Development of Band 7+8 cartridge receiver

September, 2021

Jung-Won Lee
on behalf of KASI-NAOJ team

Background & Milestones

- EA ALMA collaboration project from 2015

  cf. B2+3 (67-116 GHz) project led by EU ALMA

- Collaboration roles

KASI – horn(optics), WCA retrofit, cartridge integration & test
NAOJ – AlN-barrier mixer, 2SB unit, OMT and LO diplexer
ALMA legacy – cartridge body, WCA+cold multipliers, mixer bias

- important milestones

Oct. 2020 – Design review (Chair: Ming-Tang Chen of ASIAA)
Dec. 2021 – Acceptance review (tentative)

B7+8 receiver collaboration team

ALMA-EA management
Alvaro Gonzalez/Daisuke Iono

KASI ALMA management
Jongsoo Kim/Aran Lyo

KASI

Jung-Won Lee (lead)

Do-Heung Je (LO/IF/beam measurement setup)

Bangwon Lee

(splined feed horn, optics, lab test software)

Seungrae Kim (lab test)

-former member: Hyunwoo Kang

(M&C software)

NAOJ

Takafumi Kojima (EA ALMA development manager)
(formerly Yoshinori Uzawa, Alvaro Gonzalez, Shin'ichiro Asayama)

Takafumi Kojima (mixer design & evaluation)

Keiko Kaneko (component mech. design & cartridge design)

Tetsuya Ito (ASTE team)

Seiichi Sakamoto (ASTE team)

Alvaro Gonzalez (splined feed horn, OMT, LO diplexer)

Wenlei Shan (mixers, novel FPA concept)

Yasunori Fujii (test cryostat, test software MIX11)

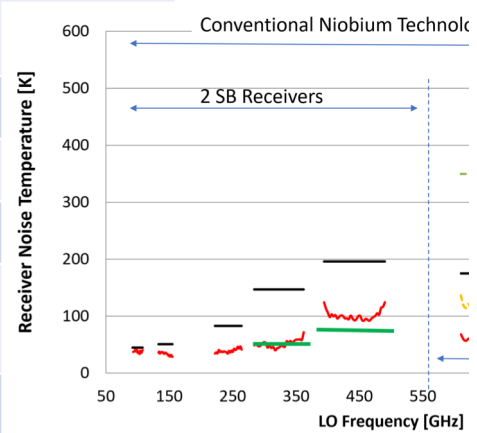
-former member: Matthias Kroug (mixer fabrication)

OPU (OMT) : 2015-2017

Yutaka Hasegawa
Hideo Ogawa

Specifications of B7+8 cartridge receiver

	specifications	
RF frequency	275- 373 GHz, 385-500 GHz	Band7+8
SSB noise temperature	275-373 GHz : 147 K(80%), 219 K (any frequency) 385-500 GHz: 196 K(80%), 292 K (any frequency)	
polarization	dual linear polarization	
IF frequency	4-8 GHz (USB/LSB per each pol.)	
LO frequency	283-365 GHz, 393-492 GHz	
Image rejection	≥ 10 dB over 90% of IF frequency range ≥ 7 dB over entire IF frequency range	
Gain stability	Allan variances ≤4.0 x 10-7 (0.05 s ≤ T ≤ 100 s) ≤3.0 x 10-6 @ 300 s	
Gain compression	large signal gain compression <5% with 373 K and 77 K RF load	

