

# JCMT Instruments

JCMT Users Meeting 2022

Dan Bintley

# Outline

- This is a very sparse overview of the current status
- Who to contact for more information, help and suggestions in relation to instruments
- What you can do:- To improve JCMT instruments and take advantage of JCMT to build and develop new instrumentation for JCMT or future new telescopes for the Region.
- Plans for the future

# What you can do

- Your main points of contact are the **JCMT support scientists**, Harriet (Head of Operations), Sarah, Graham and David (for Scientific Software and data reduction).
- On the Instrumentation and Engineering – **we would like to get feedback** on Instrument performance, ideas for new science using our existing instrumentation or ideas for new instruments.
- If you have contacts with Instrument groups locally – we are actively looking for collaboration - for example – in building a **new backend spectrometer** for our new heterodyne instrument – **Namakanui**
- We are open to having new instruments come out to JCMT for trials and development work – hope to host a polarimeter (developed by Prof. Hua-bai Li, Chinese Univ of Hong Kong) - was coming in 2020 – before covid.

# Who are the JCMT Instrument Scientists and Engineers

- **SCUBA-2**

Shaoliang Li

Jamie Cookson, Ed Sison

- **HARP**

Izumi Mizuno, Kuan-Yu Liu

- **Namakanui**

Kuan-Yu Liu, Izumi Mizuno

Ryan Berthold

Per Friberg – Senior Scientist – all instruments, **POL-2, VLBI**

# Current status:

- <https://www.eaobservatory.org/jcmt/instrumentation/>

This page will be updated – to add Standards for U'u and Aweoweo (230GHz and 345GHz receivers in Namakanui)

<https://proposals.eaobservatory.org/jcmt/>

Links to Integration Time calculators

# HARP – 16 receptor heterodyne array



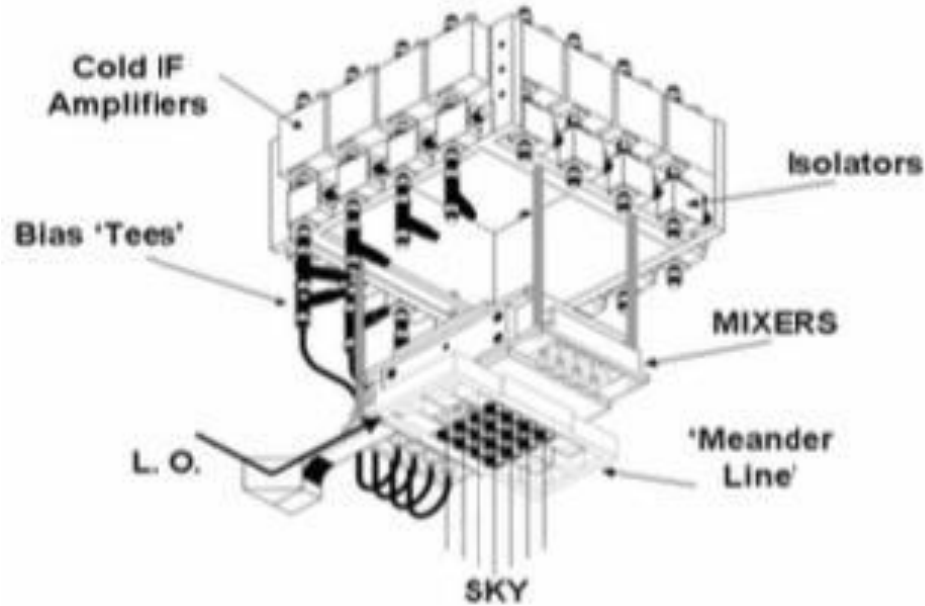
HARP (Heterodyne Array Receiver Program) is a [Single Sideband](#) (SSB) array receiver with 16 SIS mixers. HARP can be tuned between 325 and 375 GHz and has an instantaneous bandwidth of ~2 GHz and an Intermediate Frequency (IF) of 5 GHz.

**14 of the 16 receptors are working**

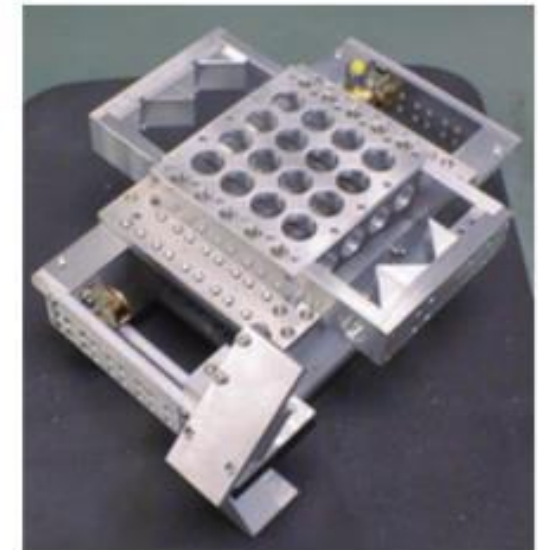
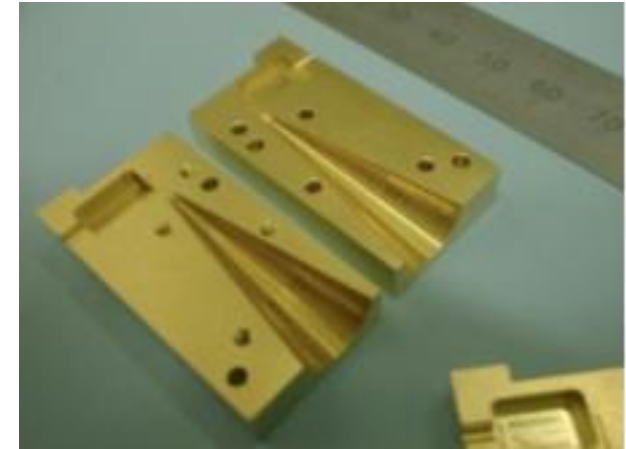
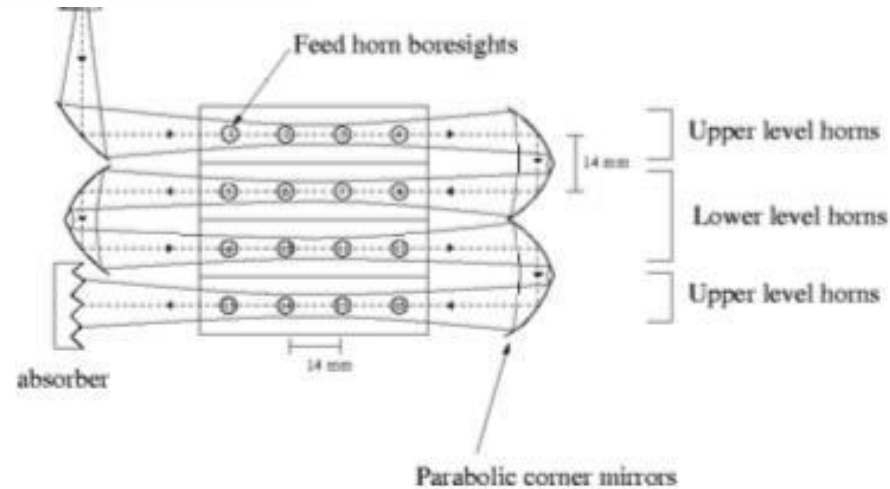
**In July 2019 – we replaced 3 SIS mixers with a new design**

