Superconducting Nanowire Single-Photon Detectors

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Nanotechnology is often billed, inspirationally, as the next frontier for active electronic and photonic devices. But so far, with the prominent exception of semiconductor devices, few optical or electronic devices with nanometer-length-scale features have found utility in real-world systems. But a new sensing technology based on superconductive nanowires may change that situation.

At present, single photon sensing in the infrared is limited, primarily because of the large bandgap of silicon, which makes silicon detectors inefficient at wavelengths above ~ 900 nanometers (the near infrared). Instead of silicon, detectors must be made out of materials like gallium arsenide, or indium phosphide. These materials suffer from a variety of non-idealities that limit the speed of the devices, and make scaling to a detector array difficult. Even photomultiplier tubes, the mainstay of single-photon detection, exhibit only ~ 1% efficiency at a wavelength of 1.55 μm (the standard wavelength of the telecommuni-

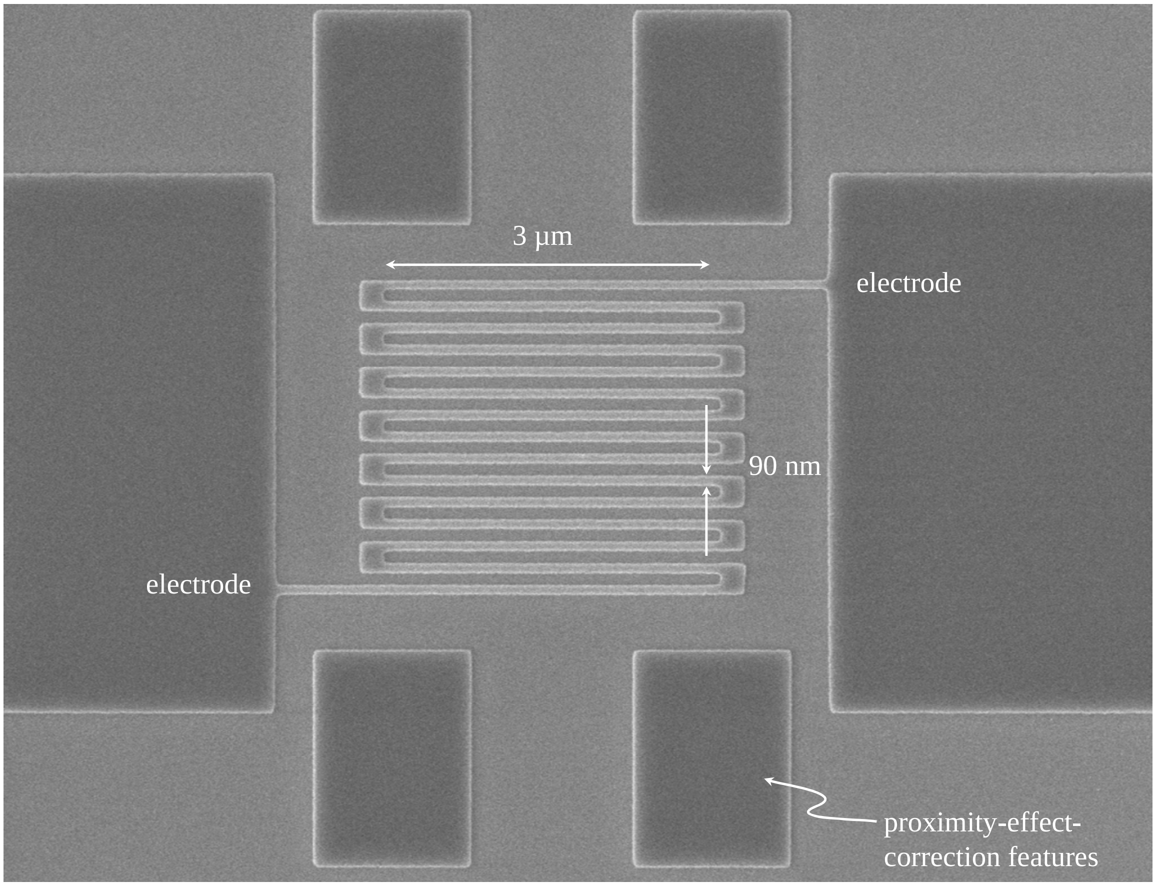

Figure 1: Top-down scanning-electron micrograph showing a "typical" device, including electrode structures and dummy features for proximity-effect correction. When integrated with an optical microcavity, the resulting 90-nm-wide superconductive nanowire can detect single photons at 1.55 μm optical wavelength with ~70% device detection efficiency, 3 ns reset time, and 30 ps jitter.

cations industry). But a new kind of single-photon detectors, invented at Moscow State Pedagogical University and the University of Rochester, and now being developed at MIT, can use nanometer-length-scale superconductive wires to detect individual infrared photons. Our group, in collaboration with MIT Lincoln Laboratory, has demonstrated a 57% detection efficiency for this device, while maintaining a reset time of 3 nanoseconds and a jitter (timing error) of only 30 picoseconds: a performance orders of magnitude beyond what would be possible using any competing photodetection technology.

The implications of this result are twofold: first of all it is an interesting example where nanoscale fabrication enables novel devices for real-world systems; and second, for photodetection, it provides a tool that can be used to sense single photons with unprecedented speed and sensitivity. The applications thus enabled include ultra-secure communication using the quantum state of single photons to encode light, high-speed infrared microscopy and imaging, and ultra-long range (even interplanetary) communication. We will focus our discussion on the required nanofabrication technology, especially novel electron-beam lithography techniques and characterization of the physical device structure, and the resulting device performance.

This work was sponsored in part by the United States Air Force under Air Force Contract #FA8721-05-C-0002. Opinions, interpretations, recommendations and conclusions are those of the authors and are not necessarily endorsed by the United States Government.