Chinese Antarctic Observatory

-- Latest Developments for DATE5

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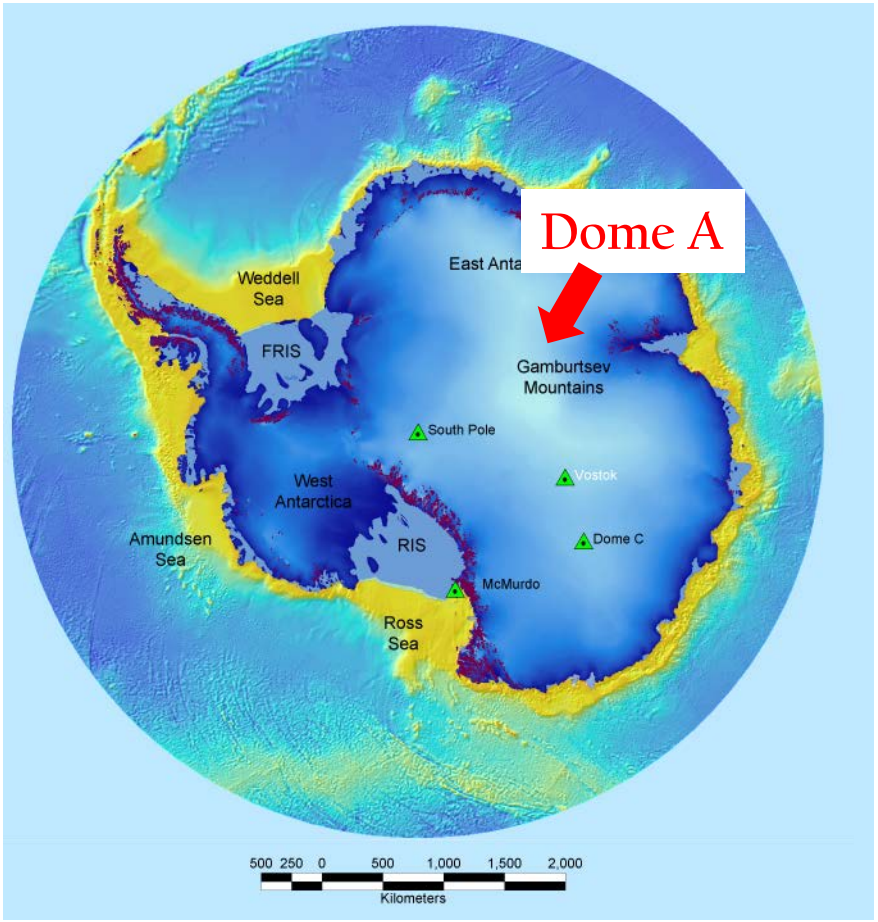
Outline

- Introduction
- DATE5 Telescope
- THz Superconducting Receivers
- THz Superconducting Imaging Array
- Conclusions

Where is Dome A?



Basic facts about Dome A

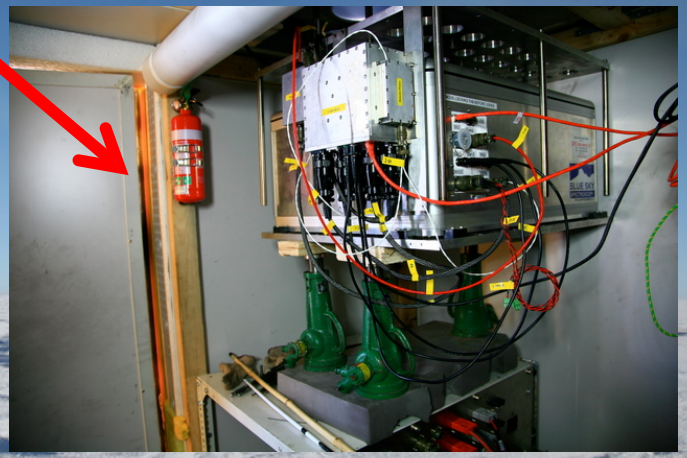
- Altitude: 4093m (60km×10km)
  - Lowest temp: -83℃
- A plateau of small fluctuation
  - 1300km from China's Zhongshan station
- Extremely good THz/IR windows

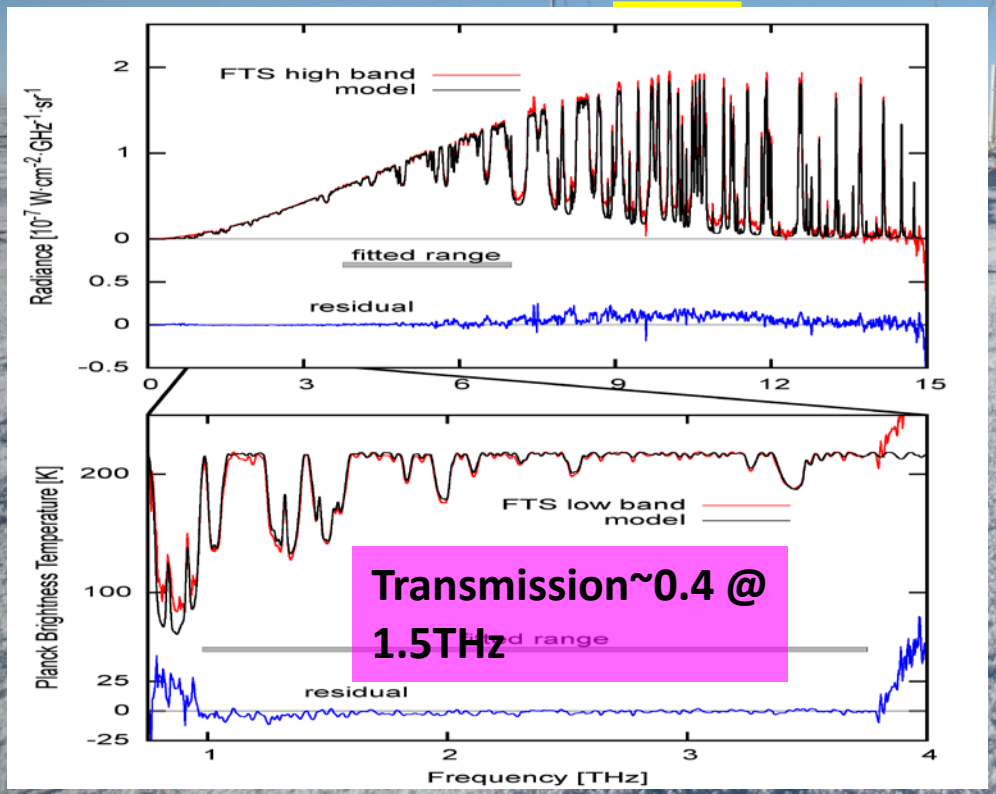
Major Relevant Features

- **Low water content (good for THz observations, and precision photometry)**
- **Low scintillation error (good for precision photometry)**
- **Continuous observing (good for time domain astronomy)**
- **Low atmospheric boundary layer (good for high spatial observations, seeing ~ 0.3 arcsec)**
- **Low temperature (good for IR observations)**

