Detector Development for SPTpol

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ANL-HEP Site Review
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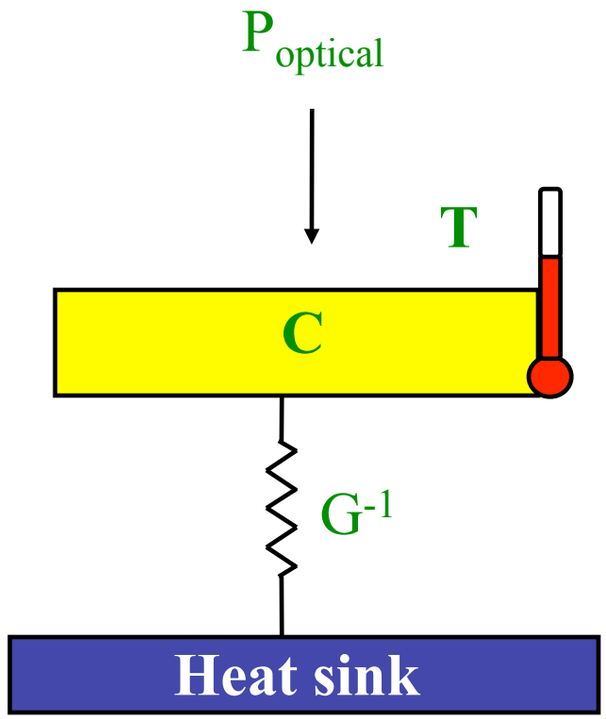
Bolometer Basics

- Measure changes in power
- Weakly heat sunk thermal mass