**This work was led by Kuan-Yu Liu – using the resources and input from colleagues at ASIAA**

# HARP 16-pixel mixer array

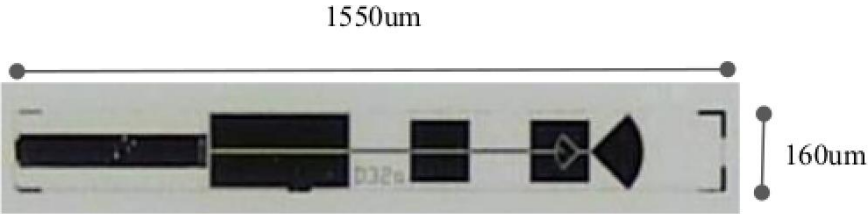


- 14 of the 16 pixels were working
- No good spare mixers
- LO is injected optically and fed to each mixer via a mylar meander line





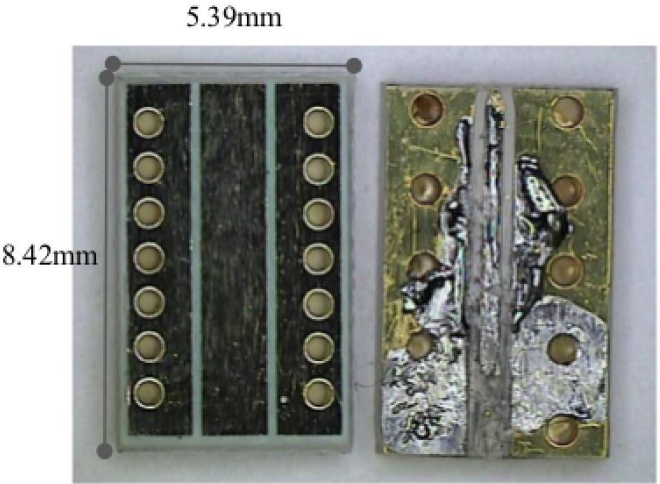
# HARP mixer upgrade in collaboration with ASIAA



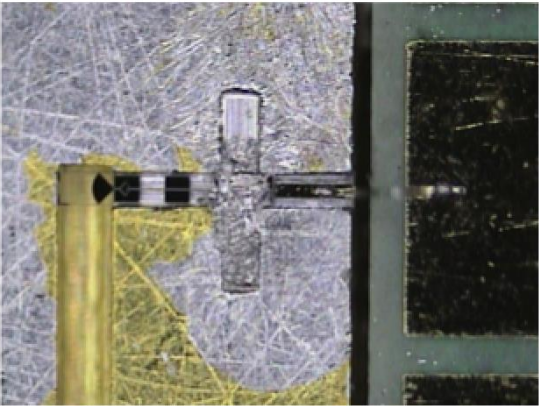
The Original Mixer Chip



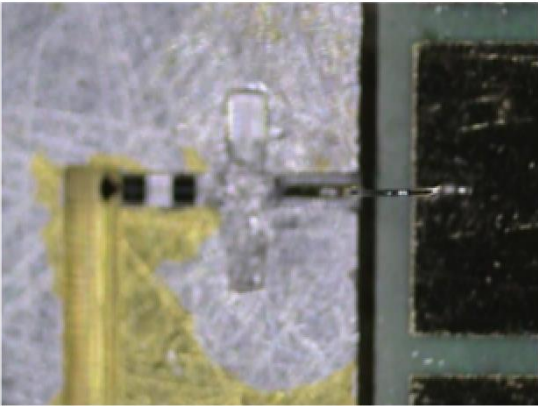
The IF Transmission Line to SMA Connector



New  
(Designed by Su-Wei Chang)  
Original  
CPW IF Transmission Line



Focus on Mixer Chip

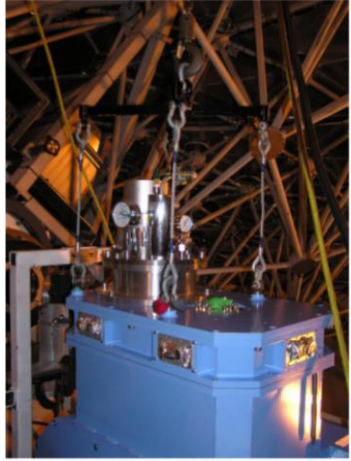


Focus on Bonding Wire

The Wire Bonding

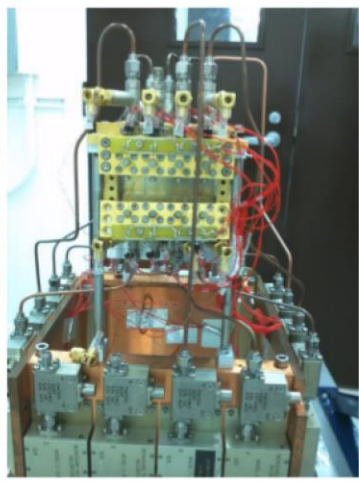
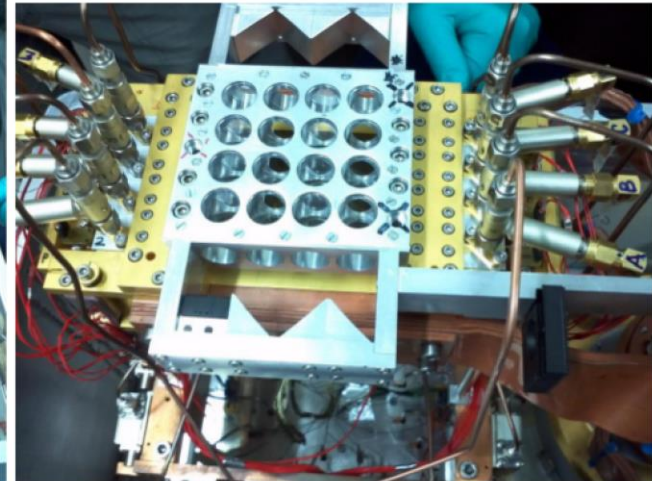
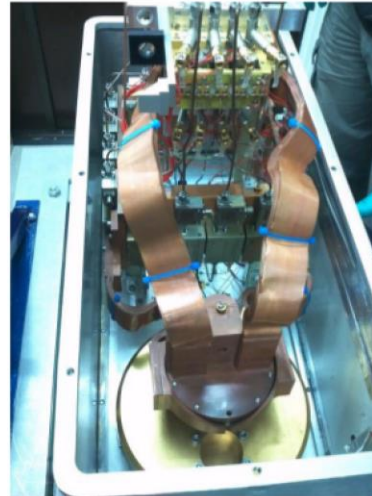


