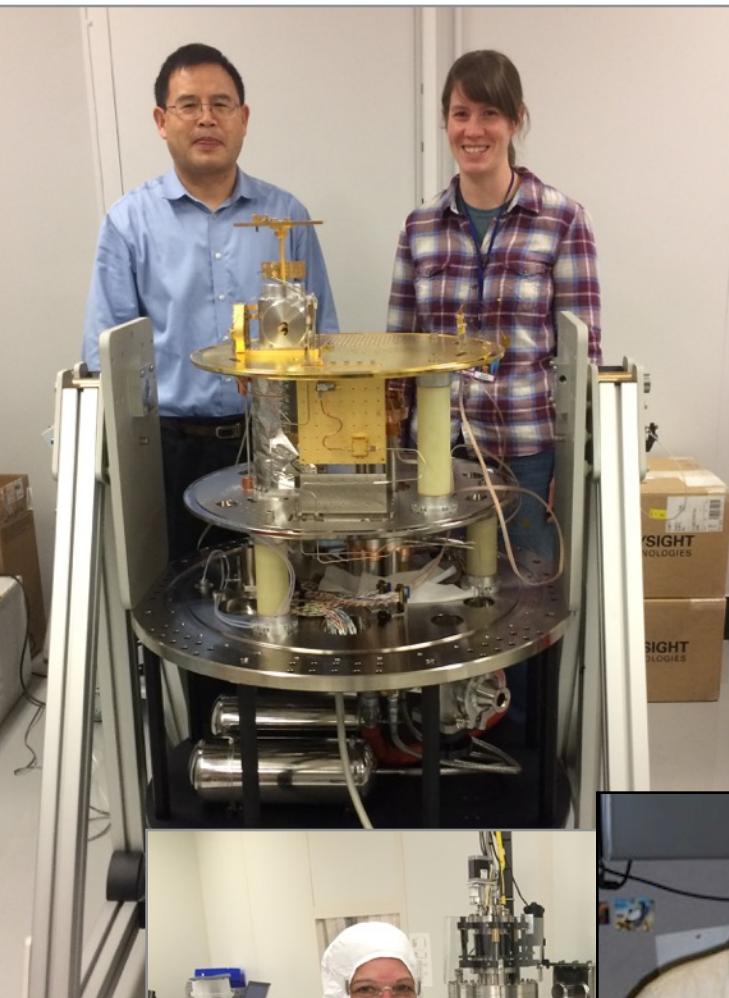


# Superconducting CMB Detectors at Argonne

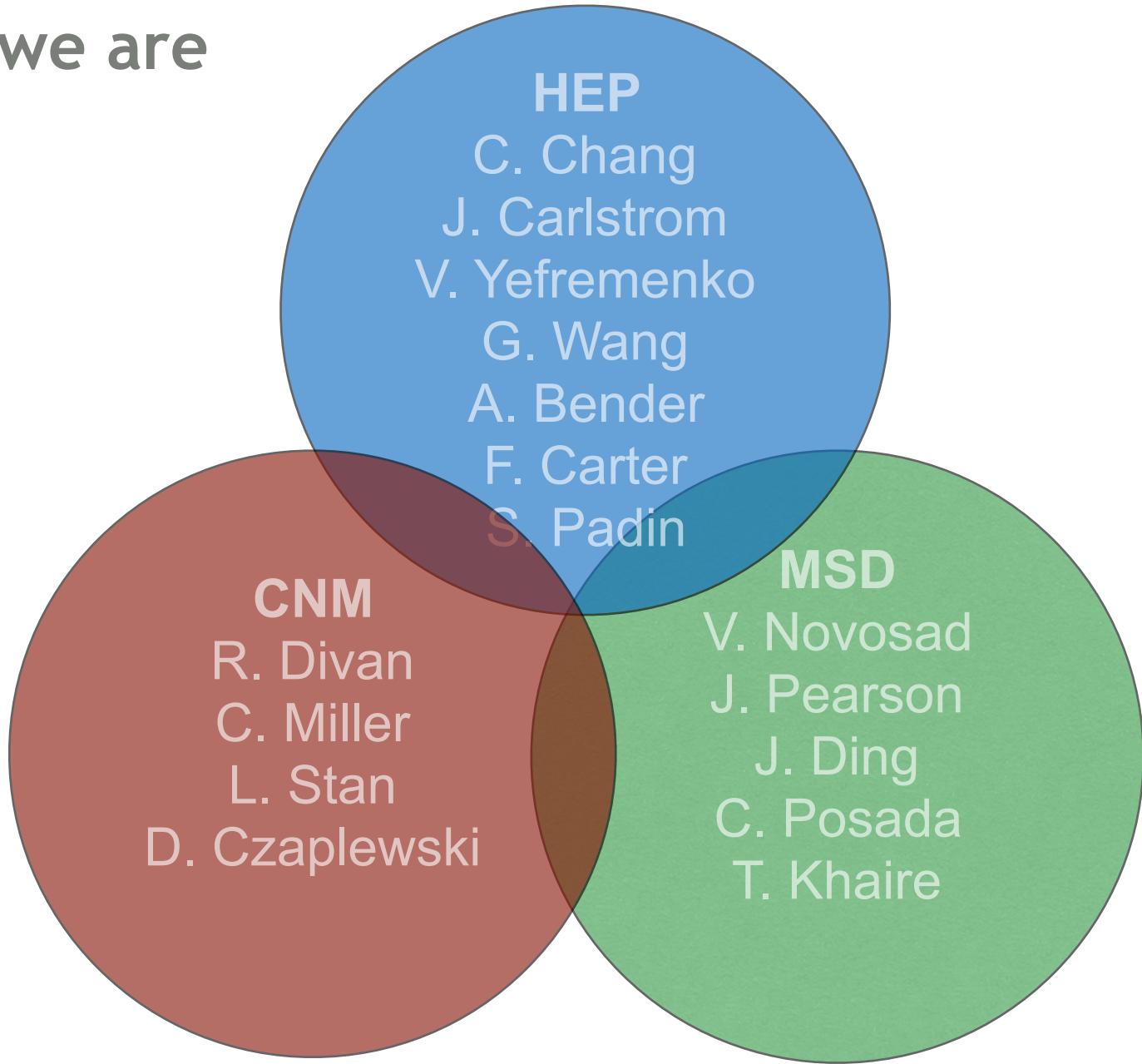
Clarence Chang  
(presented by  
John Carlstrom)

CERN  
May 2016

# Brief introduction to our group

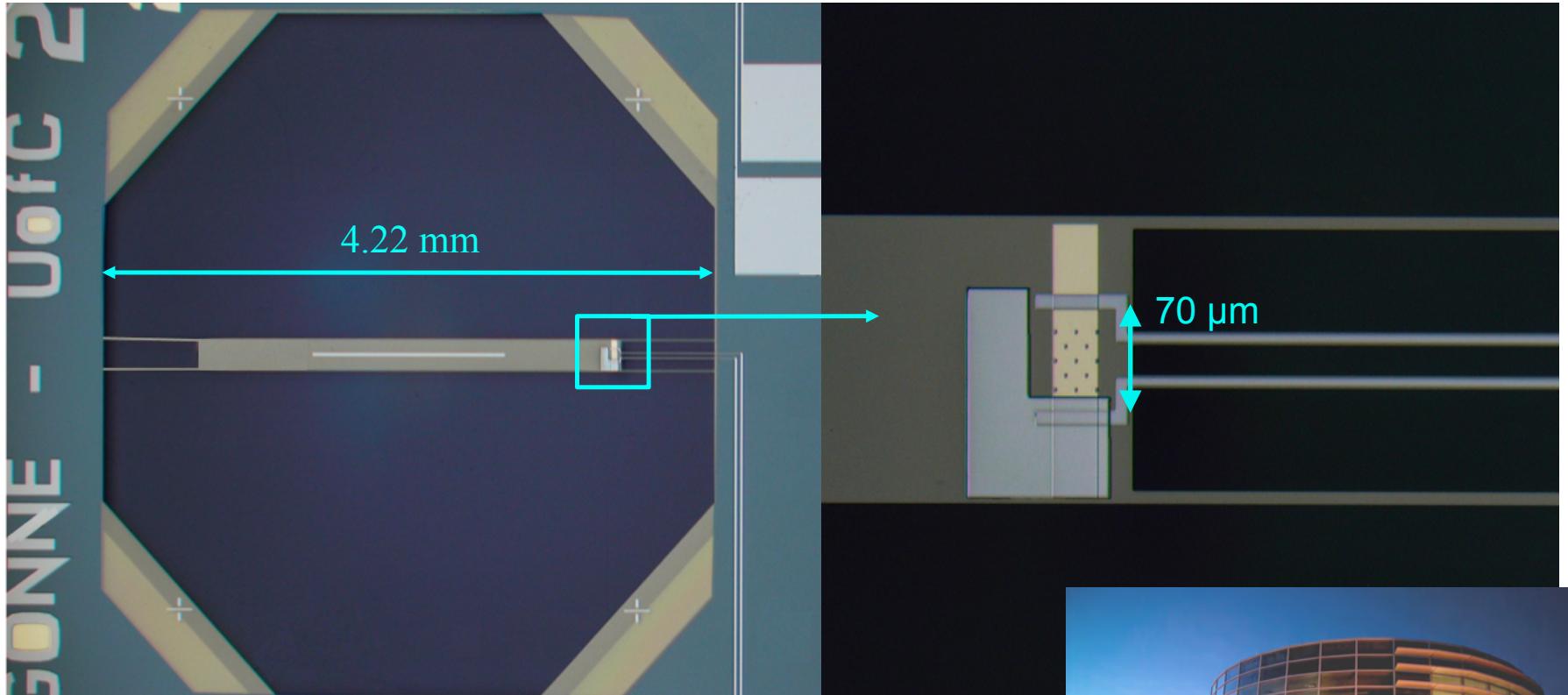


# Who we are



# Detectors for SPTpol

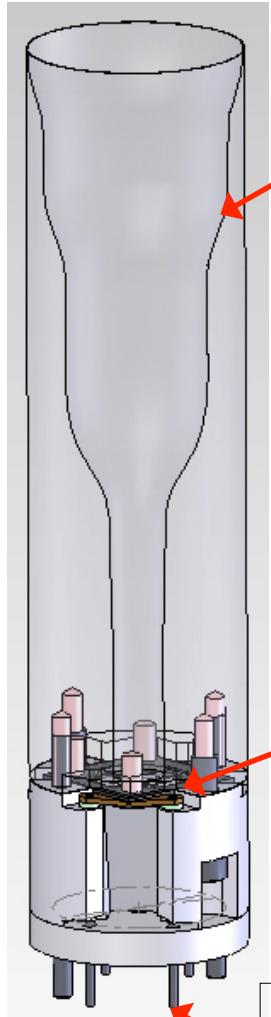
# Detectors made in CNM (SPTpol, 95 GHz)



