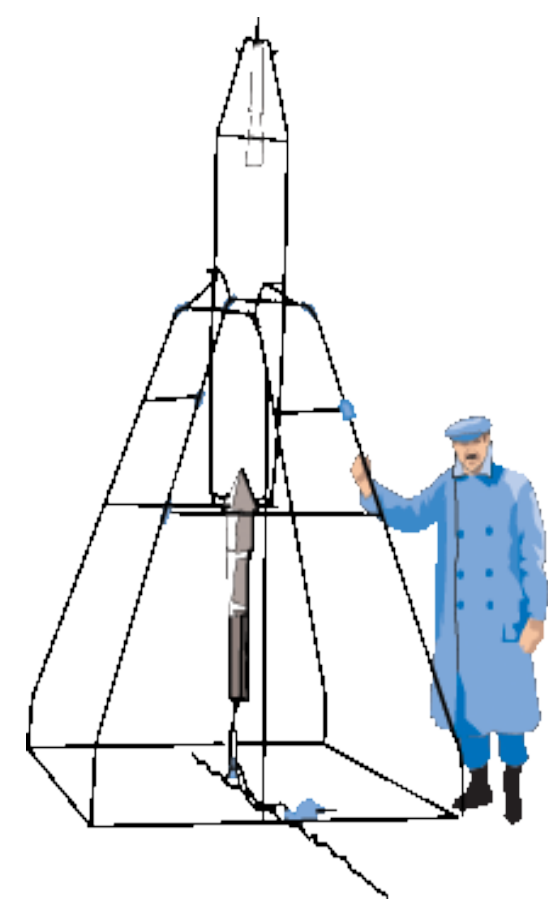


Fabrication of Transition Edge Sensor Microcalorimeters for X-ray Focal Planes



James Chervenak¹; Joseph S. Adams⁶; Heather Audley¹; Simon R. Bandler¹; Gabriele Betancourt-Martinez⁵; Megan E. Eckart¹; Fred M. Finkbeiner⁴; Richard L. Kelley¹; Caroline Kilbourne¹; Sang Jun Lee¹; Jennette Mateo³; John E. Sadleir¹; Stephen J. Smith⁶; Edward Wassell²; Wonsik Yoon¹

¹ NASA Goddard Space Flight Center, Greenbelt, MD, United States ² SGT Inc., Greenbelt, MD, United States

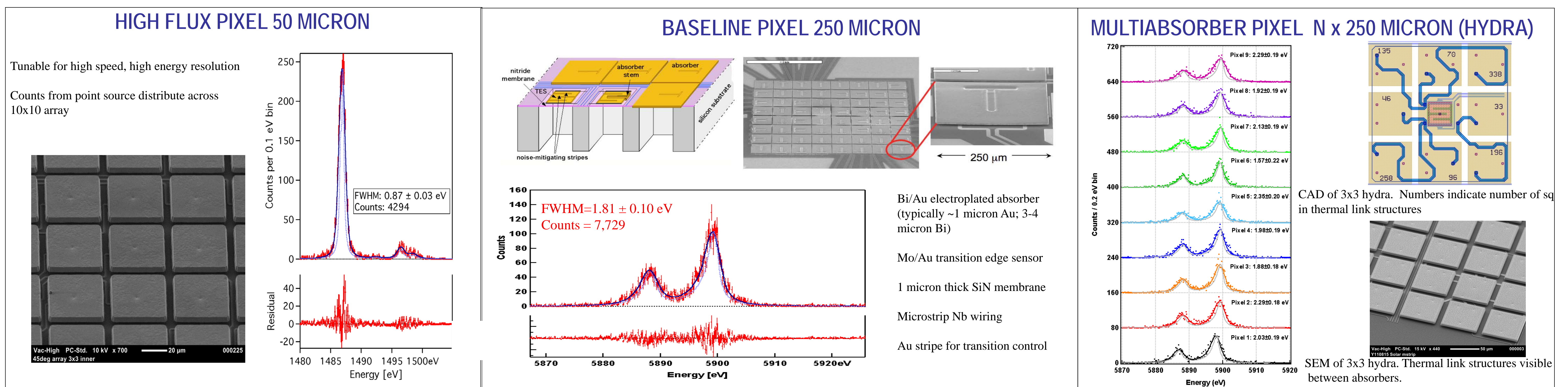
³ SB Microsystems Inc., Columbia, MD, United States ⁴ Wyle Information Systems, LLC

⁵ University of Maryland, College Park, MD, United States ⁶ University of Maryland, Baltimore County, MD, United States

ABSTRACT

Requirements for focal planes for x-ray astrophysics vary widely depending on the needs of the science application such as photon count rate, energy band, resolving power, and angular resolution. Transition edge sensor x-ray calorimeters can encounter limitations when optimized for these specific applications. Balancing specifications leads to choices in, for example, pixel size, thermal sinking arrangement, and absorber thickness and material. For the broadest specifications, instruments can benefit from multiple pixel types in the same array or focal plane. Here we describe a variety of focal plane architectures that anticipate science requirements of x-ray instruments for heliophysics and astrophysics. We describe the fabrication procedures that enable each array and explore limitations for the specifications of such arrays, including arrays with multiple pixel types on the same array.

