Introduction: Cryogenic radiation detectors using superconducting Transition Edge Sensors (TES) are widely used in astronomical observatories from the millimetre-wave region through hard X-rays. They will provide the sensitivity needed by the next generation of space-based instruments for infrared astronomy, such as SAFARI. In order to reach the target sensitivity (NEP~0.2 aW/√Hz) the nitride legs supporting the island containing the TES and absorbing film must be made extremely long to minimize the thermal conductance (Fig. 1). This leads to low filling factors.

Aiming for a flat, broadband response, we are investigating a gold-plated silicon integrating cavity (instead of the usual resonant backshort) for coupling radiation to the bolometer. The cavity is formed from two pyramidal pits made by anisotropic etching of single-crystal silicon. The cavity is fed by a square resonant backshort for coupling radiation to the bolometer. The gold-plated silicon integrating cavity (instead of the usual metal-film absorber) is modelled as a simple pyramidal cavity fed by a square waveguide. A port on the waveguide entrance is excited with the fundamental TE₁₀ mode and an input power of 1 W. The walls of the cavity are modelled as perfectly conducting boundaries. The 377-Ω metal-film absorber is modelled as a transition boundary condition and is surrounded by a rectangular air-box to help the meshing. The model is solved for a range of frequencies using a full parametric sweep, recalculating the mesh for each frequency. Integrating the surface resistive losses over the absorber gives the absorbed power, and |S₁₁|^2 gives the reflected power. Their sum gives an estimate of the error in the result.

Computational Method: Figures 2 and 3 show a model of a simple pyramidal integrating cavity fed by a square waveguide. A port on the waveguide entrance is excited with the fundamental TE₁₀ mode and an input power of 1 W. The walls of the cavity are modelled as perfectly conducting boundaries. The 377-Ω metal-film absorber is modelled as a transition boundary condition and is surrounded by a rectangular air-box to help the meshing. The model is solved for a range of frequencies using a full parametric sweep, recalculating the mesh for each frequency. Integrating the surface resistive losses over the absorber gives the absorbed power, and |S₁₁|^2 gives the reflected power. Their sum gives an estimate of the error in the result.

Results: The simple pyramidal cavity has reasonable performance but sharp, deep dips in the absorption coefficient. (Fig. 4). We made various combinations of changes to the simple cavity and compared the results. Our goal was a high absorption efficiency over a broad band with minimal spectral features. We found that offsetting the waveguide to one corner was effective, as was adding a straight section between the top and bottom of the cavity. Reducing the width of the cavity from 400 to about 300 microns also improves the efficiency, as expected; the absorber is 200 µm square. Making the top surface of the cavity flat degraded performance as expected, as did moving the absorber up from the bottom of the straight section. Figure 5 shows one of these optimized models. Note the high absorption coefficient over a broad frequency range and the absence of significant resonant features.

Conclusions: We have used Comsol Multiphysics to optimize the design of a micromachined silicon integrating cavity for arrays of far infrared TES bolometers. A cavity with a waveguide offset to one corner and a straight section of a few hundred microns gives the best performance. The performance improvement with the straight section is significant because it means that we can make the cavities with different depths, on the order of a wafer thickness, which makes a focal plane of stacked wafers feasible. Our next step will be to verify these results with W-band scale models.

References: