# Towards Large-Format Arrays of Superconducting Transition-Edge Sensor Microcalorimeters for Constellation-X


## The NIST X-ray Team

Norm Bergren
Steve Deiker
Gene Hilton
Kent Irwin
John Martinis
Aaron Miller
Sae Woo Nam
Dave Rudman
Leila Vale
Dave Wollman
Yizhi Xu

Martin Huber (CU Denver)

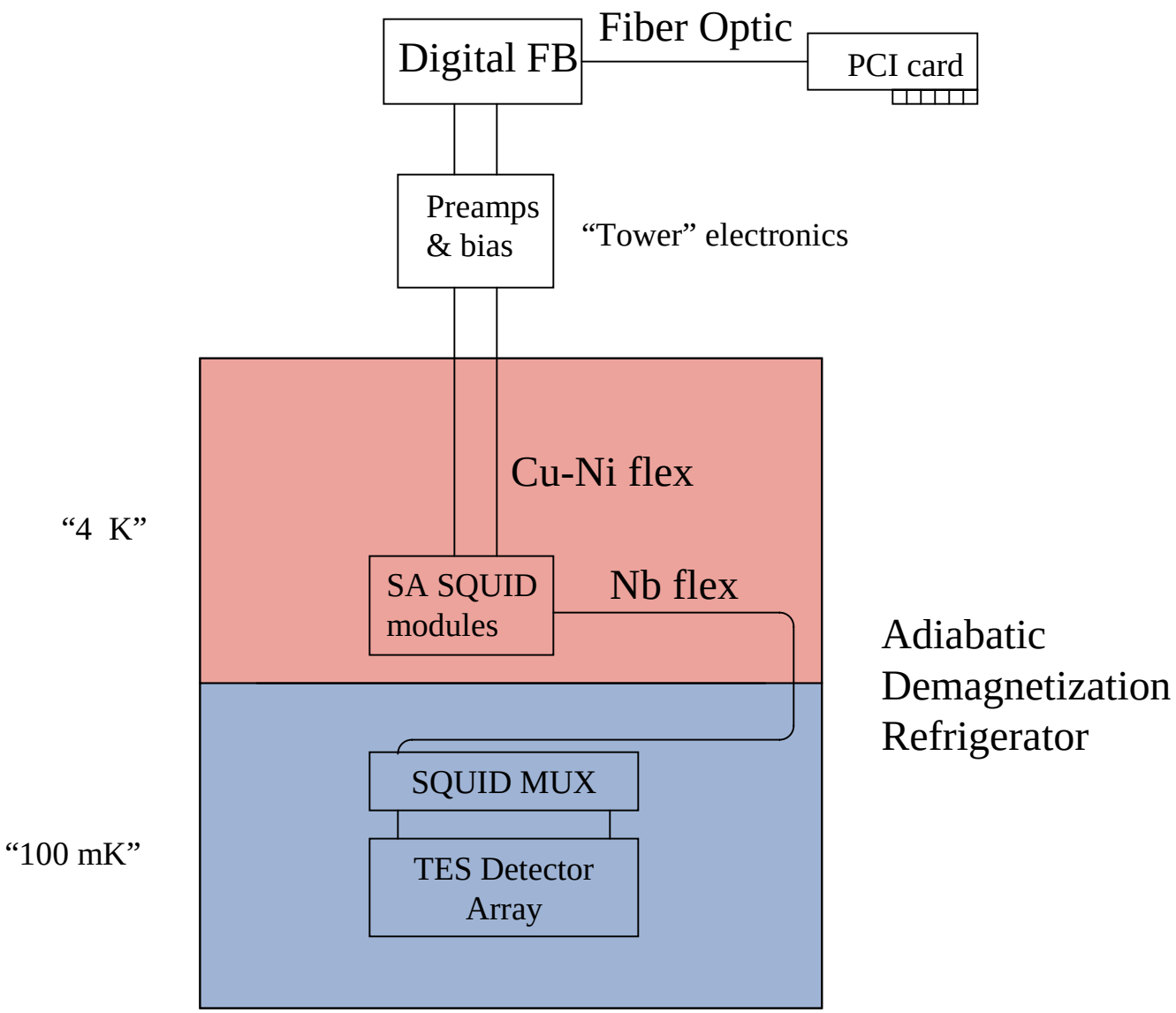


Constellation-X Facility Science Team Meeting
May 3/4, 2001
Center for Astrophysics



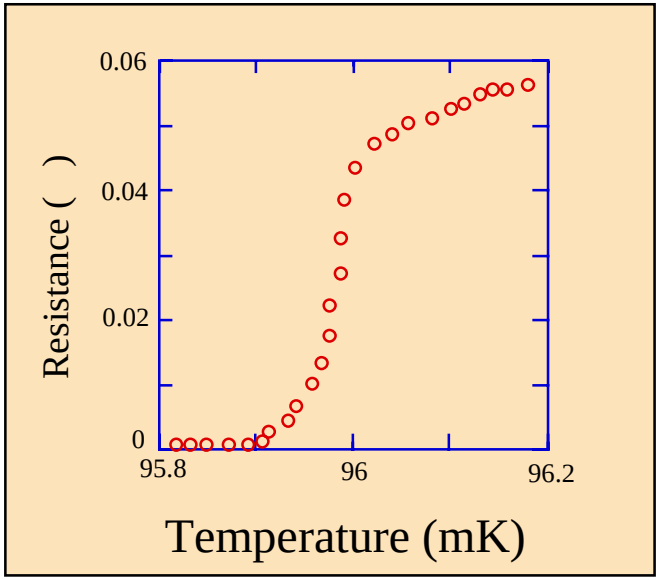
NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

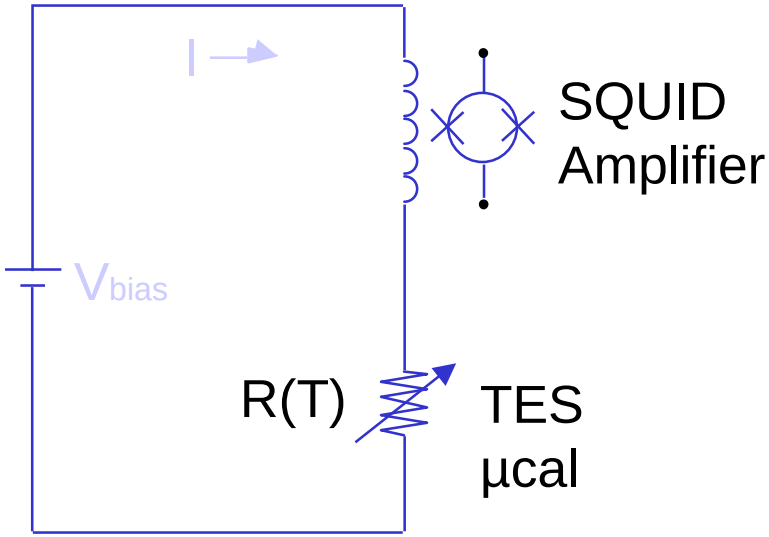
# System Components for A Large-Format Array of TES X-Ray Microcalorimeters




NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

# Voltage-Biased TES




Superconducting Transition-Edge Sensor (TES)

# Molybdenum-Copper Bilayer

- A bilayer of a thin superconducting film and a thin normal metal acts as a single superconductor with a tunable $T_c$ - the "proximity effect"

