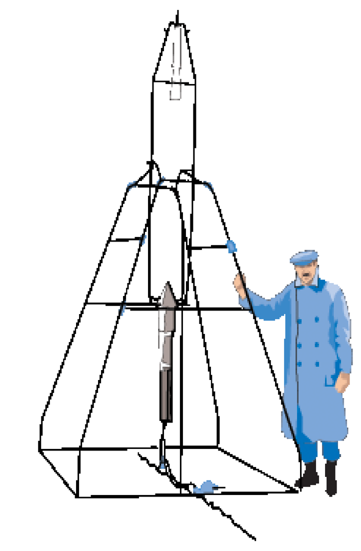
Fabrication of Transition Edge Sensor Microcalorimeters for X-ray Focal Planes



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ABSTRACT

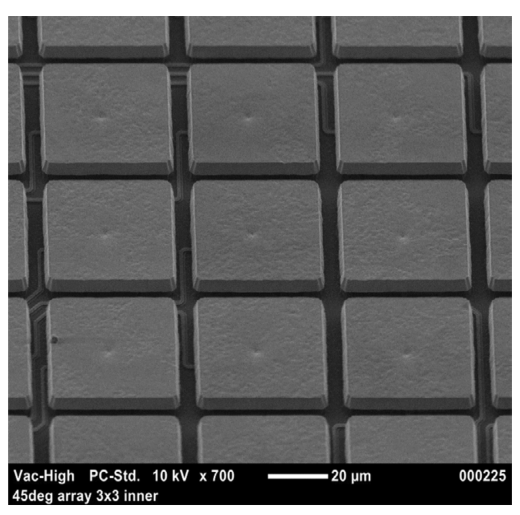
Requirements for focal planes for x-ray astrophysics vary widely depending on the needs of the science application such as photon count rate, energy band, resolving power, and angular resolution. Transition edge sensor x-ray calorimeters can encounter limitations when optimized for these specific applications. 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.

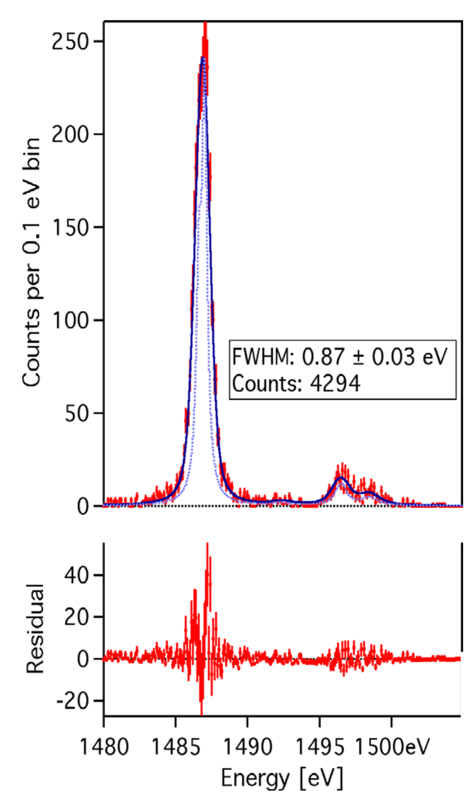
TES TECHNOLOGIES FOR X-RAY DETECTION

HIGH FLUX PIXEL 50 MICRON

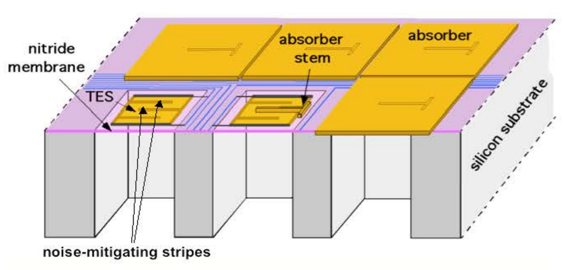
Tunable for high speed, high energy resolution

