Development of Microwave Kinetic Inductance Detector for Astronomical Observations

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Outline

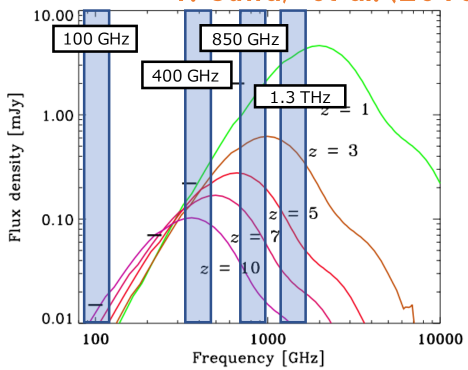
- Background
  - Scientific Motivation
  - Microwave Kinetic Inductance Detector; MKID
- How to fabricate MKID device?
- Measurement MKID device
- Future developments
- Summary

1.1 Survey of Distant Universe

How galaxies were formed and evolved?

- The dust emission from unknown distant galaxies could be observed in mm/submm/THz

T. Suwa, et al. (2010)



Example galaxy spectrum
=> color difference correspond to the difference of redshift z
=>at high-z, spectrum is shifted to lower frequency

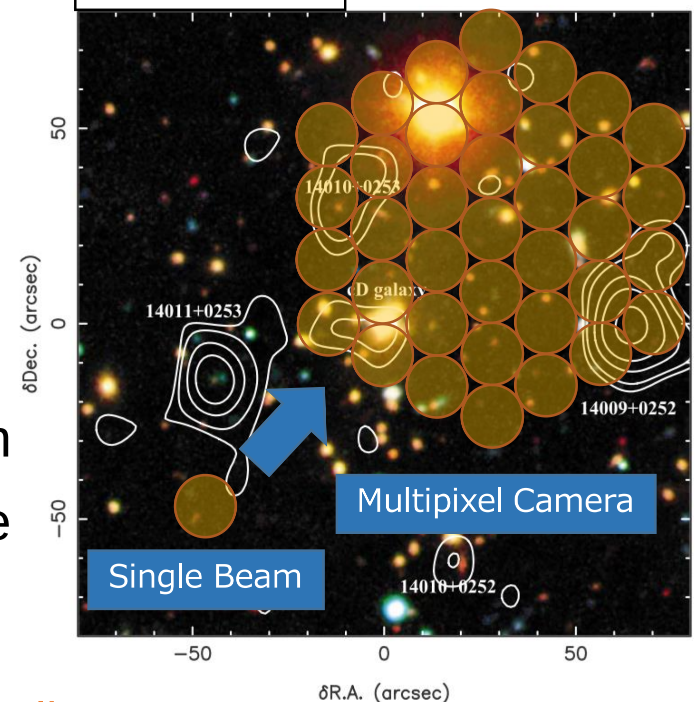
Multiband observation of the dust
=> redshift, temperature, luminosity

- For efficient survey of distant galaxies, we plan to construct Antarctic 10m Terahertz Telescope
  - ✓ Wide-field of view antenna
  - ✓ Multi-pixel radio camera

