

# Transition-Edge Sensors

Frontier Detectors for Frontier Physics

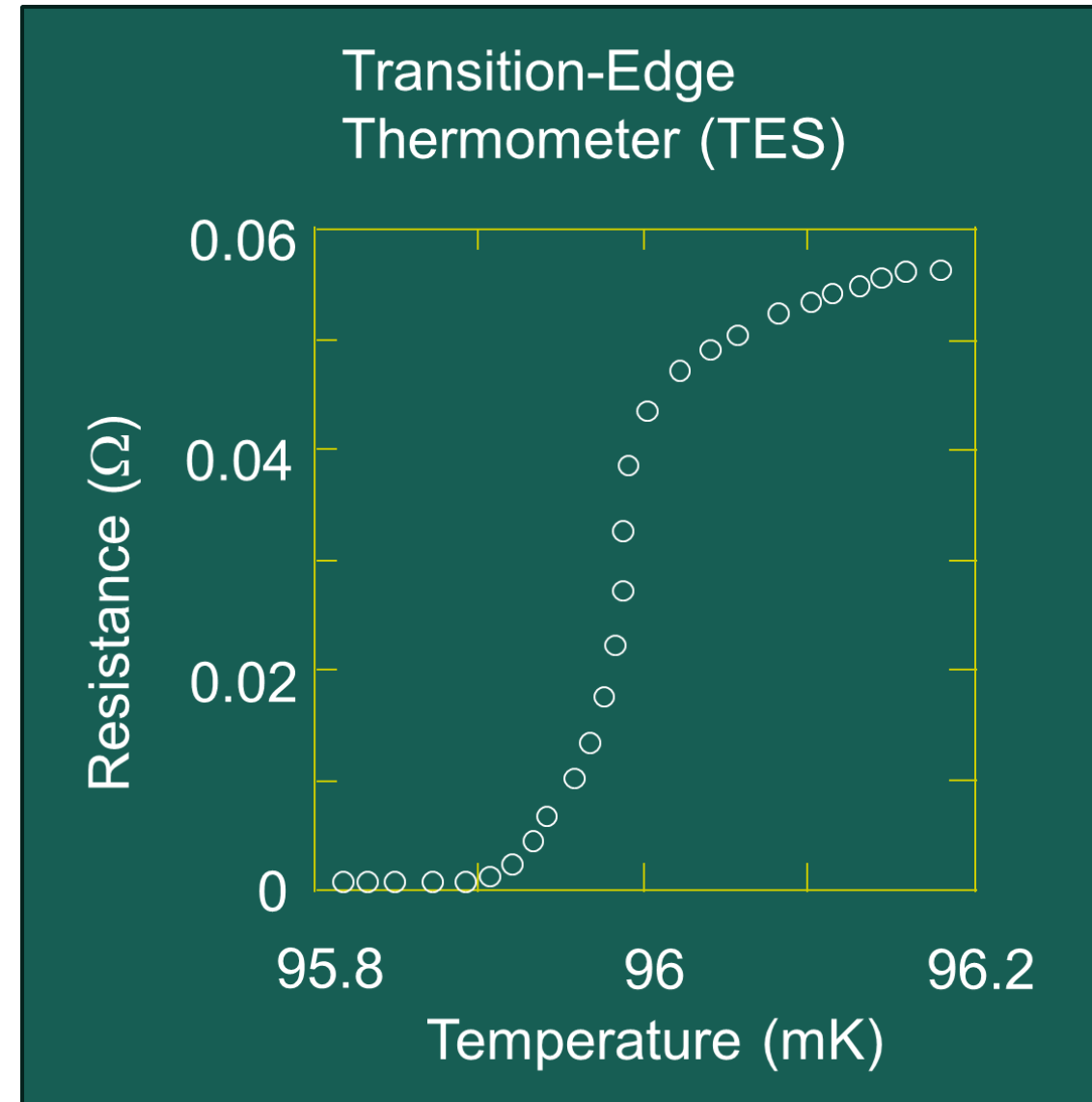
Elba, Italy

5/30/2024

Prof. Kent Irwin  
Stanford and SLAC

Thank you!