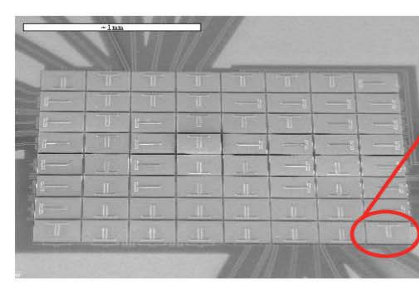
Counts from point source distribute across 10x10 array

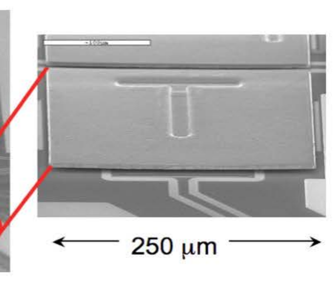


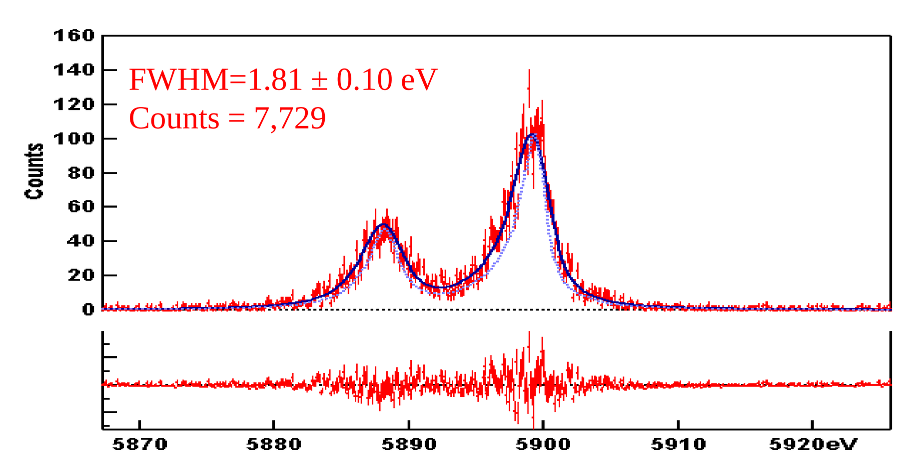


BASELINE PIXEL 250 MICRON









Bi/Au electroplated absorber (typically ~1 micron Au; 3-4 micron Bi)

