Commissioning Results of 100-GHz Band Nobeyama MKID Camera

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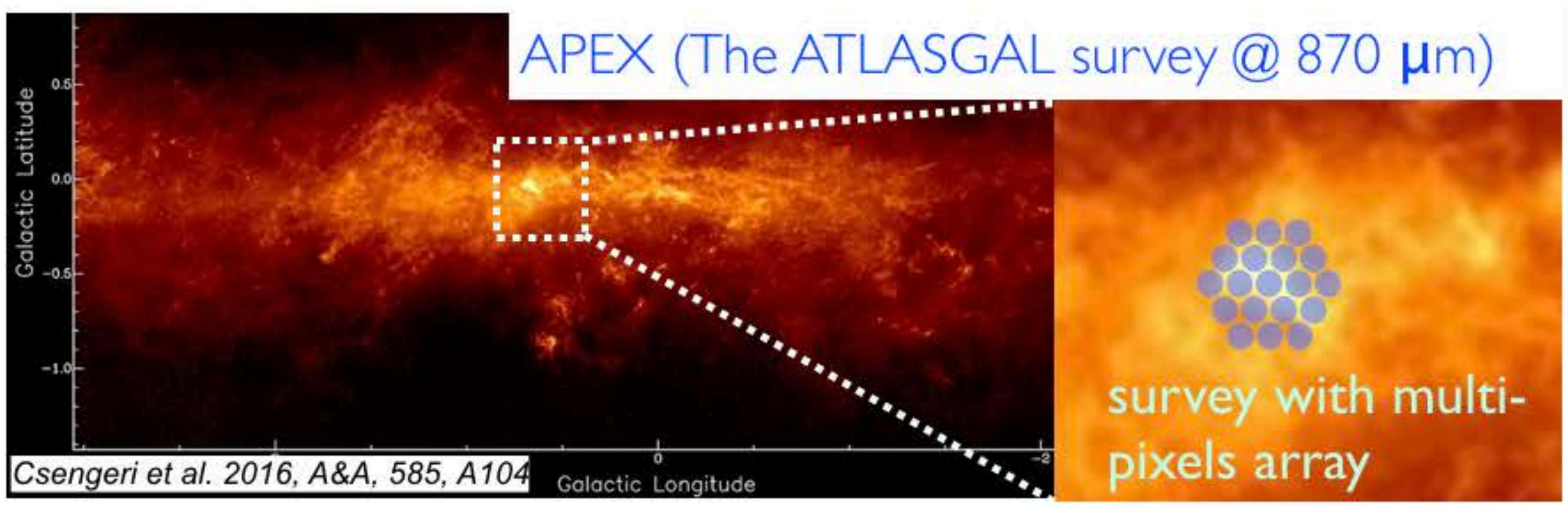
Wide-Field Continuum Camera

✳ 100-GHz band Camera (now developing)

- Camera was installed on the Nobeyama 45m telescope
- Collaboration with NAOJ
- free-free emission is dominant at the 100-GHz continuum
  - good tracer of the massive star forming region (HII region)



✳ THz band Camera (Future Plan)

- Our group is planning to construct the 1deg. FoV 10 m telescope at the Antarctica plateau.
- frequency band : 400 / 850 / 1300 GHz

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

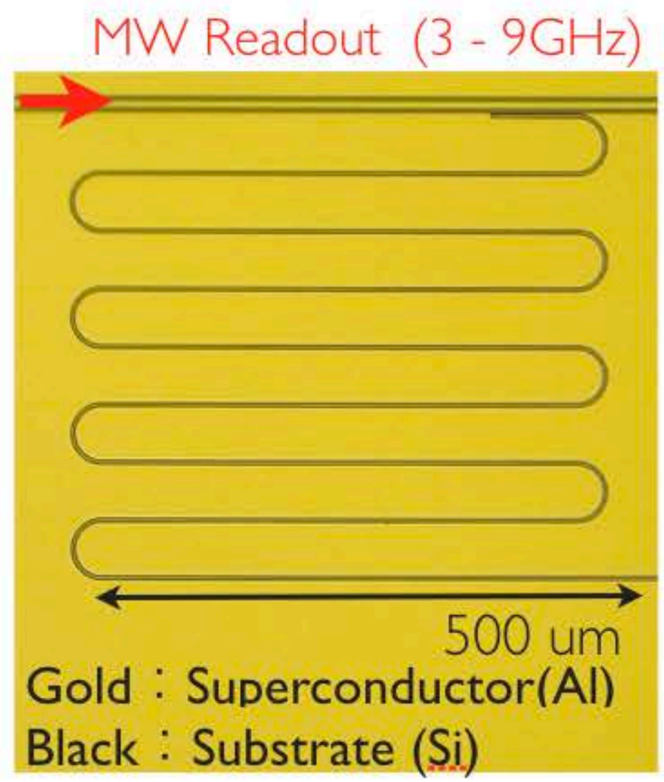
Day et al., Nature, 2003

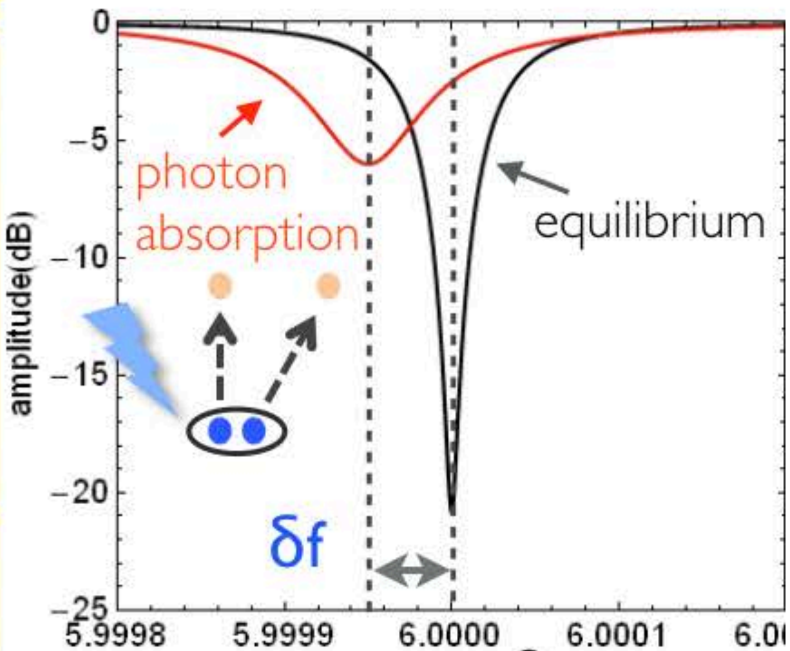
Microwave Kinetic Inductance Detector (MKID)

✳ Operation Principle

- Superconducting resonators operated in the microwave range
- Incident photons break Cooper-pair
  - → Kinetic Inductance is changed
  - → Resonance frequency of MKID is also changed

Signals from the objects are observed by monitoring the shift of the resonance frequency.