# 1938: Donald Hatch Andrews invented the superconducting transition-edge sensor (TES)



D.H. Andrews

*DH Andrews wanted to put a TES system in every automobile for infrared night-time imaging of wildlife that could run into the road.*

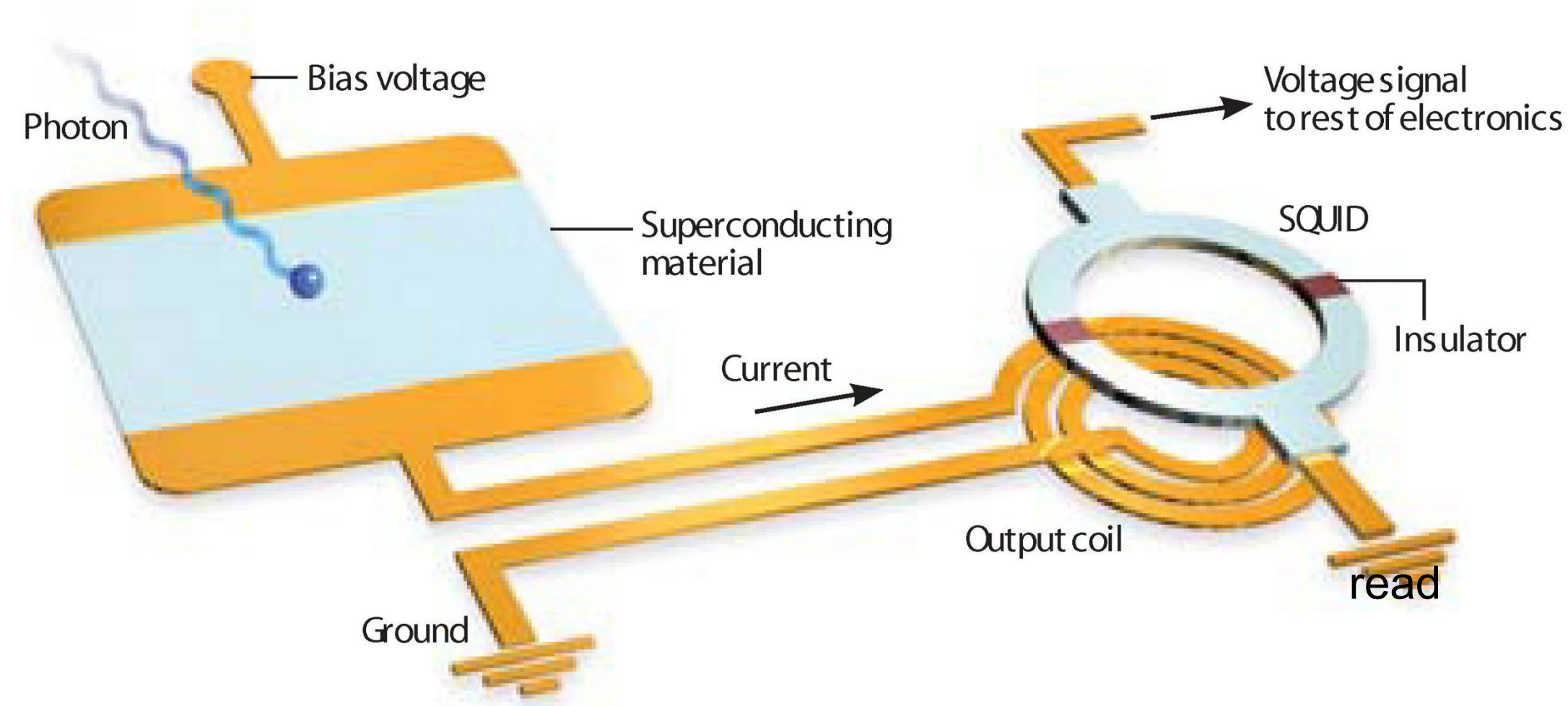


A real-time infrared image of Prof. Andrews taken with a TES in 1945

Andrews was way ahead of his time, and his work largely vanished:

