Development of SIS mixers for future receivers at NAOJ

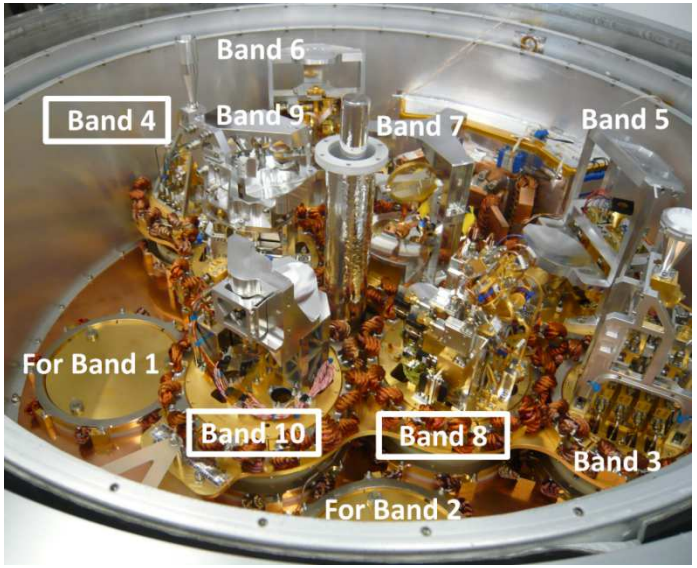
2016/05/25

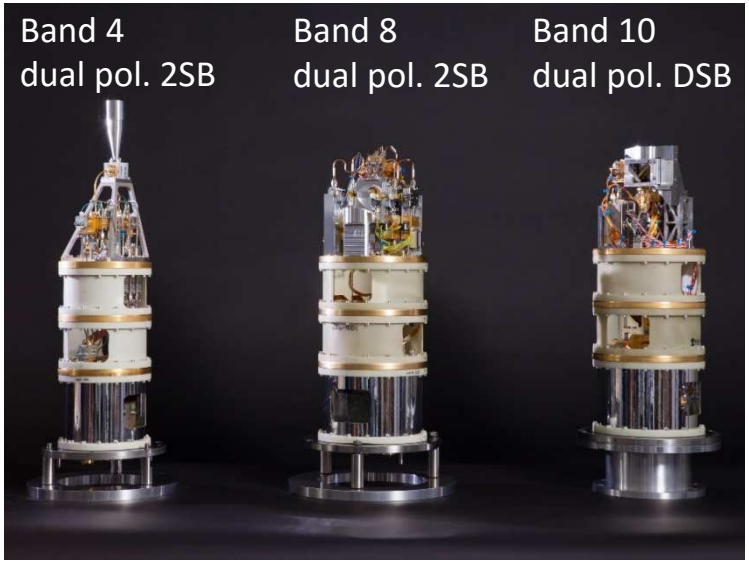
Takafumi Kojima
On behalf of NAOJ future development team

ALMA Developer’s workshop

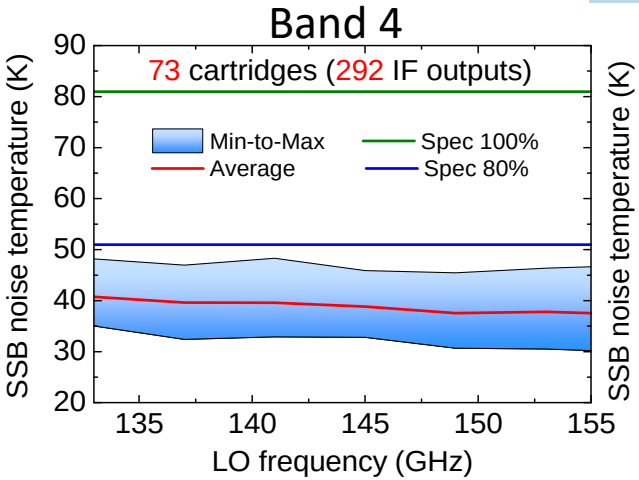
Summary of ALMA Cartridge Receivers at NAOJ

Developed and produced 73 cartridges each for bands 4, 8 and 10.
Complied with the ALMA spec and completed delivery in 2014.