# Replaced 3 mixers July 2019



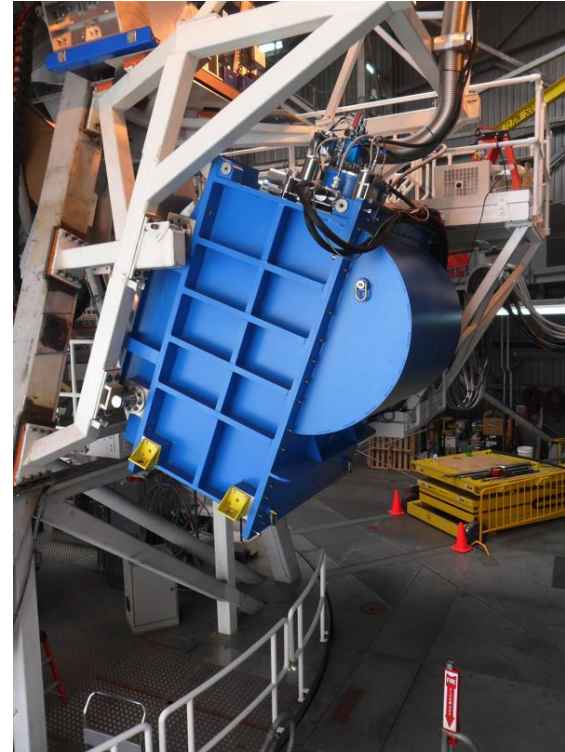
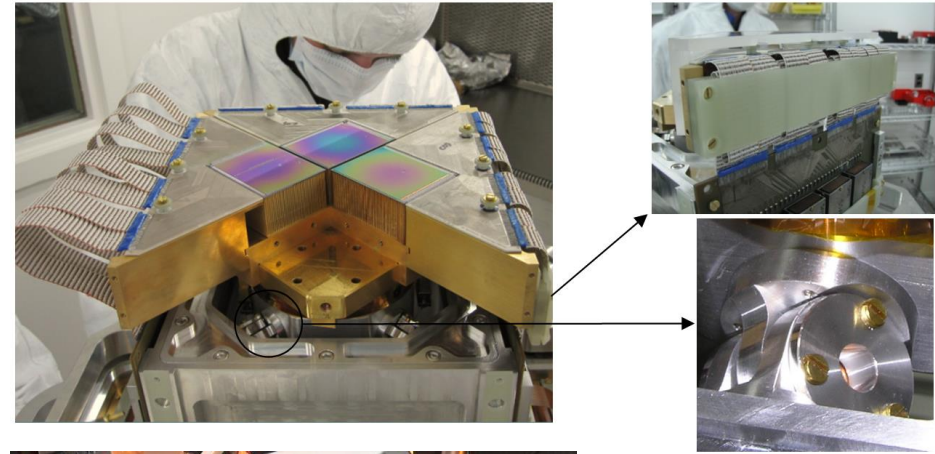
**Removed the Main Array Package (MAP) from the HARP cryostat**

**Replaced 3 mixers blocks**



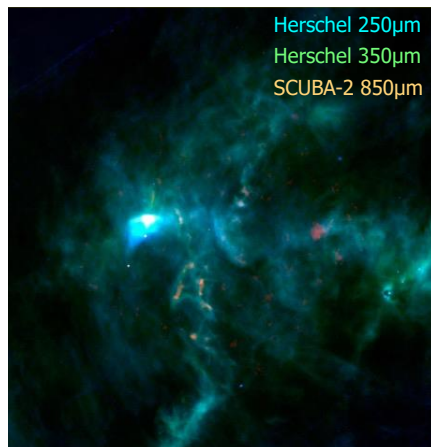
# SCUBA-2 – still the worlds best wide field submillimetre camera

- ❖ SCUBA-2 is a 10,000 pixel bolometer camera on the JCMT, operational since October 2011.
- ❖ Two focal planes, each with four 32 by 40 MoCu TES sub-arrays with inline 2-D Time Domain SQUID MUX.
- ❖ Observes simultaneously at 850 $\mu$ m and 450 $\mu$ m, with a 43 sq-arcmin field of view.
- ❖ A survey instrument: - a square degree of sky can be mapped to 6mJy/beam at 850 $\mu$ m in less than 7 hours.