- Aurora
- High relative humidity
- Difficult to access
- Less dark time

Dome A FTS & Results





Transmission~0.4 @ 1.5THz

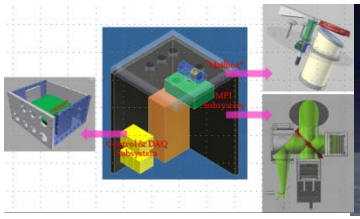
Dome A Observatory – Roadmap

2006-2008

Site Survey & Small Telescope

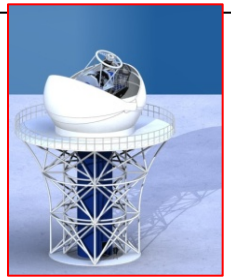
2009-2011

+Site Testing & Middle-size Telescope

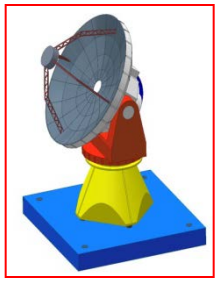


2011-2015

Dome A Observatory Phase I



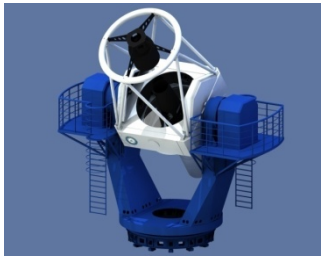
2.5m Opt/NIR
KDUST



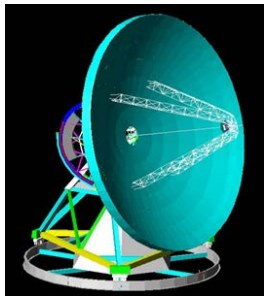
5m THz
DATE5

2016-2025

Dome A Observatory Phase II

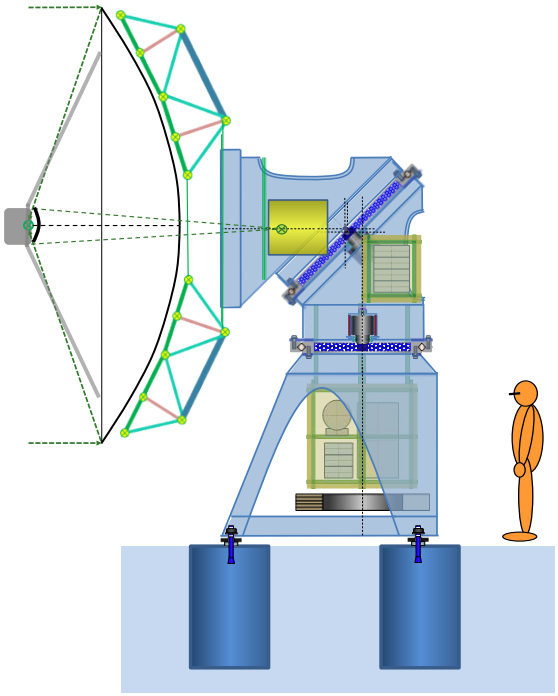


6-8m
Opt/NIR

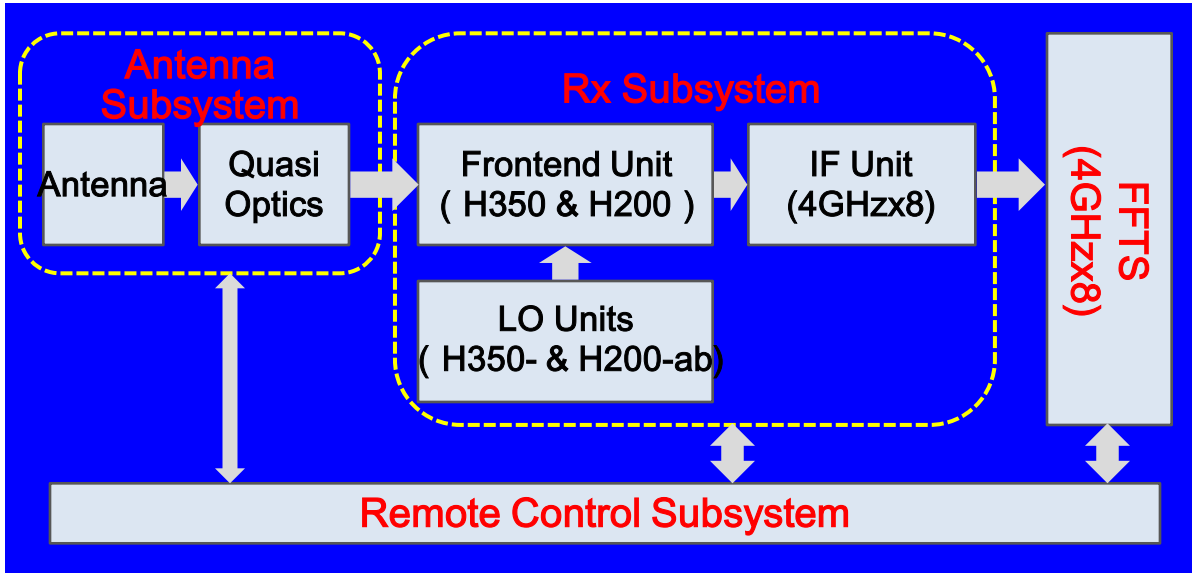


15m THz

Dome A 5m THz Telescope (DATE5)



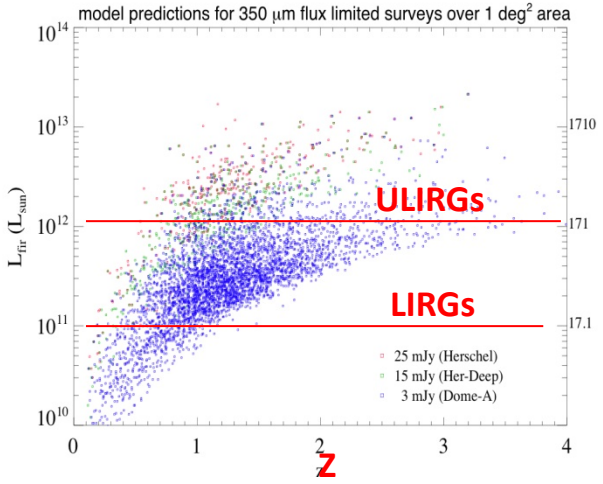
preliminary design of DATE5

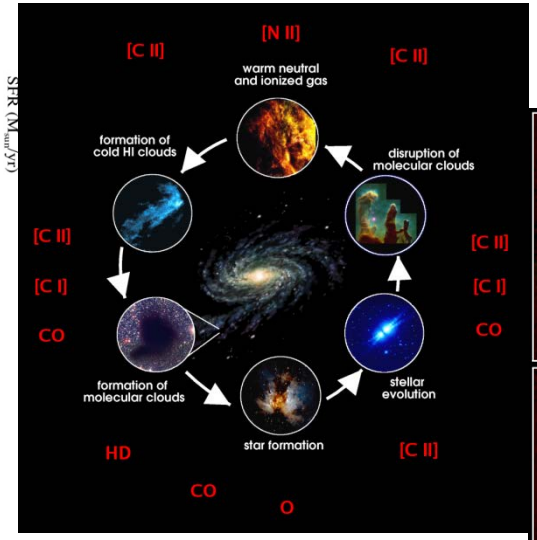


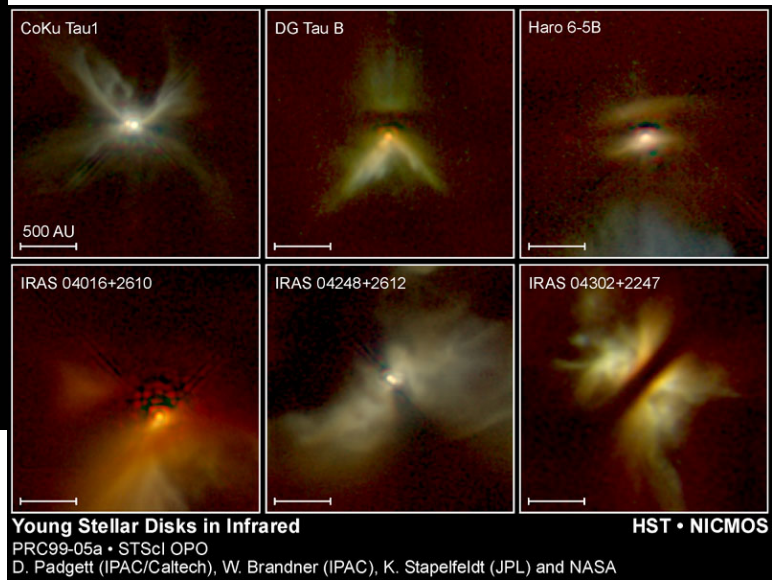
Antenna	Cassegrain
Diameter	5m, with rms accuracy <10μm
Receiver	1x4 superconducting SIS & HEB mixer
Band	350μm & 200μm
IF BW	4GHz x 4 beams x 2 bands
FOV	5′×5′ (200μm)
Pointing	≤2"

Major Science Cases for DATE5

- ✓ Galaxy formation and evolution
- ✓ Life cycle of stars/interstellar medium
- ✓ Origin of planetary systems