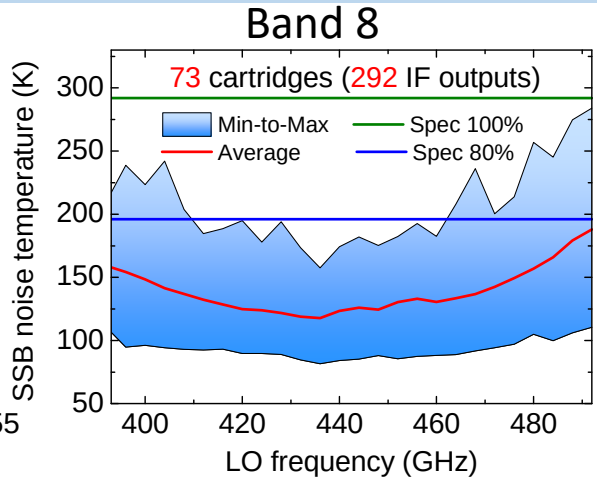




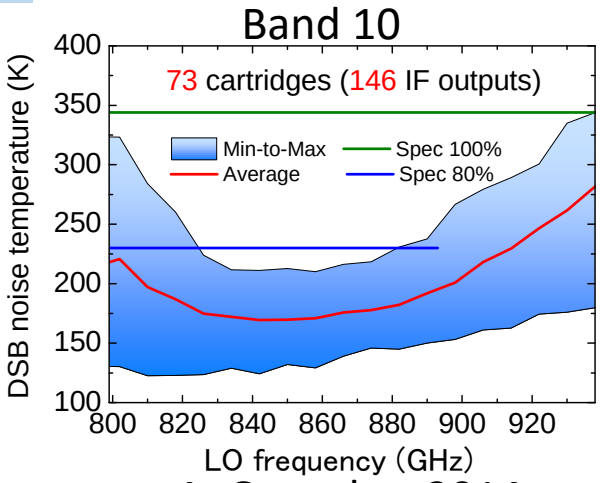
Noise performance



T. Kojima, 2015



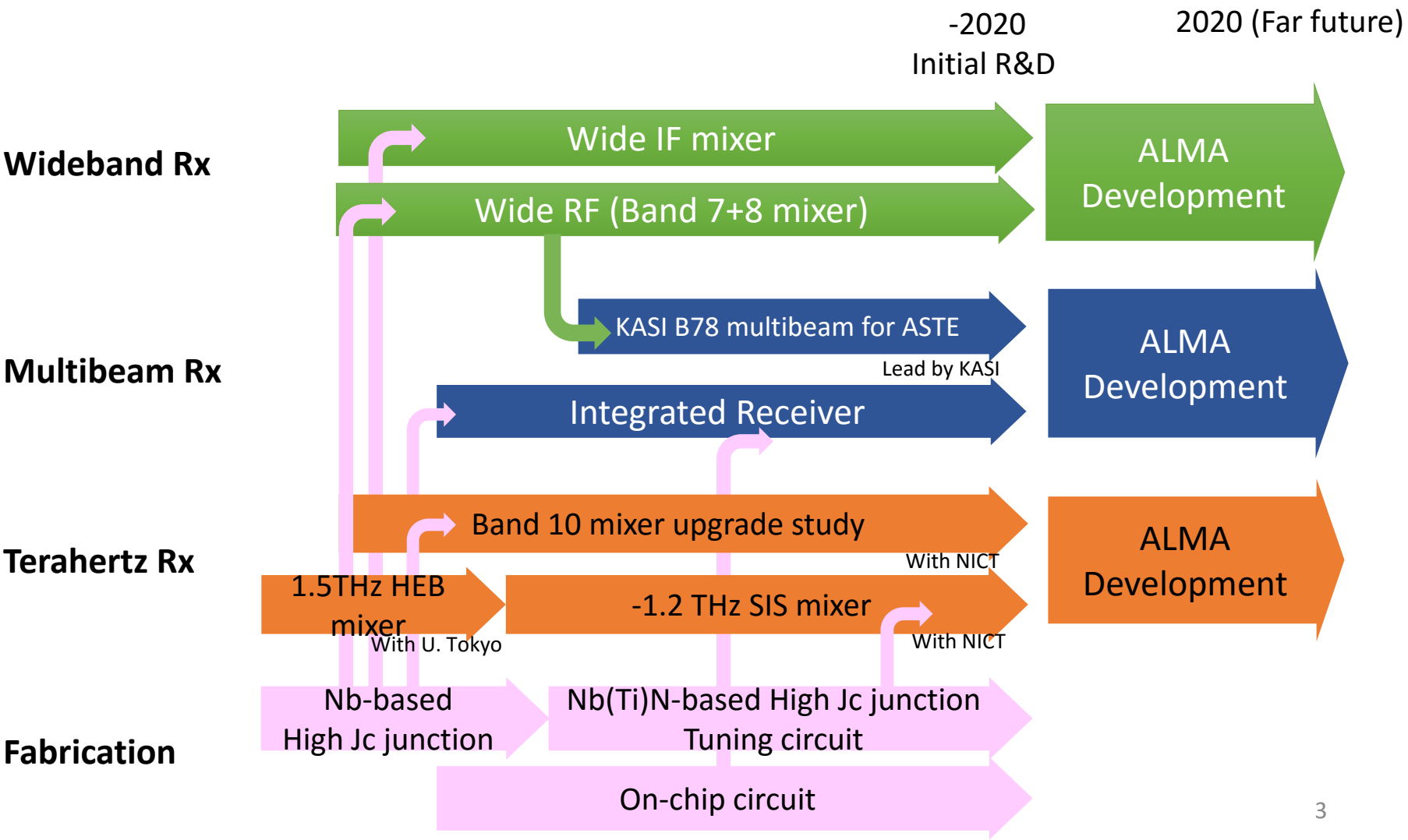
T. Tamura, 2015



A. Gonzalez, 2014

Ongoing Development Programs at NAOJ

THz, Ultra wideband and Multibeam developments are ongoing.
Our target is basically demonstration of the development items and installation for ASTE telescope until 2020



High Critical Current Density (J_c)
AlN-based Nb Junction Device Development

- High jc junction provides lower ωRC product: wider bandwidth can be expected.
- It will benefit future development, upgrade and maintenance of cartridge.
- High quality SIS junctions ranging from 10-45 kA/cm^2 have been successfully fabricated.