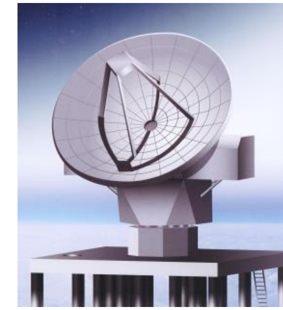
Main topic in this talk

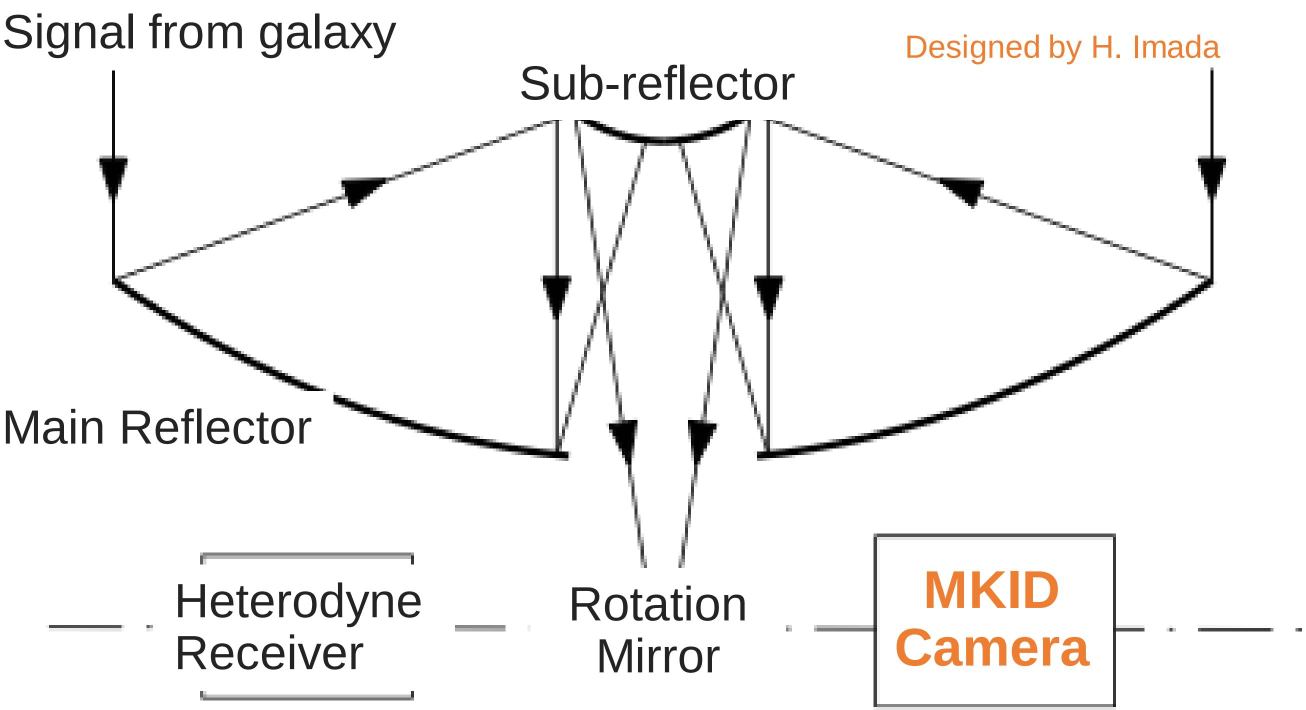
color: optical
contour: submm

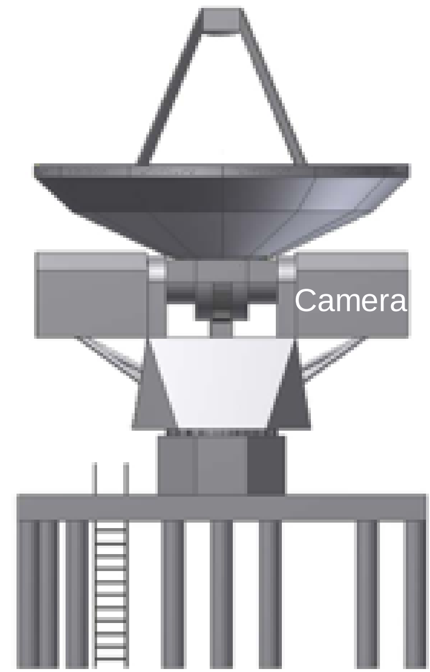
R. J. Ivison, et al. (2000)



1.2 Antarctic 10m Terahertz Telescope







- Wide field of view :1deg.
- Observation band (camera)
  - 0.4 THz, 0.85 THz, 1.3 THz

➡ *Survey of young, distant galaxies*

MKID is one of the important technology for realizing wide-field camera

1 Background

1.3 Microwave Kinetic Inductance Detector; MKID

Day, et al.(2003)