- Change in absorbed power changes temperature
- Measure temperature



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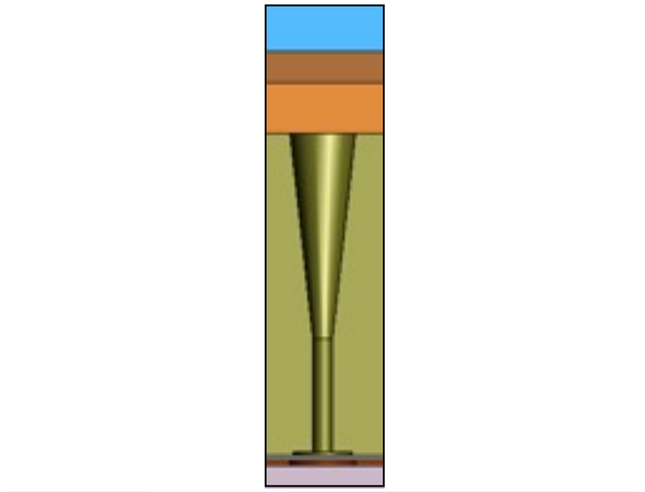
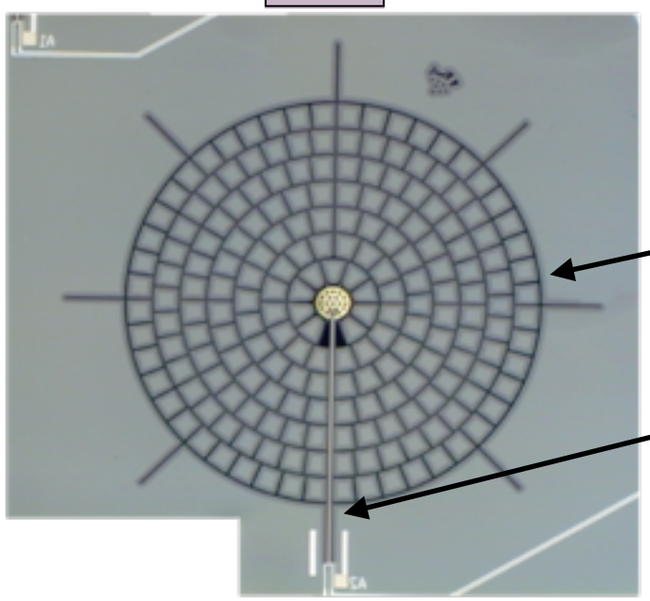
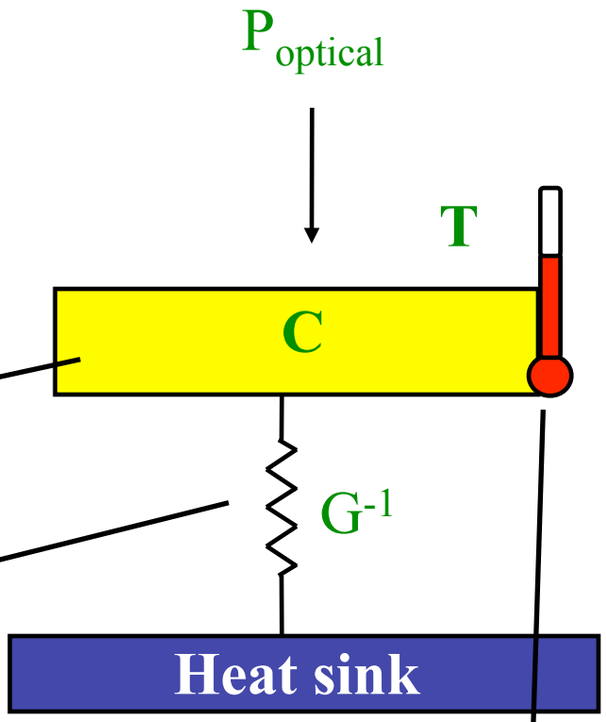
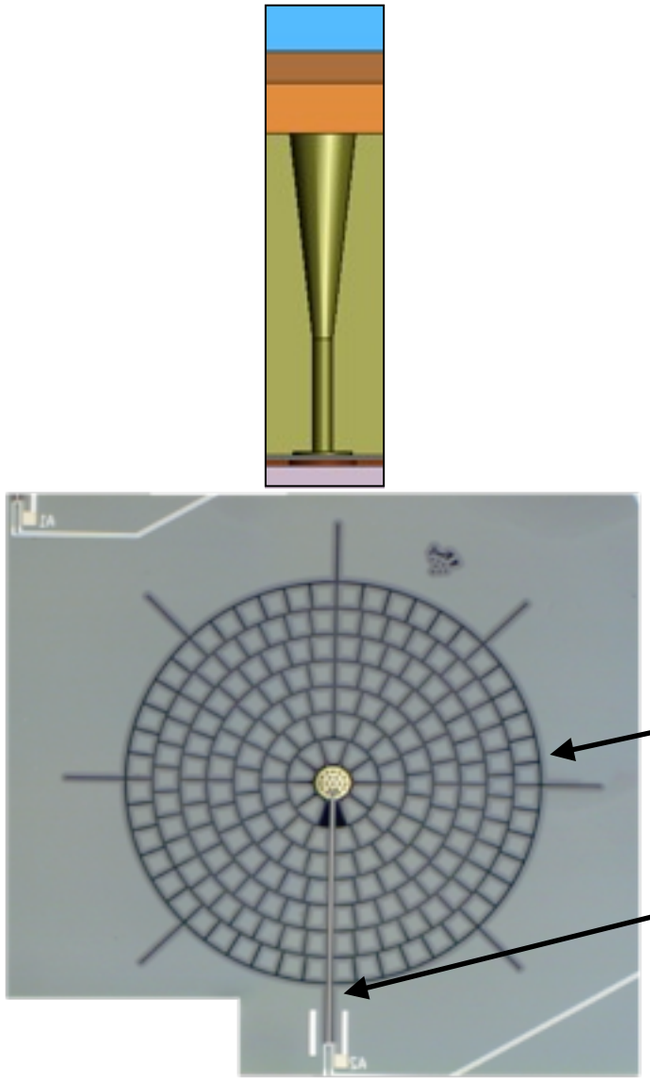






