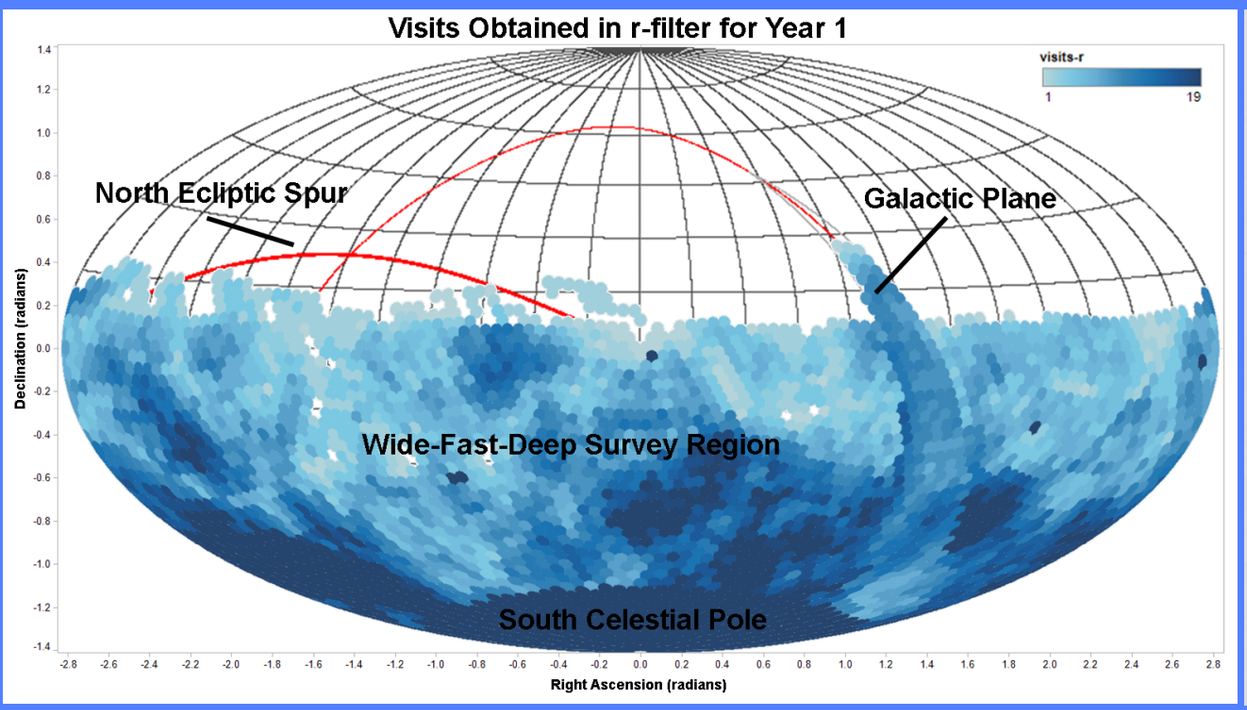
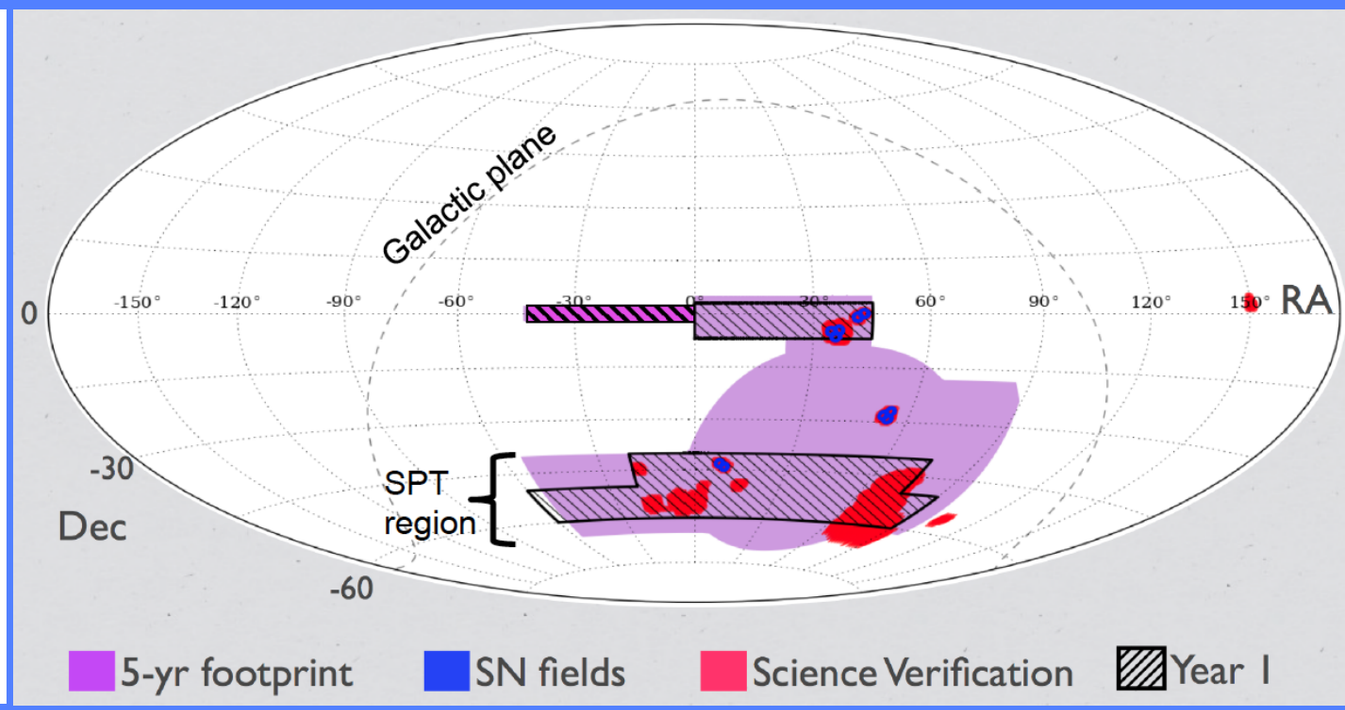
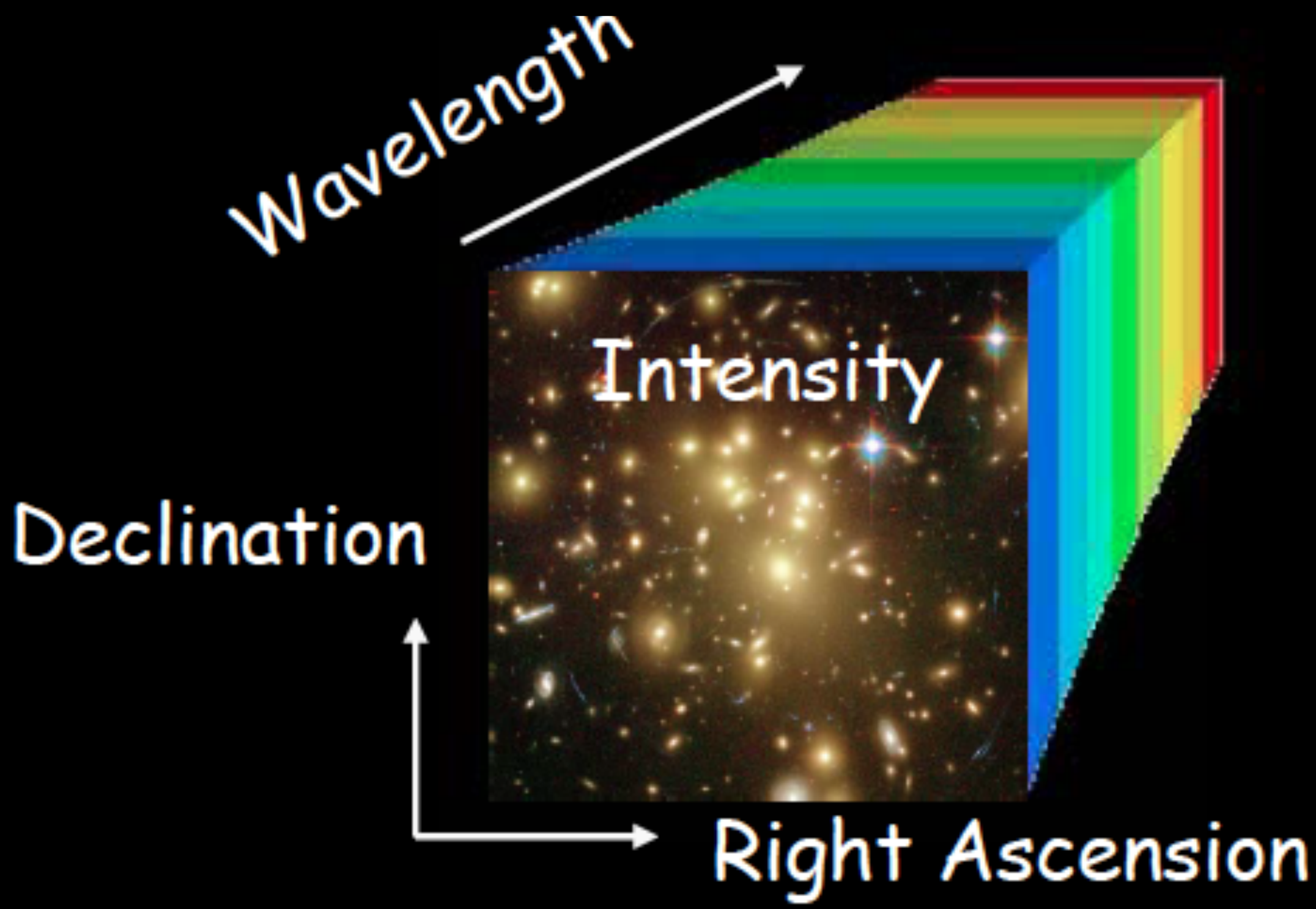
# MKIDs for follow-up in DES + LSST




Is there a new sensor technology to solve the needs for DES + LSST?

J. Estrada (Fermilab)


Wavelength
Intensity
Declination
Right Ascension

# Semiconductor (CCDs)

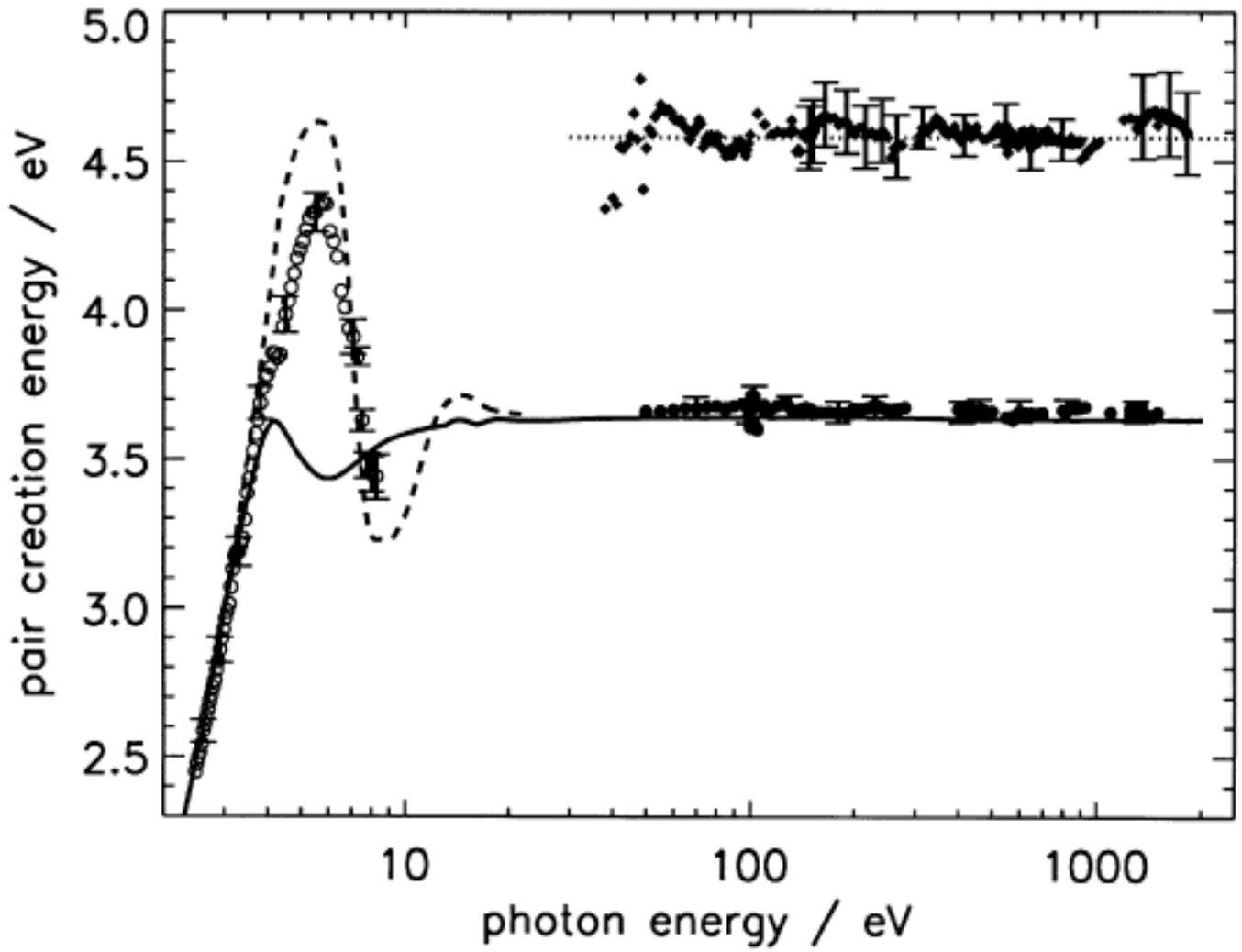
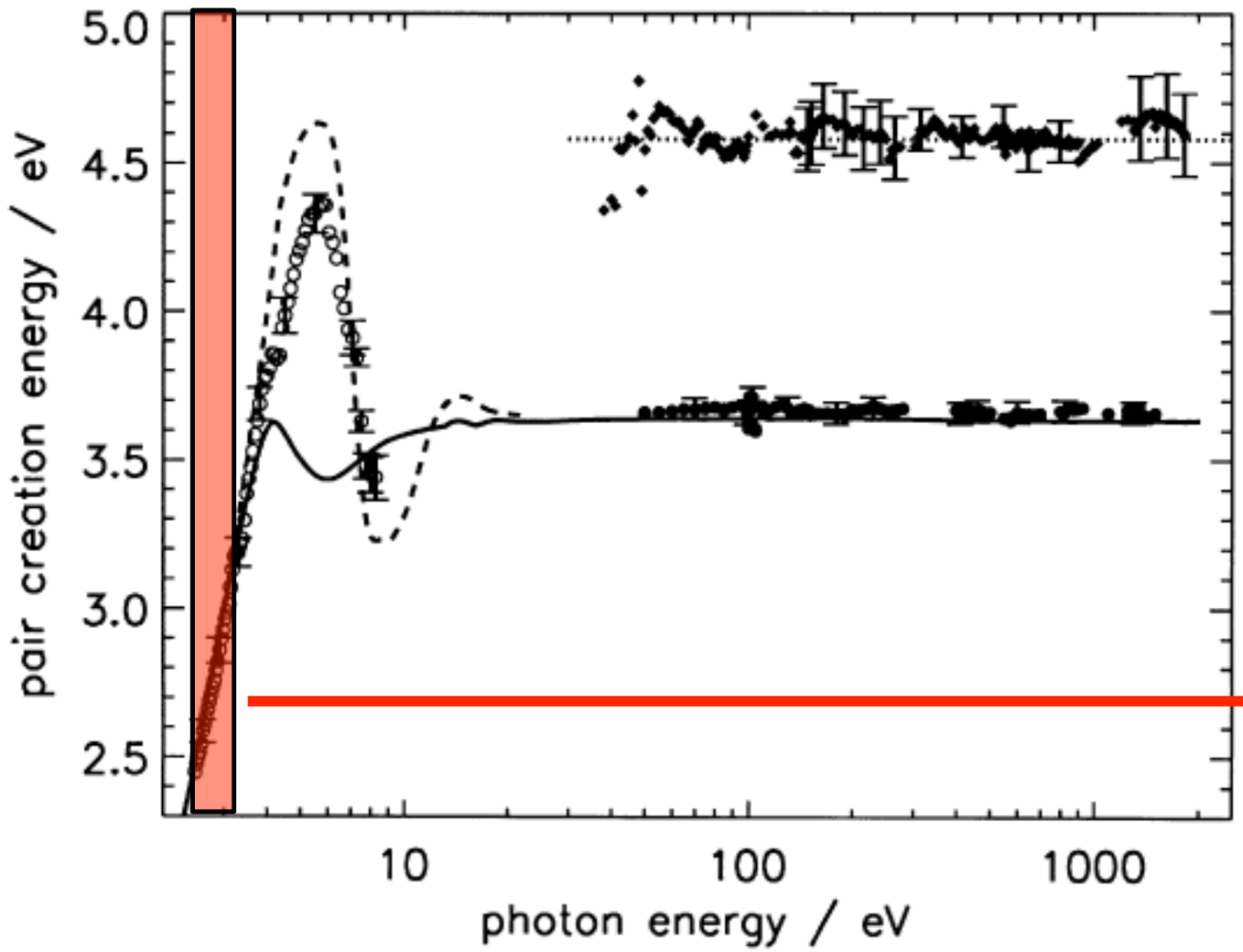



Fig. 5. Mean energy $W$ required for creating an electron-hole pair determined from $s_r$ and $s$: for silicon in the soft X-ray region [14] (closed circles) and UV and VUV region [21] (open circles) and for GaAsP in the soft X-ray region (diamonds). Typical experimental uncertainties are indicated. For silicon, calculations from Ref. [14] are shown as solid line and dashed line (see text). The points indicate the mean value of 4.58 eV for GaAsP.

