CℓOVER

Measuring gravitational-waves from Inflation

Detector and Optical Physics Group at the Cavendish Laboratory

UNIVERSITY OF CAMBRIDGE

Performance of prototype finline-coupled TES bolometers for CLOVER

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Acknowledgments

Cambridge: Michael Crane, Bob Barker, Howard Stevenson,
Dennis Molloy, Howard Stevenson, David Sawford

Cardiff: Peter Ade, Stephen Parsley, …

NIST: Kent Irwin, Gene Hilton, William Duncan, …

UBC: Mark Halpern, Elia Battistelli, …

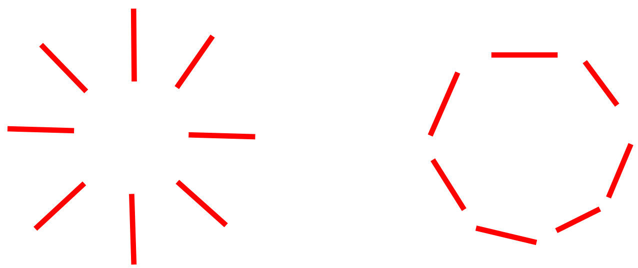
All processing done at Cambridge except DRIE (Scottish Microelectronics Centre, Edinburgh: Andrew Bunting)

What's it for?

- Thomson scattering of radiation in the early Universe causes linear polarization of Cosmic Microwave Background

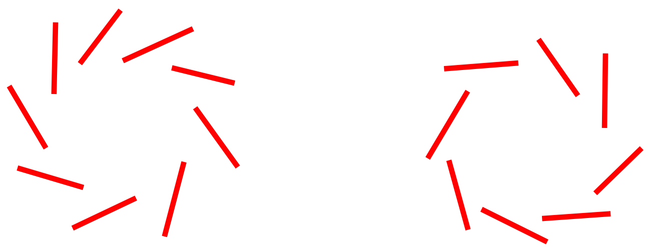
- Can decompose linear polarization map of CMB into:

- E-mode



Produced by scalar and tensor density perturbations

- B-mode



Produced by tensor perturbations only (gravitational waves)

- CLOVER aims to detect the signature of gravitational waves in the polarization of the CMB

Overview

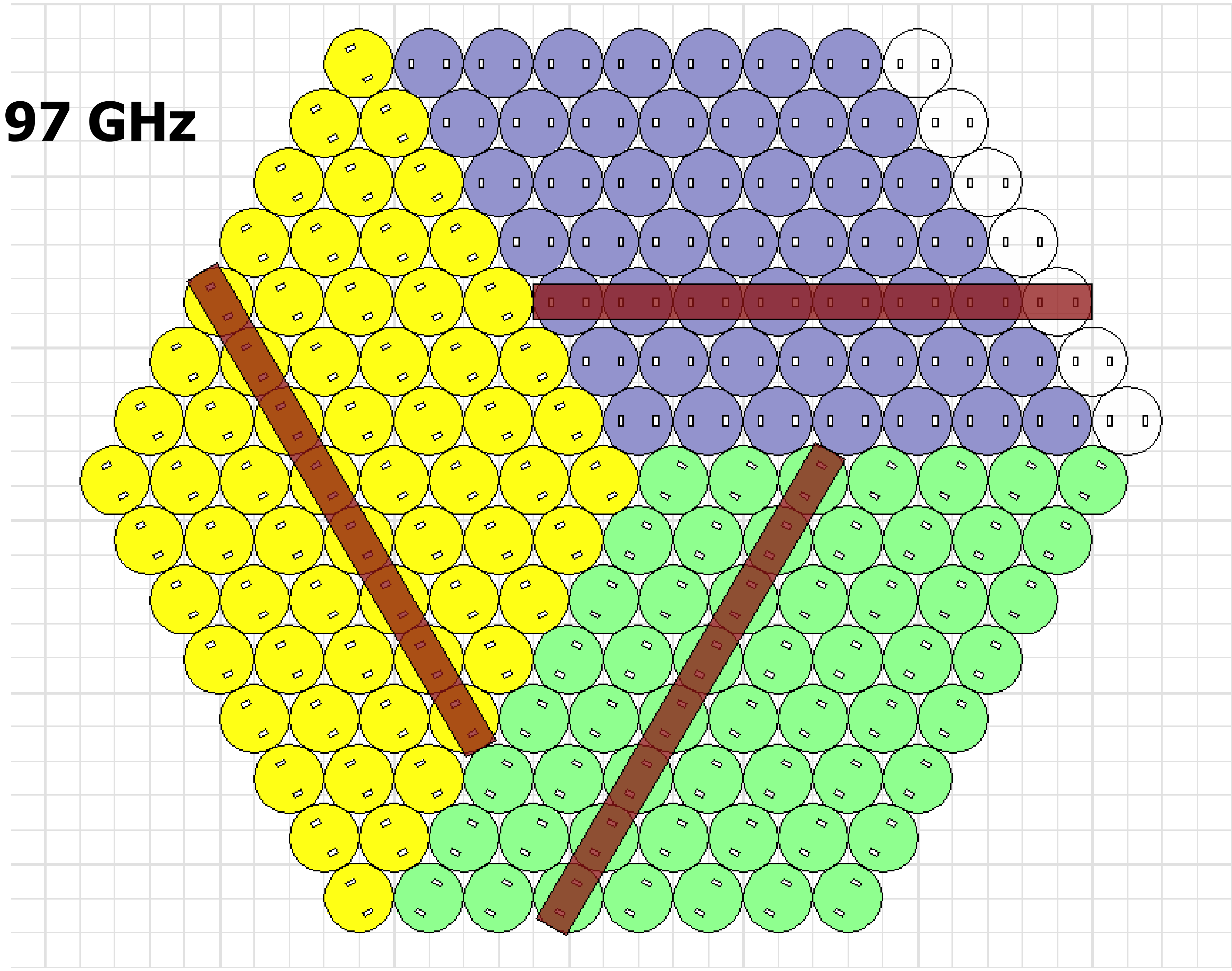
Key features of CLOVER:

- **Three telescopes measuring polarization** at 97, 150, and 220 GHz
- **Site:** Atacama Desert, Chile (Caltech)
- **Detectors:** Bolometers with MoCu bilayer TESs
- **Sensitivity:** limited by photon-noise of sky background (1.5×10^{-17} W/√Hz)
- **Operating Temperature:** 100 mK
- **Focal Plane:** hexagonal array of horns, two polarizations per horn

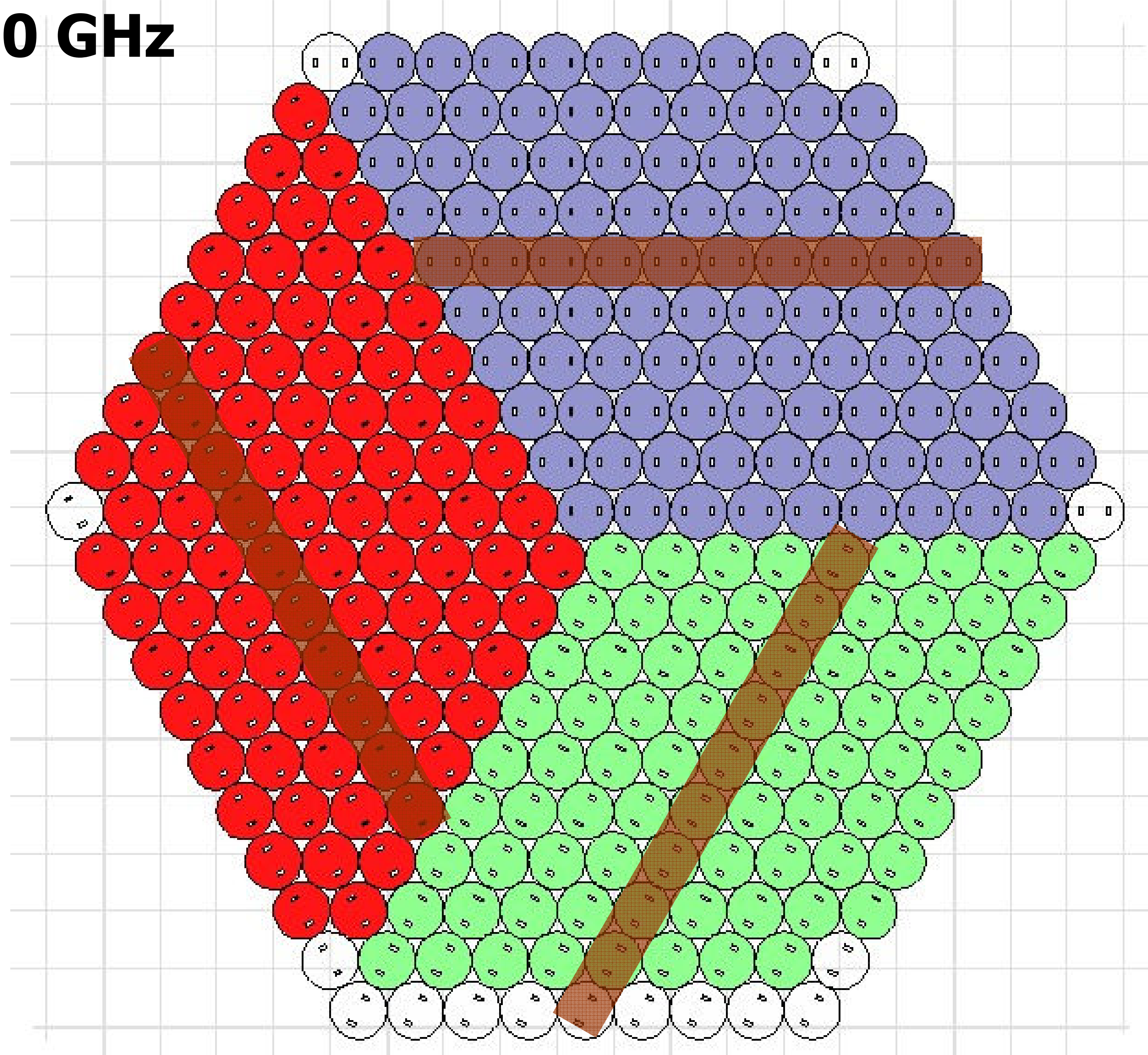
  160 horns x 2 = 320 detectors at 97 GHz