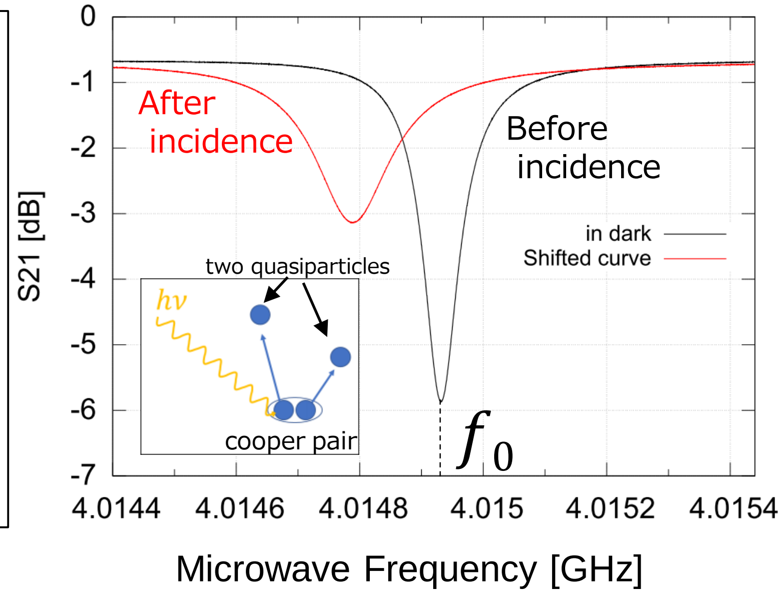
Superconducting Resonator operated in Microwave range

Resonant frequency in microwave f_0:

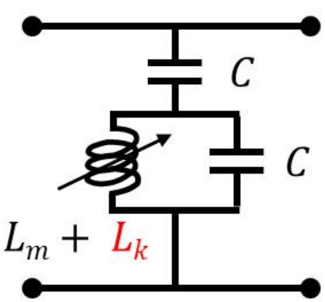
$$f_0 = \frac{1}{4l}\frac{1}{\sqrt{LC}} = \frac{1}{4l}\frac{1}{\sqrt{(L_m + L_k)C}}$$

l: Length of resonator, C: Capacitance,
L_m: Magnetic inductance, L_k: Kinetic inductance
(depend on density of cooper pair)

- The power of incident photon can be monitored from the change of resonant spectrum.



