

# Submm Receiver Development at PMO

Sheng-Cai Shi

Mm & Submm Lab (SMLab)

Purple Mt Observatory, NAOC, CAS

# Outline

- Introduction
- Development of Supercond. SIS Mixers
- Development of Supercond. HEB mixers
  - THz Direct Detectors with STJ
  - Future Plan

# Development of Mm/Submm Astronomy in CHINA

early 80's, mm

青海13.7米-100GHz



mid-90's, submm

POST30公分-492GHz



since 2001 (with ASIAA)

SMA计划 (0.2-0.9THz,  
Mauna Kea/Hawaii)

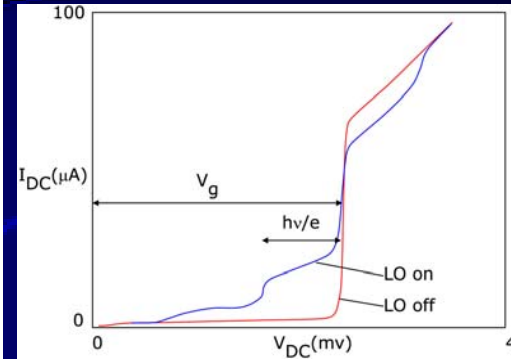
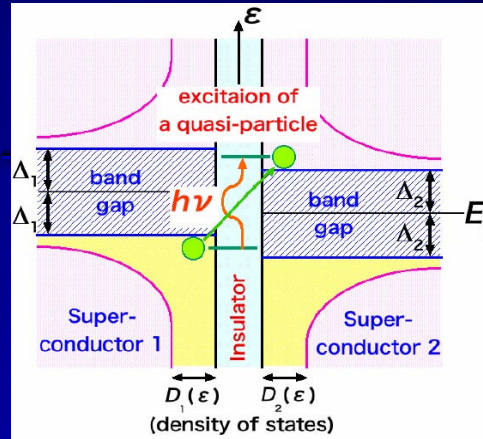
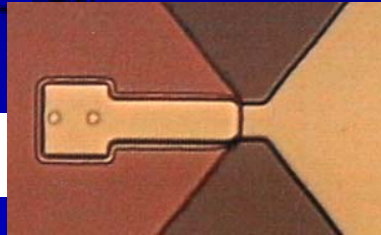


ALMA



# Superconducting Heterodyne Mixers

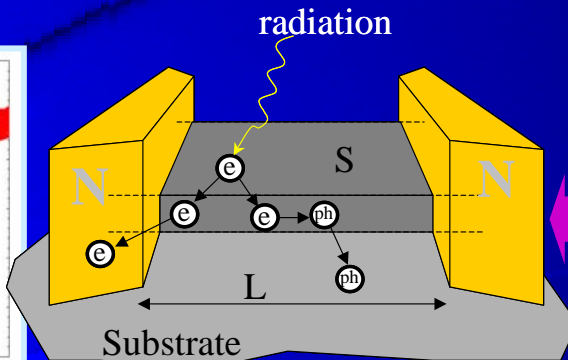
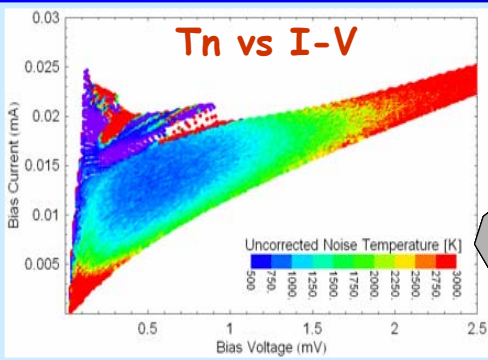
## SIS Mixers



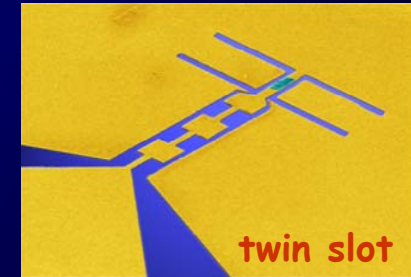
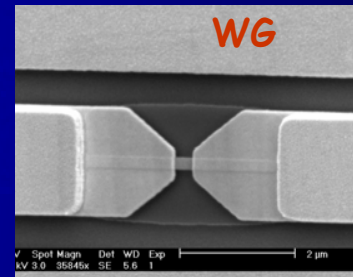
0.1 THz  $f_{gap} \sim 1.4$  THz

10~100 THz

## HEB Mixers



diffusion vs. phonon-cooled

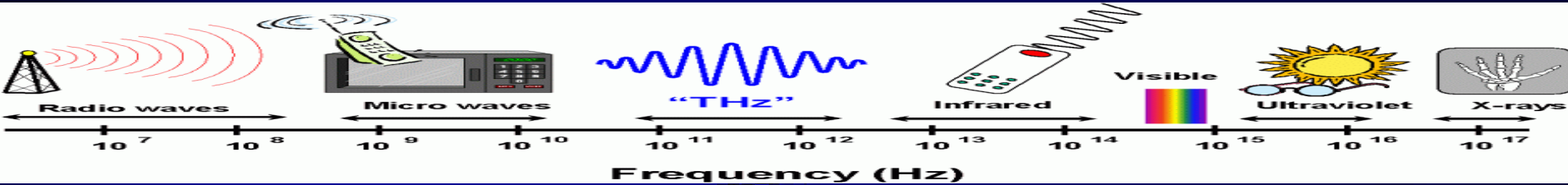


courtesy of SRON

# Technical Challenges of the Development of Summ SIS/HEB Mixers

- Small chip devices
- Properties of EM propagation in sub-micron structures
  - Physical mechanism not fully understood
- Fabrication of high-quality & low-loss devices
  - Reliable design of mixers (wideband)

# Mm & Submm Lab (SMLab)



+ ~10 students,  
on

S/HEB mixers

detectors

imaging

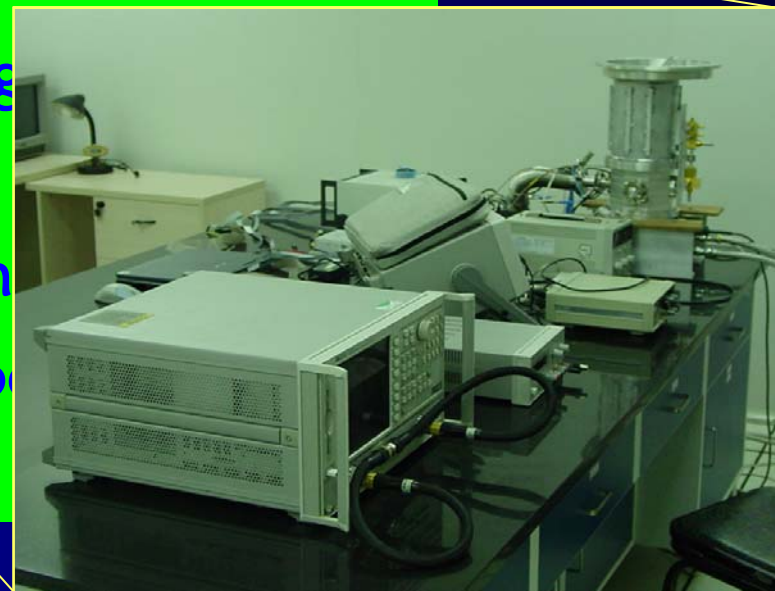


integrated SIS/FFO

digital backen

/ALMA collab

ments for 14m



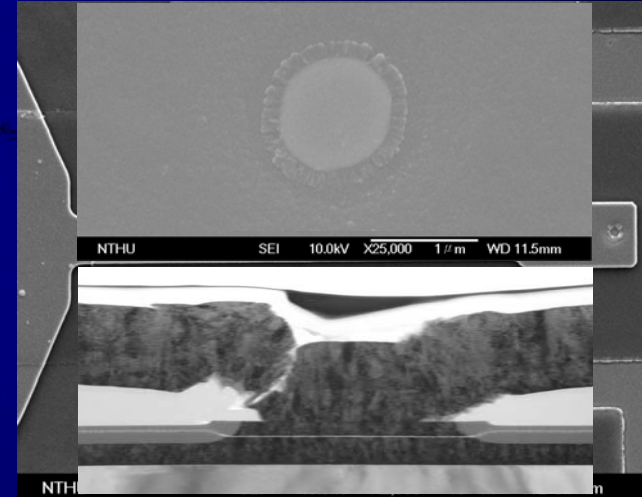
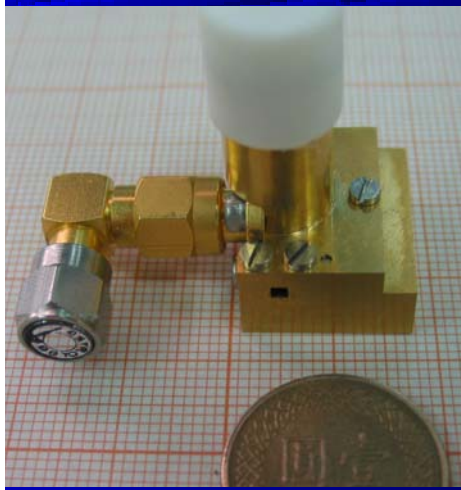
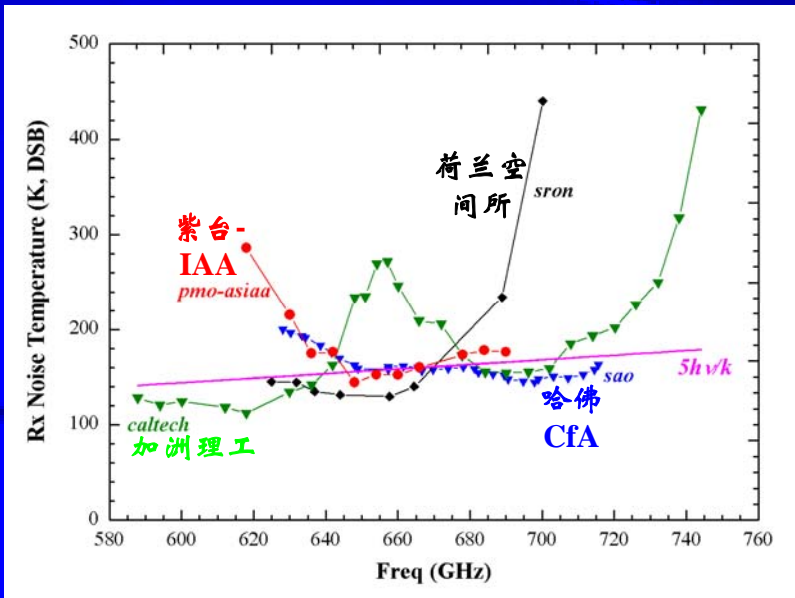
# Nb & NbN Superconducting SIS Mixers

