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Applications of superconducting electronics to quantum optics and quantum metrology

SQUIDs (superconducting quantum interference devices) have been in use for more than half a century and constitute one of the first macroscopic quantum devices. SQUIDs operating at millikelvin temperatures can act as qubits for quantum computers and the recent reports of more than 50 qubit circuits indicate how far the technology has developed. In this talk, the author will describe two other applications of SQUIDs as quantum detectors, focusing on single spin and single photon energy resolving detection. Most superconducting devices rely on tri-layer Josephson tunnel junctions which are not easily scalable to the nanoscale. We have developed a Josephson junction fabrication method, based on electron beam lithography or focused ion beam milling of a single thin film of superconductor (Nb generally) which can provide sizes down to 50 nm. These devices are particularly relevant for two main applications in quantum technology and metrology. First, by shrinking the size of the SQUID loop and the junctions to around 200 nm, the sensitivity of the SQUID for magnetization measurements is improved to the level where a single electron spin flip may be detected. This is possible at the relatively elevated temperature of 4K. We are working with Surrey University to implant single magnetic ions within the SQUID loop to provide a platform to test this combination as the basis for a new form of qubit operating at higher temperatures than the conventional Transmon superconducting devices. A second SQUID based detector which we are developing is an inductive transition edge sensor device (ISTED) for energy resolving measurements of single photons. This is based on the development of conventional transition edge sensors where we detect the change of the penetration depth of a small thin film of superconductor when it absorbs a photon. In this way, a major source of noise in conventional TES may be avoided since the absorber remains in the superconducting state at all times. In this way we have demonstrated single photon detection at 633 nm with 0.1eV resolution at operating temperature of 7.5K.

Recent Publications

1. Tianyi Li, John Gallop, Ling Hao and Edward Romans (2018) Ballistic Josephson junctions based on CVD graphene., Superconductor Science and Technology 31(4):045004.
2. John Gallop and Ling Hao (2016) Nanoscale superconducting quantum interference devices add another dimension. ACS Nano 10(9):8128–8132.
3. John Gallop, David Cox and Ling Hao (2015) Nanobridge SQUIDs as calorimetric inductive particle detectors. Superconductor Science and Technology 28:084002.
4. Ling Hao, David Cox, John Gallop and Jie Chen (2015) Fabrication and analogue applications of nanoSQUIDs using Dayem bridge junctions. IEEE Journal of Selected Topics in Quantum Electronics 21(2):9100108.
5. L Hao, J C Macfarlane, J C Gallop, D Cox, J Beyer, et al. (2008) Measurement and noise performance of nano-superconducting quantum interference devices fabricated by focused-ion-beam. Appl. Phys. Lett. 92:192507.

Biography

Ling Hao is a Principal Research Scientist in the Quantum Metrology Institute and National Graphene Metrology Centre at the UK's National Physical Laboratory (NPL). She is a Fellow of the Institute of Physics, Chartered Physicist and a Visiting Professor at Imperial College London, Fudan University (Shanghai) and Harbin Institute of Technology, China. She has published more than 180 research papers in refereed journals as well as five book chapters. She is working on applications of quantum science, nanoscience, superconducting electronics and microwave technology for quantum metrology and technology and precision measurements, aimed at single particle measurements and quantum sensor and metrology with nanoSQUIDs, nanoelectromechanical system (NEMS) resonators and high Q microwave resonators; also on transport measurements and applications of quantum materials (graphene, other 2D materials and carbon nanotubes).

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