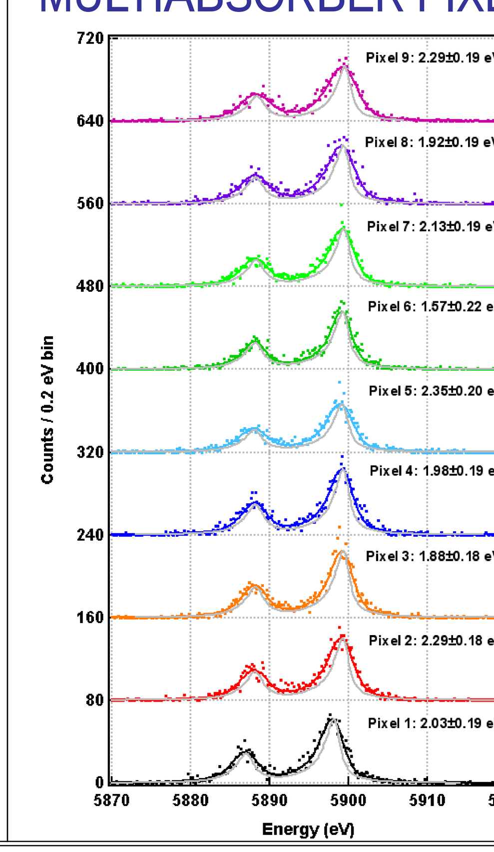
Mo/Au transition edge sensor

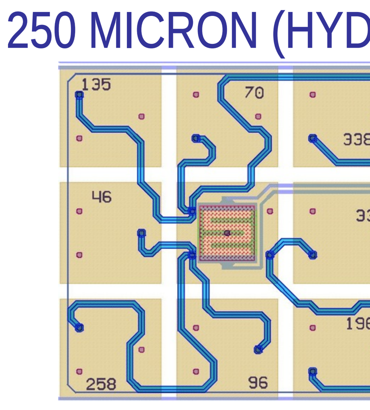
1 micron thick SiN membrane

Microstrip Nb wiring

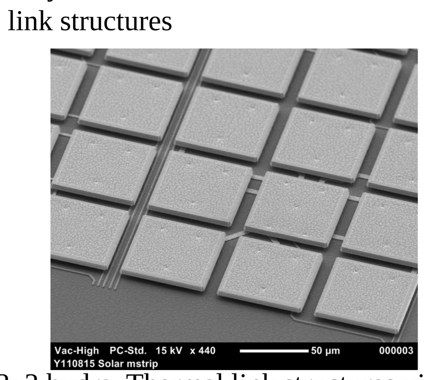
Au stripe for transition control

MULTIABSORBER PIXEL N x 250 MICRON (HYDRA)





CAD of 3x3 hydra. Numbers indicate number of sq in thermal link structures



SEM of 3x3 hydra. Thermal link structures visible between absorbers.

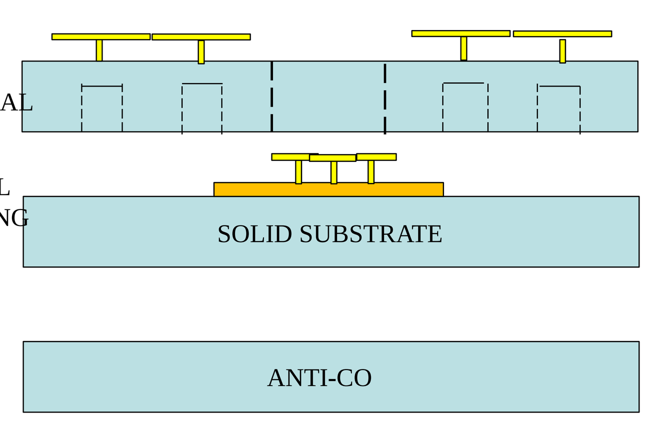
Fabrication of multiple pixel types in the same µcal array

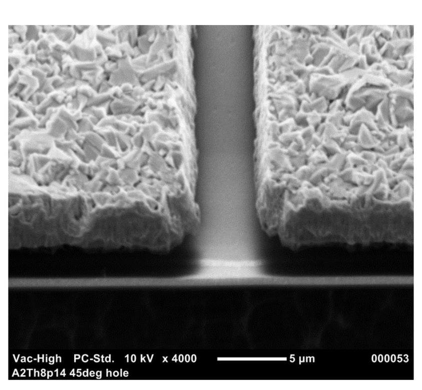
STACKED CONFIGURATION

Separate chips for arrays of each pixel type

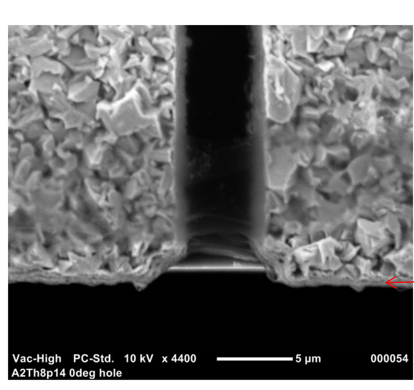
Align smaller array behind hole in larger array

Options for each chip (Tc, C_absorber, 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

