Abstract:

We are developing novel quantum-limited detection tools for the characterization of entanglement in circuits comprising superconducting quantum bits (“qubits”) and linear thin-film microwave resonators. We have realized a detector of single microwave photons based on the current-biased Josephson junction. The design is readily scalable to tens of parallelized detection channels, a configuration that will allow number-resolved counting of microwave photons. In addition, we have developed a novel low-noise microwave amplifier based on the Superconducting Low-inductance Undulatory Galvanometer (SLUG). The device should achieve noise performance approaching the standard quantum limit in the frequency range from 5-10 GHz.

Summary of Research:

We are developing two classes of novel quantum-limited detection tools for the study of entanglement in systems comprising superconducting qubits and microwave thin-film cavity resonators.

First, we are developing a novel microwave counter based on the Josephson junction. The junction is tuned to absorb single microwave photons from the incident field, after which it readily tunnels into a classically observable voltage state. Using two such detectors, we have performed a coincidence counting version of the Hanbury Brown and Twiss experiment at 4 GHz and demonstrated a clear signature of photon bunching for a thermal source. The design is readily scalable to tens of parallelized junctions, a configuration that would allow number-resolved counting of microwave photons for state reconstruction or for studies of the full counting statistics of microwave noise emitted by mesoscopic conductors. In addition, we are developing microwave amplifiers based on the Superconducting Low-inductance Undulatory Galvanometer (SLUG). The low-inductance gain element is integrated into a microwave thin-film resonator, providing for efficient coupling of a microwave-frequency signal to the SLUG. Gain in excess of 20 dB has been demonstrated at frequencies over 8 GHz, with bandwidth of order 100 MHz. System noise temperatures of 1 K have been measured; the amplifier noise is currently limited by hot electron effects. We expect that optimized devices should achieve noise performance approaching the standard quantum limit for linear phase-insensitive amplifiers.

We have used the CNF to fabricate reticles that are needed for the preparation of thin-film superconducting devices at the Wisconsin Center for Applied Microelectronics (WCAM). Superconducting aluminum and niobium thin films are grown by sputter deposition, while dielectric films are grown by plasma-enhanced chemical vapor deposition. The films are patterned photolithographically and etched with chlorine- and fluorine-based reactive ion etching. Device characterization is performed at millikelvin temperatures in our laboratories at the University of Wisconsin.
Figure 1: Multiplexed microwave photon counter sample comprising two fluxed-biased Josephson junctions coupled to a single microwave cavity.

Figure 2: Superconducting Low-inductance Undulatory Galvanometer (SLUG) gain element used in ultralow-noise microwave amplifier.