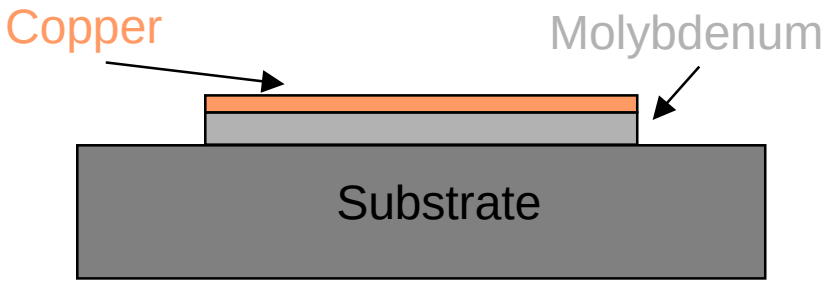
- Molybdenum-copper

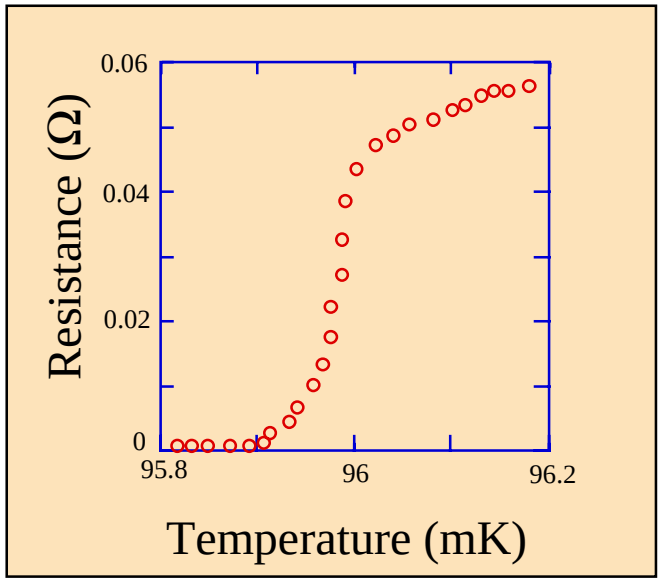
  Robust and temperature stable

  Molybdenum Tc ~ .92 K

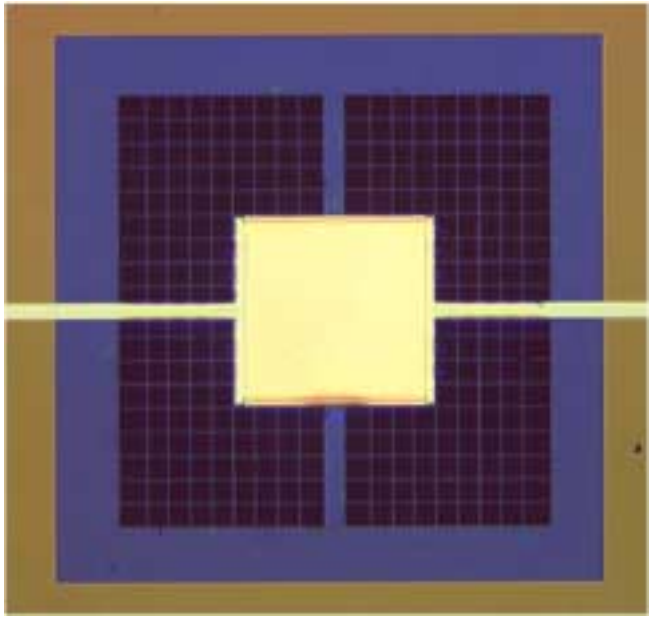
  Copper normal

- Sharp
- Reproducible <~ 5 mK
- Tunable
- Robust

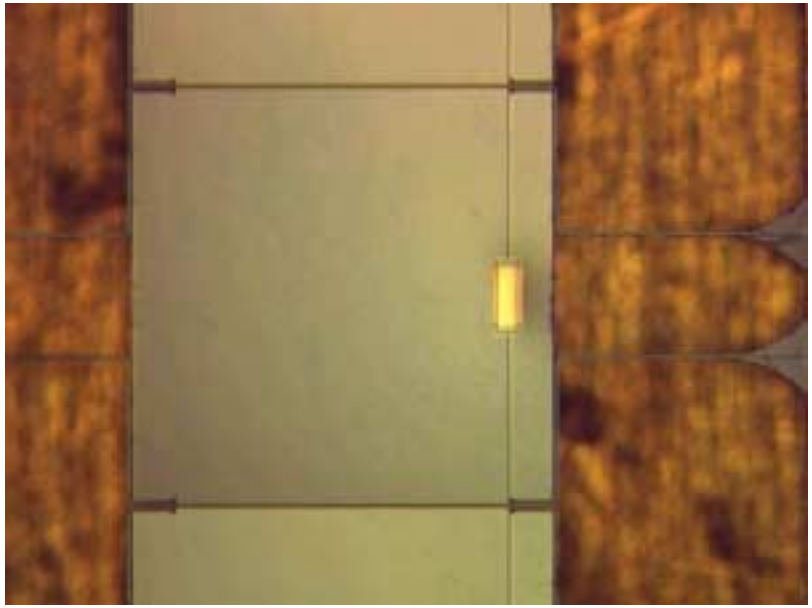


# TES Device Processing



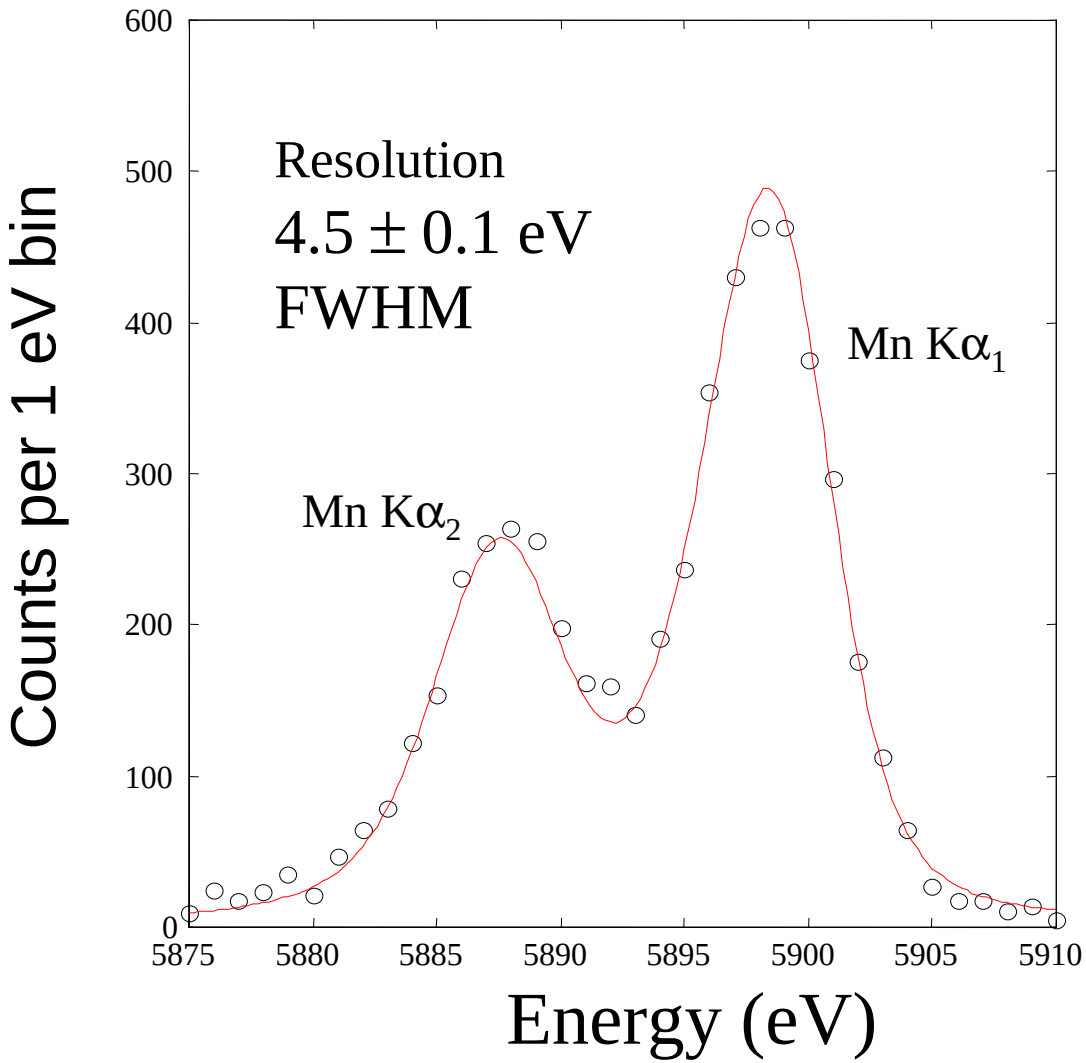
High resolution micromachined Mo/Cu x-ray detector