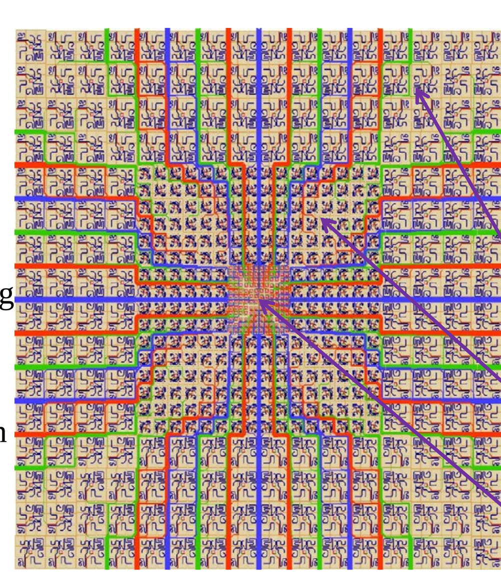
PLANAR CONFIGURATION

Layout of multiple pixel types shown

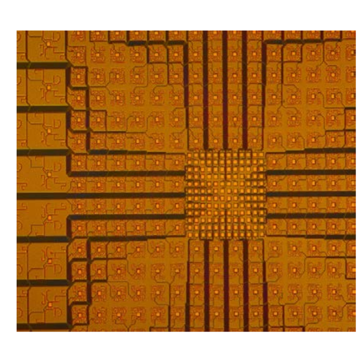
With less muntins in outer arrays, wiring density limits size of innermost array

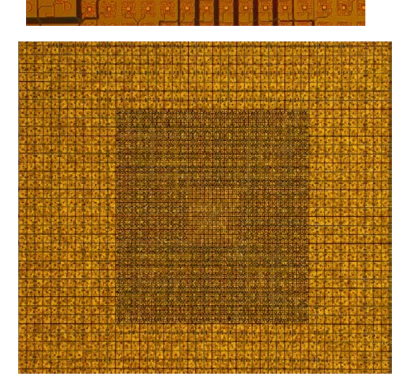
Pixel types can require different heatsinking Arrangements

We have substituted backside deposition on small pixel array membrane but observed higher than expected crosstalk



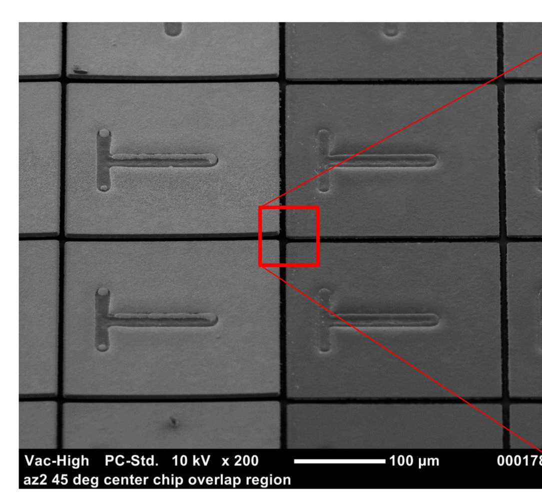
CAD rendering of three-tiered soft x-ray spectrometer prototype. Pixels and thermal links in blue, wire bundles in red/green/blue