# Semiconductor (CCDs)

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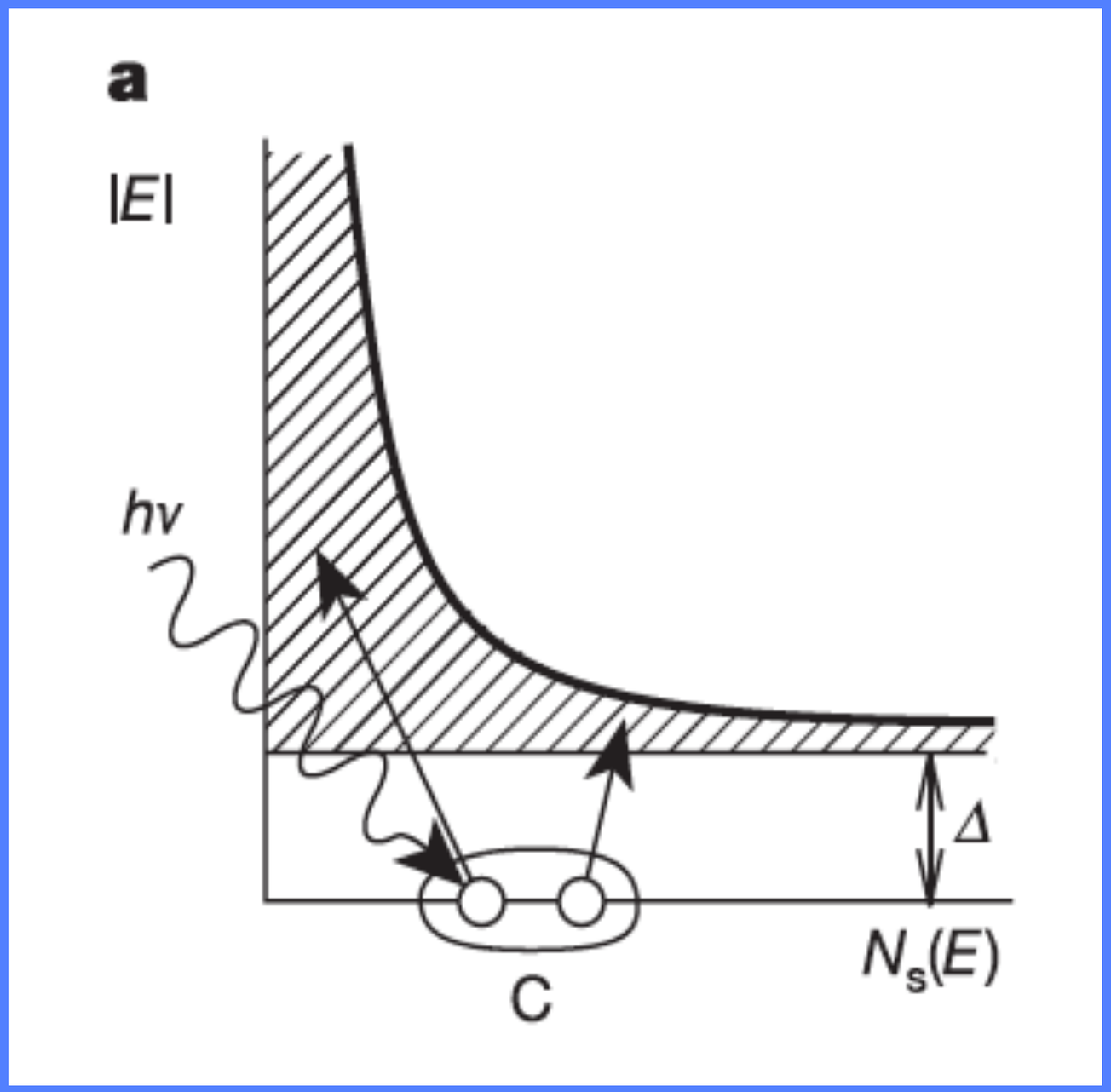
This is the optical range... unfortunately the 1e/photon here. That is why we a need spectrograph to follow up.

# Superconductor




quasiparticles:

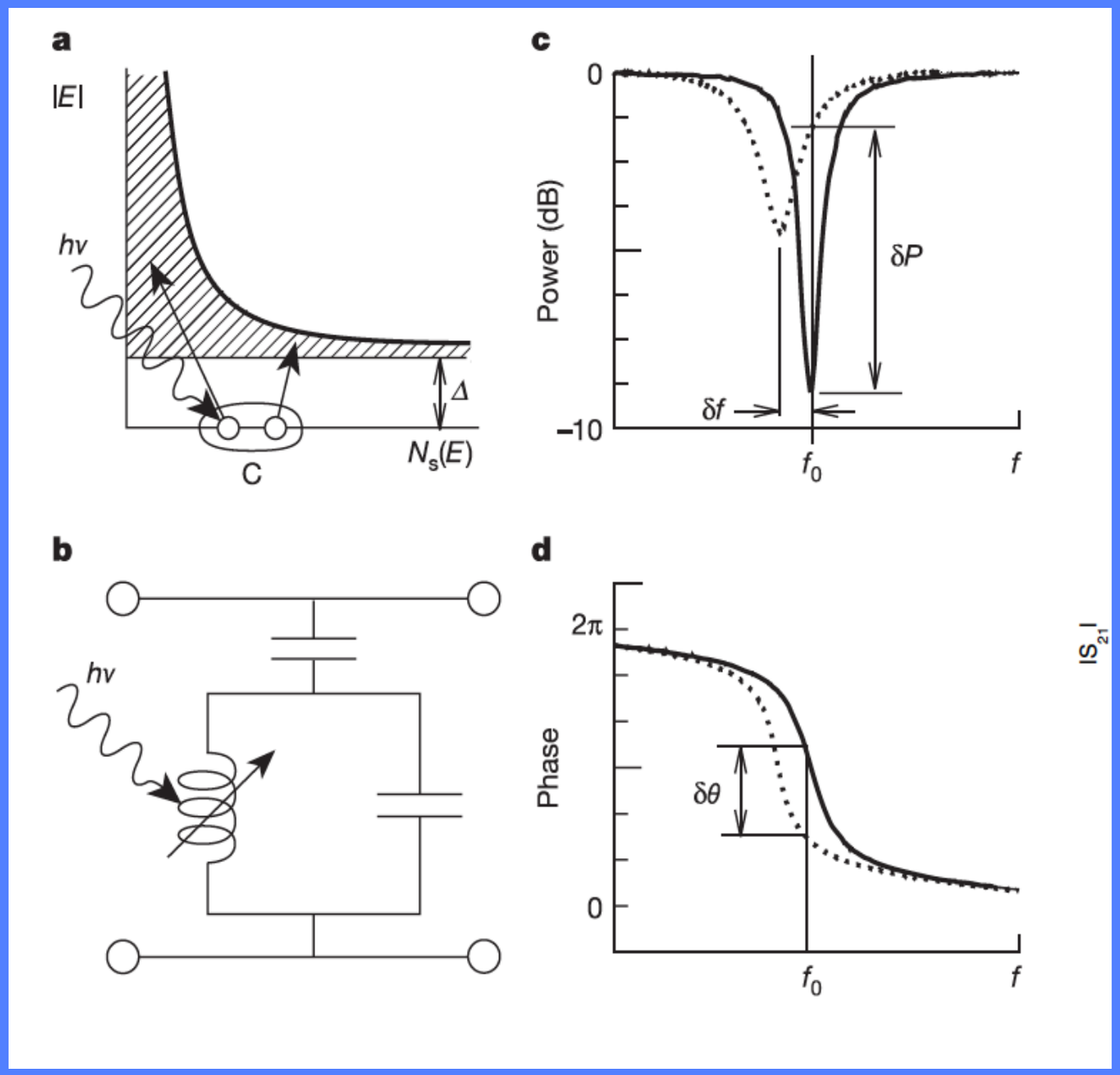
$$N_{qp} = \eta h \nu / \Delta$$

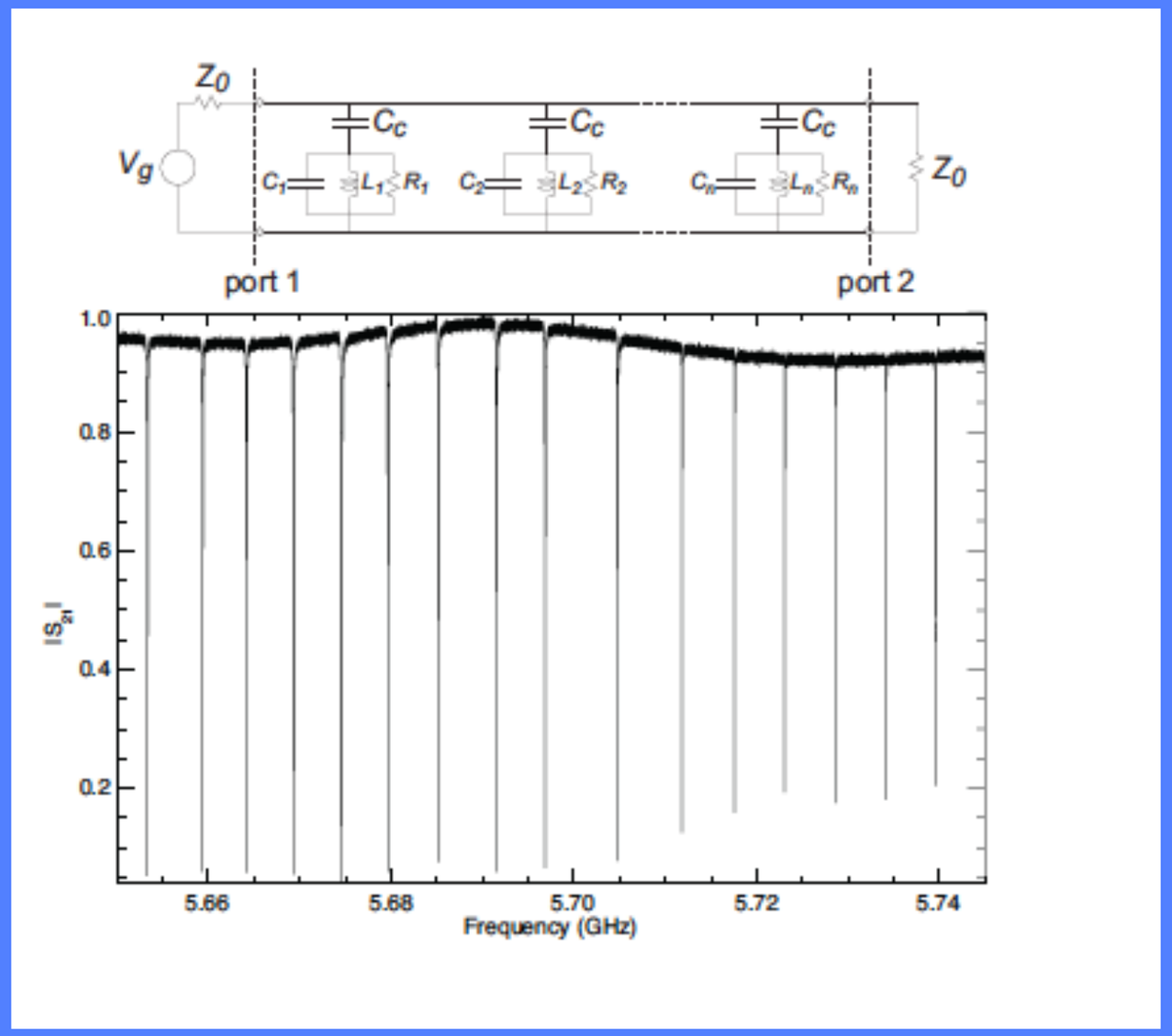
$\Delta$ : Energy gap
~ 0.001 eV

$\eta$ : is an efficiency
~ 0.6

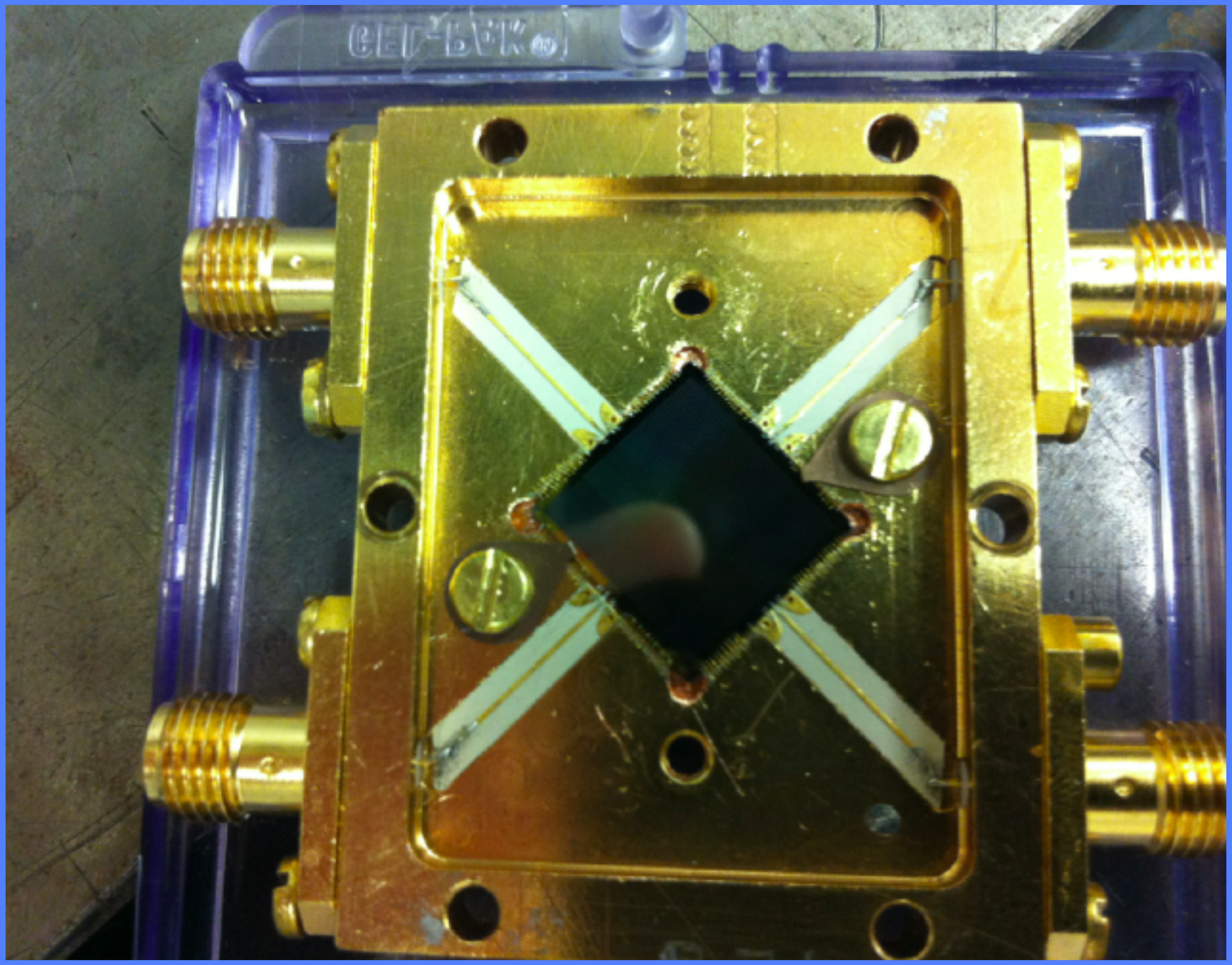
~5000 quasiparticles/ visible photon !

