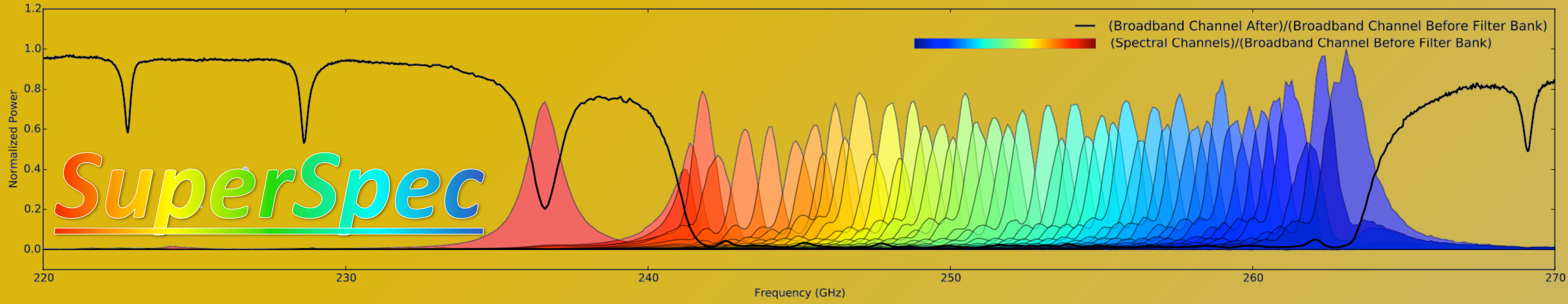

SuperSpec: mm-Wave On-Chip Spectrometer

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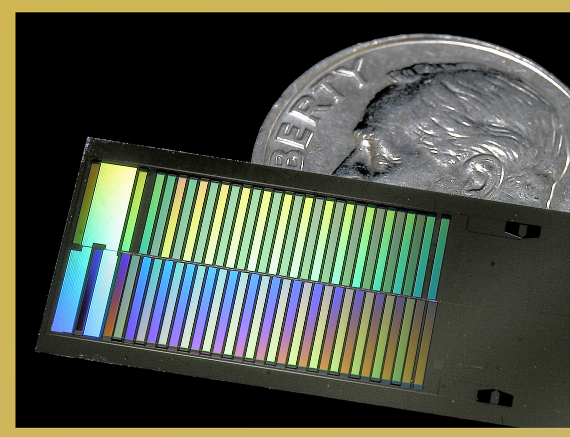


Introduction

SuperSpec is a new technology for millimeter and submillimeter spectroscopy. It is an on-chip spectrometer being developed for multi-object, moderate resolution (R = 100–500), large bandwidth survey spectroscopy of high-redshift galaxies for the 1 mm atmospheric window. SuperSpec employs a novel architecture in which detectors are coupled to a series of resonant filters along a single microwave feedline, creating a full spectrometer occupying only ~10 cm² of silicon.