Band-10 SIS mixer upgrade study

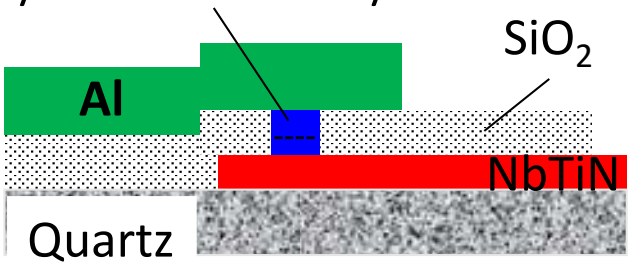
Currently: Limited tolerance margin in terms of noise and bandwidth.
Upgrade: Higher Jc => Lower loss tuning circuit and wider bandwidth.

Current Band 10

Current mixer structure (1.5dB Loss)

Y. Uzawa et al./Physica C 494 (2013) 189–194

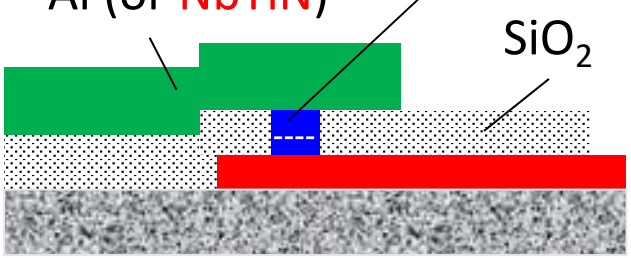
Nb/AlOx/Nb with ~13 kA/cm^2

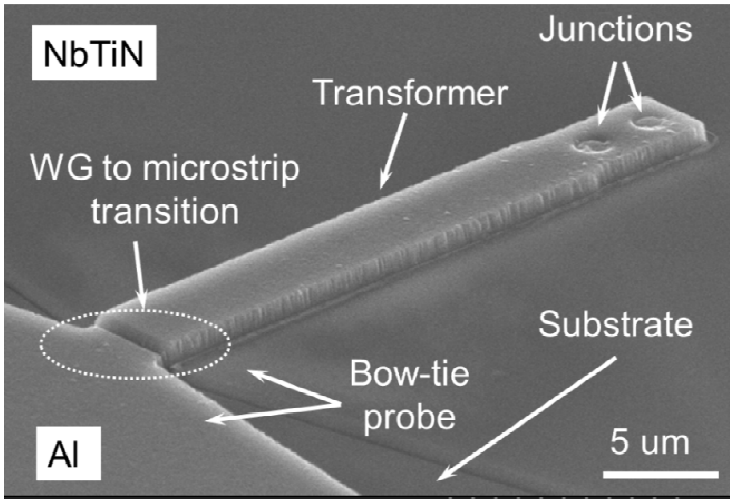


Upgrade

wideband and Lower loss

High-Jc Nb/AlNx/Nb





Ongoing:

-Fabrication of mixer with Higher Jc junction (will be tested soon)

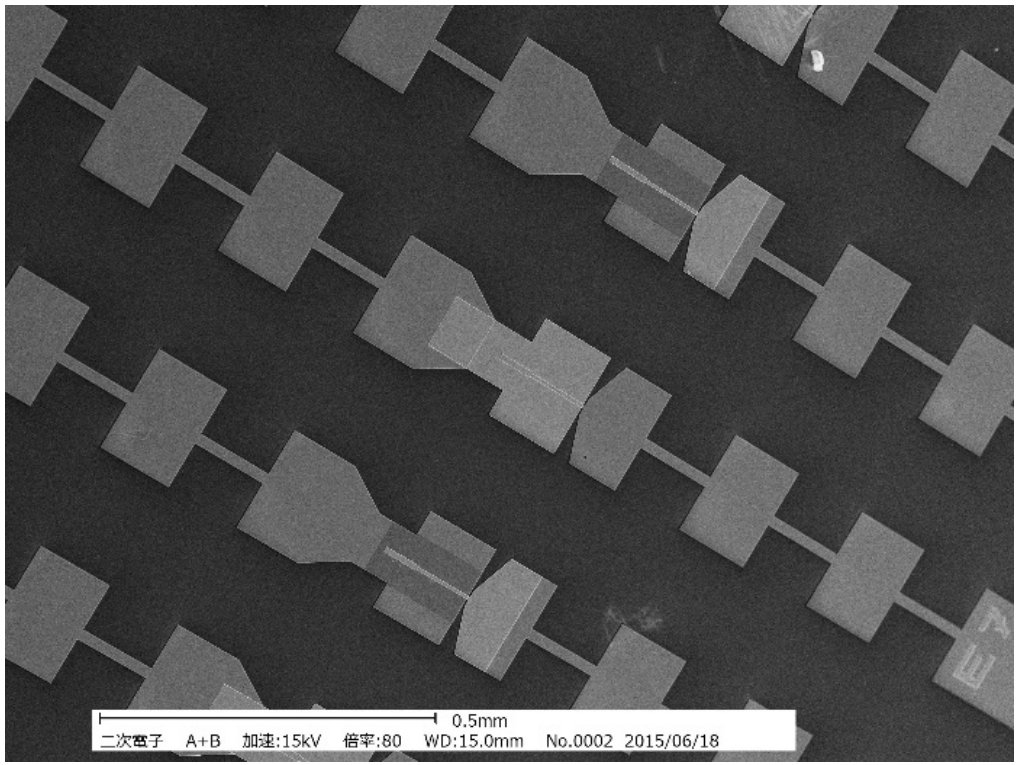
Investigating (by Uzawa in NICT):

