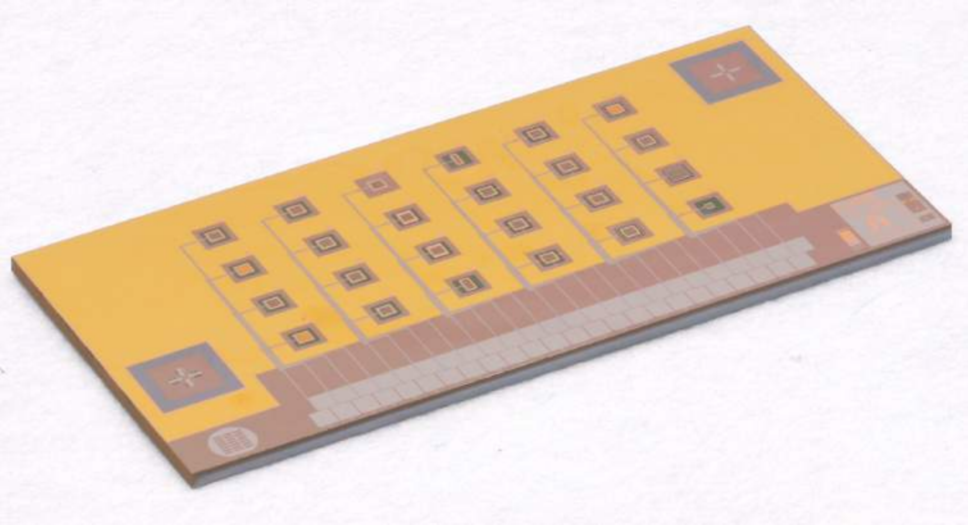
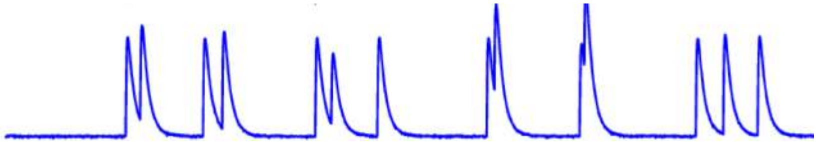


Thermal Conductance Engineering for High-Speed TES Microcalorimeters

motivation, design, and initial characterization

James Hays-Wehle
NIST: D. Schmidt, D. Swetz, and J. Ullom
LANL: M. Croce and M. Rabin
U MiB: A. Nucciotti
U Genoa: F. Gatti

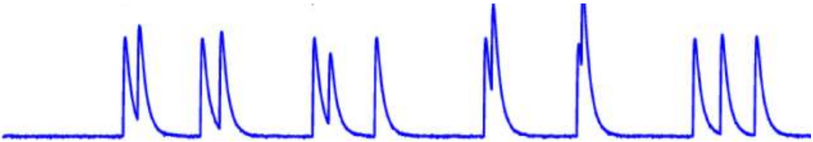
Need for Speed



Preventing Pile-up

- Need to match rep-rates at light sources
- 100 Kcps arrays planned

Need for Speed



Preventing Pile-up

- Need to match rep-rates at light sources
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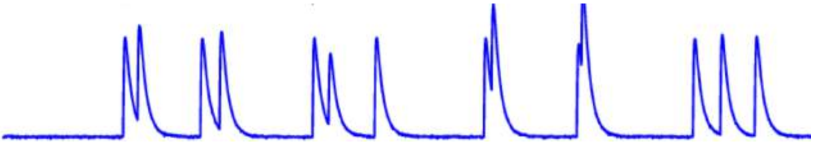
Identifying Pile-up

- Coincident pulses that could distort spectra can be cut

Need for Speed



Preventing Pile-up

- Need to match rep-rates at light sources
- 100 Kcps arrays planned

Identifying Pile-up

- Coincident pulses that could distort spectra can be cut

Now have the bandwidth to achieve this

- See J.A.B. Mates, J. D. Gard, *et al.* on Tuesday

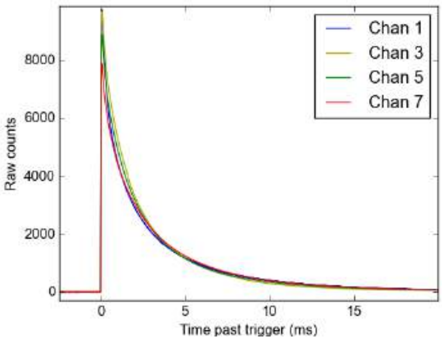
Constraints on Sensor Design

TES parameters

- C and α set by targeted energy range.
- $E_{\max} \propto C/\alpha$
- $\Delta E \propto \sqrt{4k_b T^2 C/\alpha}$
- Pulse speed chiefly determined by thermal conductance
- $\tau \propto C/G$

Goal

Increase G to improve pixel speed while maintaining resolution performance

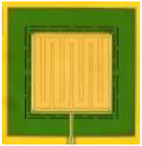


Current generation X-ray pulses. $\tau > 1$ms

Historical control of G

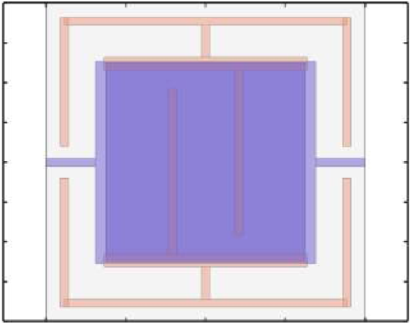
- TES thermally isolated on a SiN_x membrane.

