Infrared Spectroscopic Imaging Array based on Single-Photon Calorimetry

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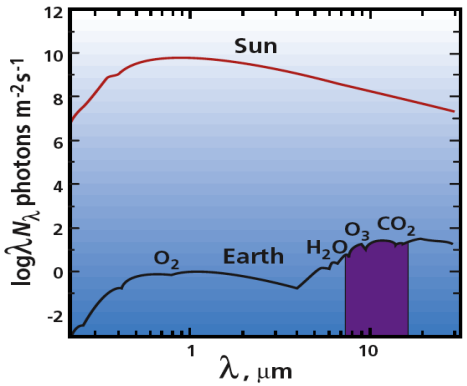
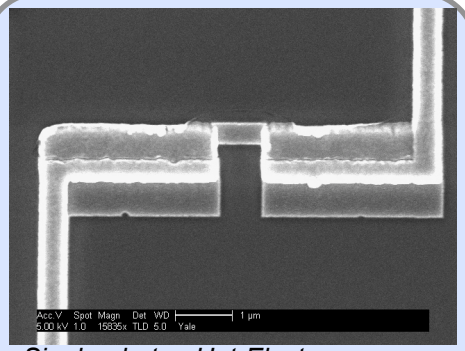
Motivation



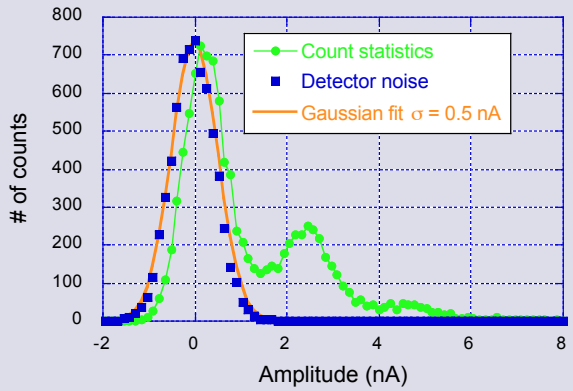
- *Spectroscopy of life-tracing molecules in atmospheres of Earth-like exoplanets*
- *Spectral resolution $\lambda/\delta\lambda$ ~ 50 is needed; photon flux ~ 0.5 photon/sec.*

New Insight: Quantum Calorimeter



Single-photon Hot-Electron Nanobolometer (nano-HEB) can provide energy resolution ~ 100 in in the mid-IR without using dispersion optical elements

Achievements



- Detection of single 8-μm photons with the energy resolution ~ 2 has been achieved
- Submicron-size nano-HEBs coupled to mid-IR micorantennas have been developed and fabricated

HOW IT WORKS:

- Radiation couples to the superconducting nano-HEB via a small antenna
- One single mid-IR photon increases the device temperature so much that it becomes almost normal metal
- Because of the small device volume and low temperature the noise is small so ~ 1% differences in the photon energy can be distinguished
- Large array of single-photon calorimeters would provide a spectral image of the faint IR objects in space

Future Work

- Comprehensive study of energy resolution, count rate, and quantum efficiency vs temperature, wavelength, and device size
- Characterization of the radiation coupling efficiency in antenna-coupled devices
- Optimization of the nano-HEB material (reduction of T_C, smaller superconducting film thickness, antenna impedance match to the device resistance)
- Design and characterization of the optical front-end using either a plate of germanium lenslets or silver halide single-mode fibers
- Demonstration of a small single-photon calorimeter array with the SQUID multiplexed readout

External Interest

- Yale University will be the academic partner in the future work
- Non-NASA applications could be in single-molecule spectroscopy (NSF) and in quantum information and metrology (NSF, DARPA)

Will allow for simultaneous acquisition of spectral and spatial information from weak IR sources in space