-Quality of a NbTiN film (top layer) on SiO_2

-Junction Heating

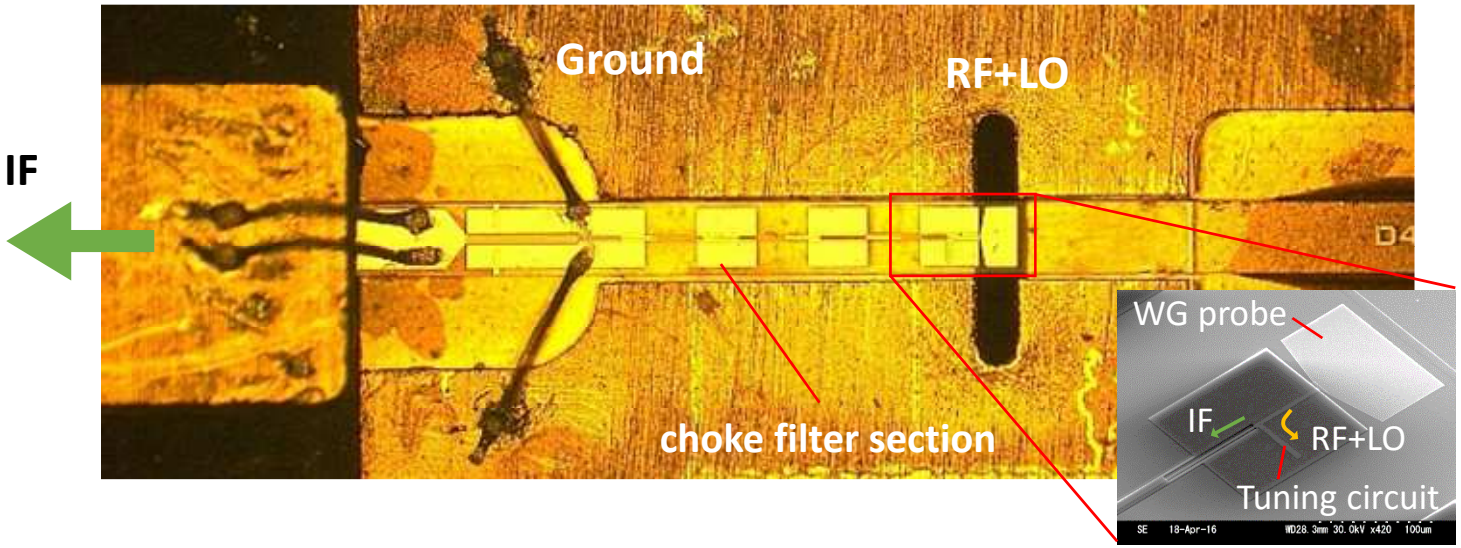
High-Jc Mixer performance at Band 8

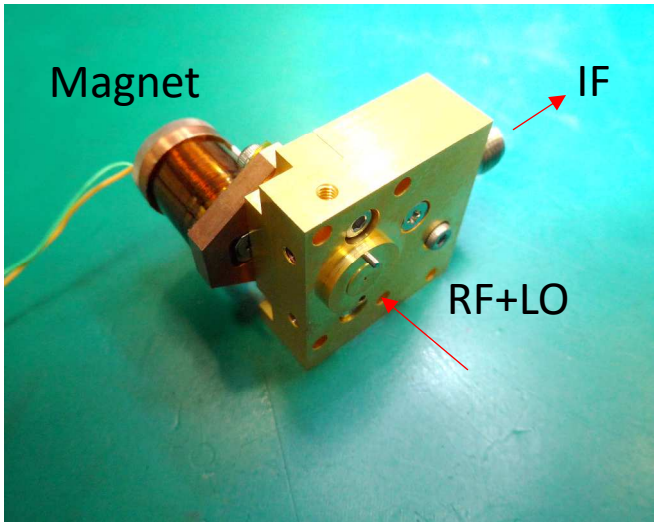
- As well as band 10, band-8 receiver performance at band edge degrade due to limited bandwidth
- Low noise and wideband RF performance have been demonstrated at Band 8 frequency.