- TES sensor (current biased) was unstable to thermal runaway. You could never operate more than one.
- Available amplifiers in 1938 were not sensitive enough.
- No good refrigerators

# Solution: voltage bias TES, multiplexed SQUID readout

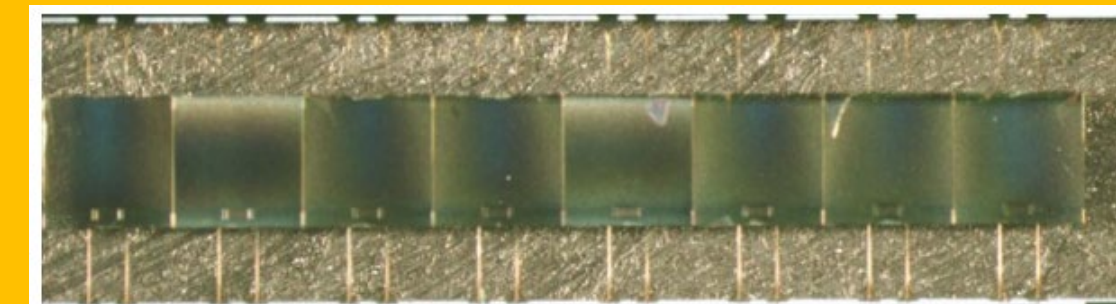


- Voltage bias prevents thermal runaway.
- Stably operate large TES arrays.

$$P = \frac{V^2}{R}$$

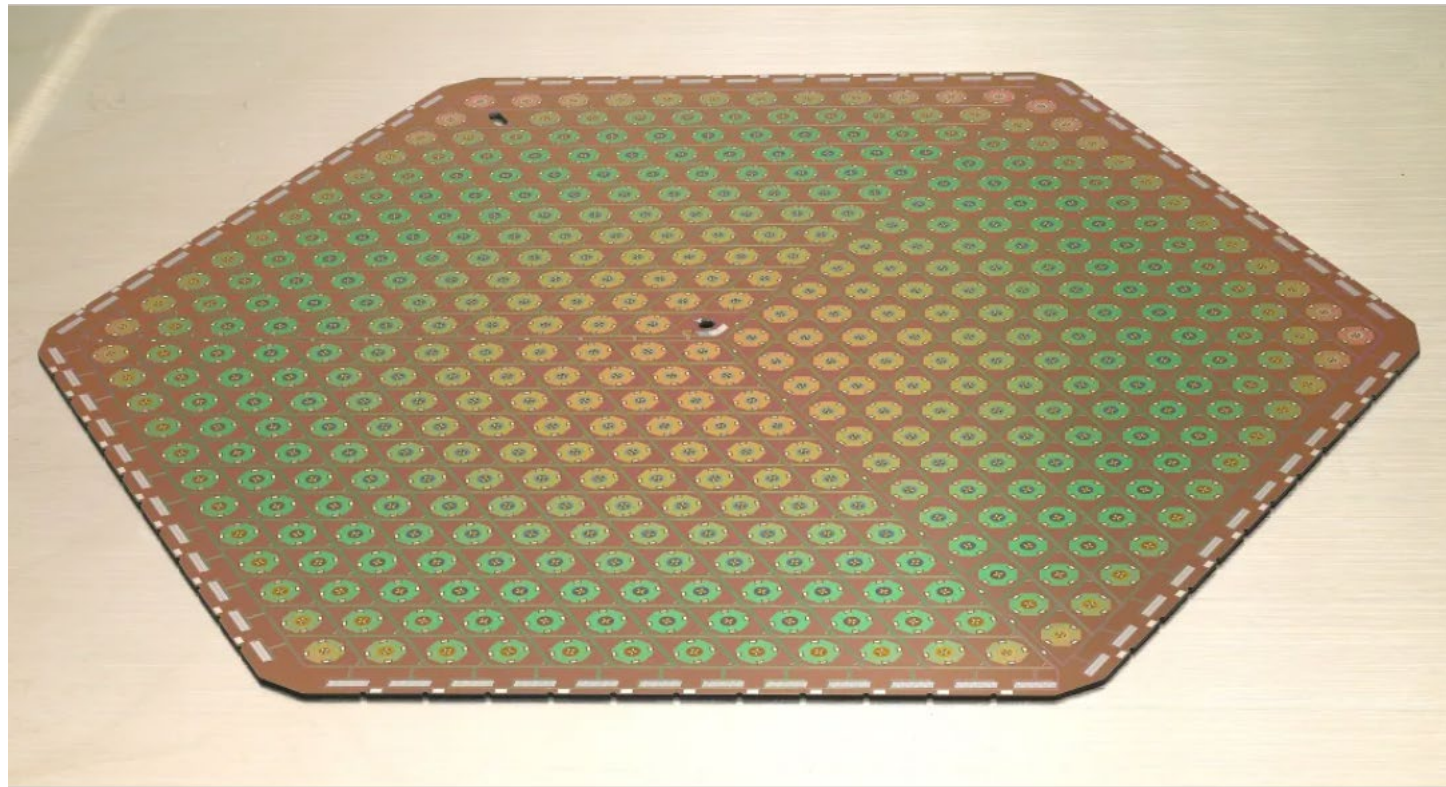
As the film cools,  $R \rightarrow 0$ ,  
and  $P_{\text{joule}}$  increases.