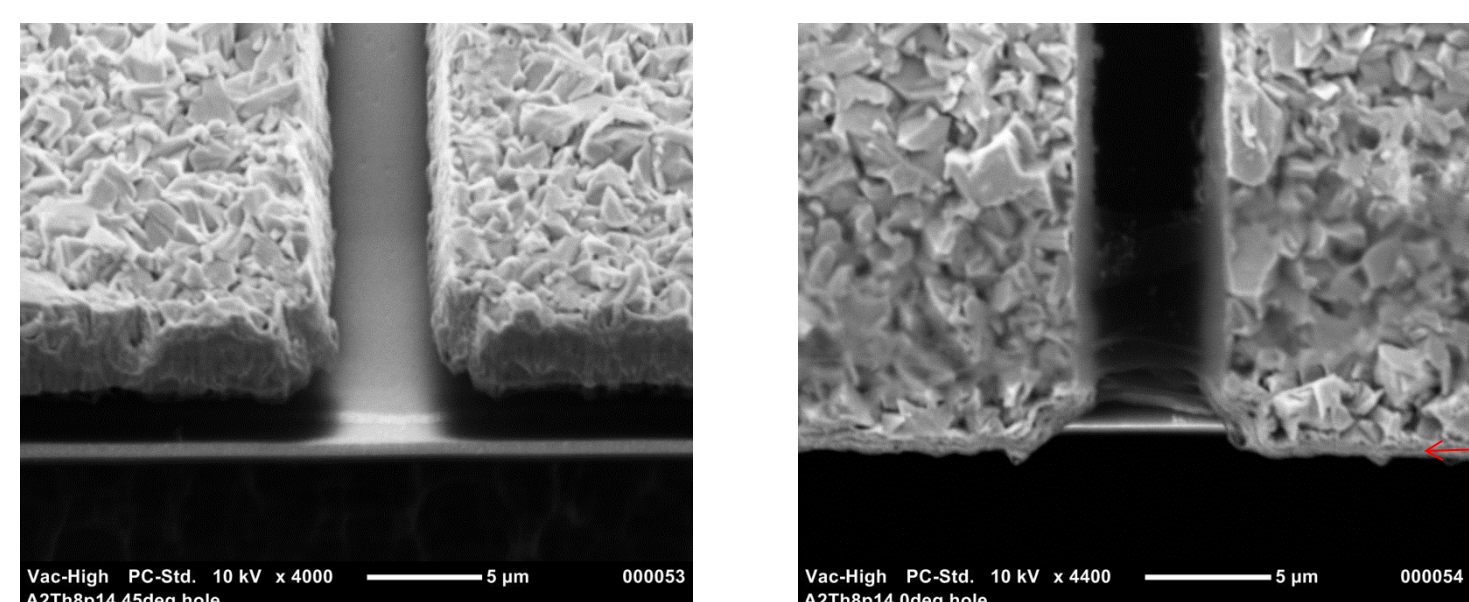
TES TECHNOLOGIES FOR X-RAY DETECTION



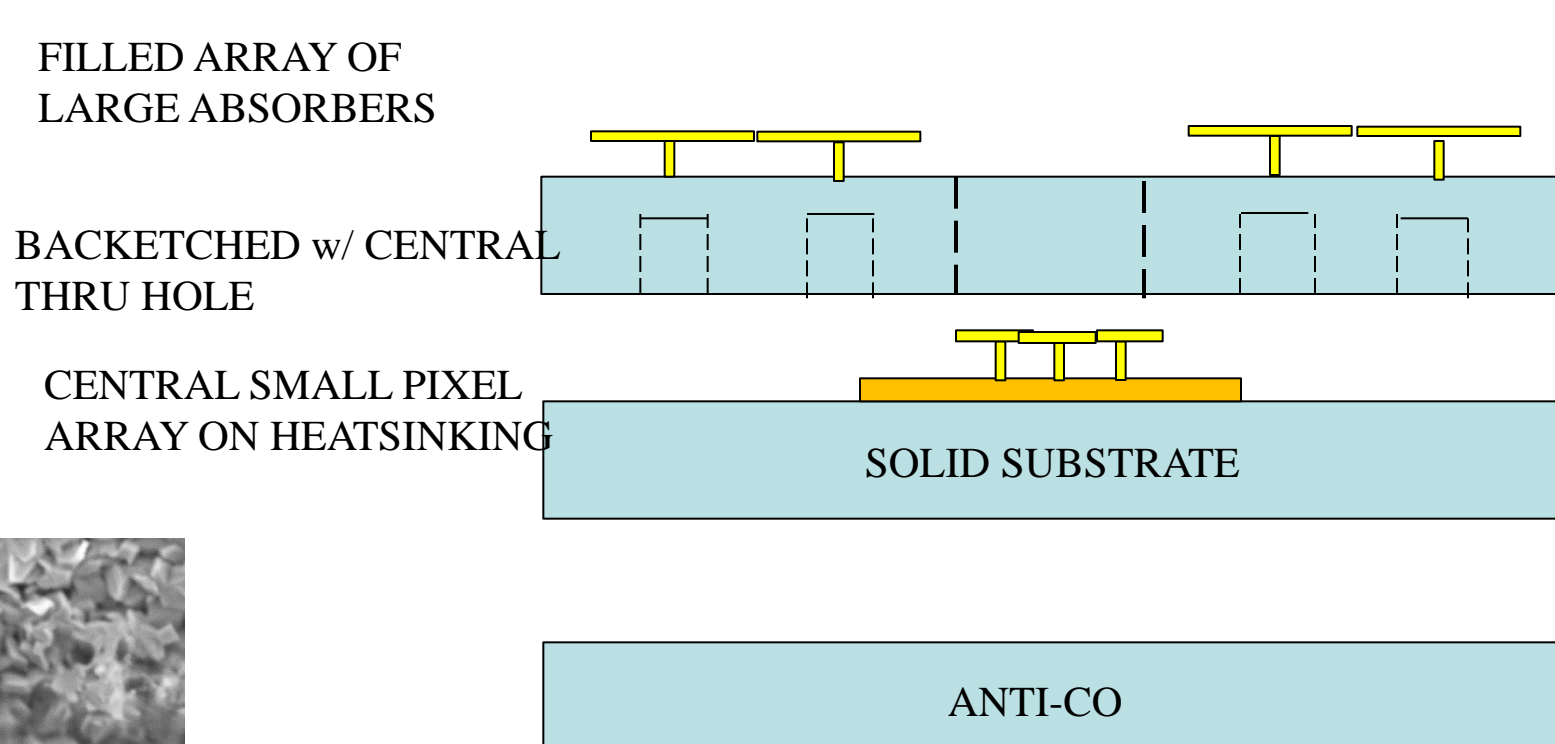
Fabrication of multiple pixel types in the same μ cal array

STACKED CONFIGURATION

- Separate chips for arrays of each pixel type