- Joint Development of Submm SIS Mixers for SMA (with ASIAA)
- Joint Development of Band 8 & 10 SIS Mixers for ALMA (with NAOJ)
- Development of NbN SIS Mixers for POST
  - 100-GHz Multibeam Receiver for 13.7m

# Development of Submm SIS Mixers for SMA

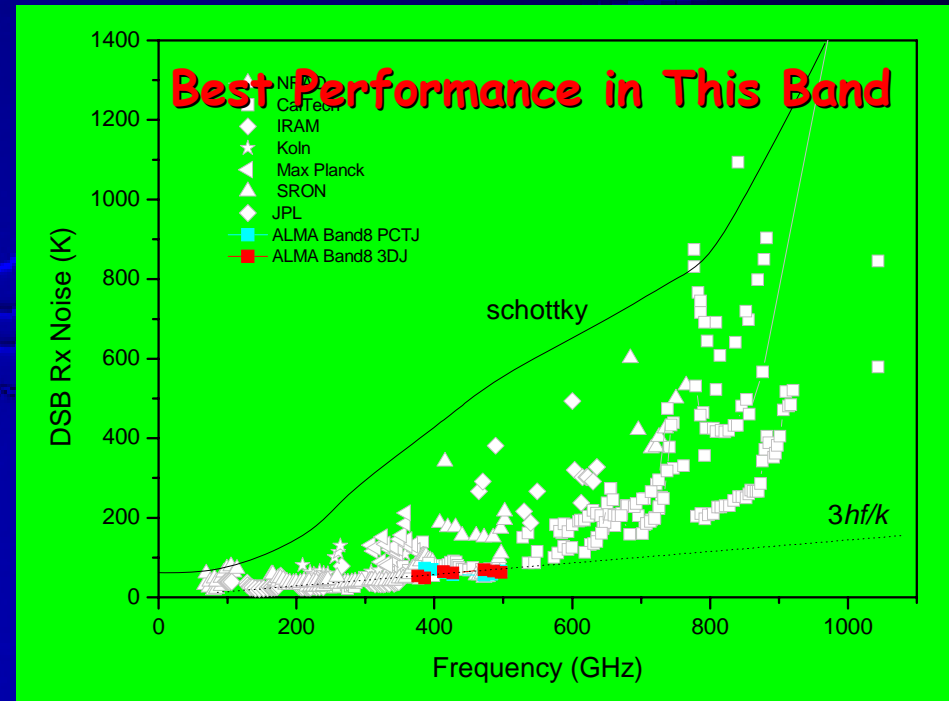
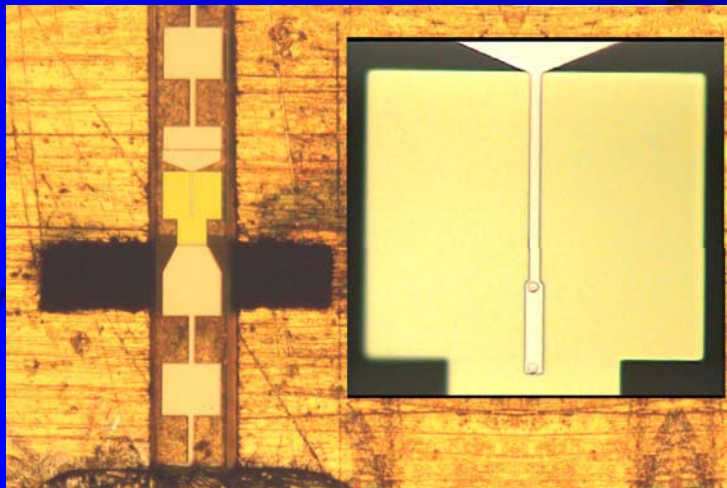
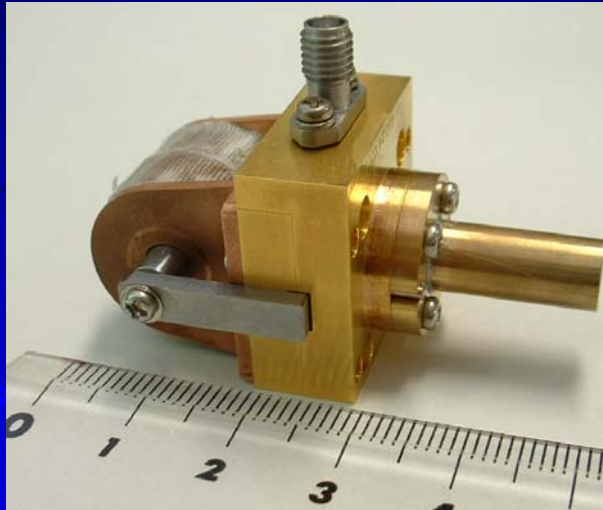


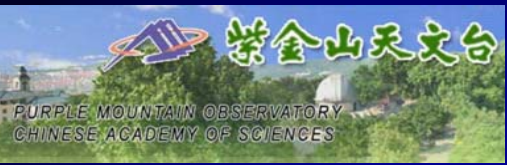
courtesy of SMA





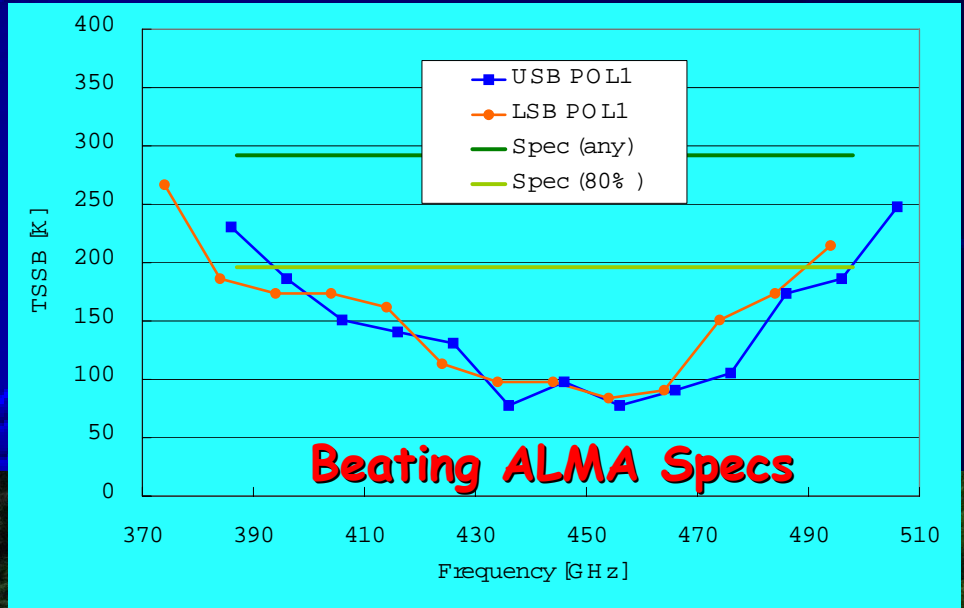
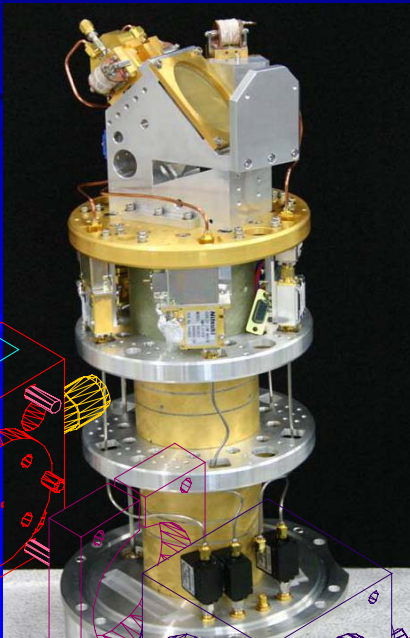
# Development of Band-8 SIS Mixers for ALMA





# ALMA Band 8 385-500 GHz Cartridge

*National Astronomical Observatory of Japan  
Purple Mountain Observatory, NAOC, China*