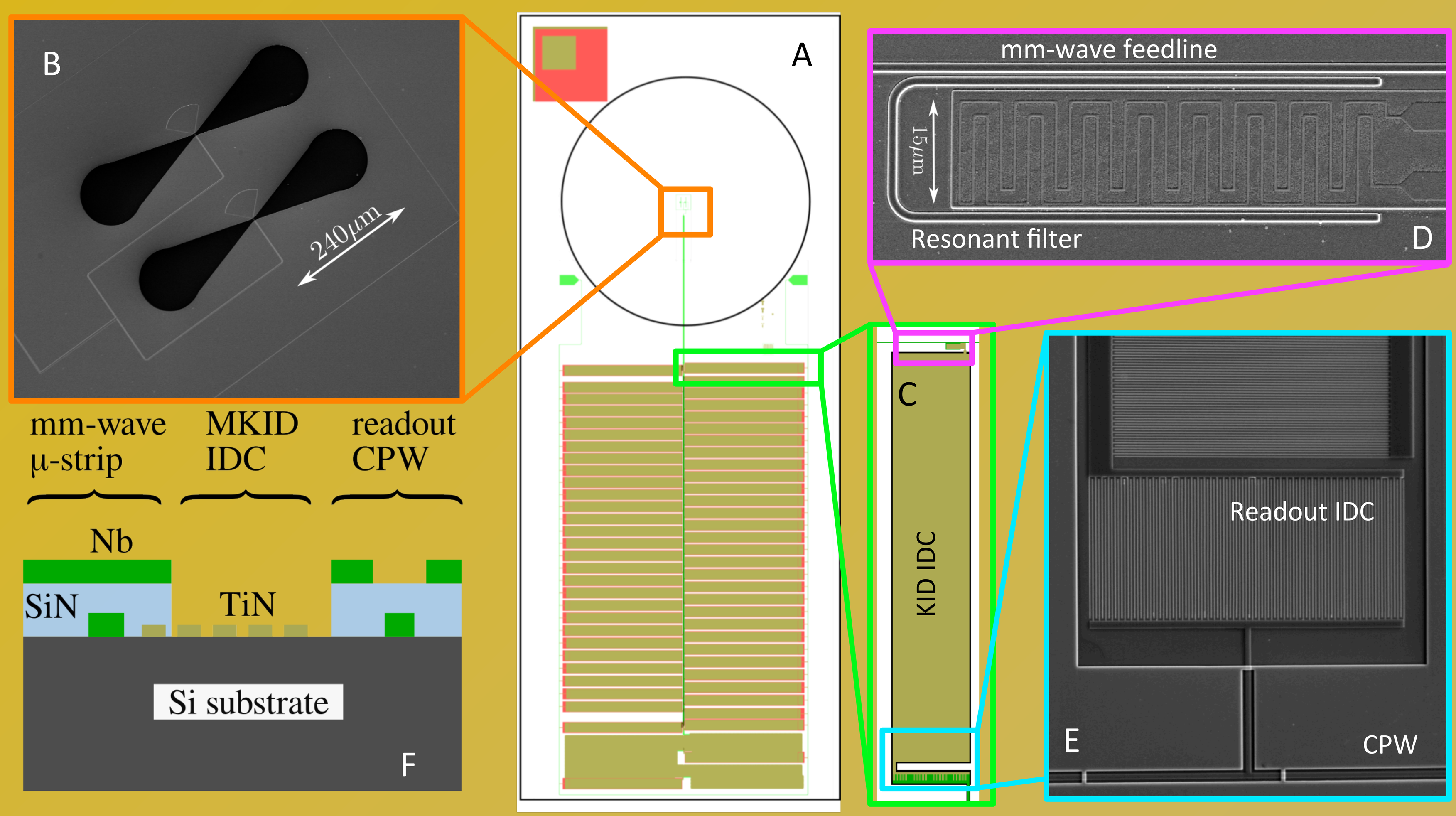