Equivalent circuit

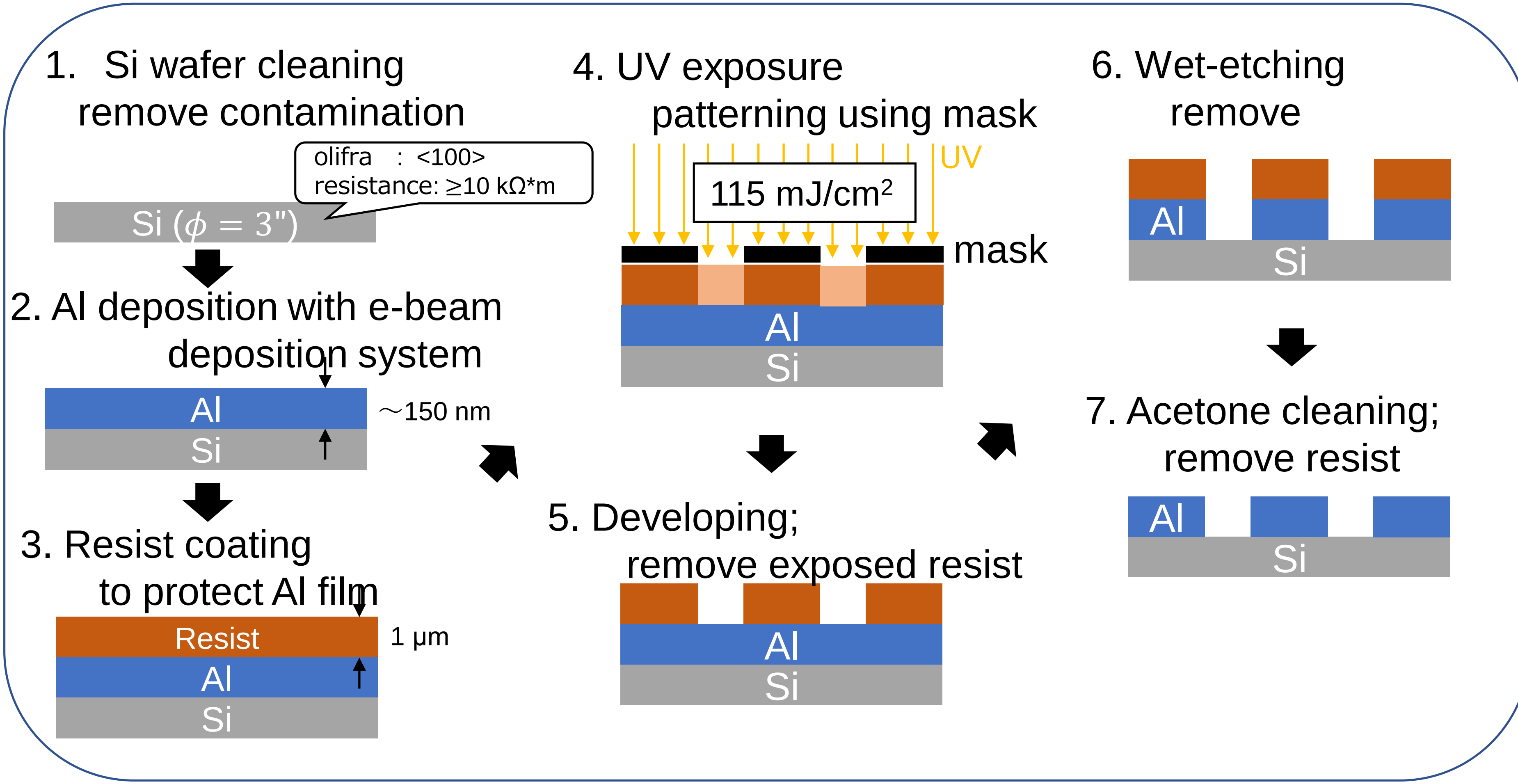


- 100-GHz band camera
- mm-wavelength observation
- This camera will be installed to Nobeyama 45m telescope

=> prototype of Antarctic telescope camera

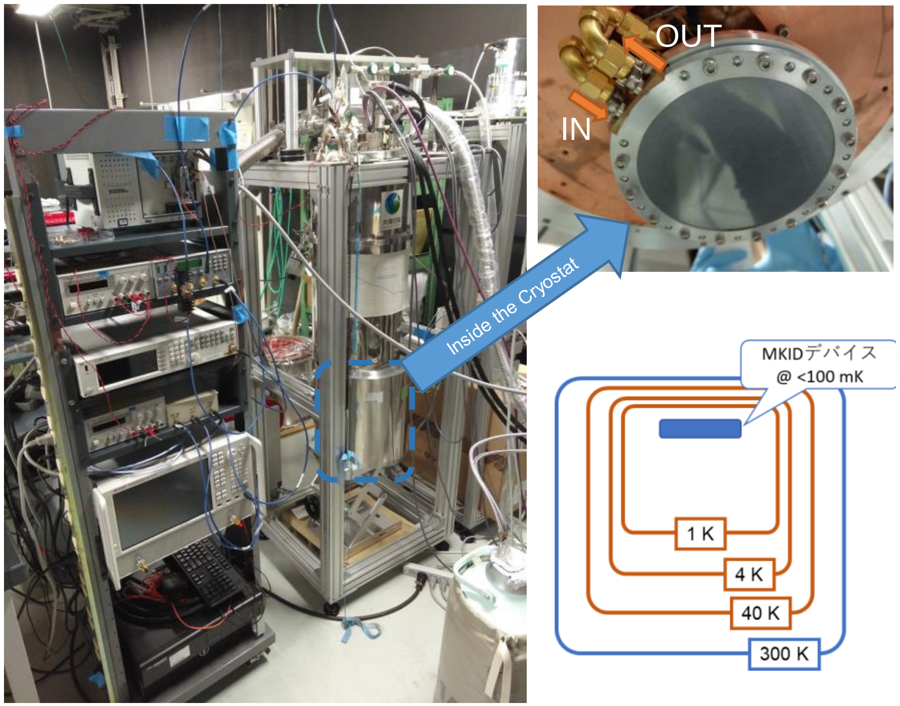
2. Fabrication of 109-pixel MKID device

MKID devices have been fabricated in ATC cleanroom, National Astronomical Observatory in Japan