# Band 10 Cartridge PDR Project Status

2008 February 26-27



ASIAA

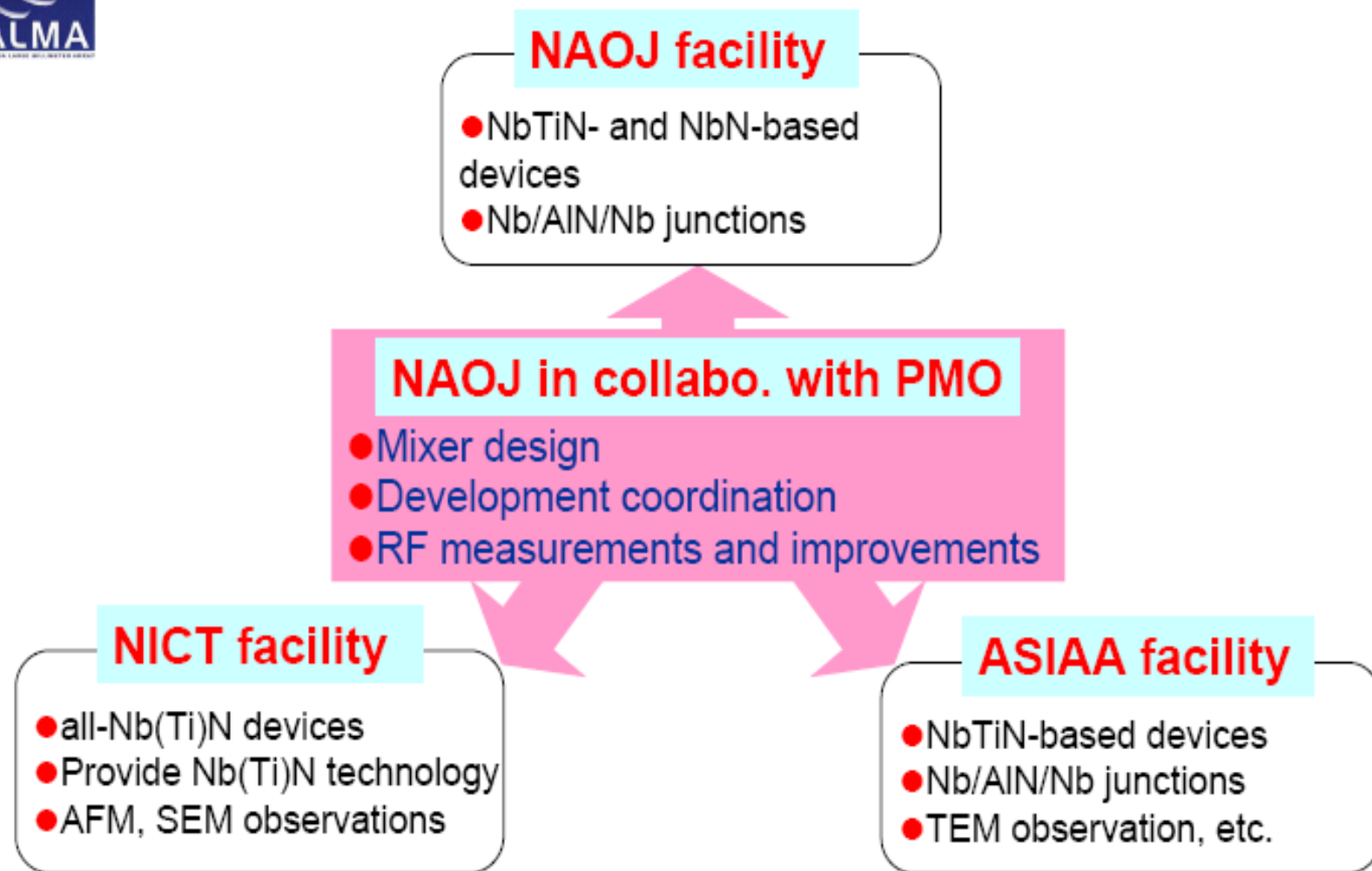


NTHU



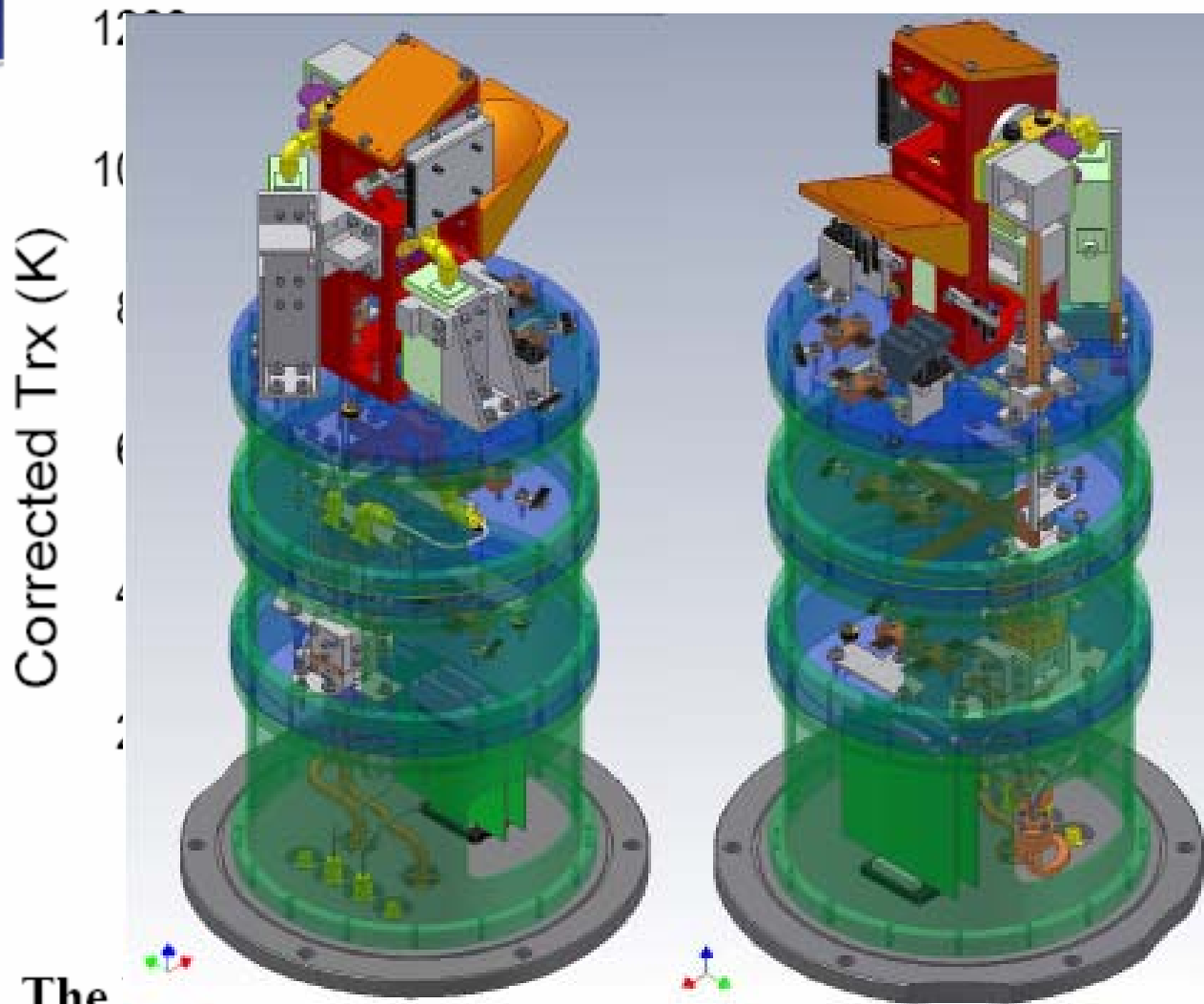


# SIS Junction Development





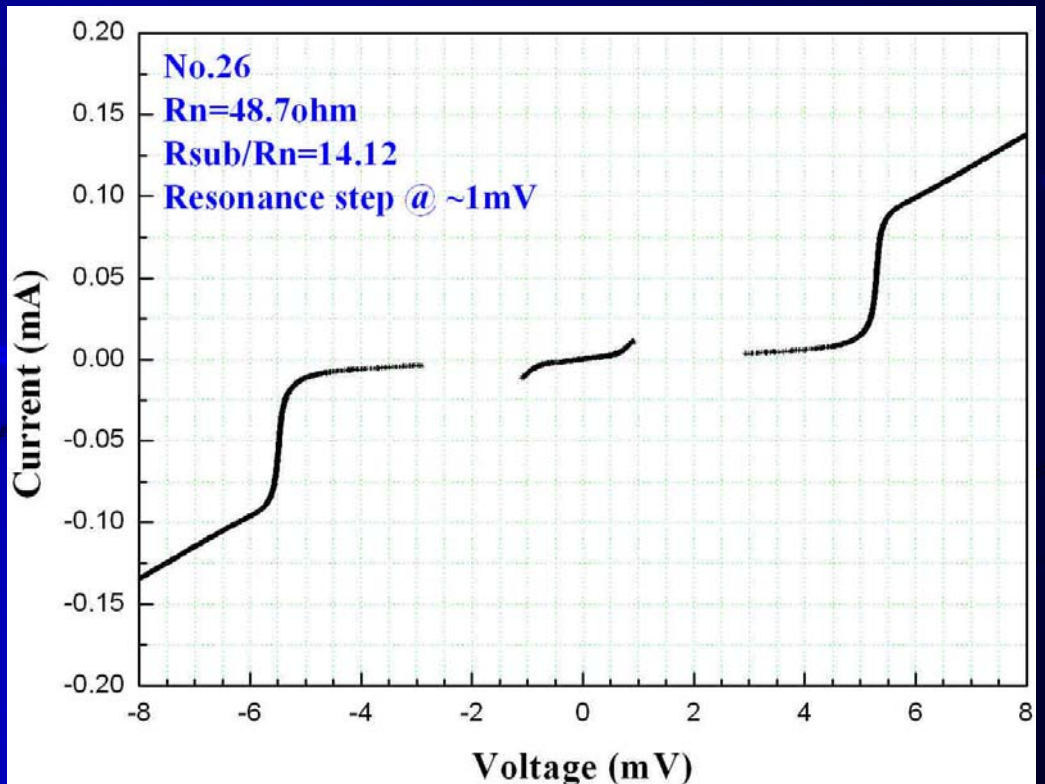
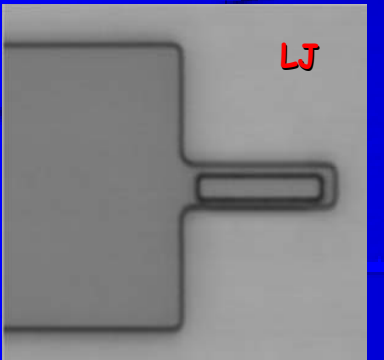
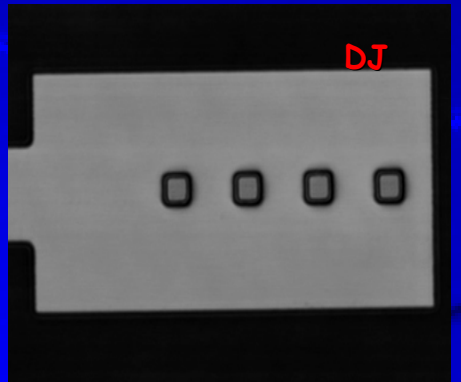
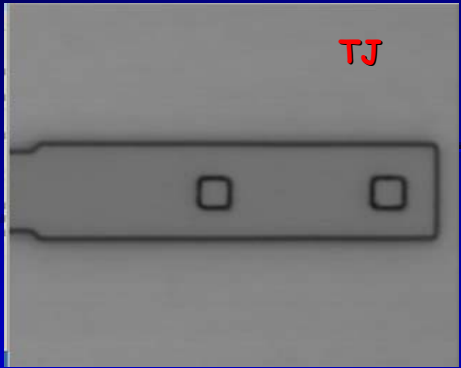
# Status of Mixer Performance at 4K