CLC et al., JLTP June 2012, Volume 167, Issue 5-6, pp 865-871



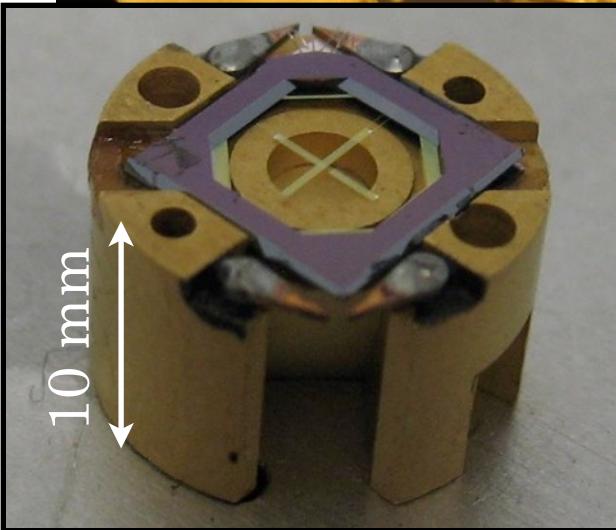
# 95 GHz Single Pixel PSBs



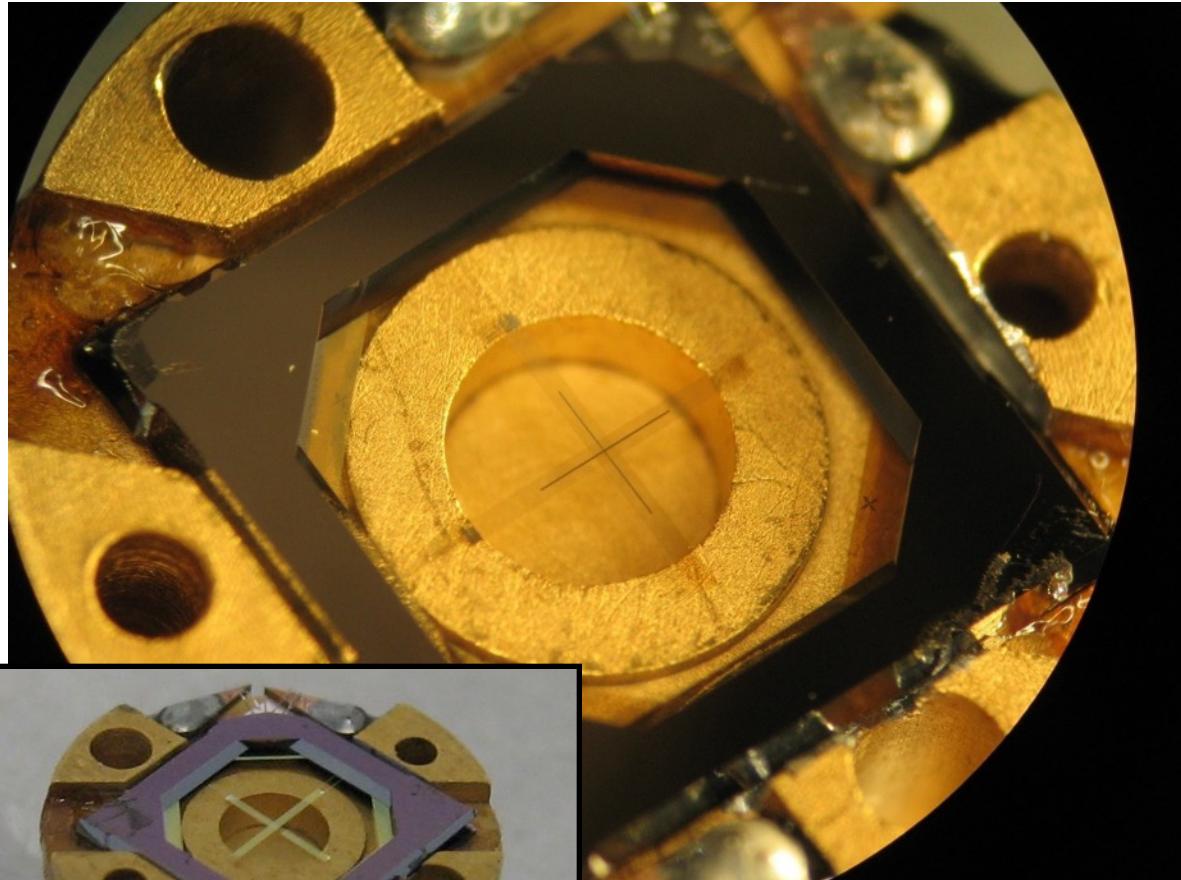
Contoured feed horn; maintains polarization angle