3. Measurement of 109-pixel MKID device

Measurement condition:
Dark (MKID device was enclosed
by 1-Kelvin shield)
Cryostat and Measurement system in ATC

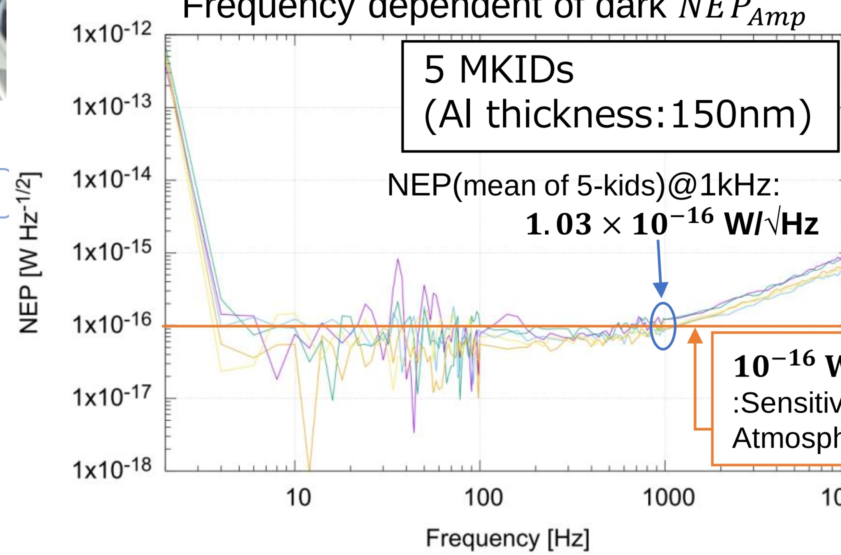


By using measured parameters, we can calculate NEP

$$NEP_{Amp}^{2}(\omega) = S_A(\omega)\frac{1}{\left[\frac{\eta\tau}{\Delta}\frac{\partial A}{\partial N_{qp}}\right]^2}(1+\omega^2\tau^2)(1+\omega^2\tau_r^2)$$

Baselmans et al., 2008

Frequency dependent of dark NEP_{Amp}



There were 95 resonances in the signal.
Yield: 87%(=95/109)