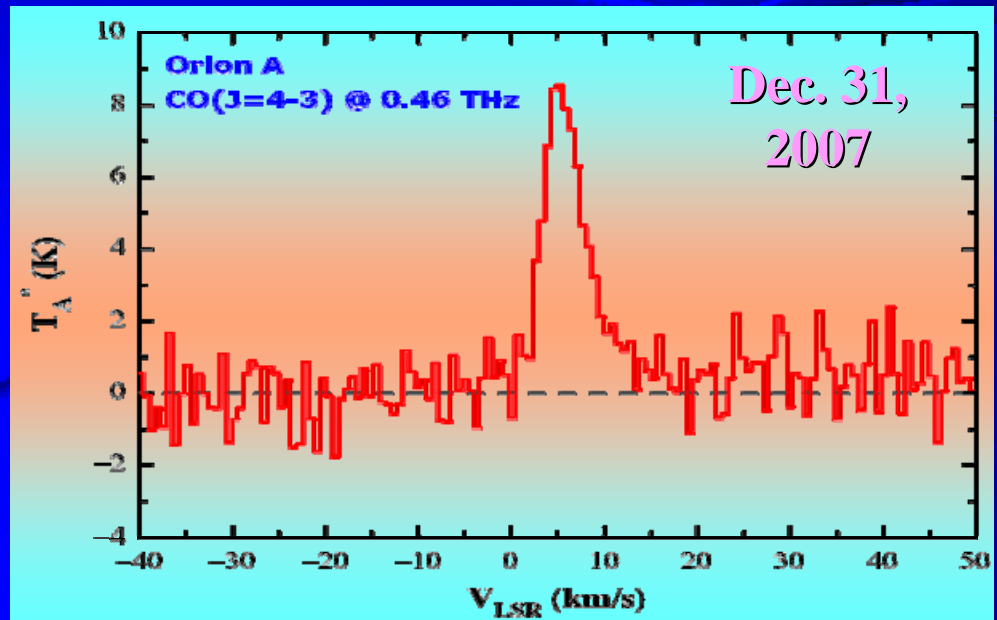
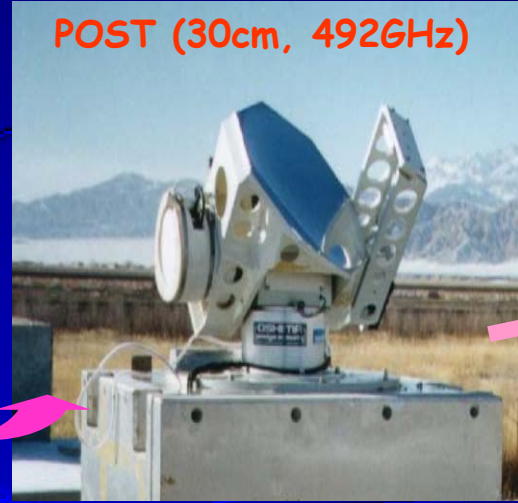
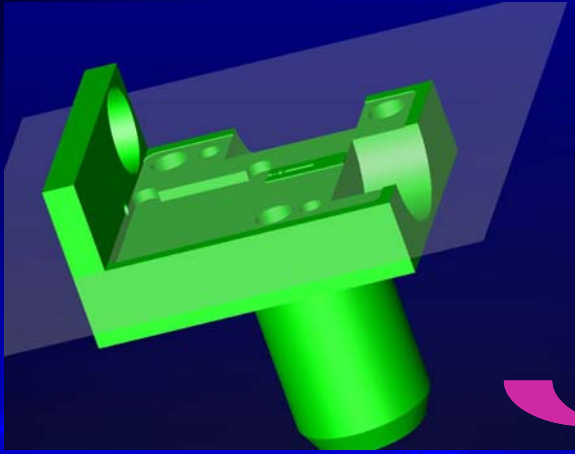
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# Development of a 500-GHz NbN SIS Mixer



# Development of a 500-GHz NbN SIS Mixer



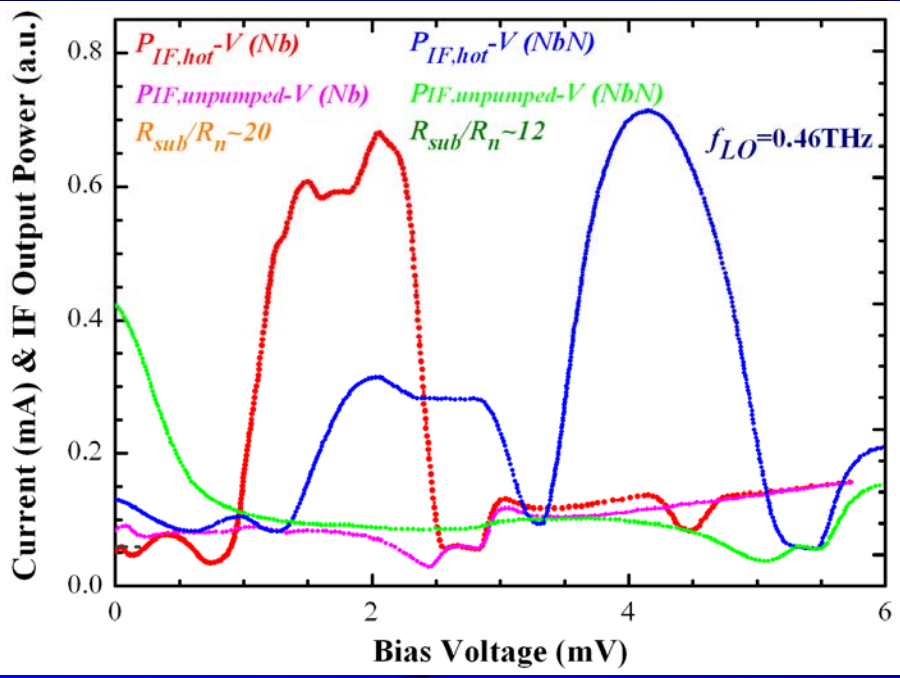
$T_{\text{sys}} = 149\text{K} @ 460/490\text{ GHz}$

$\tau_0 = 1.5-2.0$

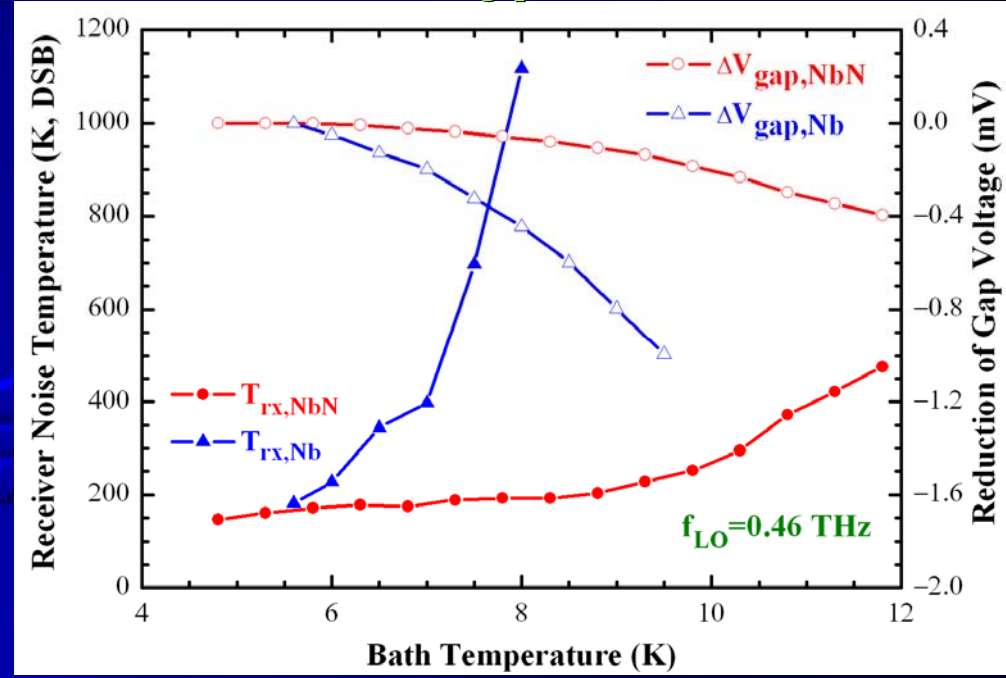
First astronomical detection ever made with NbN SIS mixers