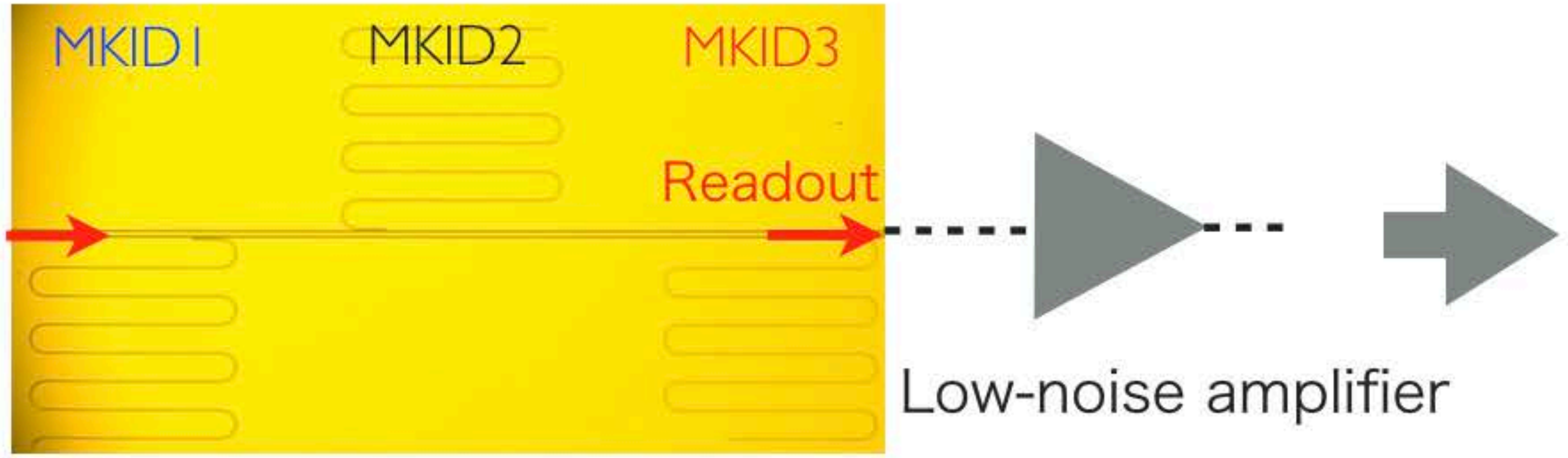


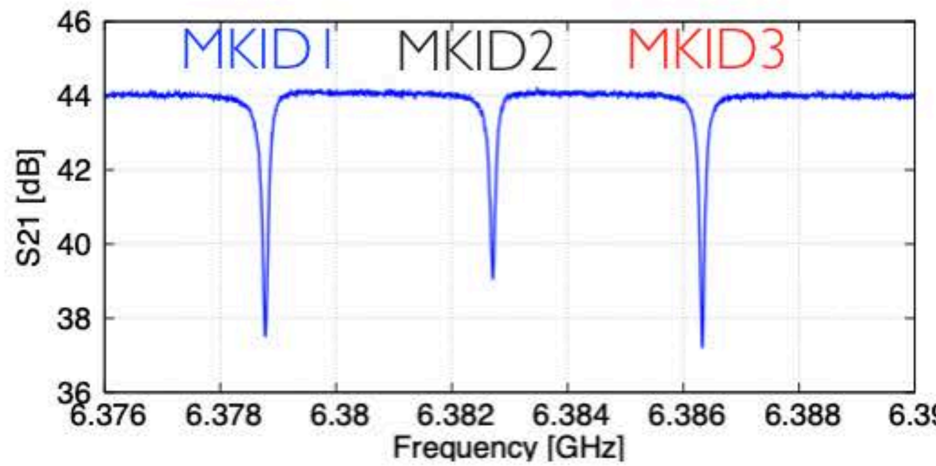


$$\omega_0 = \frac{2\pi}{4l\sqrt{(L_g + L_k)C}}$$

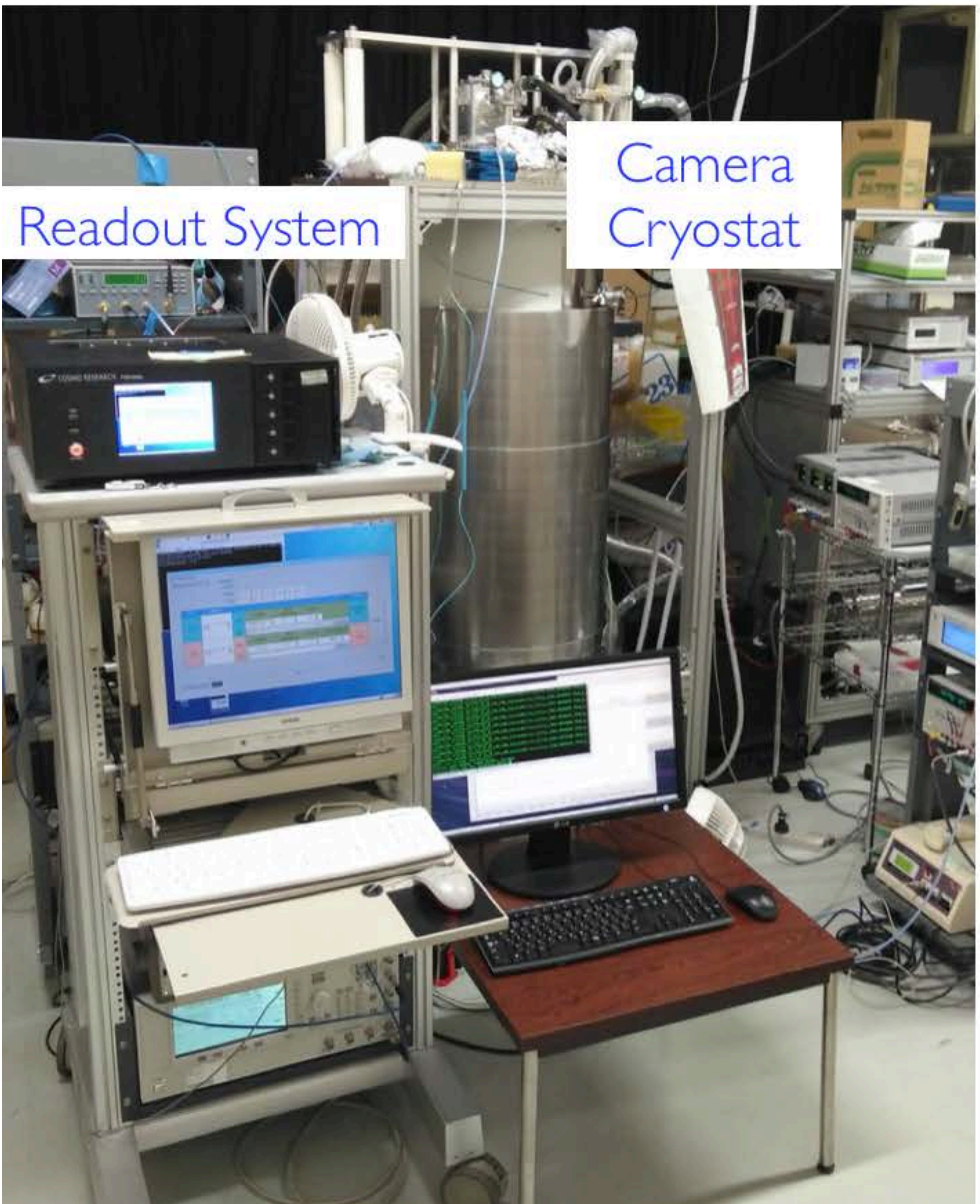
✳ Advantage of MKID

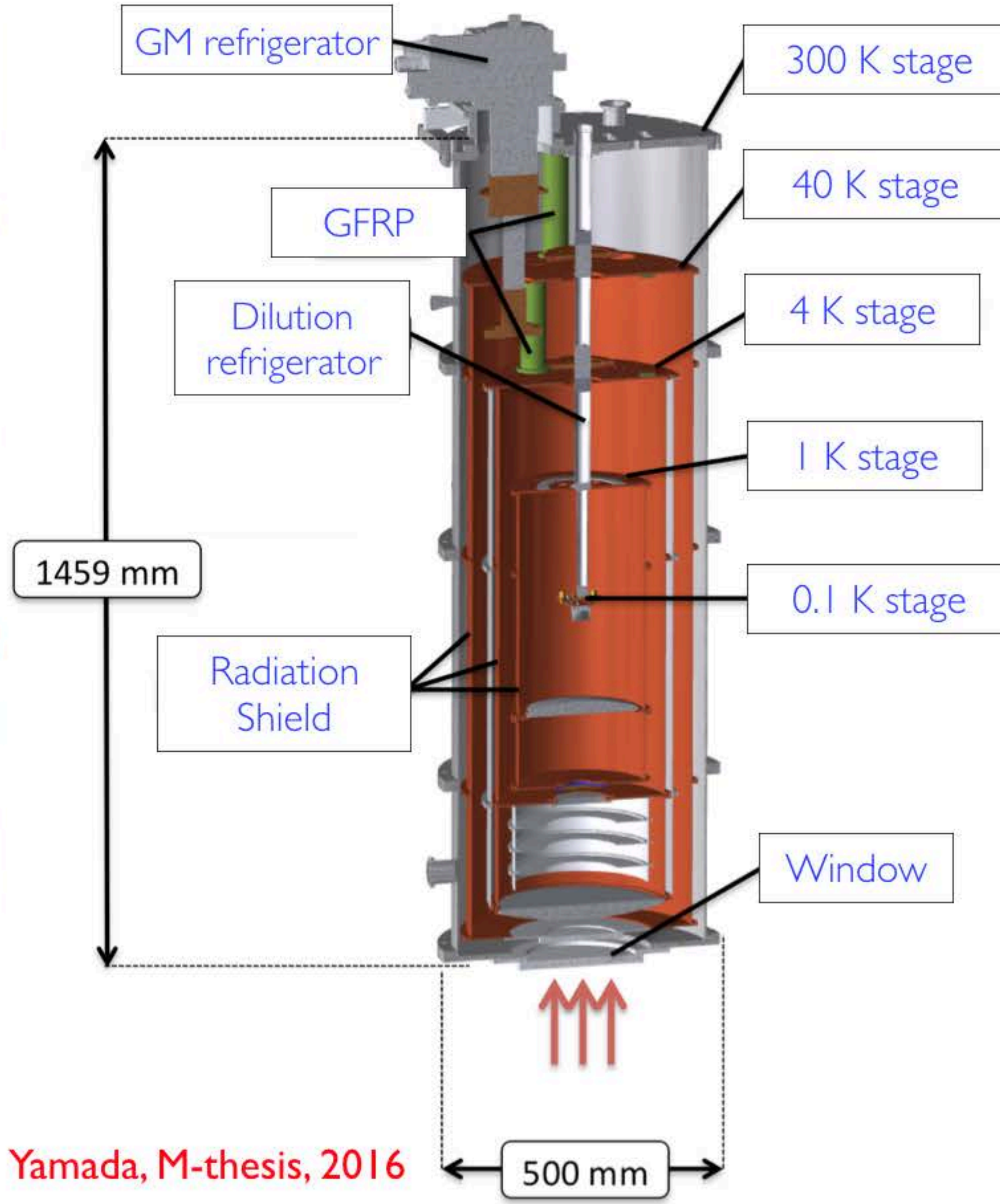
- High-detector yield is expected because the MKID fabrication process is relatively simple