Detector in wave-guide section with  $\lambda/4$  backshort

Readout from back via pins



10 mm

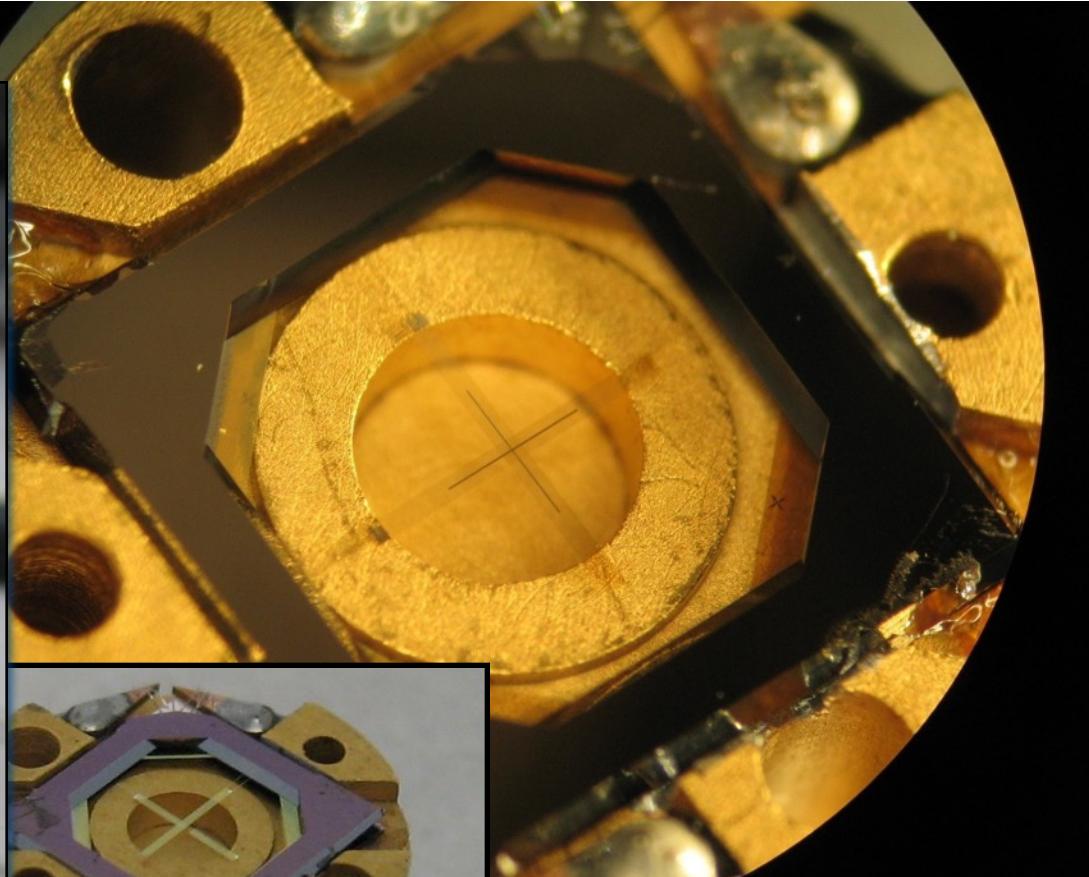


Fabricated by Vlad Yefremenko at ANL

# 95 GHz Single Pixel PSBs

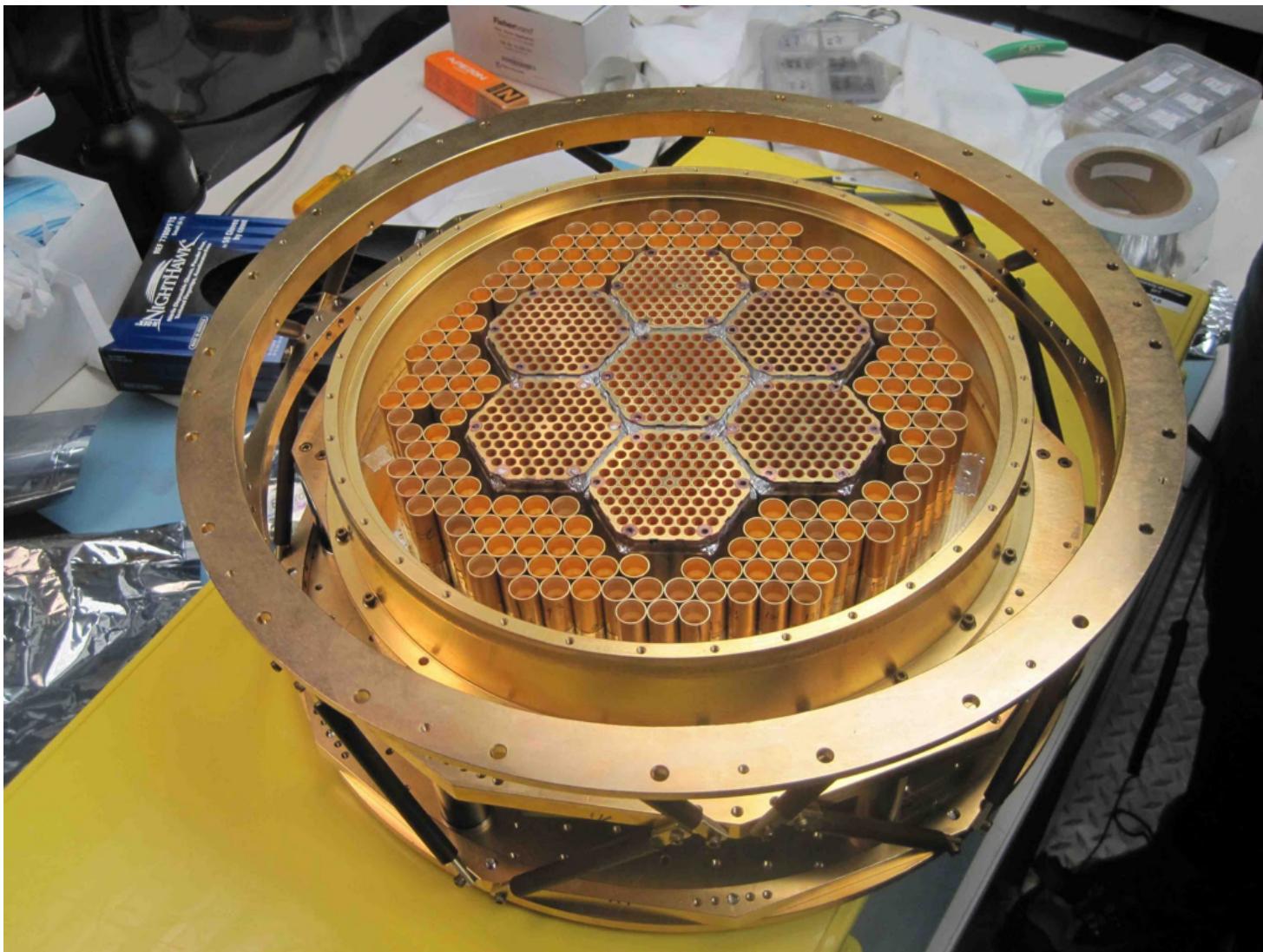


Readout  
from back  
via pins



Fabricated by Vlad  
Yefremenko at ANL

# The SPTpol Focal Plane

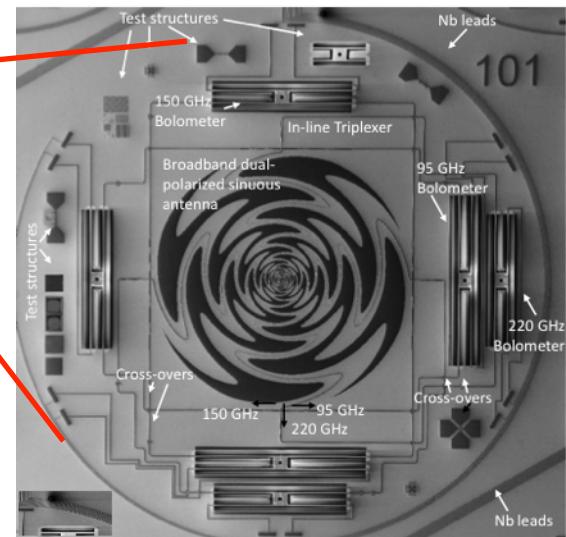
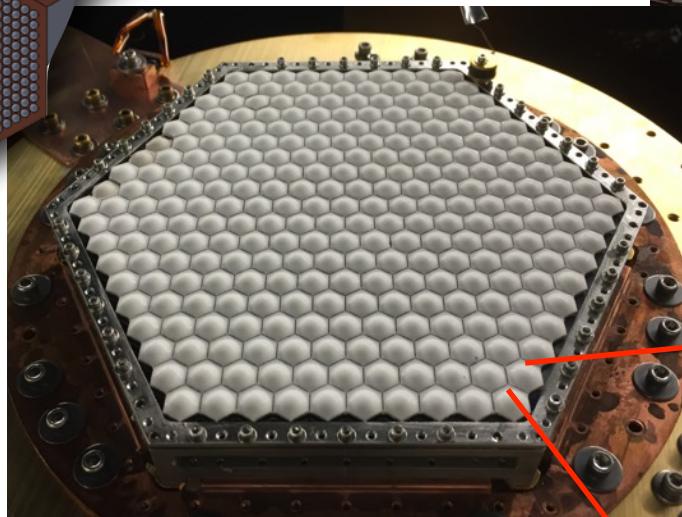
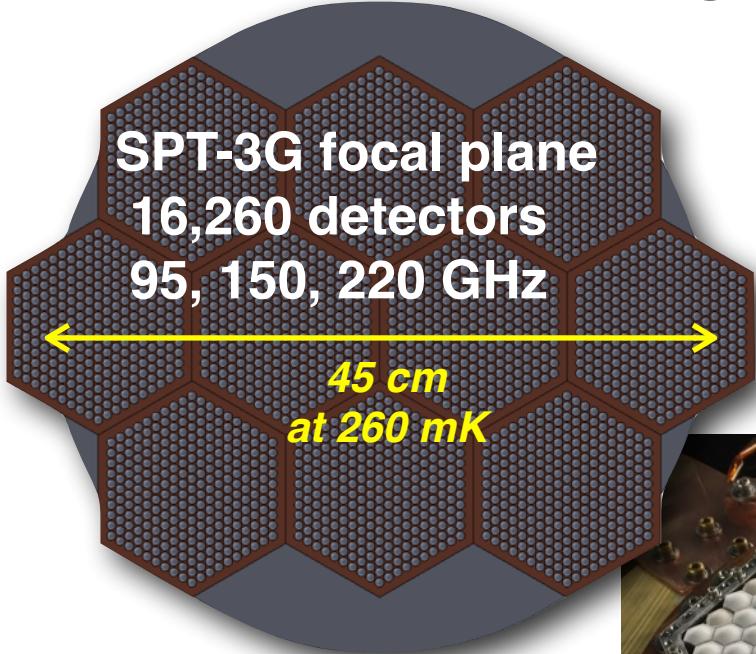


NIST  
  
Argonne  
NATIONAL  
LABORATORY



# Detectors for SPT-3G

# Current focus: delivering SPT-3G focal plane



- Detector fabrication at Argonne National Labs on 150 mm silicon wafers
- Using lenslet coupled, 3-band sinuous antenna coupled TES detector design from UCB (Polarbear2/ Simons Array, EBEX10k, LiteBIRD)
- Collaborating with UC Berkeley

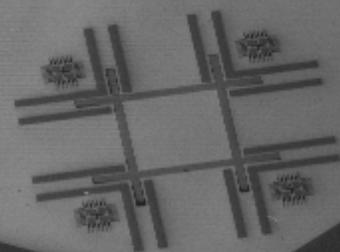
SPT-3G will use a 3-color  
variant of multi-chroic pixel

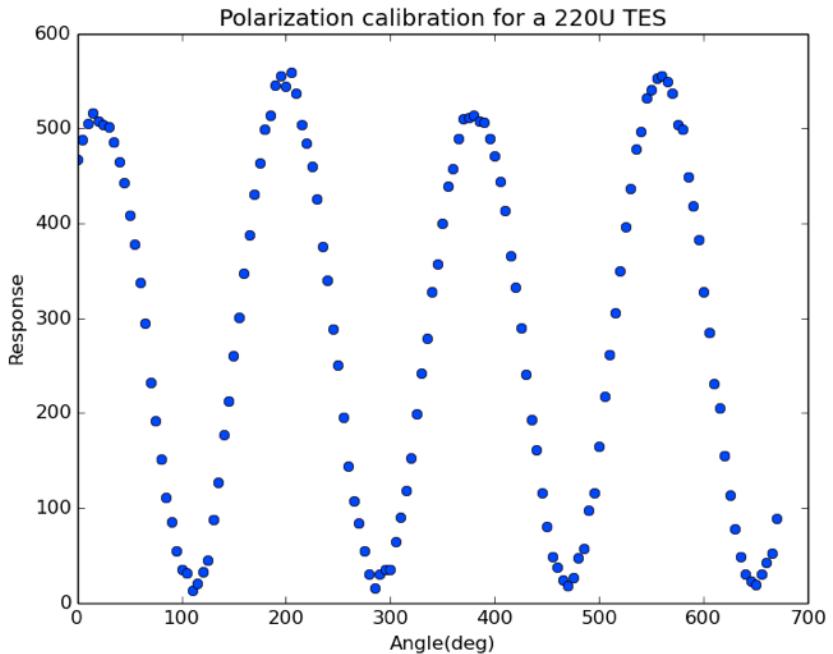
O'Brient R et al 2013 Appl. Phys.  
Lett. 102 063506