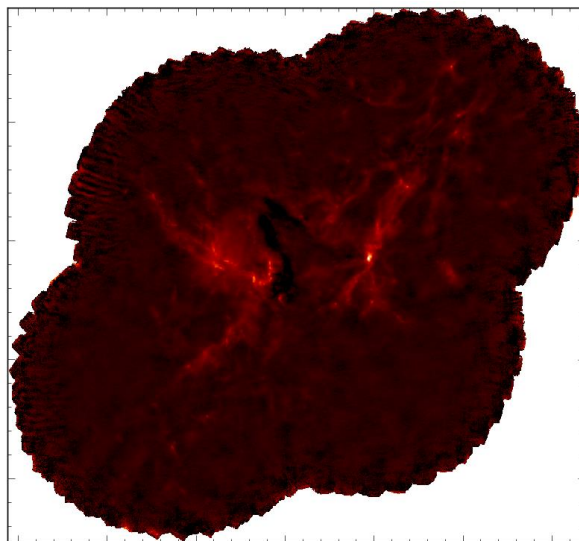




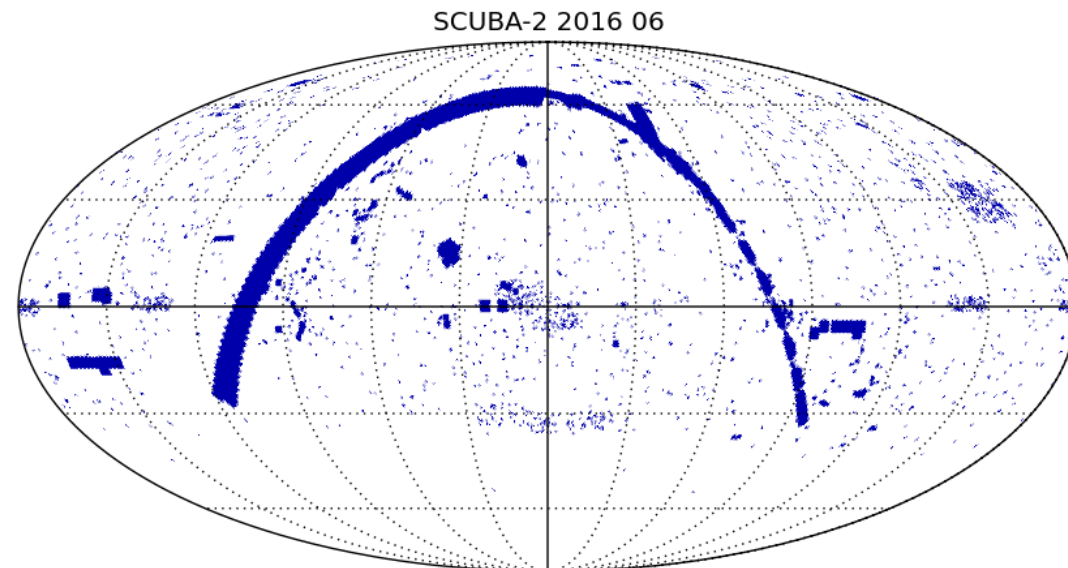
# SCUBA-2 has been remarkable success



Credit:  
JCMT/Herschel  
Gould Belt Survey



The First 5 Years of science



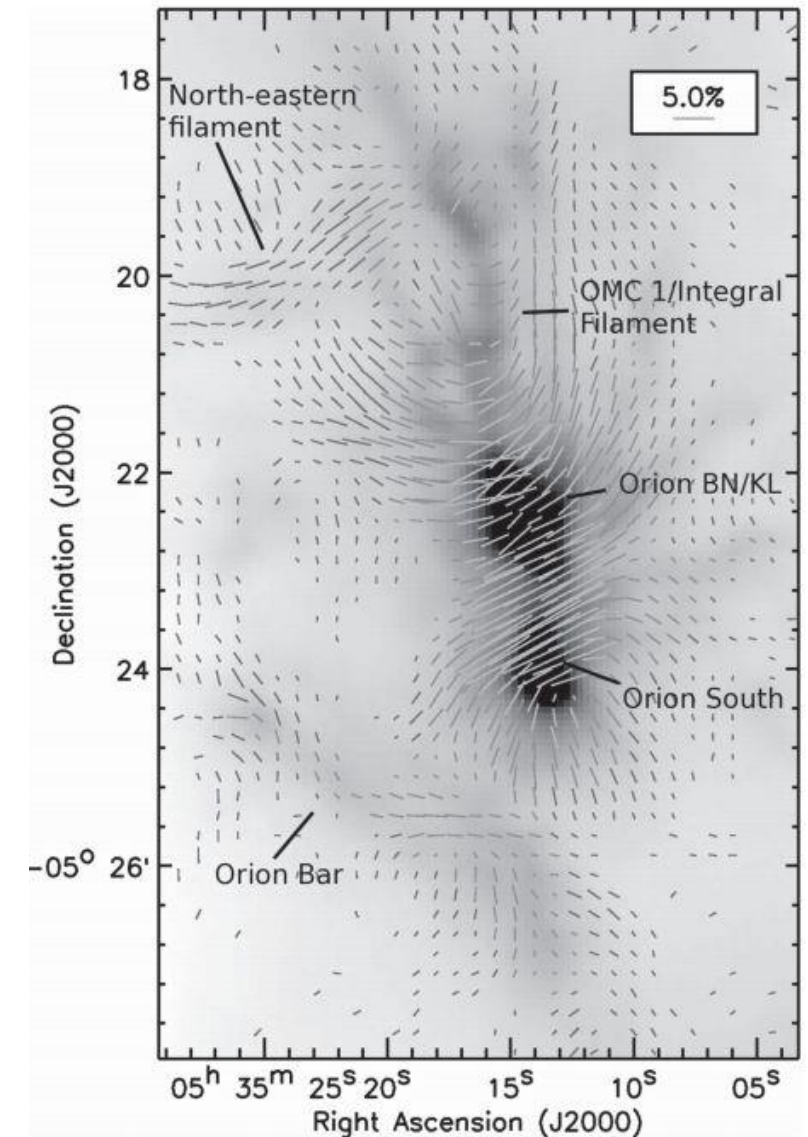
1850.9 square degrees

**19 Large SCUBA-2 /POL-2 surveys, 9 currently in progress**  
**Scores of PI projects (50% of the time allocated)**

# POL-2 has added a unique extra capability

POL-2 and SCUBA-2 currently provides the only capability for fast, accurate detection of submillimeter polarisation on crucial intermediate size scales - between the low-resolution polarization maps of Planck and BLASTPOL and the arcsec scales measured by ALMA and SMA

BISTRO Polarisation map of OMC 1,



# Namakanui – our new 3 receiver instrument

- Namakanui is on loan from the GLT.
- 3 ALMA style receiver cartridges (86GHz, 230GHz and 345GHz)
- Commissioning 230Ghz (almost complete) and 345GHz (progressing rapidly) - the 86GHz – which will mainly be used for VLBI is planned to be available later this year.
- The 230GHz (U'u) and 345Ghz (Aweoweo) offer new opportunities for science compared to RxA (retired) and HARP





# Performance of U'u and Aweoweo

- Both receivers are working excellently.
- The 230 and 345 GHz inserts have dual polarization 2-sideband mixers, producing four Intermediate Frequencies (IFs) with bandwidths of 4 – 12 GHz (230) and 5 -9 GHz (345)
- Please note that, at present, the [ACSYS](#) IF system only supports IFs of 4 – 7.3 GHz.



# `Ü`ü 230GHz receiver

- The accessible `Ü`ü tunable LO frequency range is currently 221-264.6 GHz, so observable sky frequency range with ACSIS is 215 – 270.6 GHz with an IF = 6 GHz
- `Ü`ü can be used in Stare, Jiggle and Raster observing modes.
- Trx is typically better than 70K over the tunable range.