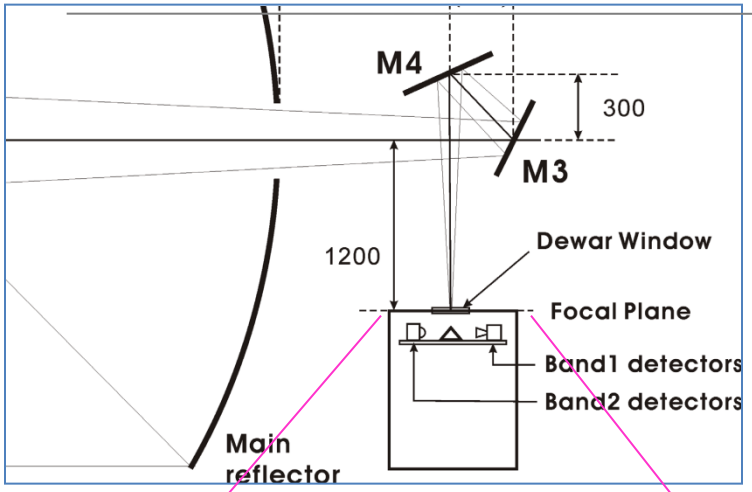


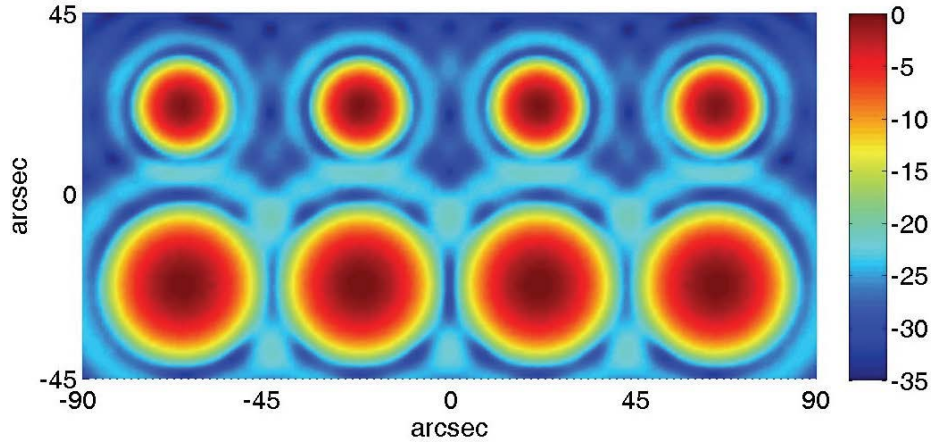


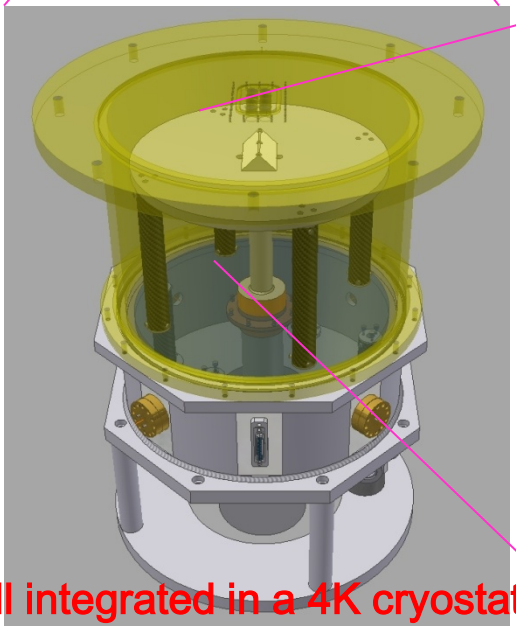


Credit: DATE5 science team

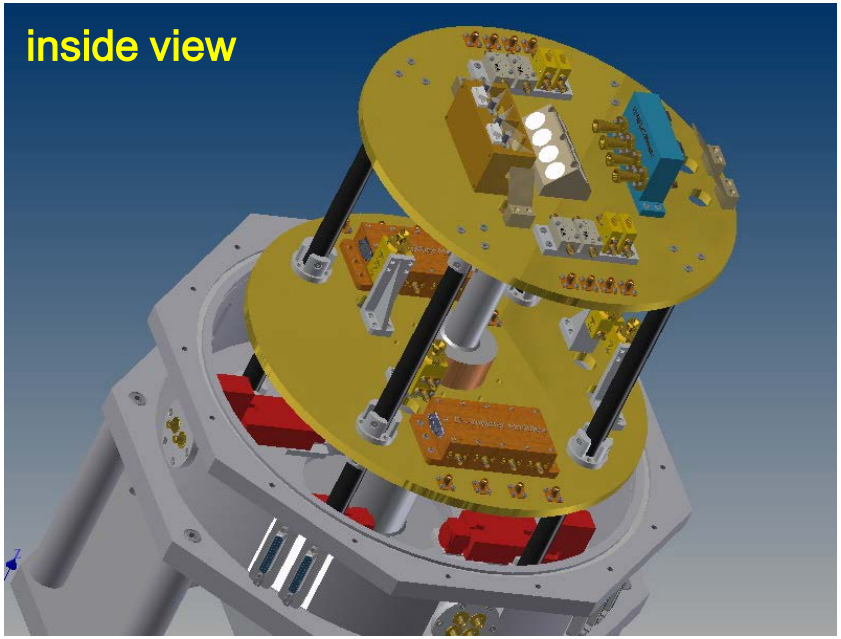
Quasi-Optics & Rx of DATE5



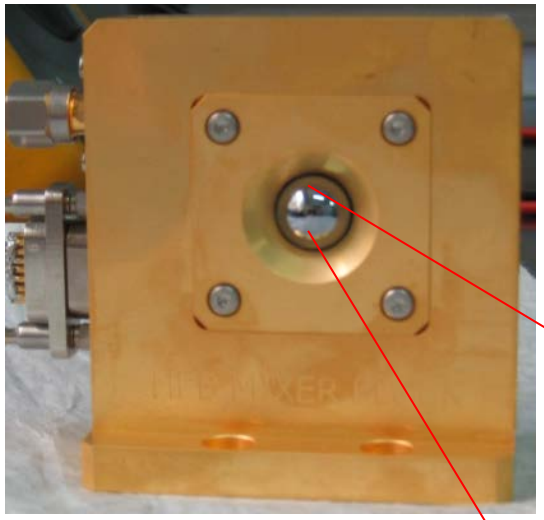




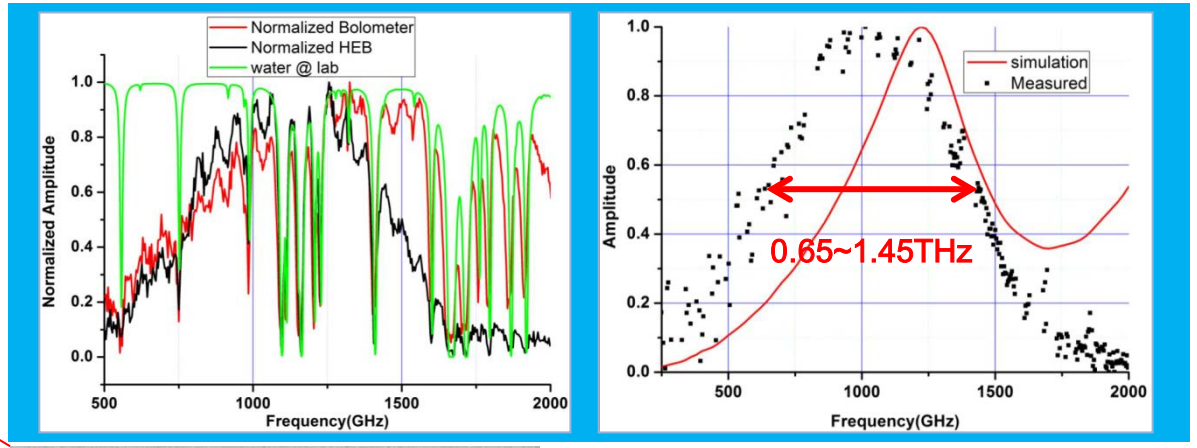
All integrated in a 4K cryostat

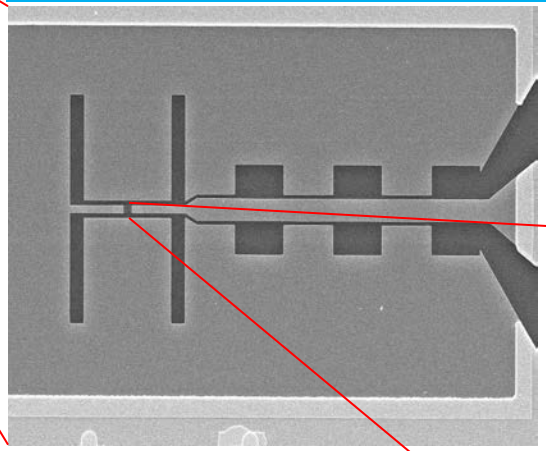


1.4THz Supercond HEB Mixer

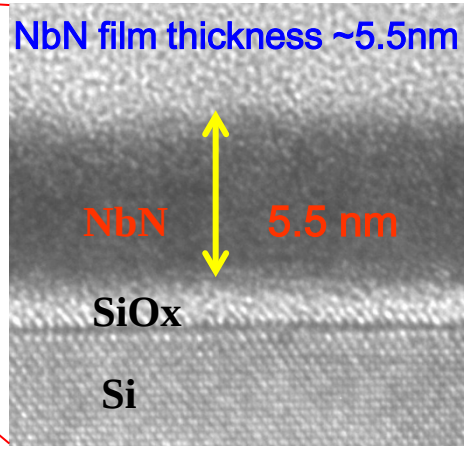


H200 HEB mixer



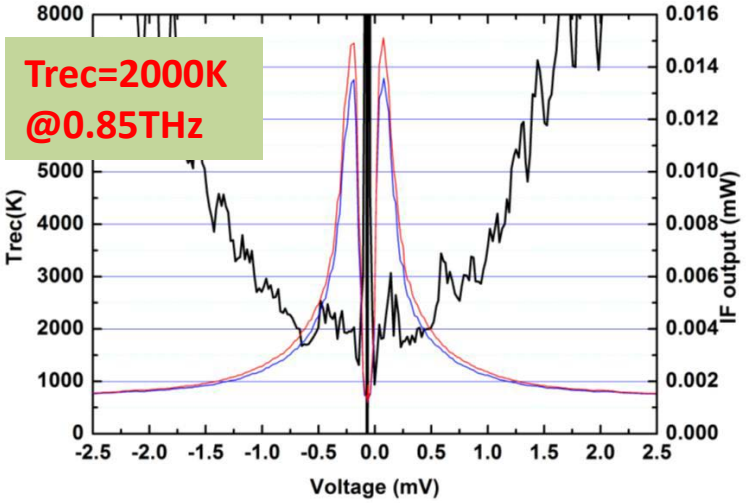


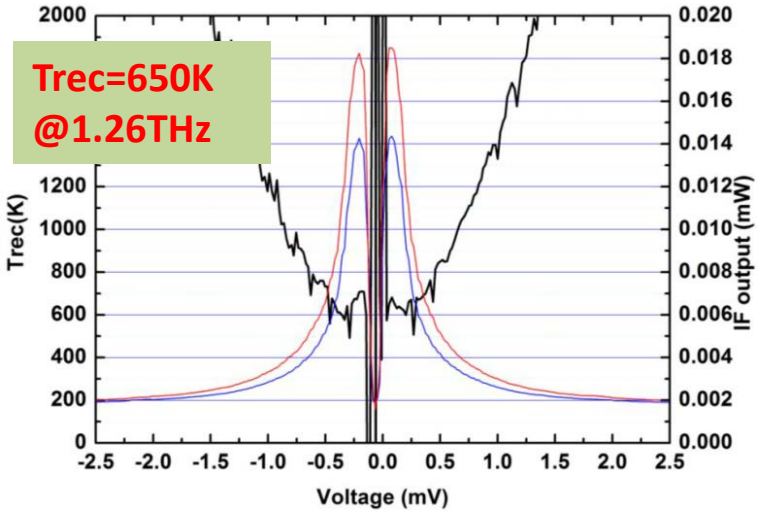
H200 HEB mixer chip



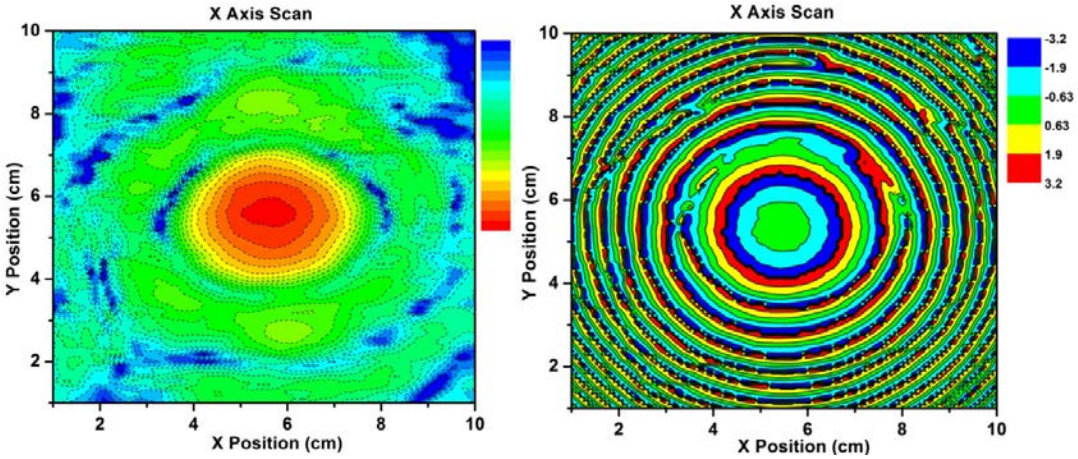