Multiplexing: read out  
many SQUIDs / TESs  
per wire

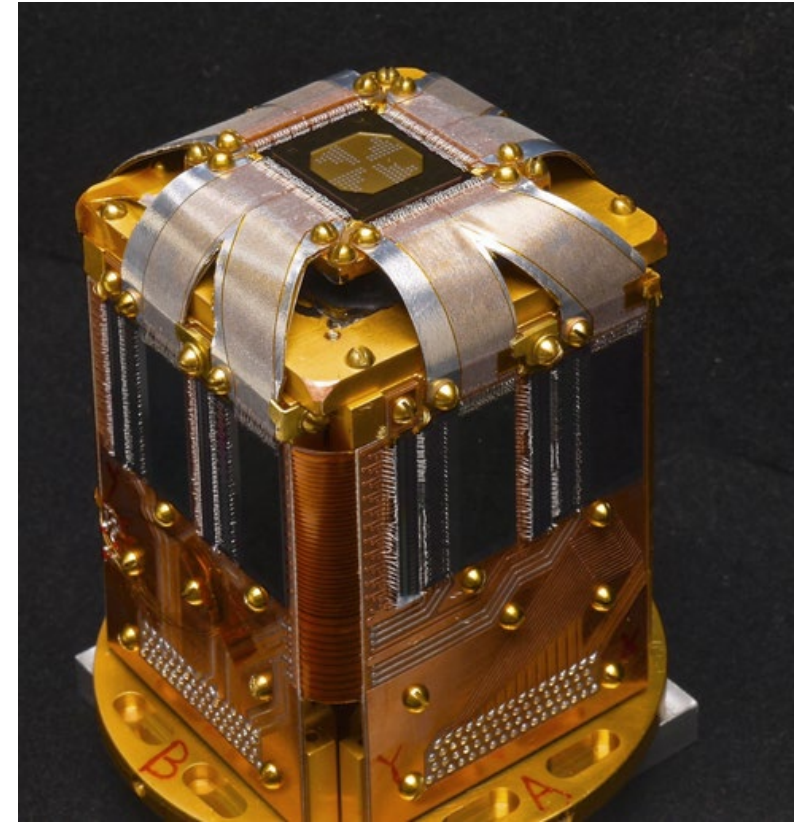


First multiplexed TES array: FIBRE at  
the Caltech Submillimeter  
8-pixel TES Fabry-Perot spectrometer  
Observatory (June, 2001)