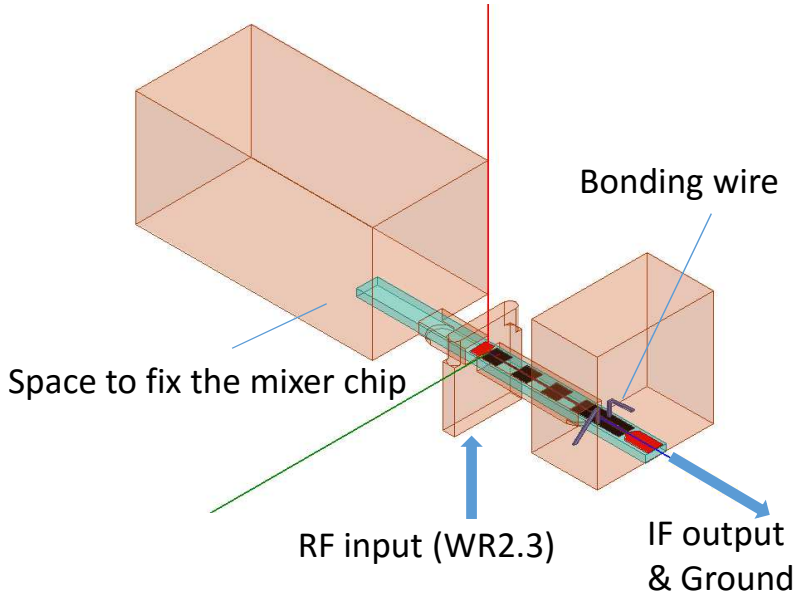


First test of Band 7+8 mixer performance at Band 8

Mixer tuning circuit was tuned at band 8 frequencies.

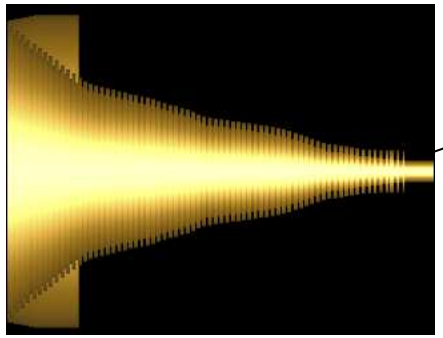


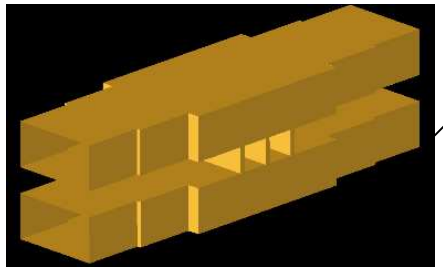


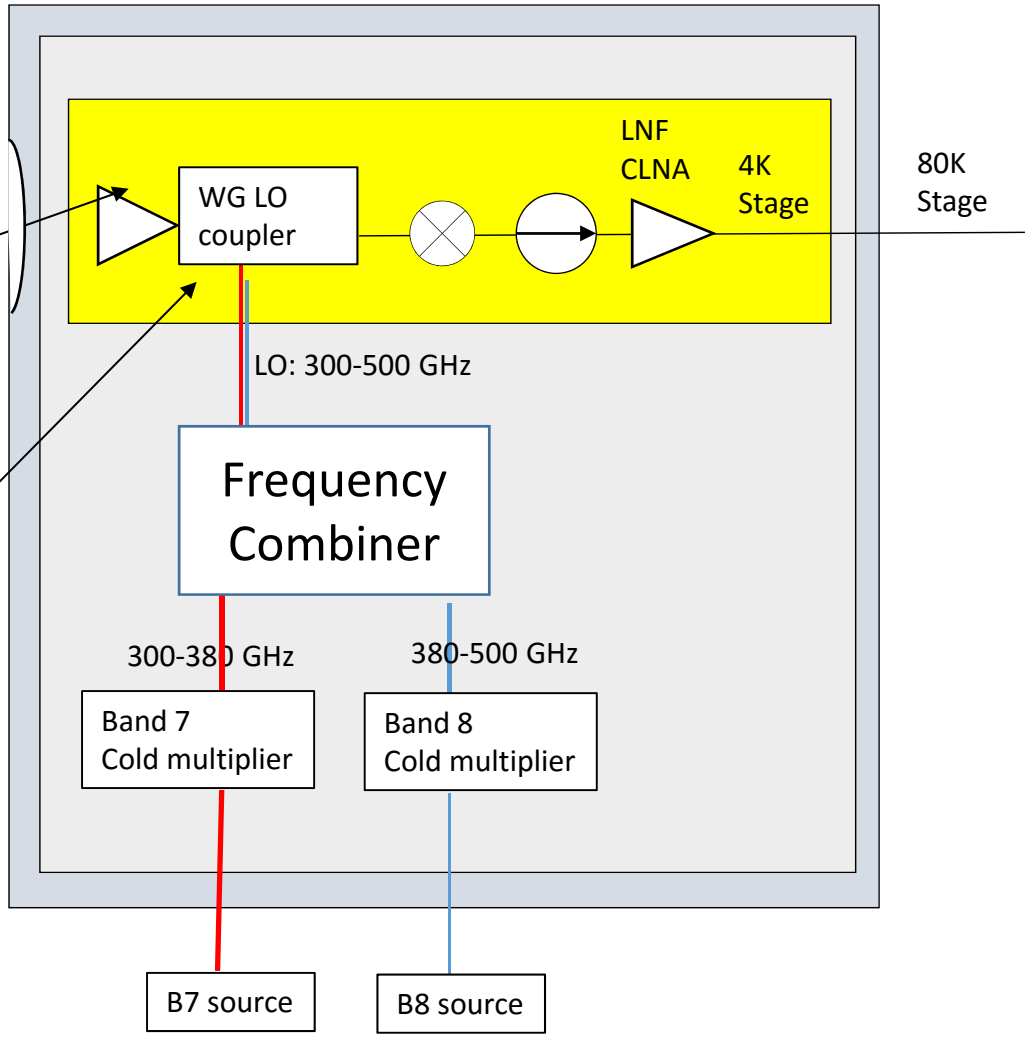


WG component design for Band 7+8 mixer measurement setup

In order to cover whole band, two sources and frequency combiner will be used.