Bolometer Basics

- Background limit $\delta P_{optical} \sim \delta G$
- Increase sensitivity with more detectors



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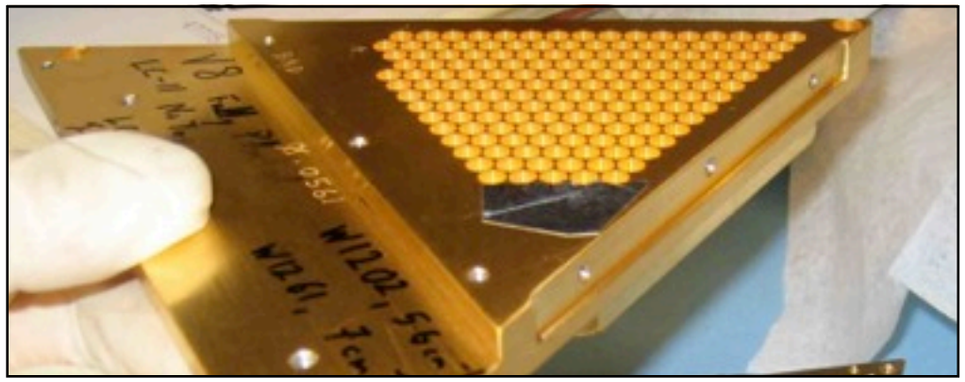
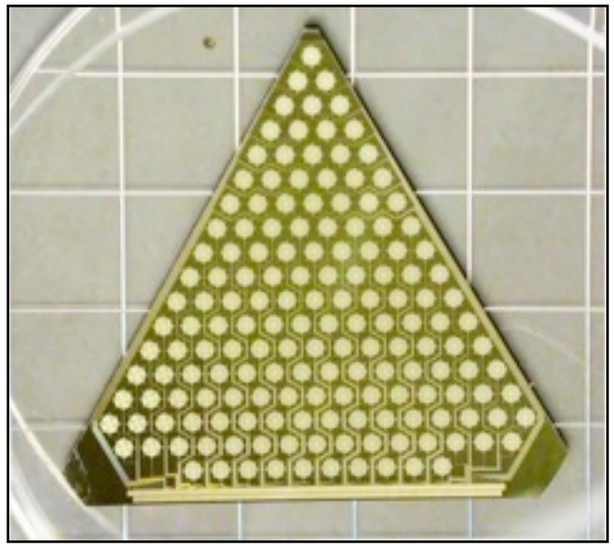
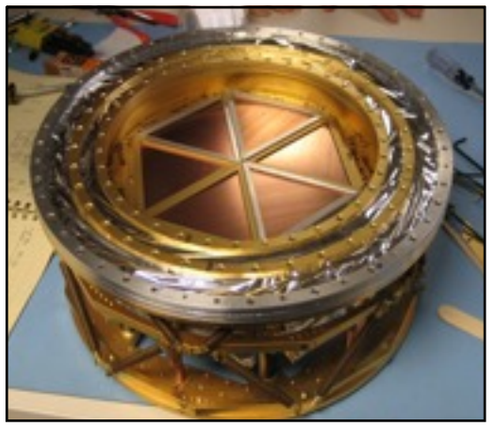
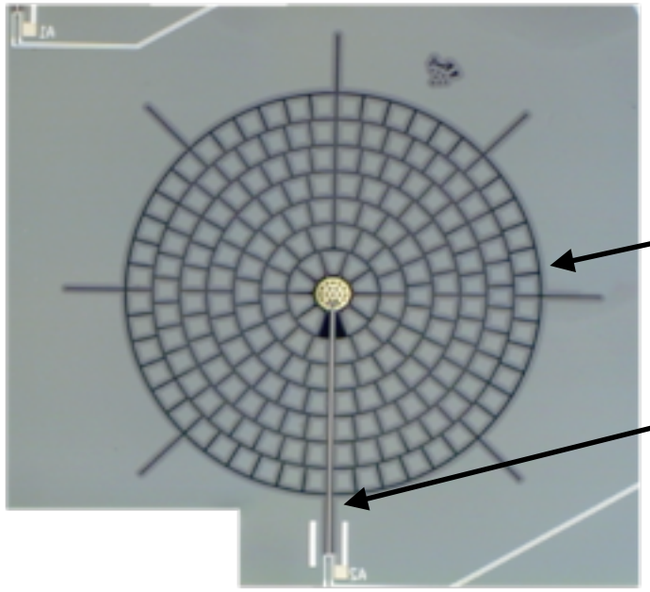






14”



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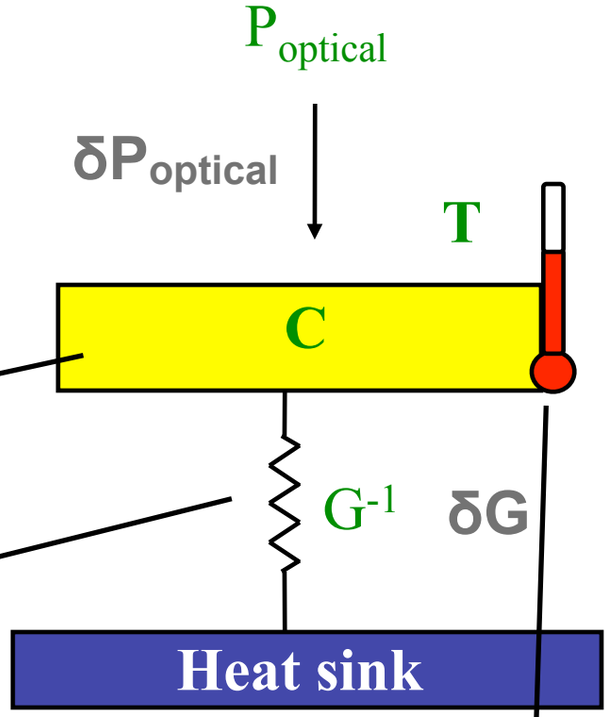
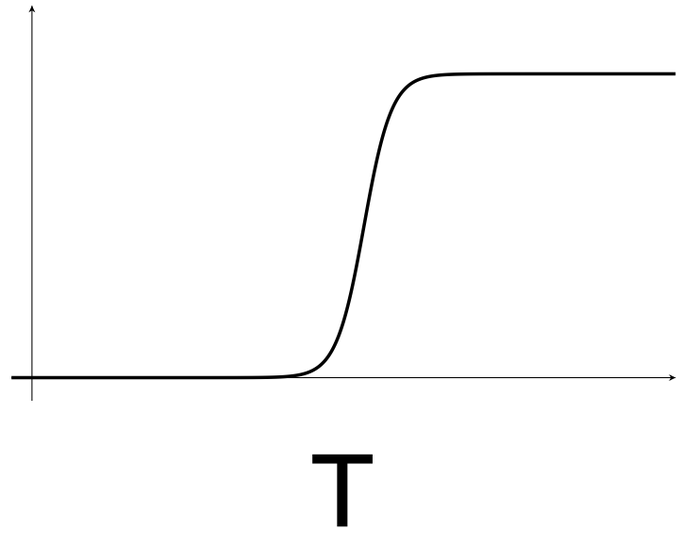


