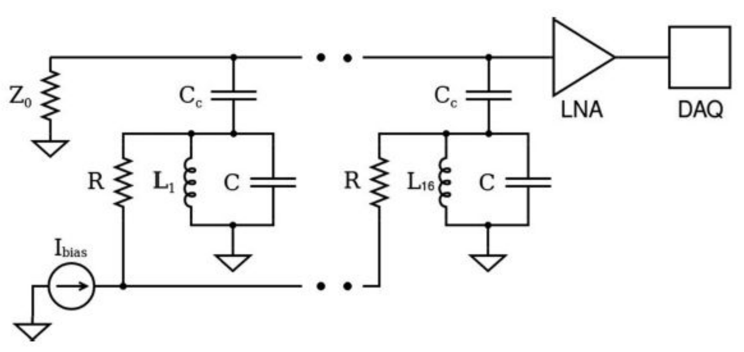
Properties of a Frequency Multiplexed Superconducting Nanowire Kinetic Inductance Detector Array

J. Glasby[1], A. Sinclair[1,2], P. Mauskopf[1,2], H. Mani[2], D. Zhu[3], M. Colangelo[3], K. Berggren[3]

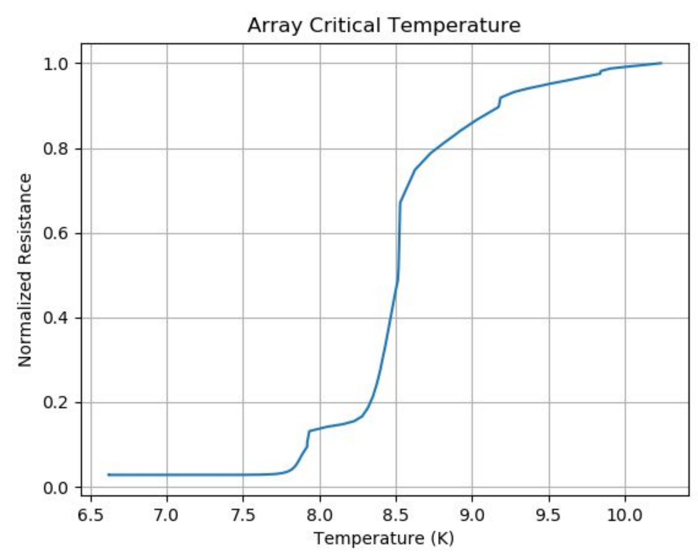
1) Arizona State University, Department of Physics
2) Arizona State University, School of Earth and Space Exploration
3) Massachusetts Institute of Technology, Research Laboratory of Electronics

Design

Superconducting nanowire single photon detectors (SNSPDs) show many promising characteristics including high detection efficiency, low dark count rate, short reset time, and short timing jitter. The major drawback in implementation is reading out a large array of cryogenically cooled detectors. To overcome this, we take advantage of the well developed kinetic inductance detector (KID) frequency multiplexed readout scheme by inserting an NbN nanowire meander to the inductive element of each KID in an array. With this setup we hope to realize some of the applications SNSPDs has to offer (e.g. intensity interferometry, deep space communication, quantum information systems).