- Intrinsic frequency multiplexing capability → ~1000 pixels can be measured with one LNA





Camera Cryostat





Yamada, M-thesis, 2016

Focal Plane Array

✳100-GHz band MKID Array

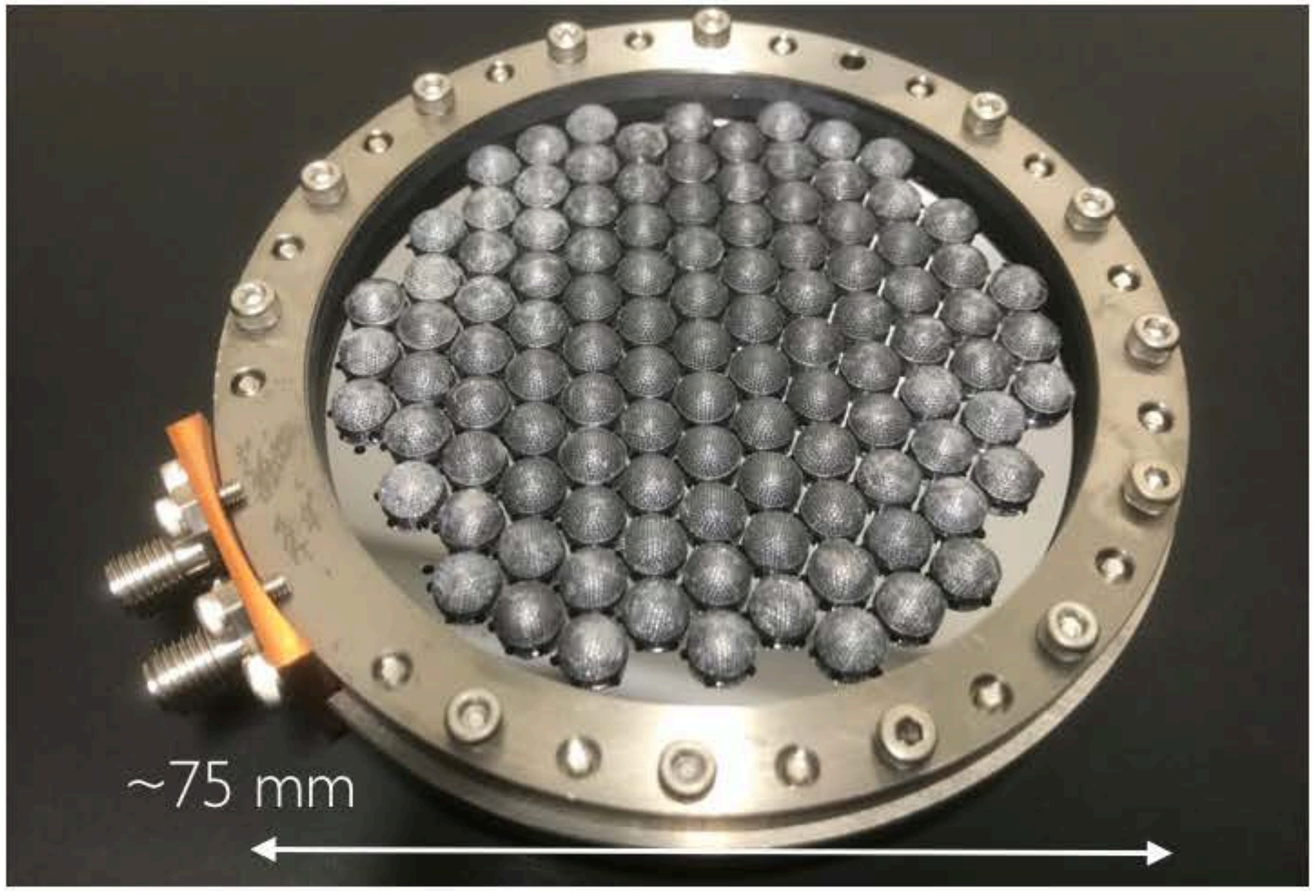
Murayama et al. in prep

- Al-NbTiN 109 pixel MKIDs
  - − 50 nm Al & 200 nm NbTiN
- Double-slot antenna & Si lens array
- Glass beads AR coating