Transition Edge Sensors (TES)

- **Steep R(T) transition**

$$\alpha = \frac{d\ \ln R}{d\ \ln T}$$

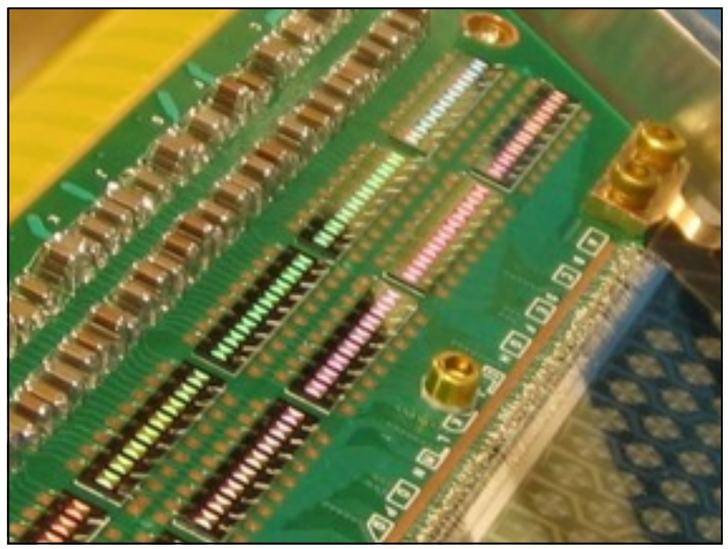


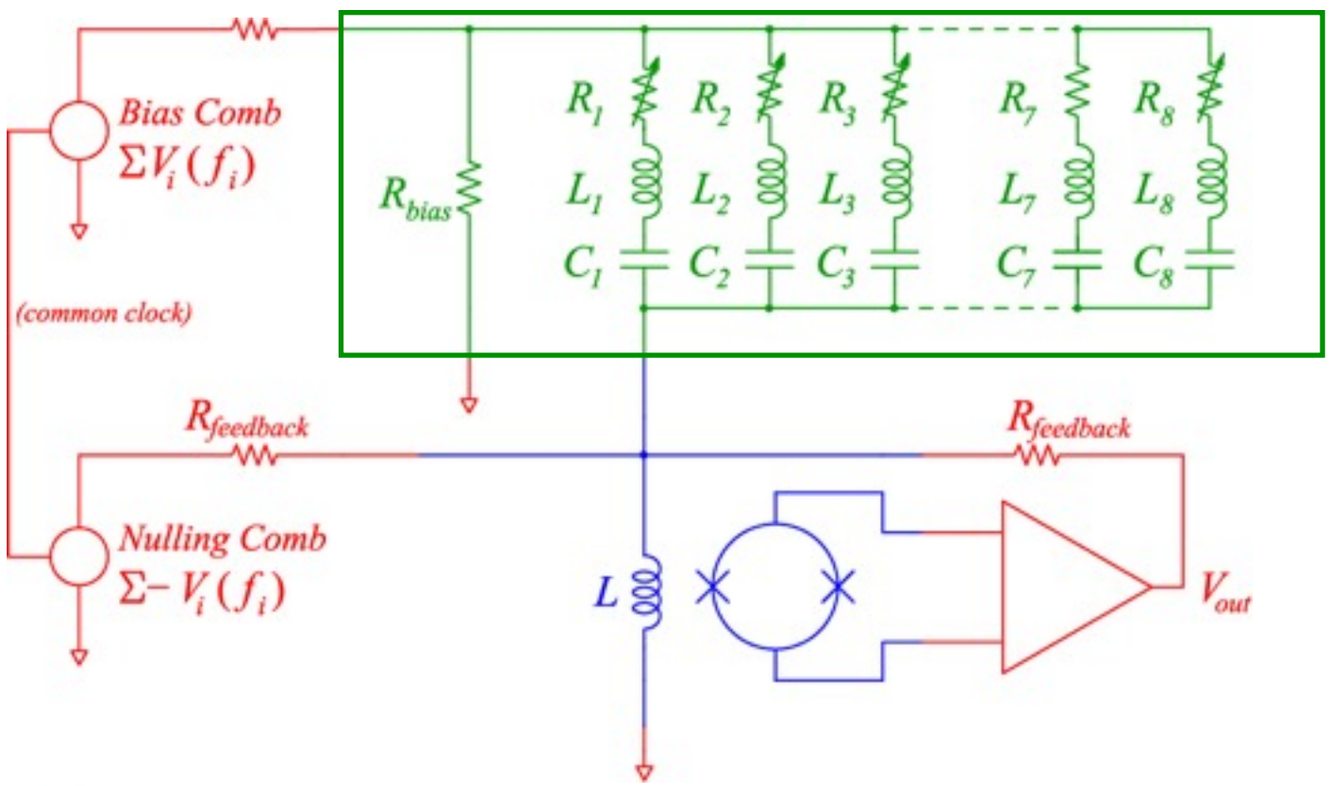
- **Thermal equilibrium**
  - balance between cooling through weak link, absorbed optical power and Joule heating

