Summary

Noise, often perceived as a disturbance, can provide crucial insights into the properties of mesoscopic systems. Quantum noise, defined as current-current correlation, can offer insights into quantum transport that conductance alone cannot. It has been instrumental in studying various quantum phenomena, including quantum statistics, wave-particle duality, and has been used as an entanglement detector as well, study the charge of transported particles. There are two distinct contributions to quantum noise: shot noise and thermal noise.

In this thesis, we explore charge transport in different mesoscopic junctions through charge quantum shot noise at zero temperature as well as temperature gradient-generated Δ_T noise. In chapters 2 and 3, we investigate different pairing symmetries of unconventional superconductors in one or two dimensions, distinguishing them via quantum shot noise auto-correlation or cross-correlation. In chapter 4, we examine the Δ_T noise at zero bias voltage with finite temperature gradient in mesoscopic hybrid junctions with an insulator at the interface.

Distinguishing different pairing symmetries in unconventional superconductors has always been challenging. One such outstanding problem is in Iron Pnictide superconductors, wherein the unambiguous detection of the two-band and sign-reversed pairing symmetry is not yet experimentally possible. In this thesis, through the differential conductance and differential shot noise in both metal-insulator-metal-insulator-Iron Pnictide superconductor junction as well as in ferromagnet-insulator-metal-insulator-Iron Pnictide superconductor junction, we probe the pairing symmetry of Iron Pnictide superconductors. In the tunnel limit, differential shot noise vanishes for $s_{\pm}$ pairing, whereas it

remains finite for s_{++} pairing, enabling an effective distinction between these two pairing symmetries.

Furthermore, unconventional superconductors can be classified as either topological or non-topological based on the preservation or breaking of time-reversal symmetry, chiral symmetry, and particle-hole symmetry. Using non-local shot-noise correlations (Hanbury Brown and Twiss (HBT) correlations) and non-local conductance in metal–unconventional superconductor–metal junctions, we explore the pairing symmetries: topological vs. non-topological in unconventional superconductors. We find that the Hanbury Brown–Twiss (HBT) correlations (or, shot-noise cross-correlations) is positive for the s, $d_{x^2-y^2}$, chiral-p, and chiral-d pairing symmetries, whereas it remains negative for the $p_x\hat{z}$ and d_{xy} symmetries over the entire bias voltage range V_2. In the transparent limit, the correlations vanish at $V_2 = -V_1$ for all pairing symmetries, while exhibiting distinct behavior for different pairing symmetries in the tunnel limit. HBT correlations for topological superconductors (chiral-p and chiral-d), vanish at $V_2 = -V_1$, remain positive over small bias voltage range, and become negative as the bias approaches $eV_2 \rightarrow \pm\Delta$ in the tunnel limit. In contrast, for non-topological superconductors (s and $d_{x^2-y^2}$), the correlations vanish at zero bias ($V_2 \rightarrow 0$) and change sign with the polarity of V_2 in the tunnel limit. For non-topological ($p_x\hat{z}$ and d_{xy}) superconductors, the HBT correlations in the tunnel limit are negative across all bias voltages. Topological superconductors are linked to Majorana fermions, which are crucial for topological quantum computing. By differentiating topological from non-topological superconductors, our study contributes to the search for Majorana fermions, aiding in the design of topological quantum computers.

Finally, unintentional temperature differences in experimental measurements can sometimes result in abrupt noise, potentially being mistaken for noise stemming from other subtle effects. This Δ_T noise, which arises because of a finite temperature difference at vanishing charge current has been a recent area of focus in mesoscopic physics. In our work, we investigate the Δ_T noise both at zero applied voltage bias but at a finite temperature gradient in a mesoscopic normal metal-insulator-normal metal (NIN) junction with an insulator. Δ_T noise increases quadratically with an increase in temperature gradient ΔT in a NIN junction.