# Microwave Kinetic Inductance Detector :



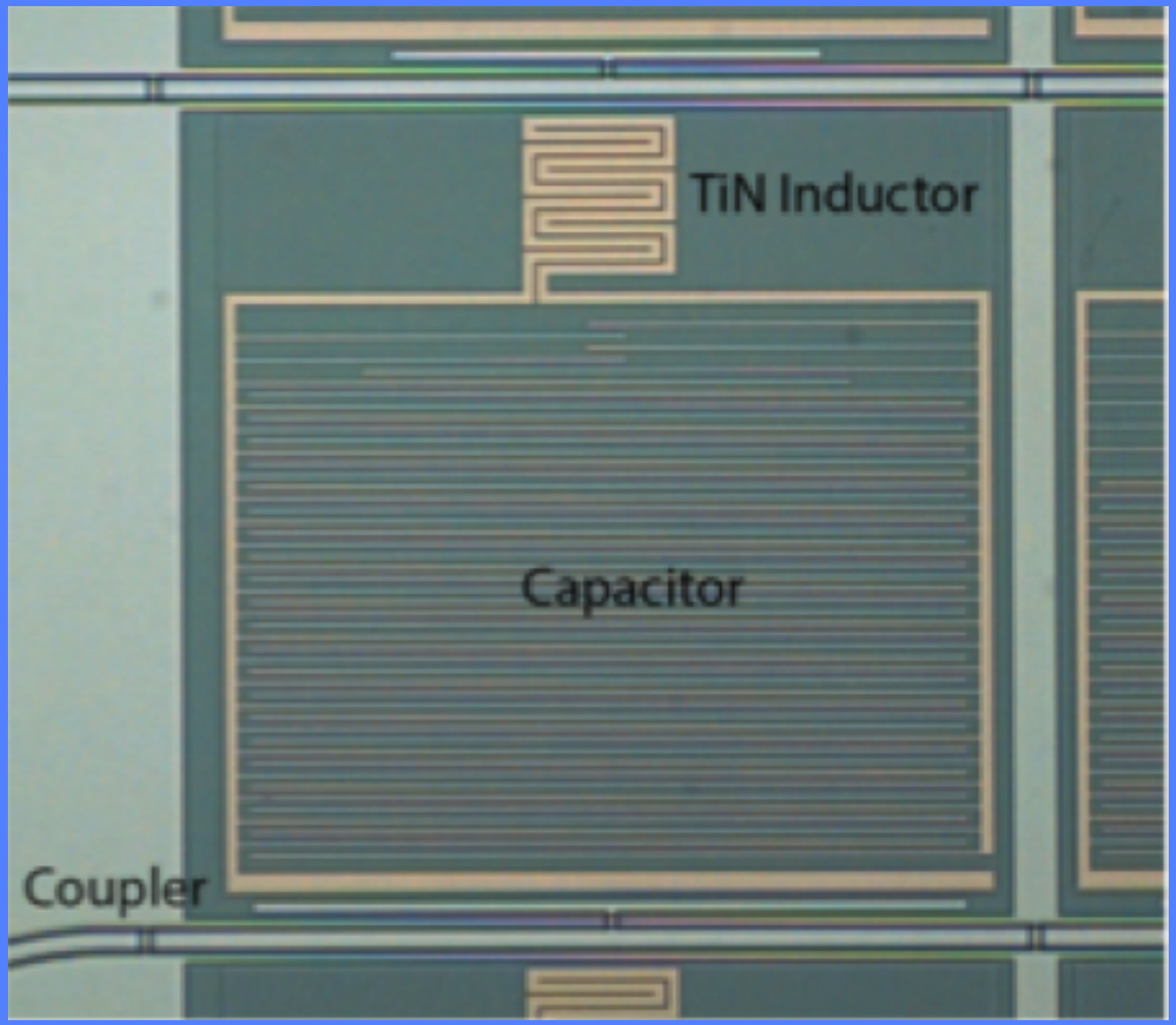




The relatively new development allow for large multiplexing factors for arrays of superconductor detectors with a simple readout ( “digital FM” )

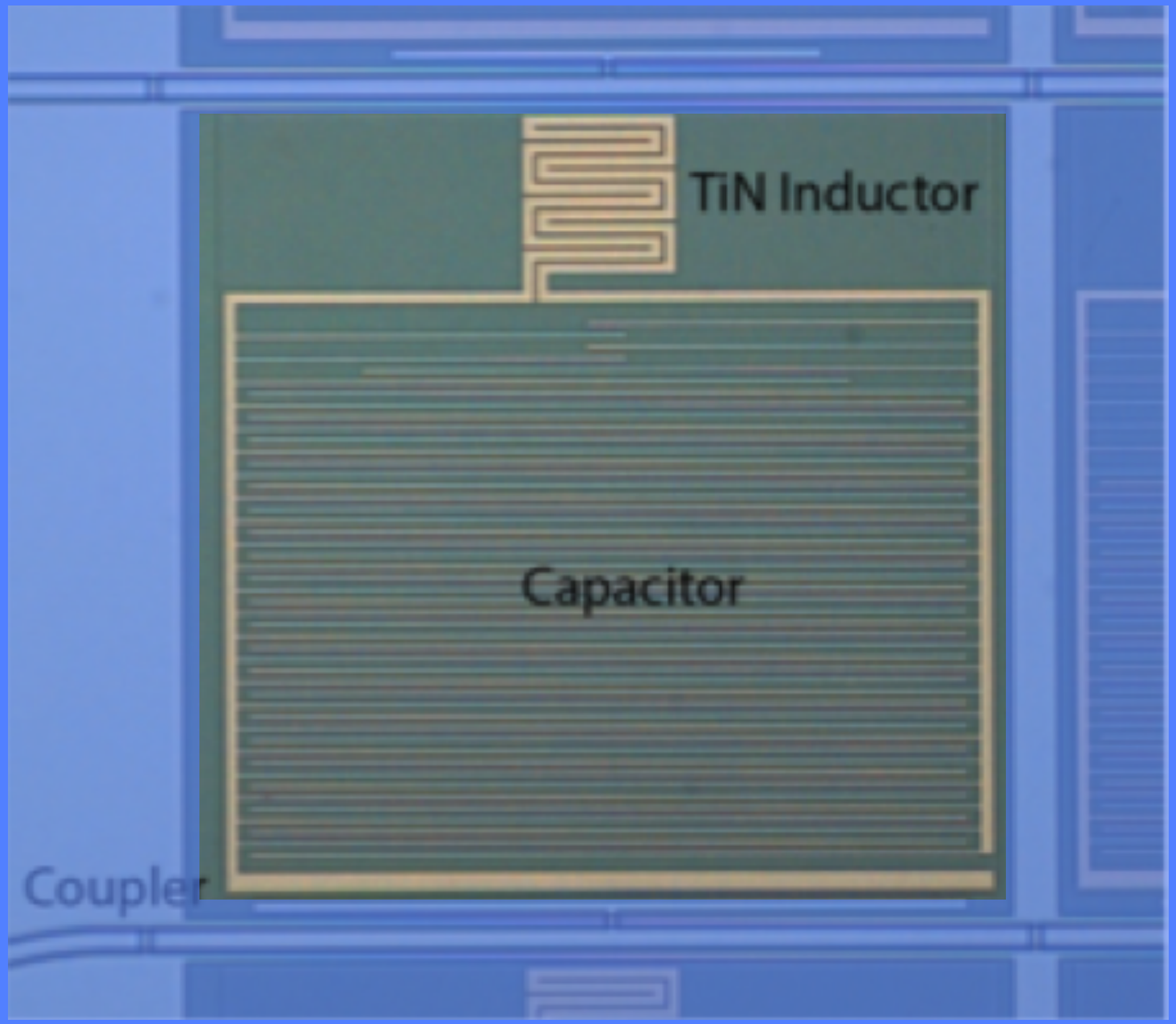



2K pixels detector designed at UCSB (Prof. Mazin)

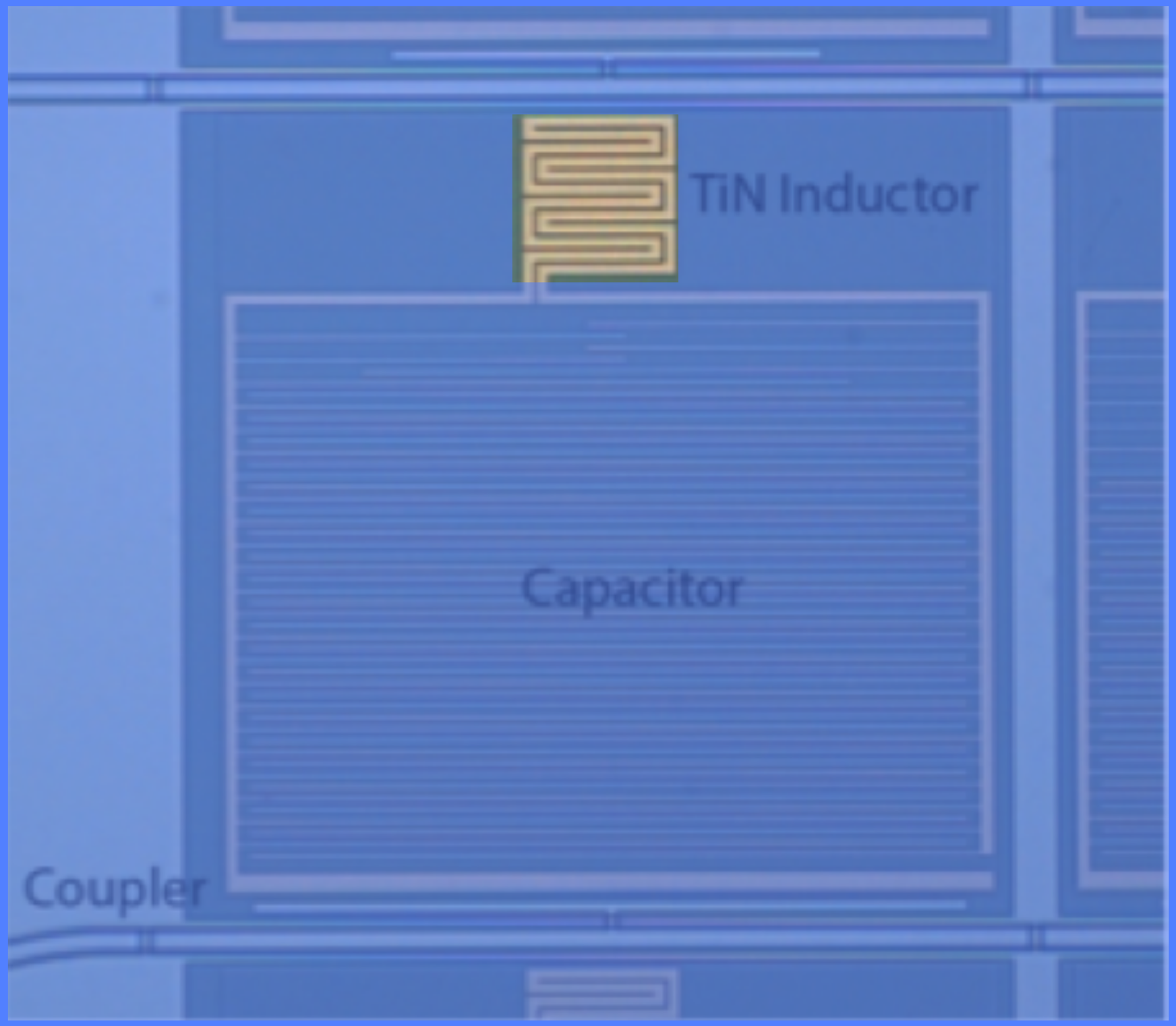
# MKID pixel



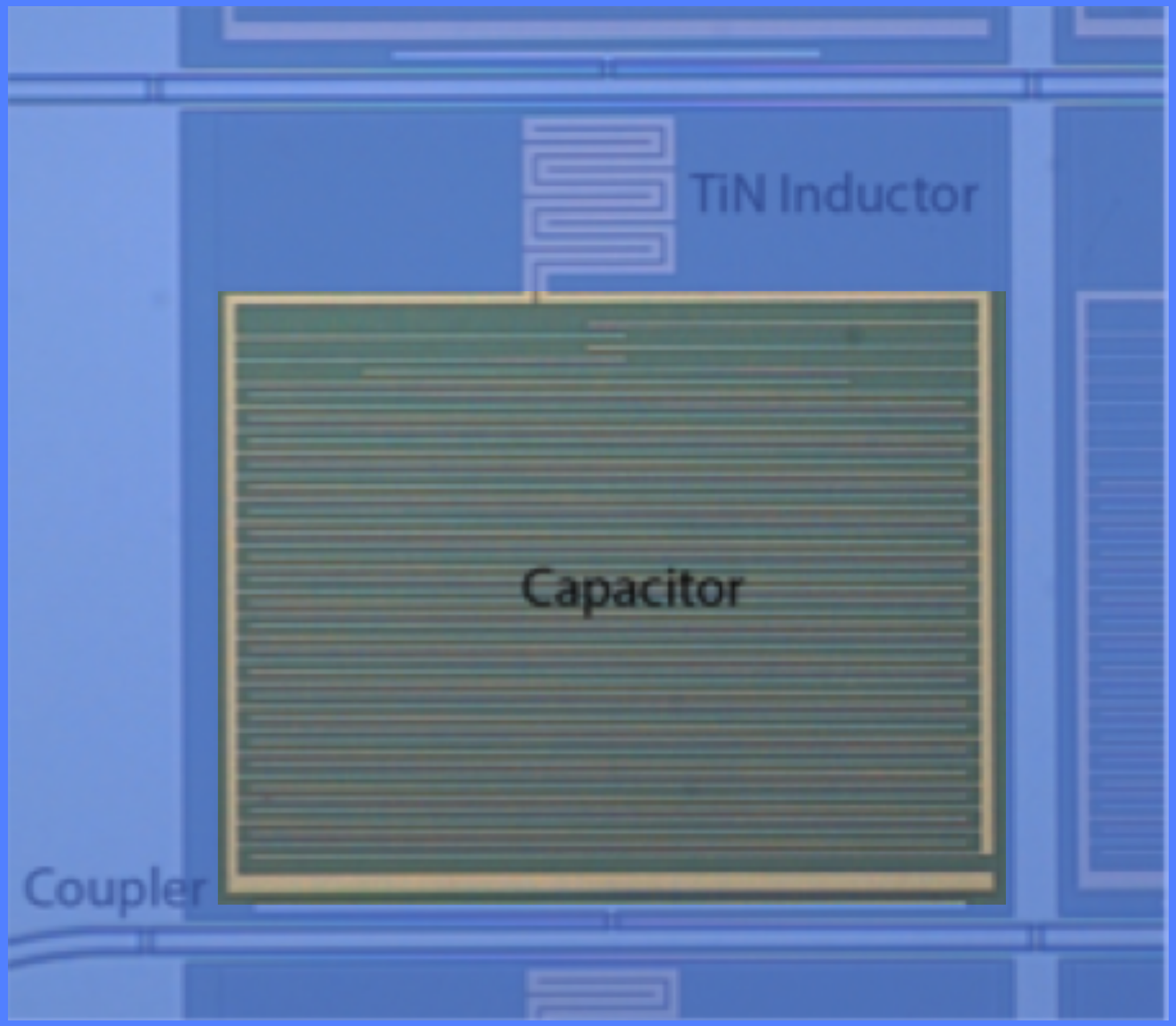
# Single pixel has an inductor and a capacitor