  256 horns x 2 = 512 detectors each at 150 and 220 GHz

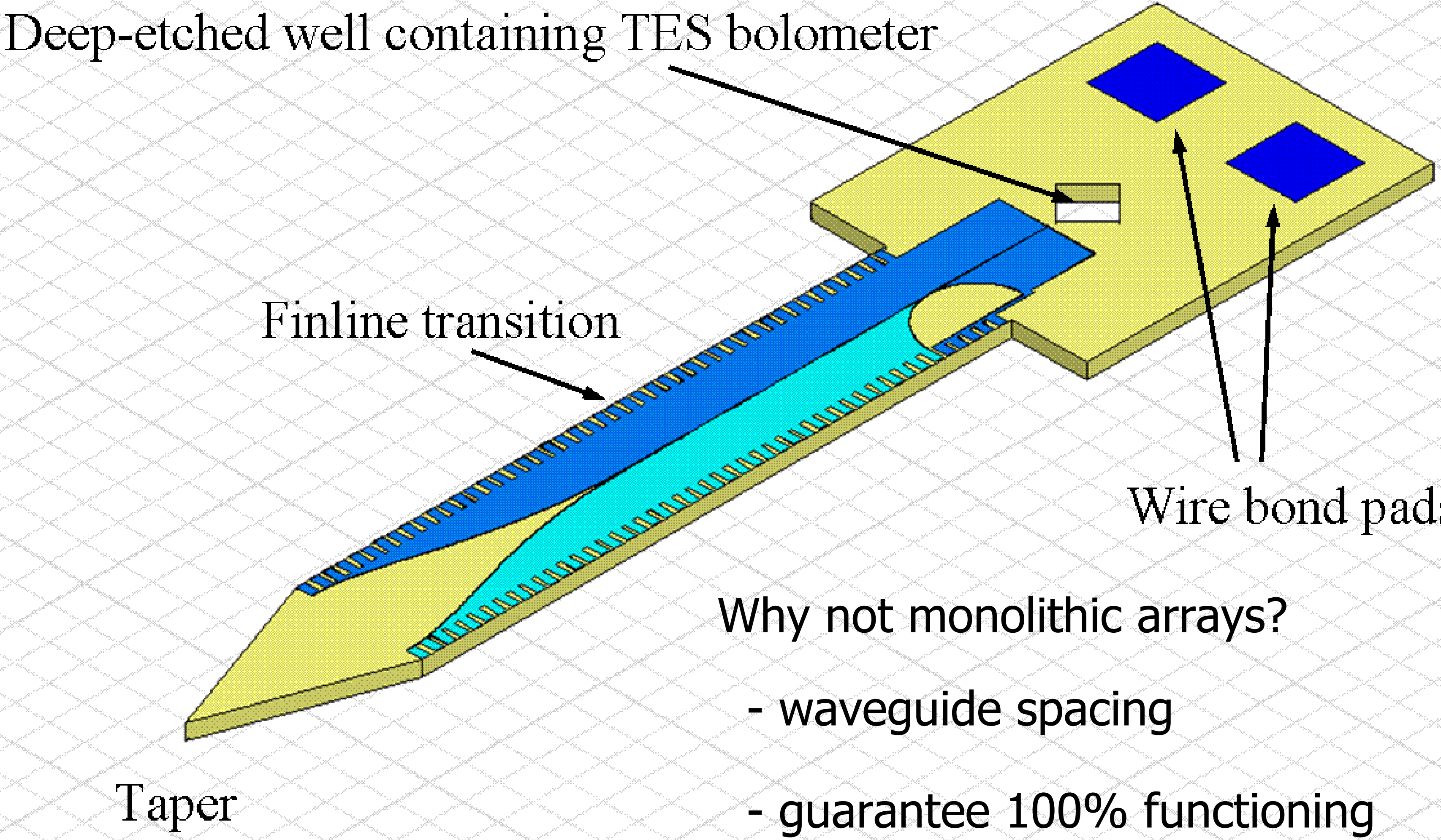
- **Detector Blocks:** Linear sub-arrays of TES detectors
  with time-division SQUID multiplexer (NIST, UBC)


97 GHz

150, 220 GHz



CLOVER 97-GHz Detector Chip

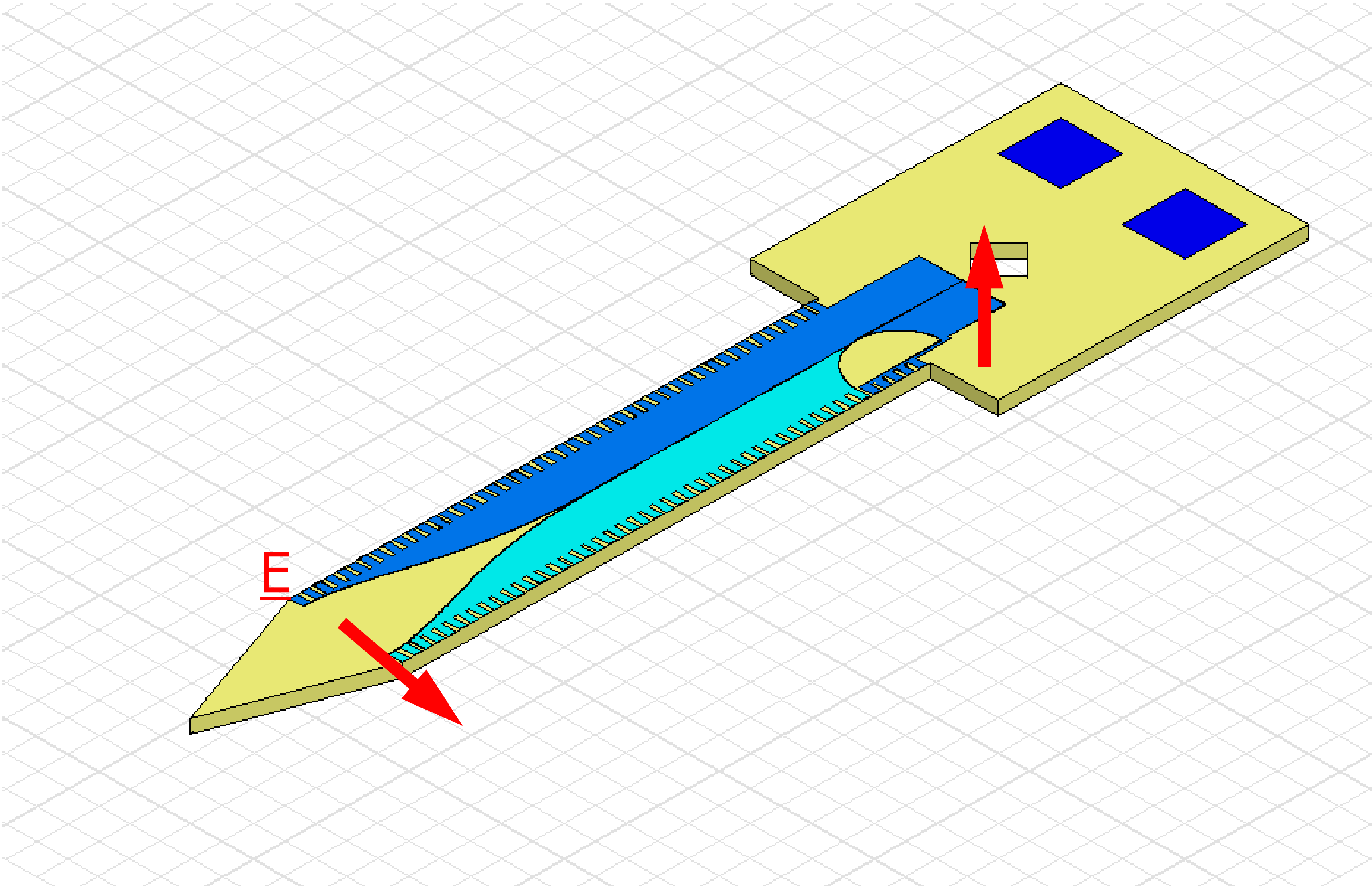


Why not monolithic arrays?