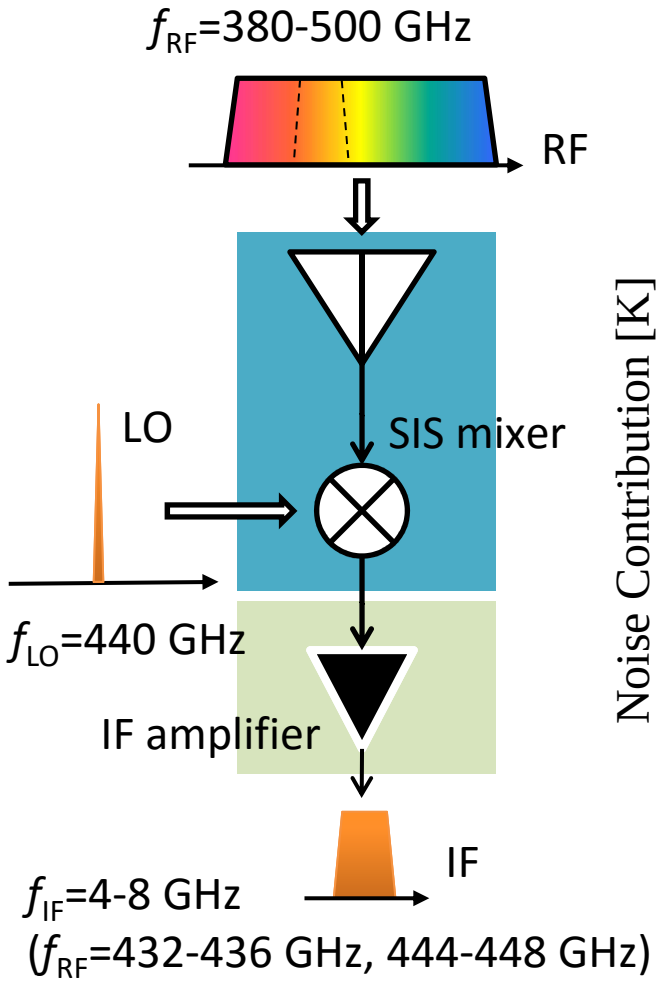




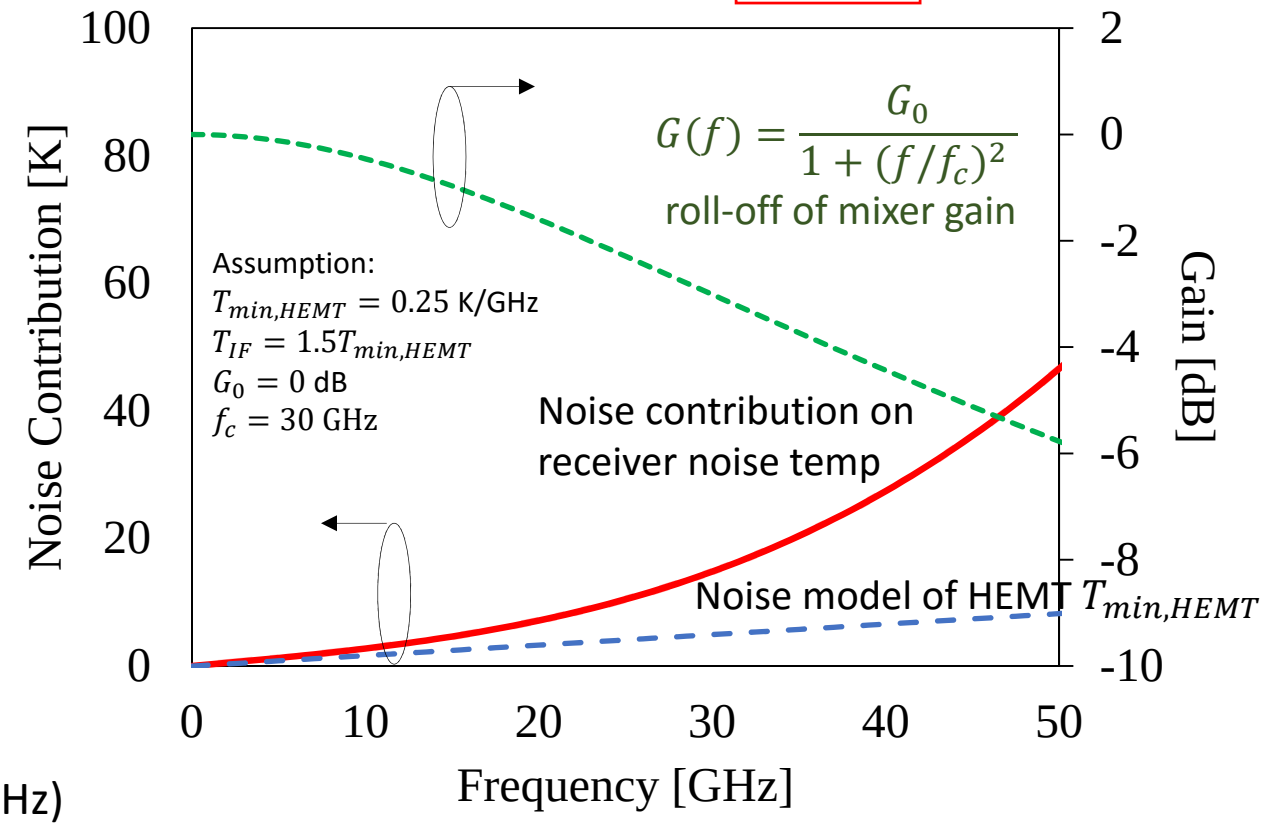
See presentation by A. Gonzalez

Wide **IF** Receiver (wide instantaneous)

The mixer noise has almost reached quantum limited performance.
At high IF, keep high mixer gain and low noise performance of IF amplifier.
Acceptable IF noise contribution might be below 20-30 GHz at most.