Suzuki et al 2014 J. Low Temp. Phys.  
176 650–6

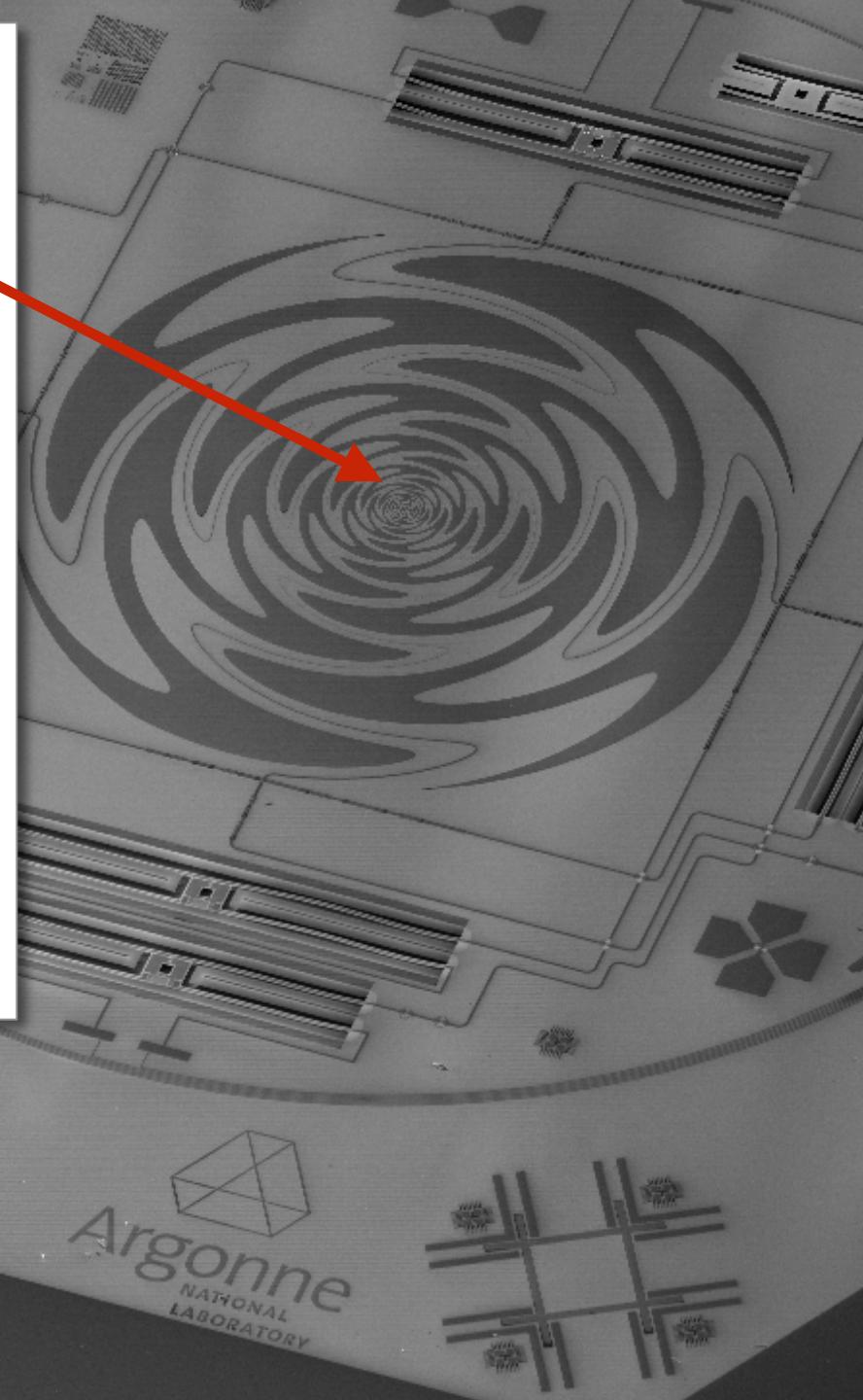
Berkeley  
UNIVERSITY OF CALIFORNIA

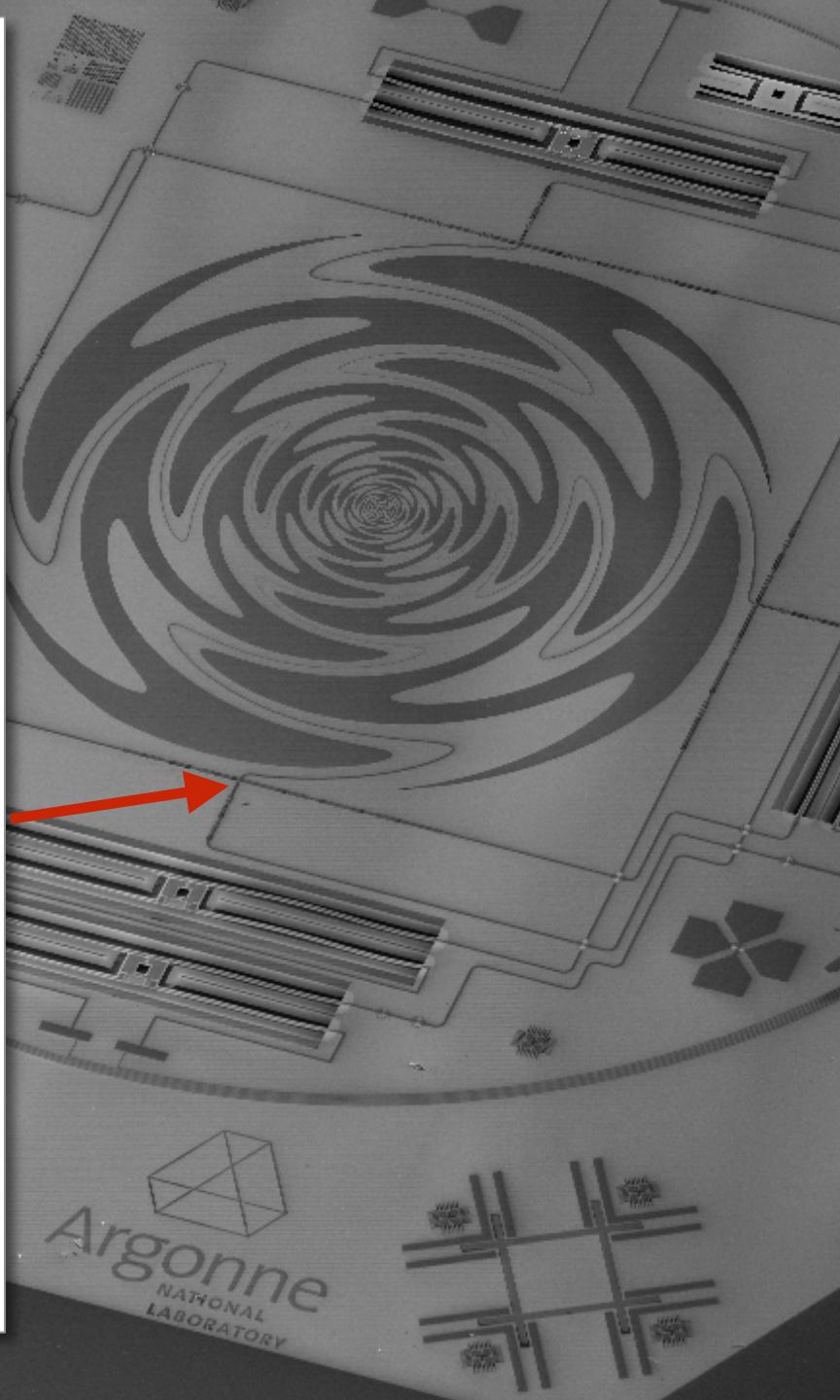
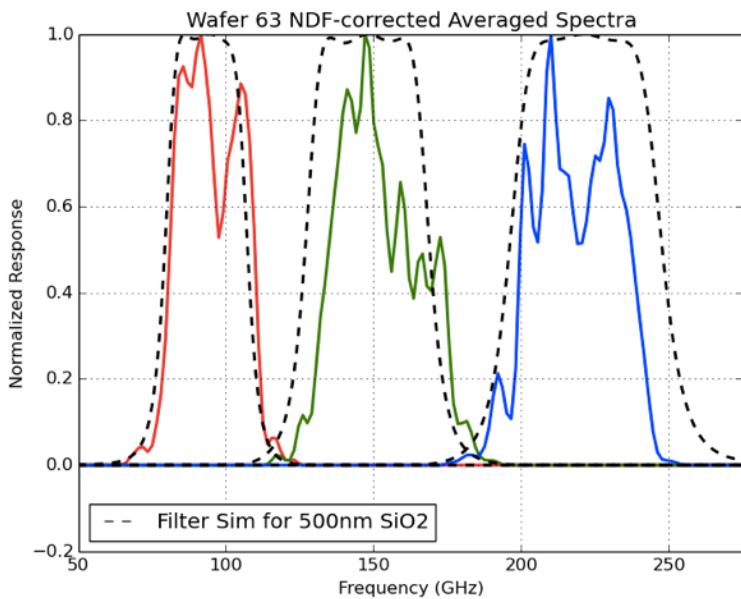
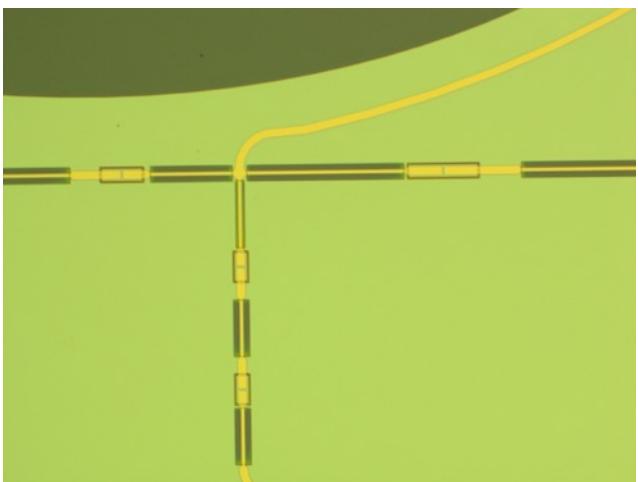
Argonne  
NATIONAL  
LABORATORY





Sinuous antenna gives polarization sensitivity and good coupling over large (2+ octaves) bandwidth.





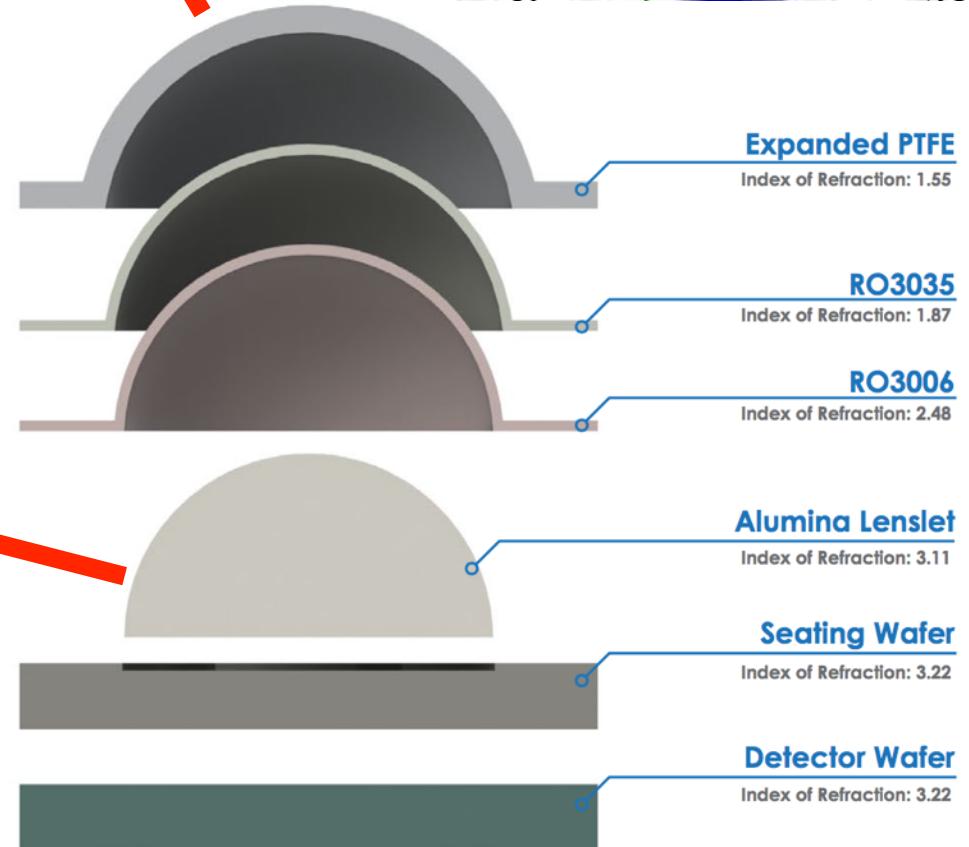
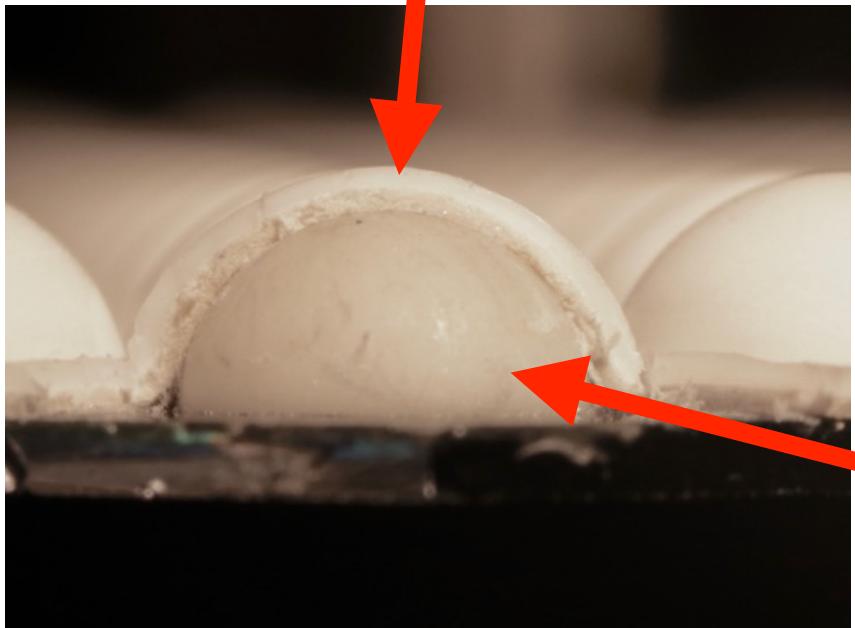
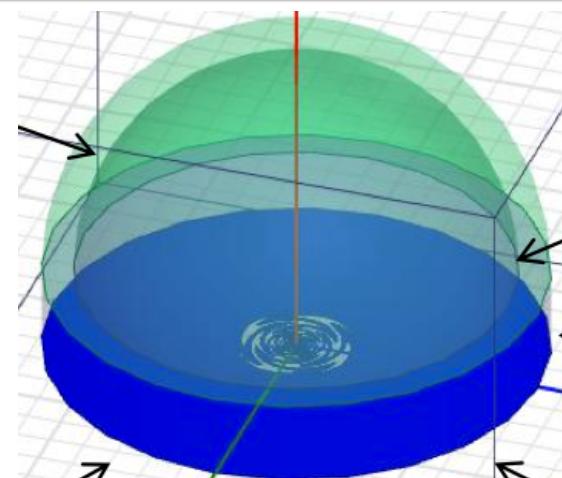
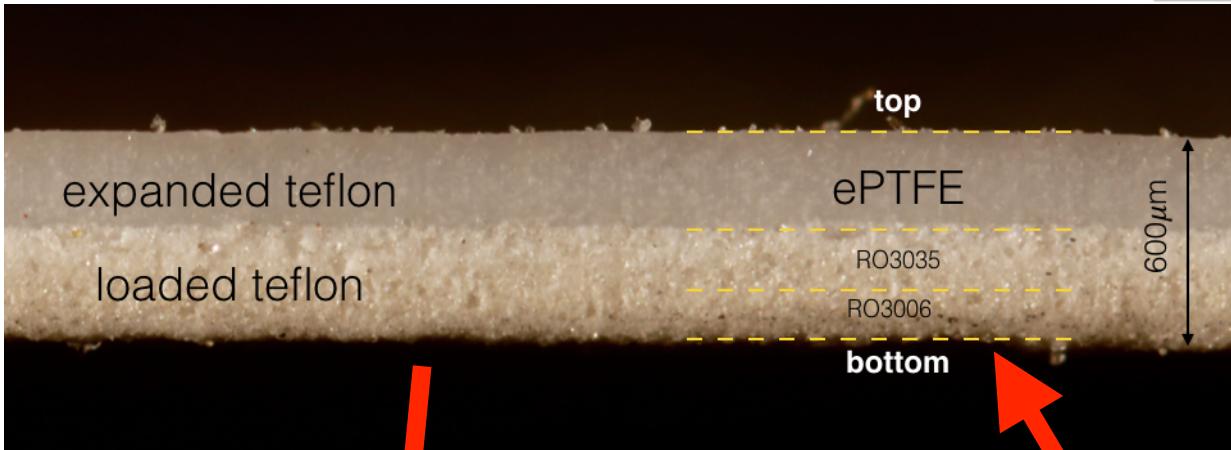
Lumped element in-line triplexer partitions radiation into three passbands