TEM image of the HEB microbridge

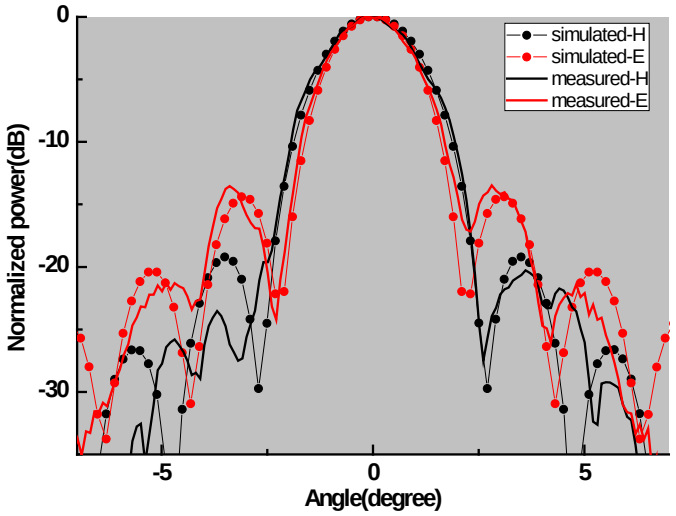
1.4THz Supercond HEB Mixer





Noise temperatures (uncorrected) measured @ 0.85THz & 1.26THz

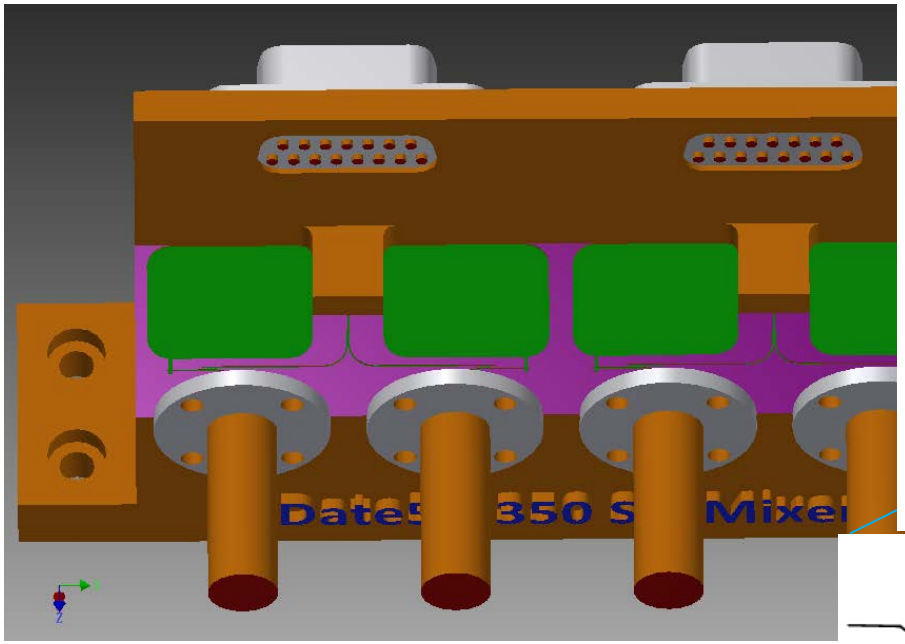


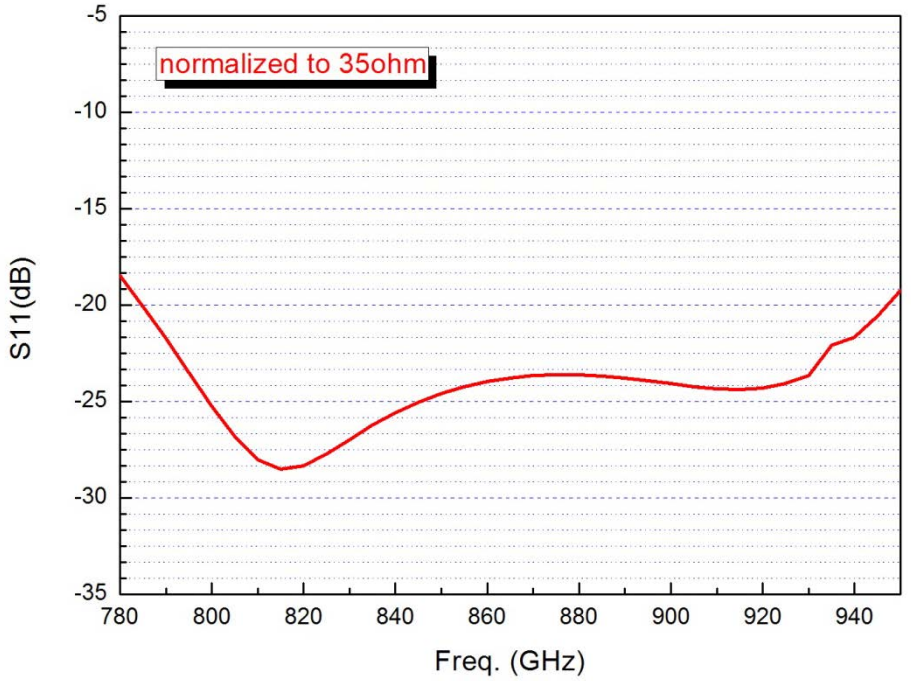


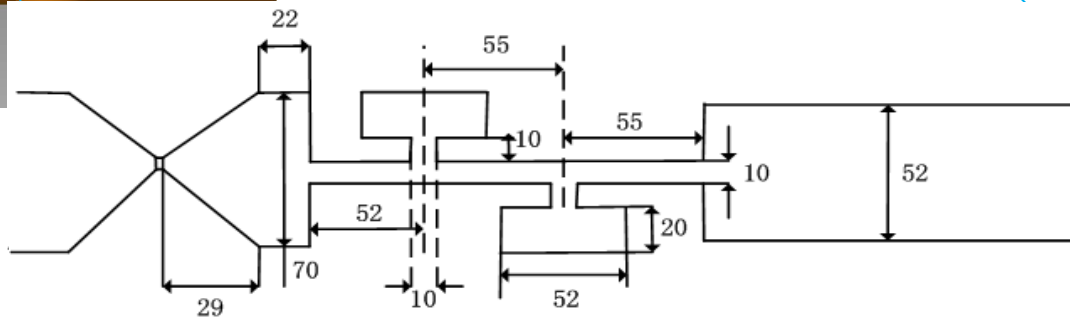
Measured and simulated near-field and far-field beam patterns @ 0.85THz

0.85THz Supercond SIS Mixer

1x4 beam H350 SIS mixer







H350 waveguide SIS mixer circuit

A 2GHz Bandwidth FFTS

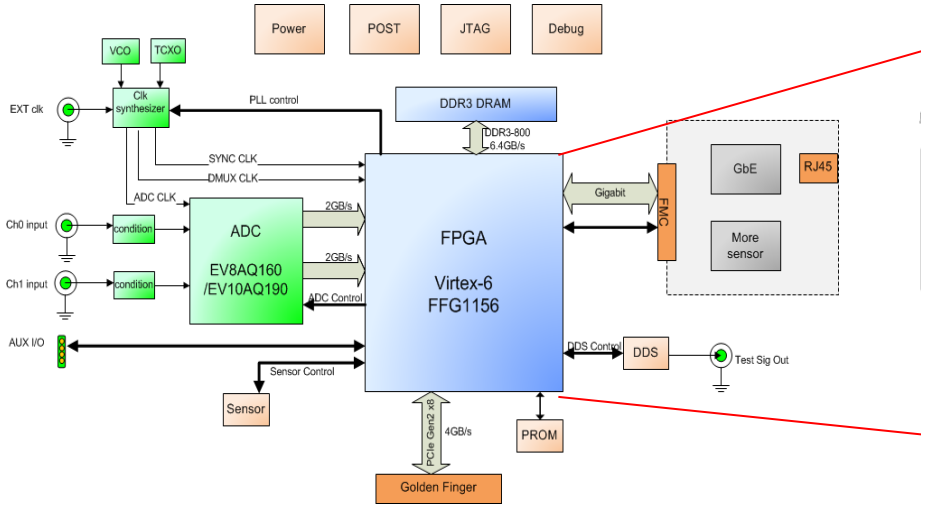
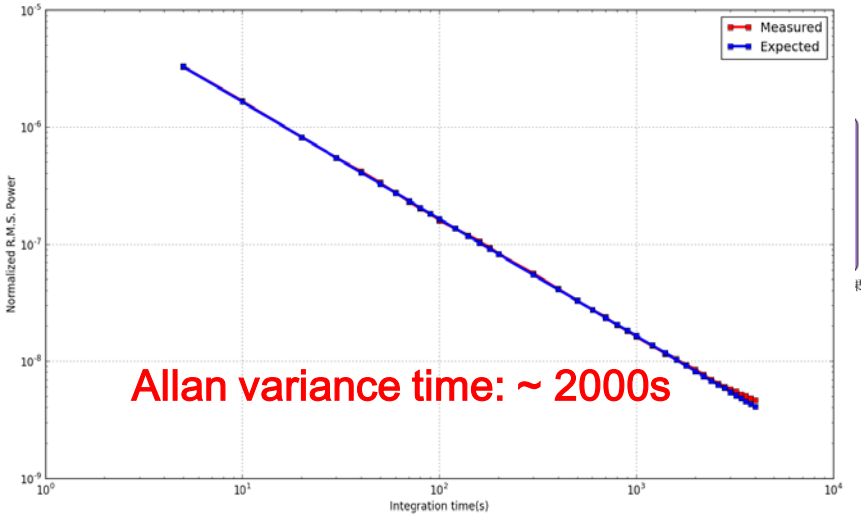
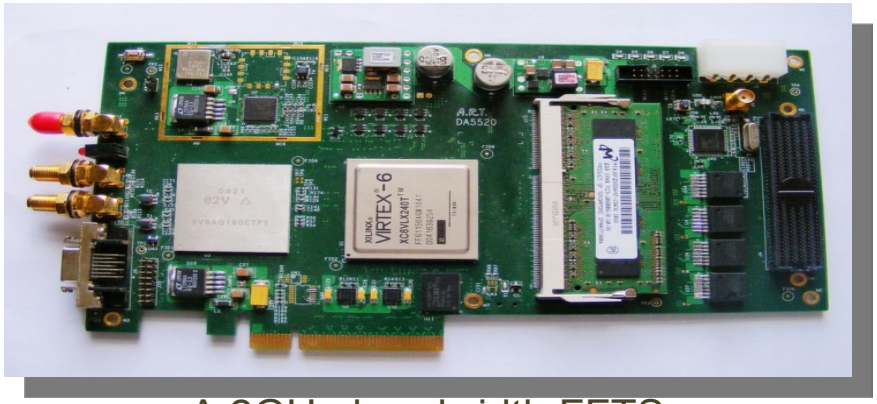