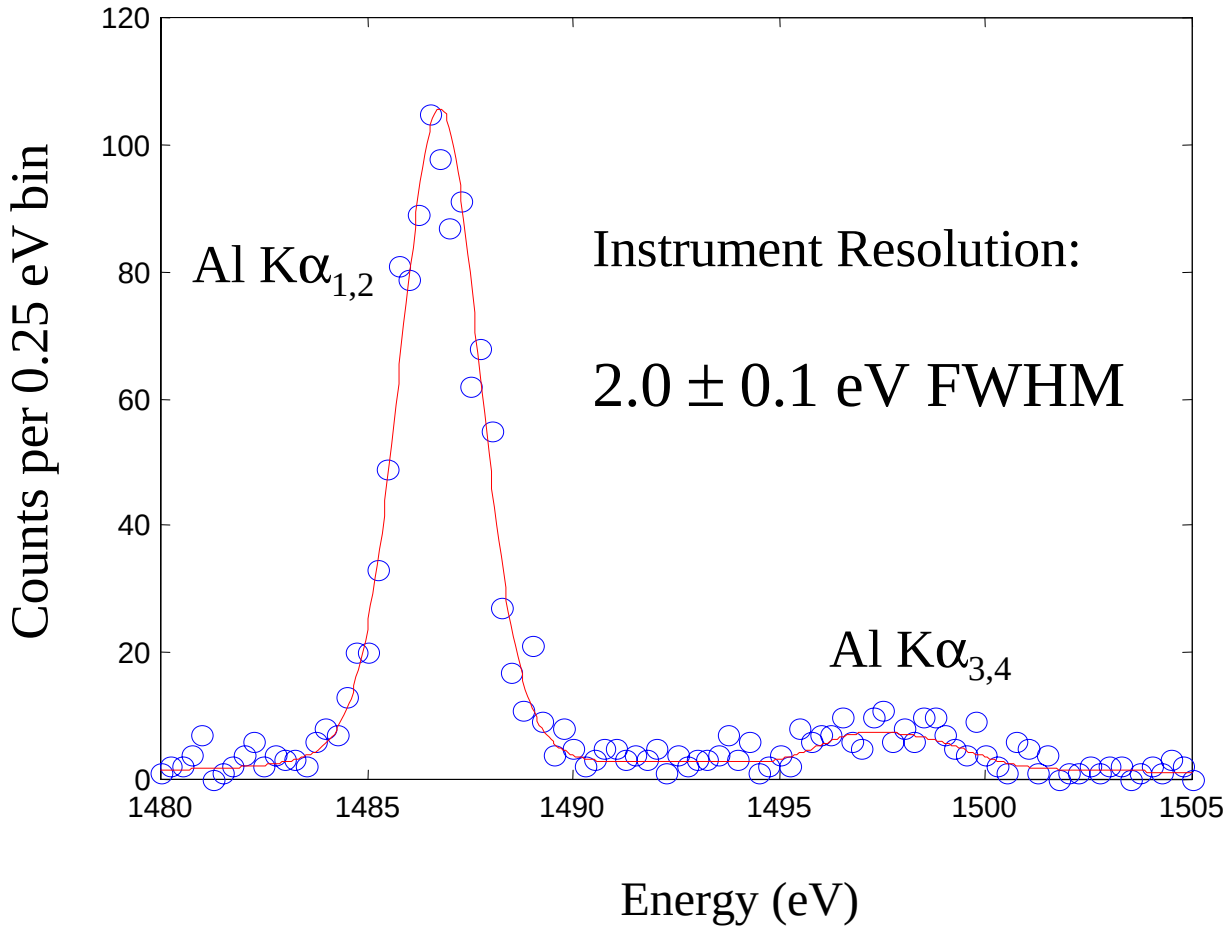
Phonon noise limited Mo/Cu "pop-up" IR detector

