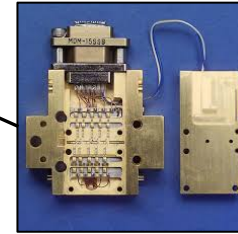
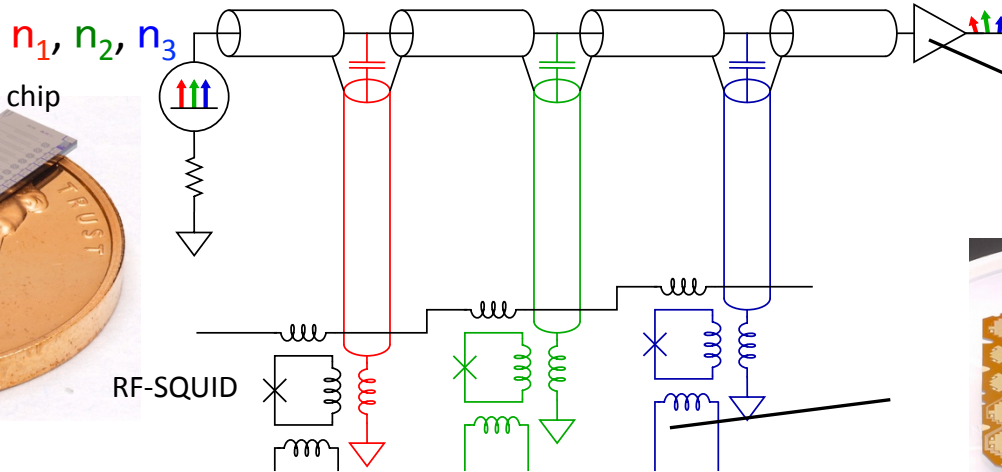
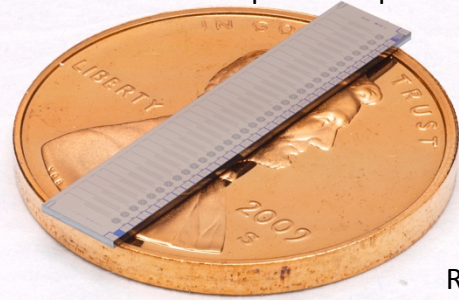


# Microwave SQUID Multiplexing ( $\mu$ MUX)

- combines advantages of microwave resonator-based readout with advantages of TES sensors

33-channel  $\mu$ MUX chip



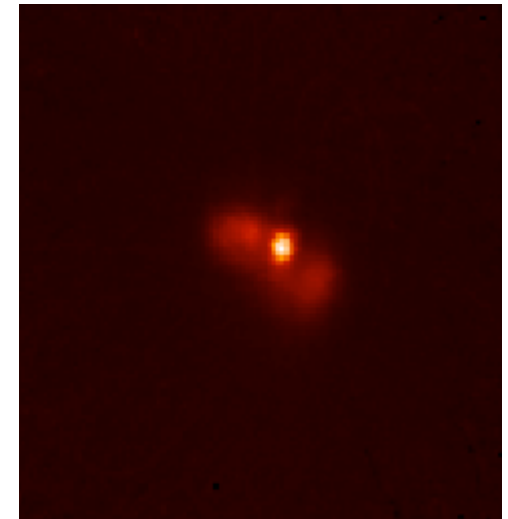
HEMT amplifier



TES array

- low noise:  $I_N < 20 \text{ pA}/\sqrt{\text{Hz}}$ 
  - order of magnitude lower than expected photon noise for CMB-S4
  - no multiplexed disadvantage
- clear path to MKID-like multiplexing factors or significantly higher with hybrid multiplexing schemes (i.e. CDM or FDM within  $\mu$ wave SQUID)
- on-sky demonstration with MUSTANG2 (proven readout with no noise degradation)
- ROACH2 control electronics with software and firmware to manipulate tones and perform flux ramp demodulation (NIST & UPenn/NRAO versions)

M87 observed with MUSTANG and  $\mu$ MUX



# ROACH2 electronics for MKIDs and TESs

SCALED ARCONS

VIRTEX 6

2, 550 MSPS ADCs

2, 1 GSPS DACs

QDR MEMORY

CAN READ OUT >1000

RESONATORS PER CH.

BALLOON READY: BLAST

FPGA  
ADCs  
DACs  
Demixer  
Mixer  
Attenuators



# LCLS Readout Electronics

Warm (300 K) electronics are needed to synthesize input microwave tones and to channelize and demodulate the output microwave tones

- ATCA based RF/ADC/DAC/FPGA module

Base module in design at SLAC for LCLS-II project and LCLS-I accelerator upgrade

- Kintex Ultrascale FPGA

Packaged in

- multi-module crate or
- single-module Ethernet pizza-box

Status

- Prototype circuits working, integrated module version in development



Multi-slot ATCA crate

Working breadboard version