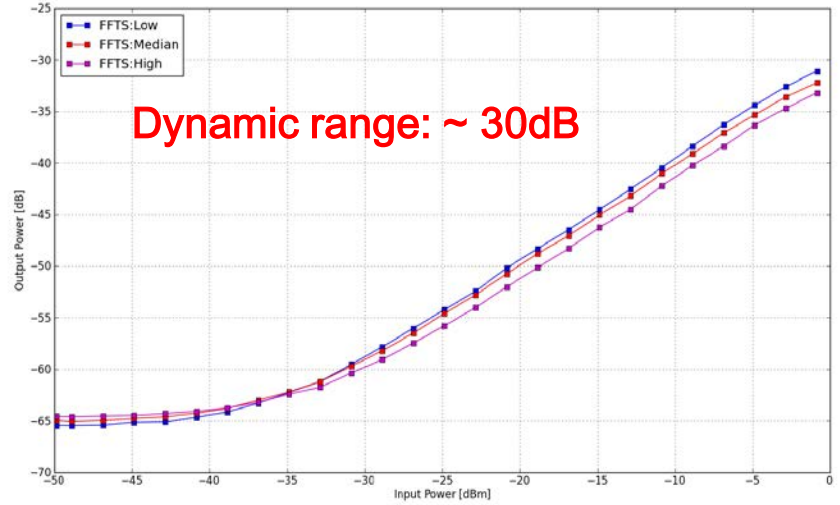
Diagram of 2GHz-bandwidth FFTS



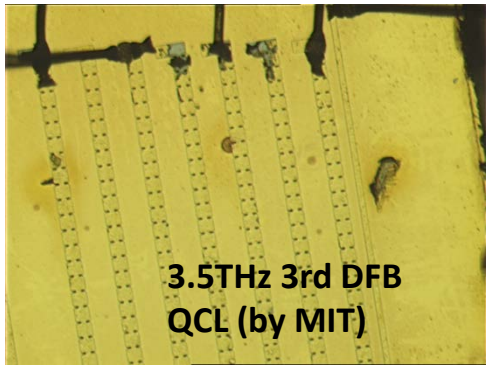
based 32k channels FFTS

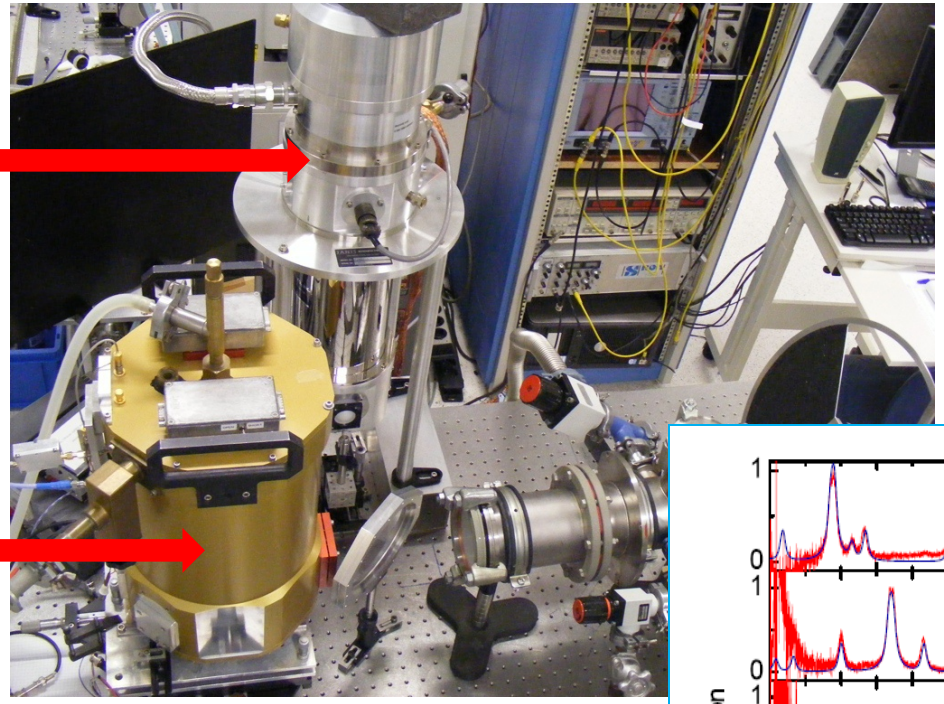


A 2GHz-bandwidth FFTS

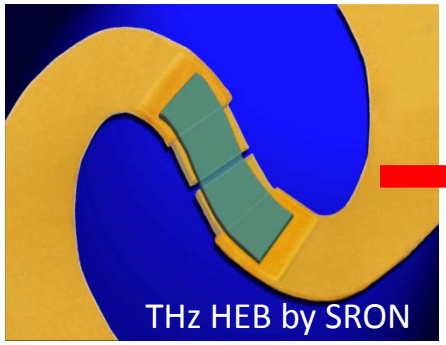


THz QCL Integrated with HEB

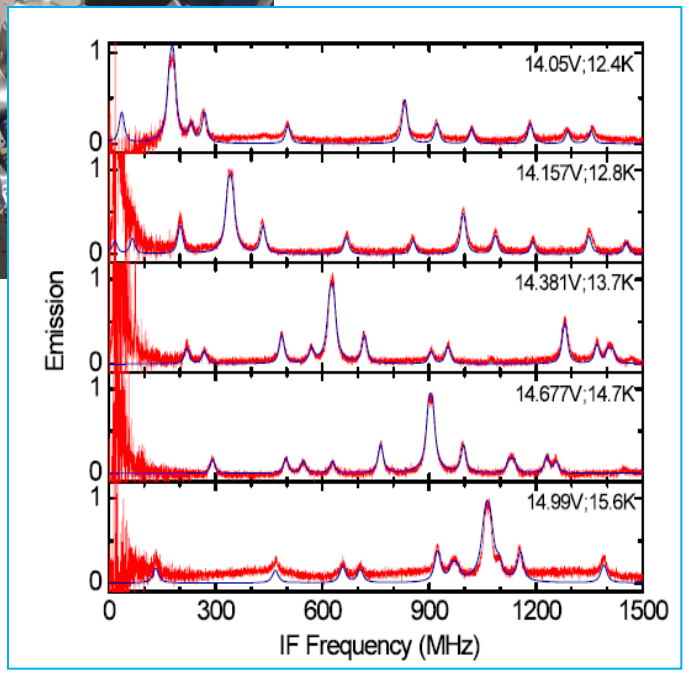




SRON/TUDelft
PMO
MIT
…



Combined THz QCL & HEB with a Gas Cell for the detection of 3.5THz methanol line

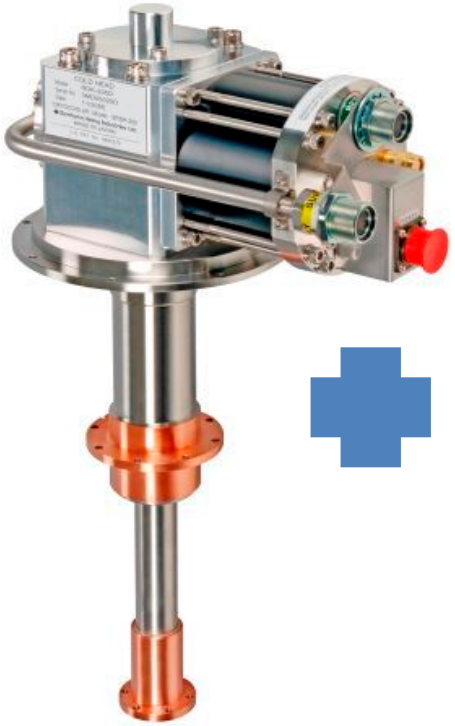


Measured 3.5THz methanol line

Y. Ren, et al., App. Phys. Lett., 97, 161105 (2010)
Y. Ren, et al., App. Phys. Lett, 98, 231109 (2011)
Y. Ren, et al., Appl. Phys. Lett. 100, 041111 (2012)
Y.Ren, et al., Appl. Phys. Lett. , 101111 (2012)

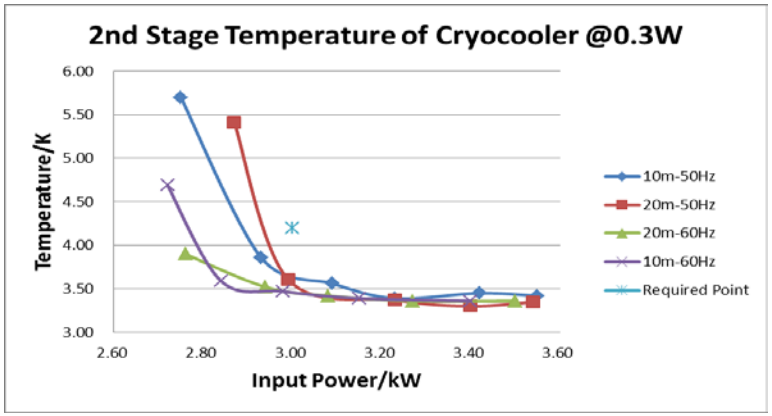
Development of 4K Cryocooler of Low-Power Consumption

Developed jointly with SHI Shanghai, with the help of SHI Japan
Goal: 1) ~3kW power consumption,
2) able to operate at low temperatures about -20°C and to store at low temperatures about -40°C