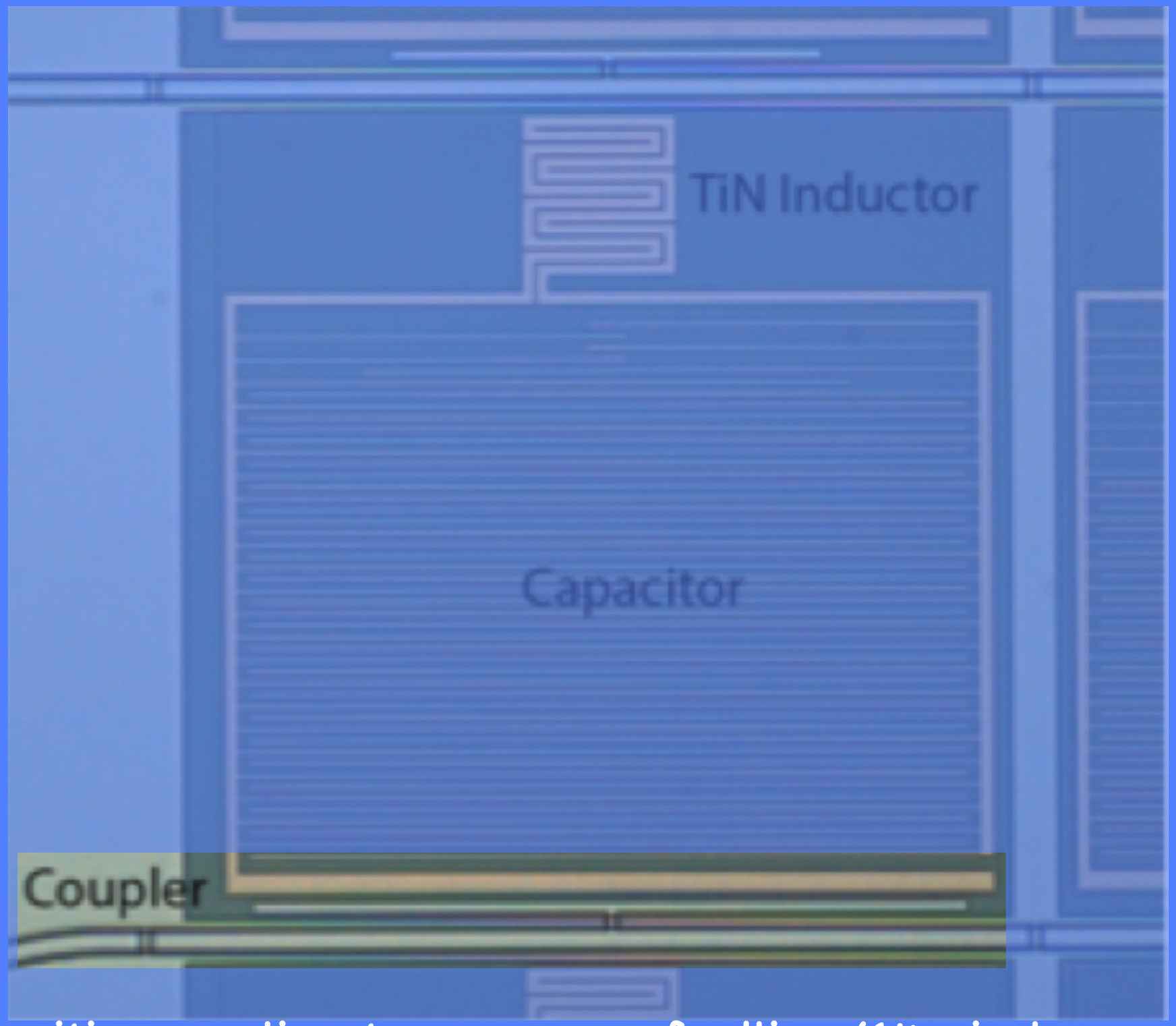


# Light is collected at the inductor

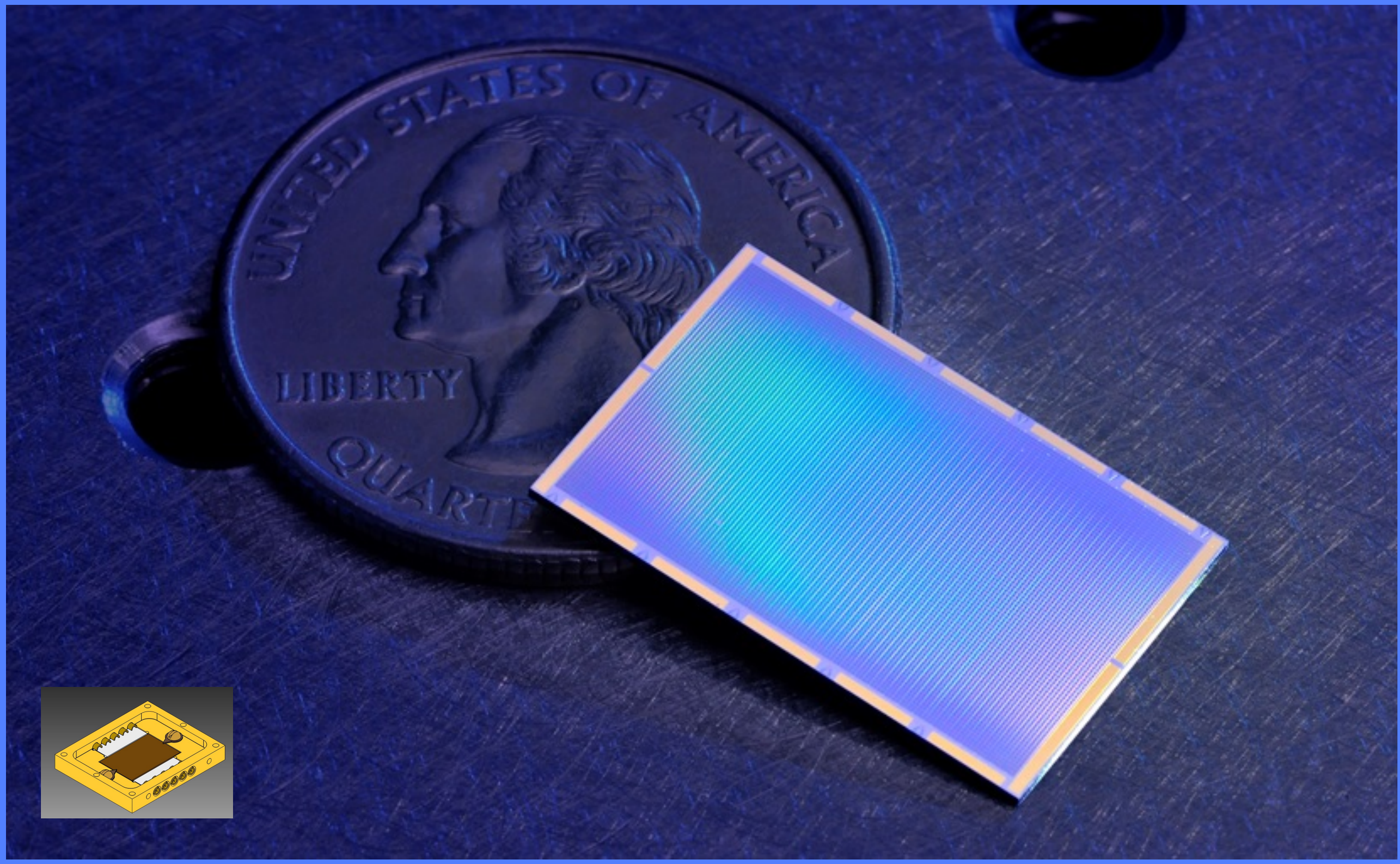


Capacitor is tuned to give a different resonance frequency to each pixel



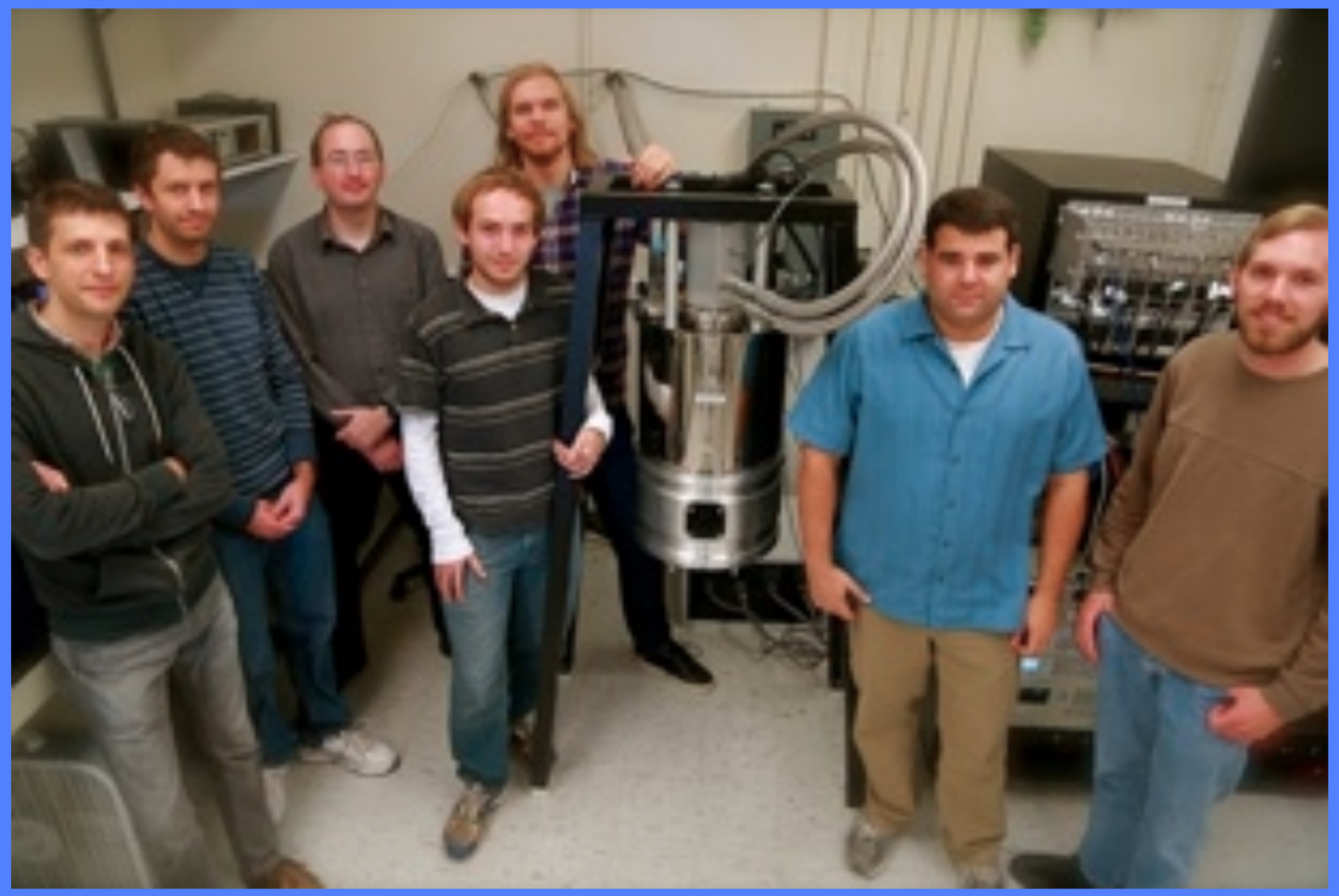


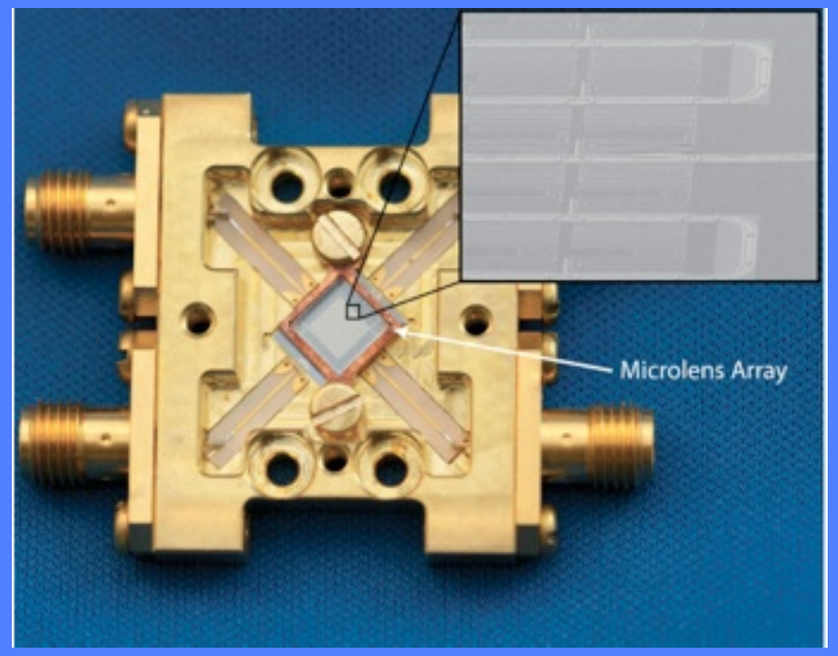

Capacitive coupling to a common feedline (1K pixels per feedline)



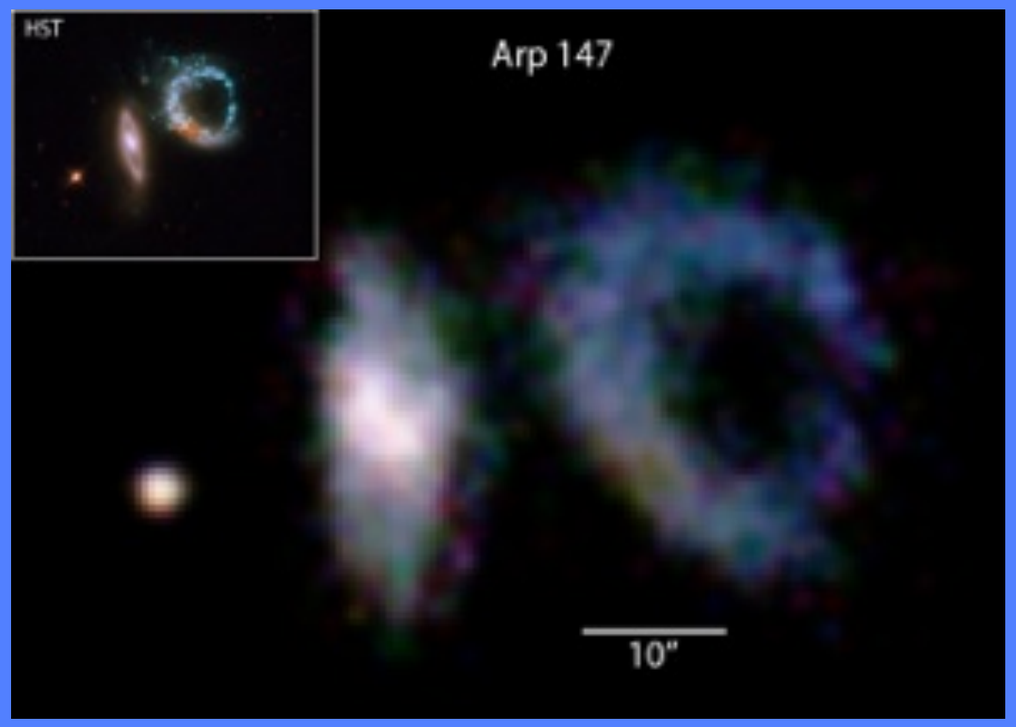

**10 K resonators device (B.Mazin UCSB)**

Optical MKIDs developed by tested in a small stronomical instrument 1k pixels in 2011, “2k” pixels in 2012.