# `Äweoweo 345Ghz receiver

- The `Äweoweo tunable LO frequency range is currently 282 – 365 GHz, so the observable sky frequency range with ACSIS is 277 – 370 GHz with LO = 5 GHz (LO of 5GHz provides best noise performance).
- Same observing modes as U'u
- Trx is typically better than

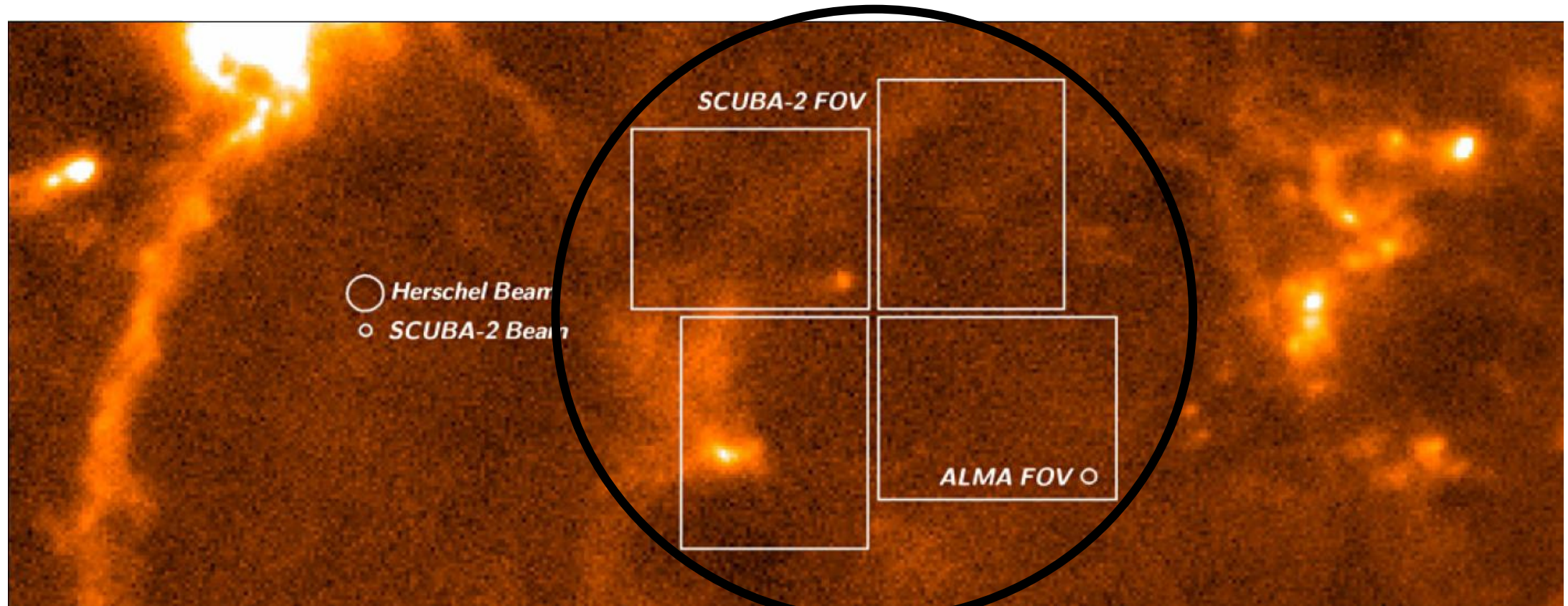
# Capability for VLBI

- JCMT is part of the EHT and future will be part of EAVN
- Capable of VLBI at 230GHz, 345GHz and 86GHz (with new 86GHz optics being installed this summer)
- Dual polarisation recorded to Mark 6 recorders

# Future Instrument Plans

- New Spectrometer for Namakanui – we have hardware available to build a new wider band spectrometer. Looking for partners to help develop the FPGA code
- New Continuum Camera to replace SCUBA-2
  - working with NIST to design and fabricate MKID arrays
  - At least factor 10 improvement in mapping speed
- New large heterodyne array to replace HARP

# JCMT Beam Size ( $850\mu\text{m}$ ) and Field of View compared to ALMA and Herschel



Field of View of new 850μm  
MKID Instrument

# Why do we need a better continuum instrument than SCUBA-2 ?

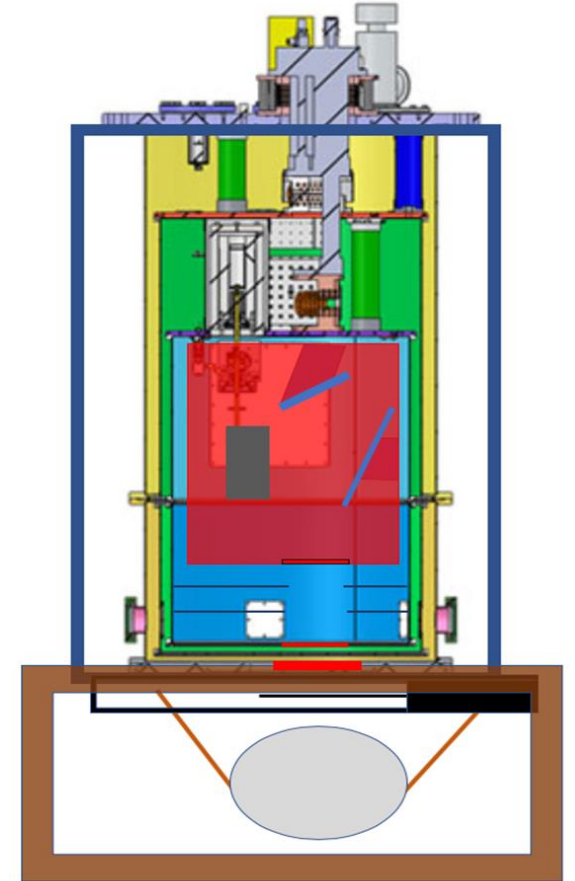
- JCMT is in a unique and critical position in the current submillimeter community.
  - With a 15m dish and a potential 12 arcmin field of view – JCMT is ideal for conducting largescale and deep surveys, using a large format multi-pixel instrument.
  - There is a pressing need for source-finding and mid to large-scale complements to ALMA's high-resolution science. JCMT provides these capabilities, and at the shorter and more critical wavelengths.
- SCUBA-2, and in combination with POL-2, is in extremely high demand - limited only by what can be realistically be observed in a reasonable time.
- New, larger single-dish observatories at 850um and shorter wavelengths, are a minimum of a decade away.