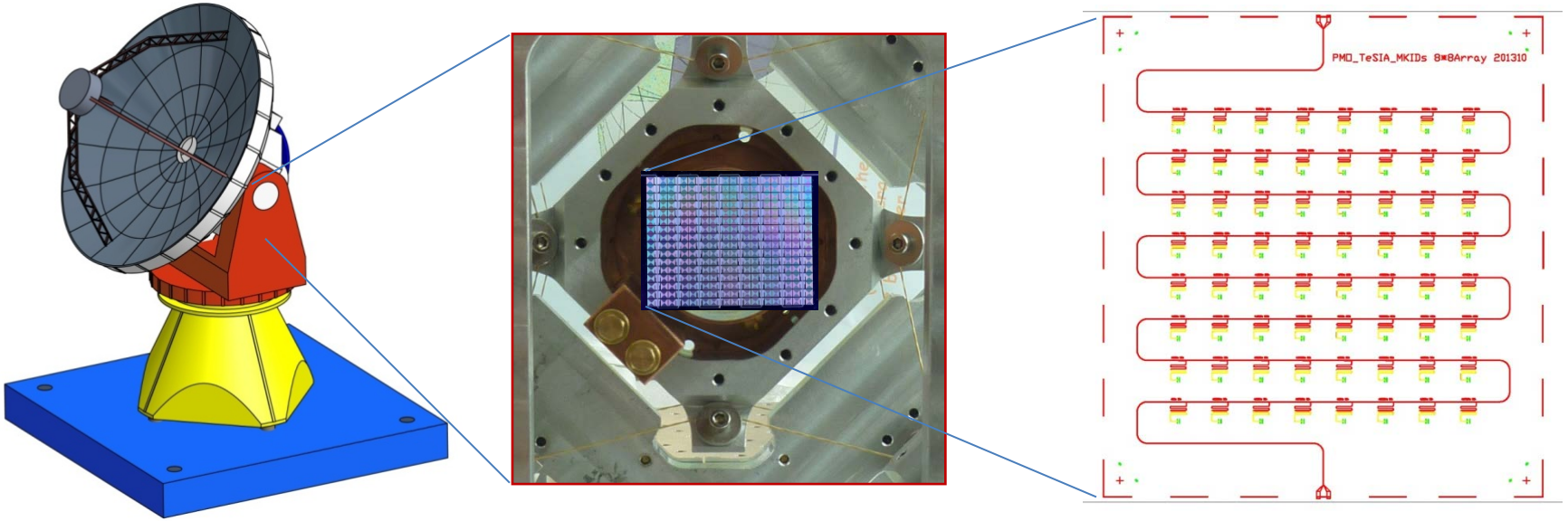


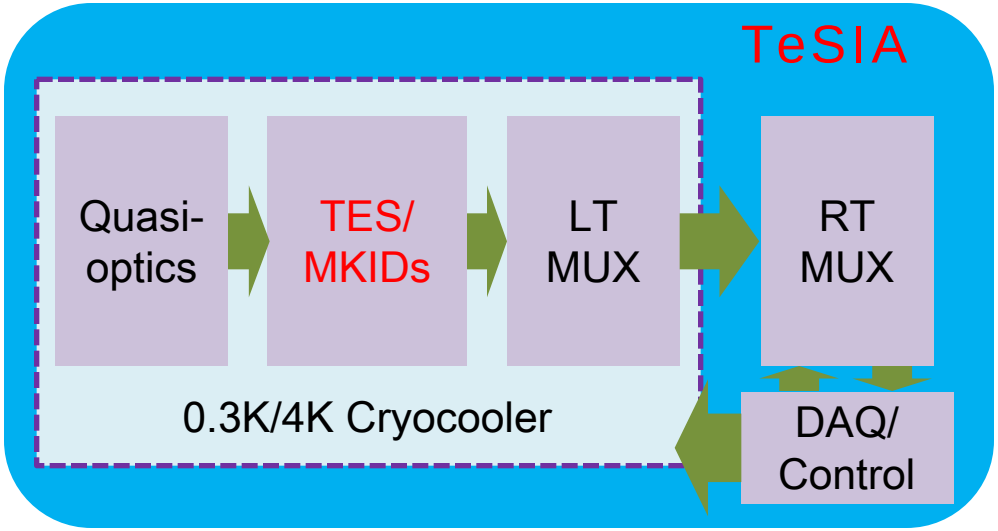
SHI RDK-205D
0.5W @ 4.2K
5W @ 40K

Latest cooling result



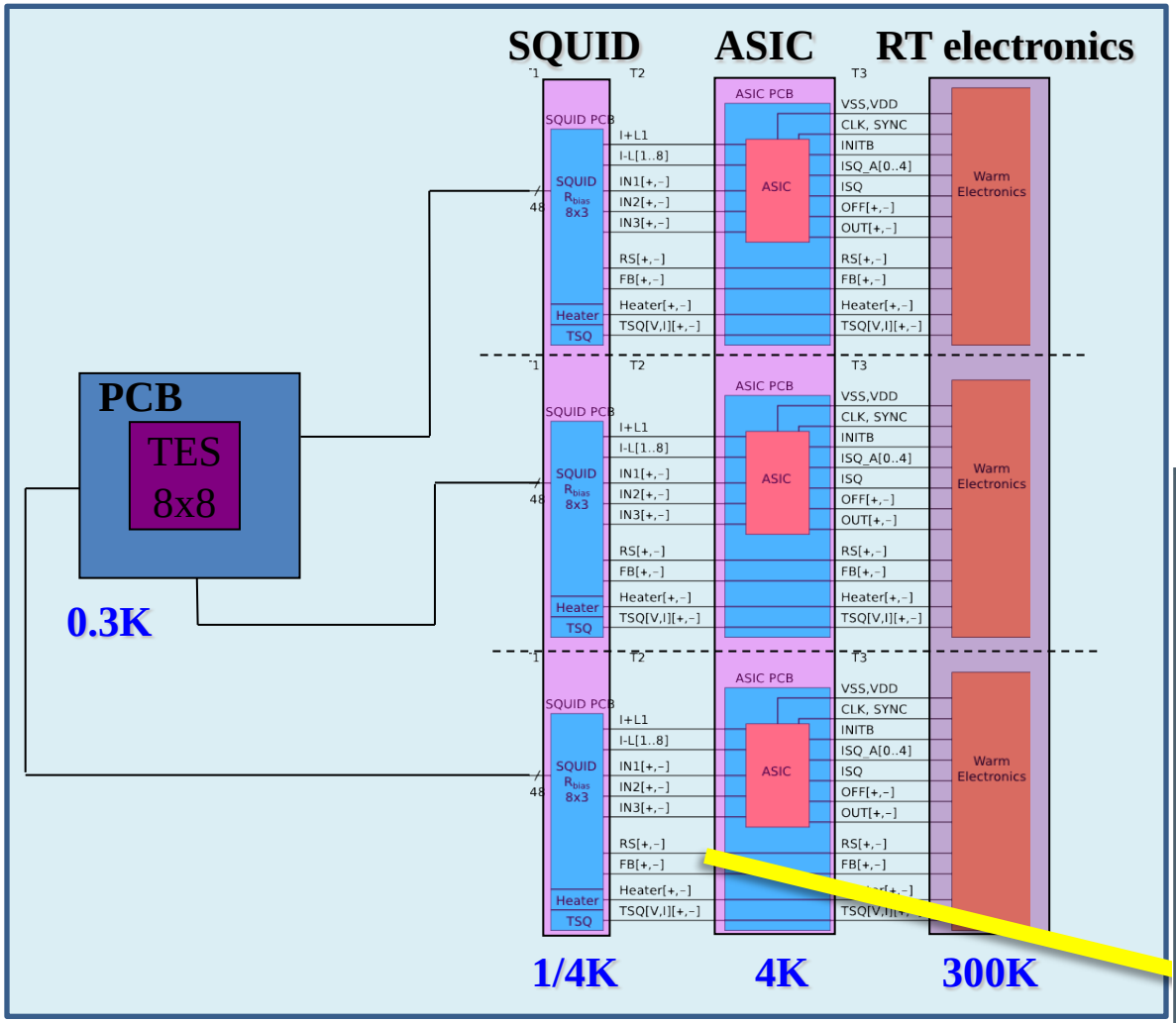
THz Superconducting Imaging Array (TeSIA)



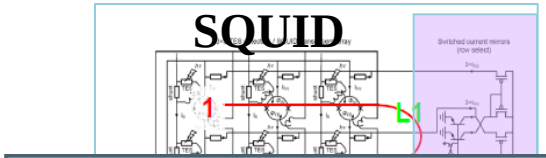


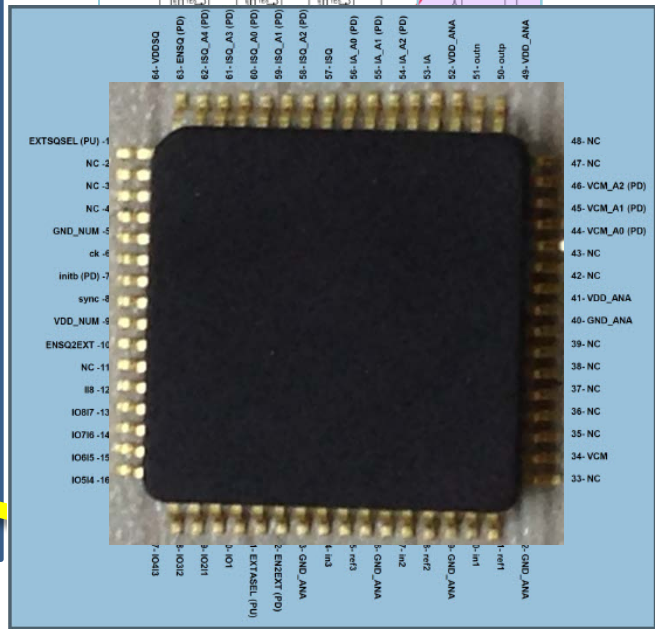
Detector	TES or MKIDs
Array size	32x32
Band	350μm
Sensitivity	BGLP, $1x10^{-16}W/Hz^{0.5}$