operating temperature = 100 mK

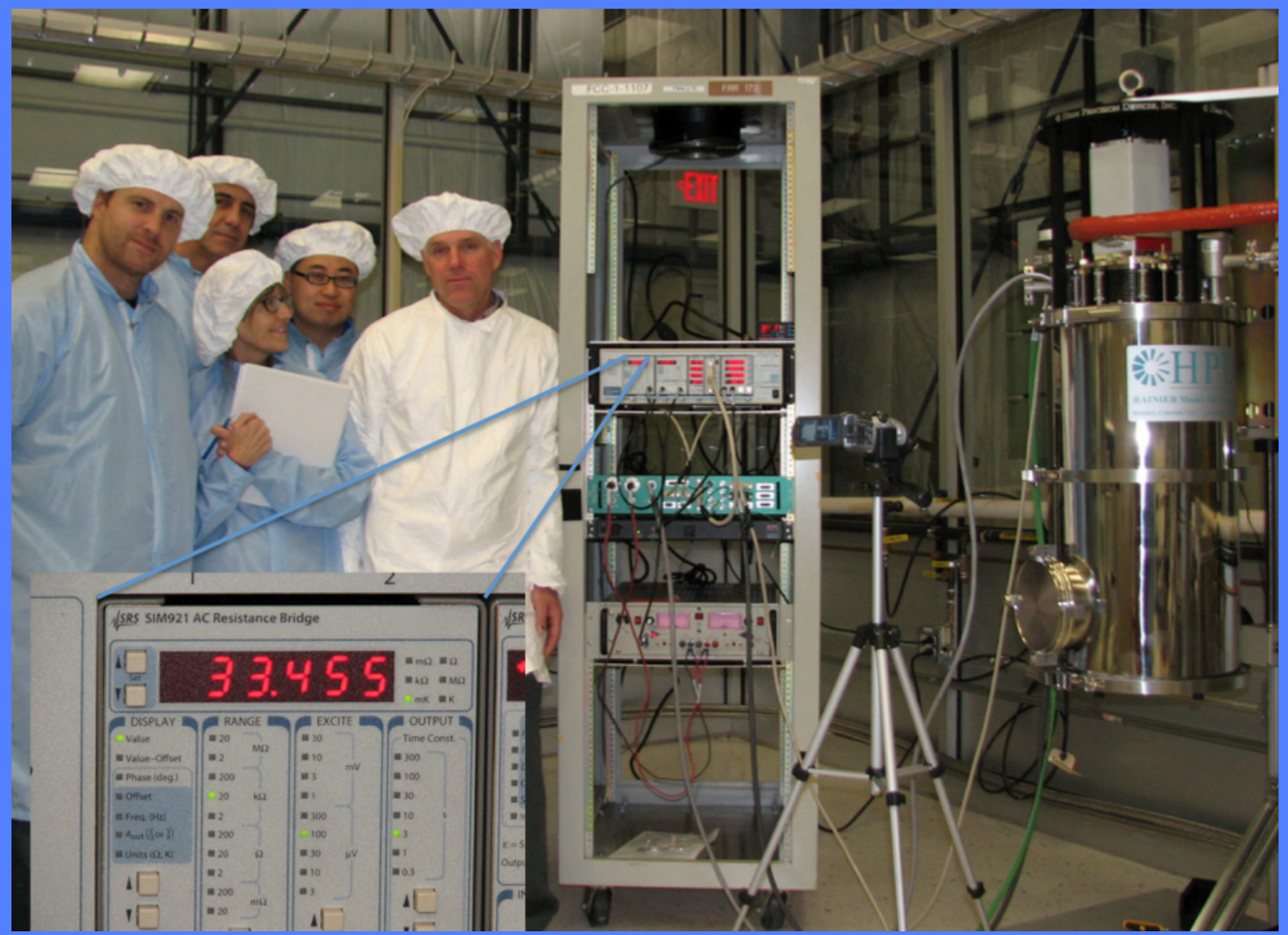


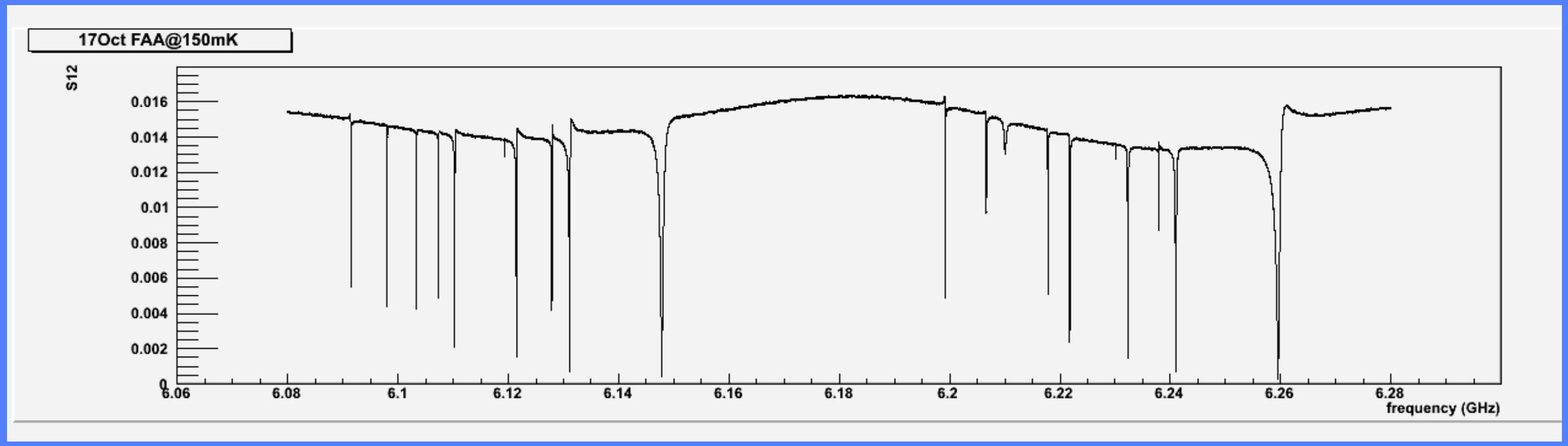

preliminary mosaic of Arp 147 taken with ARCONS at the Palomar 200”

# MKIDs @ FNAL

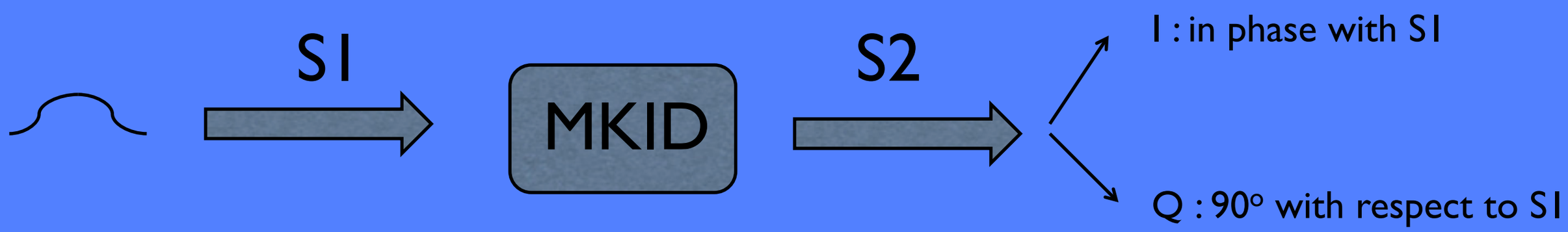
MKIDs work at 100mK, but now this is easy.

In two days installed and commissioned an ADR to 33mK temperature.

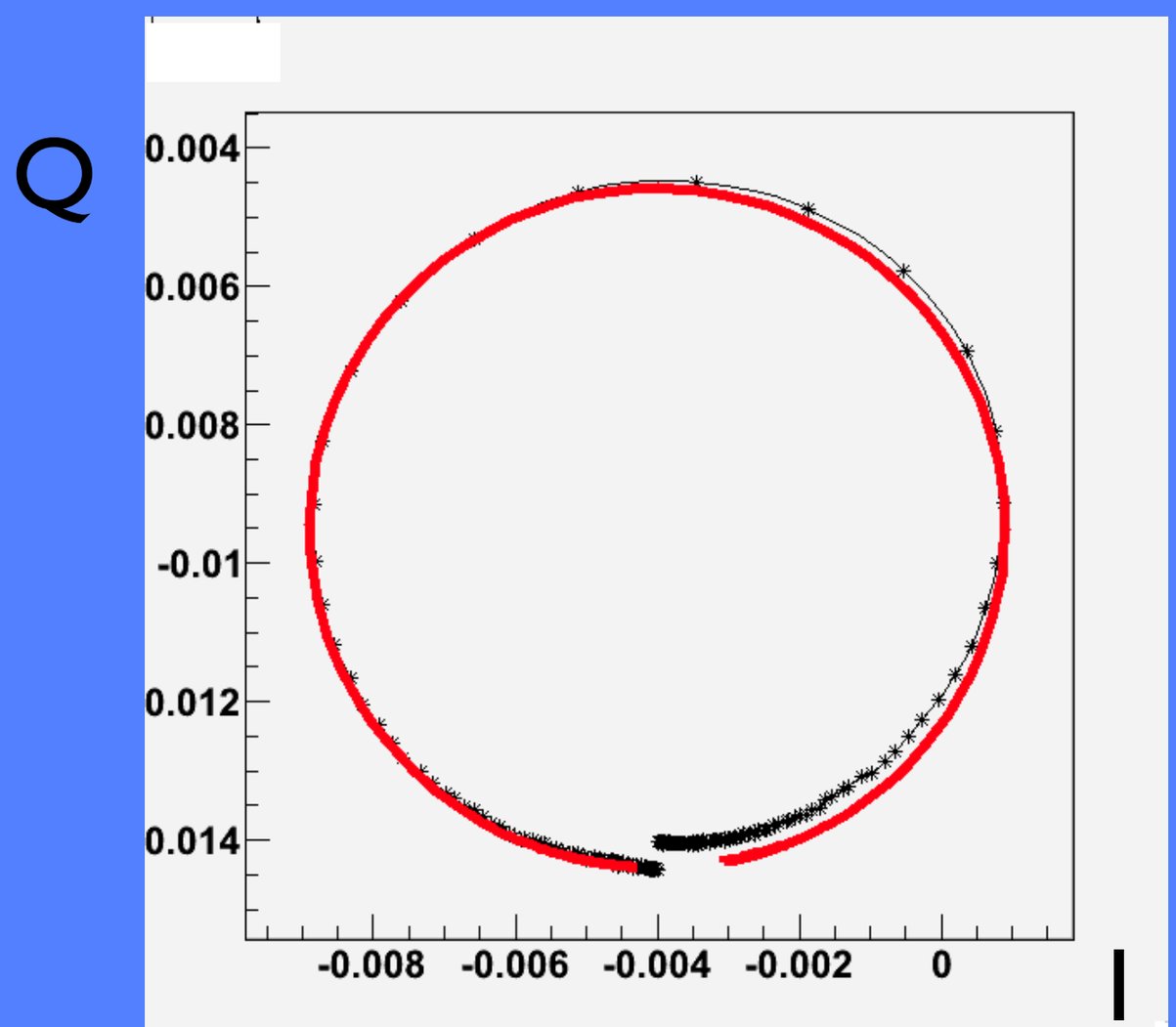


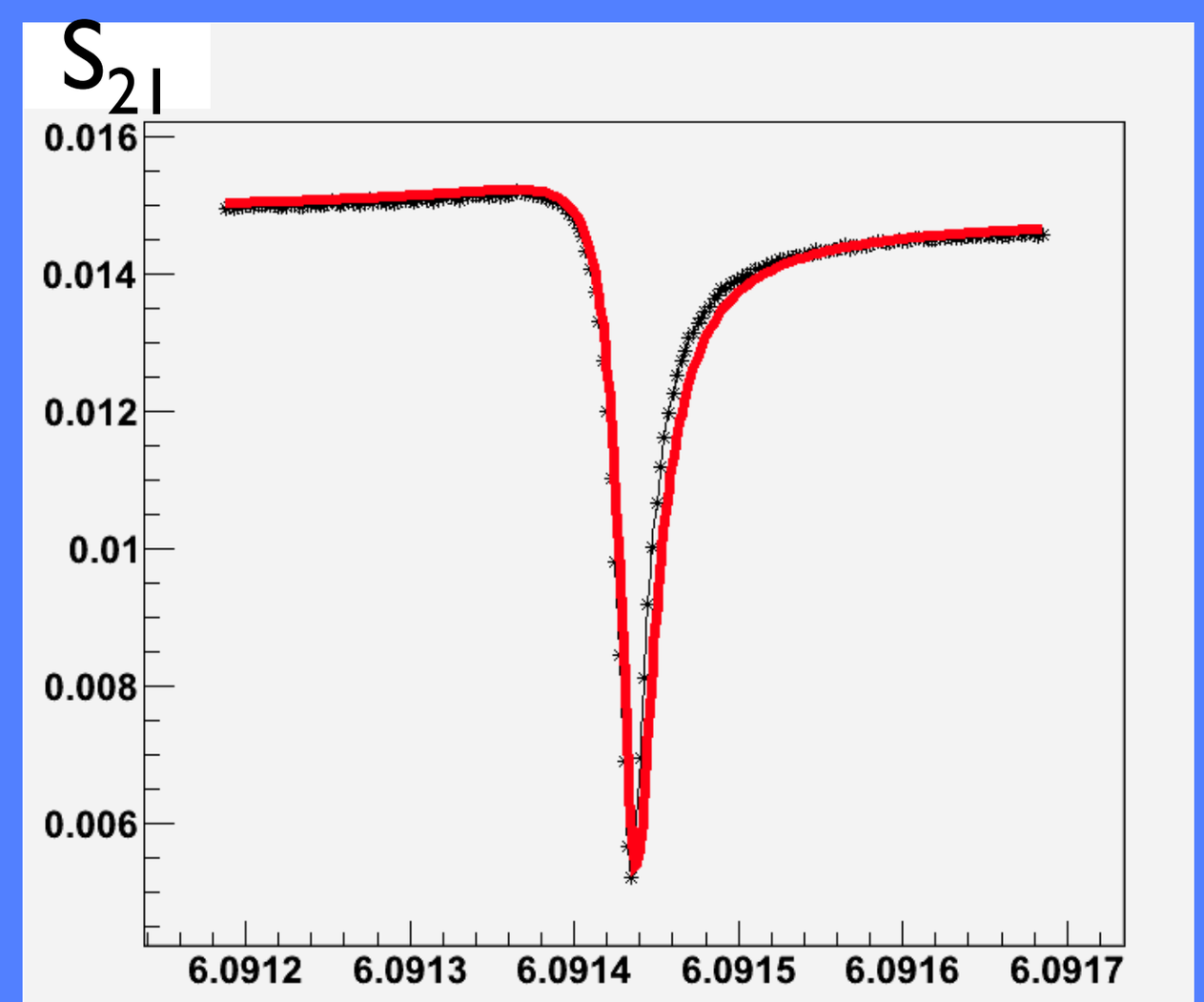




A couple of months after that, we started operating a 20 pixel MKID fabricated at Argonne National Laboratory.