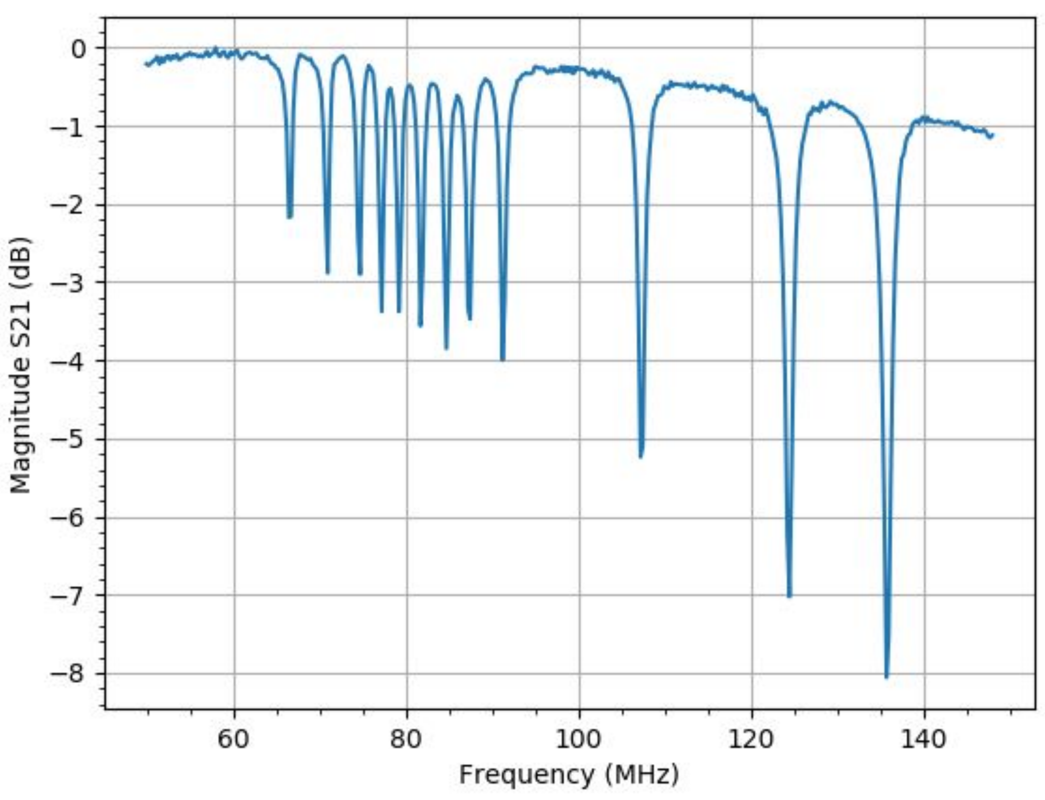


The circuit diagram of the array has a transmission line capacitively coupled (C_C) to each LC circuit. The normal inductive element is varied to determine the resonant frequency of each detector. The DC bias runs current through the inductive element, which includes the nanowire. The LNA amplifies the signal for readout.

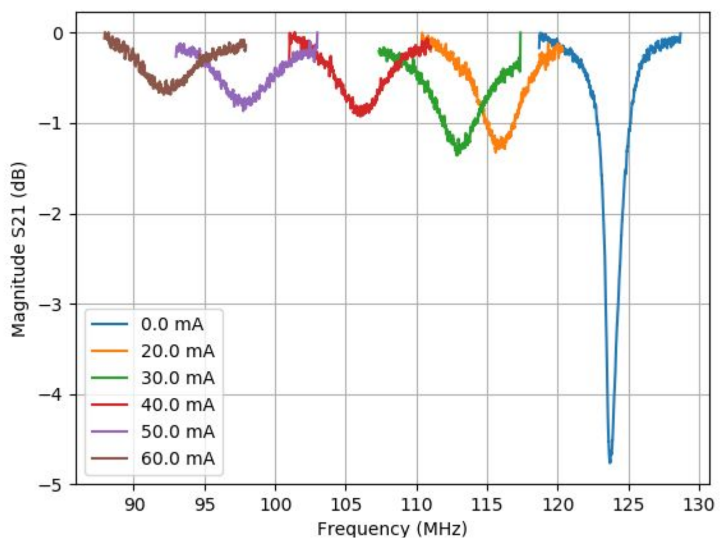


Resistance was measured through the DC bias at different temperatures to determine the critical temperature for the array. At least one of the nanowires has a lower T_C than the others.

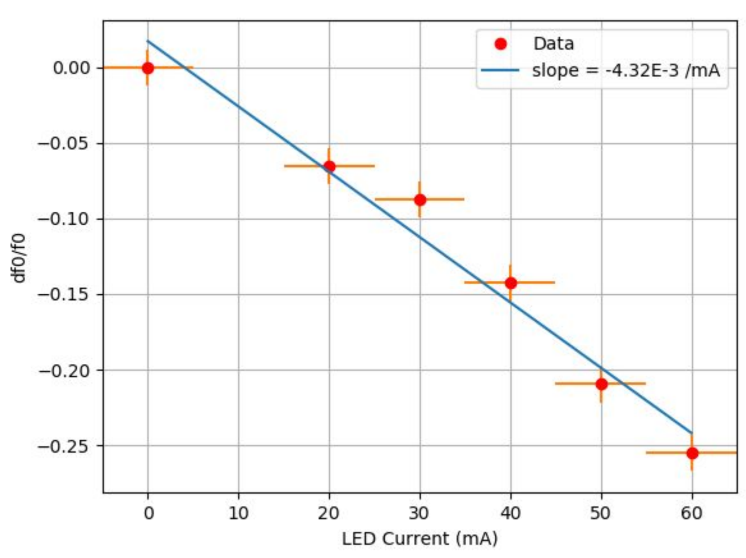
Kinetic Inductance Detector



With no DC bias, power is sent down the transmission line sweeping across the range of frequencies of interest. The dips represent the resonant frequency of each detector.