# Now more than 100,000 TES pixels in use



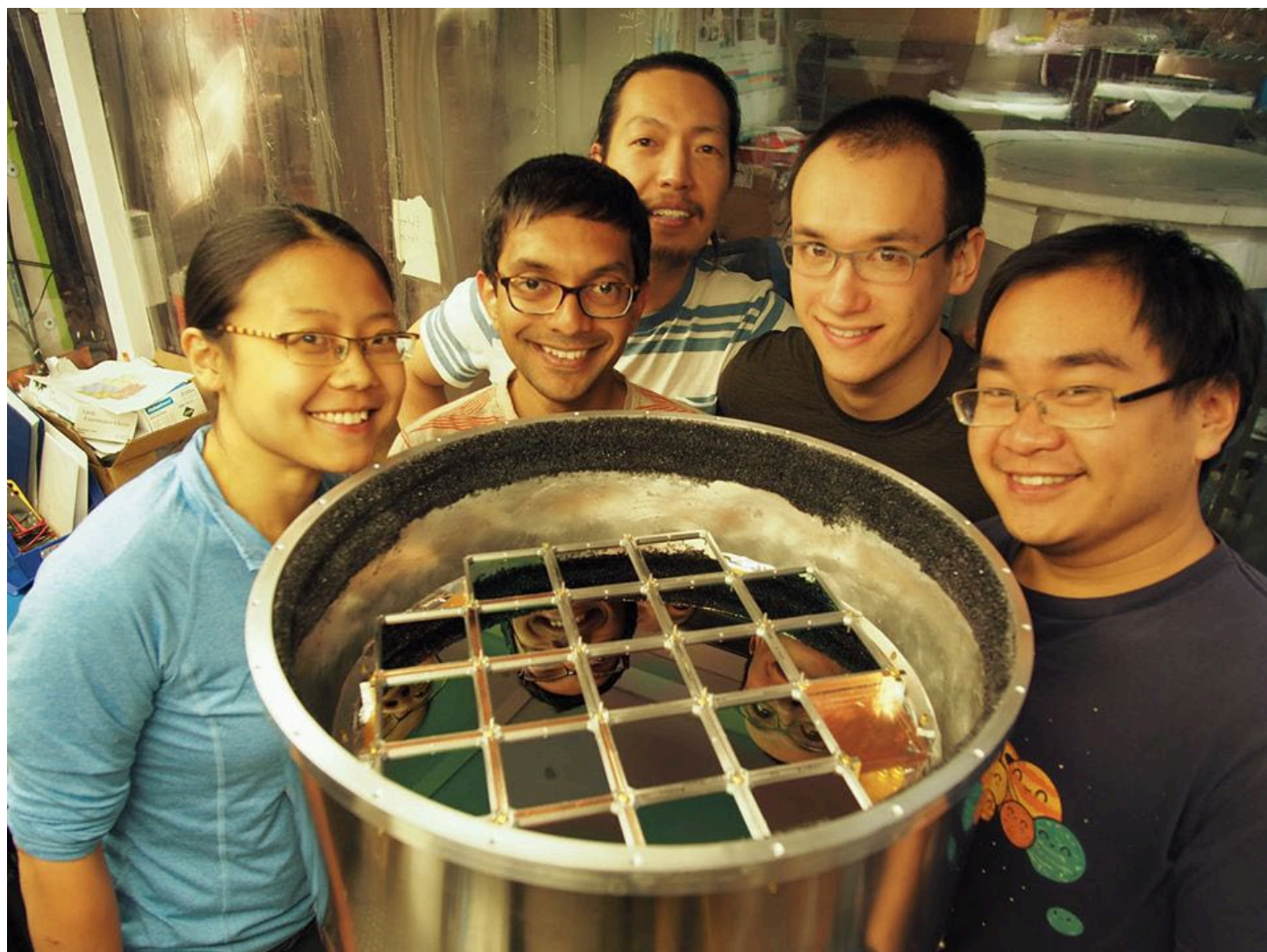
*Simons Observatory - Chile*