- Align smaller array behind hole in larger array
- Options for each chip (Tc, C_{abs}, heatsinking arrangement)



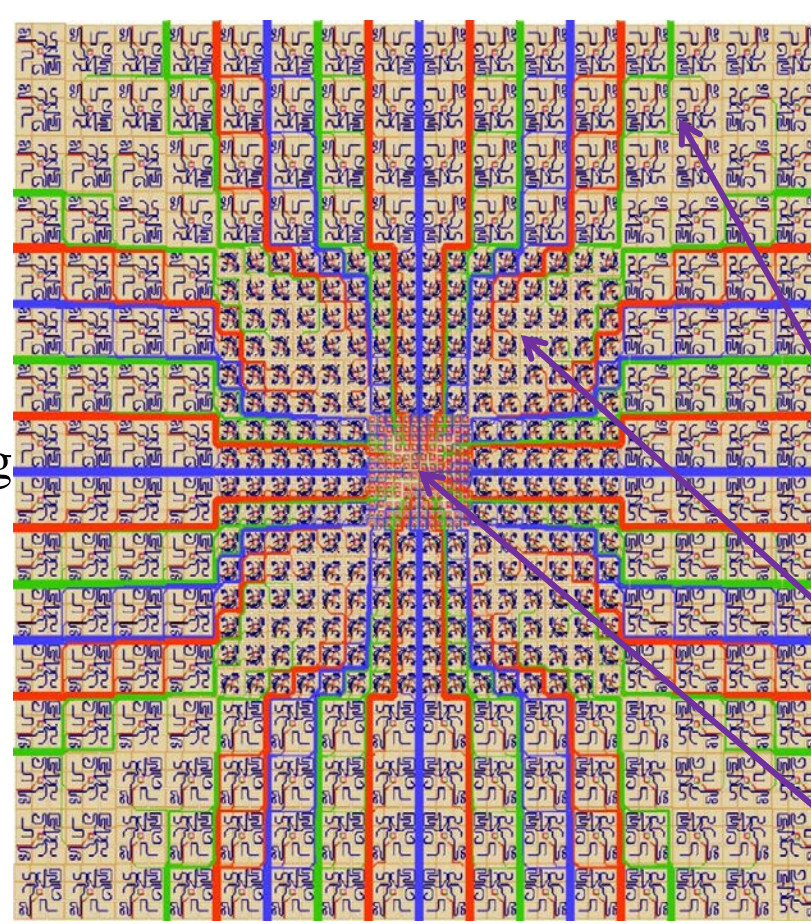
SEM at angle to show deep etch sidewall SEM at 90 degree to show 1 μm overhang