# Design Requirements

- Take full advantage of the 850 $\mu$ m atmospheric window and the JCMT field-of-view
- Be restricted in first-generation as a single-wavelength instrument
- Achieve *at least* a factor of 10 faster mapping speed than SCUBA-2 at 850 $\mu$ m
- Have intrinsic polarisation measurement capabilities
- Detect and map polarised emission at least 20 times faster than POL-2
- Be operational on the JCMT by 2023

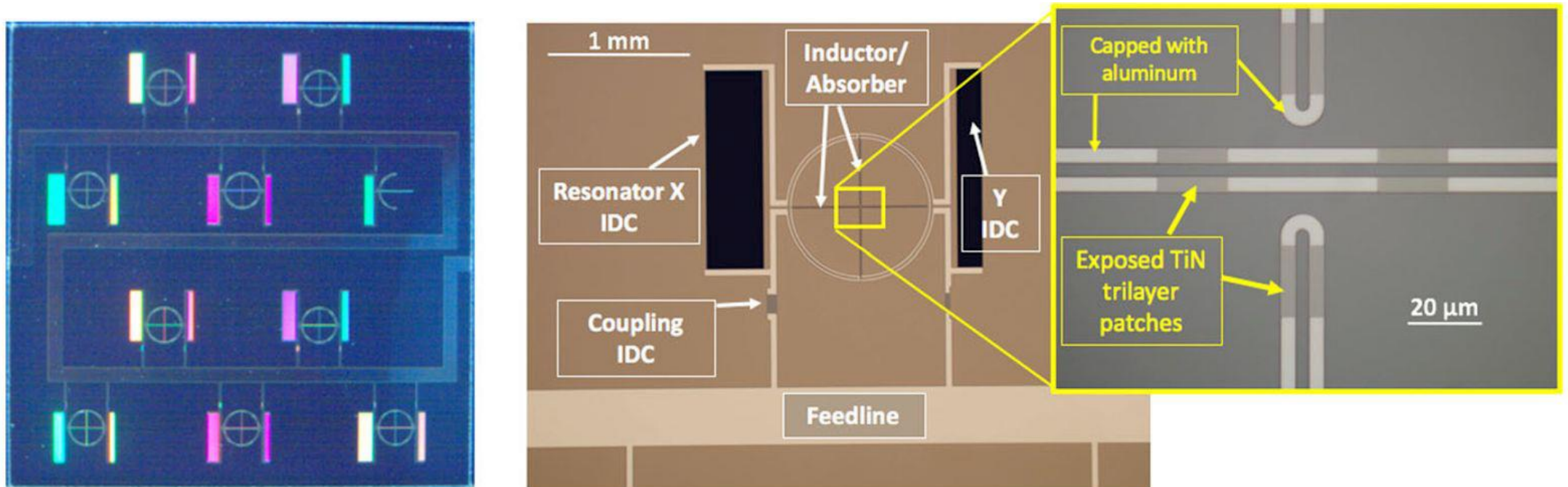
# New 850 $\mu$ m MKID Camera

- Circular 12 arcmin FOV
- $1f\lambda$  spaced, hexagonal closed packed pixels, each with 2 detectors
- A smoothwall feedhorn design, that terminates in 850 $\mu$ m matched waveguide section
- Focal plane temperature < 200mk
- 1K enclosure surrounding array and final mirrors
- Effective baffles at 4K
- Rotating half-wave plate for polarimetry



