Advances in small pixel TES-based X-ray microcalorimeter arrays for solar physics and astrophysics


X-ray Astrophysics Laboratory & Detector Development Laboratory, NASA/GSFC

- Solar TES microcalorimeters
  - small & fast!
- Basic design & previous single pixel results
- Results from new 32x32 arrays
- Uniformity
- Hydras
- Applications / missions
Thermal link (G): Kapitza

Thermal cross-talk < 0.01% between nearest neighbors
- F.M. Finkbeiner et al,
ASC-2010
Absorber: 57 μm x 57 μm
Pixel pitch = 150 μm
Au: 9 μm thick

LTD-14, 2011
Absorber: 57 μm x 57 μm
Pixel pitch = 150 μm
Au: 4.5 μm thick

ASC-2012
Absorber 65 μm x 65 μm
Pixel pitch = 75 μm - close-packed
Au: 5.0 μm thick

- Arrays with 75 μm pitch developed - largest fitting TES chosen => greater speed
- Unclear whether stripes help - lower Tc with stripes (~5 mK)
- Today: arrays of 35 μm TESs - without stripes & normal metal banks
Gain calibration remarkably linear

- Highly current dependent transition
- Much higher $\beta$

**Graph:**
- Measured Energy (eV) vs. Actual Energy (eV)
- Two curves: 35 $\mu$m pixel $C \sim 0.1$ pJ/K and 140 $\mu$m pixel $C \sim 0.1$ pJ/K
- Markers for K-\(\alpha\), K-\(\beta\), Cr-\(\alpha\), Cr-\(\beta\), Cu-\(\alpha\), Cu-\(\beta\), Al-\(\alpha\)
- Legend: 35 $\mu$m (red), 140 $\mu$m (blue)

**Graph:**
- Resistance vs. Temperature
- Cross symbol indicating some transition

**Graph:**
- TES Current vs. Temperature
- Resistance as a parameter

TES W/ ASC meeting, Portland, 2012
- 32x32 arrays
- TES on 75 μm pitch – *compact wiring*
- Absorber gold: 65μm x 65 μm x 5.0 μm
- Planar wiring
- Stripline wiring
**TES on 75 micron pitch**

Absorber: $65 \mu m \times 65 \mu m \times 5.0 \mu m$

$T_c \sim 53$ mK

⇒ Pixels relatively slow

⇒ $T_c$’s trade count-rate & linearity vs energy resolution
• Low $T_c$ pixel results match best resolution at 6 keV
• Non-linearity from low C at low T, and low bias point
• 6 keV spectrum utilizing non-linear, non-stationary noise analysis

- talk by S.E. Busch  3 EG – 03

TES-VI / ASC meeting, Portland, 2012
Optimizing field for each pixel:
Still small residual variations between pixels \( I_c(T) \) & \( T_c \sim +/- 0.15 \text{ mK} \)

*Trapped Field uniformity, non-uniform fabrication?*
"Sahara" - Spectral Analysis with High Angular Resolution Astronomy - *(Mushotzky et al., 2011)*

- **Single pixels - 50 μm (2.5’’)**
  - 0.5 - 1.5 eV FWHM
  - 12x12 array – 30’’x30’’

- **3x3 Hydras - 50 μm pixels (2.5’’)**
  - 1.5 - 3.0 eV FWHM
  - 20x20 hydra, 60x60 pixels – 2.5’’x2.5’’

- **3x3 Hydras - 100 μm pixels (5’’)**
  - 2.0 - 3.0 eV FWHM
  - 32x32 Hydra, 96x96 array – 8’’x8’’

**Shorter focal length (4m) => Small pixels + high angular resolution**

- Different design types in different regions on a single wafer substrate

- **12k pixels, with only 1344 TESs read-out !**
AXSIO XMS Array Concept

Main array:
- 40 x 40 pixels, 6” each
- 4.0 arcmin FOV
- 300 μm pixels
- < 3 eV resolution (FWHM)
- 80% event throughput at 50 cps/pixel
- 2x2 Hydras <6 eV resolution in outer regions

Inner point source array (PSA):
- 16 x 16 pixels, 1.5” each, 75 μm
- 24” FOV
- 2 eV resolution (FWHM)
- 80% throughput at 300 cps/pixel
- 256 TESs

Total = 1120 TESs
Conclusions:

• Excellent energy resolution achieved in small, low heat capacity x-ray microcalorimeters with low Tc
  ♦ FWHM = 0.9 eV at 1.5 keV
  ♦ FWHM = 1.6 eV at 6 keV
• Excellent energy resolution demonstrated in 2x2 & 3x3 Hydras
  ♦ FWHM = 2.1 eV @ 6 keV in 3x3 Hydra
• More uniform arrays being produced
• Suitable for solar physics & astrophysics applications