# Development of a 500-GHz NbN SIS Mixer

## IF Output Power Response



## $T_{rx}$ & $\Delta V_{gap}$ vs. Temp.



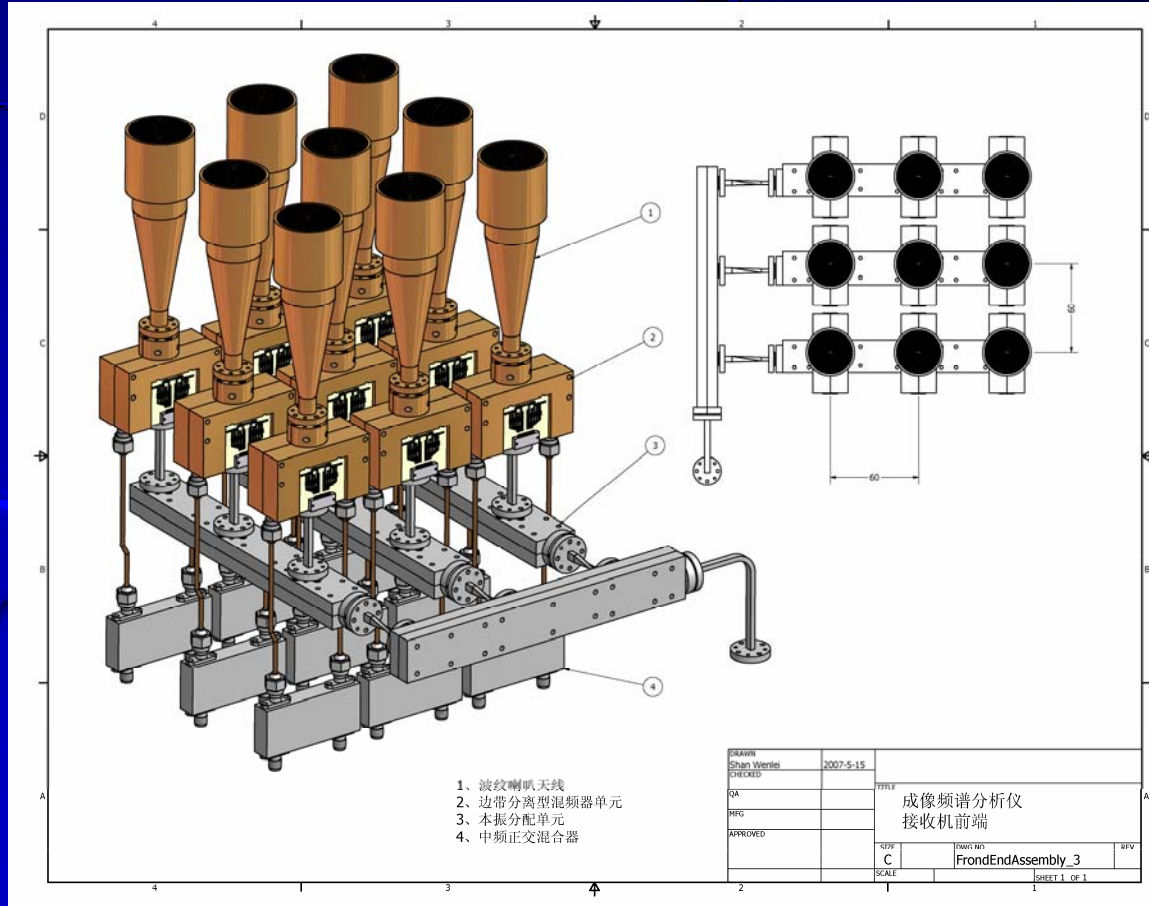
Less Josephson effect noise  
higher stability

Low noise measured  $\sim 10$  K for NbN  
relaxed cooling requirements



# A 3x3 Beam SIS Receiver for 100 GHz

青海13.7米-100GHz

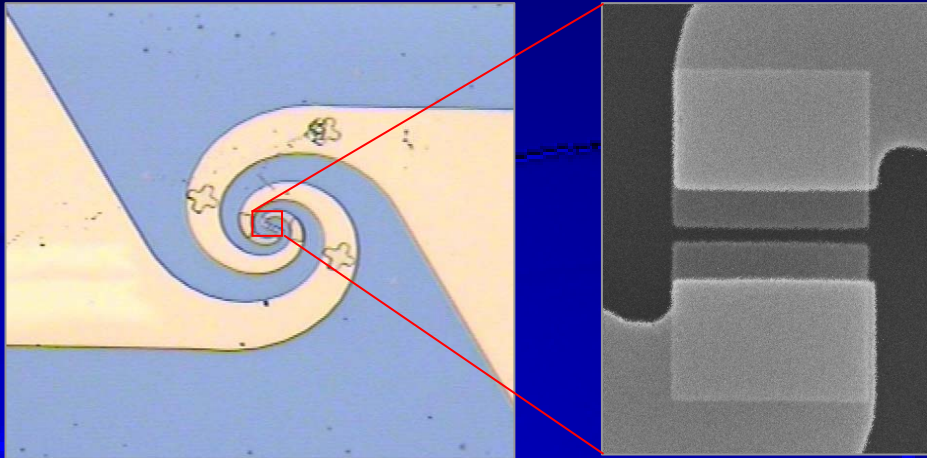


# Phonon-Cooled NbN Superconducting HEB Mixer

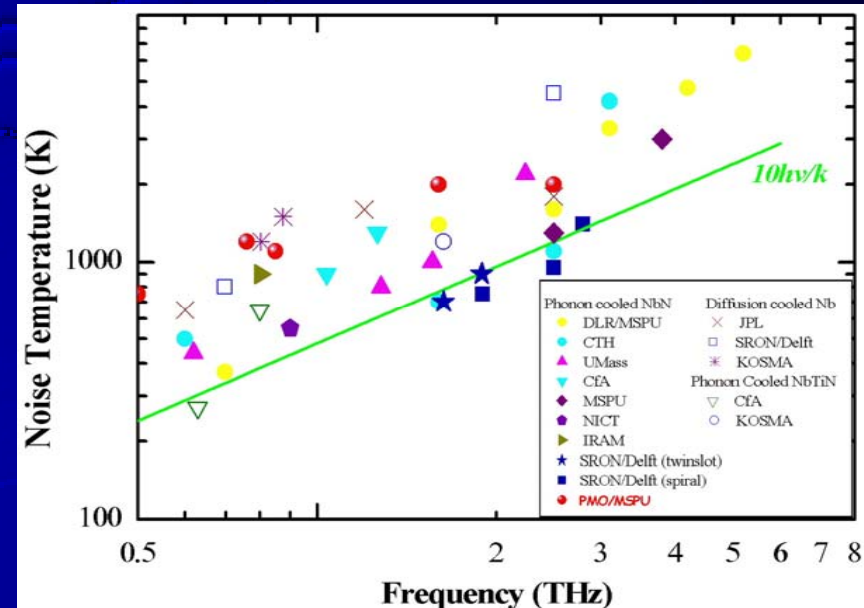
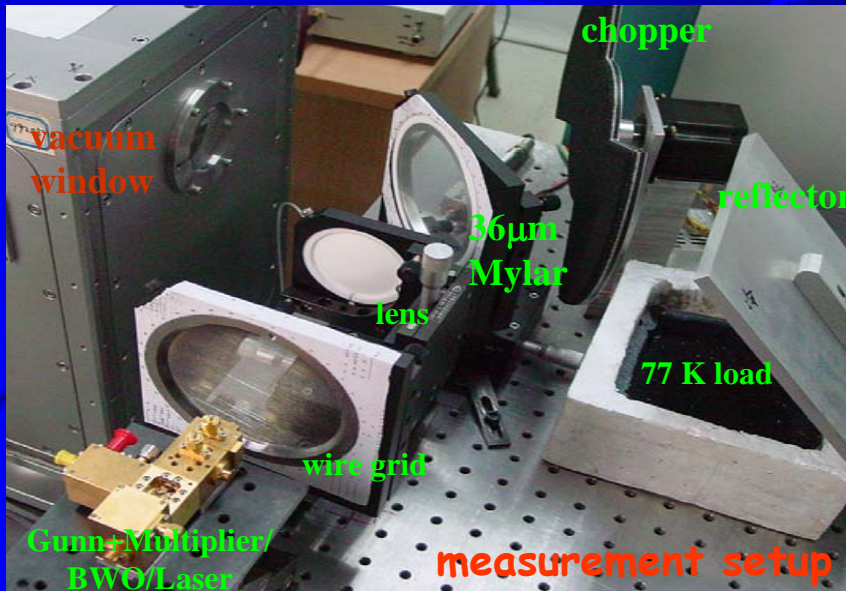
- In collaboration with MSPU
- First HEB demonstration with 4-K close-cycled cryocooler
  - IF-Power Stability & LO-power requirement
    - Polarization of Planar Antenna
  - Antenna & 2-D Hot-Spot Model Simulation

