Microwave Kinetic Inductance Detectors

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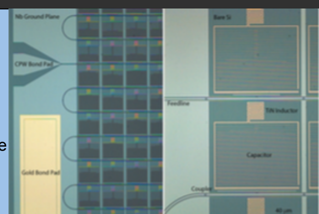
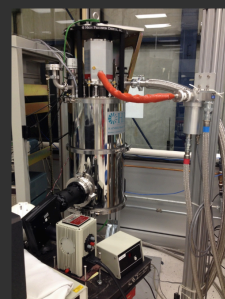
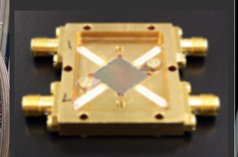
Microwave kinetic inductance detectors are cryogenic photon detectors used for astronomical observation. Introduced by Drs. Rick LeDuc and Jonas Zmuidzinas at the California Institute of Technology and the NASA Jet Propulsion Laboratory, MKID technology provides a break from semiconductor-based detector field, where advancements are quickly plateauing. MKIDs use microwave frequencies to measure the change in surface impedance of a superconductor. They operate at temperatures near 100 mK, thereby decreasing sources of thermal noise. In order to more completely understand the functionality of the device, it was necessary to test the response and resolution of individual pixel detectors, as well as investigate causes of pixel failure. Tests were run using monochromatic 400 nm light, and the output frequency data for analyzed and interpreted. MKID detector technology allows for multiplexing, and has the capacity to be scaled economically. The ultimate goal of the project is to improve the consistency and precision of this device so that it may be widely employed as a means of astronomical observation.

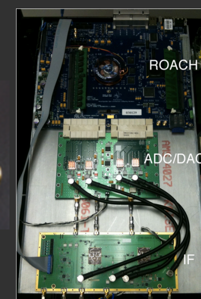
Advantages of MKIDs include:

- Reduced thermal noise
- No dark current
- Precise time resolution:
  Measures photon arrival times to μs.
- Multiplexing
  Allows MKIDs to be economically scaled to a large array of pixels
- Electron gap =milli eV
  One photon breaks 1000s of Cooper pairs







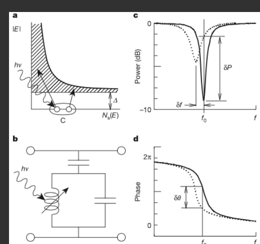


Disadvantages of current detection methods

Spectroscopy and CCDs:

- **CCDs are not capable of determining time and energy of incident photons.**
- **Filters are required to create full images, which is inefficient**
- **They only produce 2-D images**
- **Spectrographs break up light detected by CCDs**

MKIDs work on the principle of the kinetic inductance effect, or the principle that super current is stored in a superconductor, and when an incident photon strikes, it elicits a change in the current, and therefore a change in the kinetic energy. This results in a change in inductance. Inductors are placed in a resonator with a tuned microwave probe, and any changes in the inductance are recognized as changes in phase and amplitude of the probe signal. Below is a detailed description of the steps:



Labview
- "Raw" data collected from network analyzer
- Broken into 4 freq. ranges because we only have 1 IF board

→ WideSweep → A series of programs that compute LO freq. Roach config. → Configure beammap → Templar (-LO freq. can be manipulated; -DAC and LUT configured; -Attenuation sweep) → Fitting Software → Templar, again (Loops are rotated and translated) → Channelizer (-Photons detected by significant phase variation; -Threshold calculated to determine photons from noise) → ARCONS Dashboard → Raw observation data → Analysis in Arcons Pipeline

Readout Operations

Resonator is excited with resonant microwave signal
A microwave probe signal signal sent through the MKID array at certain attenuation

↓

Incident photon strikes and increases inductance

↓

Contributes to lower resonant frequency and change in amplitude

↓

Thus energy of the absorbed photon found by measuring the degree of phase and amplitude **shift**

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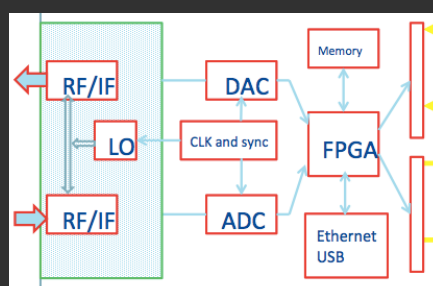
Amplified by HEMT at 3K

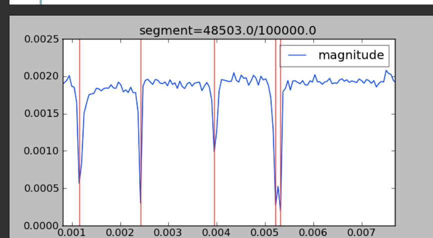
↓

Processed by firmware on FPGA

↓

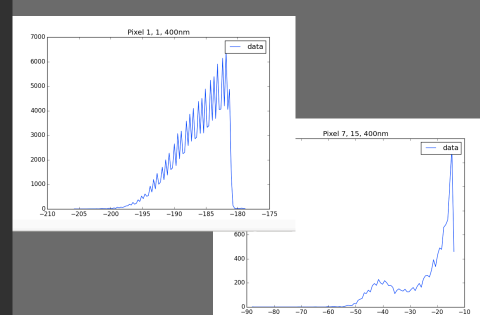
Sent to control computer for data analysis





Pictured above are pixels that appeared abnormally close together in WideSweep. This is reputed to be caused by variations in TiN gap.
Qualitatively, it was found that at ~250 kHz distance, the pixels exhibited very poor quality.

Tests were done to determine whether the load oscillation frequency value contributed to the performance quality of the resonant frequency set. The LO value was varied from the specified value in .1 GHz intervals.
The first as well and fourth set of frequencies were tested using these parameters. Altering the LO freq. did not effect the quality of poor performance set, as was hoped.



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August 2015

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