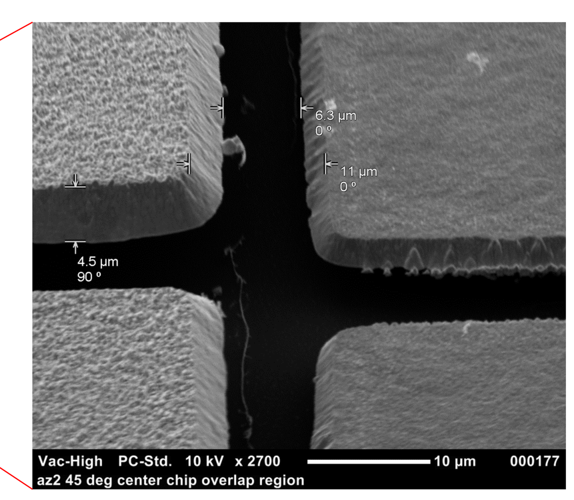




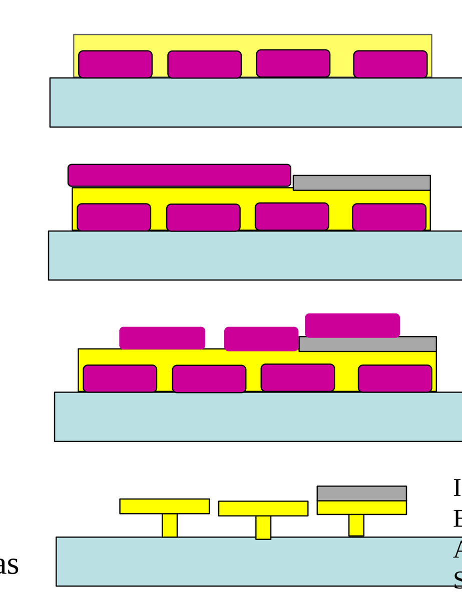
TES Array realized with all gold absorber on 3 micron thick copper heatsinking layer w/ W+SiO2 dielectric barrier 0.3 microns thick

Making a µcal array with two absorber thicknesses

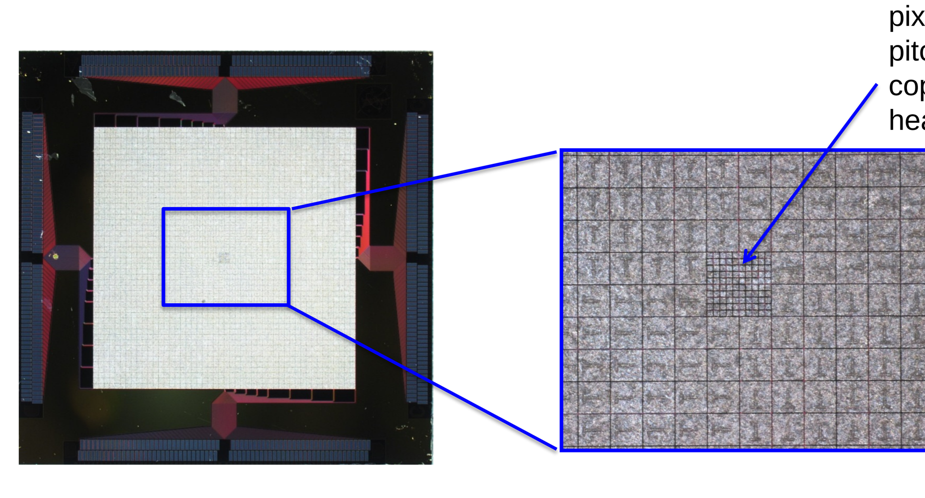




Neighboring absorbers with 2 and 4 micron thickness. 2nd absorber deposition has rougher appearance. Narrowed gaps slow etch rate to reduce overetch in thinner areas



Making a µcal array with two operation temperatures



Array with 250 and 50 micron pixels in same array simultaneously biased

ΔTc~35 mK with lead spacing (25 and 130 micron) and normal metal stripe perpendicular to bias current (0, 3 resp.)

For larger ΔTc, 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 ~ 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)

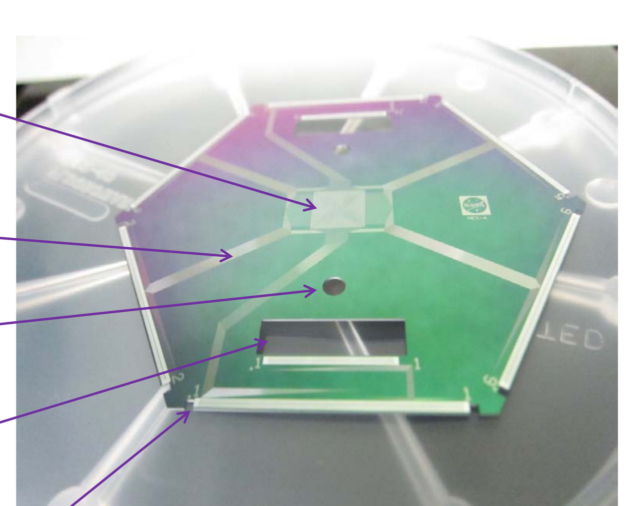
Dummy detector array (contents TBD but in progress prototype mask set to be released Aug 30)