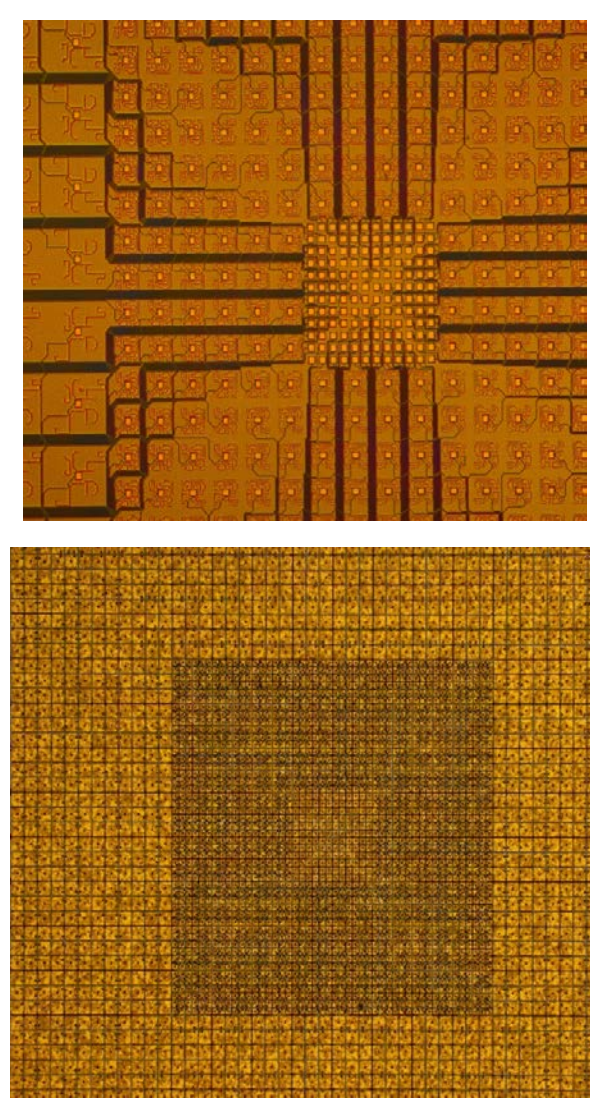
Demonstration of Bi/Au absorbers overhanging edge deep etch well

PLANAR CONFIGURATION

- Layout of multiple pixel types shown
- With less muntins in outer arrays, wiring density limits size of innermost array
- Pixel types can require different heatsinking Arrangements
- We have substituted backside deposition on small pixel array membrane but observed higher than expected crosstalk

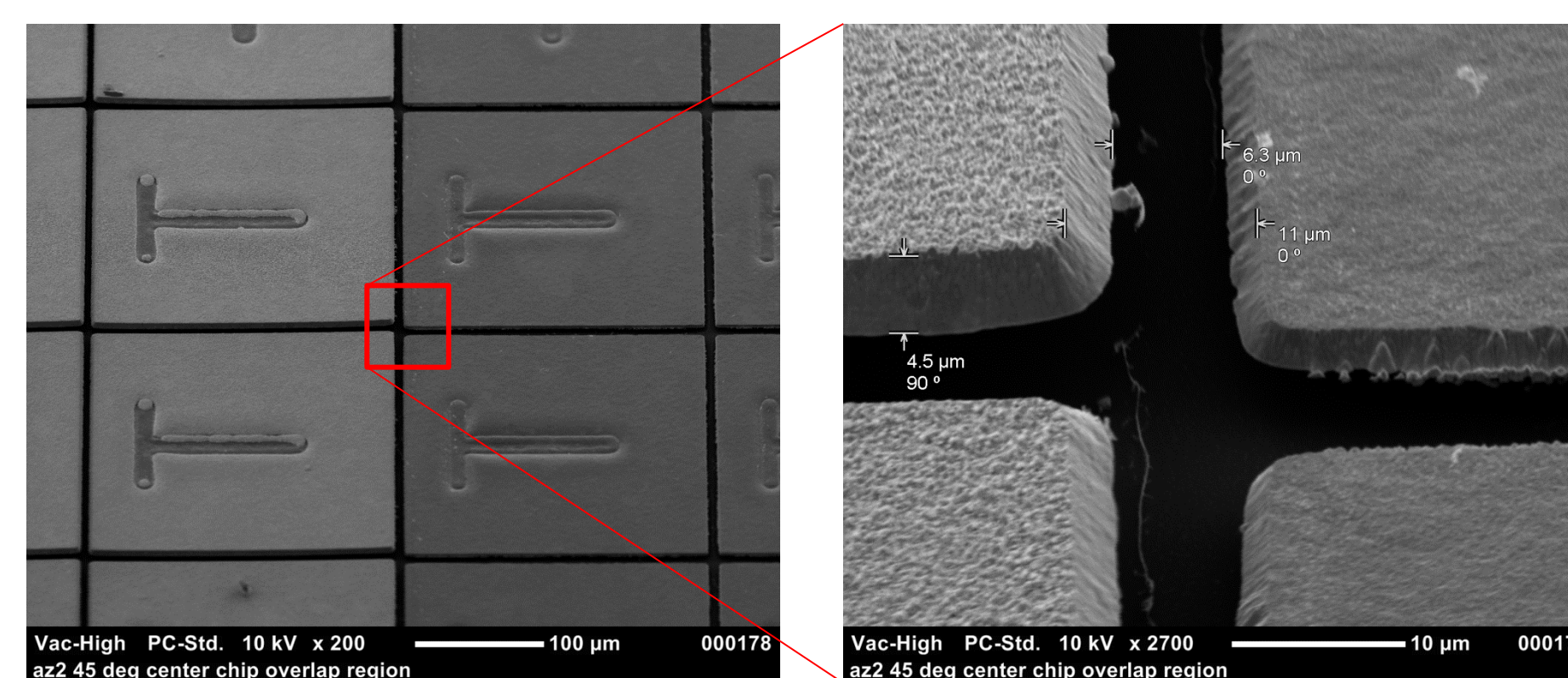


CAD rendering of three-tiered soft x-ray spectrometer prototype. Pixels and thermal links in blue, wire bundles in red/green/blue