Q & I measured relative to S1
$S_{21}$ is the sum in quadrature of Q & I

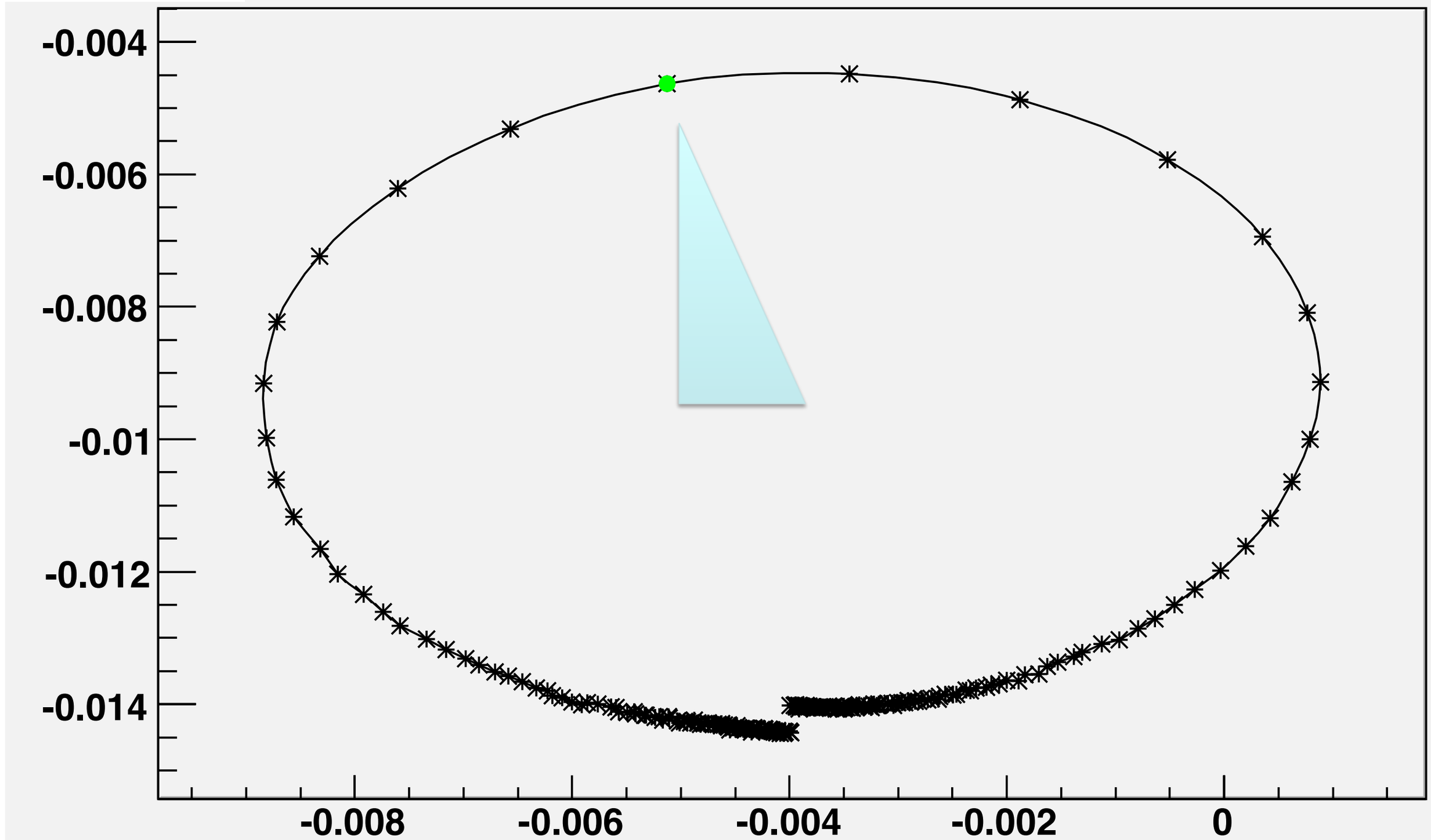


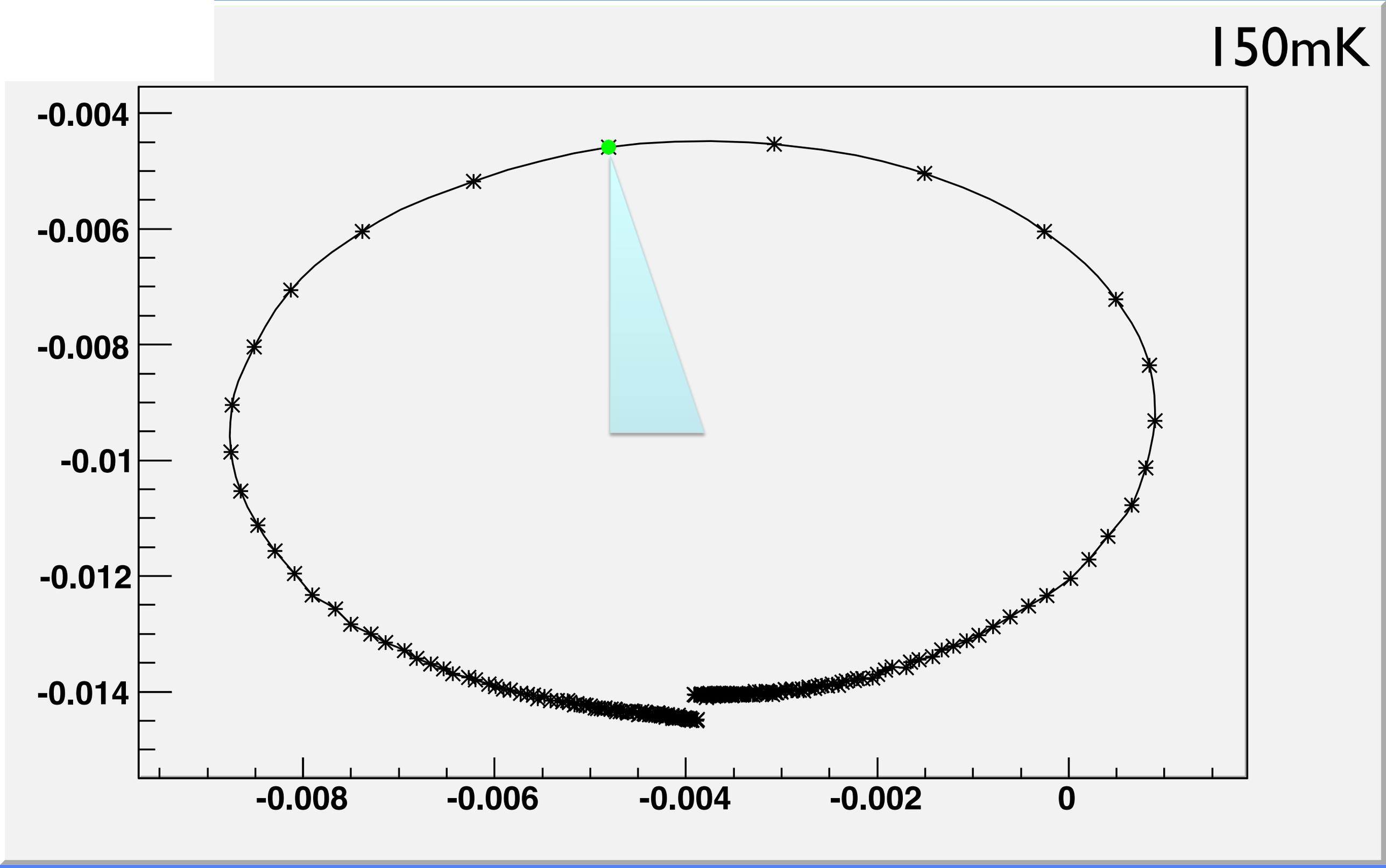




Pixel 1: Q=187k , f0=6.09143 Ghz

freq. (Ghz)

100mK

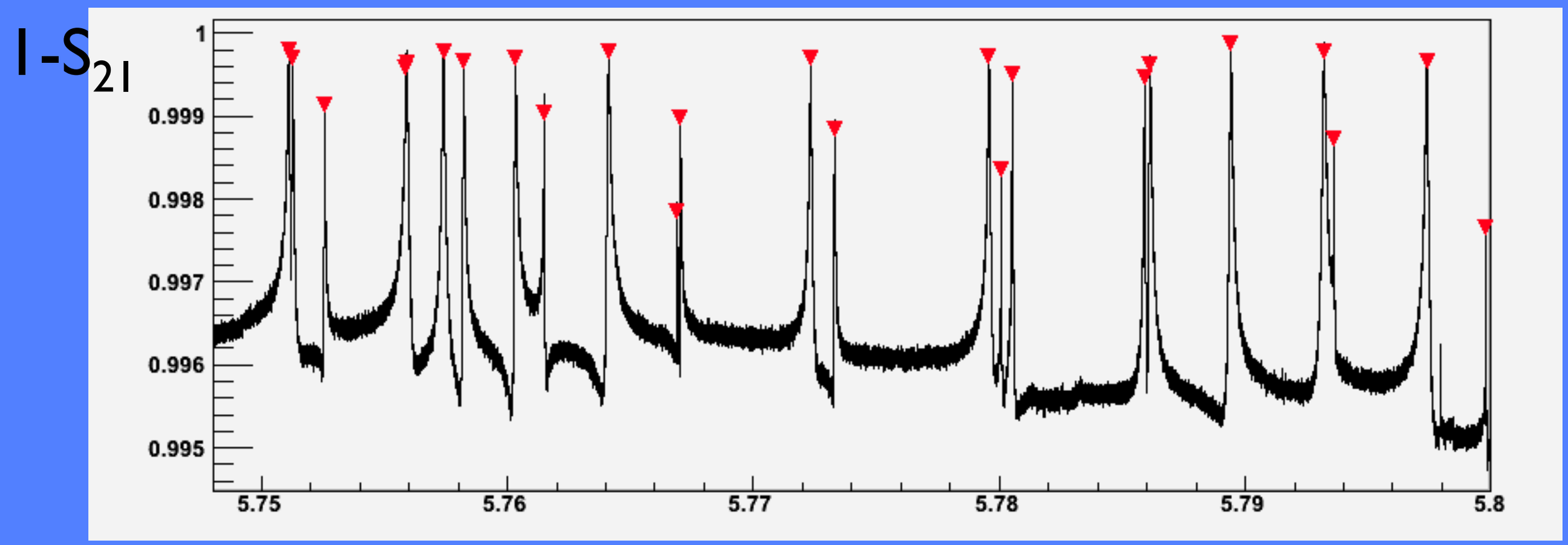





Change in quasi-particle density equivalent to low Energy X-ray photon (~3keV)

There is still a lot of work to do

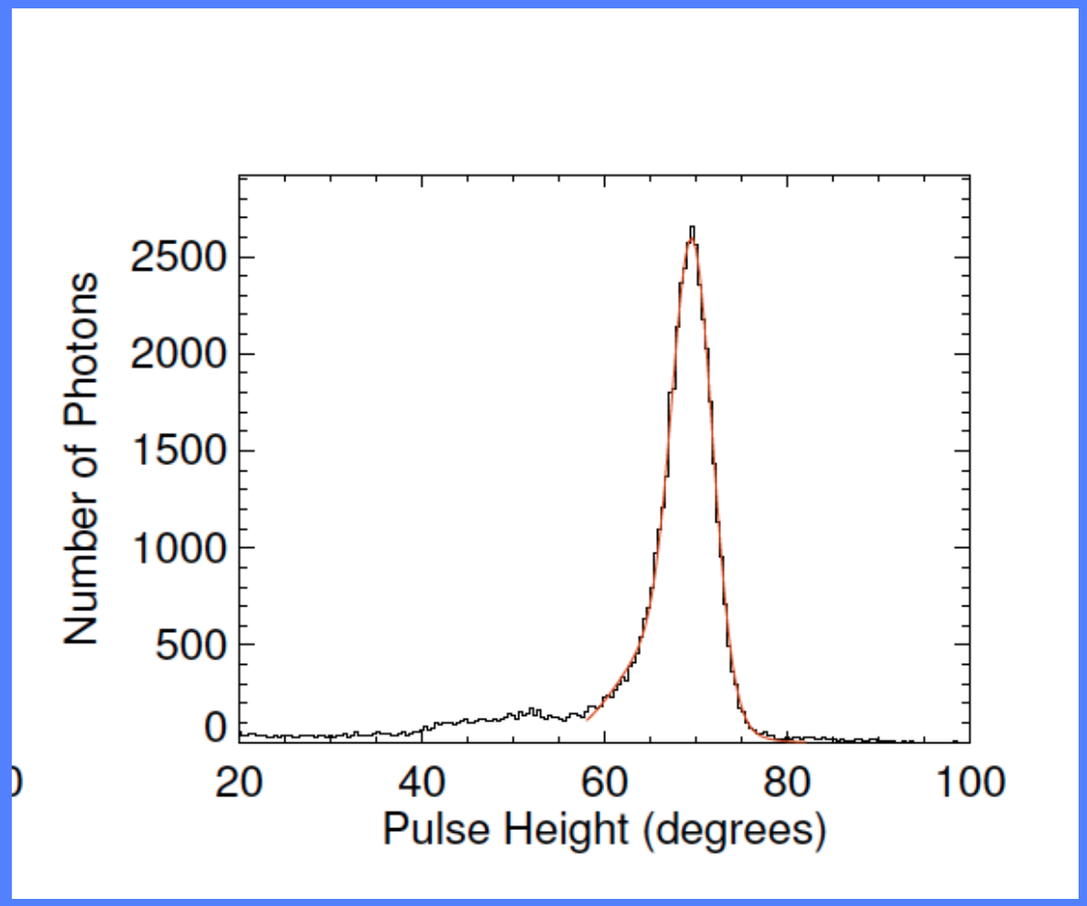
- Pixel overlap
- Pixel non-uniformity (Q
- Pixel spacing

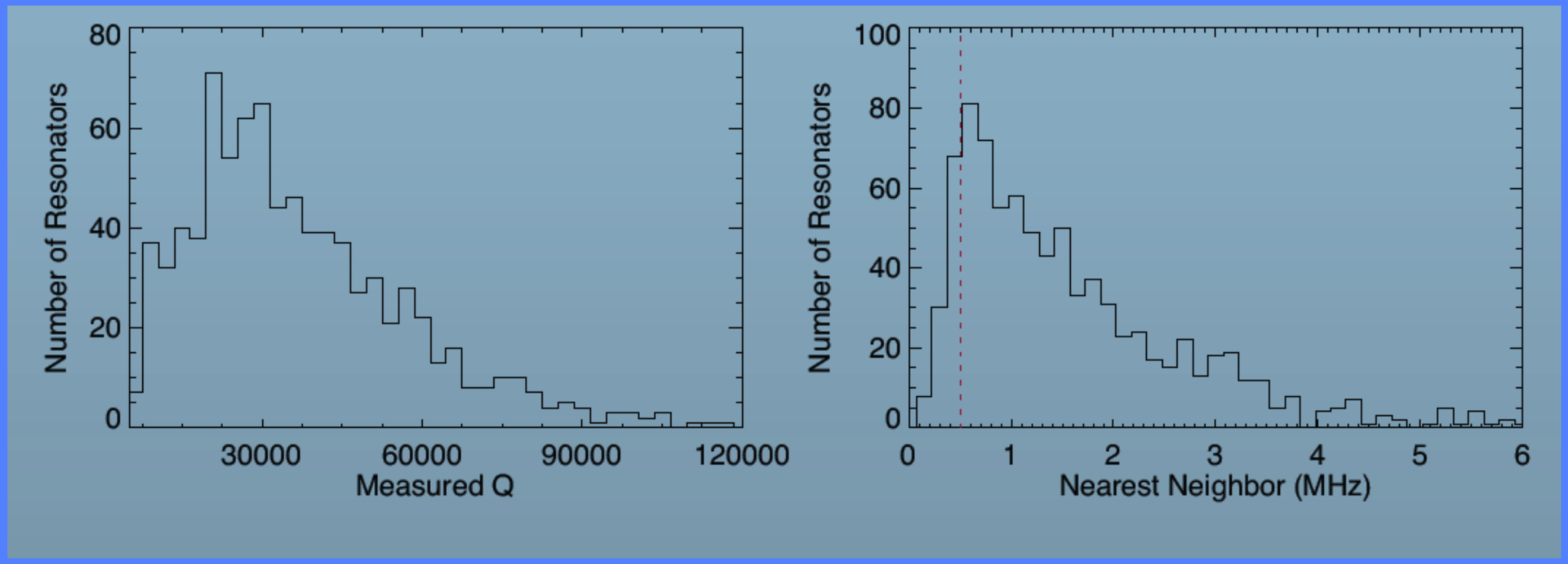


R= E/δE = 16 @250nm

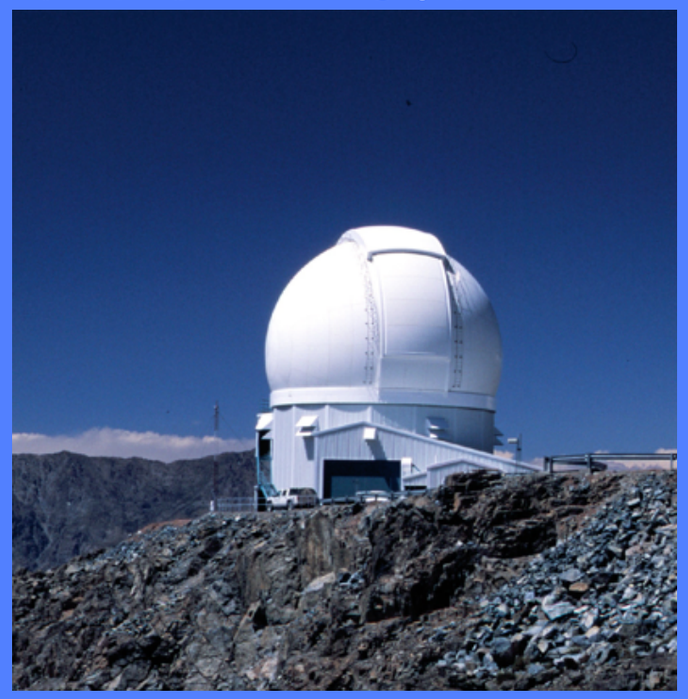
Theoretical limit for the MKIDs is R=180… there is still ways to go.

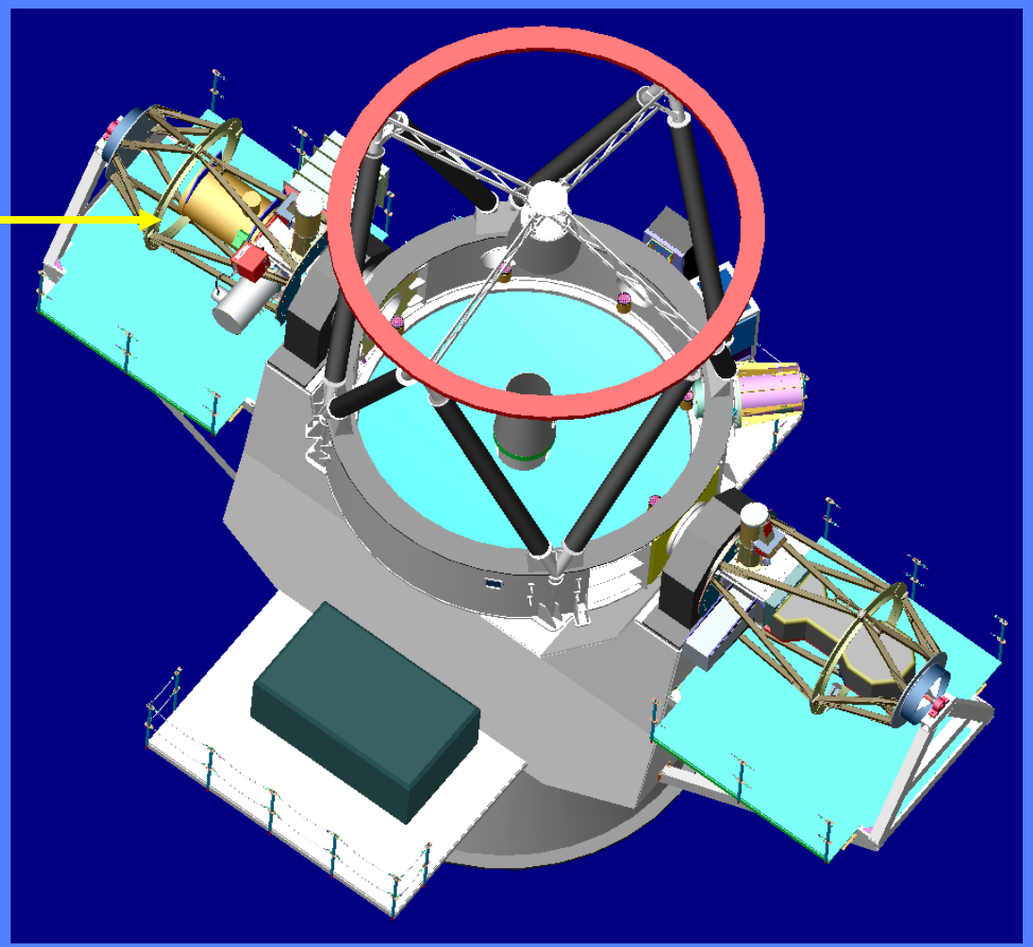
Q is not always the same.
Frequency steps are not constant.



