in a microcavity, we find a complex polariton band structure which we probe using polarization-resolved Fourier imaging. As in the case of open cavity, we realize polaritons with polarization-tuned light-matter coupling. The inherently dissipative nature of the exciton-polaritons makes this the ideal platform for observing exceptional points (EPs), which showcase the non-trivial topology of the system. Further detailed study using transverse electric (TE) and transverse magnetic (TM) polarized modes of incident light reveals Fermi arcs in the polariton band structure. We develop an anisotropic Lorentz oscillator model which explains the observed polariton bands.

The realization of anisotropic exciton-polaritons with non-trivial topology serves as a stepping-stone to realize intriguing phenomena like thresholdless Raman lasing and optical polarization and coherence switches. Thus, this work creates a rich platform which can be utilized to observe non-Hermitian condensed matter phenomena in a hybrid light-matter system.

**Keywords:** Two-dimensional materials, Anisotropic exciton, Rhenium disulfide ( $\text{ReS}_2$ ), Exciton-polariton, Light-matter interaction, Non-Hermitian topology.