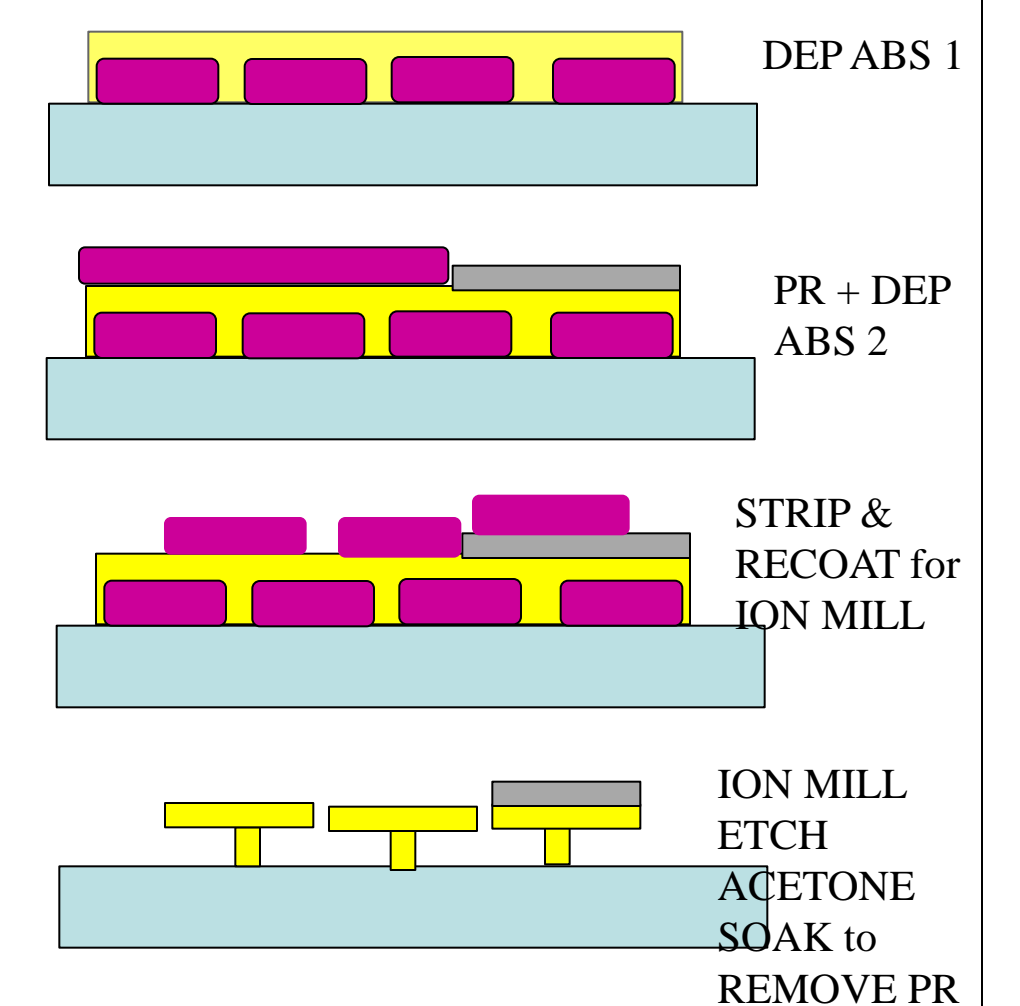


TES Array realized with all gold absorber on 3 micron thick copper heatsinking layer w/ W+SiO₂ dielectric barrier 0.3 microns thick