5 MKIDs in the device :
We got good NEP(1kHz) around 10^{-16} W/√Hz in dark condition

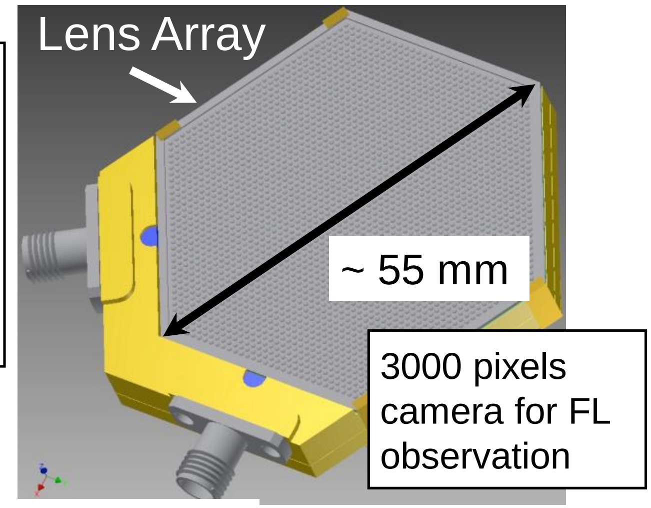
Next step: optical NEP measurement

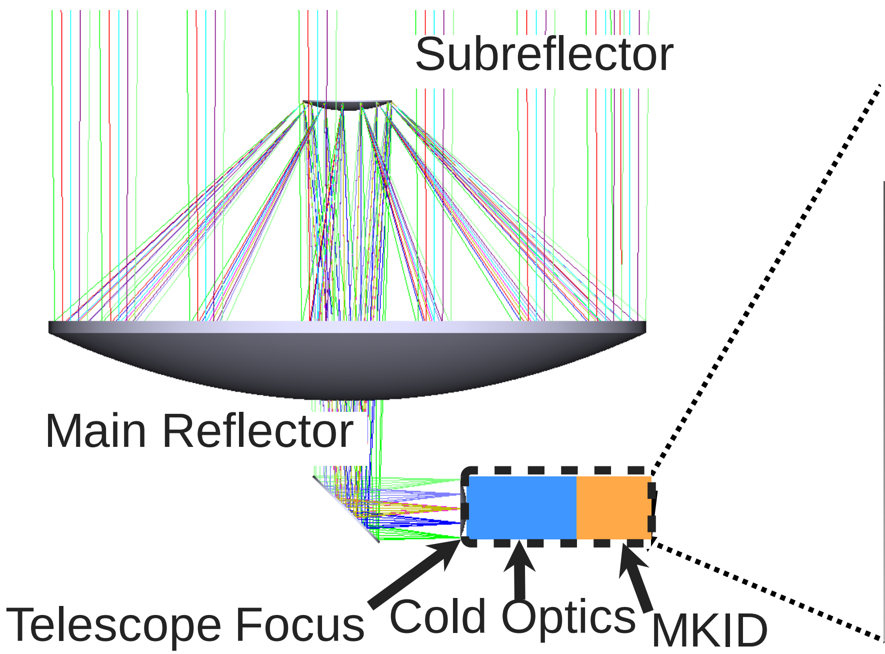
5. Future development

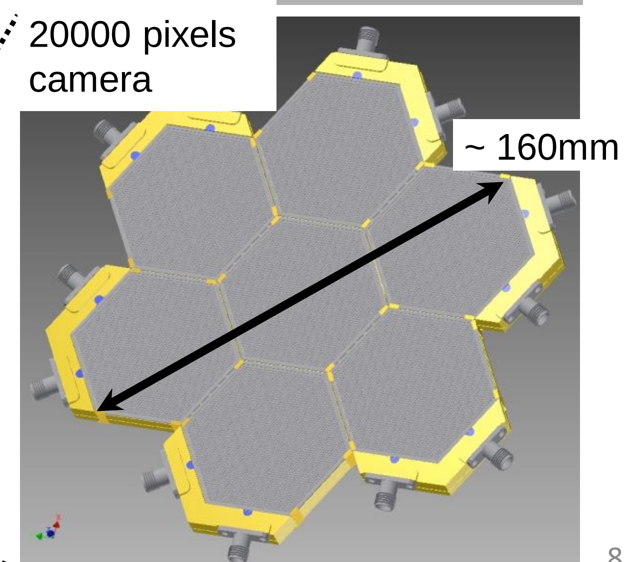
MKID camera for Antarctic 10m Terahertz Telescope

Sekimoto et al., 2014

- 0.85 THz band camera
  - based on NRO45m MKID camera
  - First light module: ~3000-pixel (right fig.)
- 3-bands(0.4, 0.85, 1.3 THz) camera
  - totally 20000-pixel







5. Summary

✓ **Microwave Kinetic Inductance Detector; MKID**

- Pair breaking photon detector by using Superconducting resonator
- Highly frequency domain multiplexing
- Simple structure and easy to fabrication

✓ **MKID Camera for mm~THz Astronomical Observation**

- 100GHz band 109-pixel MKID camera for NRO45m

  Yield ~87% and $NEP_{Amp}(1kHz) \cong 10^{-16}$ W/√Hz (5MKIDs,dark)

- MKID camera for Antarctic 10m Terahertz Telescope

  Totally 20000-pixel camera(0.4, 0.85, 1.3 THz bands)