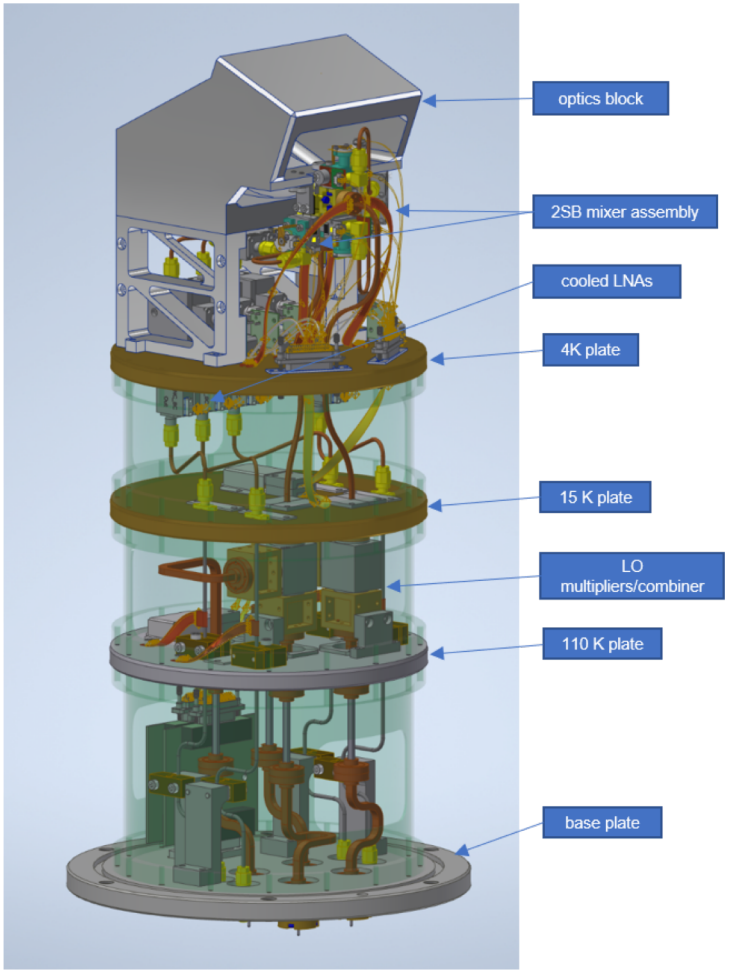


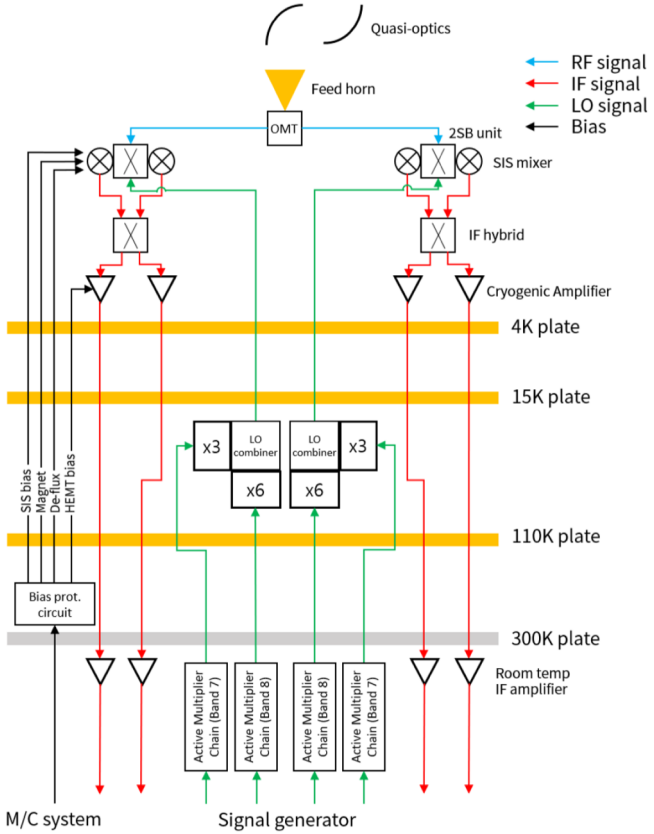
Combined band 7 and band 8 receiver development was initiated according to demand of the regional astronomical users at EA ALMA development workshop in 2014.