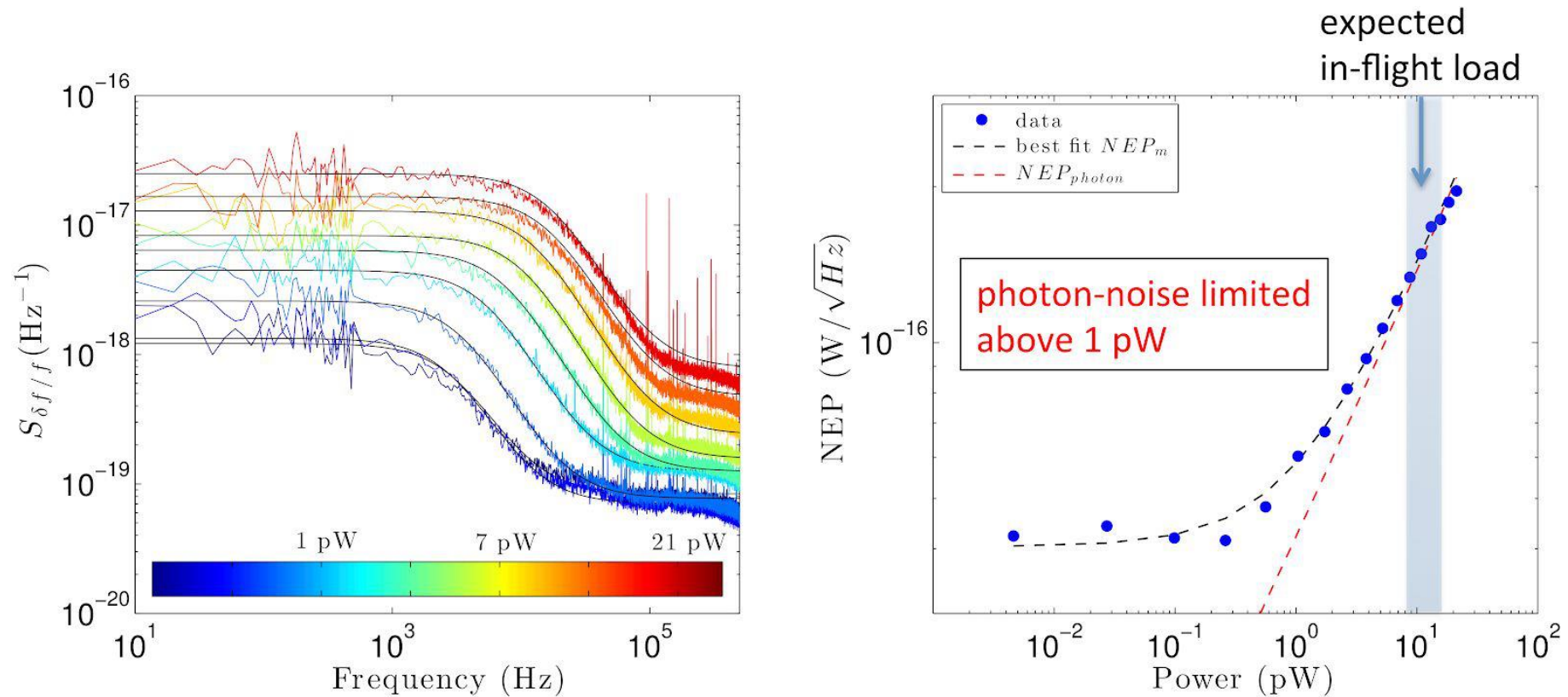


# MKID Detectors – from NIST



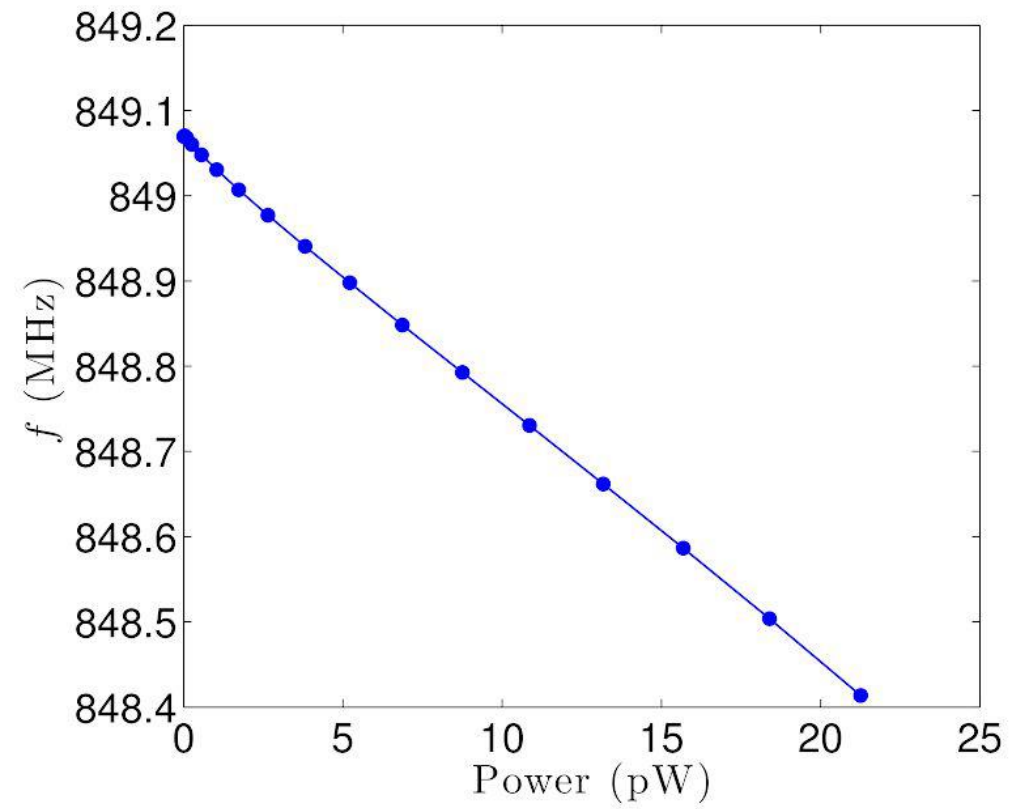
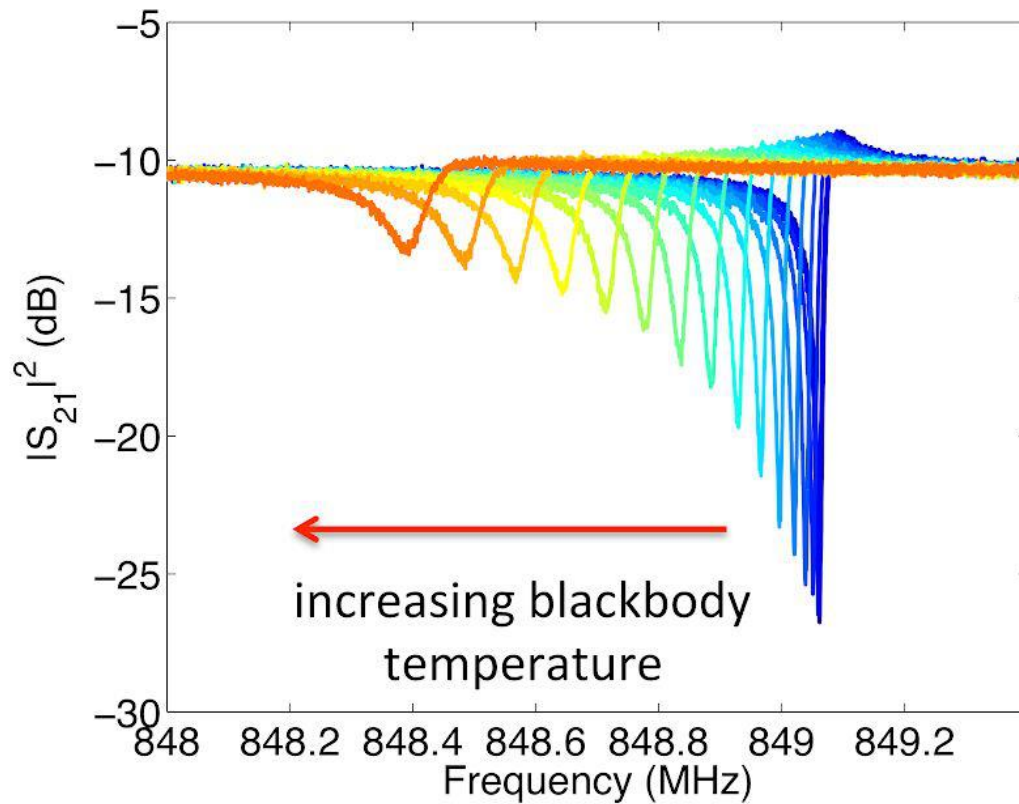
Prototype NIST 10 pixel 1.1 mm array. (Center) The layout of a single dual polarisation pixel and (Right) an expanded view of the inductor/absorbers. The new JCMT MKID pixel will have a similar design optimised for 850 μm

# Optical power loading noise measurements



Test results of NIST pixel design, The (BLAST-TNG) NIST MKID is photon noise limited for optical loads greater than 1pW.