- **Electro-thermal feedback**
  - Voltage biased: Joule heating $V^2/R(T)$
  - Increase in T reduces Joule heating → Negative feedback
  - open loop gain proportional to α
  - linearized response (good!)
  - increases bandwidth

Multiplexing

- TES is low impedance (~1 Ω)
- Current measured by SQUID amplifier
- SQUIDs have 2-10 MHz good noise bandwidth
- Multipliex (MUX): distribute large SQUID bandwidth across many different detectors
  - sky signal <100 Hz
- Optimization
  - negative feedback increases detector bandwidth
  - MUX wants lower detector bandwidth





Unique ANL Resources

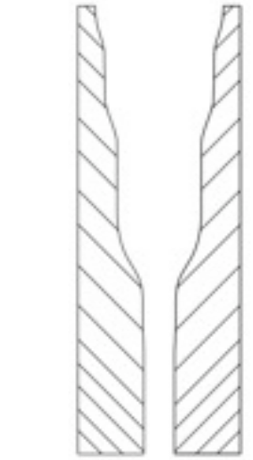
- **Center for Nano-Scale Materials**
  - Focus on science
  - State of the art tooling for lithography
  - Technical support

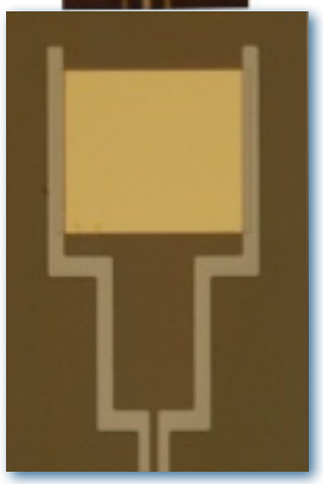
- **Material Sciences Division**
  - Dedicated deposition system
  - Expertise and tools for understanding material properties

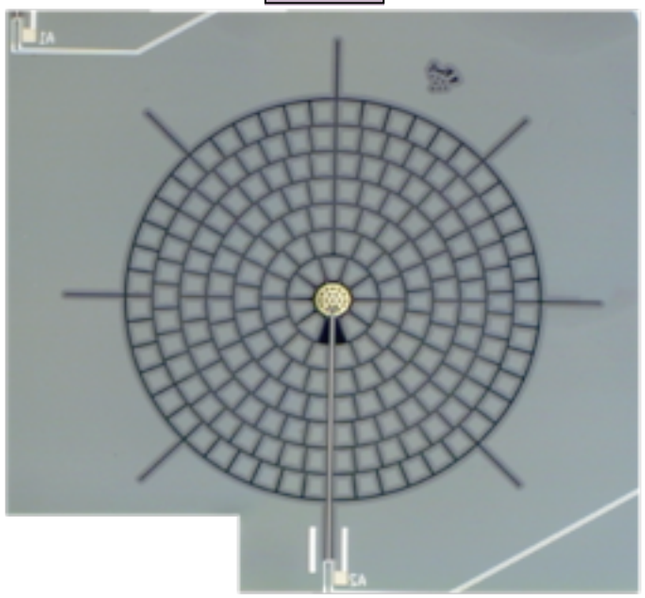
Build up expertise for CMB bolometer development and production

Anatomy of ANL Polarimeter

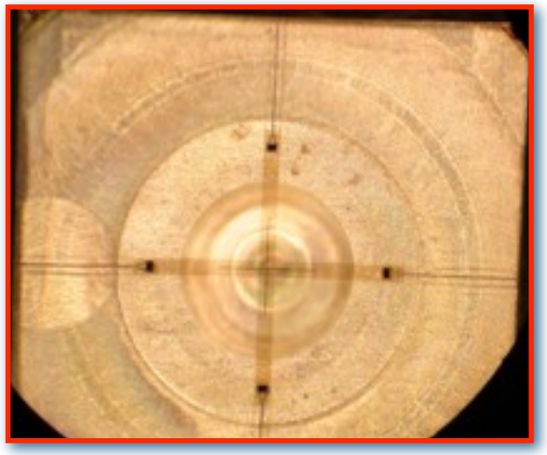
LDRD investment to develop CMB polarimeters at ANL.