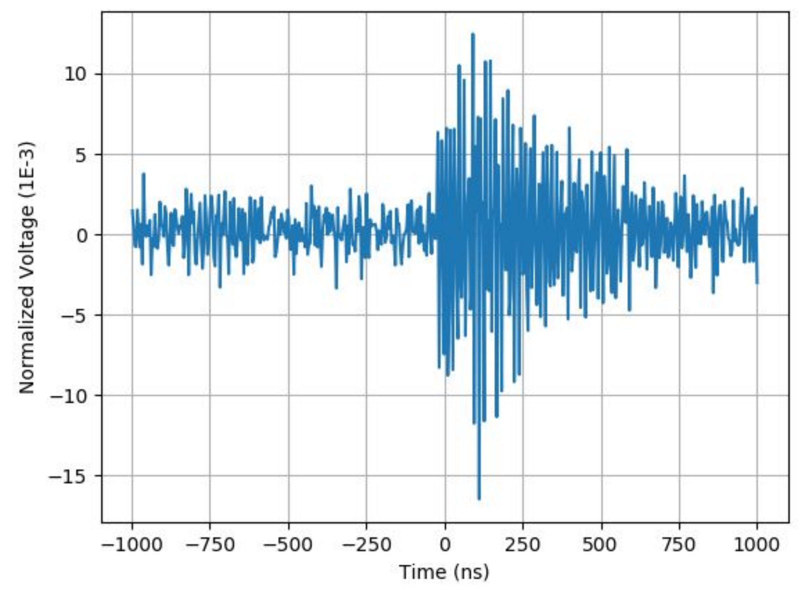
A 1300 nm LED incident on the 123 MHz detector changes the quasiparticle density shifting the resonant frequency as a function of LED bias current. The absorbed photon does not generate a pulse when operating in this mode.



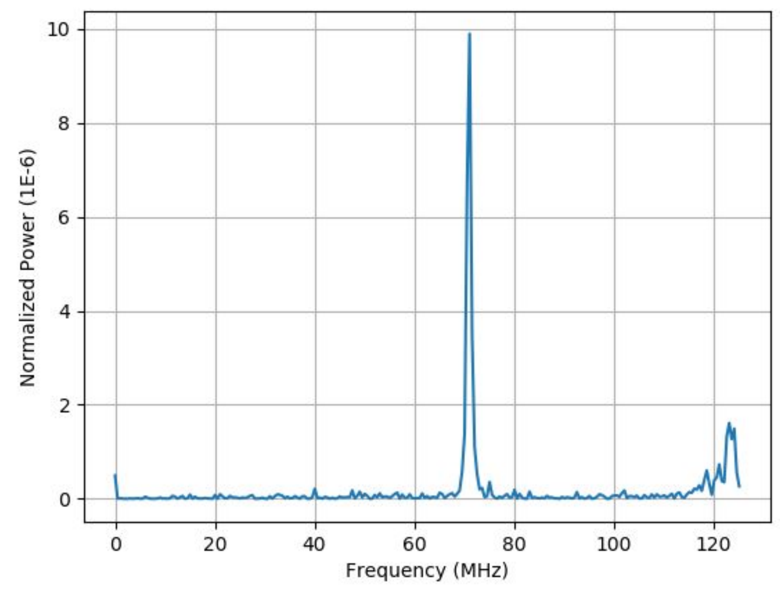
The resonant frequencies above show a linear relationship with LED bias current. For 123 MHz, a shift of about 0.5 MHz/mA in resonant frequency is observed.