TeSIA Developed with TES

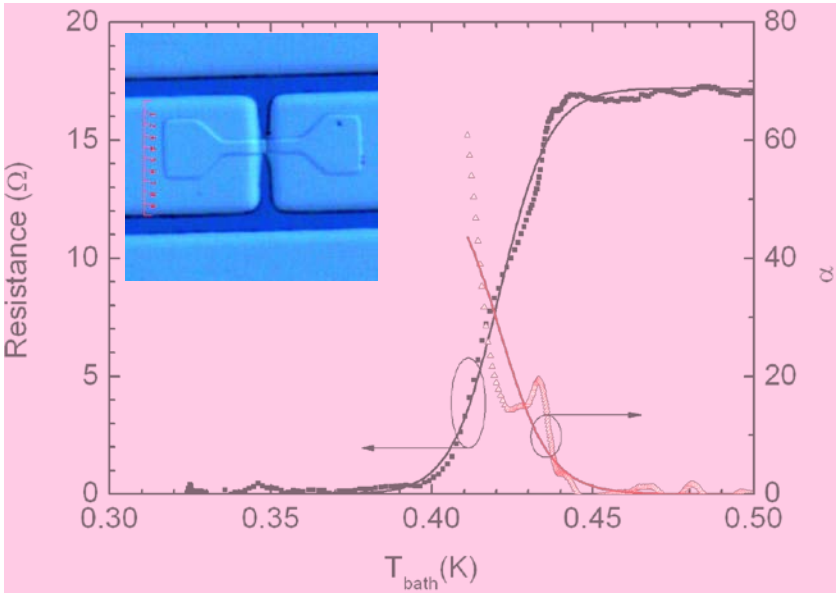


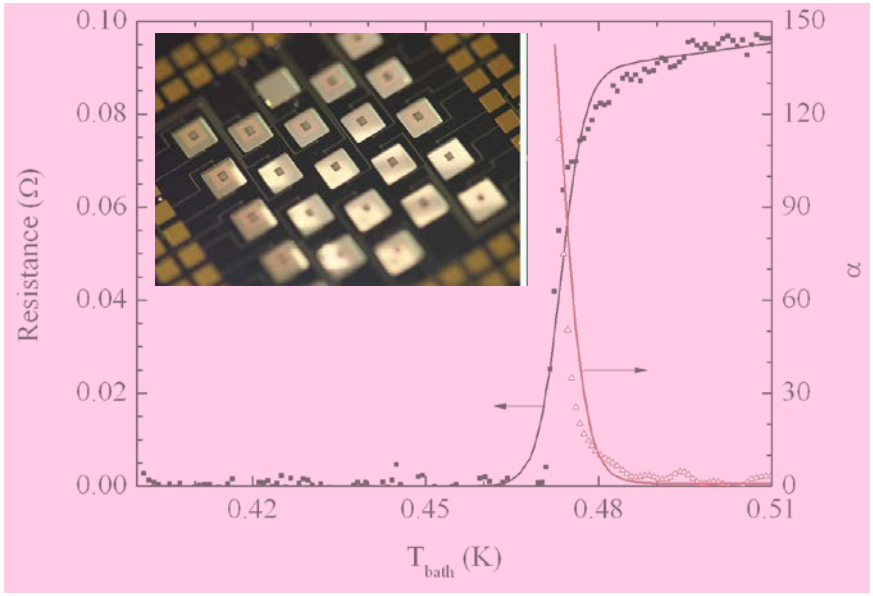
TES Array (8x8 @ 850um) with TDM





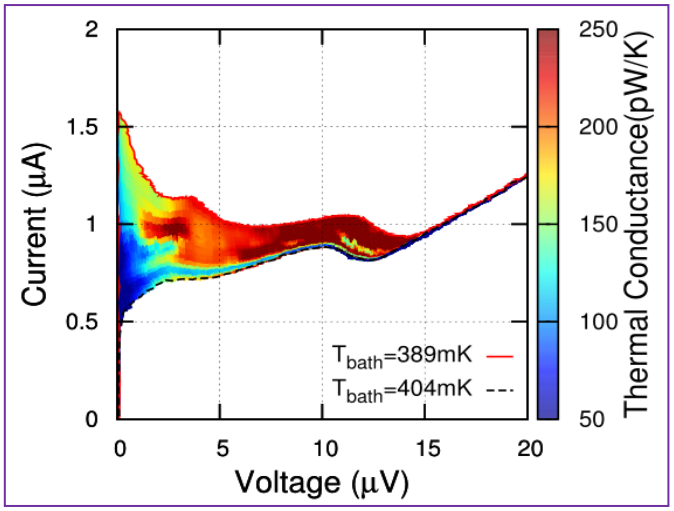
Ti & NbSi Superconducting TES

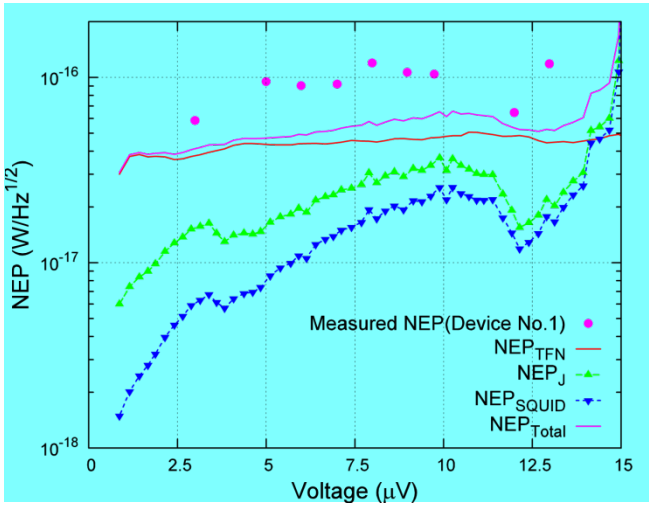




Measured R-T for Ti (l) & NbSi (r) devices

Ti & NbSi Superconducting TES

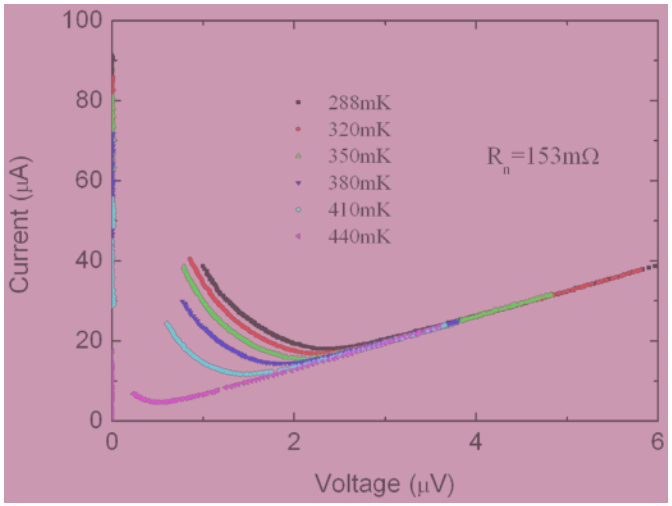


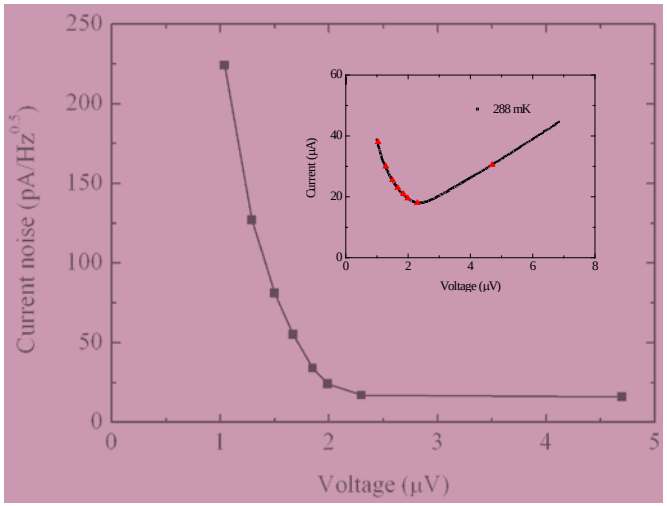


Ti TES

G=170~ 280 pW/K

NEP_{dark}≈6.5e-17W/$Hz^{0.5}$





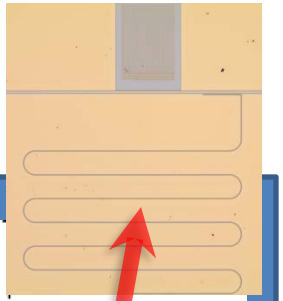
NbSi TES

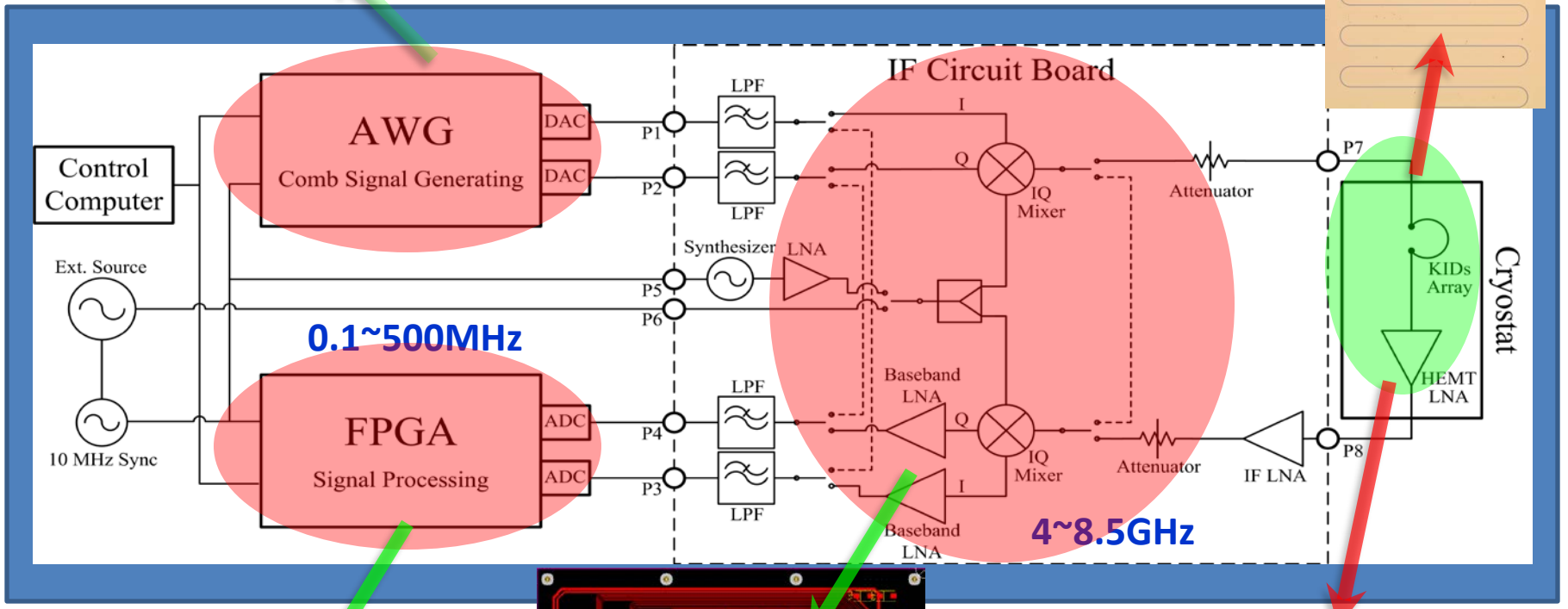
G=345 pW/K

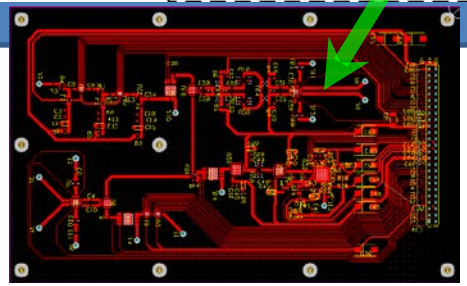
NEP_{dark}≈5.4e-17W/$Hz^{0.5}$

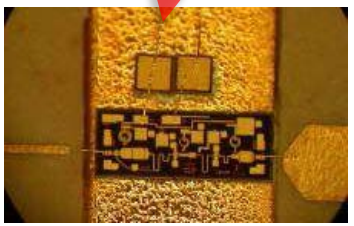
TeSIA Developed with MKIDs

MKIDs Array (8x8 @ 850um) with FDM

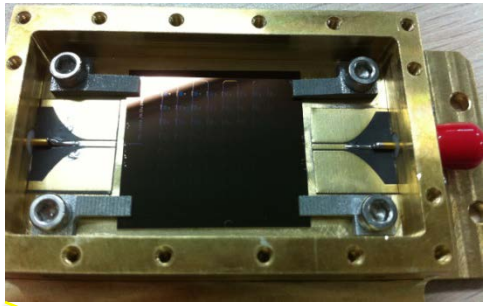


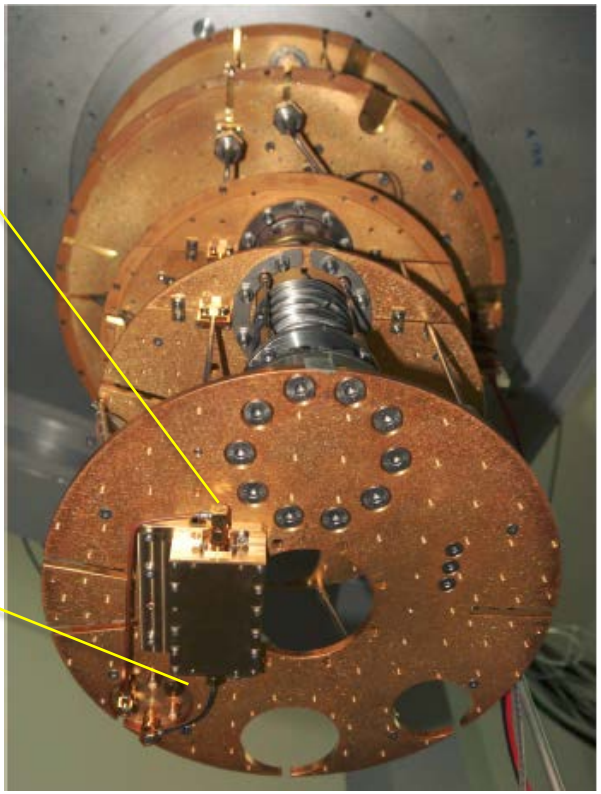


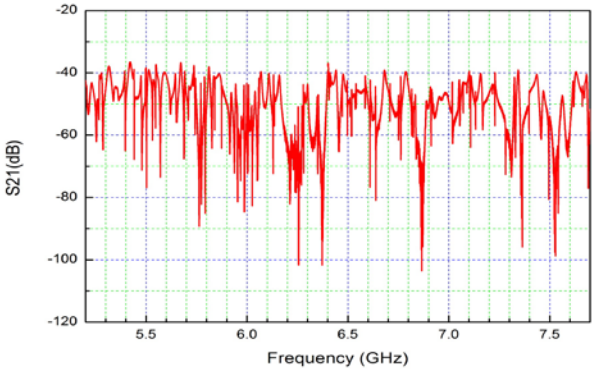


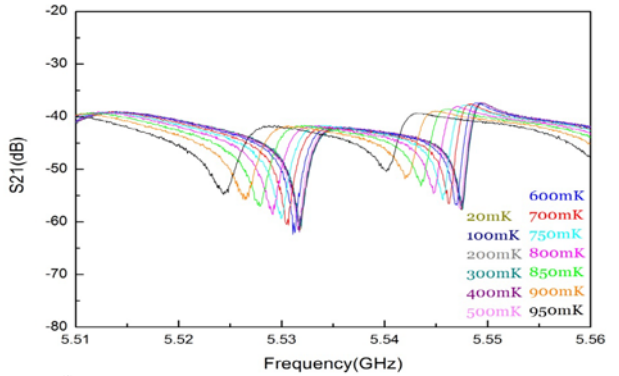


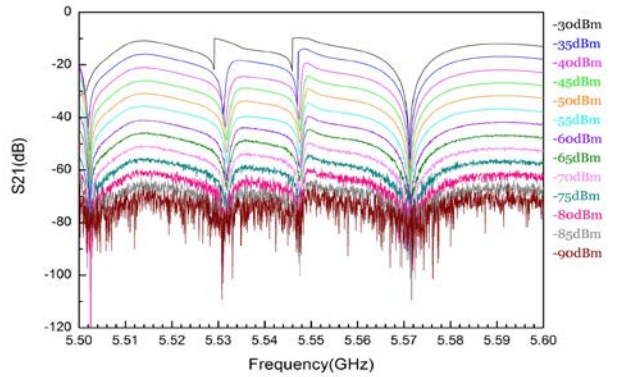
Measured 8x8 TiN MKIDs