C M Posada et al 2015  
Supercond. Sci.  
Technol. 28 094002

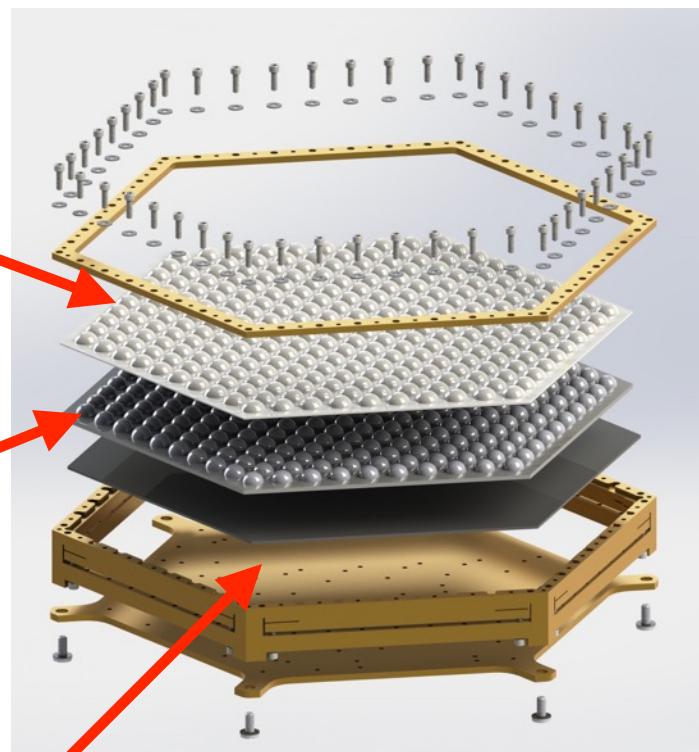
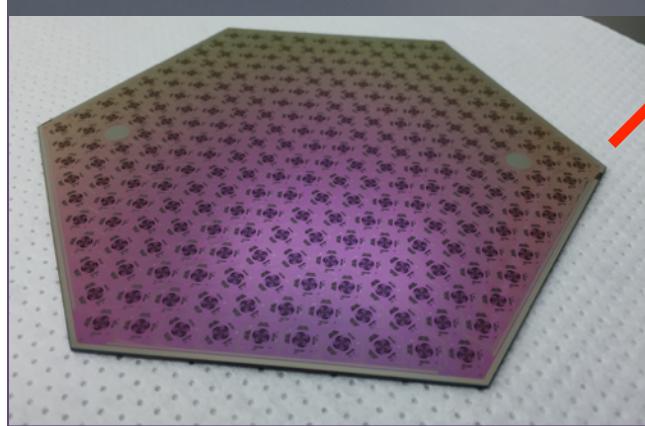
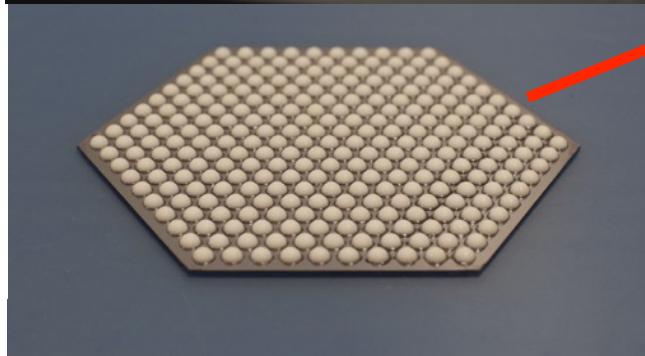
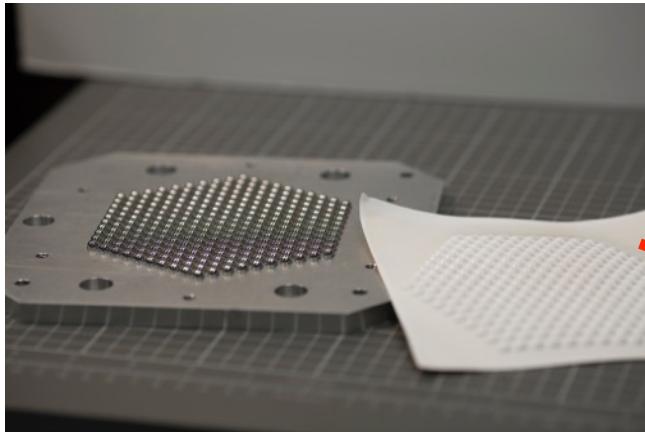
5 mm

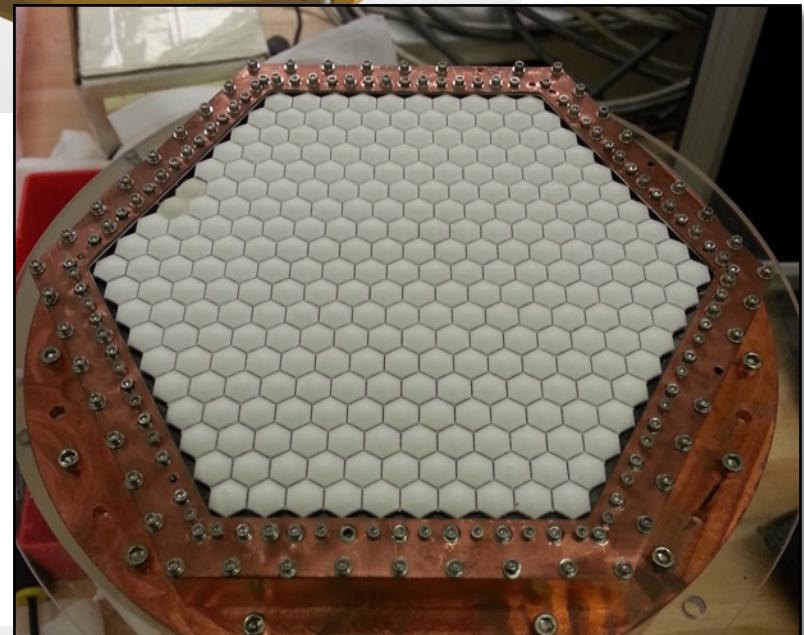
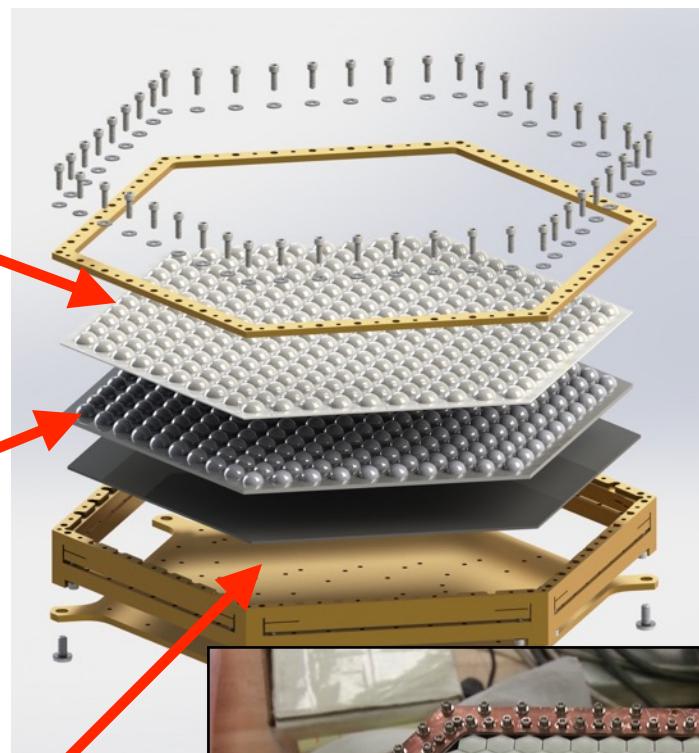
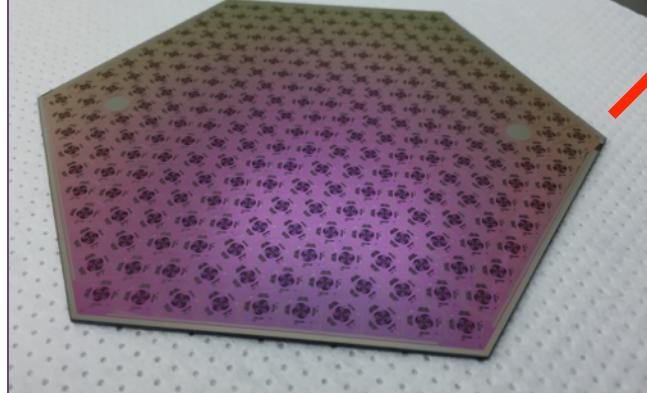
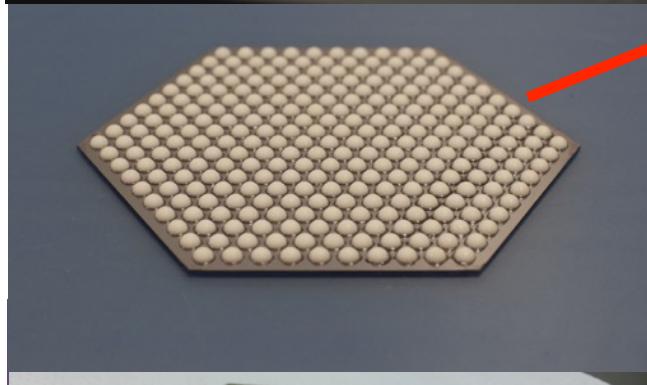
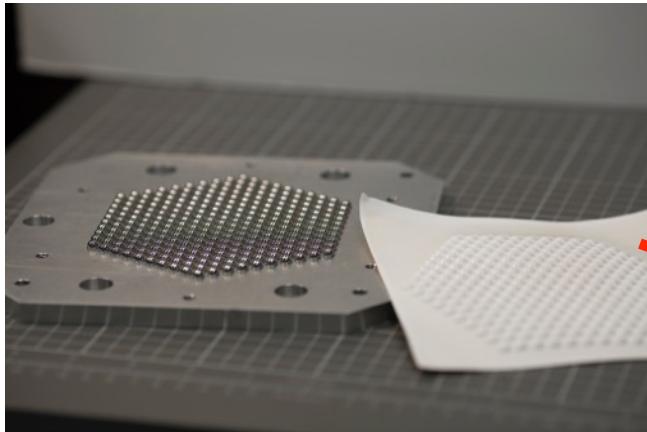
# Lenslets