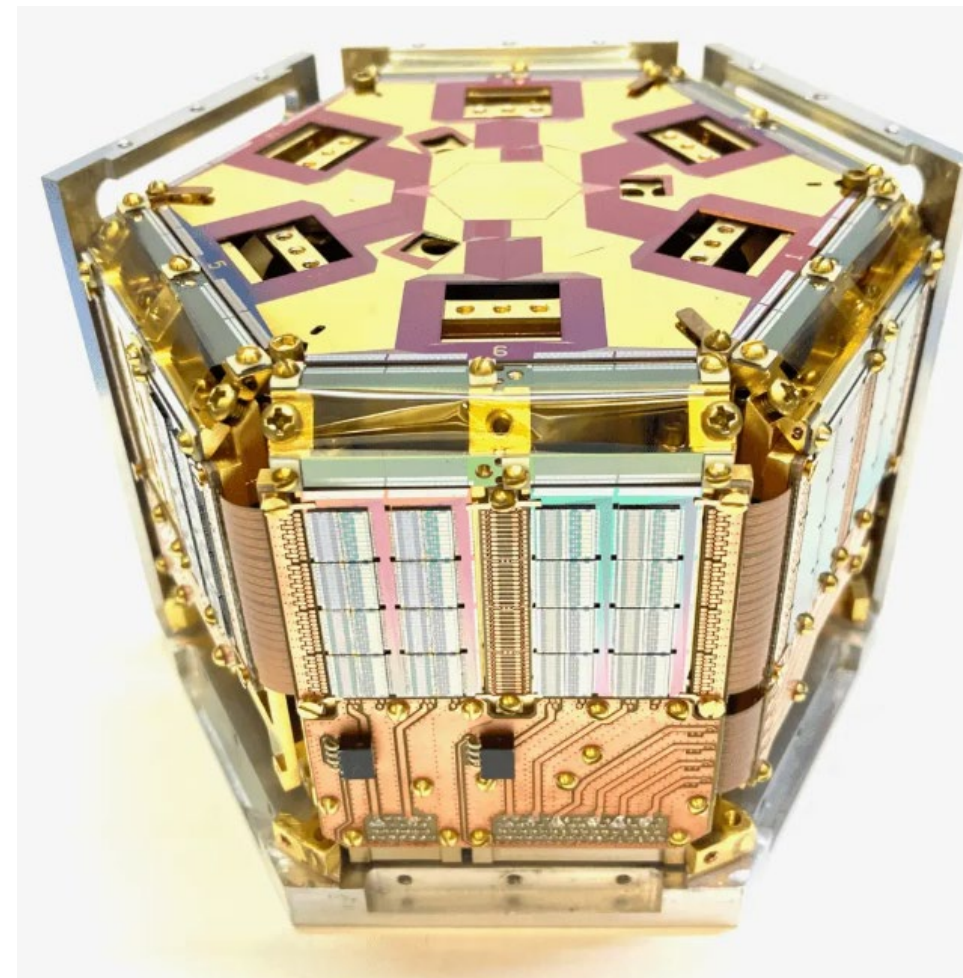
*X-ray spectrometer:  
SSRL, SLAC*



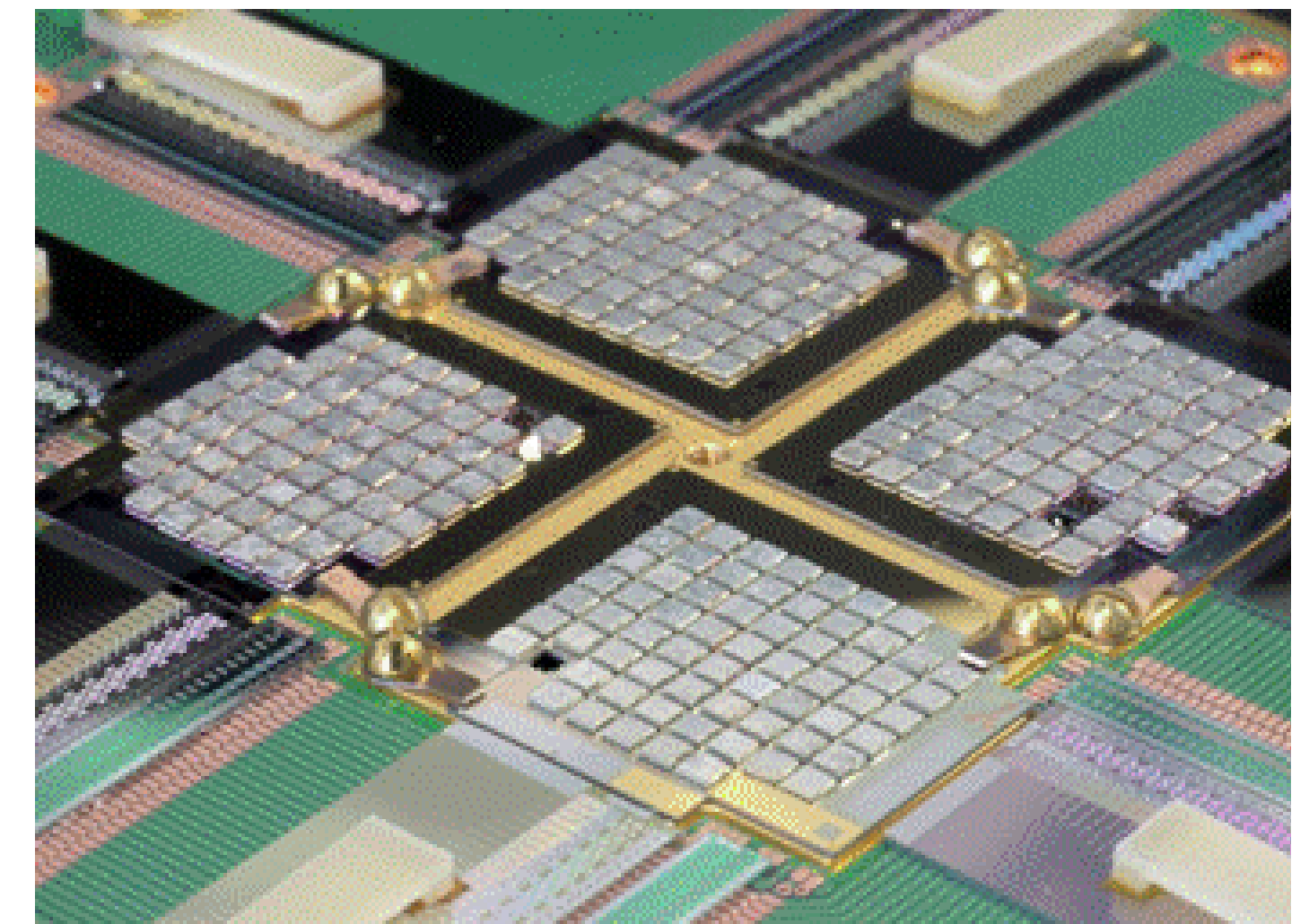
*Super CDMS (dark matter)*



*BICEP Array – South Pole*



*Athena X-IFU*



*$\gamma$ -ray spectrometer (NIST)*