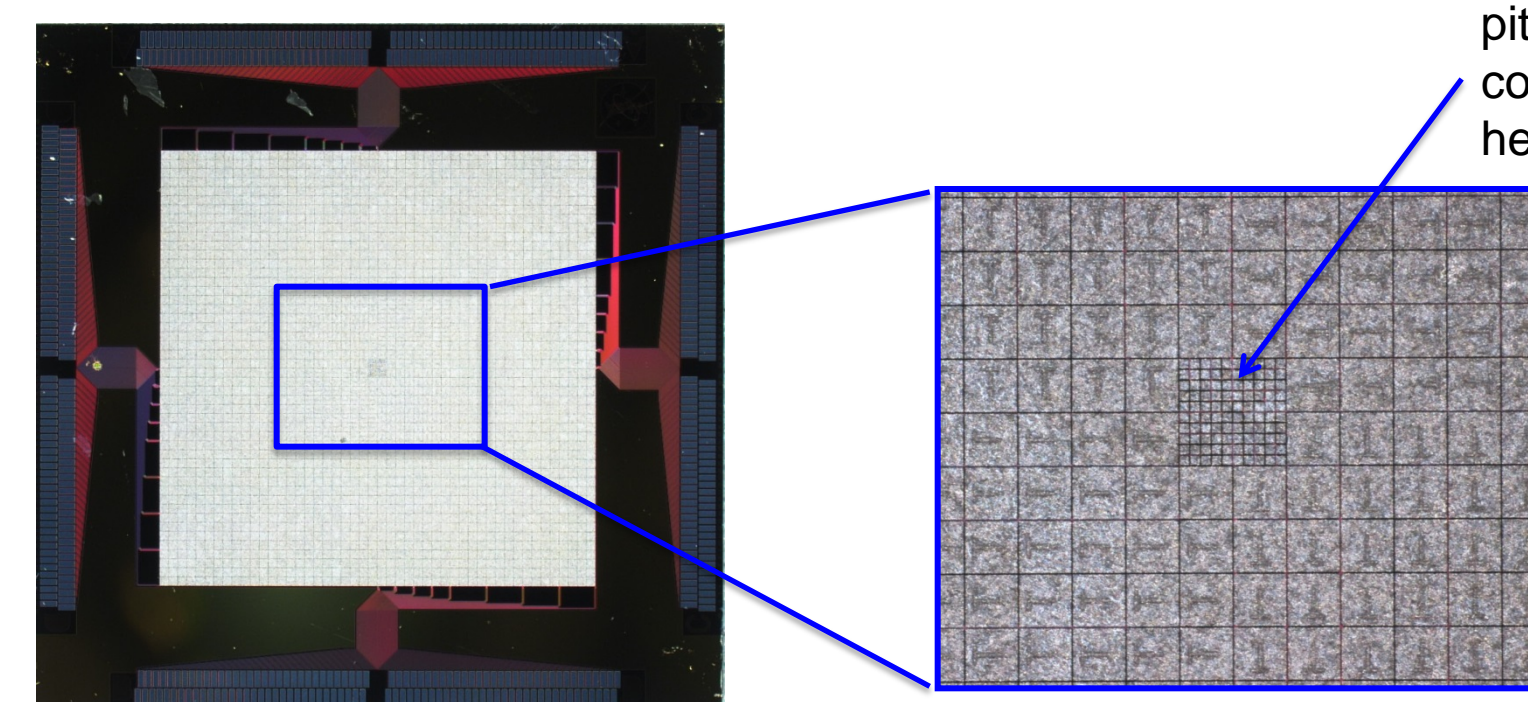
Making a μ cal array with two absorber thicknesses



Neighboring absorbers with 2 and 4 micron thickness. 2nd absorber deposition has rougher appearance. Narrowed gaps slow etch rate to reduce overetch in thinner areas



Making a μ cal array with two operation temperatures



Array with 250 and 50 micron pixels in same array simultaneously biased
 $\Delta T_c \sim 35$ mK with lead spacing (25 and 130 micron) and normal metal stripe perpendicular to bias current (0, 3 resp.)