# Noise Temperature Measurement

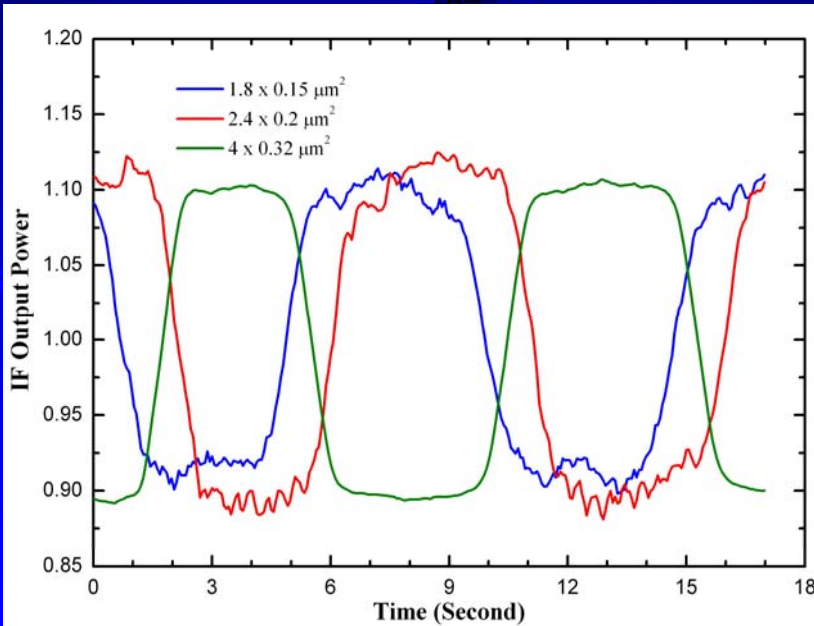
photo of the measured sample



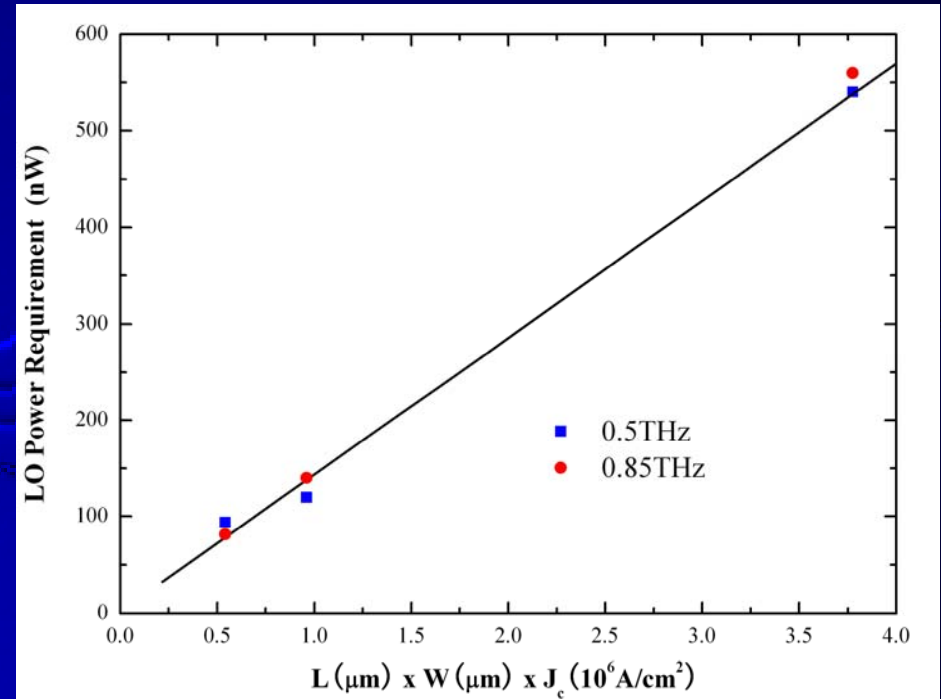
hyper-hemispherical Lens with Parylene coating



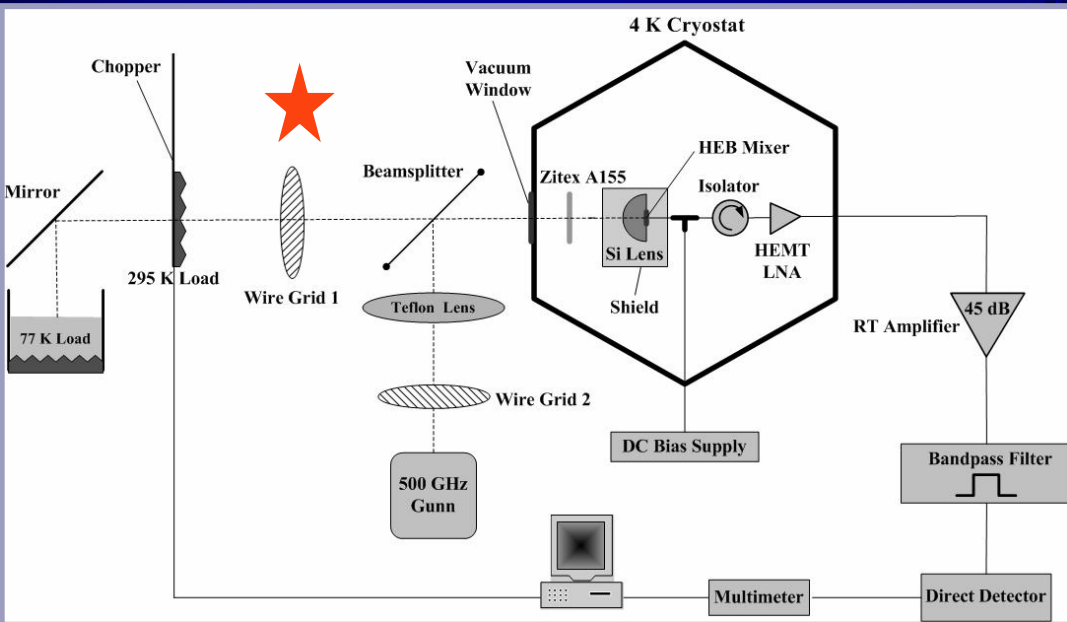
# Stability & LO Power of HEB Mixers vs. Bridge Size



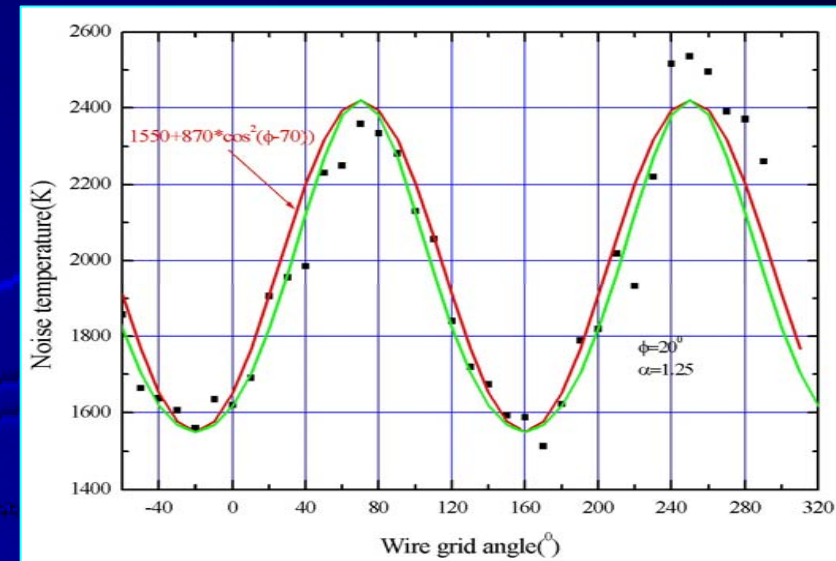
chopped IF output power vs time



# Polarization of HEB Mixers

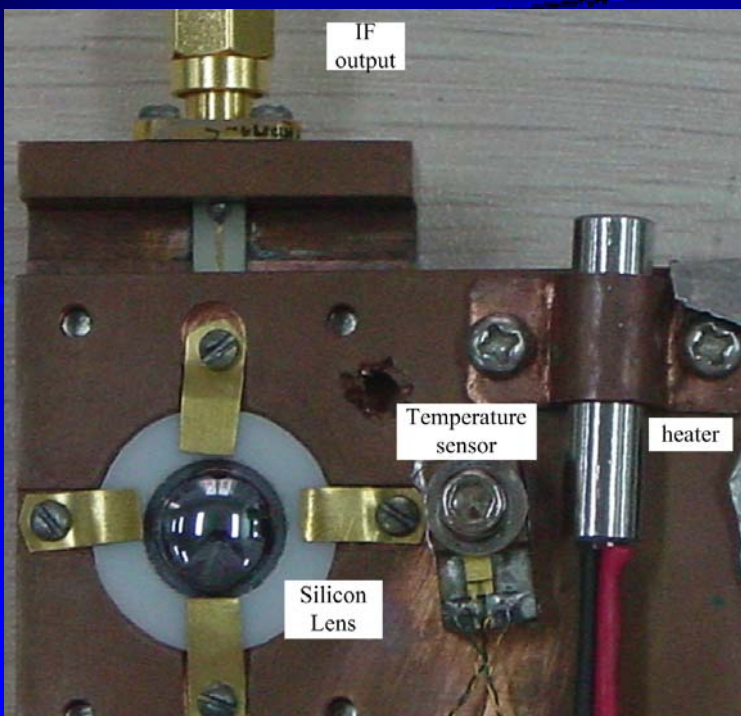


measurement setup

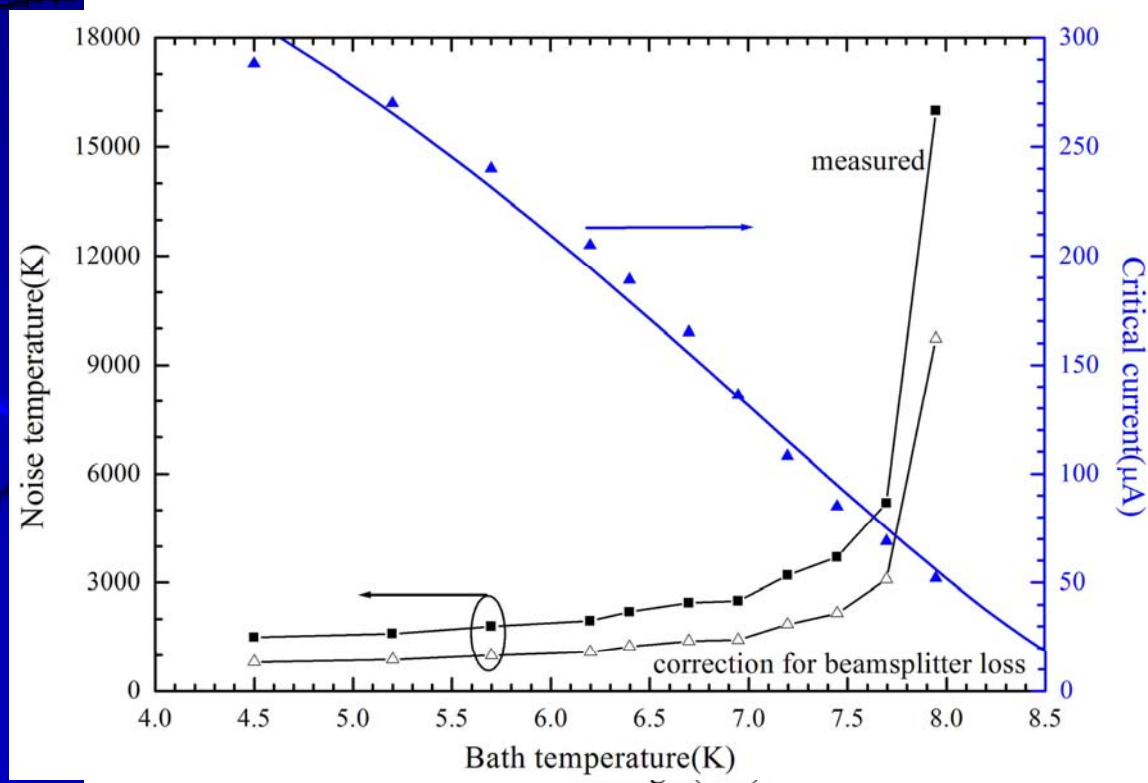


A novel method proposed to evaluate the polarization behavior of spiral antenna in situ.