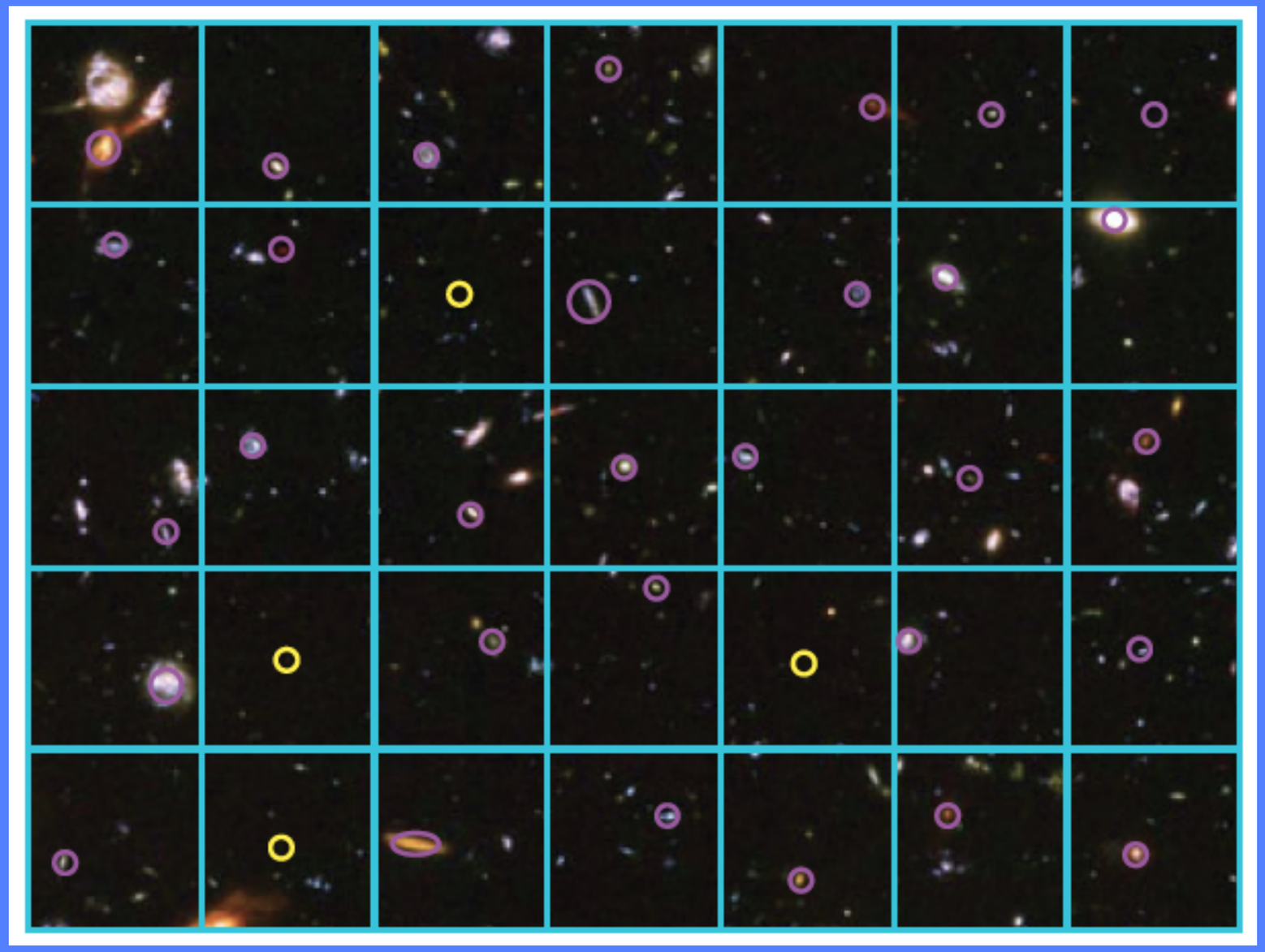
# SOAR 4m telescope R&D instrument





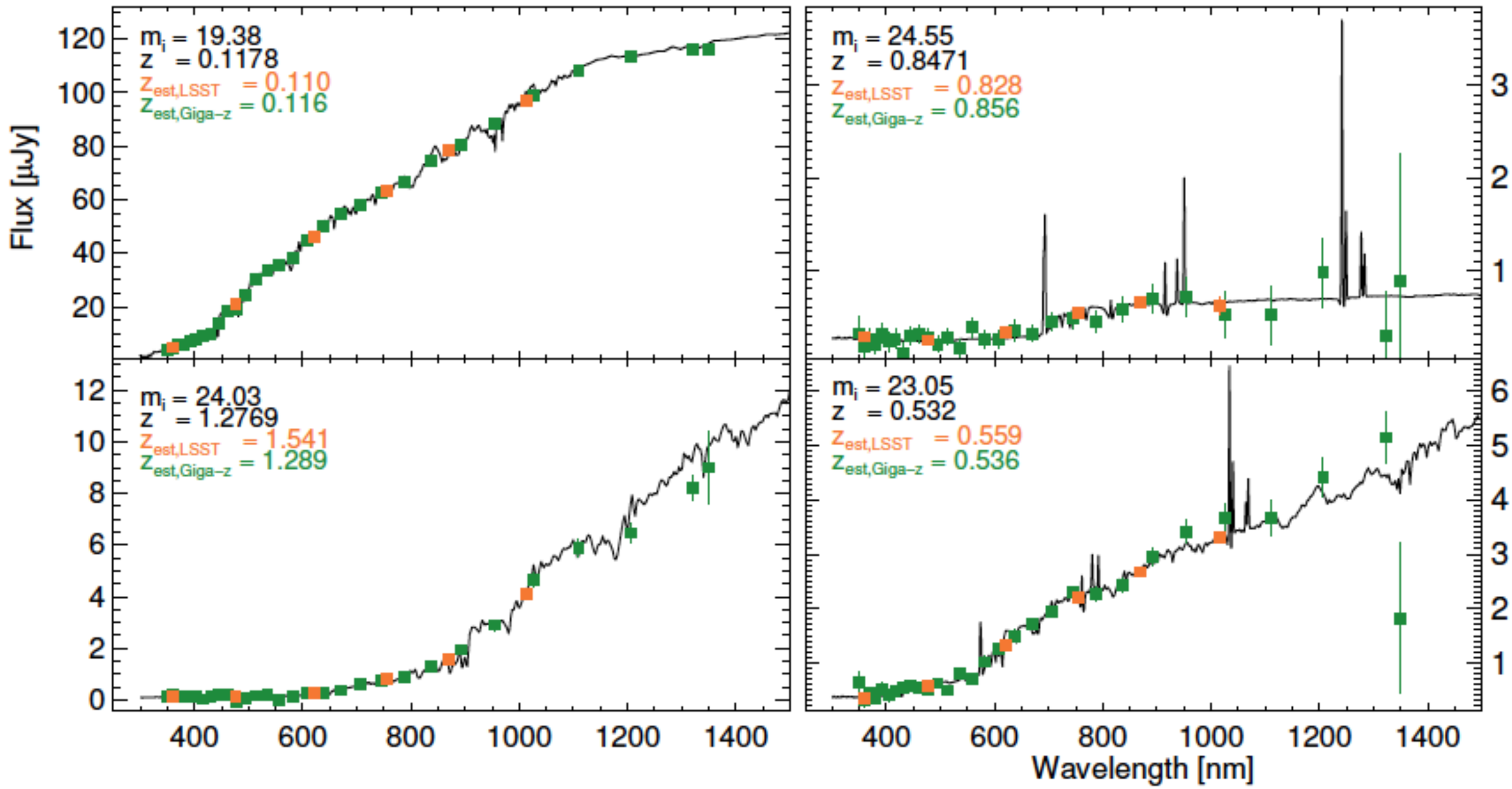

Effort now concentrated on building an R&D instrument for the SOAR 4m telescope. Imager with ~50,000 pixels. Demonstrate scalability and look at DES objects.

# GigaZ concept (Marsden et al 2013)



Since an MKID megapix array is still far away. We could make large pixels, and use mask to select a galaxy for each pixel. 100,000 spectroscopic channels in 1 square deg. is possible. R~30 .

# GigaZ concept (Marsden et al 2013)




Spectrometer, DES/LSST and MKIDs

R~30 @ 428nm

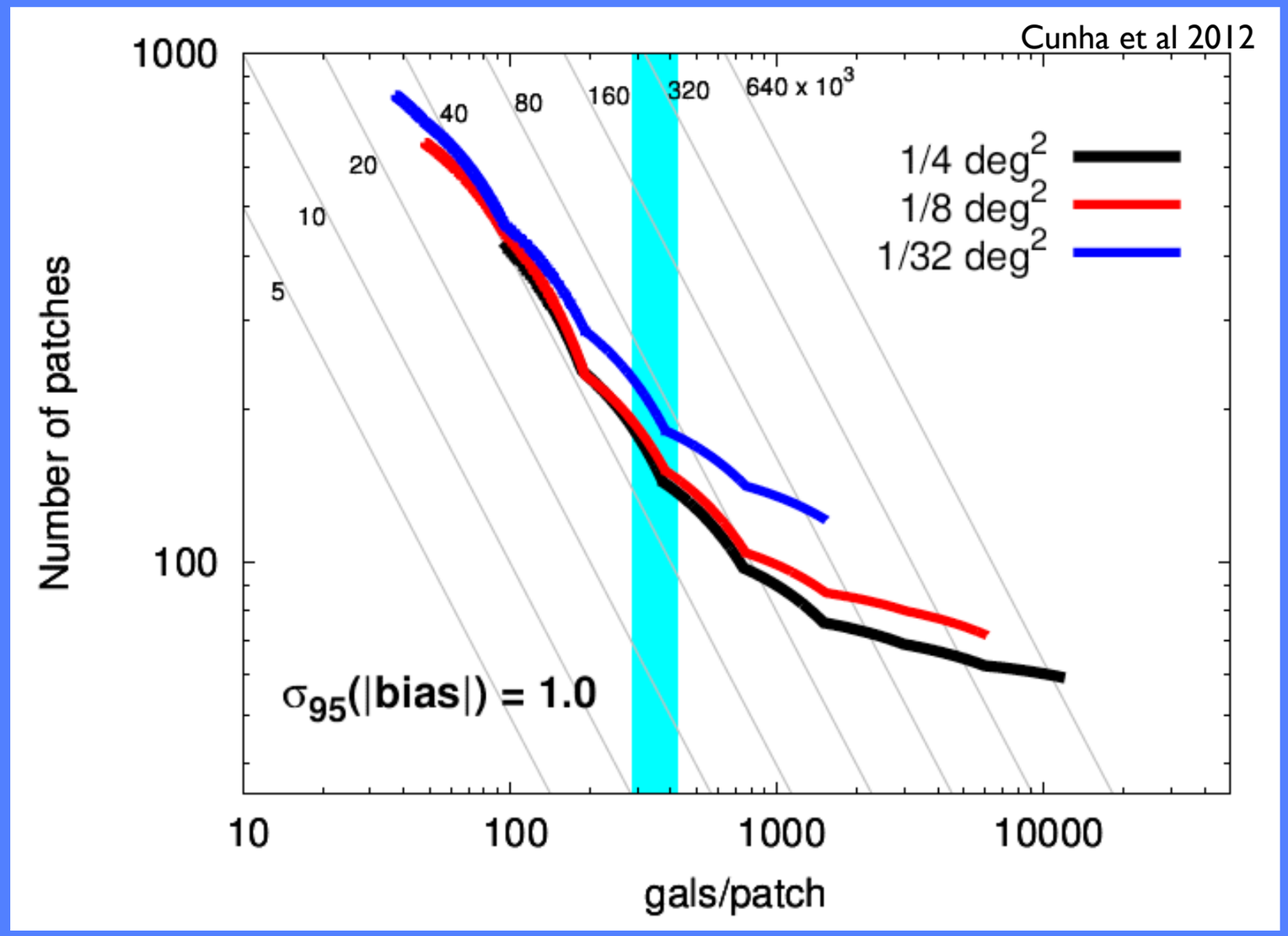
# GigaZ concept (Marsden et al 2013)

TABLE 4

A COMPARISON OF REDSHIFT RECOVERY STATISTICS BETWEEN MULTI-BAND PHOTOMETRY OR MULTI-OBJECT SPECTROSCOPY EXPERIMENTS, BOTH PAST AND PLANNED.

| Experiment | $N_{gals}$ | Area [deg$^2$] | Magnitude Limit | $N_{filts}$/Resolution | Scatter | Cat. Failure Rate |
|---|---|---|---|---|---|---|
| COMBO 17 [a] | $\sim$10,000 | $\sim$0.25 | $R < 24$ | 17 | 0.06 | $\lesssim 5\%$ |
| COSMOS [b] | $\sim$100,000 | 2 | $i^+_{AB} \sim 24$ | 30 | 0.06 | $\sim 20\%$ |
| | $\sim$30,000 | 2 | $i^+ < 22.5$ | 30 | 0.007 | $< 1\%$ |
| CFHTLS - Deep [c] | 244,701 | 4 | $i'_{AB} < 24$ | 5 | 0.028 | 3.5% |
| CFHTLS - Wide [c] | 592,891 | 35 | $i'_{AB} < 22.5$ | 5 | 0.036 | 2.8% |
| PRIMUS [d] | 120,000 | 9.1 | $i_{AB} \sim 23.5$ | $R_{423} \sim 90$ | $\sim$ 0.005 | $\sim$2% |
| WiggleZ [e] | 238,000 | 1,000 | $20 < r < 22.5$ | $R_{423} = 845$ | $\lesssim 0.001$ | $\lesssim 30\%$ |
| Alhambra [f] | 500,000 | 4 | $I \leq 25$ | 23 | 0.03 | ... |
| BOSS [g] | 1,500,000 | 10,000 | $i_{AB} \leq 19.9$ | $R_{423} \sim 1600$ | $\lesssim$0.005 | $\sim$2% |
| DES [h] | 300,000,000 | 5,000 | $r_{AB} \lesssim 24$ | 5 | 0.1 | ... |
| EUCLID [i] | 2,000,000,000 | 15,000 | Y,J,K $\lesssim 24$ | $3^+$ | $\lesssim 0.05$ | $\lesssim 10\%$ |
| | 50,000,000 | 15,000 | $H_\alpha \geq$ 3e-16 erg/s/cm$^2$ | $R_{1\mu m} \sim 250$ | $\lesssim 0.001$ | $< 20\%$ |
| LSST [j] | 3,000,000,000 | 20,000 | $i_{AB} \lesssim 26.5$ | 6 | $\lesssim 0.05$ | $\lesssim 10\%$ |
| Giga-$z$ | 2,000,000,000 | 20,000 | $i_{AB} \lesssim 25.0$ | $R_{423} = 30$ | 0.03 | $\sim 19\%$ |
| | 224,000,000 | 20,000 | $i_{AB} \lesssim 22.5$ | $R_{423} = 30$ | 0.01 | 0.3% |

DES redshift estimation needs to be calibrated using a spectrograph (same for LSST). The calibration sample needed is big, and has to cover a large area.




MKIDs provide an efficient way to collect a high quality sample for calibration.

# Challenges for this technology

- Sensor performance : R

- Number of channels per feed line is currently limited to digital signal processing and ADC speed.

- MKID packaging is not mechanically or thermally viable for a large array.

- MKID DAQ: 2 TBytes/sec (100 parallel 20 GSPS 8 bit ADC). Data rates on the scale of a particle physics experiment.

  Hard problem, we are working on this in Collaboration with UCSB, Oxford, SOAR telescope and Argonne to build the next version prototype.

  R&D instrument at SOAR will help.

## DES follow-up needs

What kind of spectroscopic survey is needed to maximize the science output from DES?

Few main ideas:

- We need to get to $10^5$ per z bin beat the shot noise.
- Cosmic variance is a big deal. Need to attack this problem by distributing the sample over many patches in the sky.
- Failures in the spectroscopic determination of redshifts are a big issue (large bias in w), a lot more important that the precision of successful redshifts.

# This is were we believe MKIDs could help. Get a huge sample with low failure rate.

- Failures in the spectroscopic determination of redshifts are a big issue (large bias in w), a lot more important that the precision of successful redshifts.

# Conclusion

- We have a new technology that will give us the ability of collecting huge number of low resolution spectra.