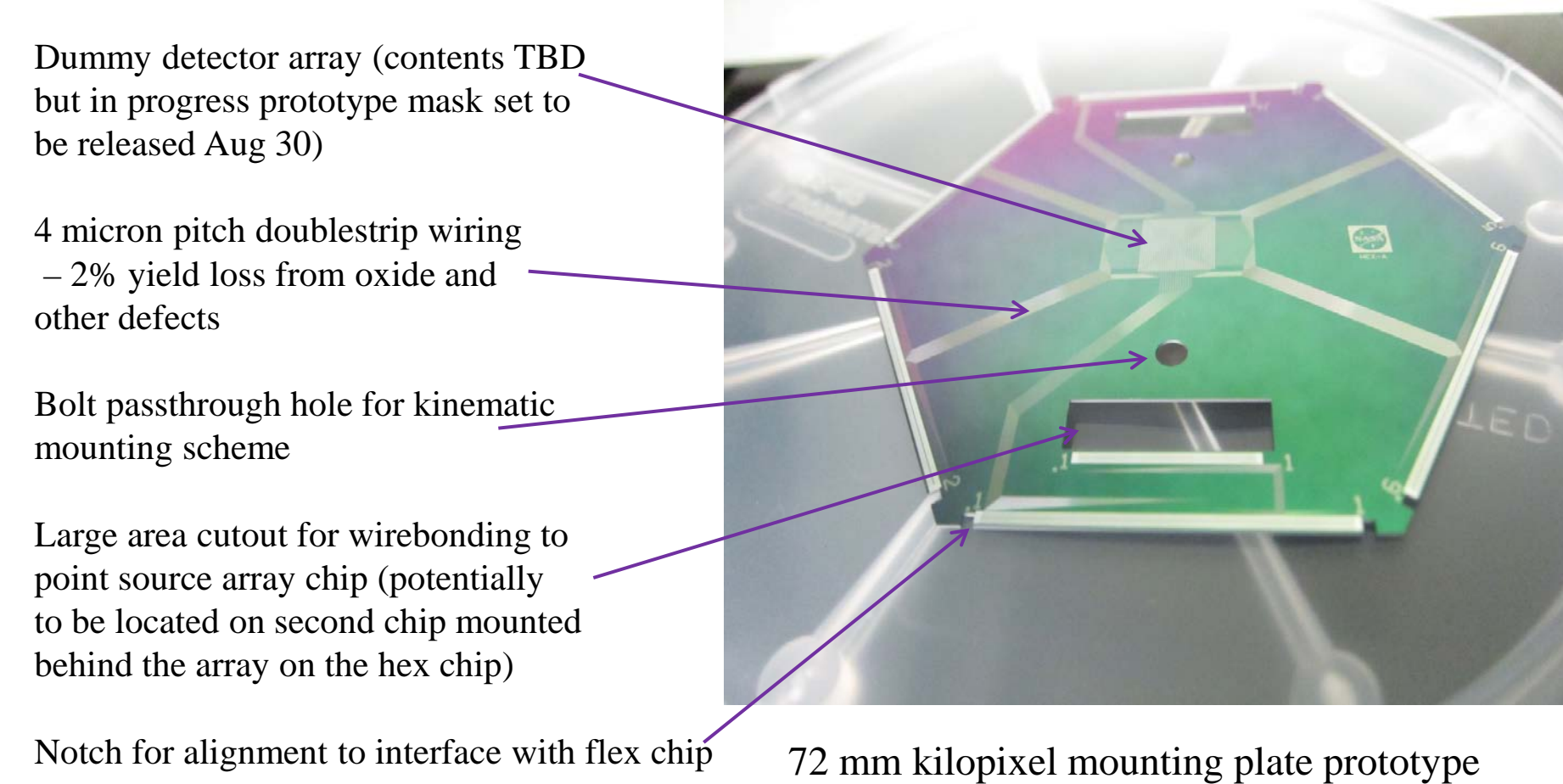
Inner 10x10 of pixels on 50 μm pitch had backside copper applied for heatsinking

For larger ΔT_c , thicker Au in low Tc regions can be added (per above fab steps) prior to TES ion mill step (Typically 1 nm Au/mK)

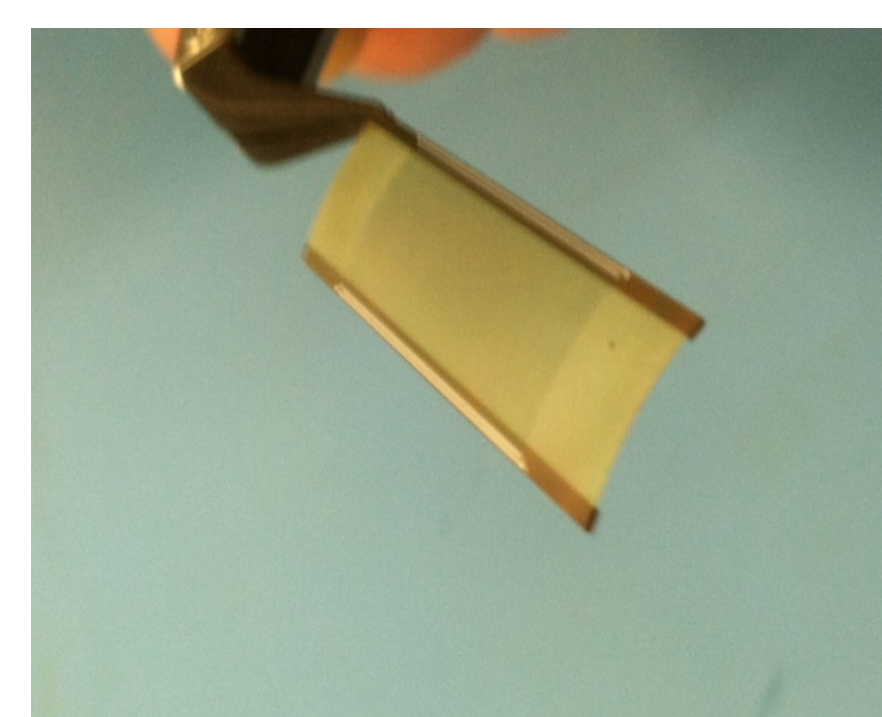
Rn change $\sim 0.5\%/mK$

Transition sharpness of added metal TES to be verified.