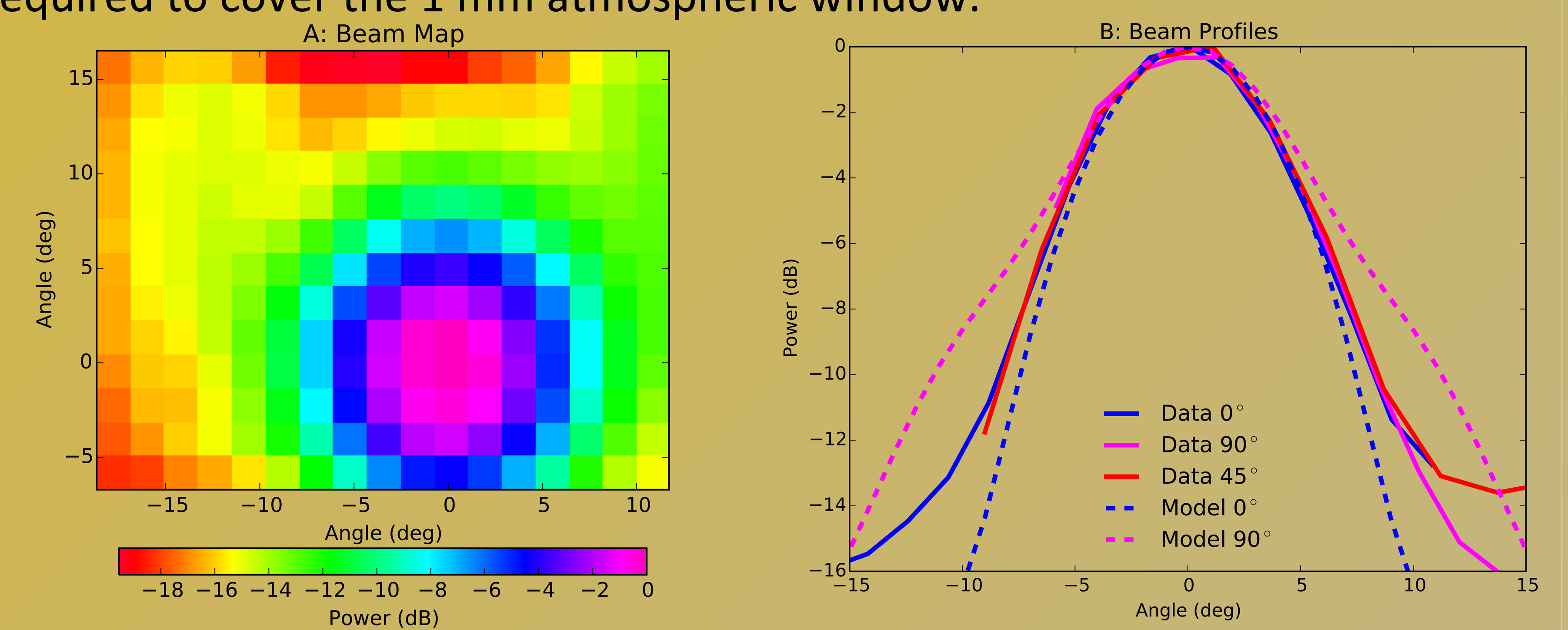


