Quantum filter has 20,000 Josephson junctions

May 3 2016, by Bob Yirka

(Phys.org)—A team of researchers at CSIRO Manufacturing, in Australia has created several test quantum filters with arrays having as many as 20,000 Josephson junctions. In their paper published in *Superconductor Science and Technology*, the team describes their filters, how they were constructed, tuned and tested and several applications that they believe may benefit from their use.

The devices are a type of superconducting quantum interference filter, which work due to the use of arrays of superconducting interference devices—loops of superconductive material that is separated by Josephson junctions . Their purpose is to detect very small magnetic fields. In this new effort the researchers employed as many as 20,000 Josephson junctions in a single array which meant they were connected together in a series and in a parallel configuration all using loops. Josephson junctions in this context were devices made from two superconductive metals separated by a very thin insulator—current flowed via tunneling and it could be made to oscillate.

The Josephson junctions were constructed with loop areas of different sizes, by adding in step-like bits on top of a magnesium-oxide base. They were then covered in a very thin layer of YBCO and then an even thinner layer of gold. The process was finished by etching to fashion the loops. The team describes their study of several parameters that were related to the geometry of the arrays and characteristics of the junctions under different conditions. They noted also that they focused mainly on the impact the inductance factor had on sensitivity, varying the current and

inductance in the loops to fine tune their sensitivity.

In testing their filters, the researchers found that they were able to detect a magnetic field as faint as 1 μT, which was several orders of magnitude better than devices currently in use. They also report that they were able to identify electromagnetic radiation at multiple frequencies. They suggest similar filters might be used in future magnetometers which are commonly used in geology studies. They add that they could also be used with analog to digital converters, in amplifier applications and as antennas. One restraining factor is that the devices can only be operated at extremely low temperatures.

More information: E E Mitchell et al. 2D SQIF arrays using 20 000 YBCO highJosephson junctions, *Superconductor Science and Technology* (2016). DOI: 10.1088/0953-2048/29/6/06LT01

Abstract
Superconducting quantum interference filters (SQIFs) have been created using two dimensional arrays of YBCO step-edge Josephson junctions connected together in series and parallel configurations via superconducting loops with a range of loop areas and loop inductances. A SQIF response, as evidenced by a single large anti-peak at zero applied flux, is reported at 77 K for step-edge junction arrays with the junction number N = 1 000 up to 20 000. The SQIF sensitivity (slope of peak) increased linearly with N up to a maximum of 1530 V T−1. Array parameters related to geometry and average junction characteristics are investigated in order to understand and improve the SQIF performance in high temperature superconducting arrays. Initial investigations also focus on the effect of the SQUID inductance factor on the SQIF sensitivity by varying both the mean critical current and the mean inductance of the loops in the array. The RF response to a 30 MHz signal is demonstrated.