The magnetic field response of nanowire superconducting single-photon detectors

Main author:

RENEMA Jelmer

Co-authors:

Aarts Jan, Huygens-Kamerlingh Onnes Lab

de Dood Michiel, Huygens-Kamerlingh Onnes Lab

Driessen Eduard, IRAM Grenoble

Fiore Andrea, COBRA Research Institute, Eindhoven University of Technology

Gaudio Rosalinda, COBRA Research Institute, Eindhoven University of Technology

Kes Peter, Huygens-Kamerlingh Onnes Lab

Komen Irina, Huygens-Kamerlingh Onnes Lab

op 't Hoog Koen, COBRA Research Institute, Eindhoven University of Technology

Renema Jelmer, Huygens-Kamerlingh Onnes lab

Rengelink Roberts, Huygens-Kamerlingh Onnes Lab

Sahin Dondu, COBRA Research Institute, Eindhoven University of Technology

van Exter Martin, Huygens-Kamerlingh Onnes Lab

Wang Qiang, Huygens-Kamerlingh Onnes Lab

Wang Qiang, Huygens-Kamerlingh Onnes Lab

Zhou Zili, COBRA Research Institute, Eindhoven University of Technology

We investigate the photoresponse of nanowire superconducting single photon detectors (SSPDs) in an external magnetic field. We demonstrate experimentally that the change in photodetection probability is caused by direct modification of the electronic state of the wire. By observing the magnetic field scale associated with this process, we settle the question of whether it is possible to enhance the detection efficiency of an SSPD by applying a magnetic field: for a straight wire, this is not possible.

SSPDs are a crucial technology both for fundamental research and technological applications. These detectors consist of a thin film of superconducting material, patterened into a superconducting wire, typically 100 nm wide and 4 nm thick. When biased closed to the critical current, photodetection events occur in the wire. Since superconductivity is generally weakened by the application of a magnetic field, it is natural to imagine that a detector which functions by breaking superconductivity will function better in an external field.

In our work, we demonstrate that the detection mechanism is indeed enhanced by the presence of an external magnetic field. We find that for low fields (< 50 mT), curves of constant count rate depend quadratically on the applied field. This result shows excellent quantitative agreement with a prediction based on the Usadel equation as applied to a homogeneous, current-carrying wire. At higher fields, we find deviations from this behaviour, which we interpret as being due to the permanent presence of a pinned vortex at the center of the detector. In the same experiment, we measure the critical current of our samples, which consist of a short (200 nm) wire and a nanodetector bridge. We find that the decrease of critical current shows a transition from a linear induced depairing regime to a power-law flux-flow regime.

Our result has implications for the study of the detection mechanism, which is a topic that has seen a flurry of activity over the last few years. The direct modification of the electronic state had not been considered in theory as a mechanism for the enhancement of the detection efficiency in an applied magnetic field.

In our experiment, the reduction of the critical current dominates over the enhancement of the detection efficiency. From this, we conclude that no enhancement of the detection efficency is possible in the present geometry. However, since the field-dependence of the critical current depends on the geometry in a known way, our results open the way for ab-initio design of detectors which have a photoresponse which is enhanced by a magnetic field.