✳Improvement (optical efficiency)

- All Al MKID (gap E of Al : ~85 GHz) **(2018 Obs.)**
  - Loss at GND (= low efficiency)
- NbTiN-Al MKID (gap E of NbTiN : ~1.1 THz)
  - NbTiN GND and Al signal line

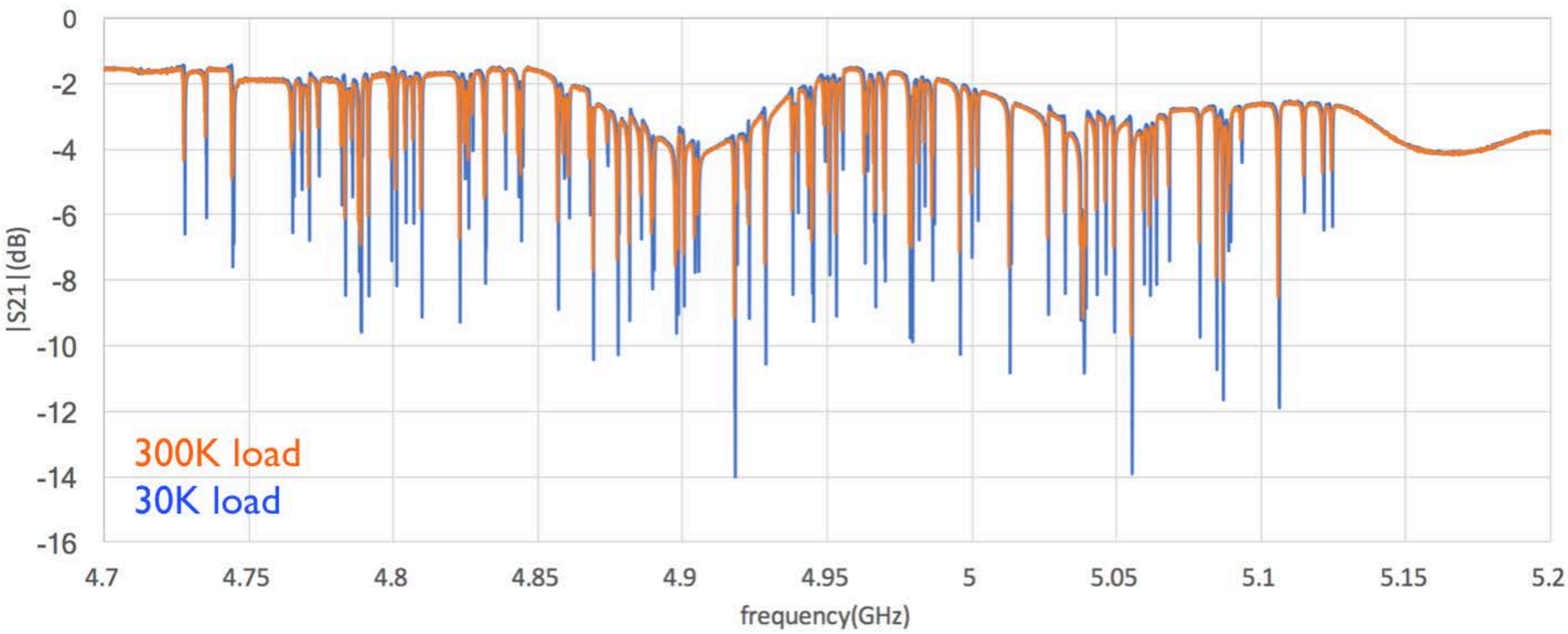
Yates et al., 2011



Optical Response

❖ Detector Yield

- 104 / 109pixels
- High yield was achieved （Good fabrication process）



Sensitivity

✳ Sensitivity Measurement (Single pixel readout)

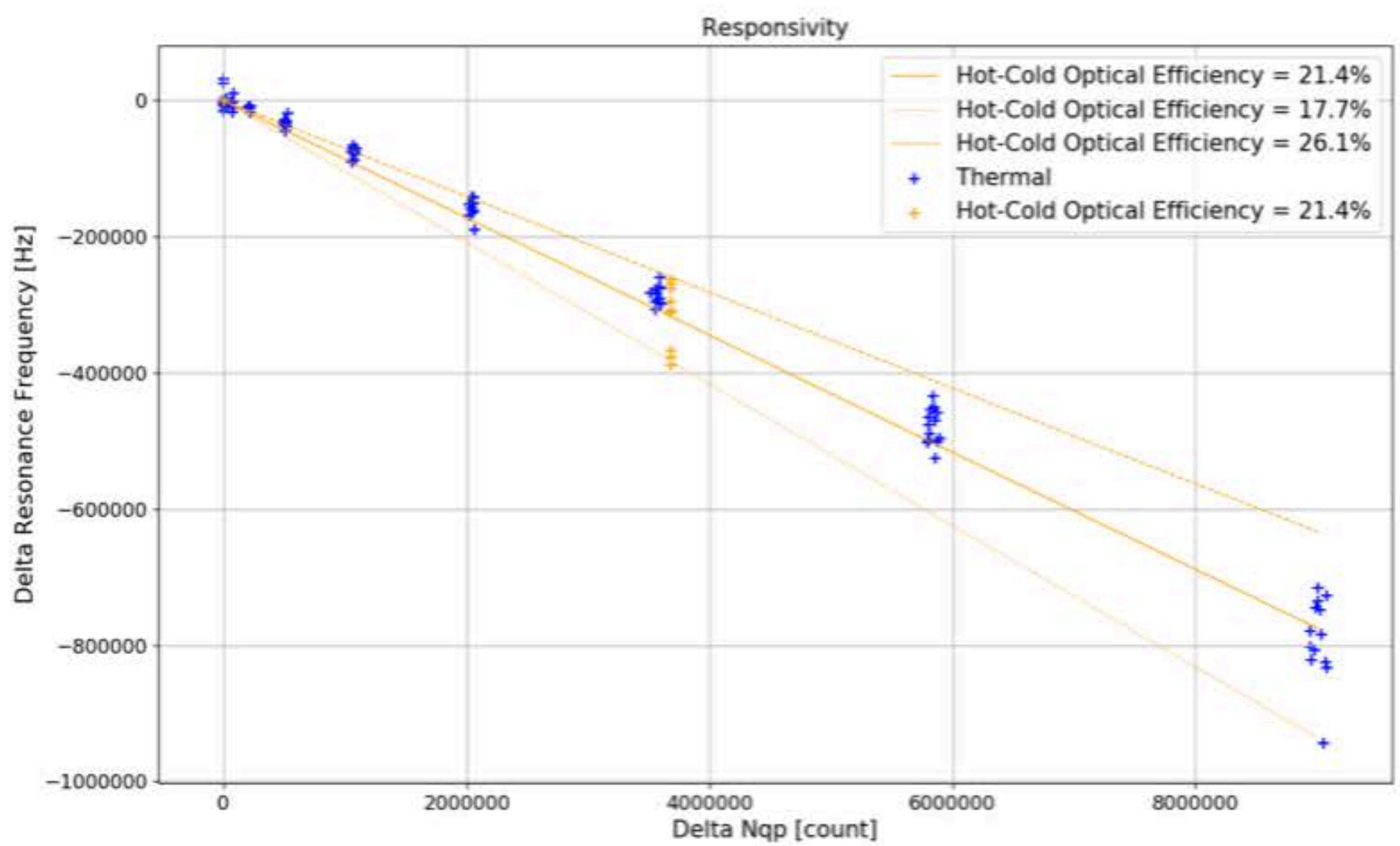
✳300 K load : 80 pW loading

✳77 K load : 20 pW loading (close to the sky condition at Nobeyama)