ILLINOIS  
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN





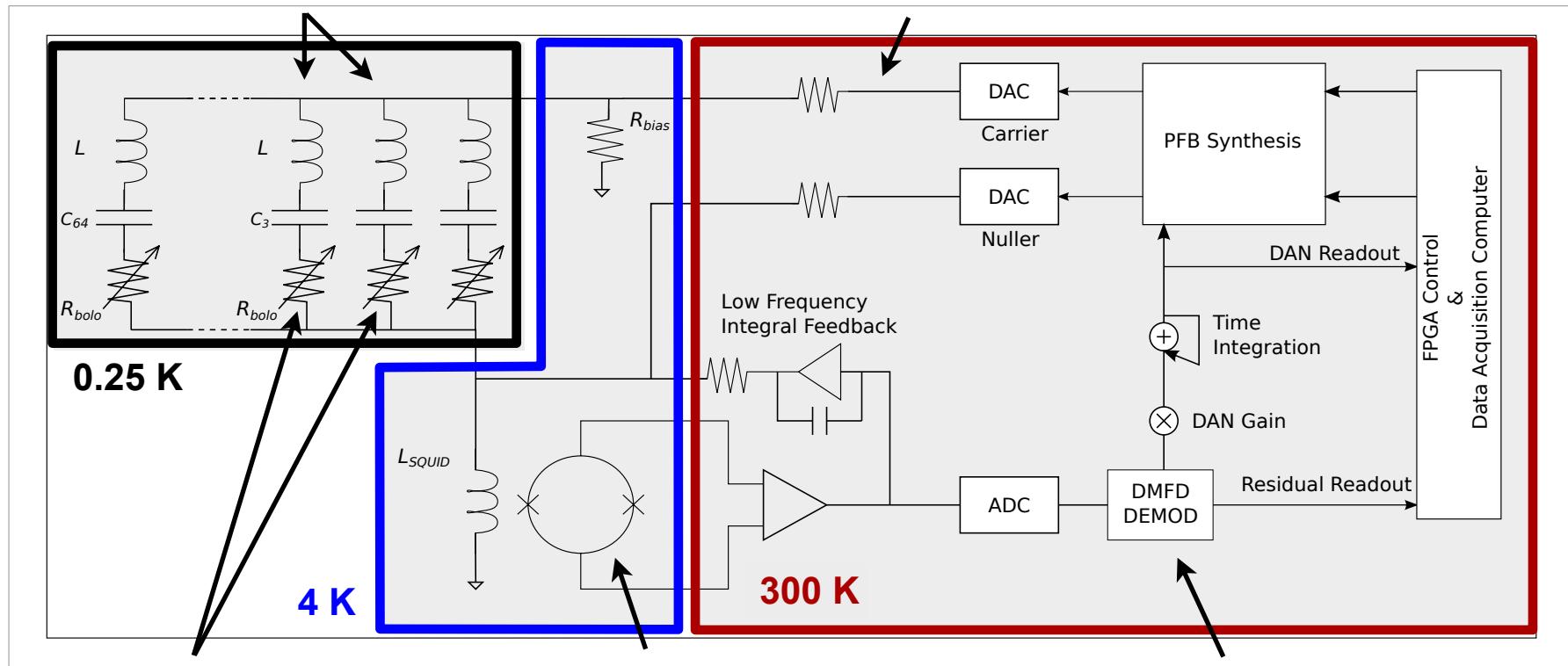
# Readout



# Digital frequency multiplexing

## LC Filters

## AC Bias

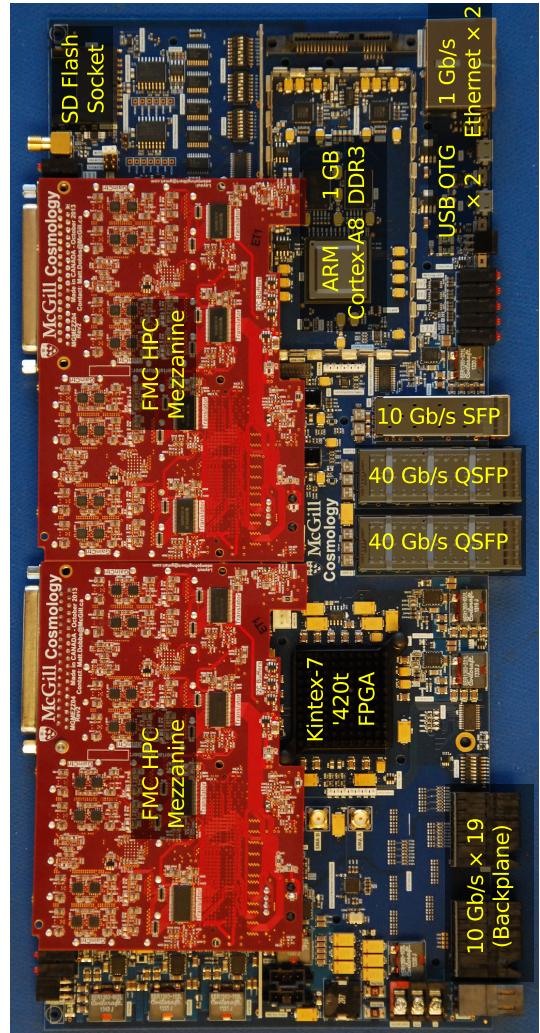
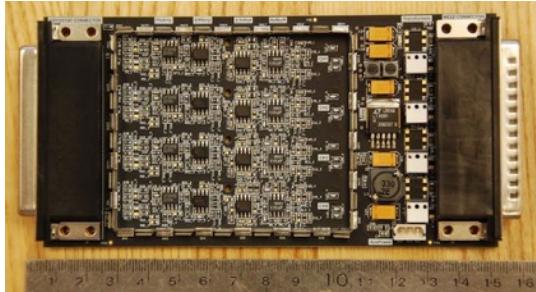
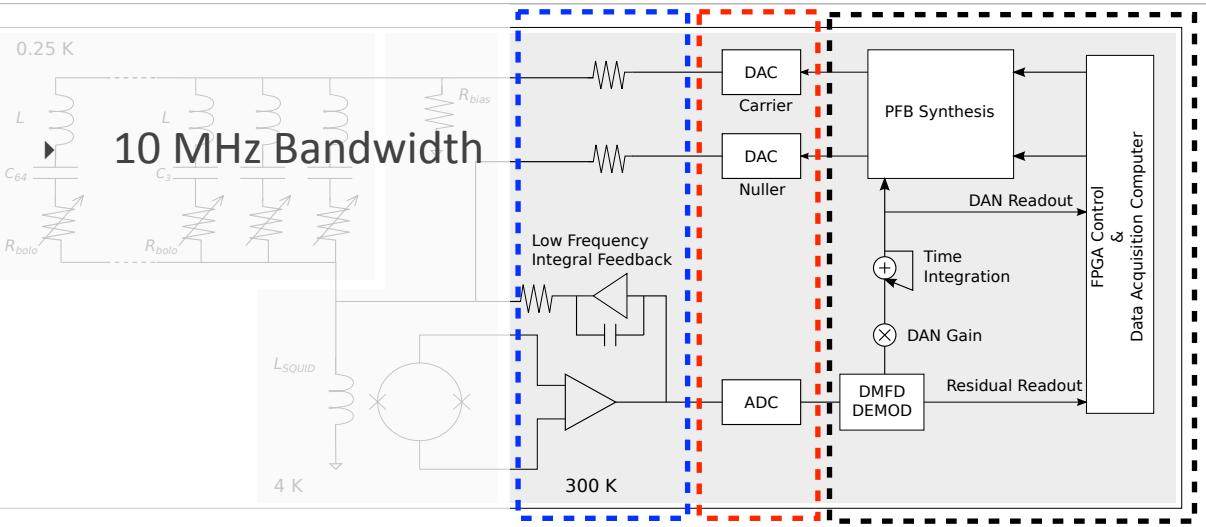