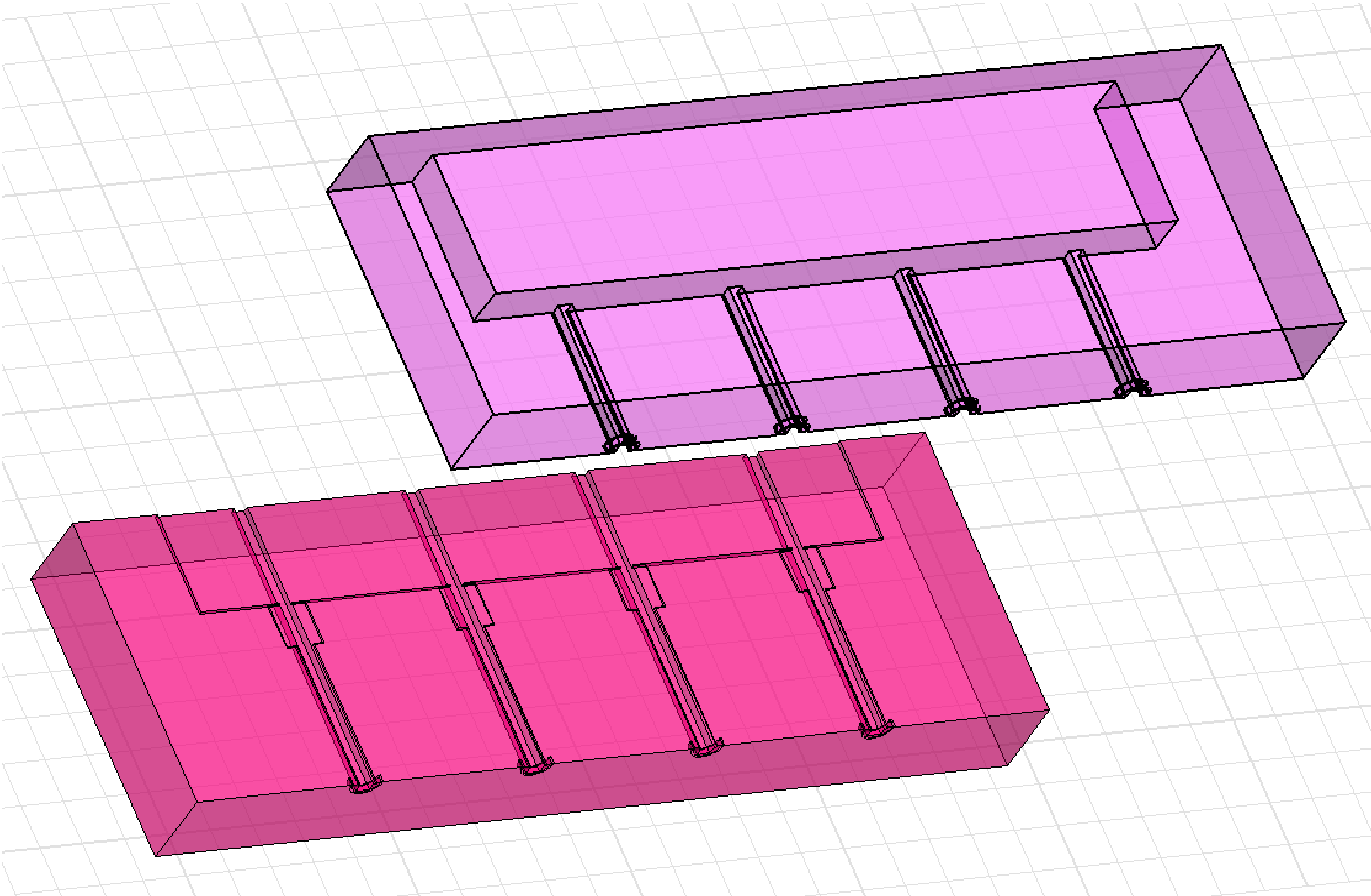
- waveguide spacing
- guarantee 100% functioning focal plane

Absorber: Finline transition

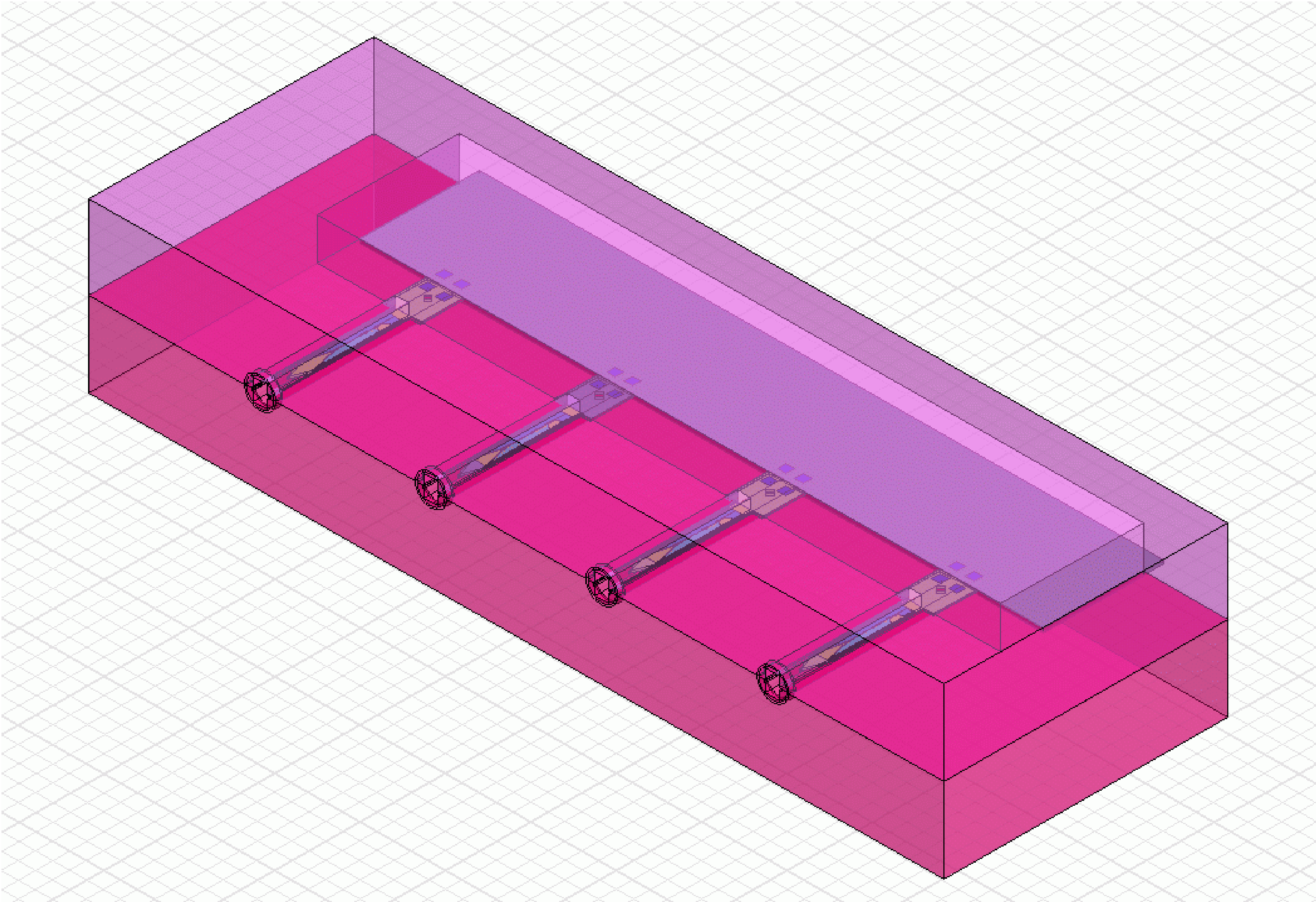
- Finline transition converts waveguide mode to microstrip mode