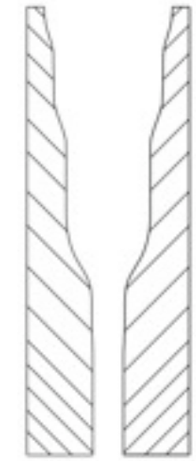


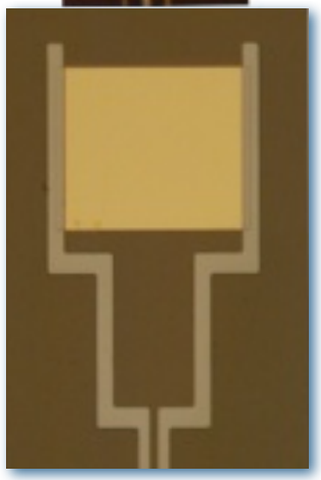


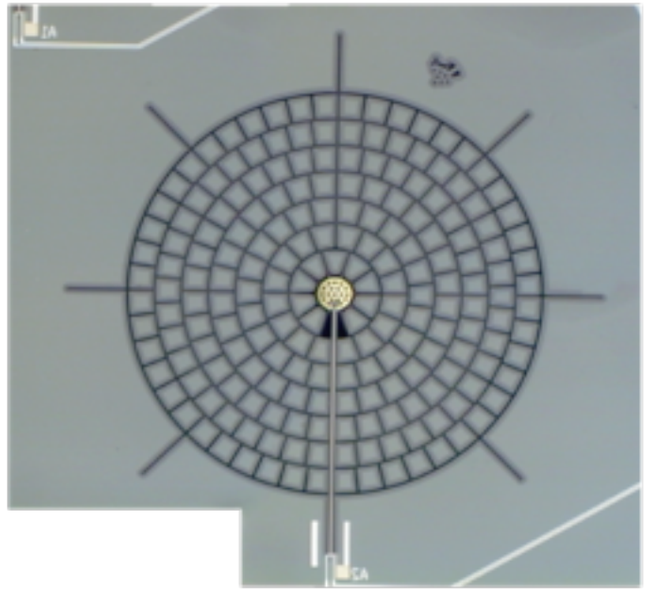


Anatomy of ANL Polarimeter









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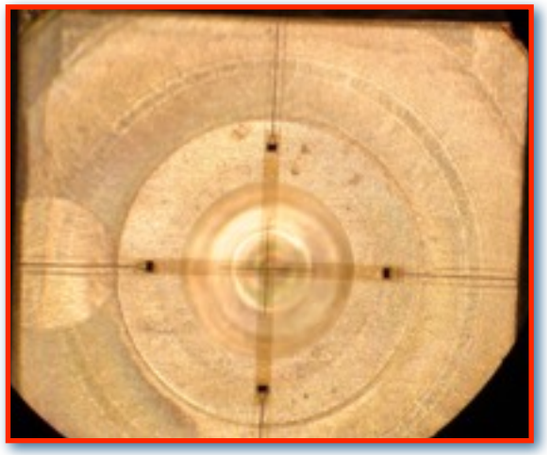
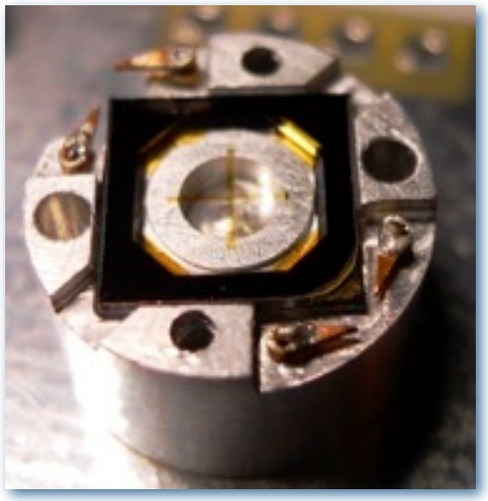
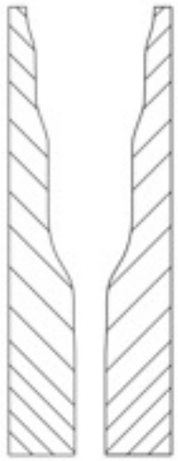
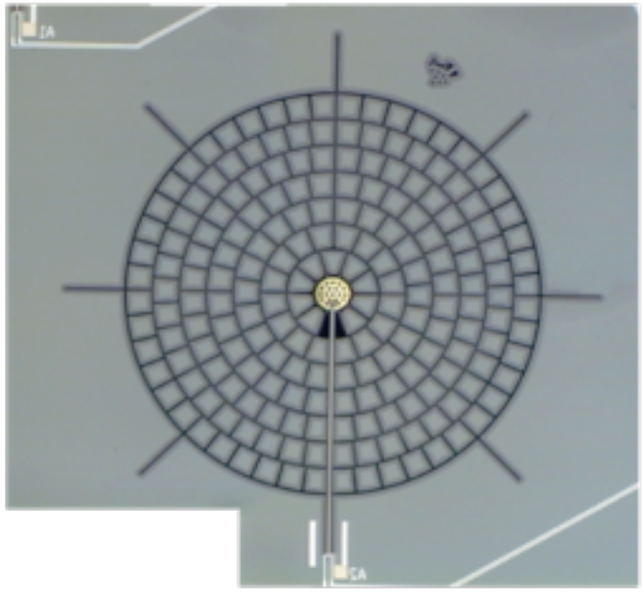