TES Bolometers

SQUID

Demodulation &  
Feedback

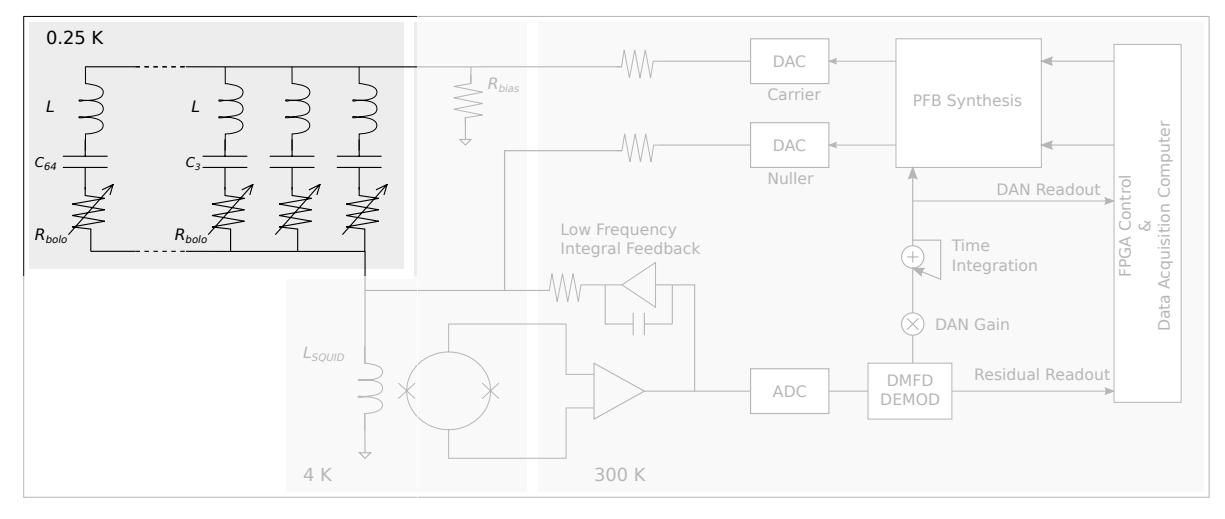
# Control Electronics



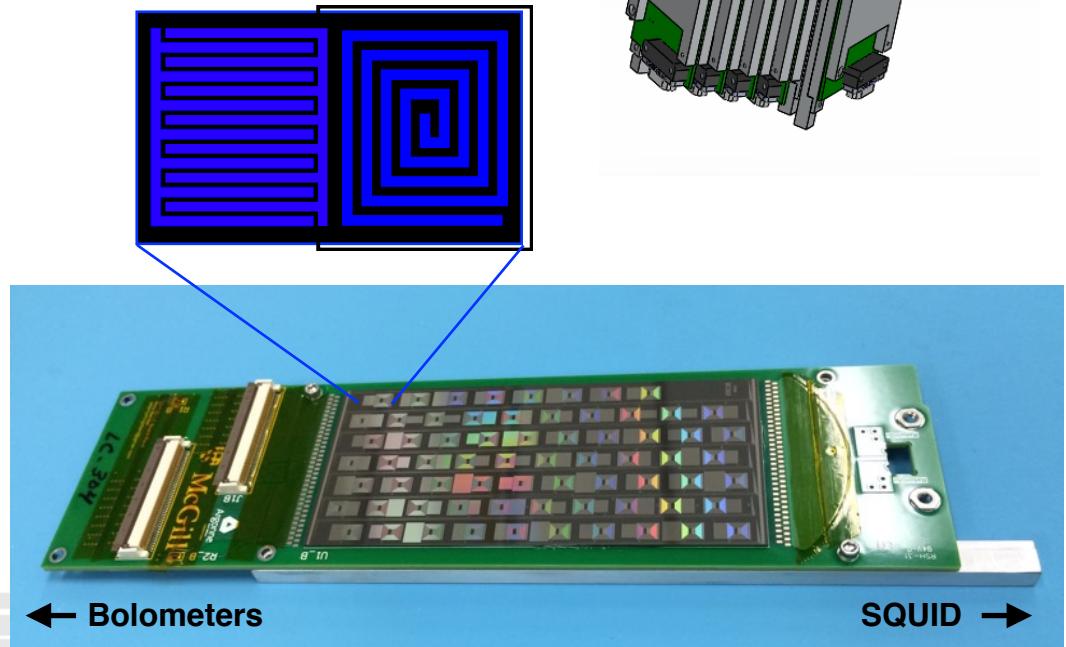
- 10 MHz bandwidth
- Xilinx Kintex-7 FPGA provides digital signal processing
- Each bolometer bias is individually optimizable
- 64X upgrade to 16X deployed on SPTpol, EBEX, & Polarbear

*A.N. Bender et al., Proc. SPIE 9153, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy VII, 91531A (2014)*

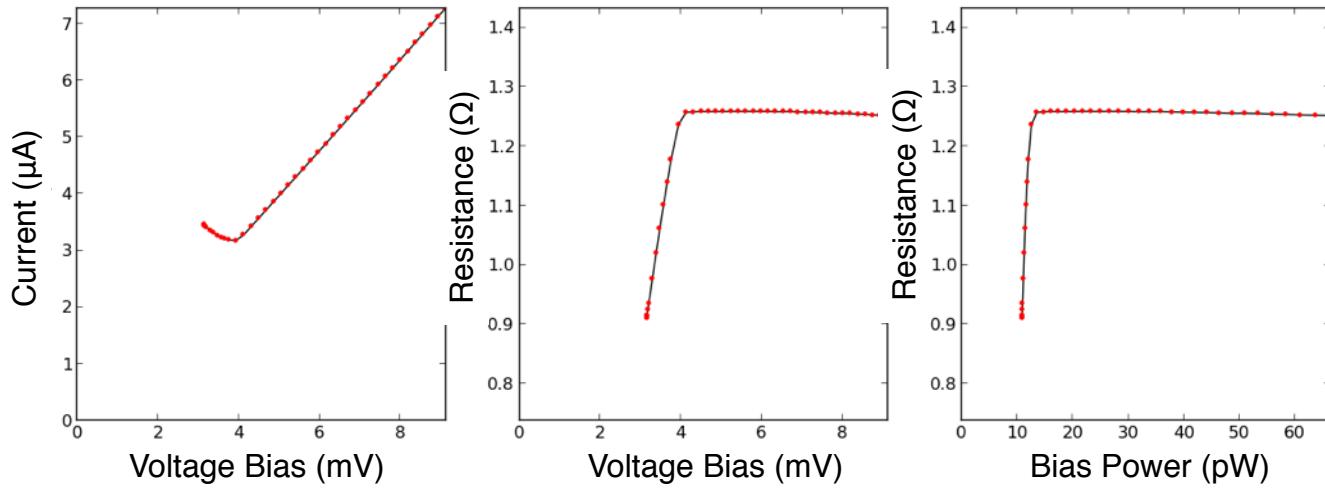
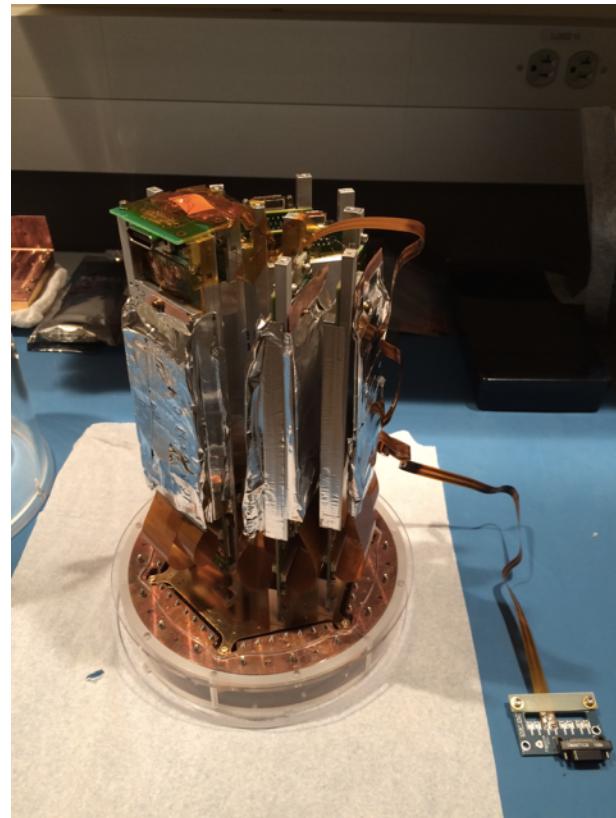
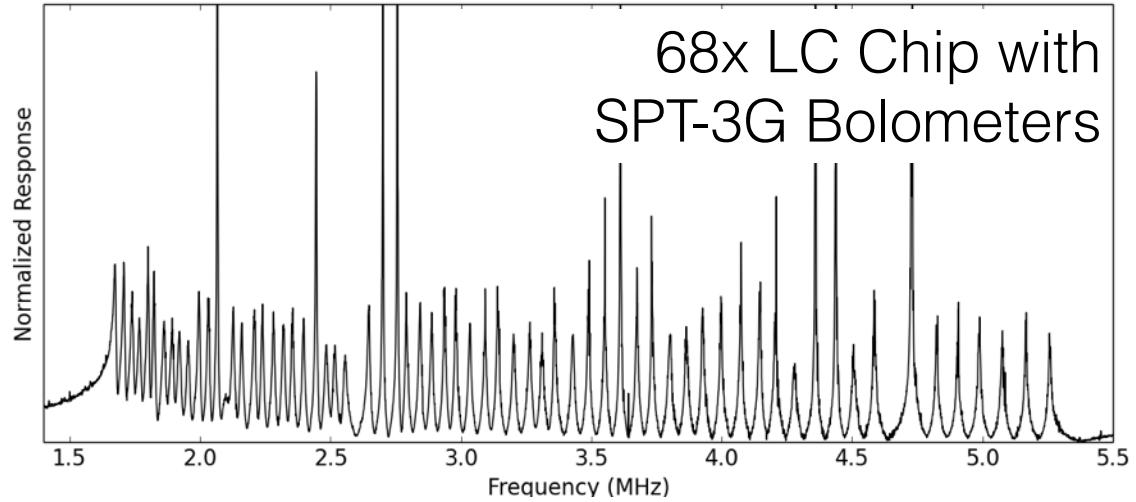
# Inductive-Capacitive Resonators



- LC circuit
  - $f = 1.6 \text{ MHz} - 5 \text{ MHz}$
  - $L = 60 \mu\text{H}$
  - $\Delta C_{\min} = 0.6 \text{ pF}$
  - $Q \sim 5000$  (ESR  $\sim 0.1 \Omega$ )
- 68 devices per chip
  - Al on Si substrate
- Fabricated at LBNL+UCB
- Comb design & characterization at ANL