Split-block waveguides

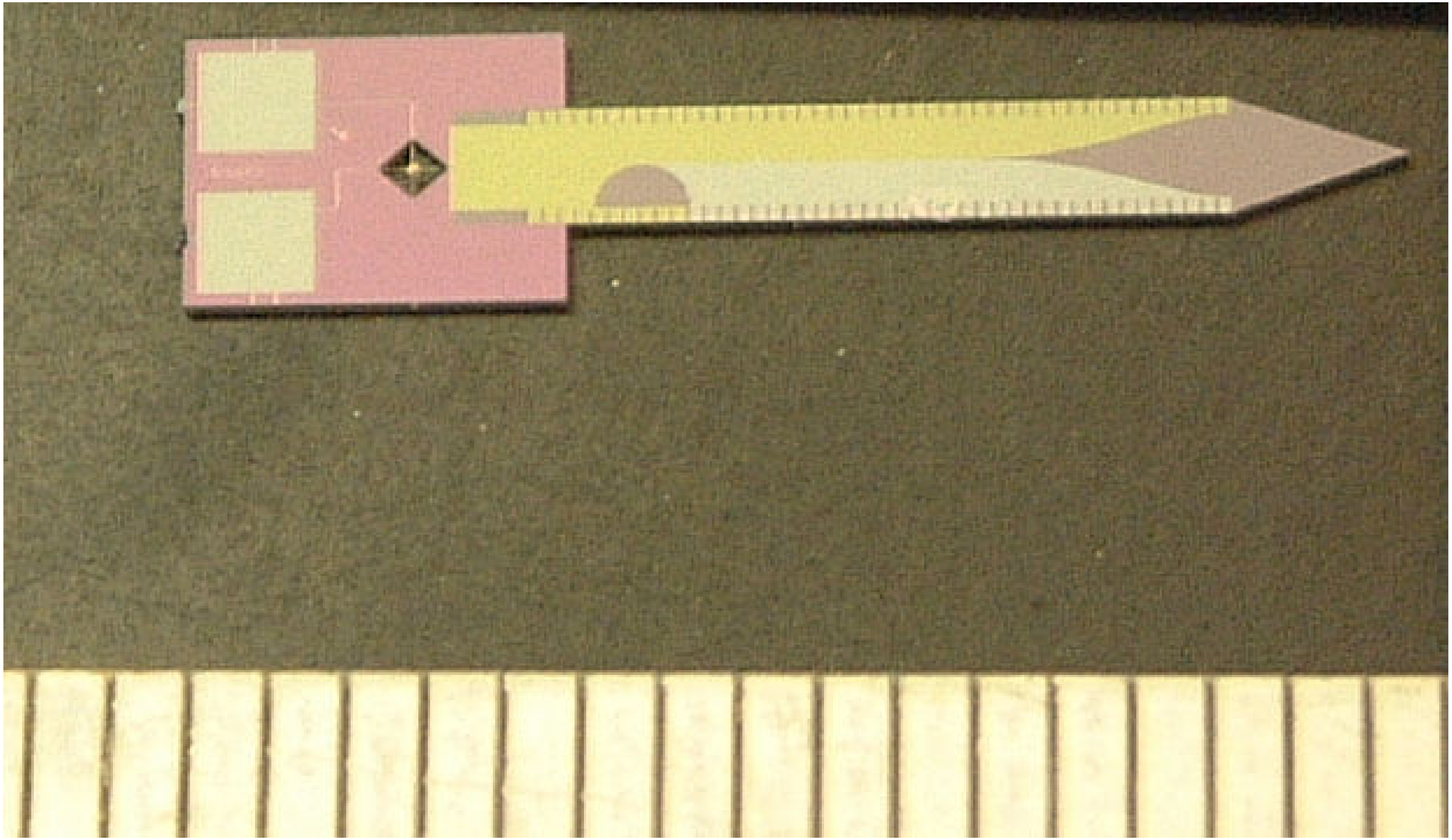


Detector Block

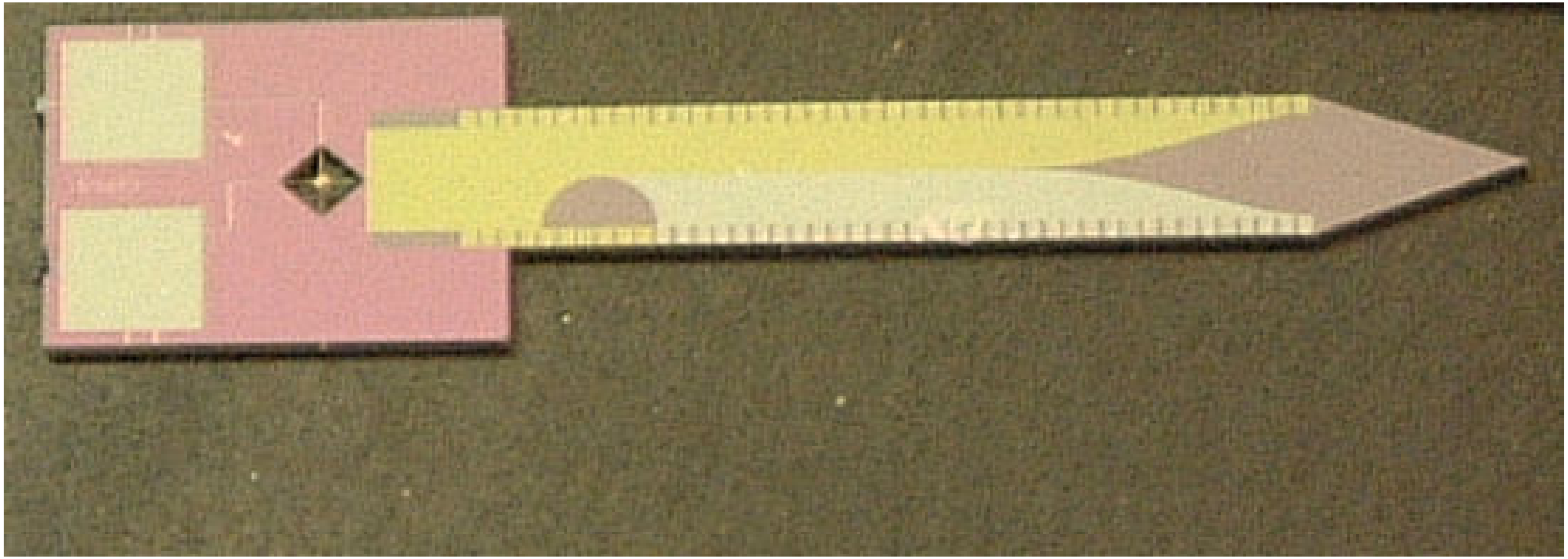


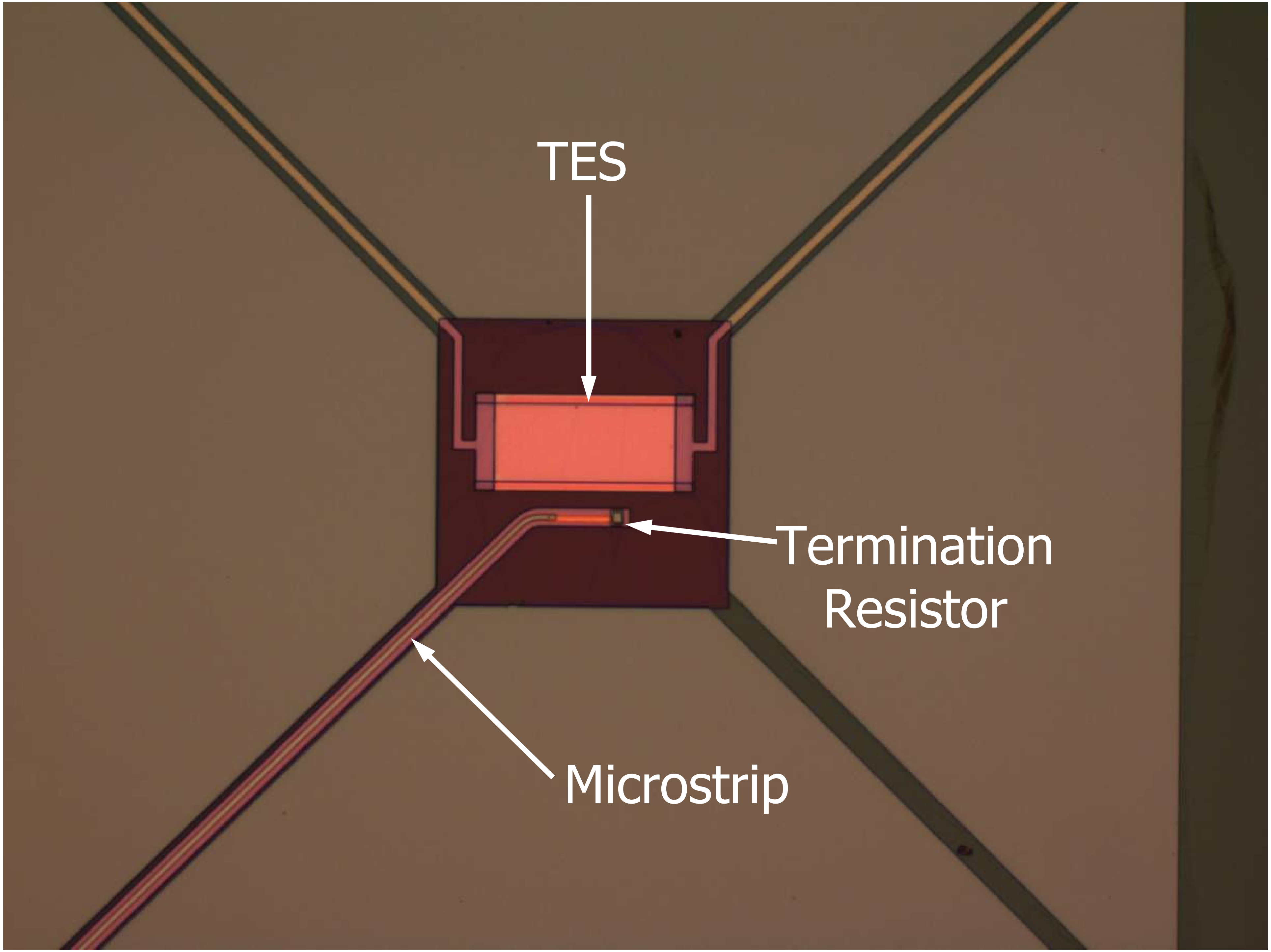
Prototype detectors on 2" wafer

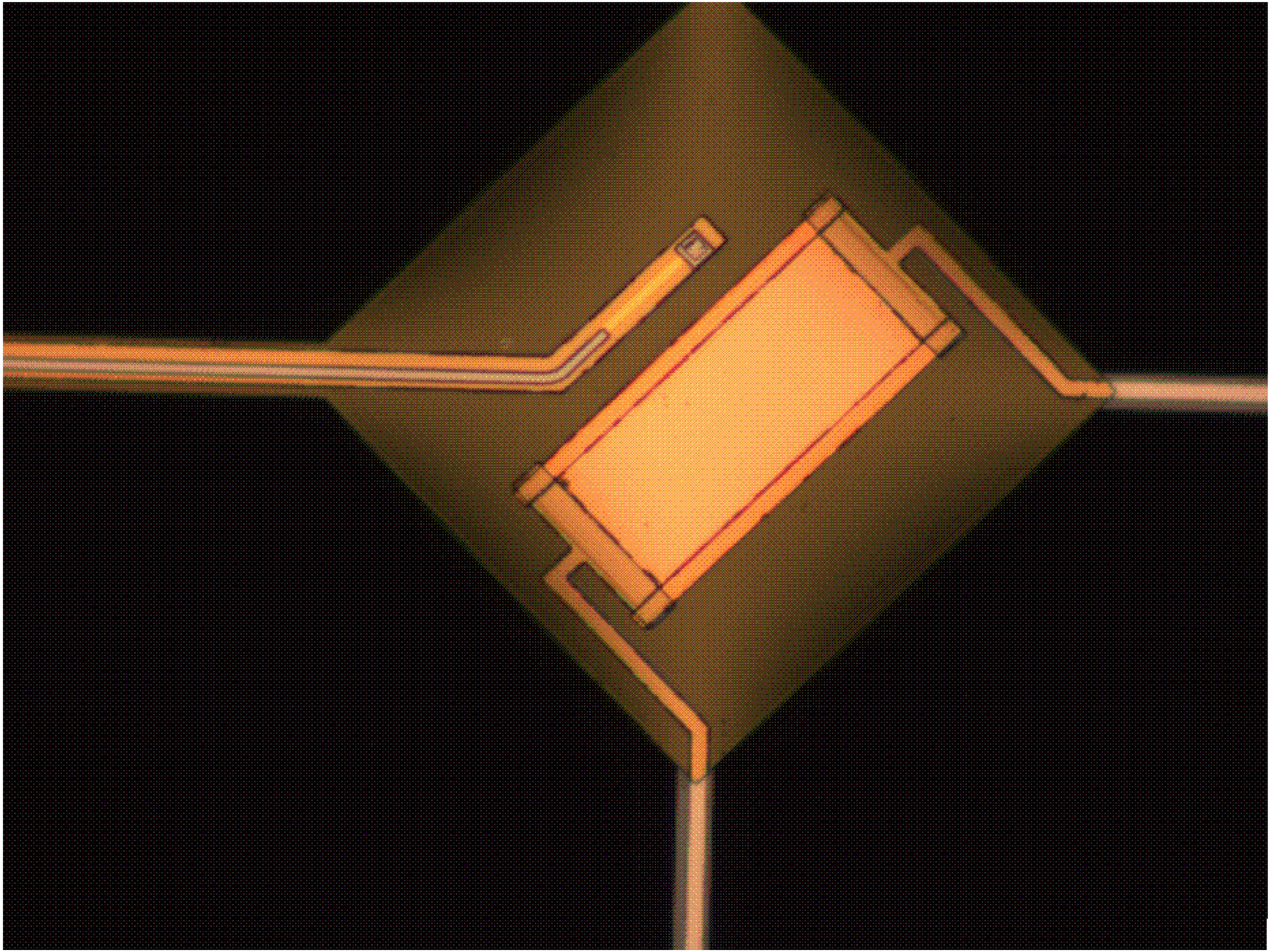
Prototype Detector