- Total optical efficiency : η_{inst} ~ 20%

  → comparison between the "optical" and "thermal " responsivity

- Optical Noise Equivalent Power : NEP_{opt} ~ 6 × 10^{-16} W/rHz @20 pW



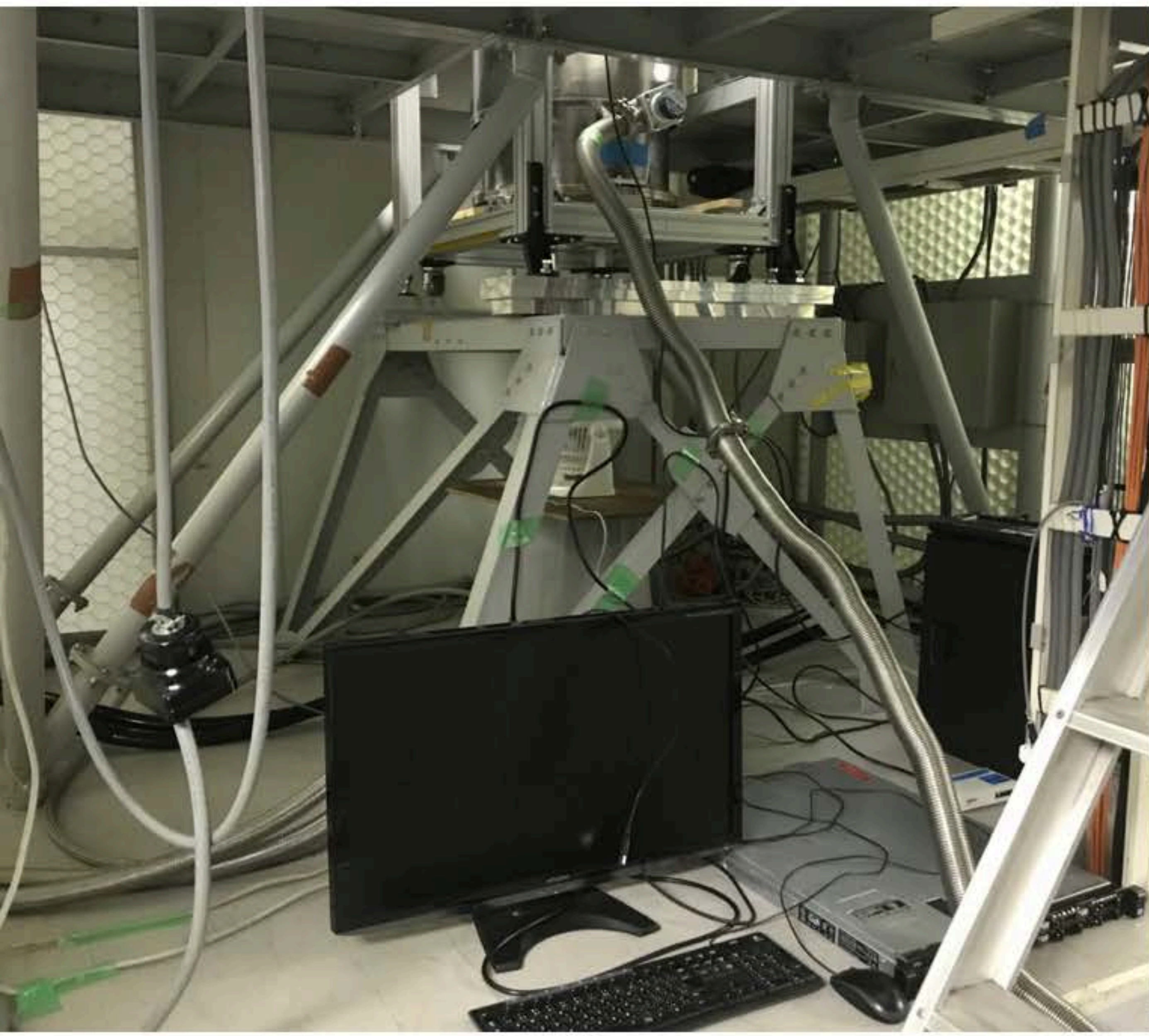
Hikawa, M-thesis, 2020

Commissioning

Camera @Receiver Cabin

✳ <u>Commissioning Period</u>

- 2021/5/30 ~ 6/8 (21 hours total)