**Mo/Cu process has been used to make high performance detectors for a variety of applications**

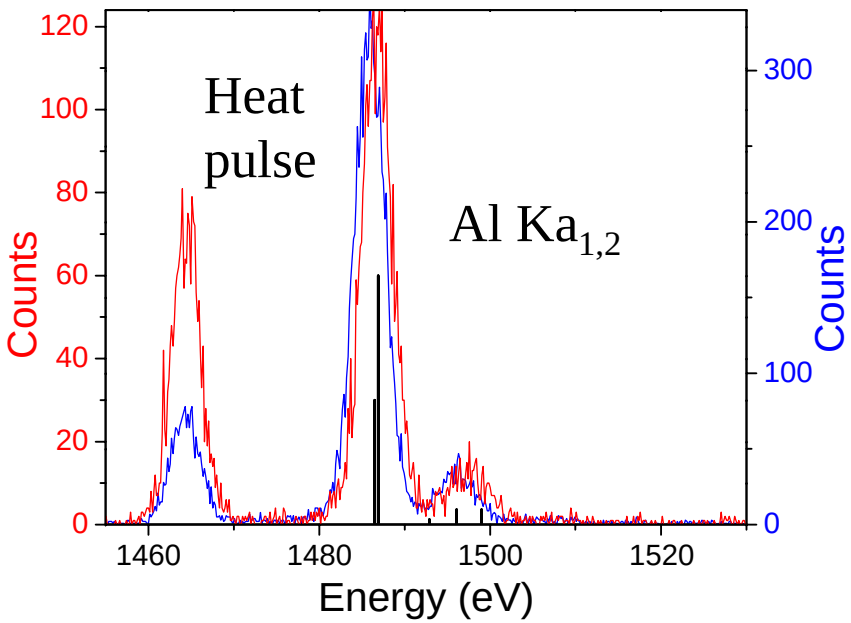
# 4.5 eV Resolution at 6 keV

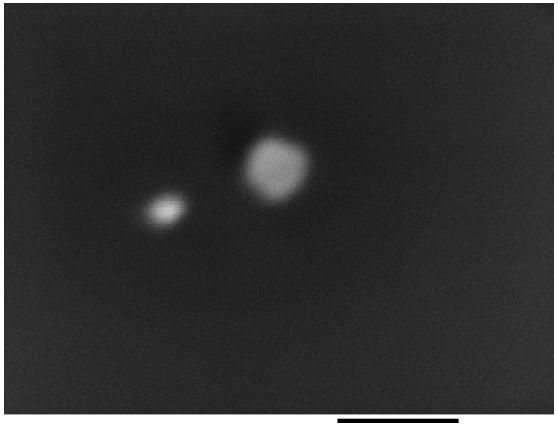


# 2.0 eV Resolution at 1.5 keV

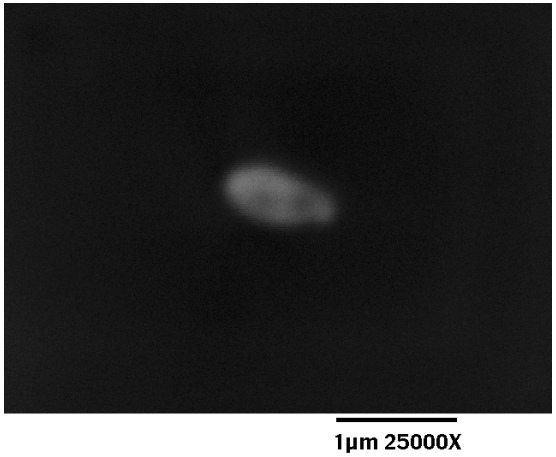


# Chemical Shift in Al - $Al_2O_3$



Al oxide particle



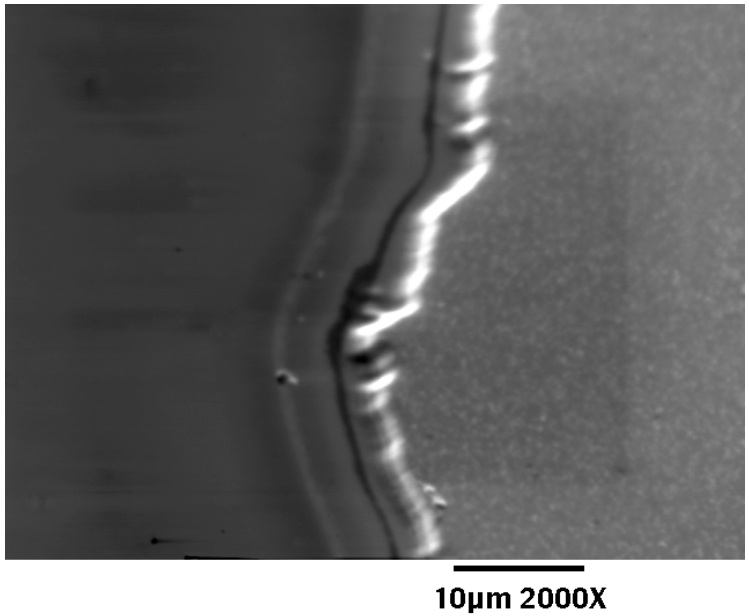

Al particle

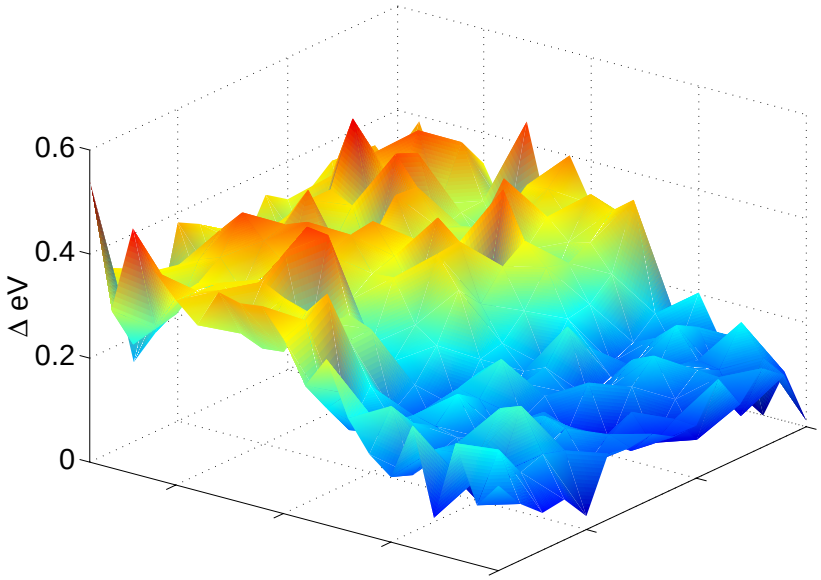
- Chemical bonding state causes small (< 1 eV) shifts in x-ray line position
- Industrially important problem: Al particles on oxide substrates.

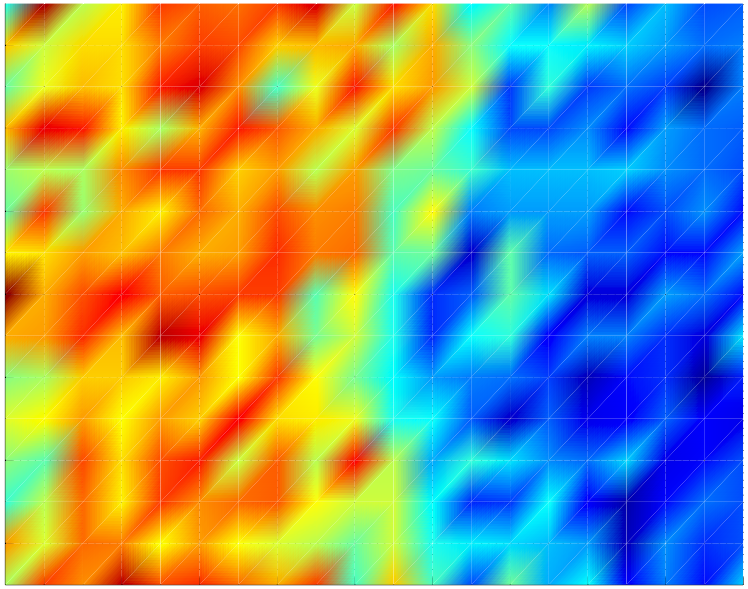
NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Particle samples provided by Alain Diebold (SEMATECH)

