

Abstract

Superconducting nanowire single-photon detectors (SNSPDs) are widely used in various fields of physics such as quantum communication and astrophysics, due to their high efficiency and timing precision. Developing an SNSPD requires a deep understanding of the superconducting and optical properties of the thin, disordered superconducting nanowires used in these detectors. This thesis is devoted to the development of a single photon detector with a strong focus on the electronic and optical properties of disordered superconductors. We present several experimental methods for thin film characterization in a broad frequency range and study thin disordered films of NbN, NbTiN, and MoC. Microwave spectroscopic measurements of disordered MoC films were performed, and from the modified complex conductivity, the Dynes broadening parameter Γ was extracted. This broadening increases the kinetic inductance of the thin films and the devices based on disordered superconductors, such as SNSPDs. Next, the effect of quantum corrections in the optical conductivity of thin NbN films was investigated, and its effect on the SNSPD absorption was numerically calculated. Moreover, we developed and evaluated the performance of a cryogenic amplifier in an SNSPD readout circuit, and a high electron mobility transistor (HEMT) was characterized at cryogenic temperatures, operating in a low-power, unsaturated regime, suitable for SNSPD applications. The experimental setup for detector measurement was developed in a ^3He sorption refrigerator and a $^3\text{He}/^4\text{He}$ dilution refrigerator with a top-loading probe, which is utilized for fast cooldown. The less-known nuances of current-voltage measurements in nanobridges/nanowires are explained, together with experimental results supporting the arguments. The time-domain pulse measurements of the SNSPD detection efficiency were performed, and the effects of interference on the experiment are discussed. Lastly, a novel method for alignment of the optical fiber to the SNSPD is presented, which complements the standard reflectivity measurement, and allows for estimation of the fiber coupling and photon absorption efficiency of the SNSPD at room temperature.

Key words: Disordered superconductors, single photon detector, optical conductivity, thin films, SNSPD