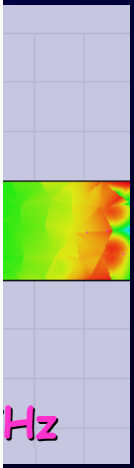
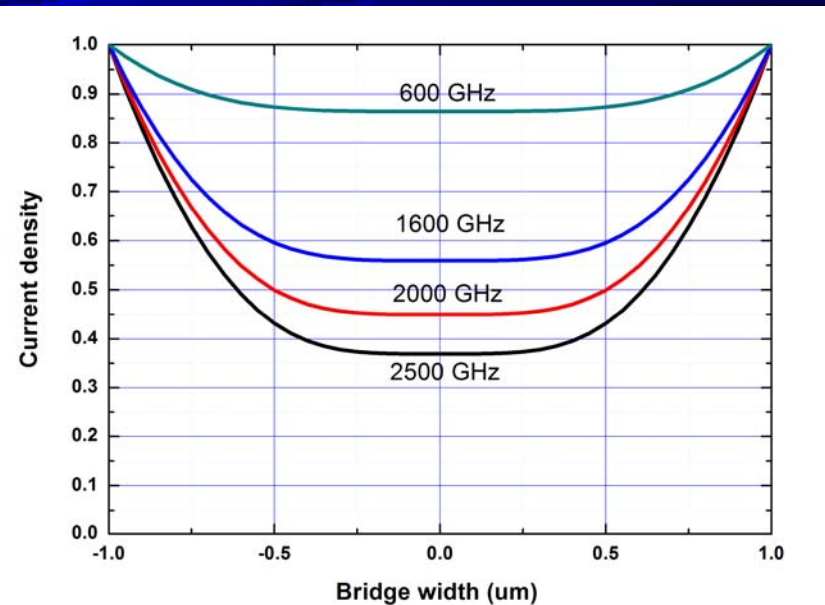
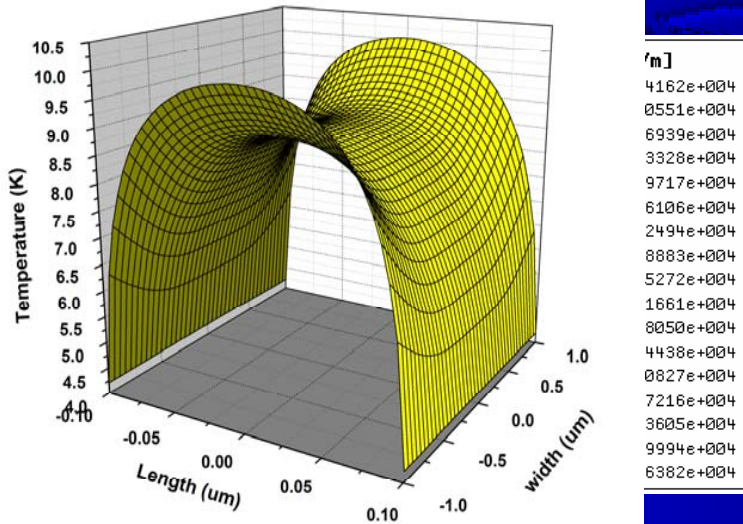
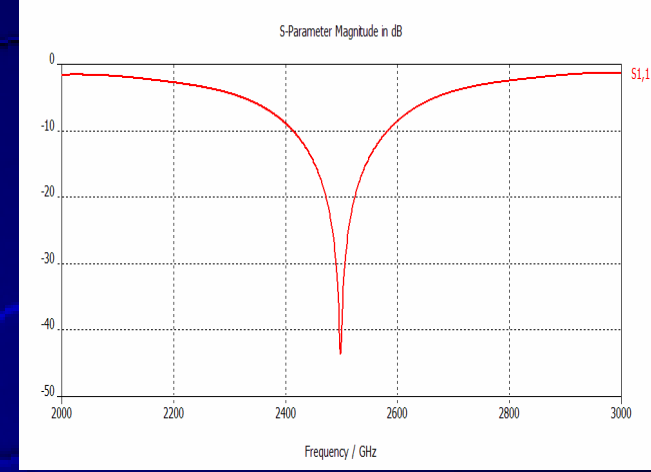
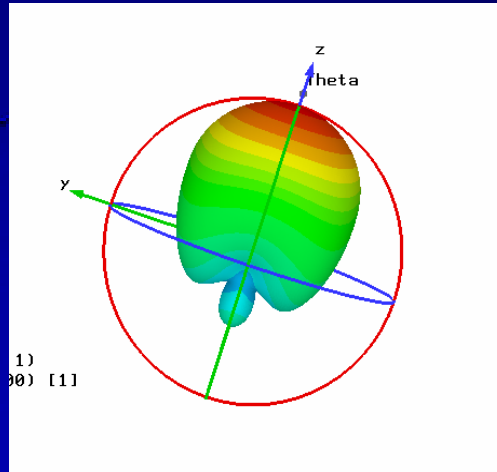
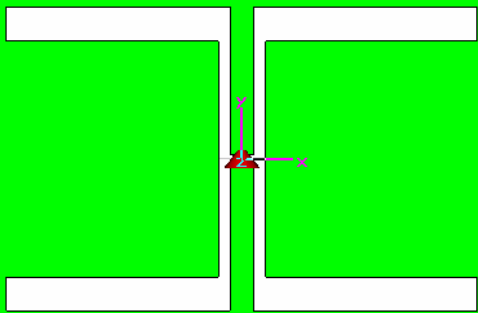
# Temperature Dependence of HEB Mixers



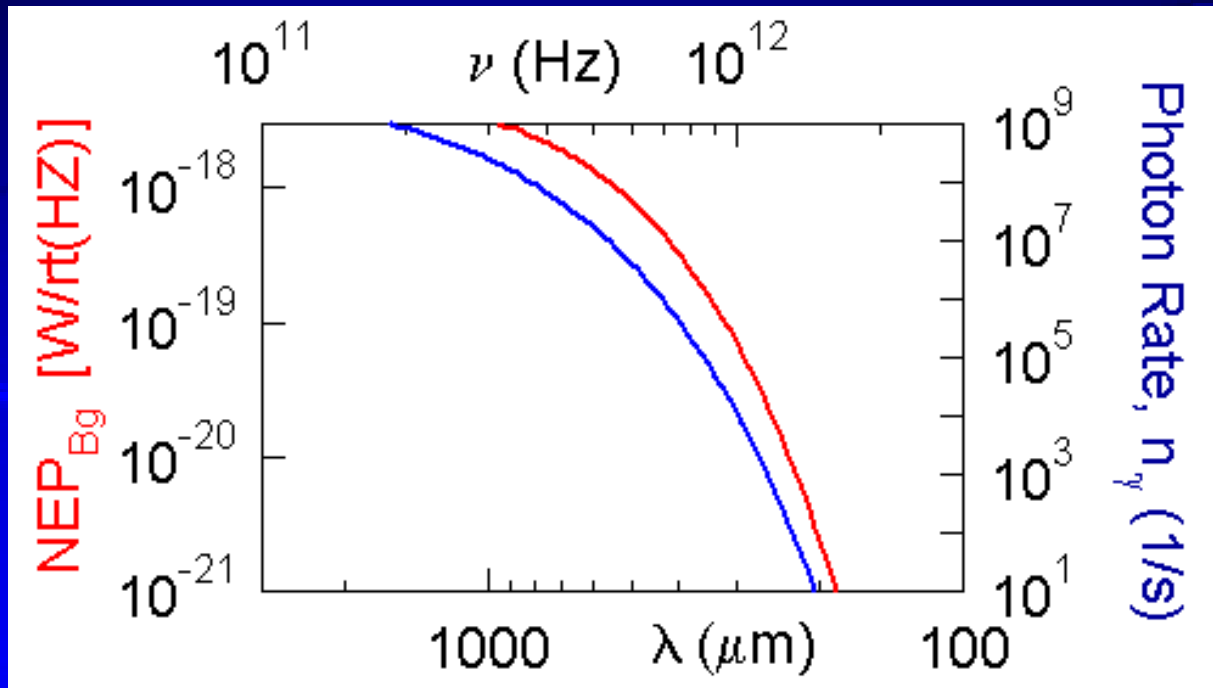
measurement setup



# Antenna & 2D Hot-Spot Model Simulation



# Superconducting Direct Detectors



3 K blackbody  
10 % BW  
single-mode

$$n_\gamma = P_{\text{inc}} / h\nu = \Delta f \langle n \rangle$$

Photon-counting (background) limit:  $\text{NEP} \sim h\nu(n_\gamma)^{1/2}$

Future projects need NEP's  $< 10^{-19}$  W/rt(Hz)  
at THz wavelengths !