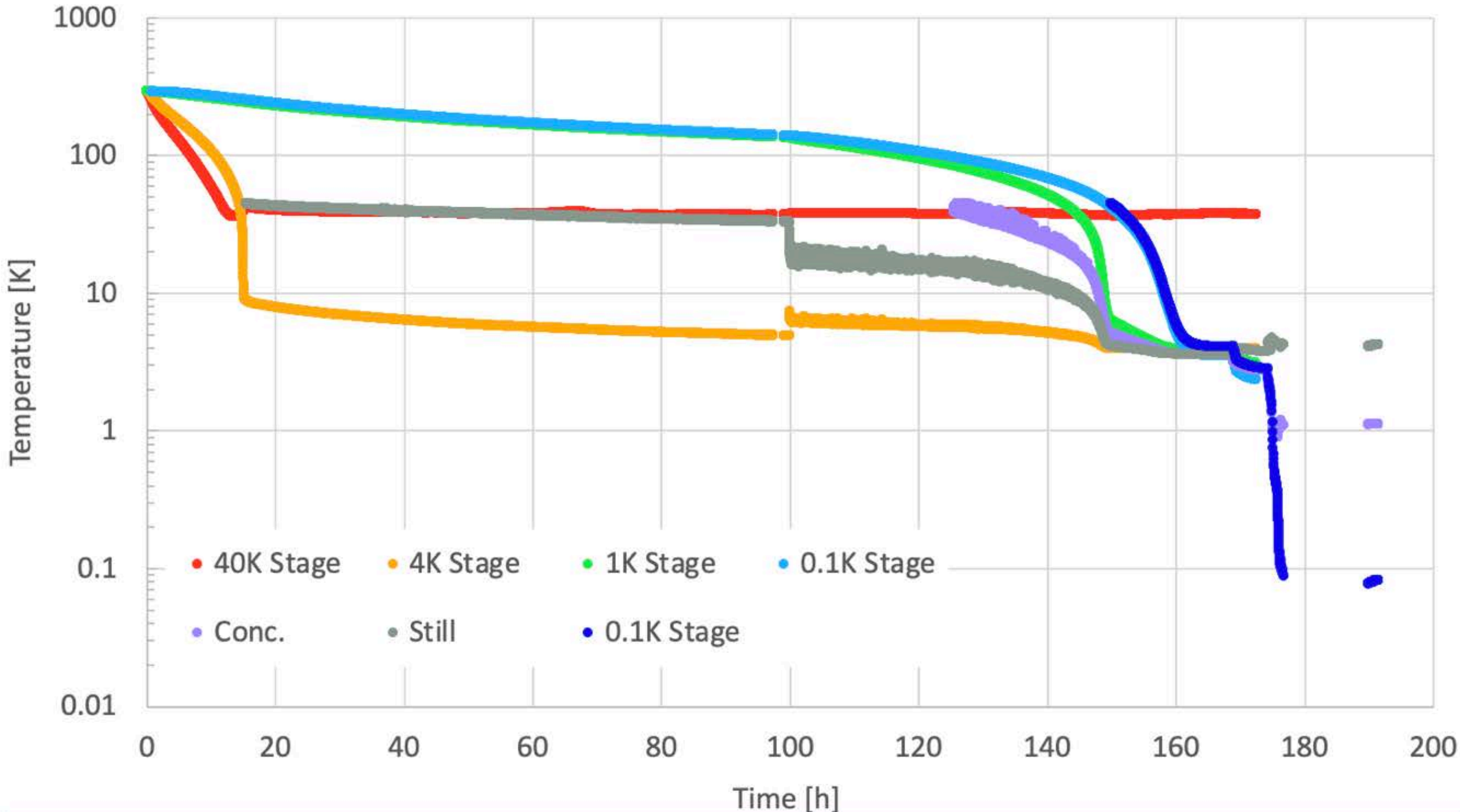


Cooling Curve

・Cooling Time : ~175 hours (~7days)

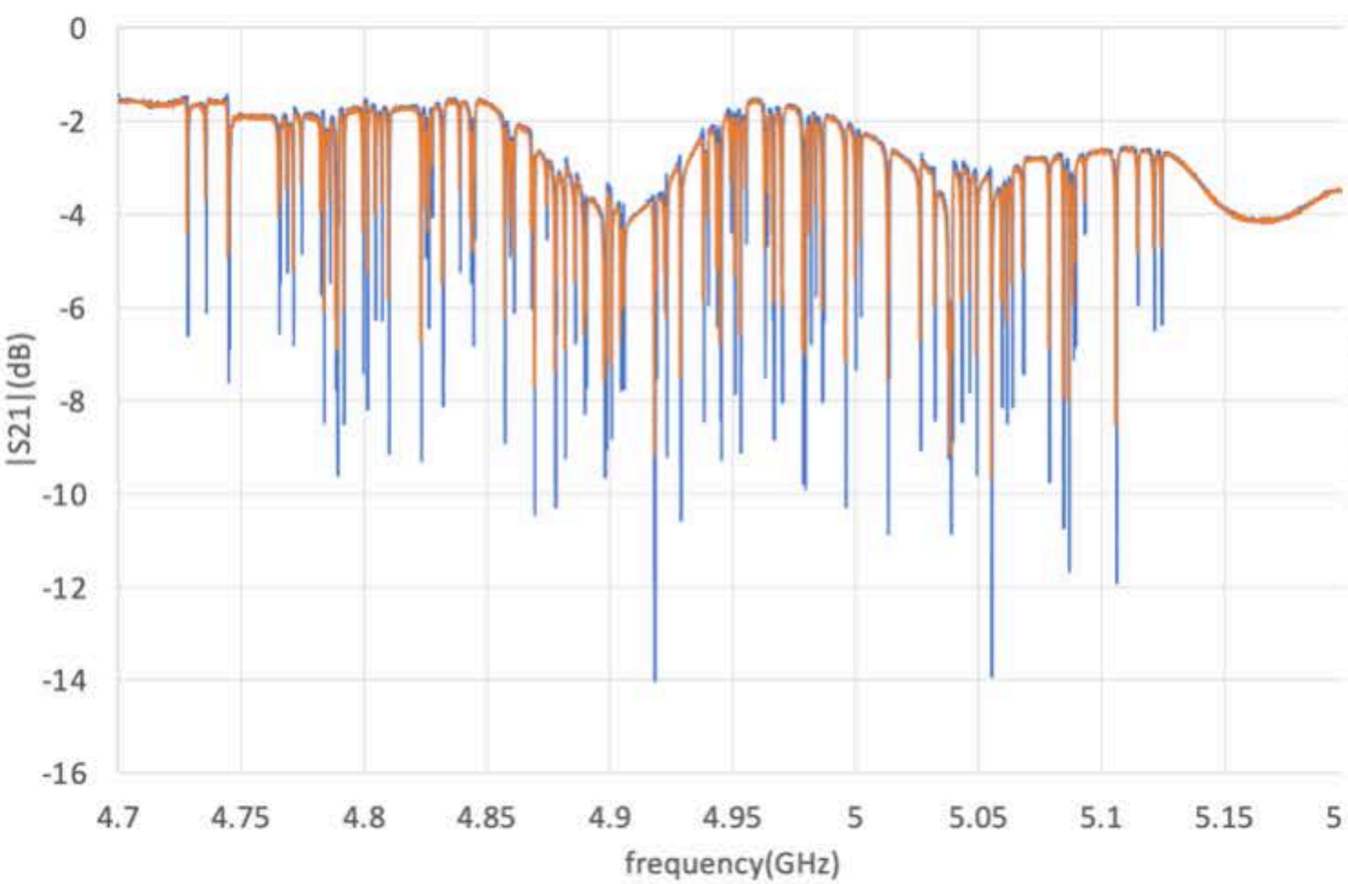
→It took longer time than lab due to the timing of the He-gas introduction