- How would this impact your science?
- Talk to us:

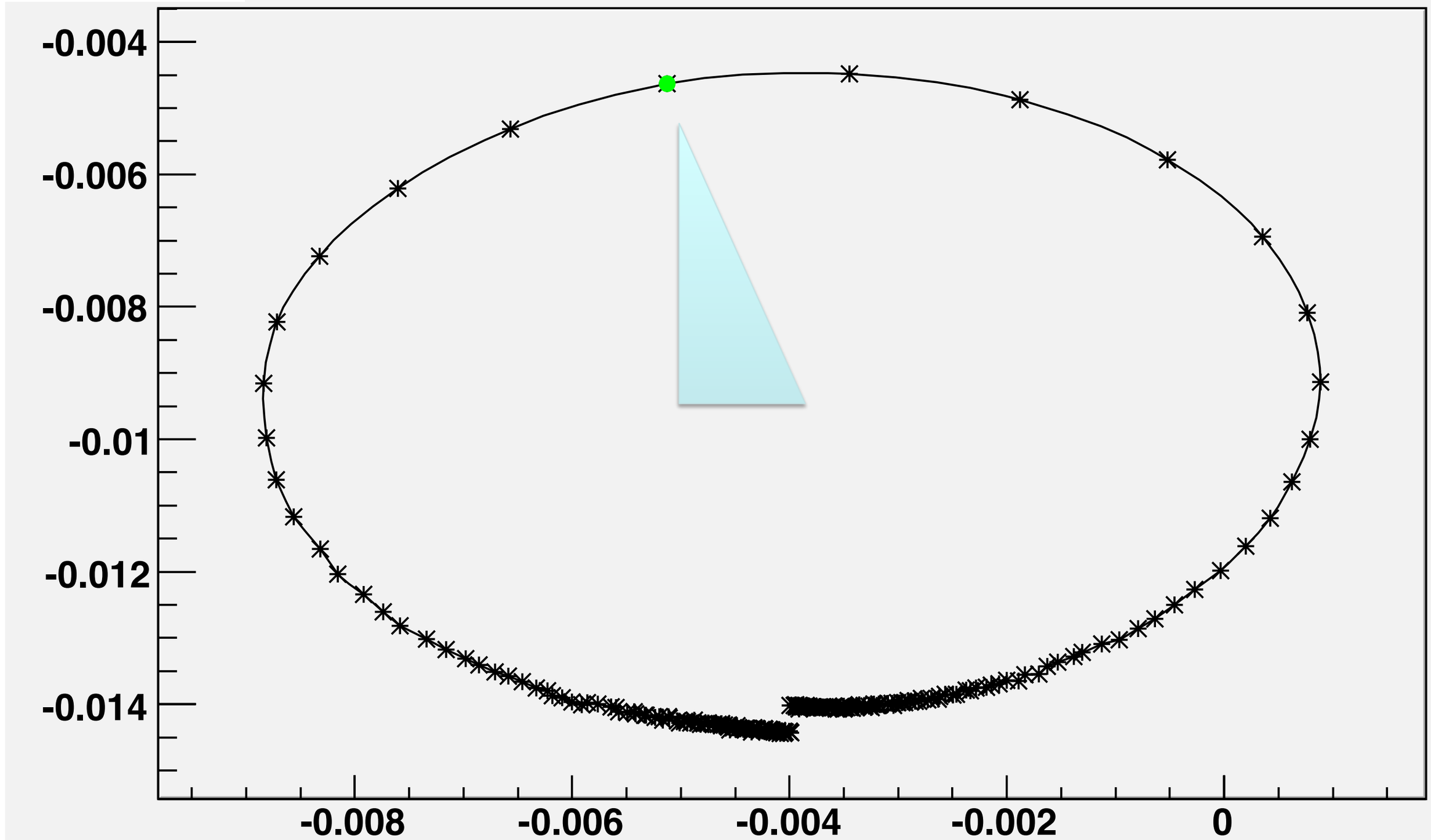
Marcelle Soares-Santos (marcelle@fnal.gov)

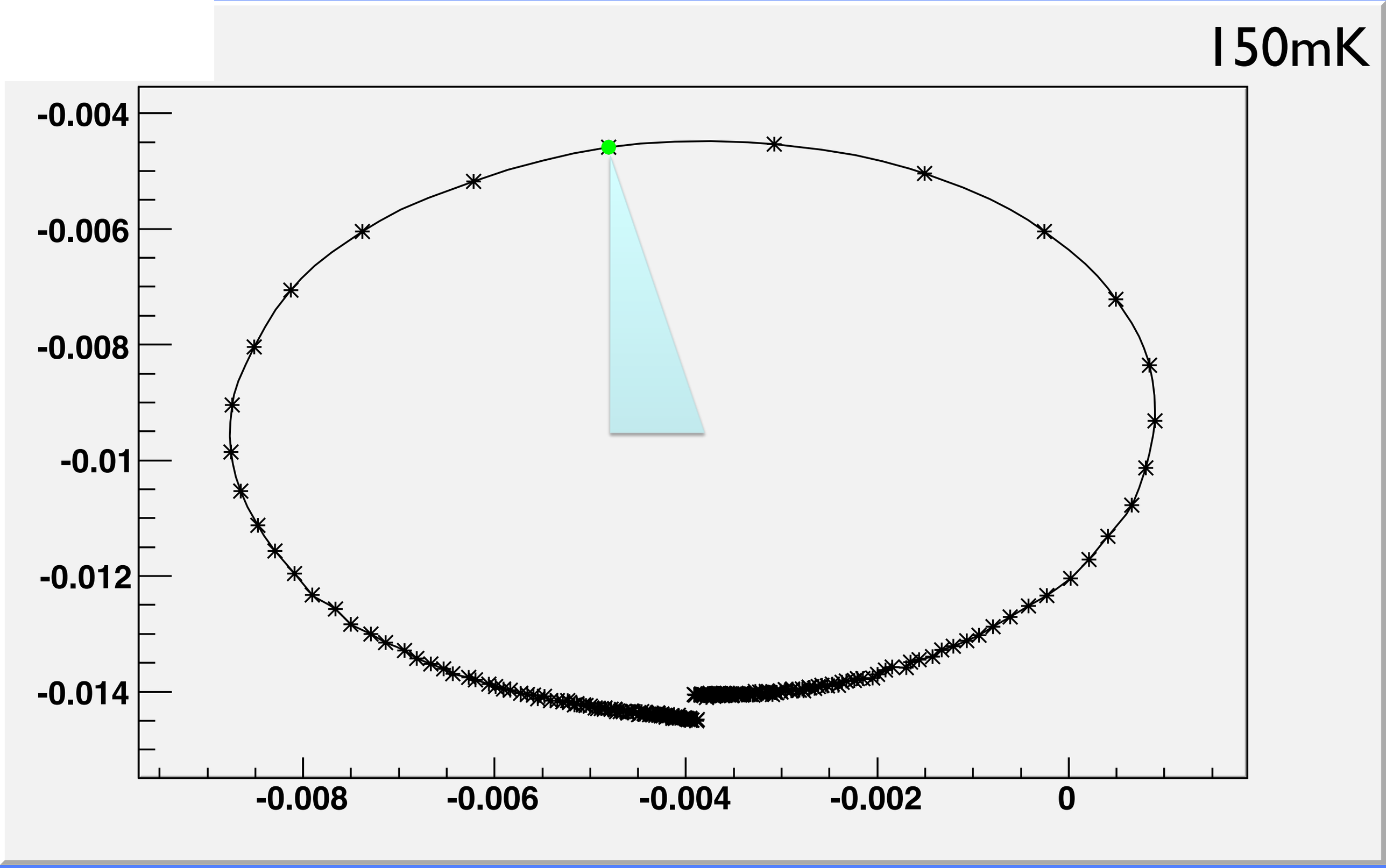
Juan Estrada (estrada@fnal.gov)

Chris Stoughton (chris.stoughton@gmail.gov)

Brian Nord (nord@fnal.gov)

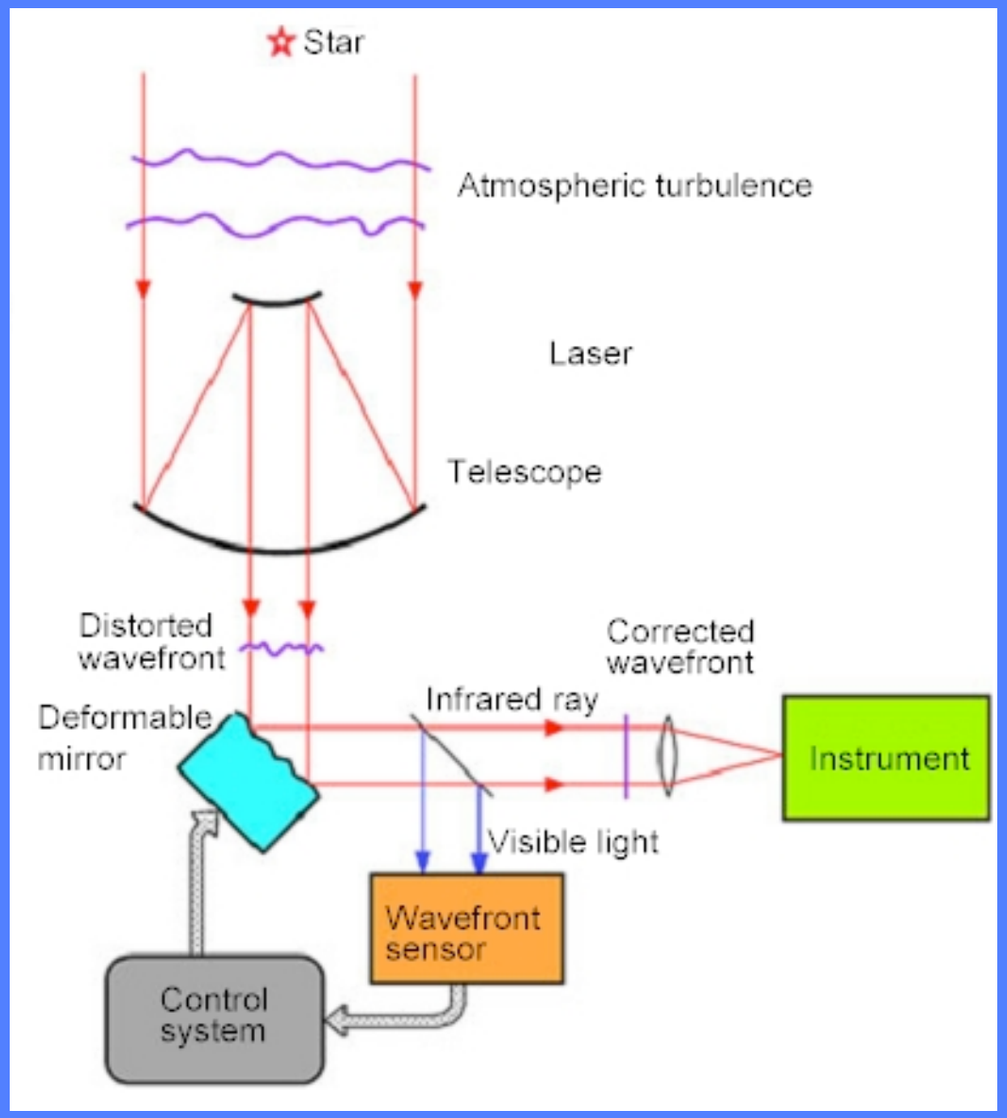
100mK






Change in quasi-particle density equivalent to low Energy X-ray photon (~3keV)

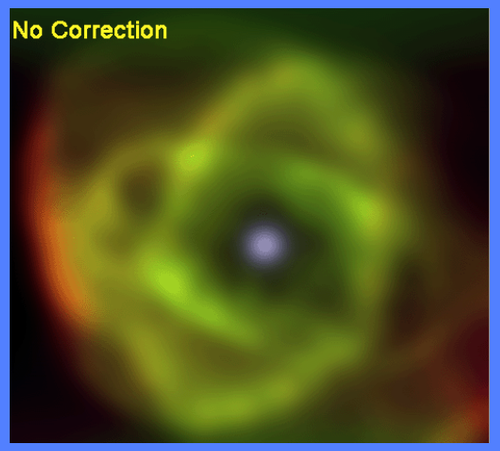
# Why is timing important in wide field imager?

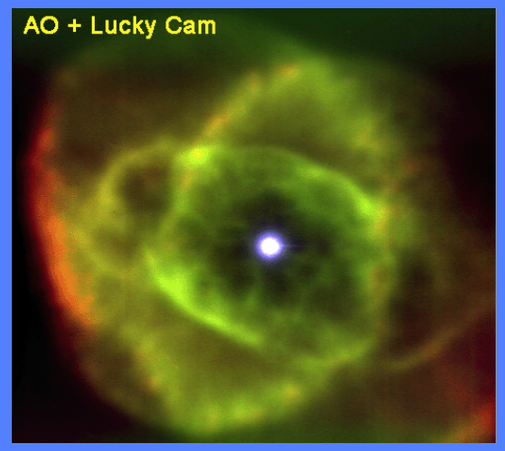



In narrow field imaging on adaptive optics is used to correct for atmospheric turbulence.

For wide fields of view this does not work because turbulence effect changes along the field.

msec timing will help with this.




http://www.ast.cam.ac.uk/research/lucky

# Abdalla et al, 0705.1437

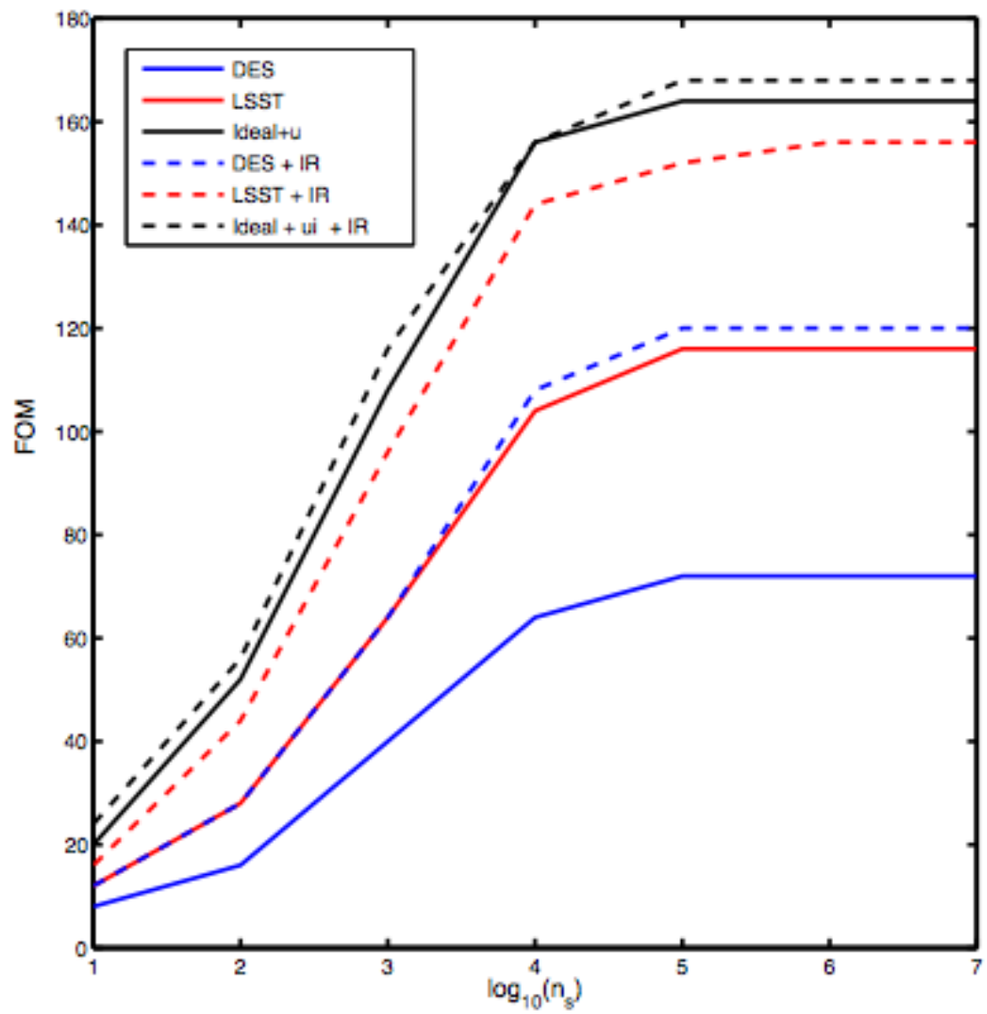



**Figure 15.** The FOM as a function of the number of spectroscopic redshifts (per bin) used to calibrate the photometric results. We can see that the FOM began to level off at $10^4$ and having more than $10^5$ spectroscopic redshifts does not increase the FOM thus meaning that the photo-z are well enough calibrated. We conclude that for a DUNE-like survey we will need

10,000 per z-bin
10 bins

Total= 100,000 spectra