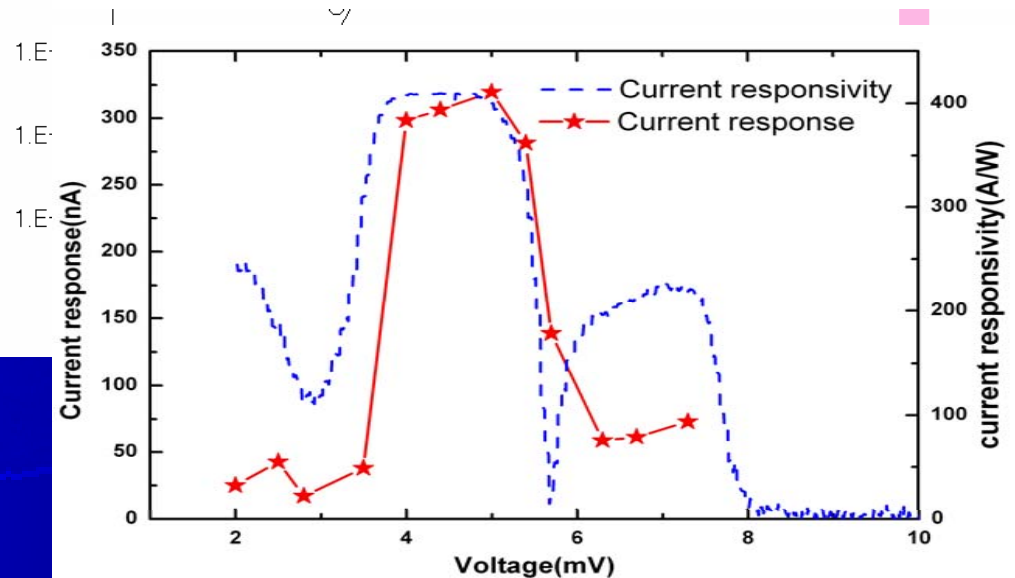
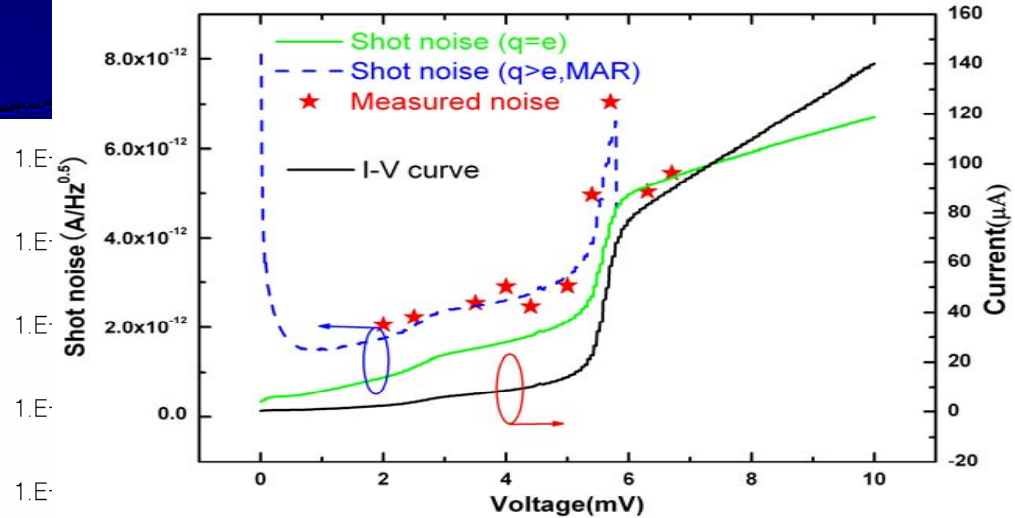
# Superconducting Direct Detectors

$$S_i = \eta \frac{\Delta I_{dc}}{P_{abs}} \approx \eta \frac{e}{h\nu} \quad [A/W]$$

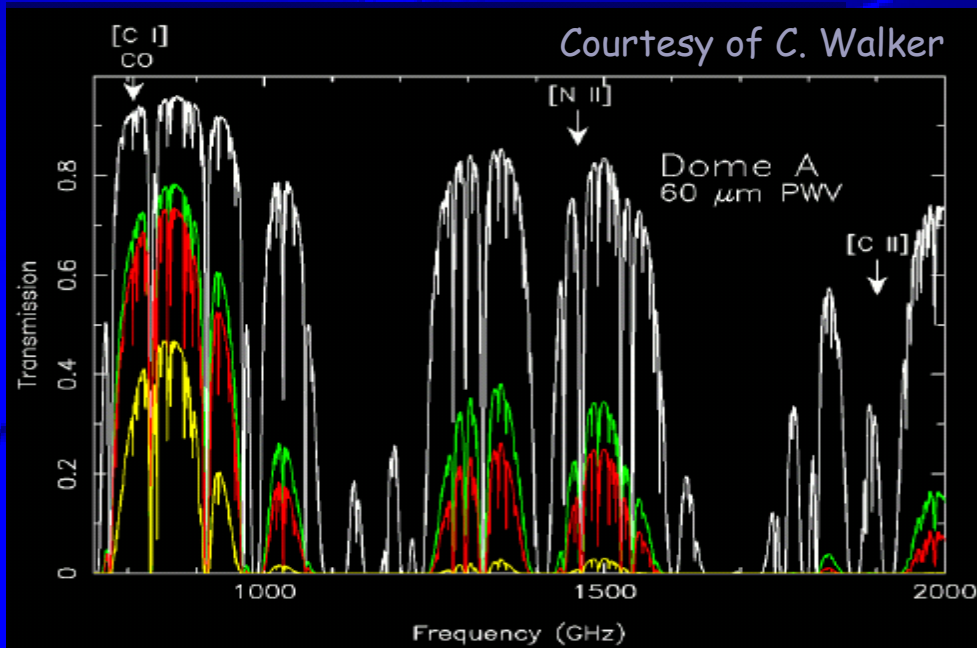
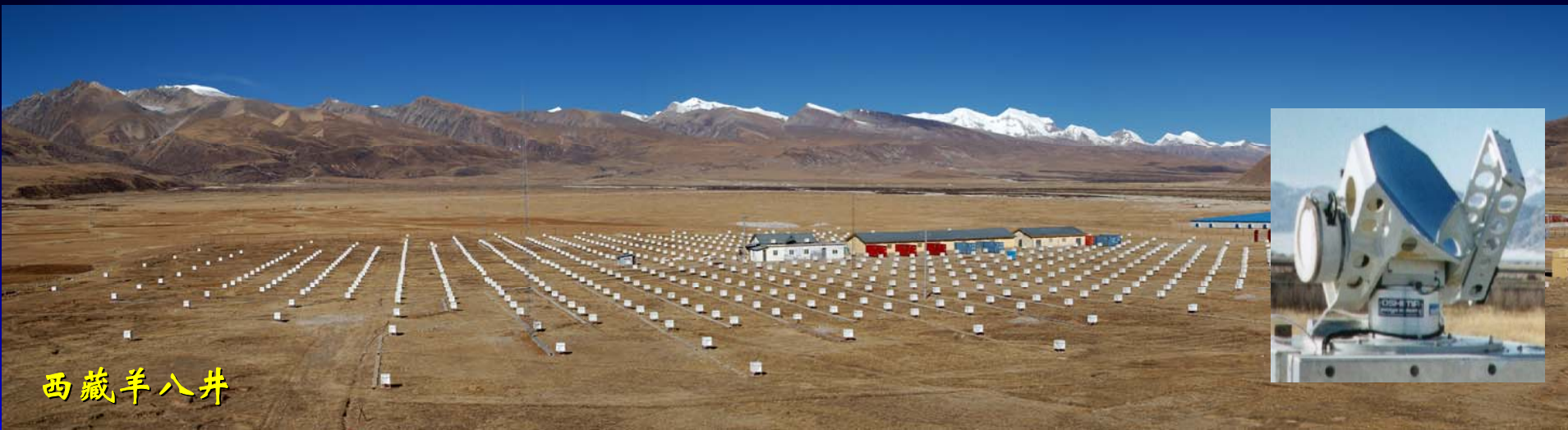
$$I_N = \sqrt{2qI_0} \quad [A/\sqrt{Hz}], \quad I_0 = I_{subgap}$$

$$NEP = \frac{I_N}{S_i} = \frac{h\nu}{\eta e} \sqrt{2qI_0} \quad [W]$$

Subgap leakage current [A]

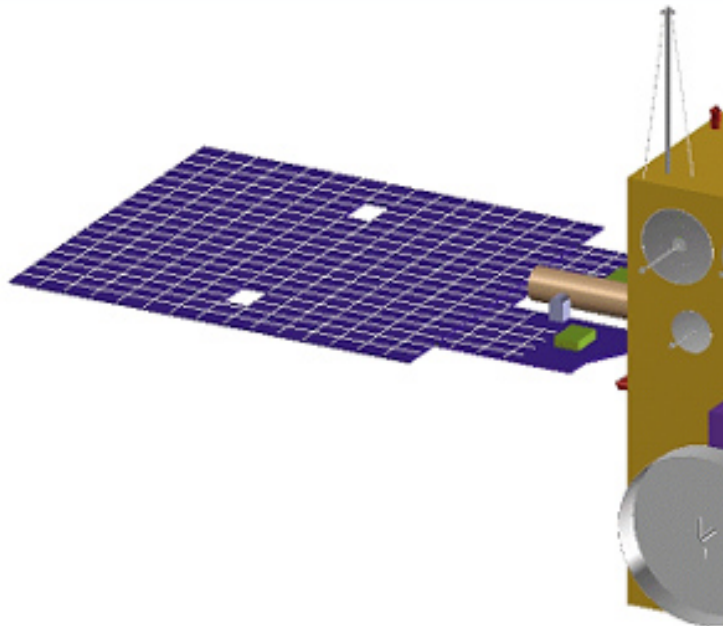


# POST in Tibet & Antarctic?



# Demonstration of THz Technologies on FY-4M or China's Space Lab?

■ Scientific goals: demonstrating the 1st THz space project (1m class) in China with high-sensitivity detectors



FY-4M to be launched ~2015



■ **1-THz direct-detector array, planetary/lunar exploration, atmospheric environment.**



**Thank you for your attention**