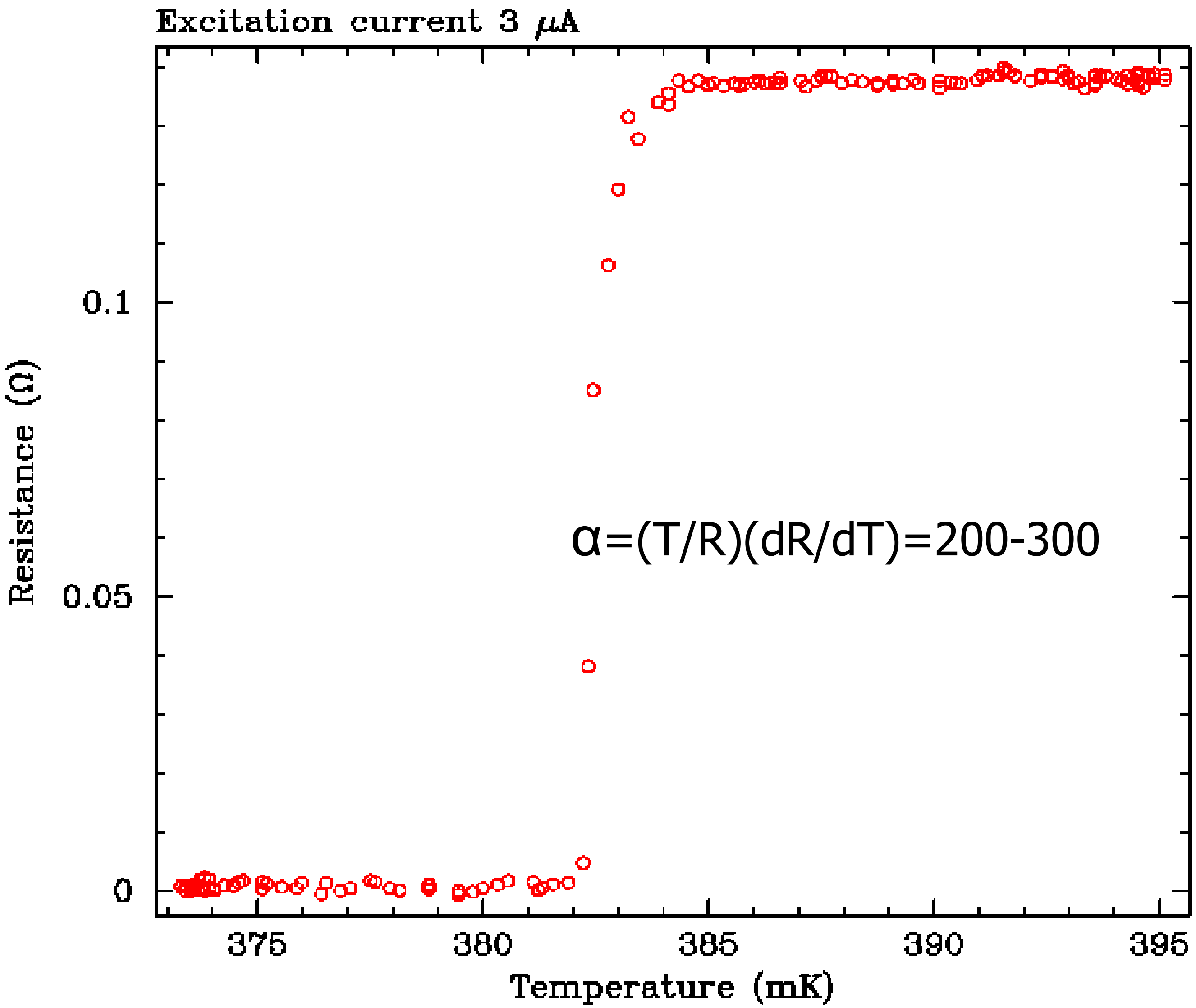
Prototype Detector



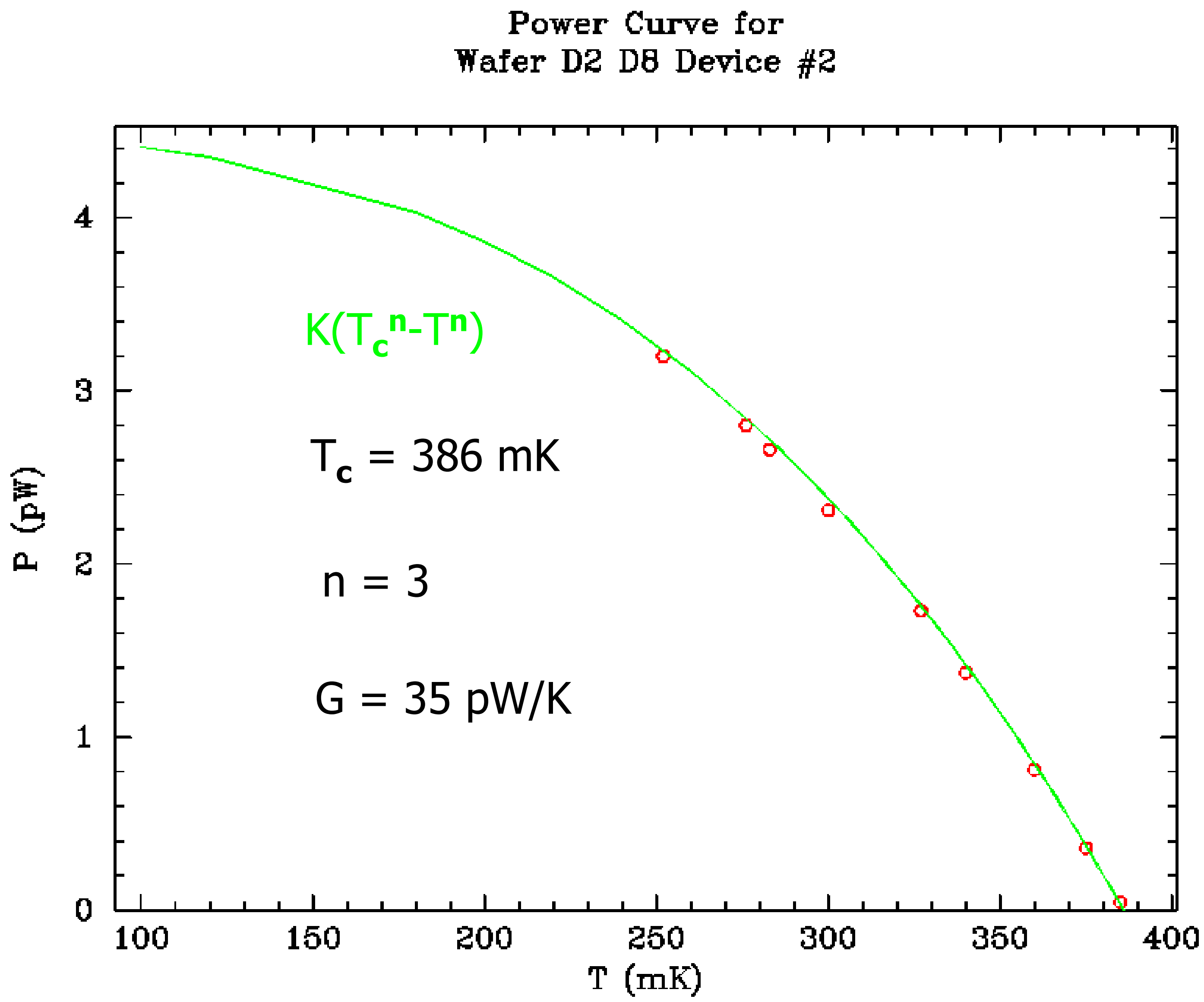

TES
Termination
Resistor
Microstrip



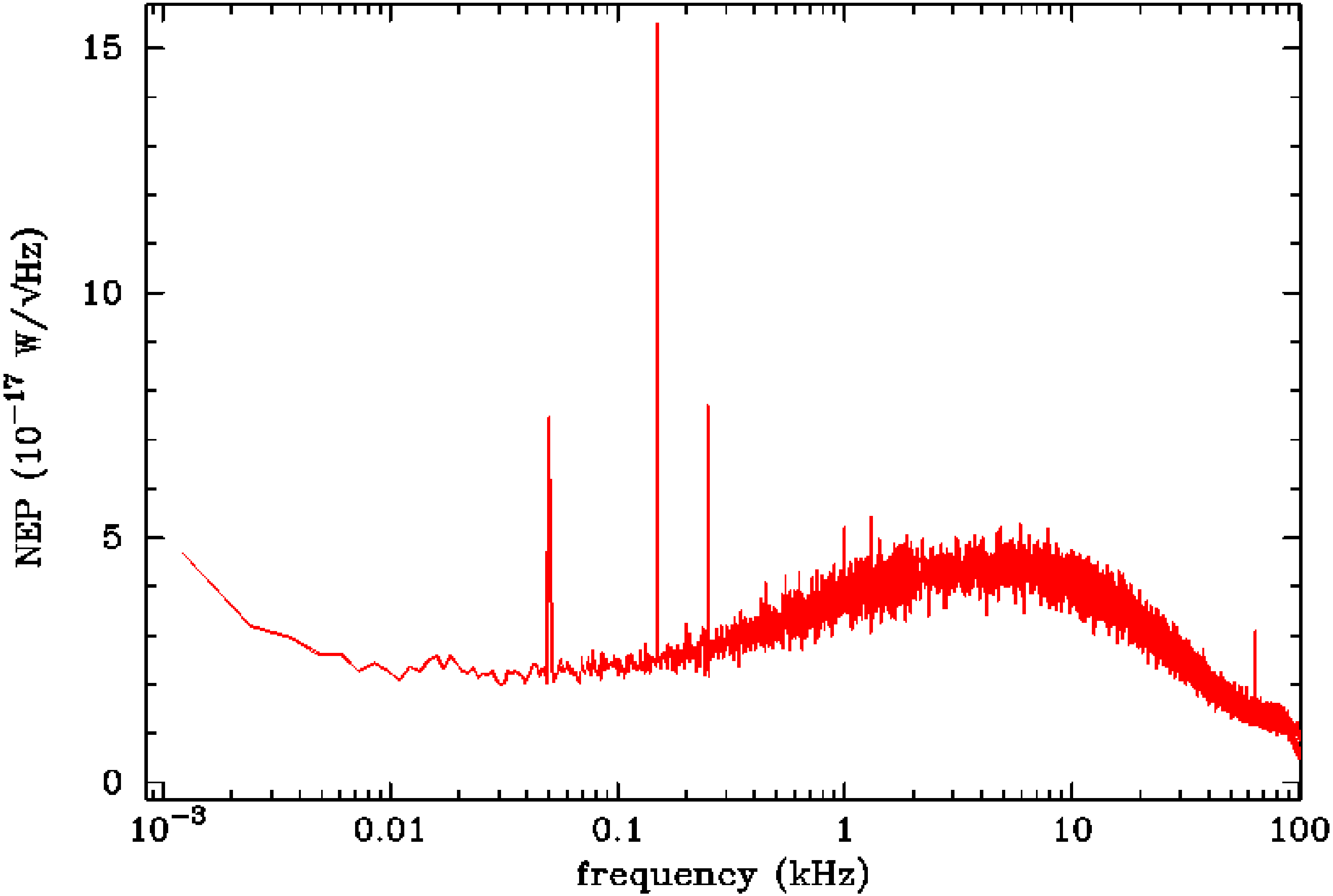
Prototype Detector



Thermal Design



Dark NEP