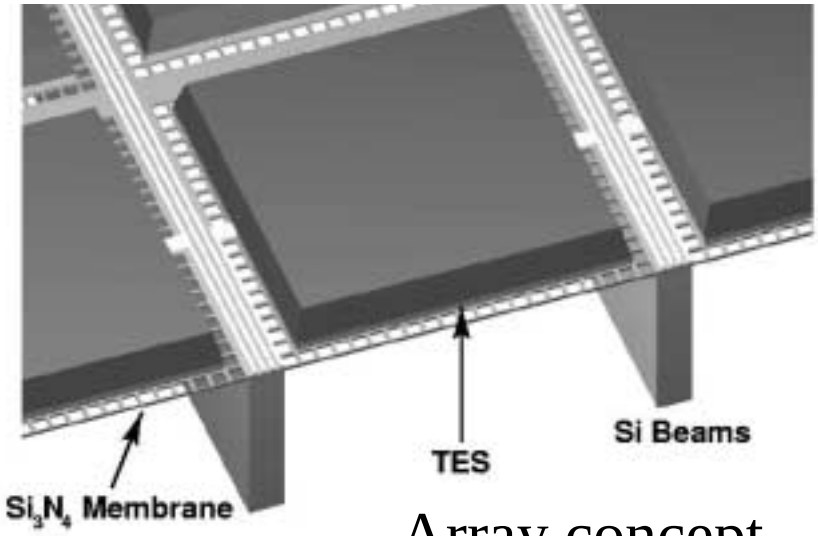
# Chemical Shift Map



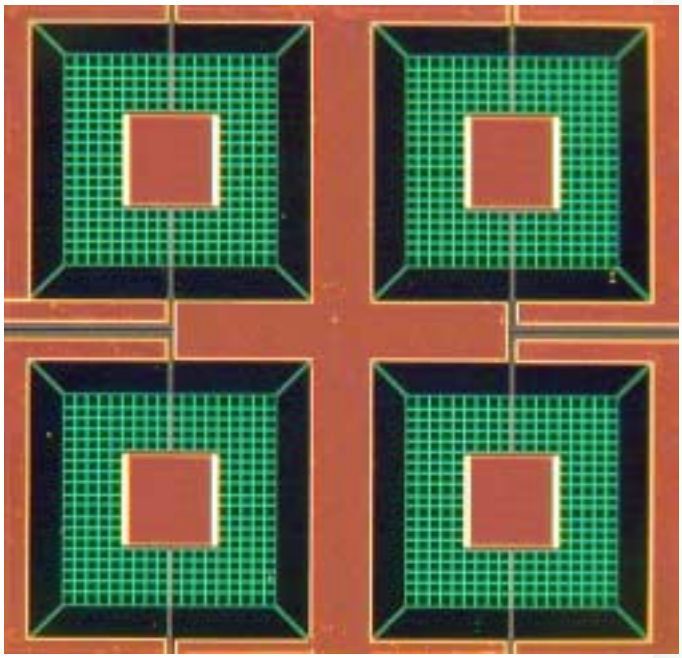



Al oxide Al

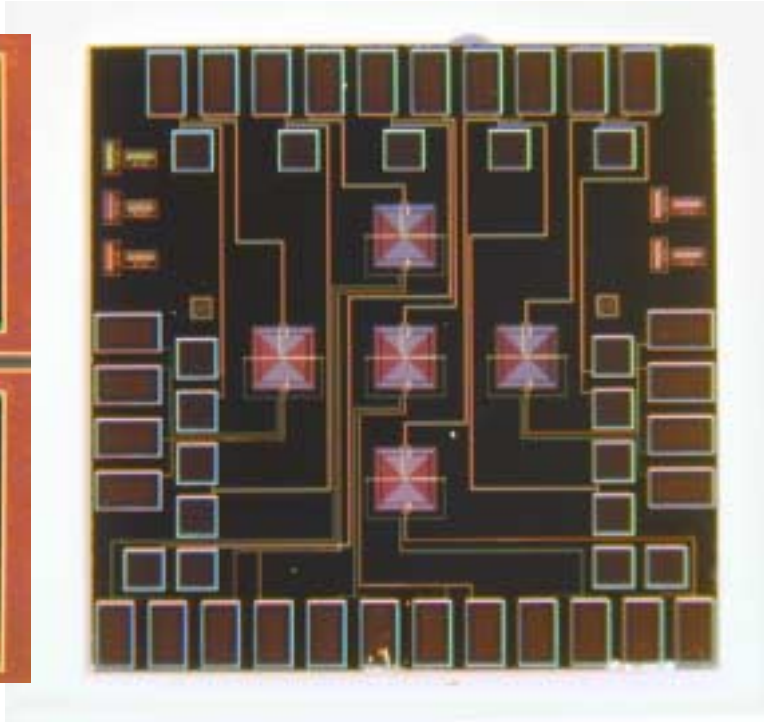



Array concept

2x2 TES test array



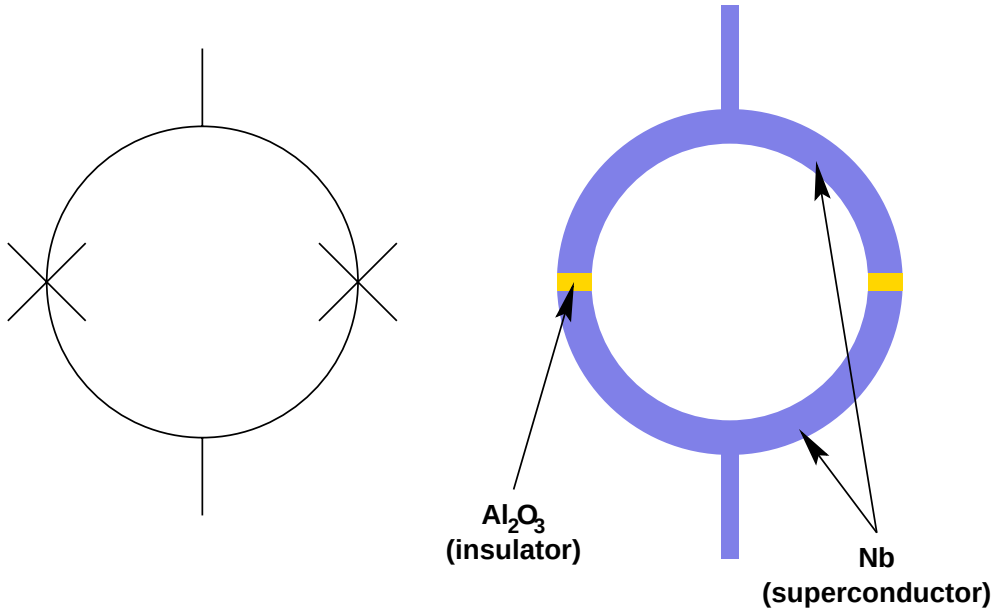
5-SQUID first stage

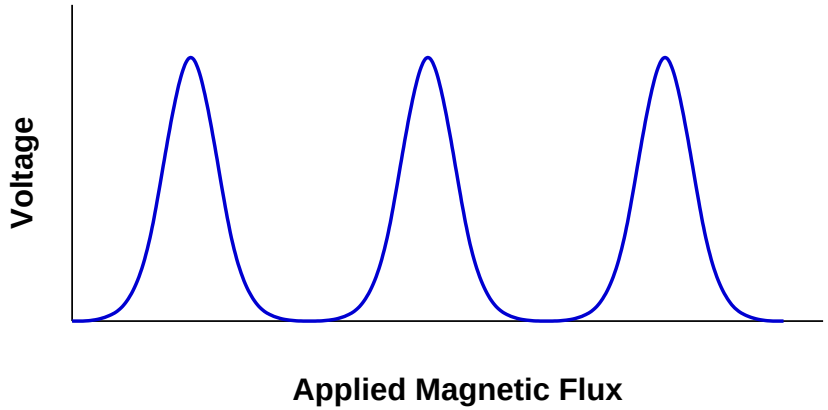


# NIST Fabrication Facilities

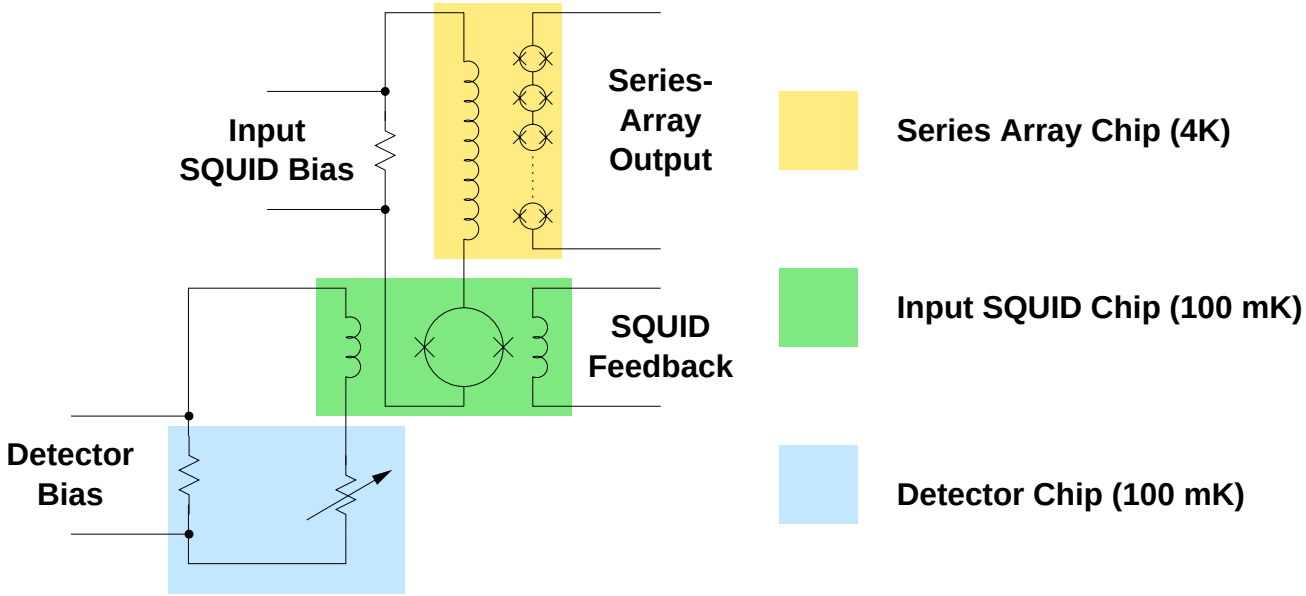
# SQUID Overview

SQUID = Superconducting Quantum Inteference Device

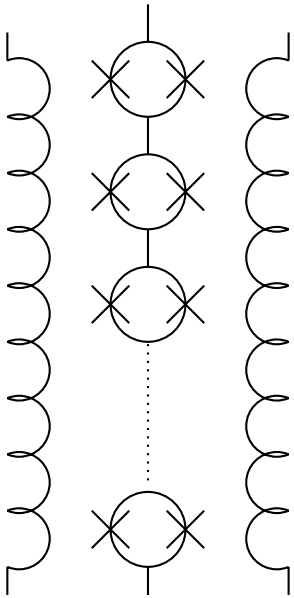


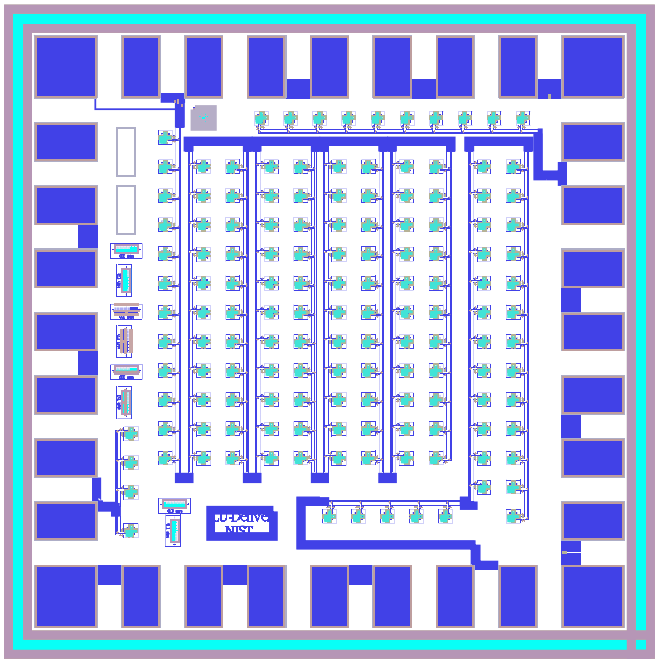
# Single-Pixel Two-Stage Detector Readout