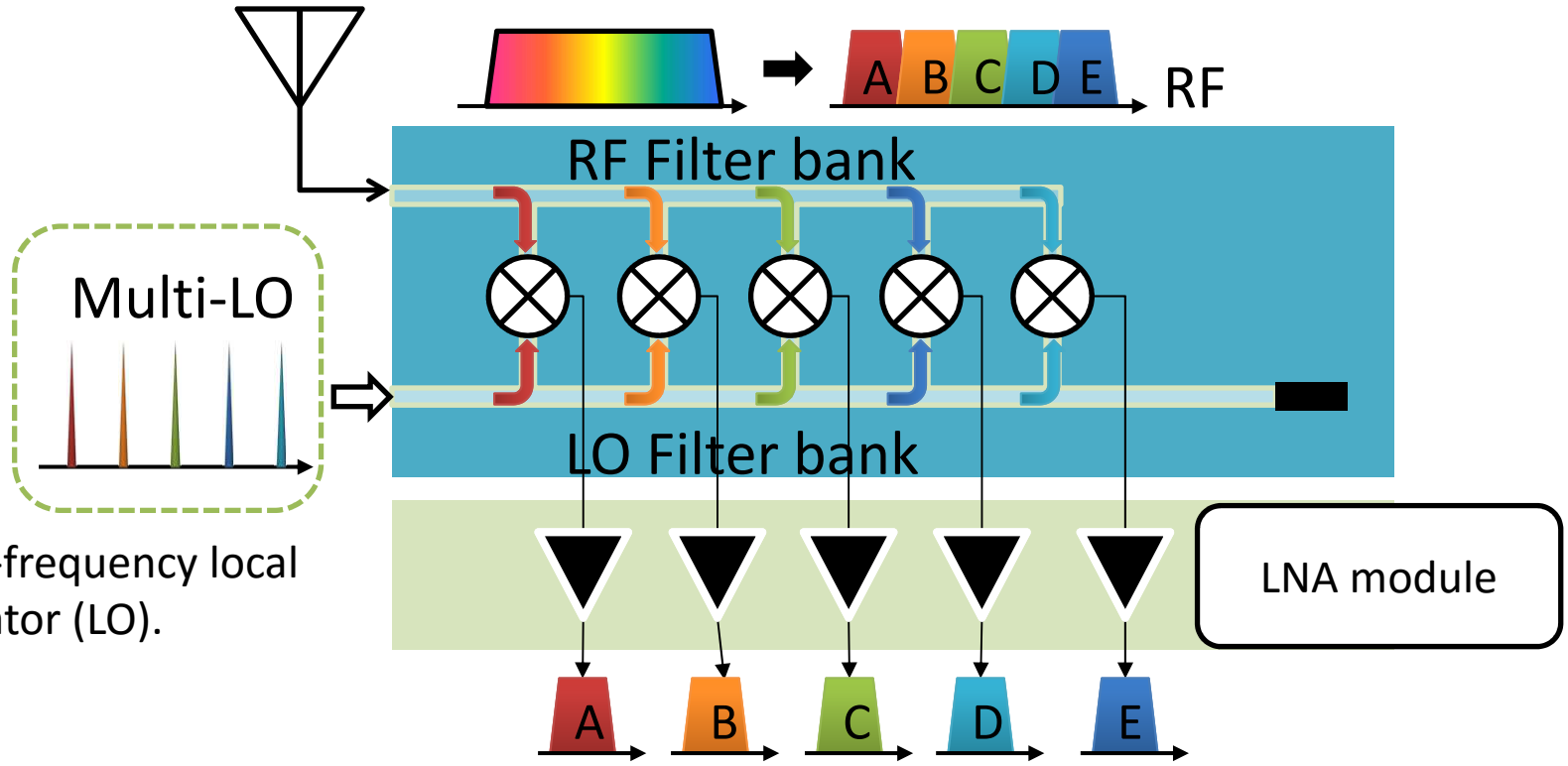
$$T_{rx}(f) = T_{mix}(f) + \frac{T_{IF}(f)}{G_{mix}(f)}$$



Approach to achieve much wider instantaneous bandwidth

・We have started study on a multiband low-noise receiver aiming at higher receiver sensitivity and simultaneous observation of multi-line spectra.