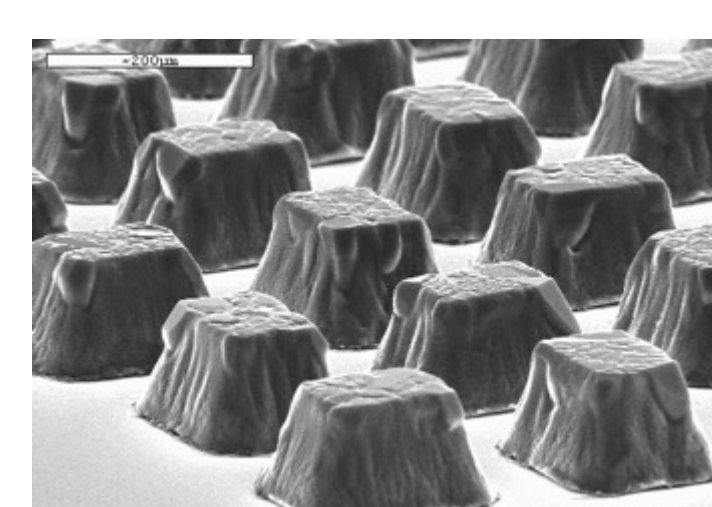
Making an array with a lot of wires / interconnects (Addition of Indium Bump Bonds to Conventional Microcalorimeter Arrays)



72 mm kilopixel mounting plate prototype

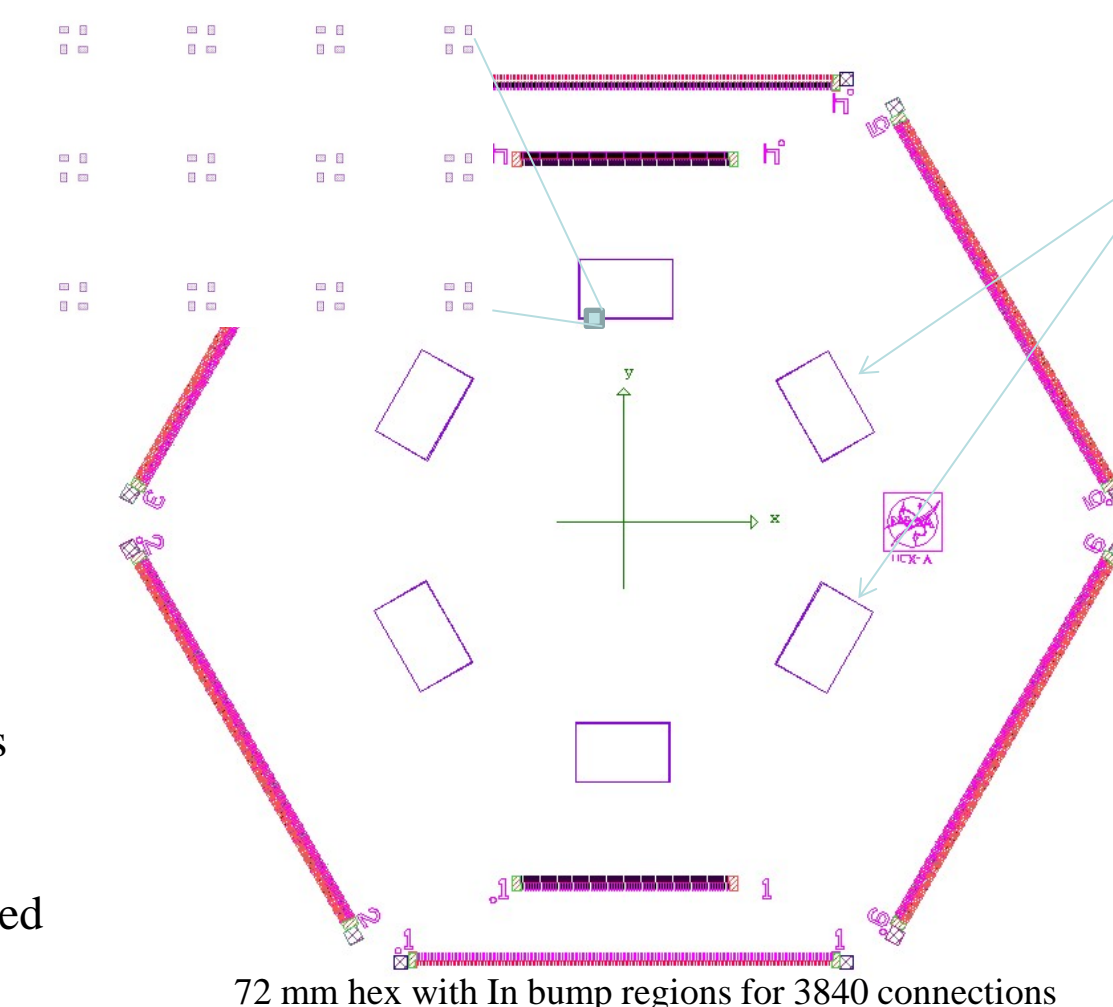


FLEX CHIP - 10+ microns polyimide with ~200 Nb microstrip conductors. Thin polyimide layer between two 0.5 micron layers of Nb



Arrays of indium bumps at the kilopixel scale will take up relatively small regions of the focal plane and flex cabling.

6 sequential attachments would be required in the hexagonal readout configuration



Boxes outline fields of four bumps per device / 200 micron pitch

Nb wiring terminated with 1 micron thick In pads on substrate

Mating flex has 10 micron Indium bumps

Annealing prior to addition of cantilevered absorber

2-sided indium will have high yield, high Ic without post-annealing (to be verified)