JPL / Caltech KID Development for Far-IR / mm-Wave Spectroscopy

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Abstract—I will provide a brief overview of two projects developing kinetic inductance detectors (KIDs) in the micro-devices laboratory (MDL) at JPL. Both systems use lumped-element resonators in the 100-400 MHz band, and have demonstrated sensitivities below (better than) the photon noise for their intended applications.

The first is the SuperSpec on-chip spectrometer. SuperSpec consists of a filterbank covering the full 190-310 GHz band patterned in superconducting niobium-on-silicon-nitride microstrip, integrated with an array of 300 titanium-nitride (TiN) kinetic inductance detectors (KIDs). Light is coupled onto the 1-micron-wide microstrip with a planar antenna, and the filterbank channels are formed with half-wavelength sections of the microstrip coupled via proximity to both the main trunk line and the TiN KIDs. The filterbank electromagnetic design has been optimized to provide high efficiency at a resolving power of ~300. The active portion of each SuperSpec KIDs is 20 nm film of TiN patterned into a meander with 0.25-micron wide lines. The total inductor volume is 3 cubic microns, the small value is key for high responsitivity and good sensitivity. We have demonstrated a noise equivalent power (NEP) of $4\text{x}10^{-18}$ W $\text{Hz}^{-1/2}$ at the operating temperature of 220 mK, and an even lower $8\text{x}10^{-19}$ W $\text{Hz}^{-1/2}$ when cooled to below 120 mK. The 1/f knee frequency is at or below 1 Hz for these devices. We are currently preparing for a SuperSpec demonstration at the Large Millimeter Telescope (LMT) in late 2018.

The second is a horn-coupled direct-absorbing aluminum device under development for far-IR applications including the proposed STARFIRE balloon-borne spectrometer covering 240-420 microns at R=500. A direct-drill multi-flare-angle horn couples incident radiation into a circular waveguide which illuminates the inductor / absorber. The inductor / absorber is 30 nm film patterned into a 300-micron diameter circular meander which couples both polarizations. The silicon substrate is etched from the backside to create a quarter-wave backshort. We have carefully characterized noise both dark and under loaded, and response using a cryogenic blackbody and 350-micron bandpass filter. The devices demonstrate optical efficiency as expected from simulations, and a device NEP of $4\text{x}10^{-18}$ W $\text{Hz}^{-1/2}$. These devices also have a 1/f knee around 1 Hz. The run of noise and response with applied load constrains the quasiparticle recombination dynamics, and we infer that the current devices have maximum quasiparticle lifetimes of ~20 microseconds, which limits the NEP. We are currently pursuing higher quality aluminum which we expect will provide longer lifetimes and thus lower NEP.