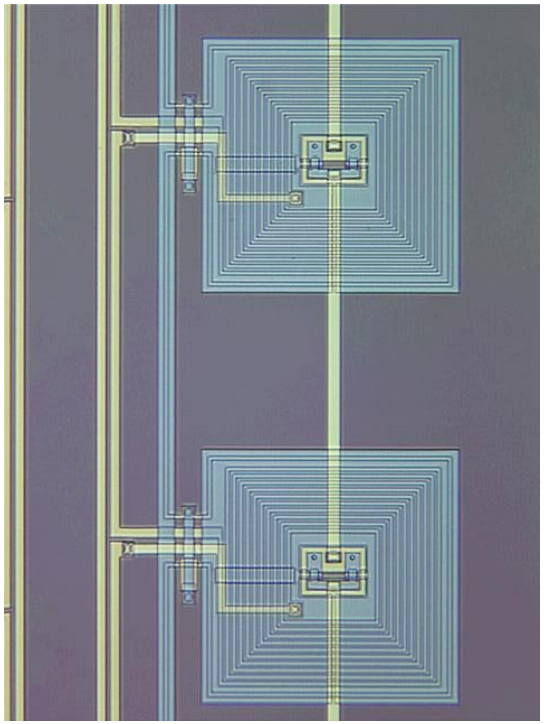
# SQUID Fabrication



Series Array Design

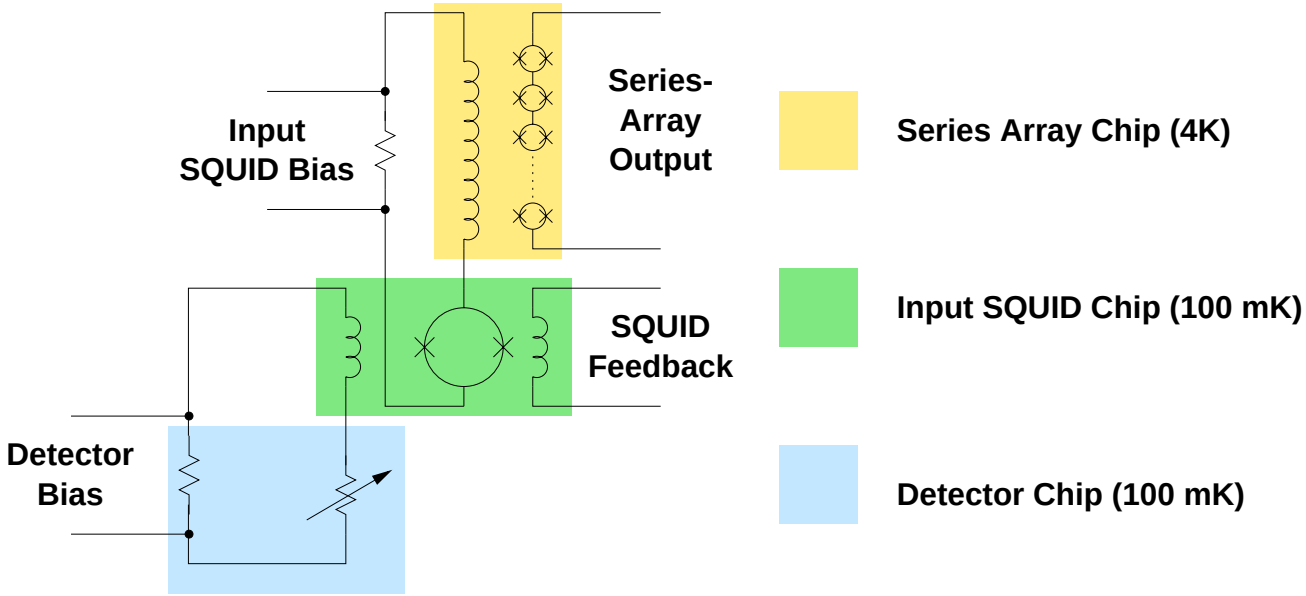


Series Array Layout

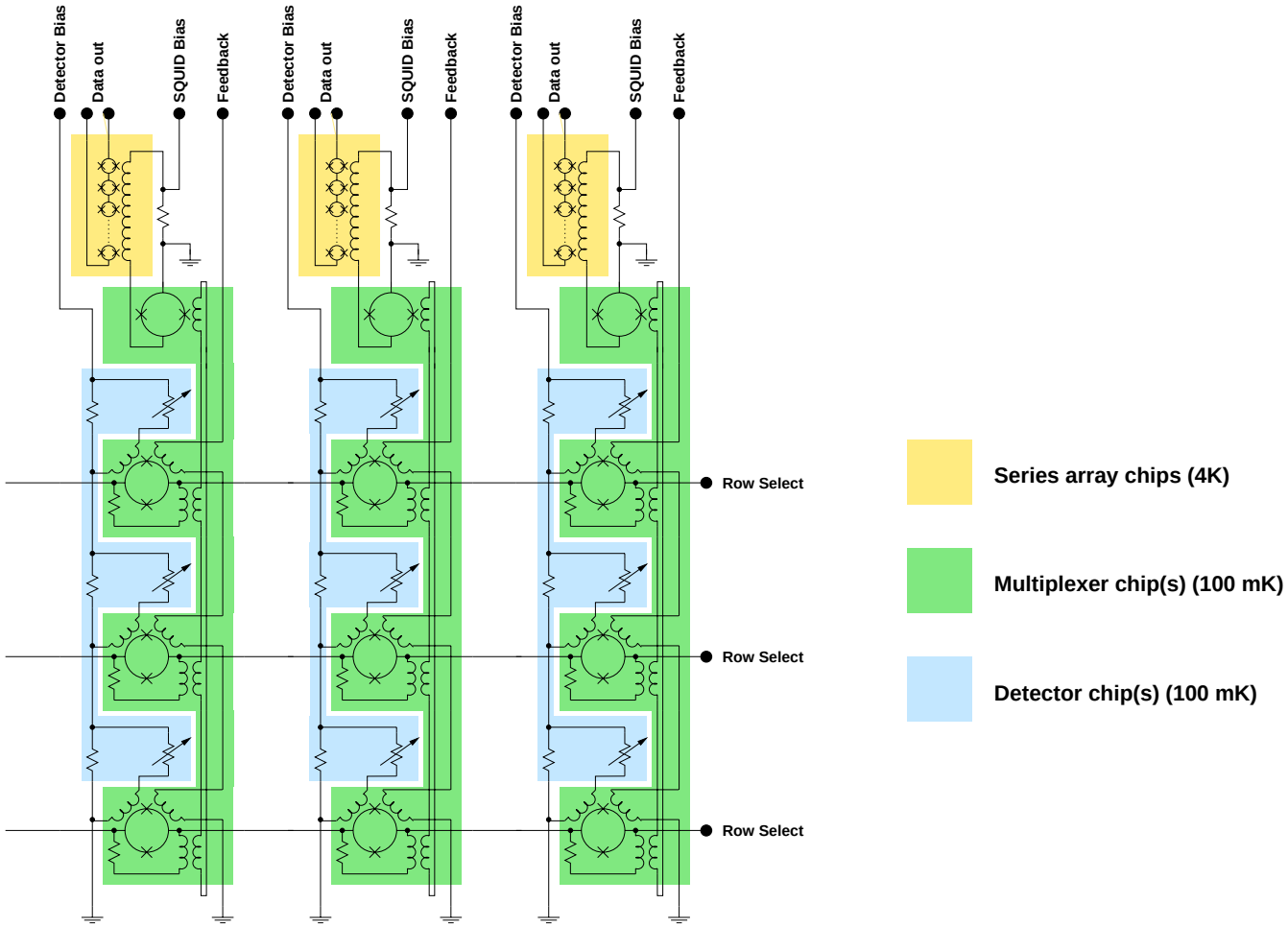


A real Series Array

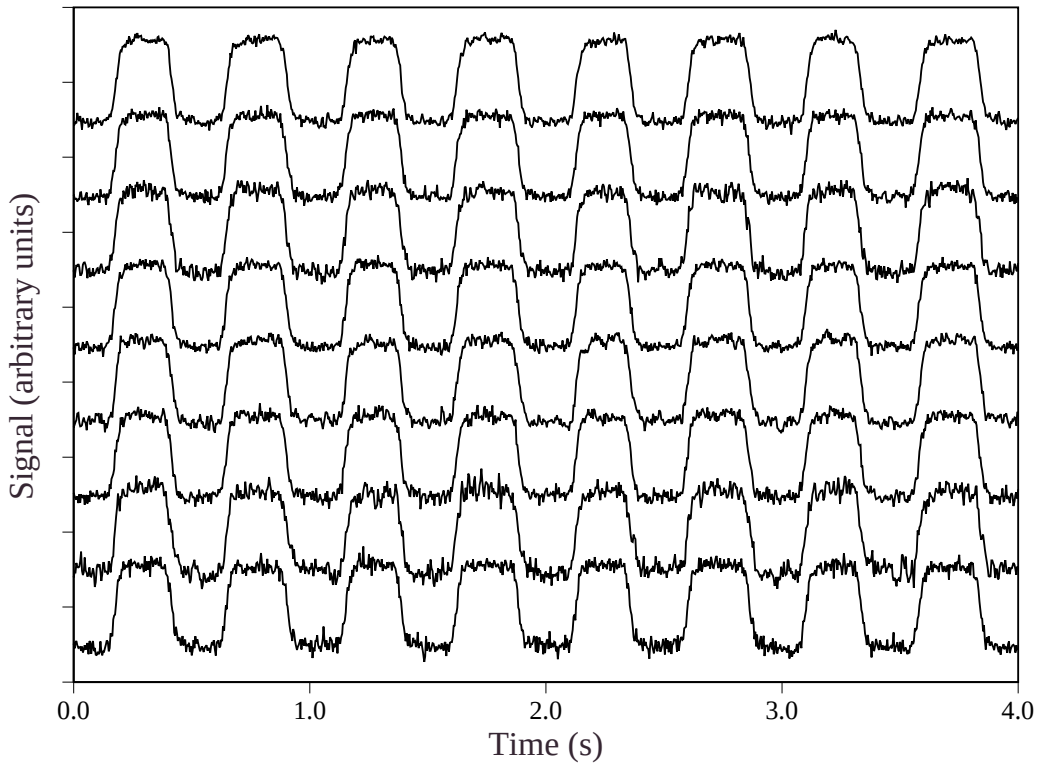
# Single-Pixel Two-Stage Detector Readout