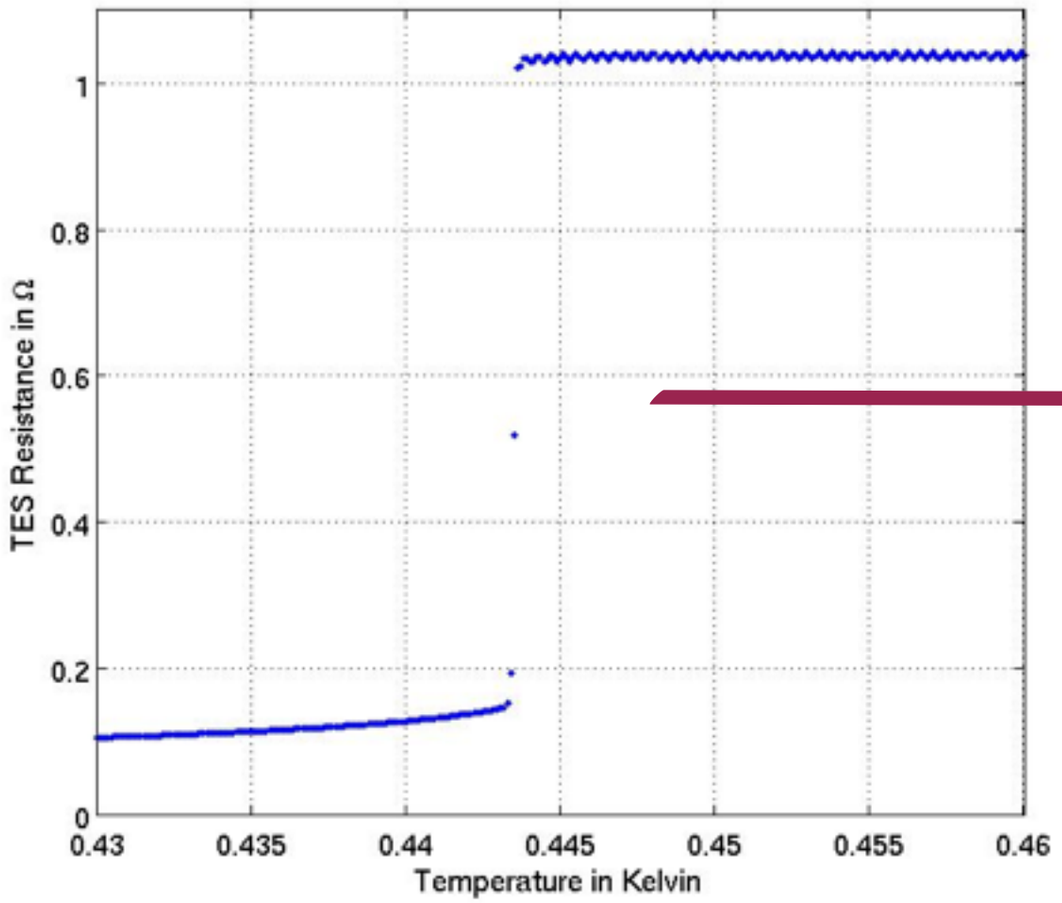


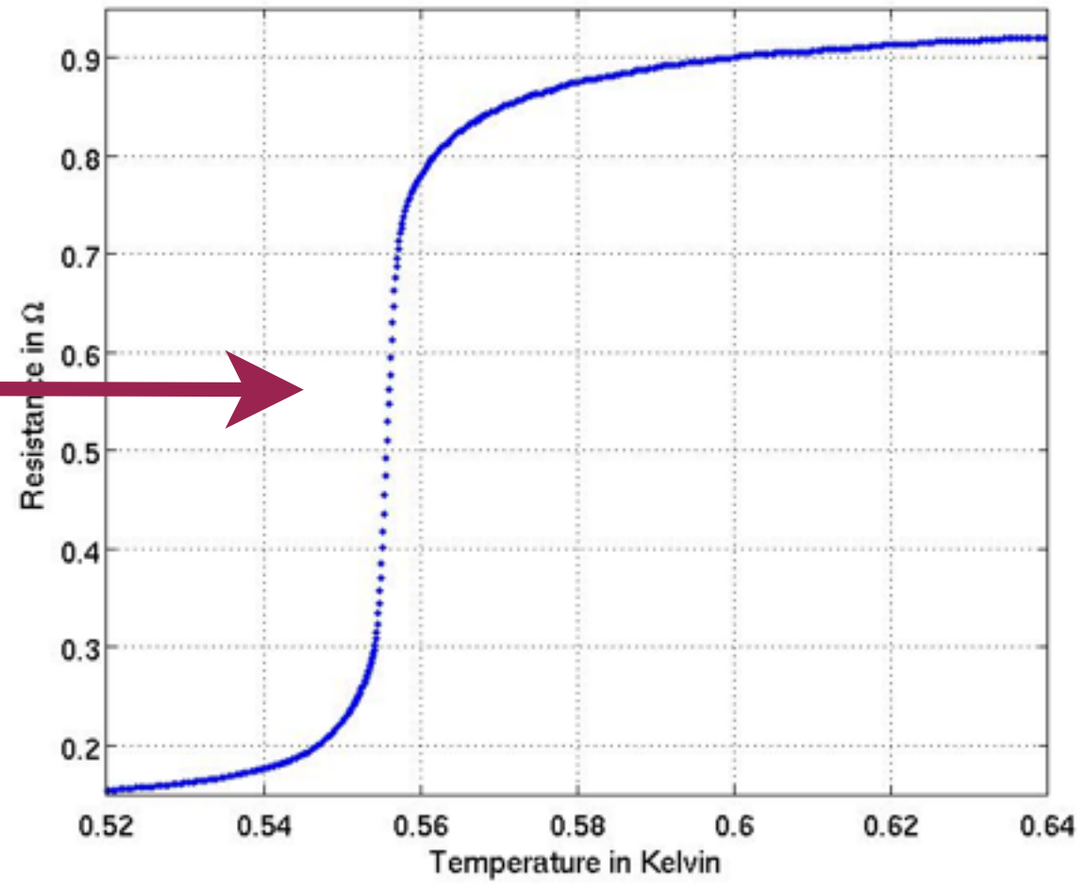


Solving bandwidth optimization

- High quality films have sharp transitions (high α; high open loop gain)

- Tune R(T) to get α just right





Initiating Production

- ✓ High broadband coupling (90% over 36% bandwidth)
- ✓ Excellent polarization isolation (<1%)
- ✓ background limited sensitivity (60 aW/rtHz)
- ✓ optimized operational bandwidth and electrical properties for multiplexing
- ✓ RF simulations
- ✓ materials characterization
- ✓ thermal modeling

"Optical Properties of Argonne/KICP TES Bolometers for CMB Polarimetry." AIP volume 1185, pages 203-206, 2009.

"TES Development for a Frequency Selective Bolometer Camera." IEEE Transactions on Applied Superconductivity, 19:548-552, June 2009.

"Optical design of Argonne/KICP Detectors for CMB Polarization." AIP,volume 1185, pages 487-489,2009b.

