Abstract

The development of quantum technologies has paved the way for applications such as quantum imaging, quantum computing, quantum information processing, and quantum communication, which are superior to earlier conventional technologies. Single-photon detectors (SPDs) are crucial elements in these emerging technologies. Superconducting Nanowire Single-Photon Detectors (SNSPDs) – a type of SPD that plays a vital role in these applications and is preferred over similar devices due to its superior performance. Compared to conventional single-photon detectors, superconducting single-photon detectors offer higher detection efficiency, lower timing jitter, and reduced dark count rates. The choice of materials, techniques, and designs is essential for utilizing these detectors for various applications. This study conducts a systematic and detailed analysis of the superconducting properties of thin and ultra-thin films of vanadium nitride produced using DC magnetron sputtering for its application as a photon detector. The thickness of the films ranged from approximately 7.5 nm to 50 nm, with the nitrogen and argon pressure in the ratio of 3:5. The critical temperature (Tc) of the films fell within the range of 5.36 K to 9.51 K. Additionally, a transition from the 3-D regime to the 2D regime is observed as the film thickness is reduced. The observed superconducting properties are excellent and are assessed in terms of critical temperature, critical magnetic field, variation in Tc with changing magnetic field, diffusivity, coherence length, and other factors. These films are then used to develop nano-structures and are tested with varying optical power at low temperatures. The alternative to nano-structure fabrication required for developing these detectors is also an open area of research. An optical detector made of NbTiN superconducting thin film patterned in spiral form with a length of ~ 72.20 mm is also demonstrated. The preliminary results align with the one already available using nano-structures and appear to

be a good substitute. The instrumentation used for characterizing SNSPDs must be precise and reliable so that no optical event gets missed. For this, an optical setup based on the 2nd-order correlation measurement is developed to characterize single-photon detectors at visible and infrared wavelengths. The response of each device used in the setup has been thoroughly characterized and studied. The setup can generate a few photons, split the beam in the ratio of 50:50 approx., align the beam in the desired direction and measure the coincidences.