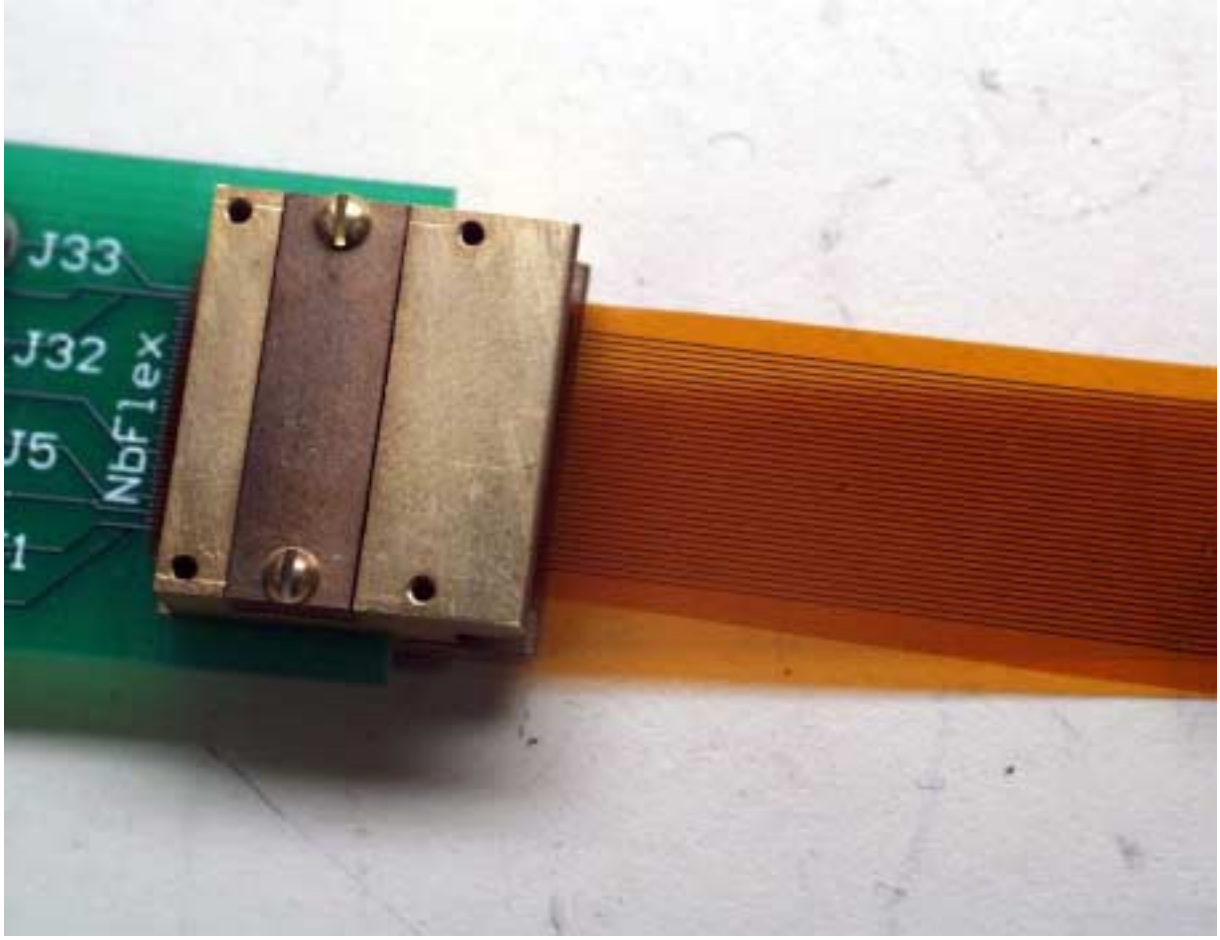
# Multiplexed Array Detector Readout



# Photometric response of multiplexed 8-pixel TES array

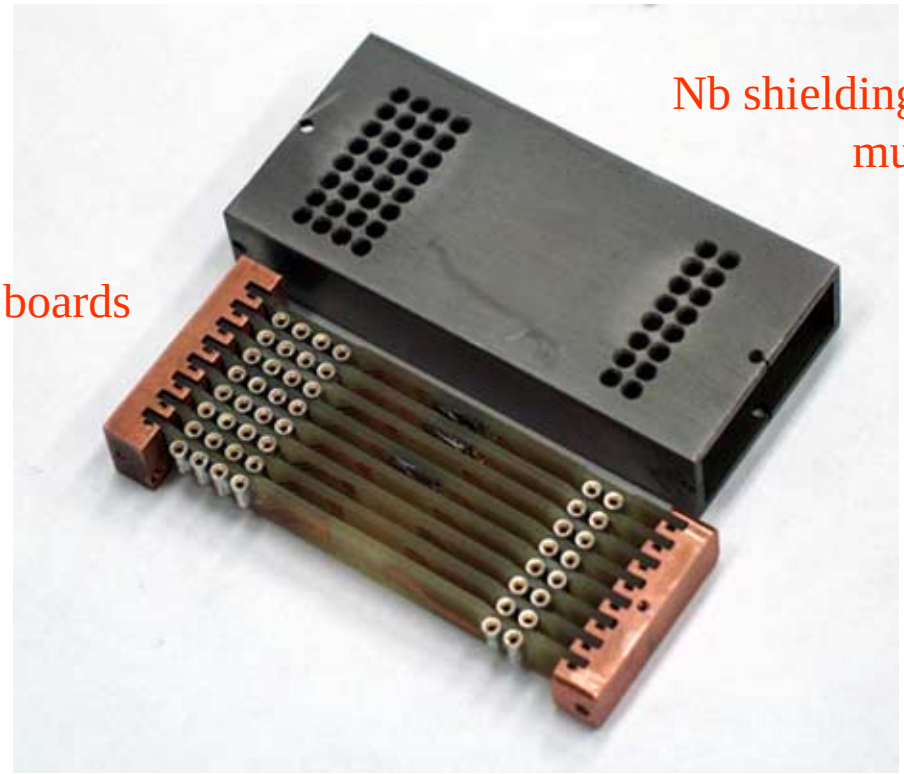


# Nb Flex




# Be-Cu springs for Nb flex connector

# 8-channel SQUID board

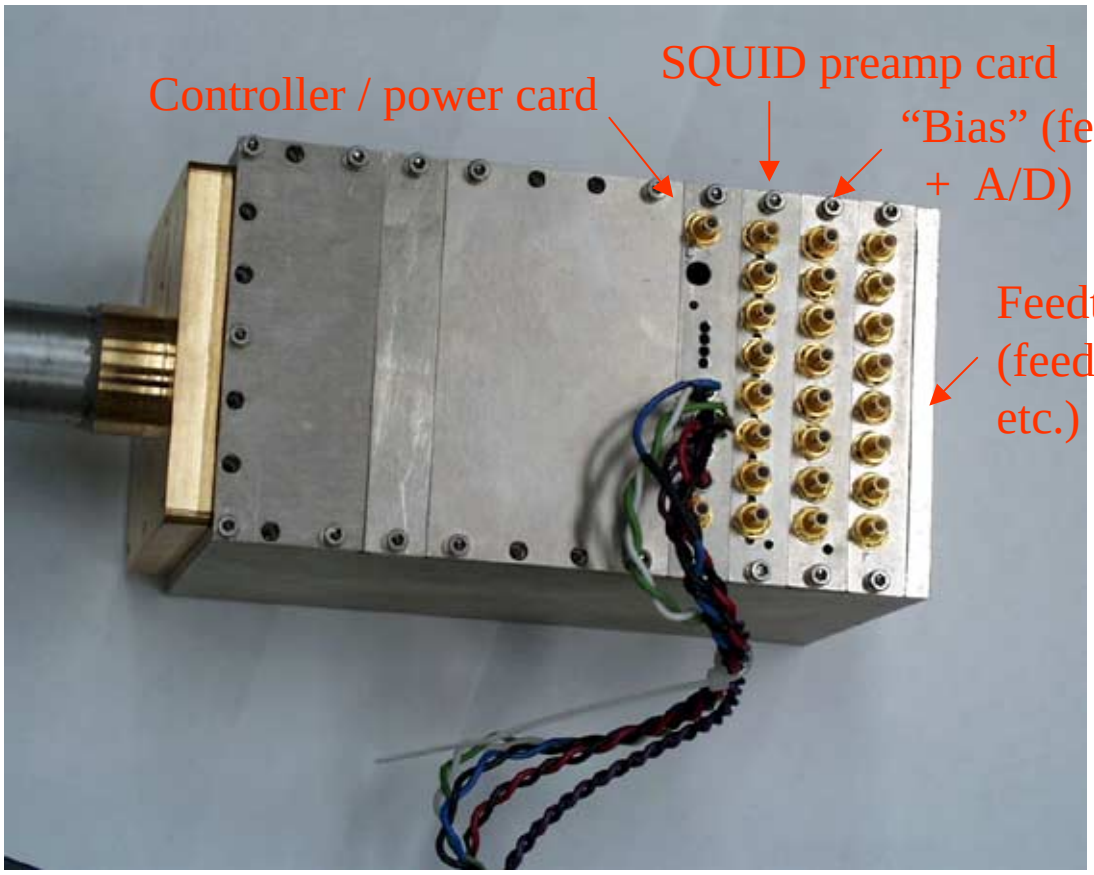


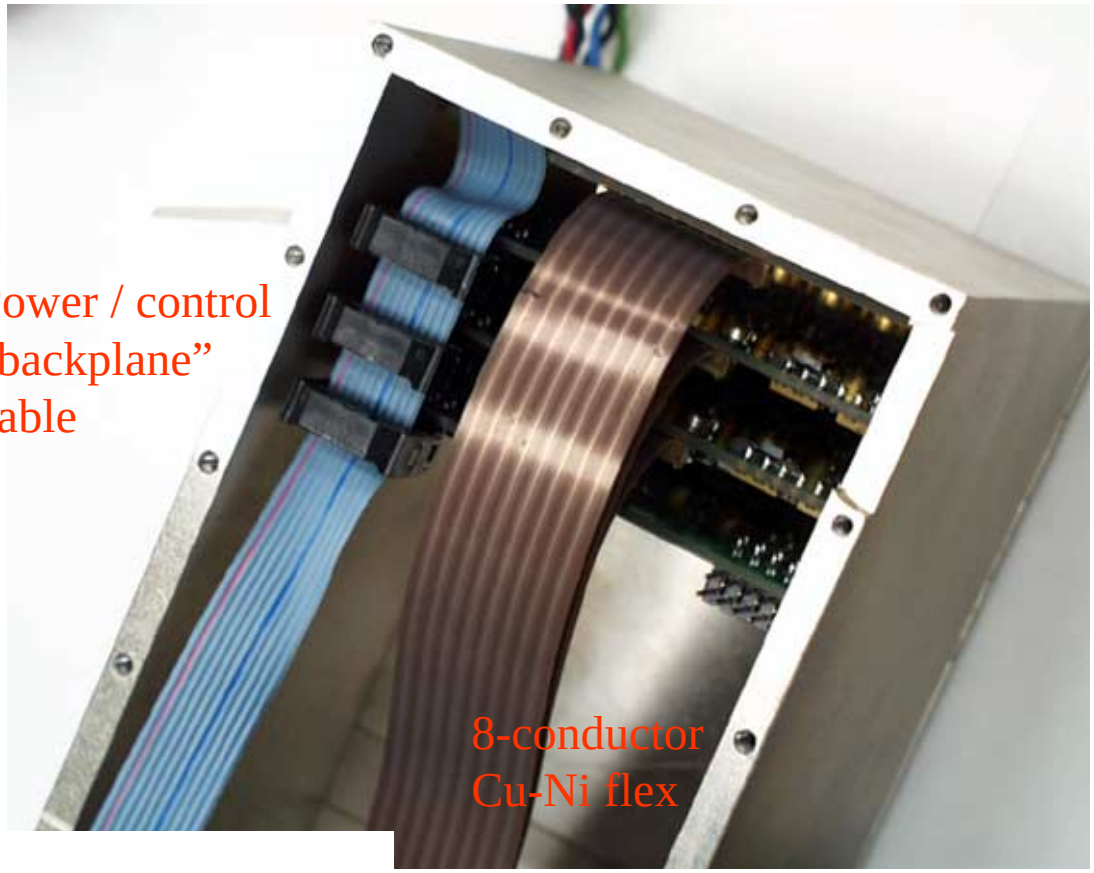

# 24-channel Cu-Ni flex cable

# Flex Vac. Feedthrough

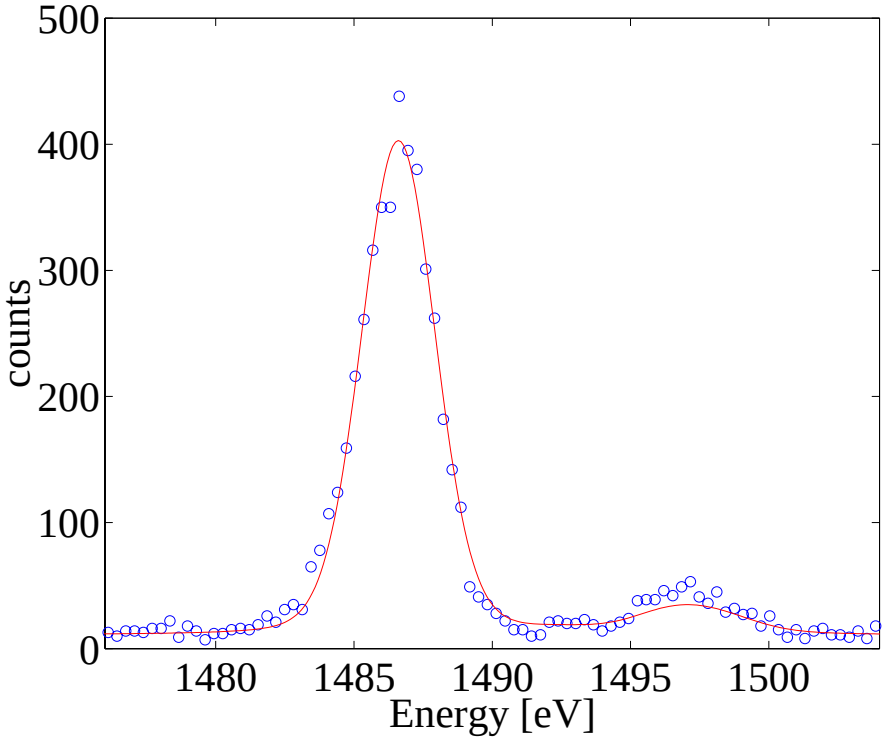
NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

# Tower


Controller / power card
SQUID preamp card
"Bias" (feedthru + A/D)
Feedthru (feedback, etc.)


Power / control "backplane" cable
8-conductor Cu-Ni flex

# Digital electronics



NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

# Conclusions

Progress is being made in single pixels

Considerable work remains in the development of other system components that will be necessary for even a laboratory demonstration of an x-ray microcalorimeter array that will meet the needs of Constellation-X.

- SQUID multiplexers
- Cryogenic wiring infrastructure
- Electronics / Firmware / Software