# Integrating Detectors & Readout

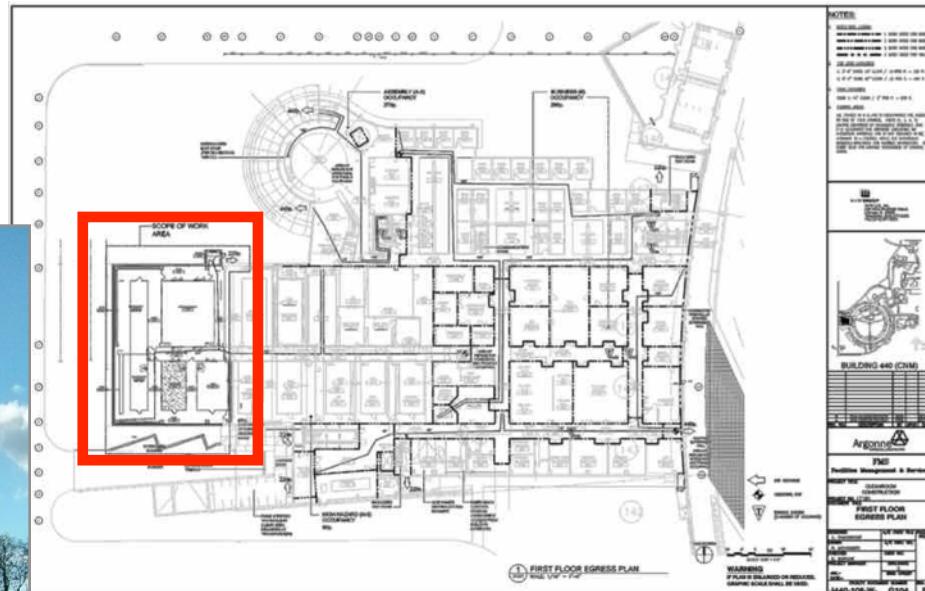


# Directions beyond SPT-3G

# Facilities expansion

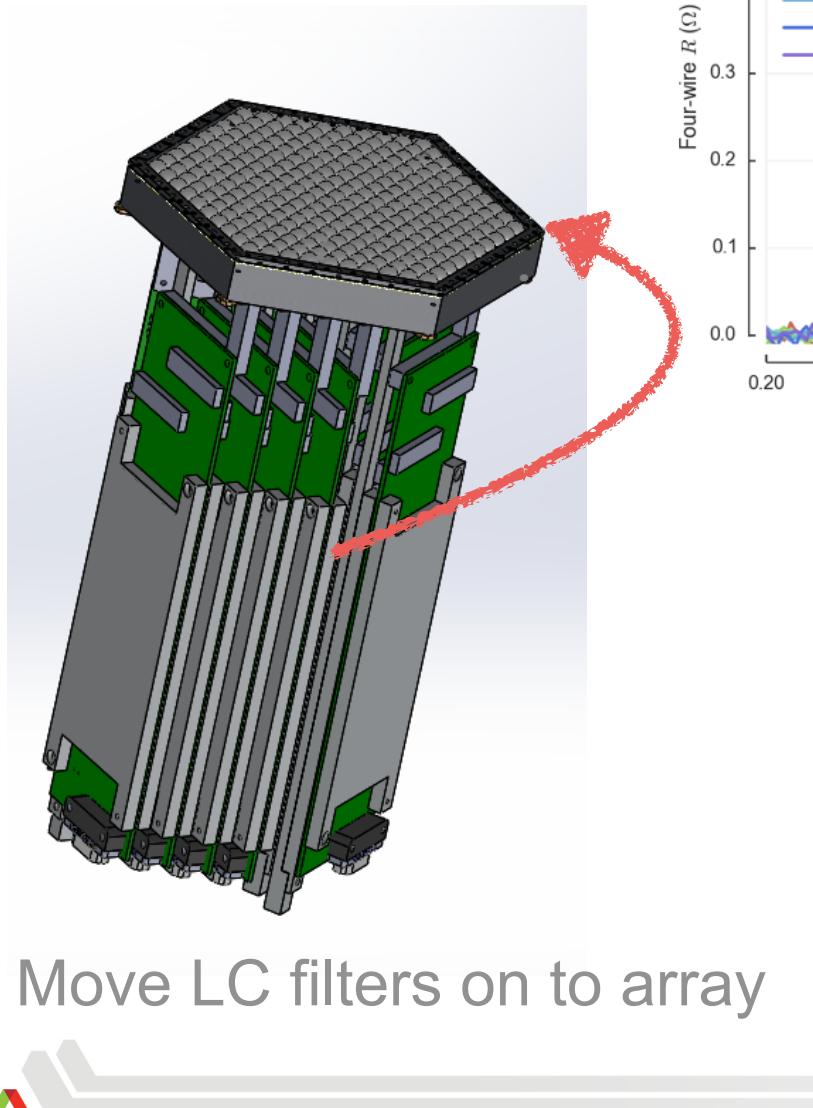


11,000 +5,000 sq ft

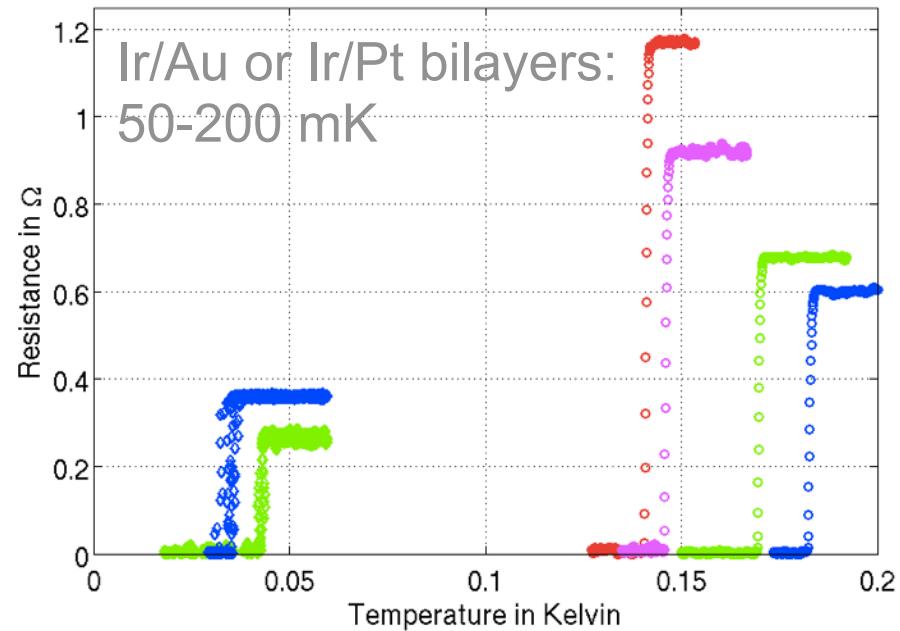
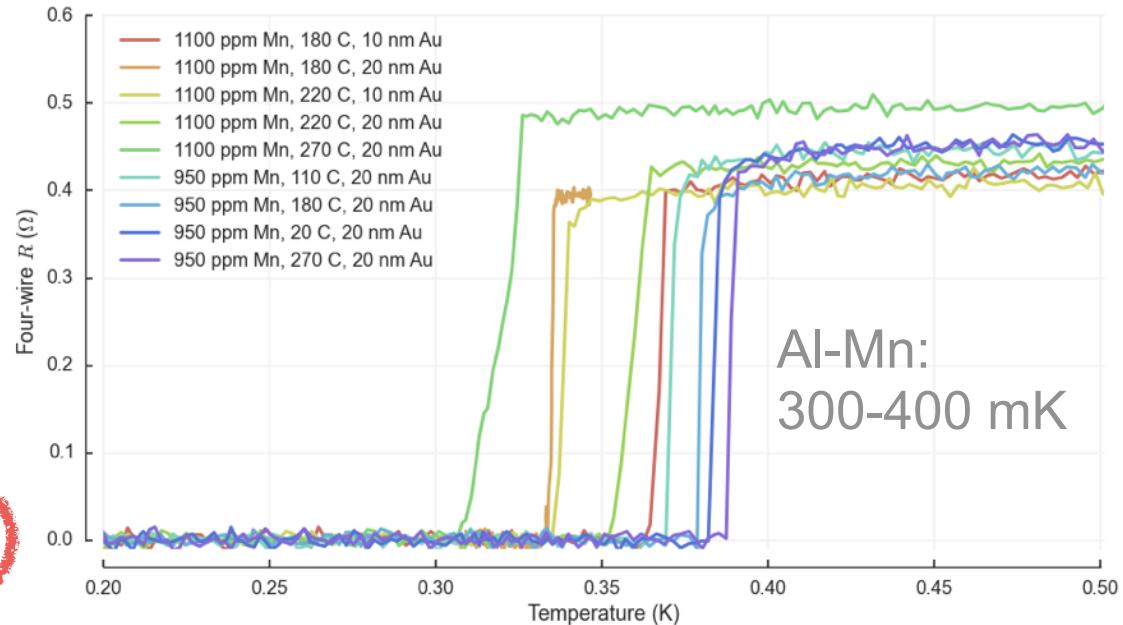


11,000 sq ft

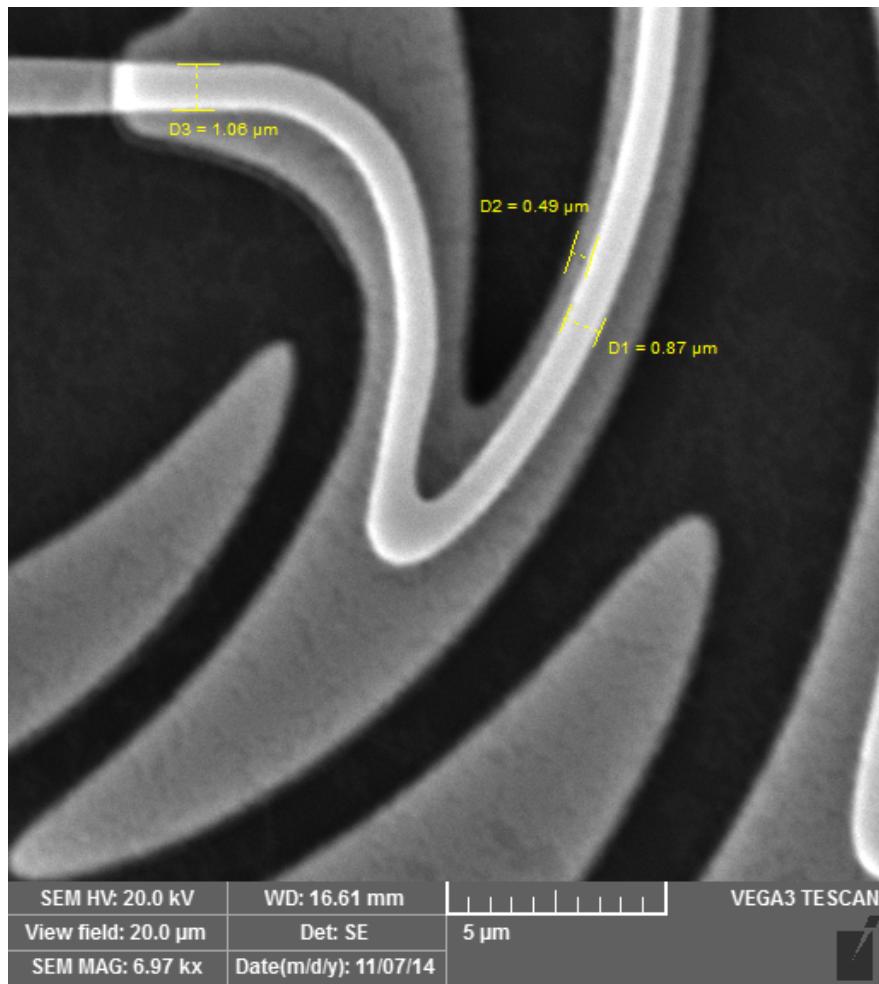
# New materials



Move LC filters on to array



# Thoughts on CORE+



- ▶ Strongest advantage is very large bandwidth
  - consolidate high frequency channels into smallest footprint
- ▶ R&D needed
  - antenna+lenslet expects flat focal plane
  - broadband AR coating to high frequencies (e.g. thermal spray coating at LBNL/Berkeley)
  - higher-frequencies require smaller features, can explore this using Argonne e-beam lithography
- ▶ fMUX
  - high TRL technology
  - merging LC filters on to array would eliminate complexity and bulk
- ▶ Low loading in space
  - can be addressed with lower Tc films
- ▶ LiteBIRD baseline plan (fab at UC Berkeley)