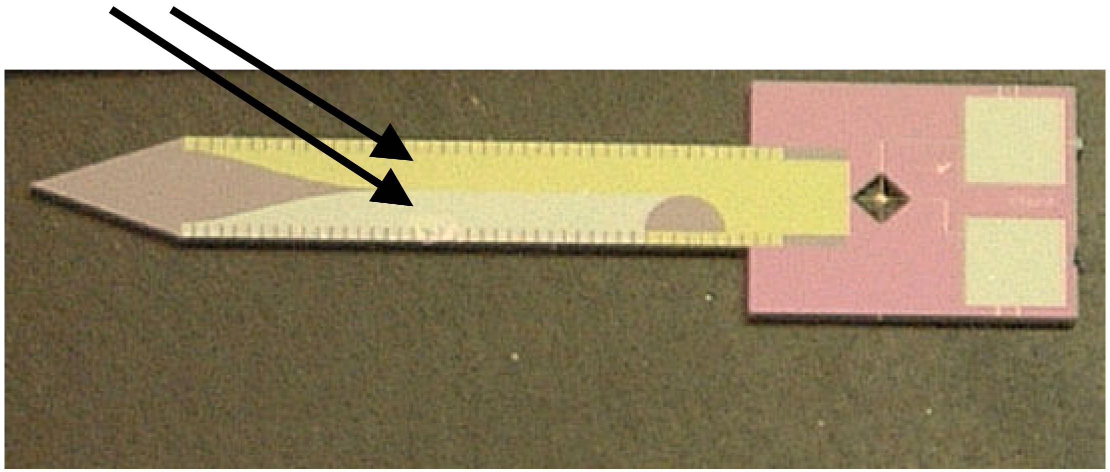


Measure Responsivity

Etch windows in oxide covering Nb finline

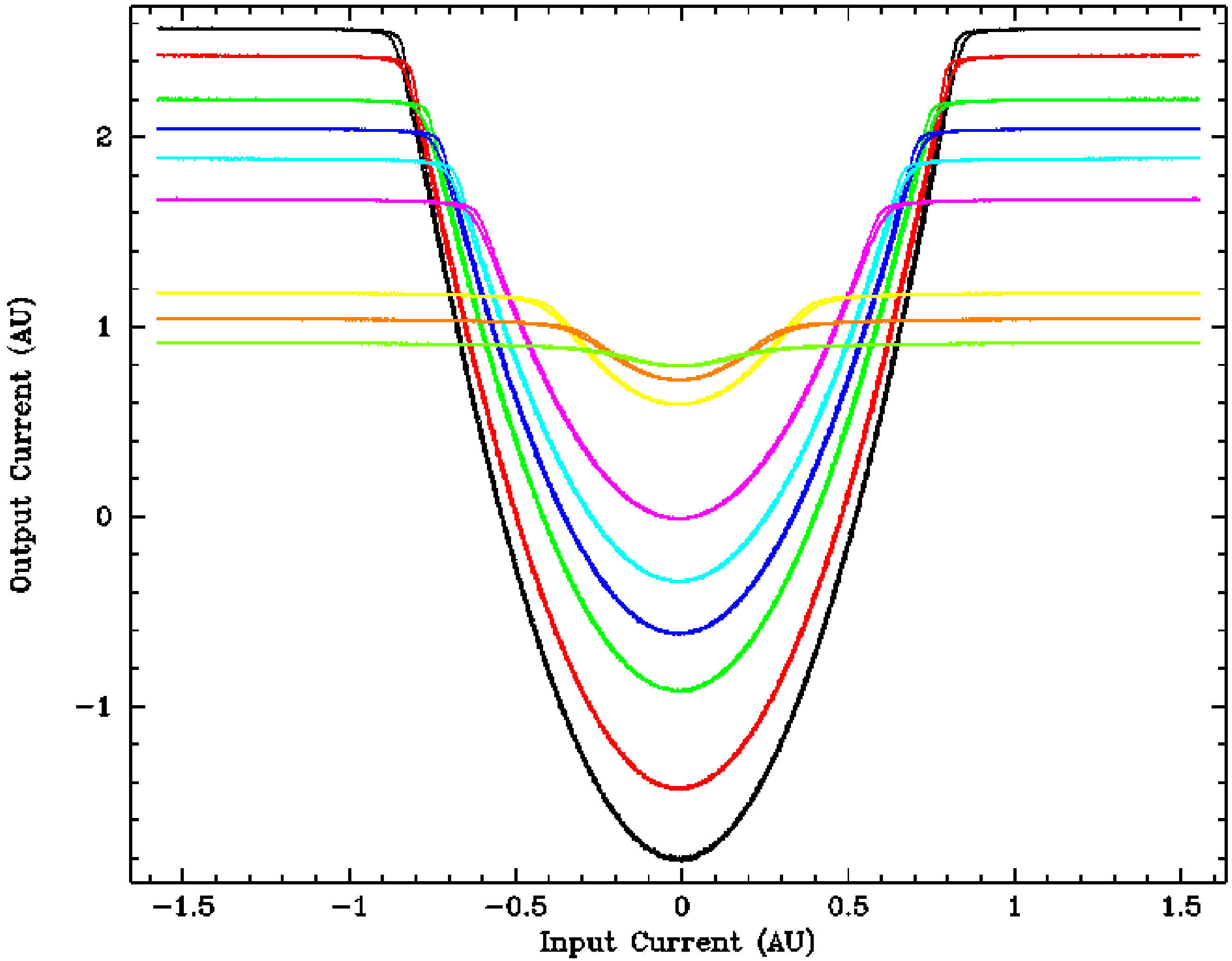
Inject current into microstrip

Wire-bond to exposed Nb

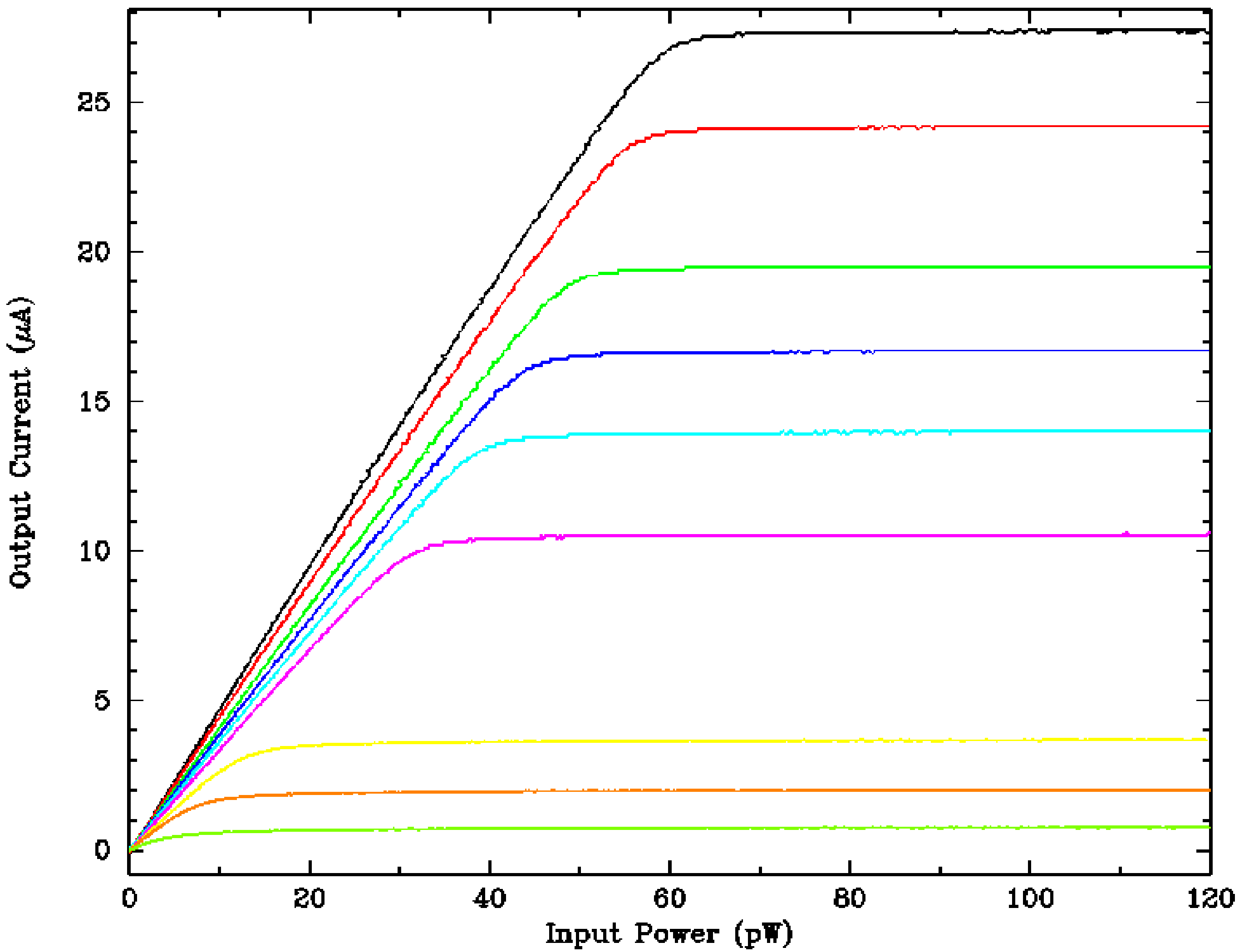


(without breaking chip)