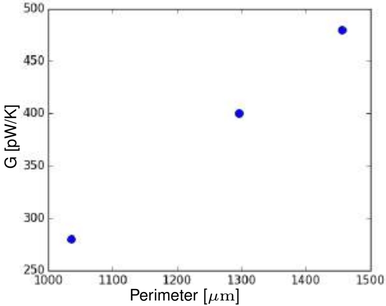
Historical control of G



- TES thermally isolated on a SiN_x membrane.
- Perforated membranes used for *smaller G* to meet bandwidth constraints.
- Bare silicon G too much, fixed.

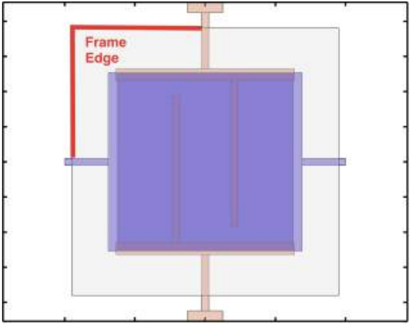
G increasing feature: perimeter

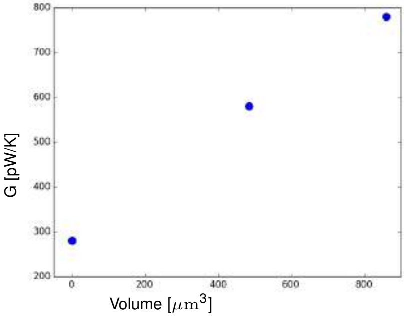




- On a membrane, *G* scales with perimeter.
  - Understood from 2-D ballistic phonon transport
- Test design doubles *G* relative to baseline device

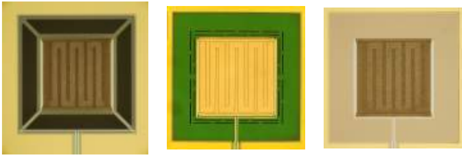
G increasing feature: patches



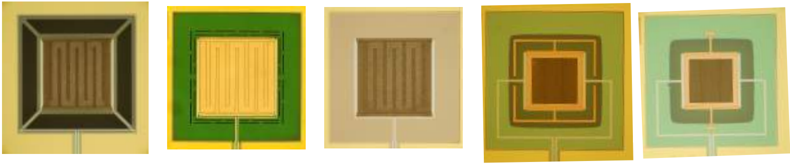


- Copper patches create thermal link directly to the frame
- Added *G* increases linearly with metal volume on frame
  - Understood from e-p coupling theory
- Test design trebles *G* of baseline device

Control of G



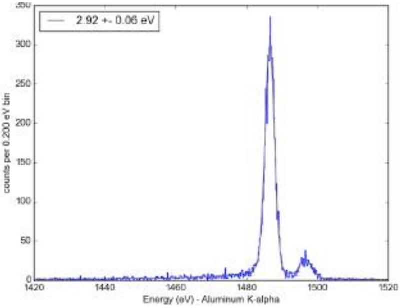
Control of G

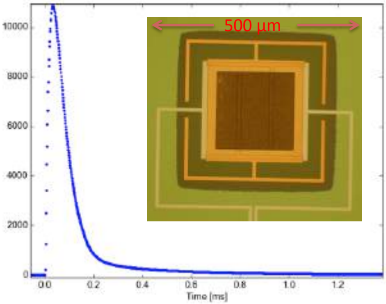


10 pW/K 1 nW/K

Predictable lithographic control of G over an order of magnitude.

Prototype Perfomance





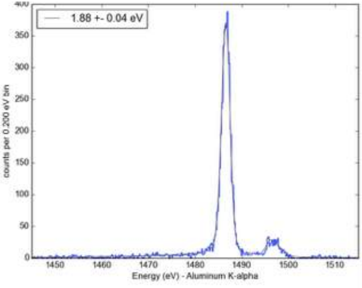
- 1/e fall time = 77 μs
- Better than 3 eV FWHM resolution demonstrated at 1.5 keV
- Dynamic range up to 4 keV

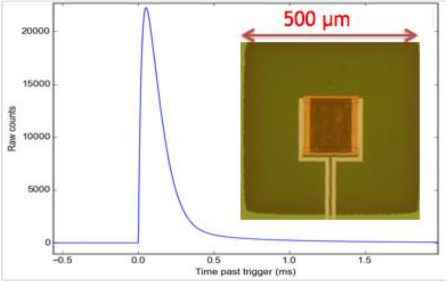
Fin

- Detector speed greatly increased with lithographic features
- Performance maintained
- See poster for details

Thank You!

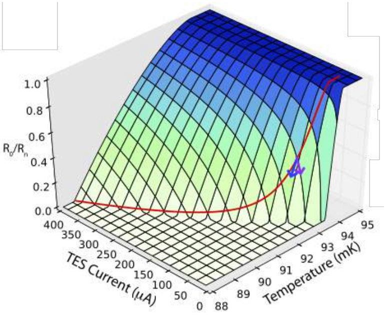
Another Prototype Perfomance



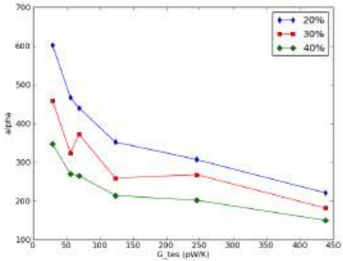


- 1/e fall time = 140 μs
- Better than 2eV FWHM resolution demonstrated at 1.5 keV
- Optimized for range up to 1 keV

Bonus Challenge



$R(I, T)$ surface in the 2-fluid model.
D. Bennett et al DOI:10.1007/s10909-011-0431-4



Previous experiments show a decreasing trend of α with G.

The two fluid model predicts that α is inversely proportional to I/I_C.
Increasing G means increasing the bias current, which in turn suppresses α.
We are exploring devices with higher resistances and fewer bars to compensate for this effect.