Fig 1: SuperSpec test device. (A) A mask with dual bowtie-slot antenna and lens footprint at the top, and feedline running vertically past an array of filters. (B) Dual bowtie-slot antenna. (C) A single mm-wave filter and KID (KID resonant frequencies are from ~100-200 MHz). (D) The millimeter-wave resonator and 250 nm line width inductor. (E) The lower portion of the large IDC, coupling IDC, and readout CPW. (F) Cross-section showing the device layers.

Broadband Bowtie-Slot Antenna

SuperSpec employs a dual bowtie-slot antenna with a 5 mm diameter silicon micro lens and 1.5 mm extension to achieve the large bandwidth required to cover the 1 mm atmospheric window.



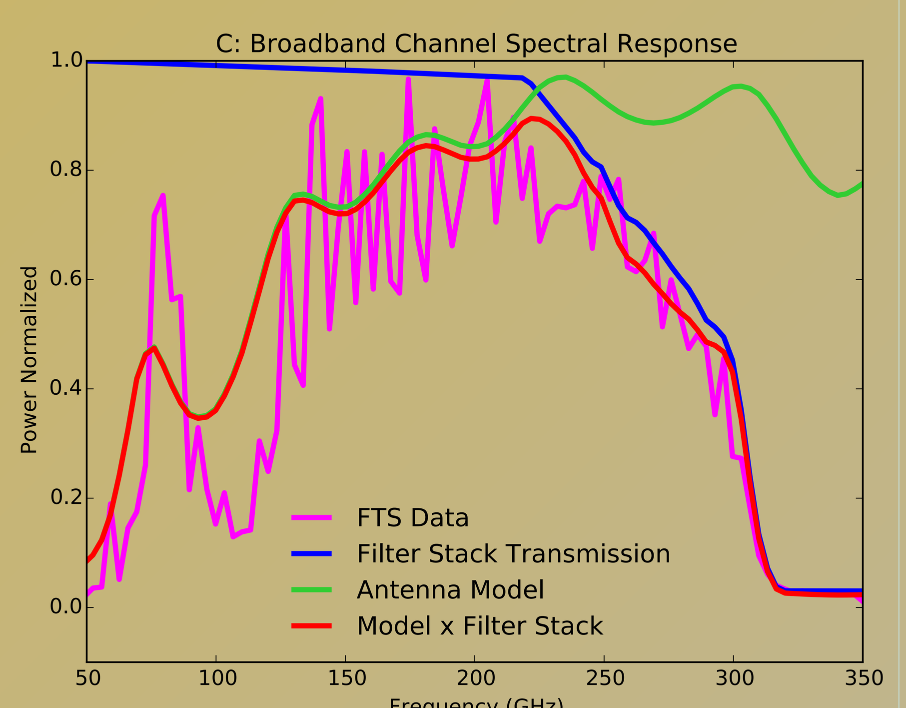


Fig 2: Results of testing new broadband dual bowtie-slot antenna (A) Beam map of spectral channels. (B) Cuts along different angles of the beam map with HFSS beam models overlaid. (C) FTS data for broadband detector at the front of the SuperSpec filter bank, along with the prediction/ measurements of our test bed transfer function and the frequency response of the antenna as modeled by HFSS. Future filter stack will be optimized for the 200 to 300 GHz band. Beam maps were taken with an unpolarized source, models are for a single polarization only.

Channel Profiles

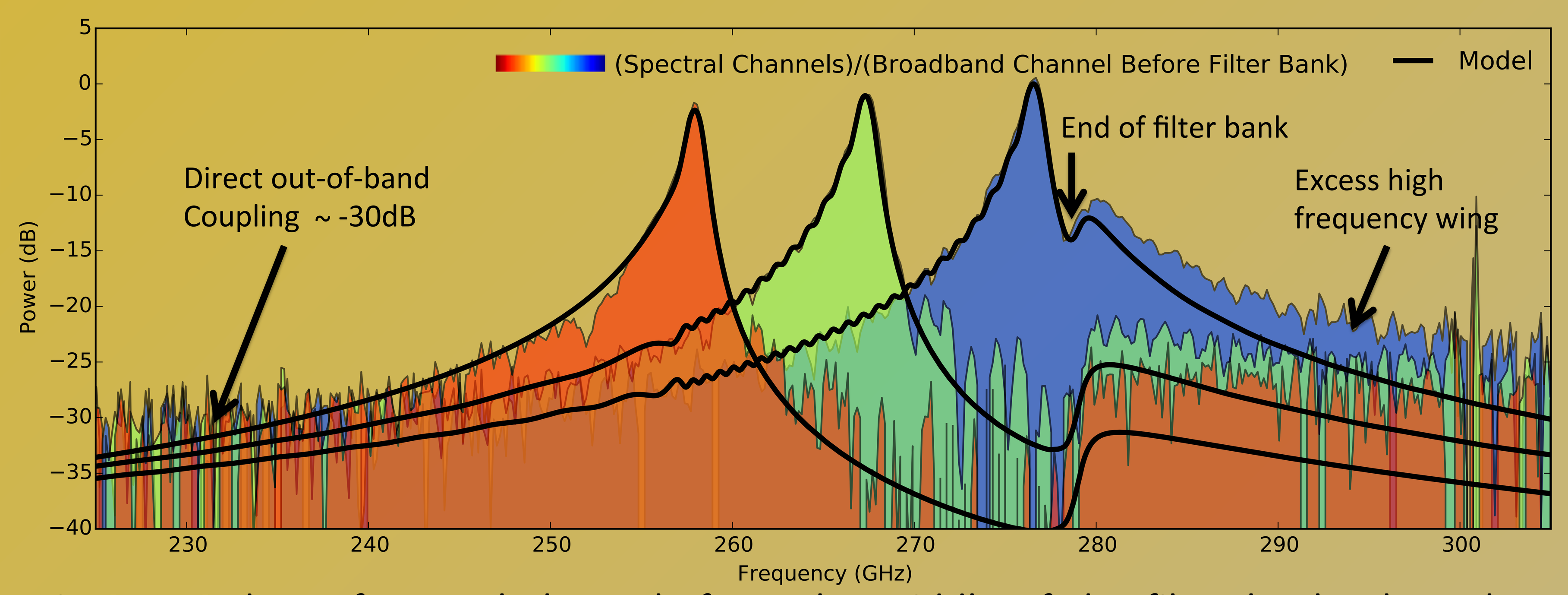
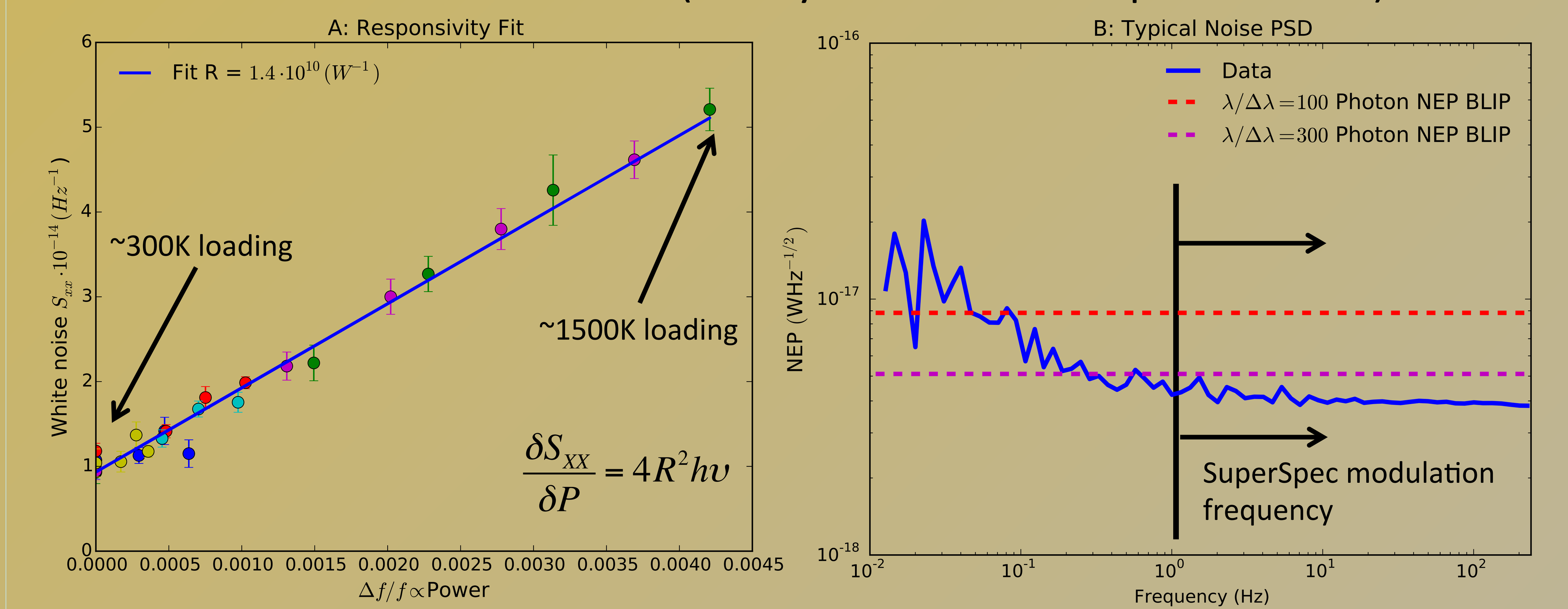