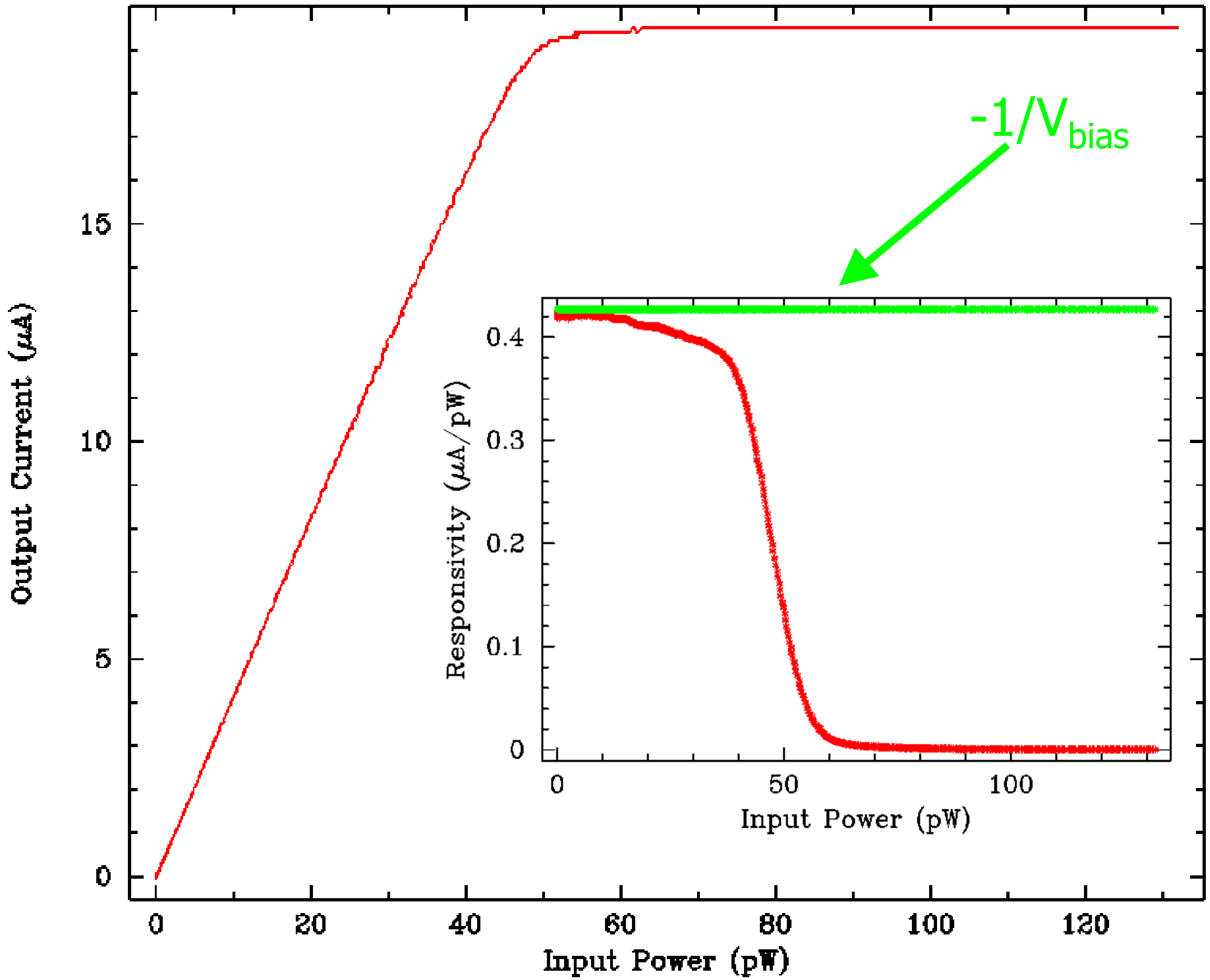
Response to injected current



Response to injected power



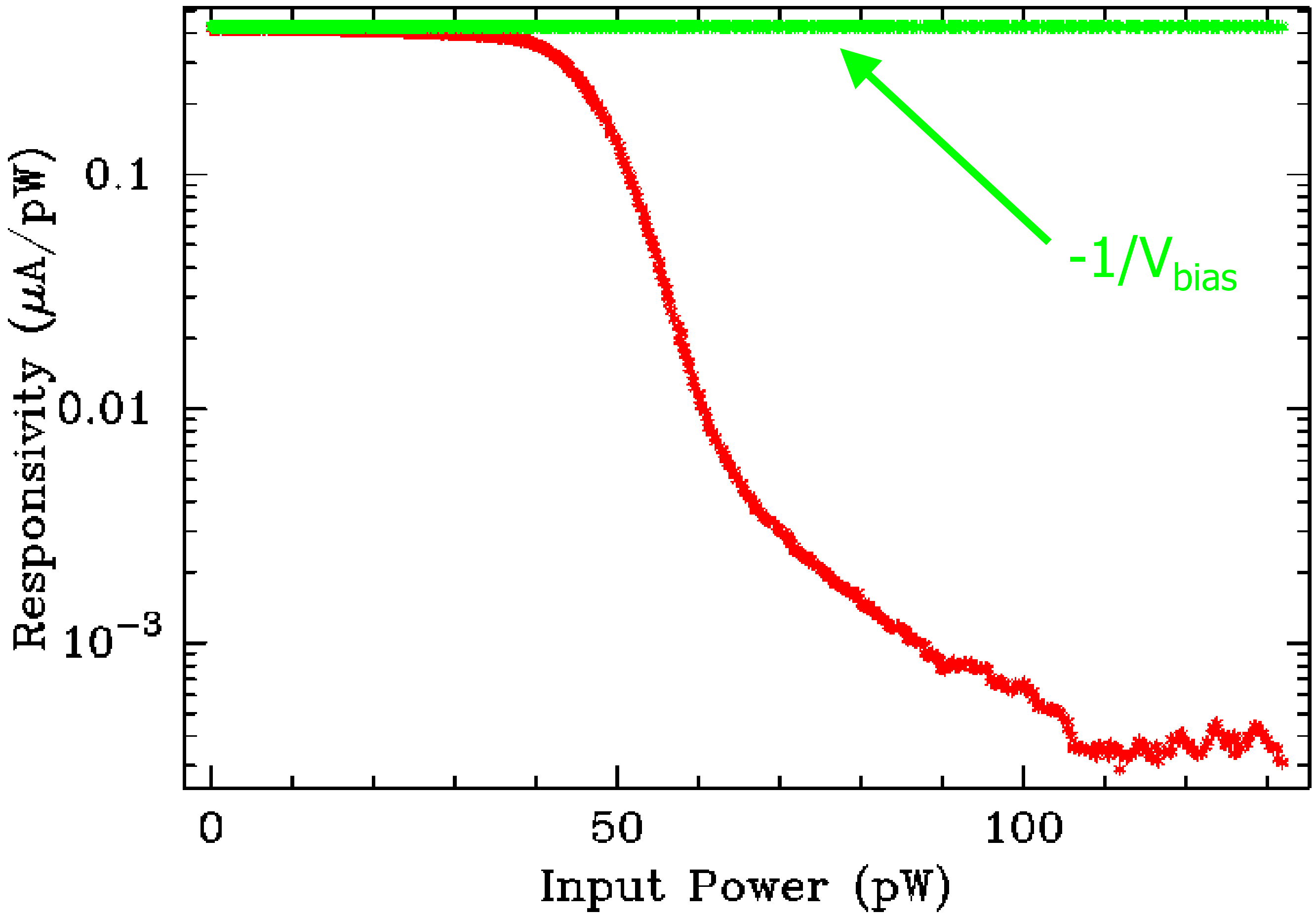
Responsivity



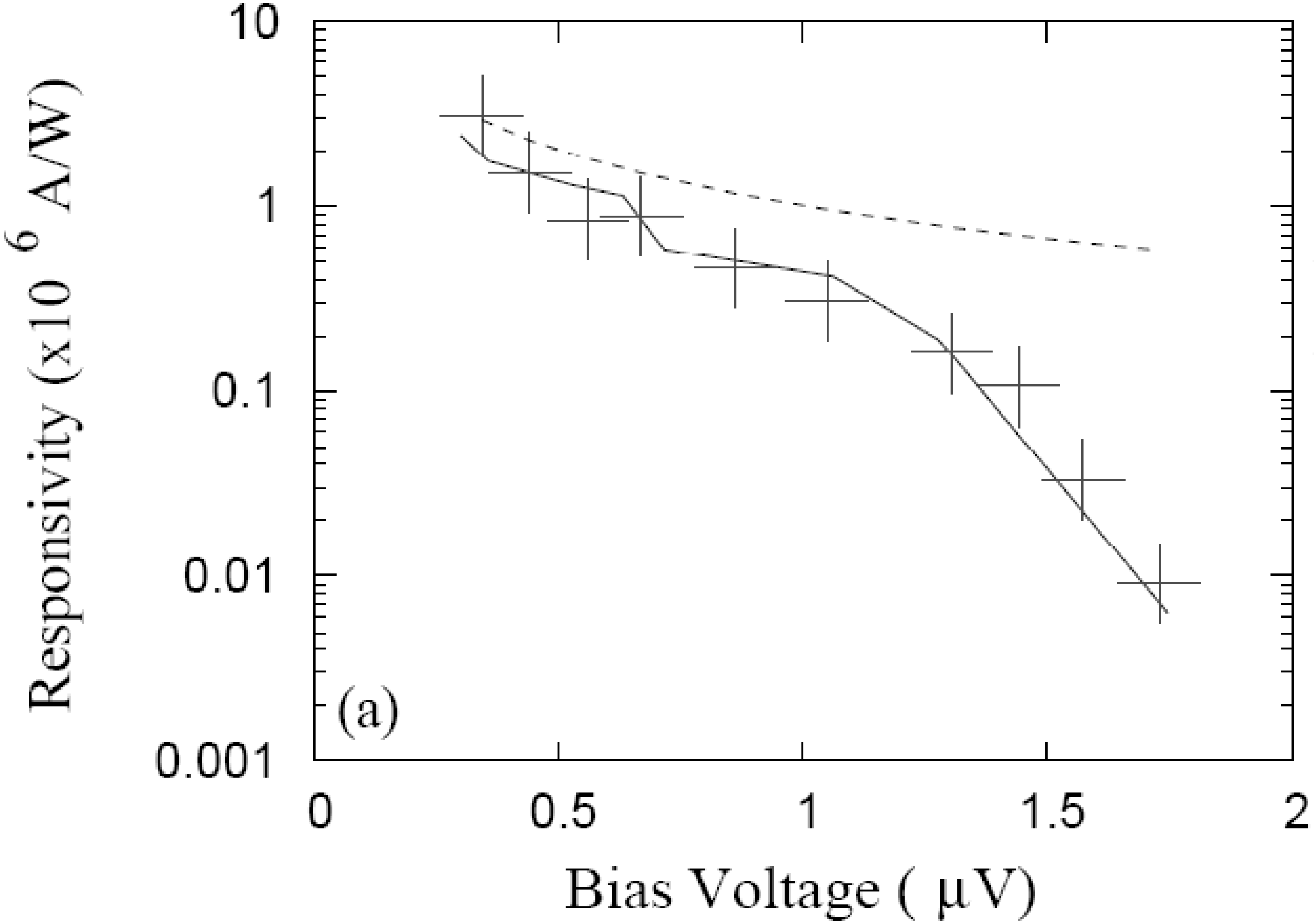
Responsivity

Can we reproduce this responsivity from electrothermal parameters?

Get α, β, C, G from IV curves and complex impedance.



Fit to Responsivity



Louisa Dunlop 2006, Proc. SPIE, **6275**

On-pixel heaters

- Submillimetre Weather:
  - → bright, time-varying sky background
  - → depends on weather
  - → if detectors optimized for good weather, can saturate in bad weather
- Heater
  - → vary heater power to keep total power falling on detectors constant
  - → switch on when weather is good
  - → switch off when weather is bad
  - → observe in all submillimetre weathers
- Disadvantages
  - → Sensitivity in good weather degraded
  - → unforseen effects (pickup in heater leads?)
- Advantages
