Abstract:

Various applications in the rapidly growing field of quantum information science require reliable and efficient quantum light sources. We observed superconducting proximity in semiconductor light-emitting diodes. These hybrid structures were proposed by us as an efficient approach for generation of entangled photons, based on Cooper-pair luminescence in semiconductors, which does not require isolated emitters. Semiconductor quantum wells, remove the light-heavy-hole degeneracy, allowing efficient photon entanglement generation in simple electrically-driven structures, taking advantage of the superconducting macroscopic coherence. Based on the developed theory we analyzed a new effect of enhanced light amplification in electrically-driven semiconductor-superconductor structures, including Cooper-pair based two-photon gain. Moreover, we proposed a compact and highly-efficient scheme for a complete Bell-state analysis using two-photon absorption in a superconducting proximity region of a semiconductor avalanche photodiode. This Cooper-pair based two-photon absorption results in a strong detection preference of a specified entangled state.

Realizing high-T_c superconductors-based quantum light sources paves the way widespread use of quantum technologies. In our experimental studies we investigated hybrid high-$T_c$superconductor-semiconductor tunnel junctions. These devices were fabricated by the newly-developed mechanical bonding technique, resulting in high-T_c semiconductor planar junctions acting as superconducting tunnel diodes. Tunneling-spectra characterization of the hybrid junctions of BSCCO combined with bulk GaAs, or a GaAs/AlGaAs quantum well, exhibits excess voltage and nonlinearity. A nanoscale thin film YBCO/GaN device was also demonstrated based on PLD growth. We produced high-temperature superconductivity in topological insulators Bi2Se3 and Bi2Te3 via proximity to BSCCO, persisting up to at least 80K – a temperature an order of magnitude higher than any previous observations.