Fig 3: FTS data of several channels from the middle of the filter bank. The colored profiles show the approximate response of the resonator filters. Each channel has been normalized by a broadband channel at the front of the filter bank removing the test bed's transfer function.

Detector NEP 4x10⁻¹⁸ W/Hz⁰·⁵

To reach the low NEP required for spectroscopy, SuperSpec utilizes ultra-low-volume TiN KIDs (2.25 μm³). We can obtain the frequency responsivity, R, from the slope of the photon noise as a function of loading when excited by a coherent local oscillator source. We find a responsivity of 1.4×10^{10} W^{-1} along with a median noise level of 2.7×10^{-15} Hz^{-1} measured at T_{det} = 210 mK yields a NEP of 4×10^{-18} W/Hz$^{0.5}$ at 1 Hz for a T_c = 0.93 K device. At lower T_{det}, even lower NEP can be achieved (see Ryan McGeehan's poster PE 61).



$$\frac{\delta S_{xx}}{\delta P} = 4R^2 h\nu$$

Fig 4: (A) Photon noise from a coherent local oscillator source as a function of loading. Each color is a different resonator. (B) Typical noise PSD for SuperSpec detectors.

SuperSpec on the LMT

SuperSpec plans for an on-sky demonstration of a 6 chip (3 pixels, 2 polarizations each) pathfinder instrument on the Large Millimeter Telescope in 2018.

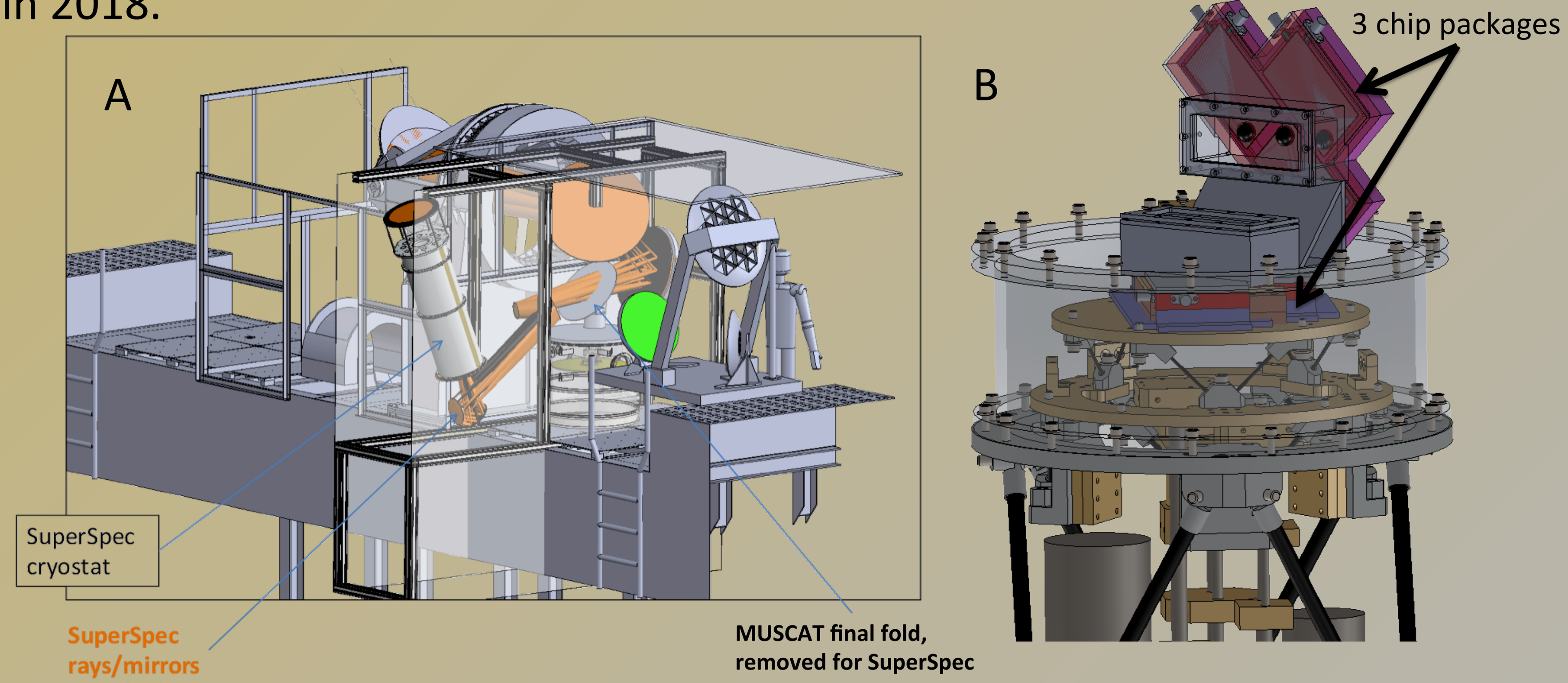


Fig 5: (A) Model of SuperSpec instrument mounted at the LMT, showing the nearly finalized optical design utilizing two mirrors for the MUSCAT instrument. (B) Model of our 6 chip 3 pixel instrument. Two 3 chip packages are perpendicularly offset and separated by a polarizing grid. Layout allows for a linear array at 7 beam spacing.

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