・Reaching Temperature : 82 mK

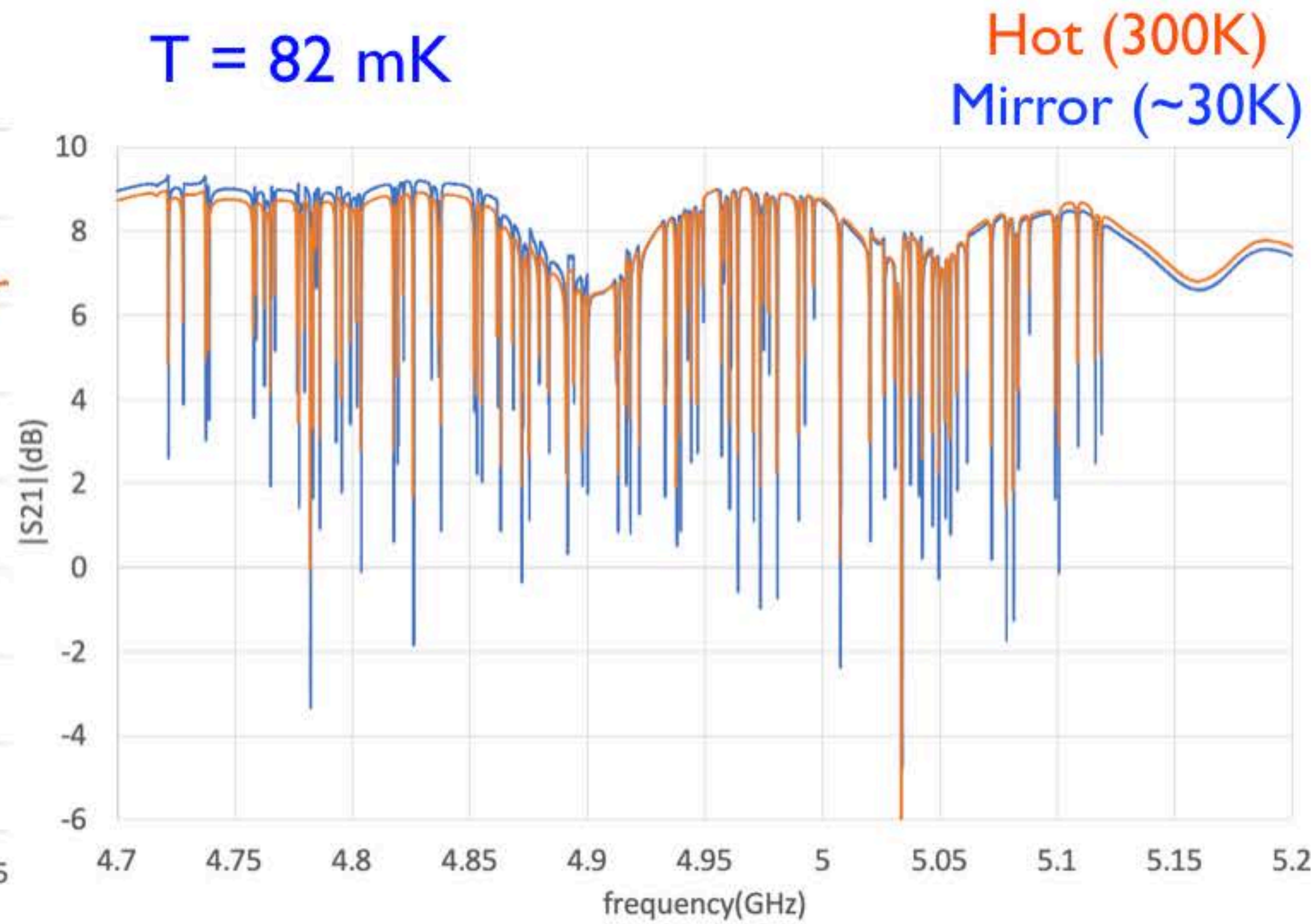


S21 Spectrum (for system checking)