Single Photon Detector

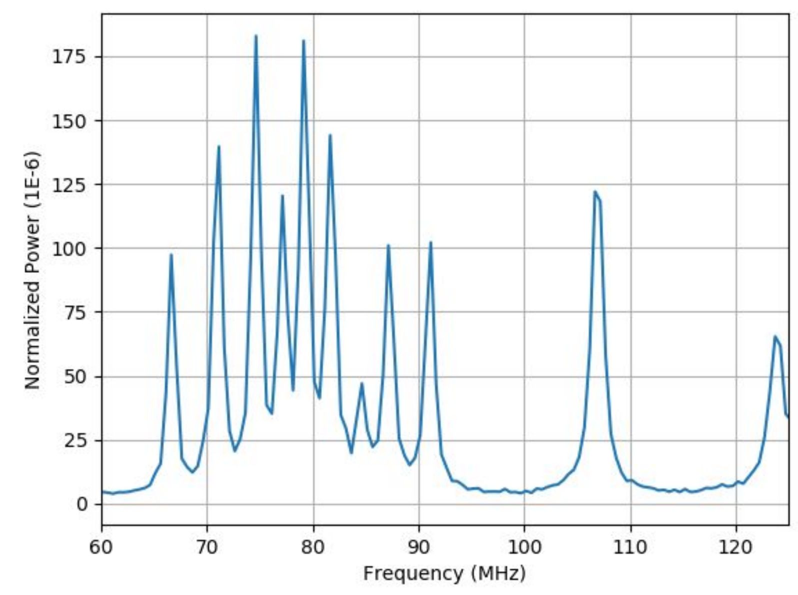
The input port on the transmission line is terminated and a DC bias is applied to the nanowires. When a photon breaks a Cooper pair a portion of the nanowire turns normal. The normal region expands to the width of the nanowire, and a voltage pulse is generated. The signal oscillates at the resonant frequency of the detector that was hit and is sent through the amplifier to be read out.



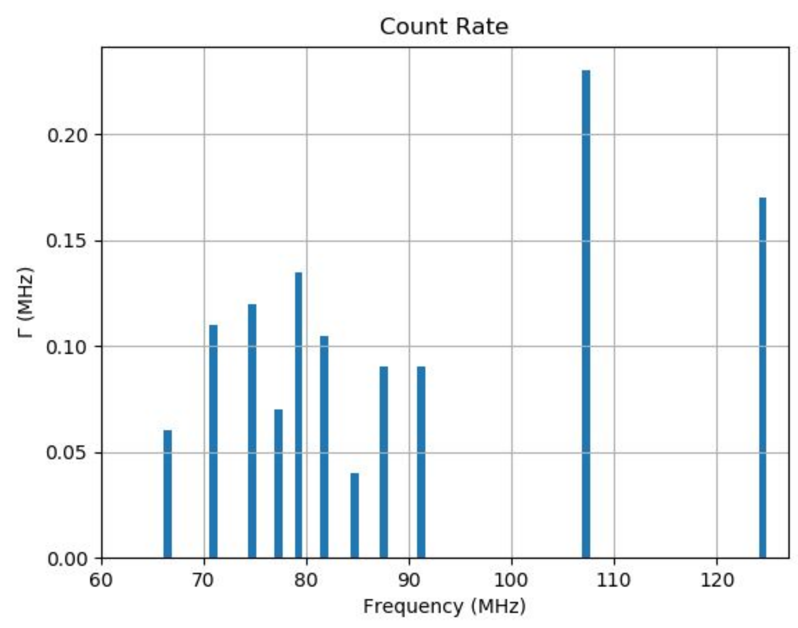
A timestream of two detectors hit near-simultaneously. The signal is amplified by a 30 dB LNA and a 40 dB Mini Circuits amplifier, then readout on a Tektronix TDS 7104 oscilloscope.



The Fourier transform of the above timestream shows which detectors were hit. The difference in amplitude results from a longer decay time in the lower frequency detectors.



A stack of each measurement in the frequency domain shows the relative power per detector. The nonuniformity is chiefly due to the positioning of the LED, however, a variation in the intrinsic properties of the nanowires appears present.



A count rate for each detector was calculated based on the occurrence in all the time streams measured. However, this is a lower limit since the measured events are a result of two separate, but nearly simultaneous detections.

Discussion: Embedding a superconducting nanowire as the inductive element of a kinetic inductance detector has shown to work as both a sensitive KID as well as a DC biased single photon detector for low energy photons. The nonuniformity in the count rate is likely due to a combination of LED positioning, and variations in intrinsic properties (e.g. quantum efficiency and critical current).

Future projects: Improve optical coupling using a fiber optic setup. Measure both timing jitter and system detection efficiency with an ultrafast light source. Develop a large array fast readout system. Fabricate single on-chip array.

22-26 JULY 2019
MILANO
LTD 18
LOW TEMPERATURE DETECTORS