  - → keep detectors biased at the same point: responsivity and time constant don't change with weather
  - → bias in upper part of transition where excess noise is lower
  - → good for calibration, investigating TES physics

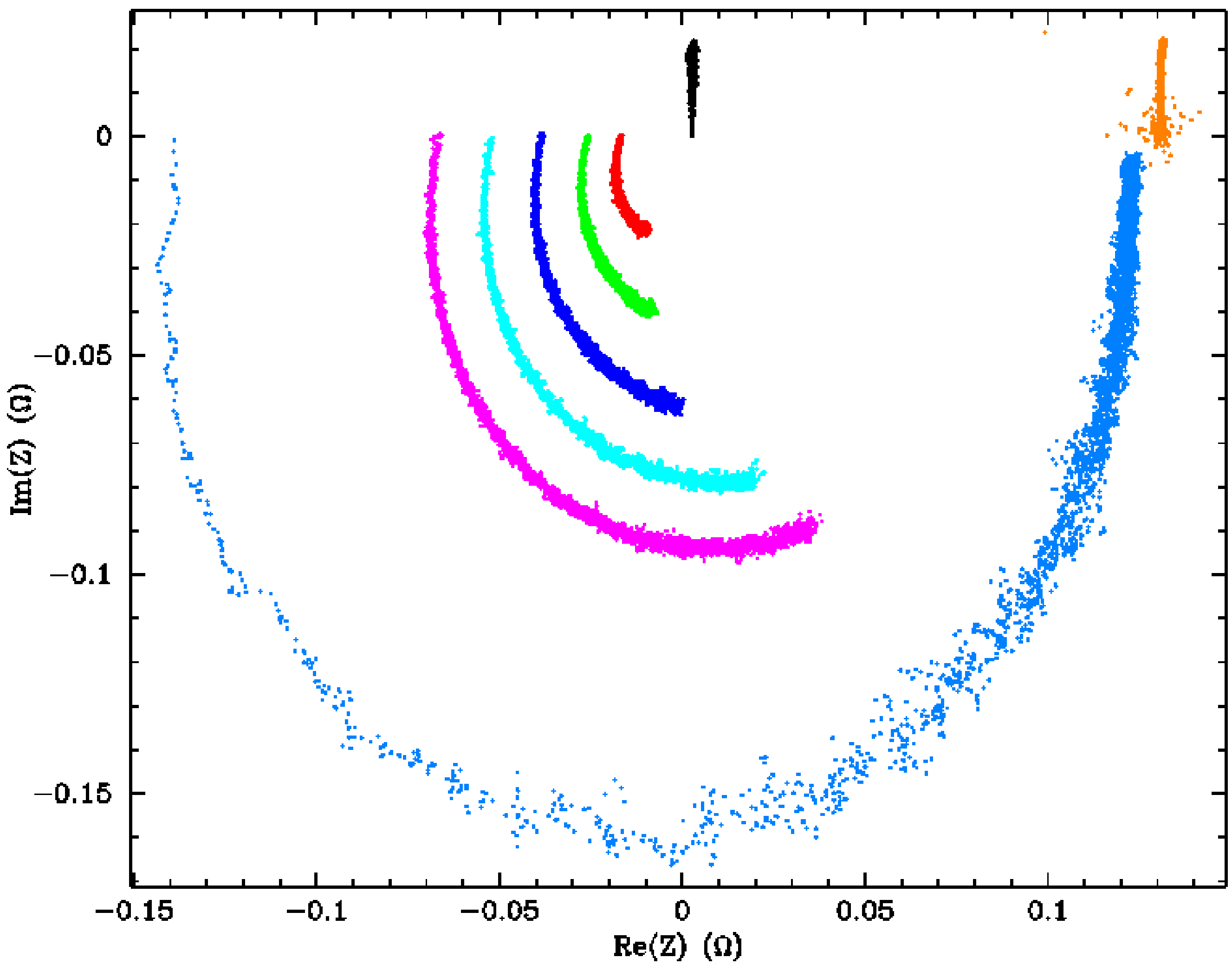
CLOVER Status

- Detectors
  - → Process for mass-producing finline-coupled TES bolometers established
  - → Optical testing with cold black-body source
  - → Verify operation of finline transition on silicon
  - → Next iteration will have extra on-pixel heater

- Single Pixel Demonstrator
  - → Demonstrate technology: compare polarimeters
  - → Decide on polarimeter for final instrument
  - → Operation begins later this year

- Deployment Schedule
  - → Deployment of 97-GHz instrument 2007
  - → Phased deployment of the three telescopes 2007—2009
  - → Full operation begins 2009 or earlier

Complex Impedance



Complex Impedance