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Design and performance of MAKO, a 350 μm camera for the CalTech Submillimeter Observatory

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We present the current status of MAKO, a far-infrared ($\lambda=350 micron$) camera built for operation at the CalTech Submillimeter Observatory (CSO). MAKO has been designed and iterated with a focus toward increasing pixel count, multiplexing density and sensitivity while simultaneously decreasing detector fabrication complexity and readout cost. A detector design of low complexity is required if far-infrared cameras are to reach the large scale ($10^{4} - 10^{5}$) arrays needed for future ground based telescopes, and can offer improved capability for existing telescopes in the interim.

To reach large-scale arrays a candidate technology must simultaneously achieve high multiplexing density, sufficient optical sensitivity, high fabrication yield, and low per pixel readout costs. The MAKO detectors are built around the lumped element kinetic inductance detector (LE-KID) chosen for its straightforward fabrication process and inherent multiplexibility. The LE-KID pixel consists of a superconducting-microresonator with a long meandered strip which serves both as an inductor and optical absorber; to generate an LC resonance frequency it is fabricated in parallel with an interdigitated capacitor. MAKO uses a new inductor geometry which allows it to absorb incident radiation in both polarizations. A single coaxial line can be used to read out potentially thousands of pixels all at their individual resonant frequency. The superconducting material has some kinetic inductance (L_{K}) from the cooper pairs. The absorption of radiation breaks these pairs creating quasiparticles and changes the inductance, shifting the resonant frequency and giving the detector its

optical response. The LE-KID architecture offers simple fabrication and high yield; the current MAKO design uses a single superconducting layer and has a fabrication pixel yield greater than 95%.

For MAKO we use Titanium Nitride (TiN) as the superconducting material. Its high normal resistivity ($\rho_{N} \sim 10^{-6} \Omega m$) allows both easy impedance matching to the incident radiation and the ability to generate inductances which are compatible with our LC frequency goals. Traditional KIDs have been made with resonant frequencies in the microwave (MKIDs); however TiN has allowed these to be pushed down in to the radio-frequency (RF) with resonant frequencies well below 250 MHz. This allows for the elimination of mixer and intermediate-frequency (IF) stages and a significant reduction in our per-pixel readout costs.

The first generation of the MAKO detectors were deployed at the CSO in April 2013 which demonstrated both reasonable detector sensitivity and the readout of more than 400 pixels on a single RF coax cable pair for operation at 350 microns. The second generation of the detector has been improved by increasing the optical response using a microlens array, and decreasing the noise through an improved capacitor design. Both on sky and lab results from that array will be presented, as well as the detector design rues that enabled the development of a 120 pixel, 850 micron array. Results from lab testing of new detectors as well as results from operation at the CSO in 2015 will be presented.