# Large linear dynamic range



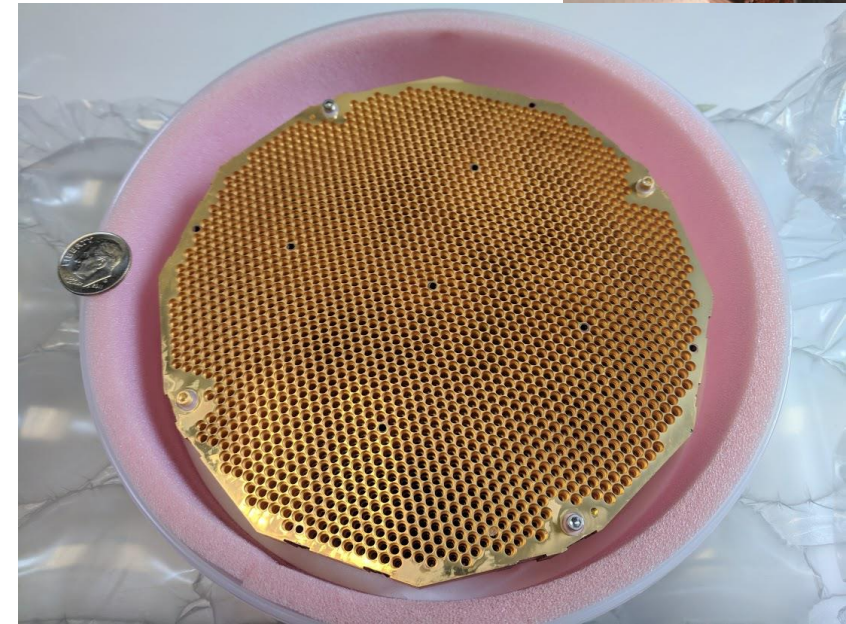
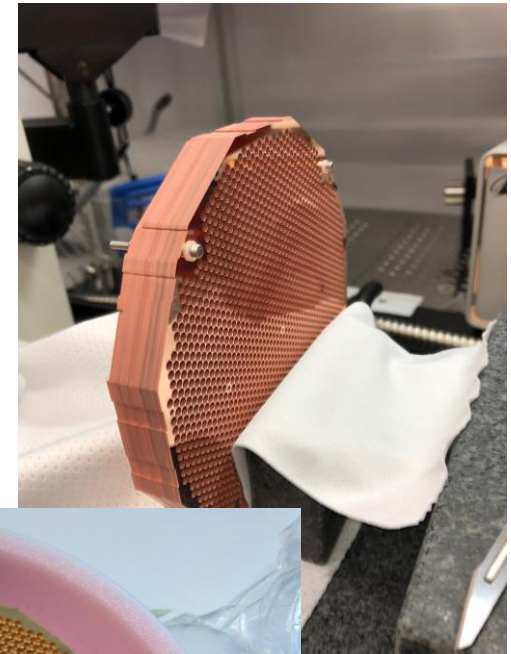
Test results of NIST pixel design, showing a large linear dynamic range under optical power loads.

# Feedhorn coupled MKID Array

Each pixel is comprised of two lumped element MKID that are sensitive to orthogonal linear polarization. The MKID form a resonant circuit consisting of an inductive strip and an interdigitated capacitor.

In the NIST MKID design arrays, the inductor is identical for each pixel, while each capacitor is trimmed to a unique value. The inductor is made from TiN/Ti multilayers, allowing the  $T_c$  to be tuned by varying the thickness and number of layers. The inductor also serves as the absorber that couples to radiation from the waveguide.

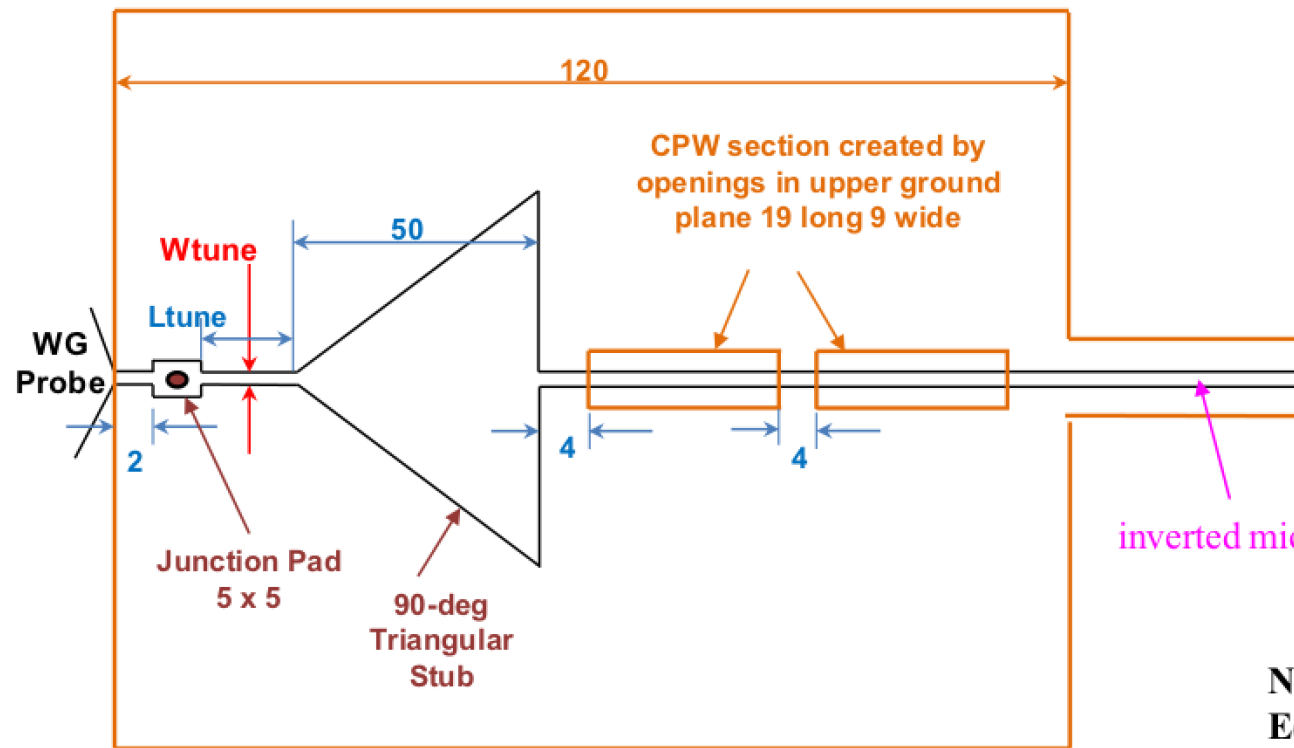
The choice of  $T_c$ , inductor geometry and impedance matching determine the optimal coupling, polarisation efficiency and saturation power. An aluminium layer over portions of the inductor provides further tuning of the optical coupling. The goal is to optimise these parameters for  $850\mu\text{m}$  observing at JCMT.



TolTEC Instrument 1.1mm Feedhorns, (Umass)



# New HARP mixer design



## Design Notes:

1. Target  $RnA = 25 \Omega\text{-}\mu\text{m}^2$
2. Junction Diameters: 1.2, 1.3 & 1.4  $\mu\text{m}$
3. 3 junction sizes & 3 values of  $W_{\text{tune}}$ . Total of 9 combinations
4. This drawing is not to scale.
5. Dimensions given in  $\mu\text{m}$ .
6. Thickness of  $\text{SiO}_2$  250 nm

**New HARP Mixer Chip**  
**Edward Tong**  
**March 13, 2018**