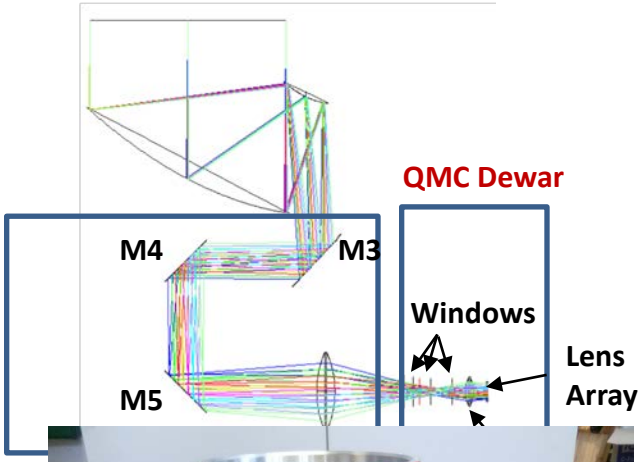


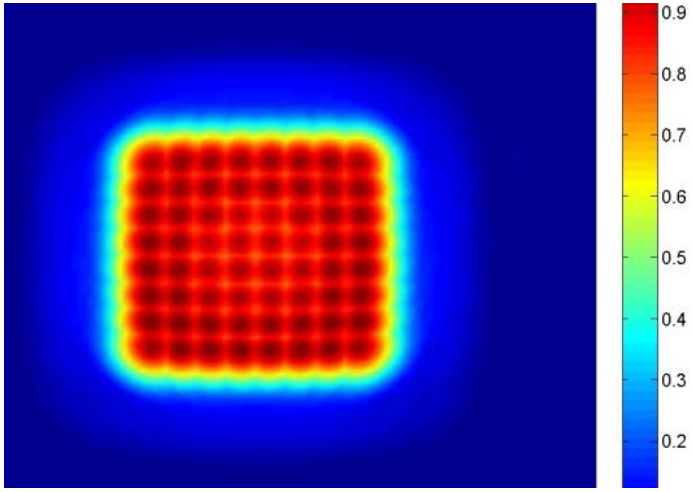


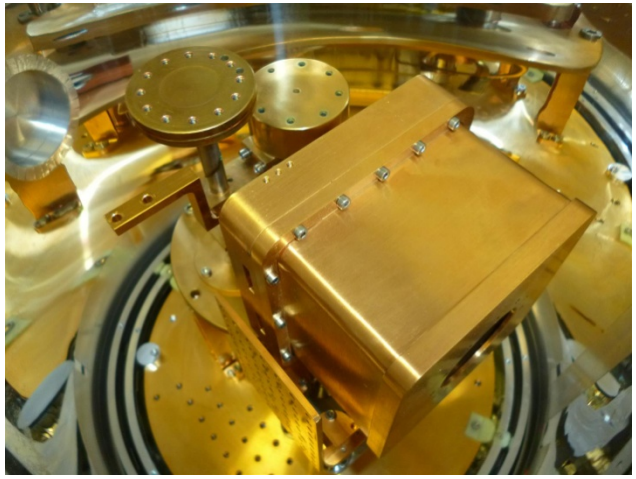


Measured S21 vs T & P
Typical Q~10^4

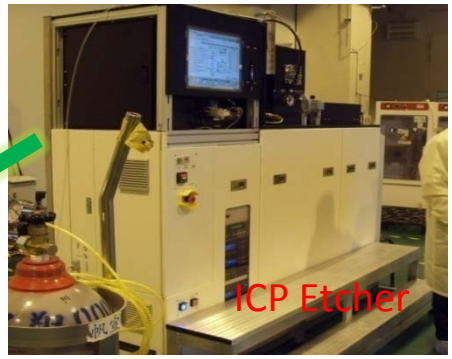
Prototype To Be Tested on POST

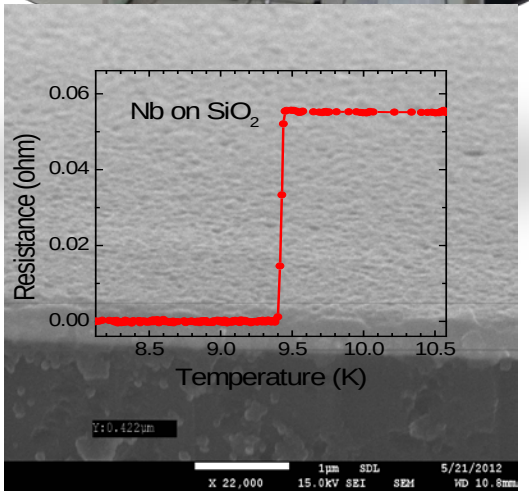


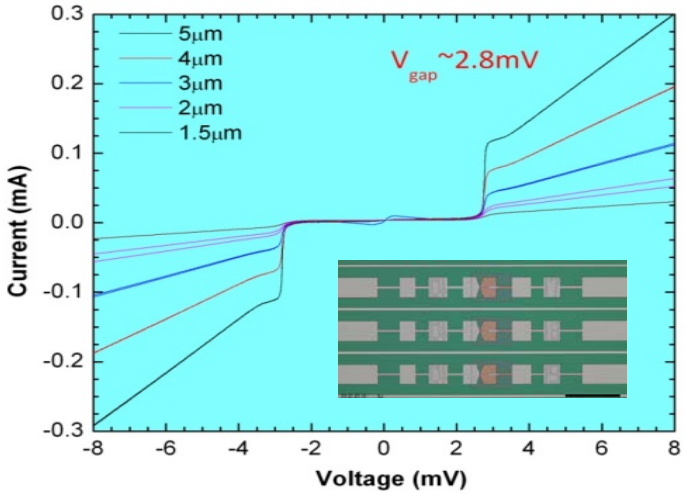




A Newly Built Clean Room Facility







Conclusion

- Atmospheric transmission from 0.75-15 THz measured directly ever at Dome A, which is a rather promising site for THz astronomy,
- First generation instrument for DATE5 telescope will be two heterodyne receivers, and a 32x32 superconducting imaging array at 350 μm (TeSIA) is under development,
- TeSIA is developed with TES and MKIDs, with TESs demonstrating a dark NEP better than 10-16 and MKIDs a reasonably high quality factor,
- Prototype imaging array (850 μm) will be demonstrated on POST in 1~2 years.

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- APC/IAS/ASIAA for the fabrication of TES devices
- RIKEN for the fabrication of MKIDs devices
- …