The full RF band into smaller bandwidths with several tens of GHz.

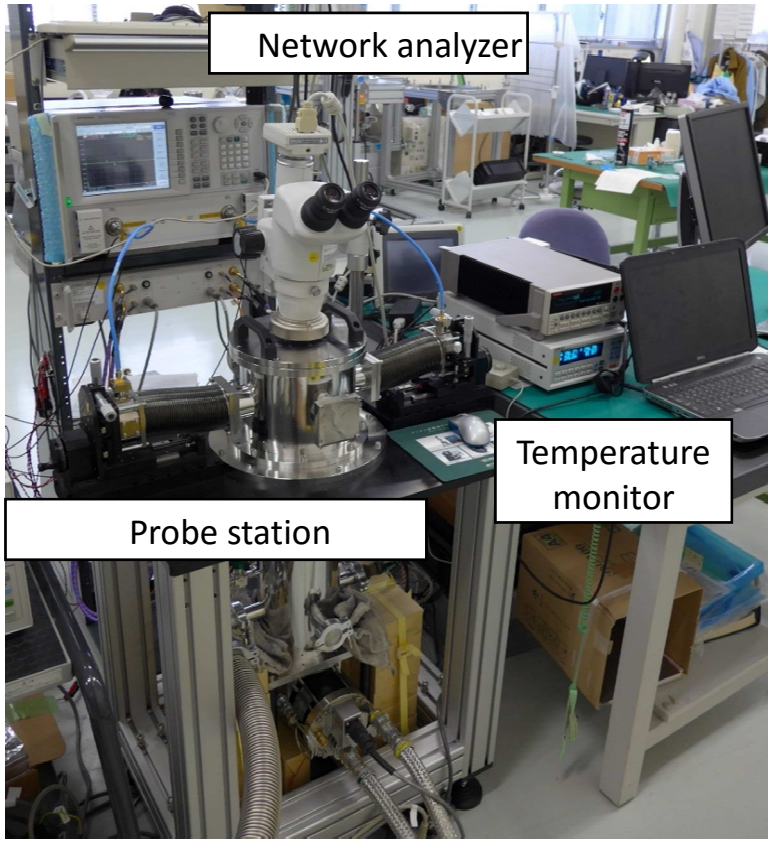


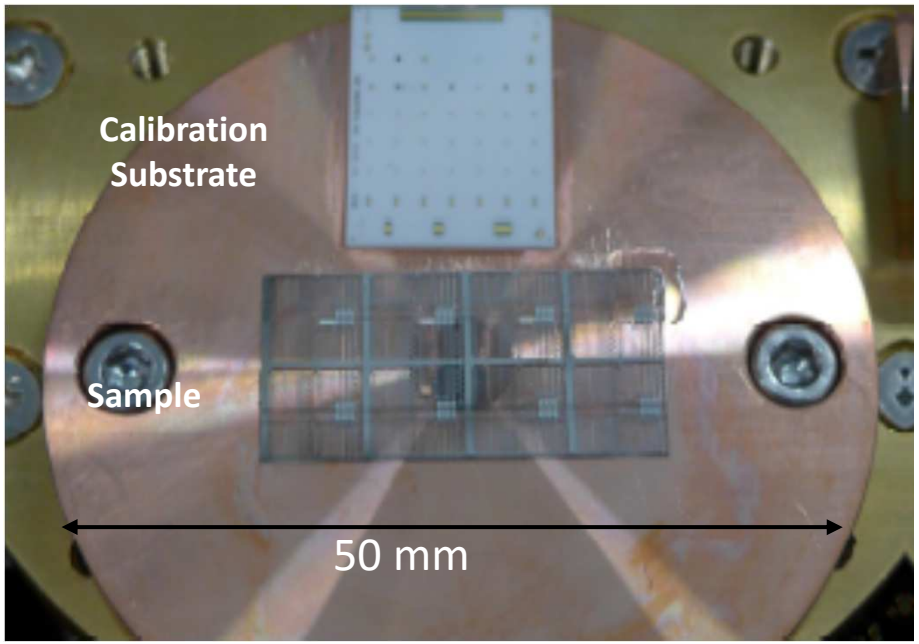
Multi-frequency local oscillator (LO).

The down-converted signals can be simultaneously amplified with dedicated similar IF amplifiers.

On-wafer device test with 4-K Probe station

- Design of mixer RF and IF circuits based on theoretical or empirical parameters
- For more accurate design, direct measurement of circuit element.
- 4-K probe station allow us to measure superconducting devices on wafer.





Temperature: 4.0 K (Allow to measure Nb-based circuit)
Cryocooler: GM Mechanical (1.5 W@4.2 K)
Frequency range: DC-67 GHz

Summary

Three development programs are now ongoing at NAOJ.

- Ultra-wideband
  Band 7+8 mixer development for RF wideband
  Multiband receiver for instantaneous wideband
- Terahertz
  Band 10 upgrade
  HEB mixer at 1.5 THz and SIS mixer at 1.2 THz
- Multibeam
  Wideband RF receiver development in collaboration with KASI
  On-chip circuit design have just stated.

Thank you for your attention!