"Design and Fabrication of Argonne/KICP Detectors for CMB Polarization." AIP, volume 1185, pages 359-362,2009.

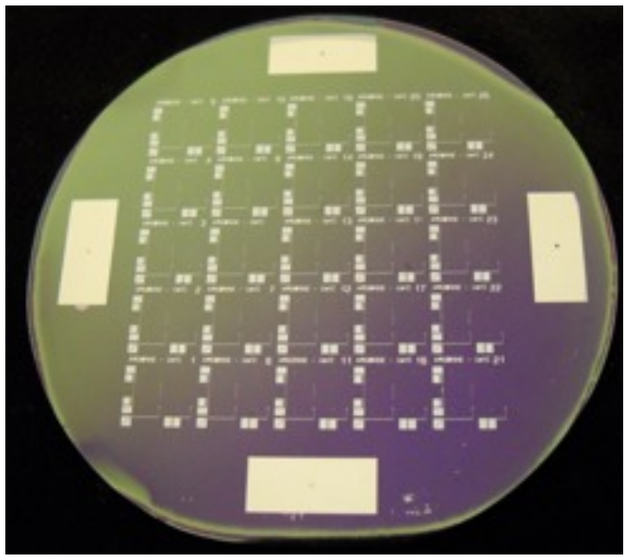
"Low temperature Thermal Transport in Partially Perforated Silicon Nitride Membranes." Applied Physics Letters, 94(18):183504,May 2009a.

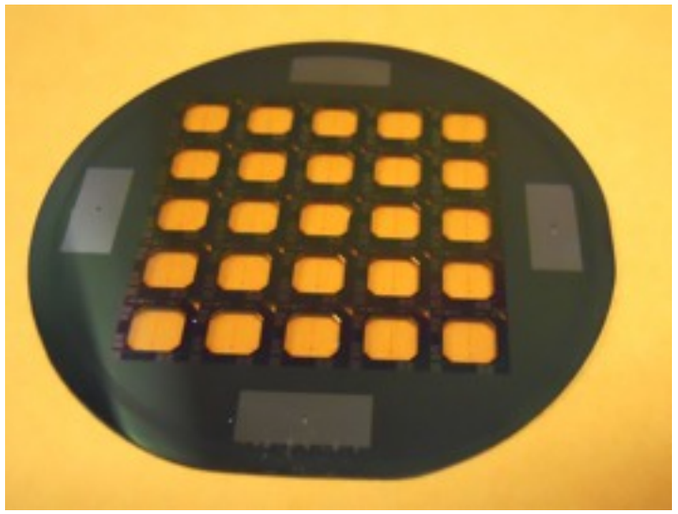
"Control of Membrane Thermal Transport Supporting Superconducting Detector Development." IEEE Transactions on Applied Superconductivity, 19:489-492, June 2009b.

Started high throughput production of 200 pixels for SPTpol

Future plans

- **2011: Deploy 200 pixels based on initial ANL prototype**
  - want to realize science from LDRD investment
- **Migrate to “monolithic” arrays**





- **Microstrip based coupling**
  - Materials properties study and optimization
  - Realize multi-chroic pixels
  - increase readout capacity

- **Aim for another 10x increase in sensitivity in 3 years**