4 micron pitch doublestrip wiring – 2% yield loss from oxide and other defects

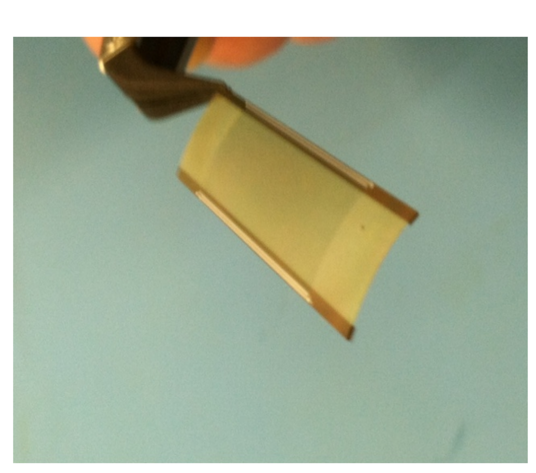
Bolt passthrough hole for kinematic mounting scheme

Large area cutout for wirebonding to point source array chip (potentially to be located on second chip mounted behind the array on the hex chip)

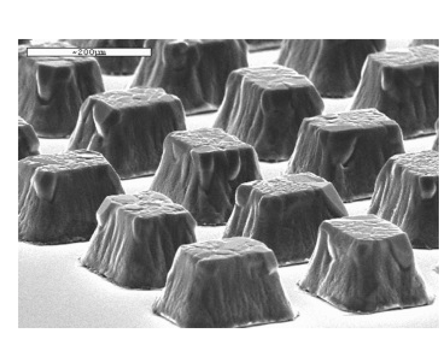
Notch for alignment to interface with flex chip



72 mm kilopixel mounting plate prototype

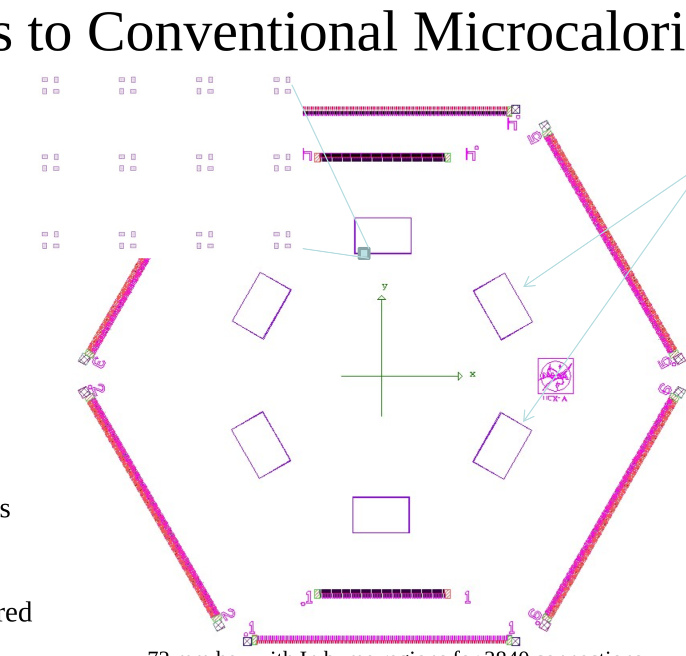


FLEX CHIP – 10+ microns polyimide with ~200 Nb microstrip conductors. Thin polyimide layer between two 0.5 micron layers of Nb



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



72 mm hex with In bump regions for 3840 connections

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)