❖ @ATC/Mitaka



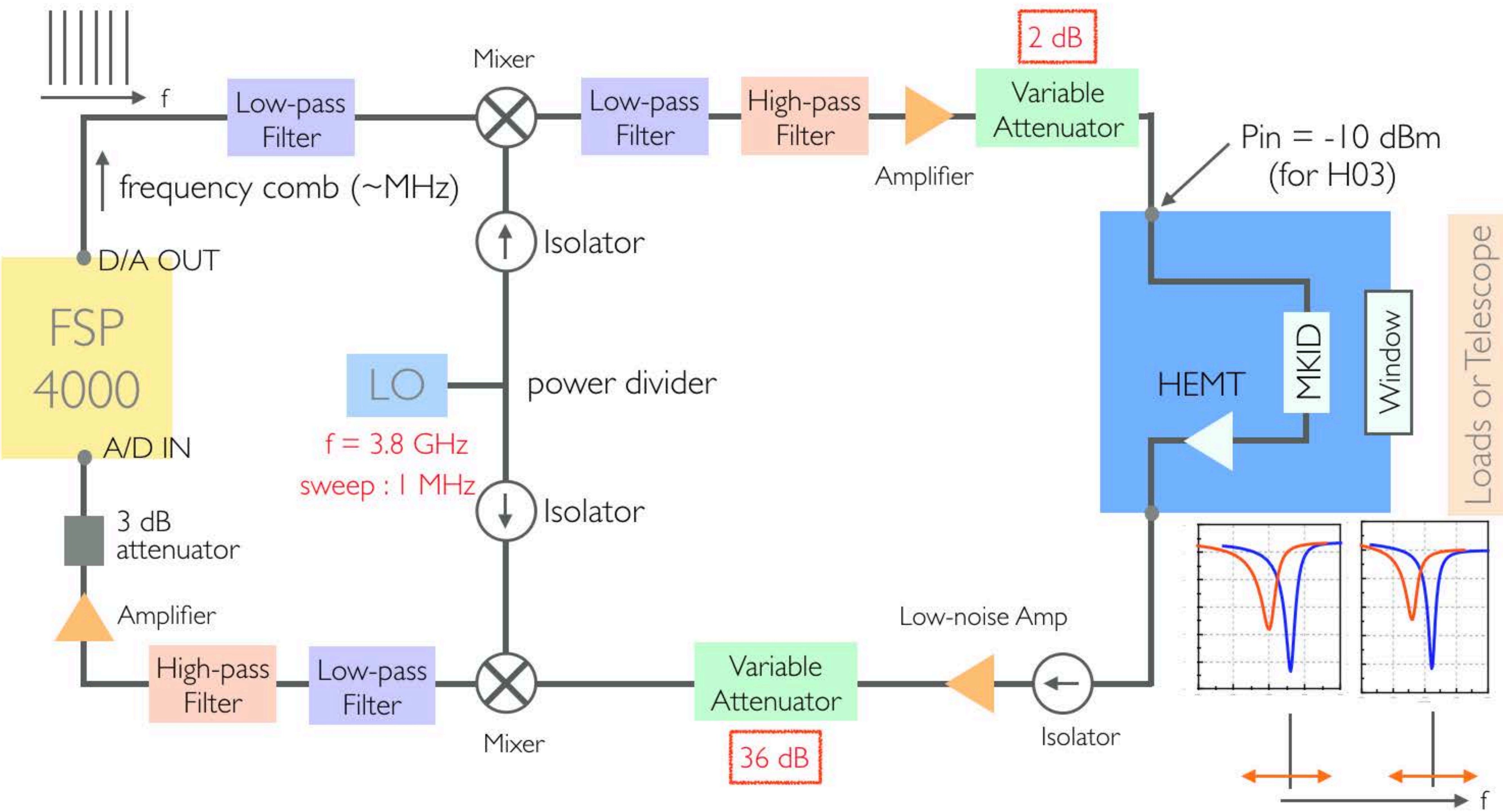
❖ @Nobeyam 45m



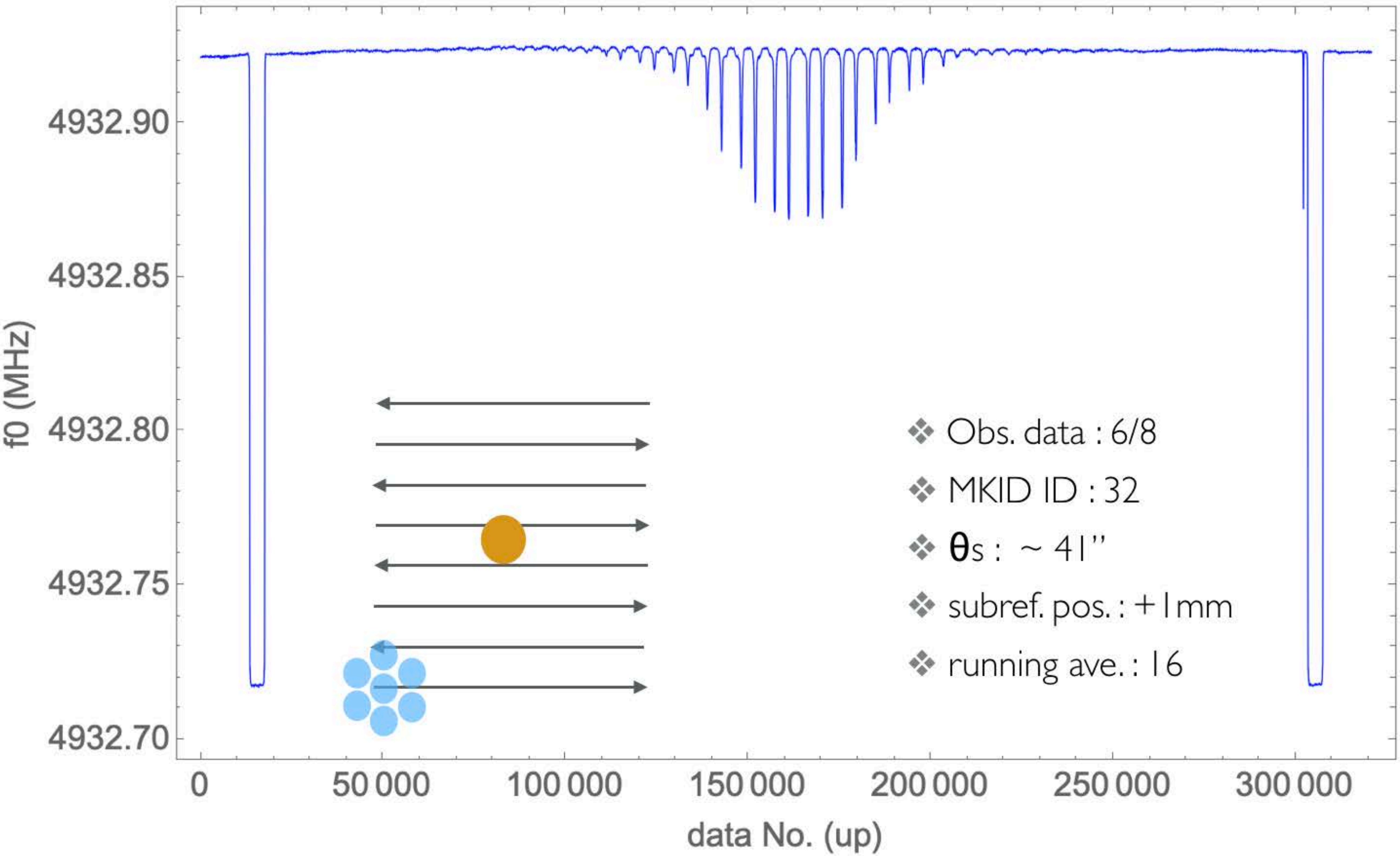
- S21 characteristic of lab and Nobeyama 45m telescope
- Measured sensitivity (Noise Equivalent Power) are very similar

Multi-pixel Readout : Hybrid

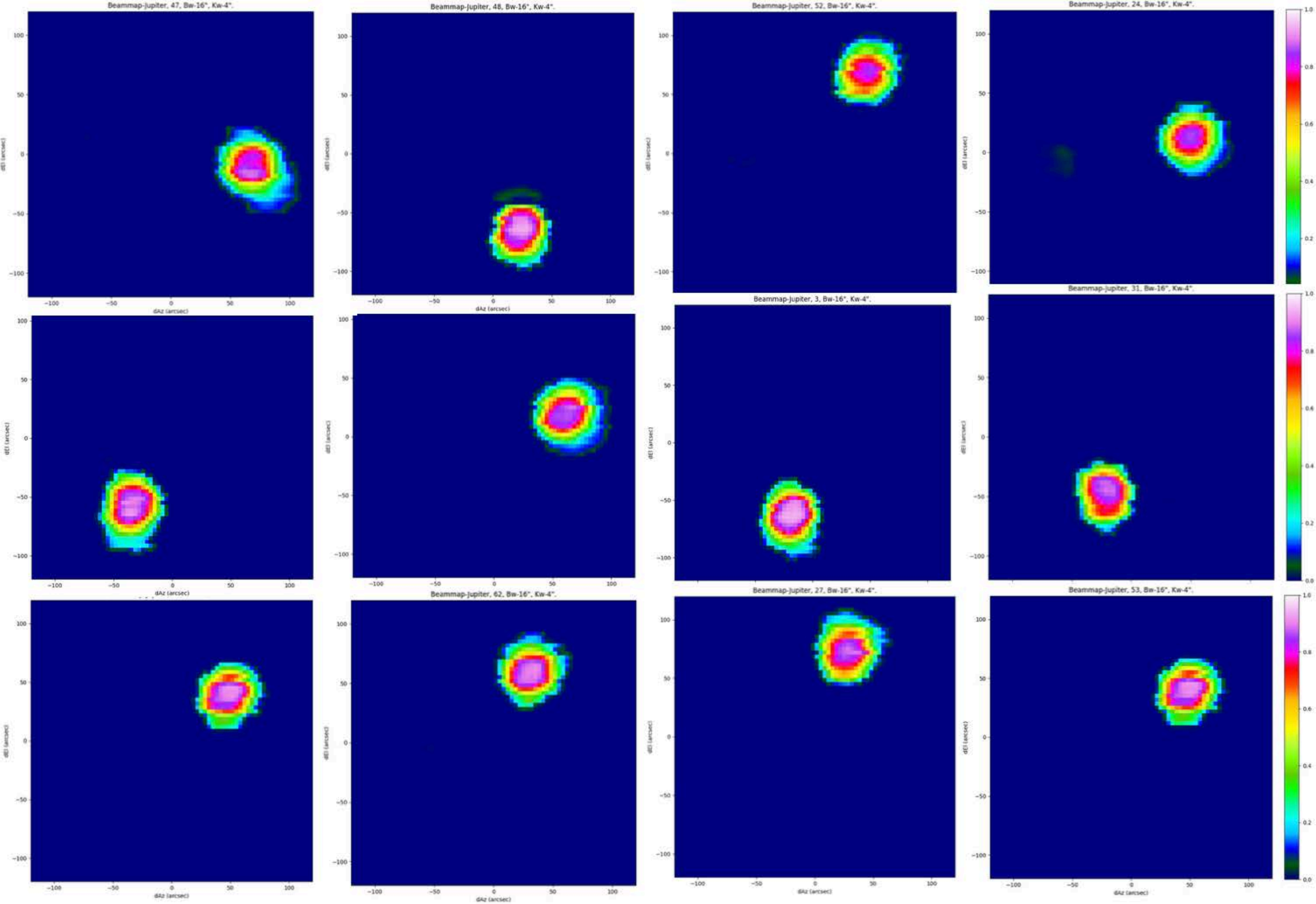
❖ FSP4000 Setup



Examples : Jupiter



- Obs. data : 6/8
- MKID ID : 32
- θ_s : ~ 41''
- subref. pos. : +1mm
- running ave. : 16



Analyzed by Pranshu MANDAL

Summary

❖ Commissioning of MKID camera @Nobeyama 45m telescope

- KID focal plane array and Si lenses used in cold optics are improved
- Sensitivity is one order higher than the previous commissioning
- Measurement of MKID camera characteristics using the planet are succeed.
- The signals from some astronomical object (QSO, galactic center) have been detected.
- We are planning to start observation from next March to April (~70 hours total).

❖ More Improvement for the Background Limited Observation

1. Upgrade of Readout Circuit
2. Cold optics for reducing the Stray Light
3. Change of the MKID Coupler part
   - Improvement of the TLS Noise (1/f Noise), coupling Q factor (improvement of total Q) and Responsivity

     →change of the material (Al → NbTiN)
4. Fabrication Process (e.g. remove oxide layer on the substrate or superconducting film)