Summary of our approaches for B7+8 receiver

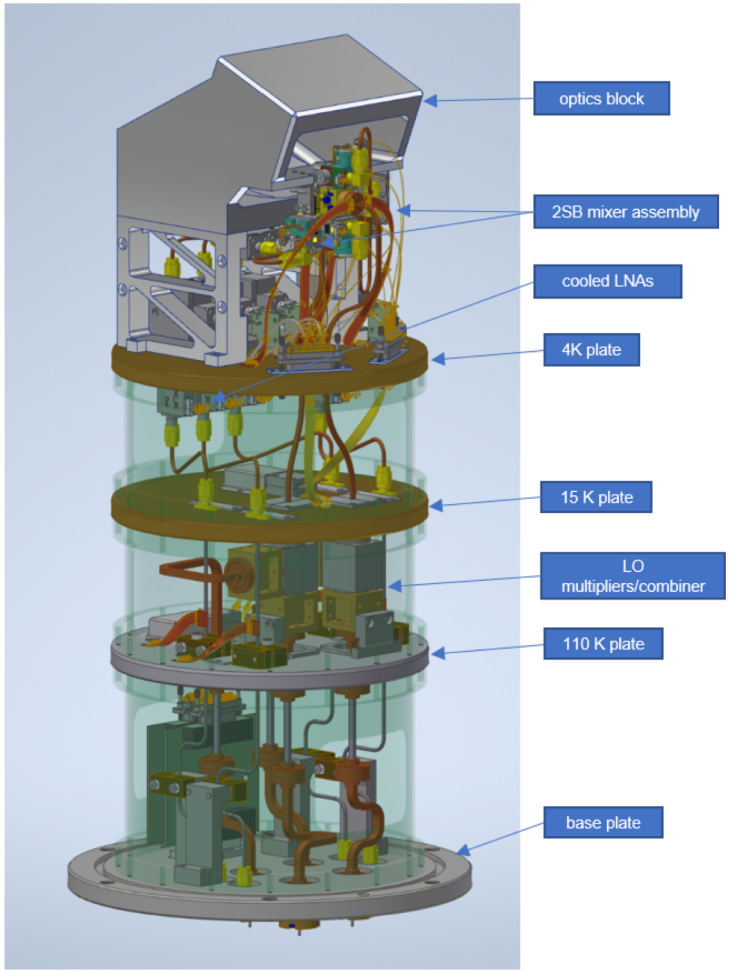
component	technical description
horn	a horn with profiled corrugations (direct-machined)
orthomode transducer	double-ridged OMT with a compact waveguide flange
RF hybrid	waveguide with wider bottom for feasible slot widths
SIS mixer	high Jc AlN-barrier junctions
LO generation	multiplexed cold multipliers + combined WCA from band 7 WCA and band 8 WCA

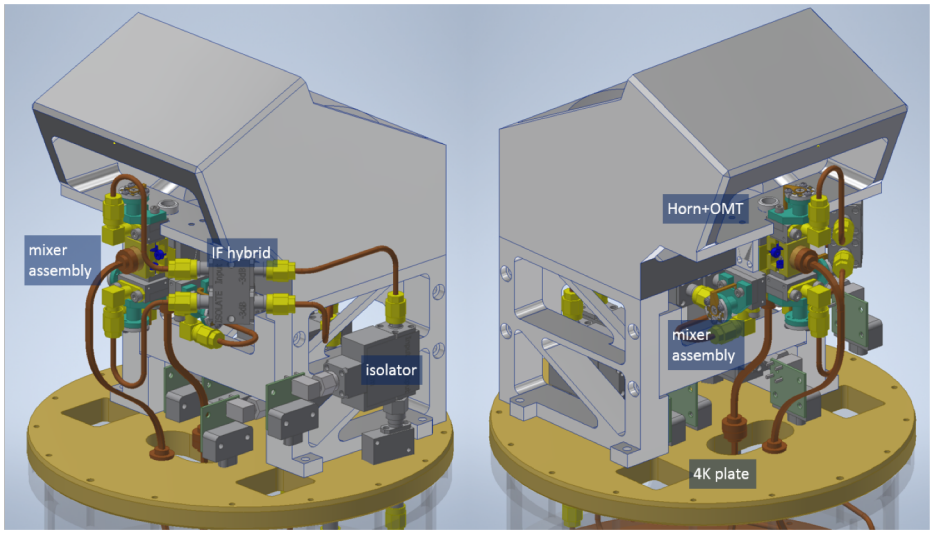
cartridge layout



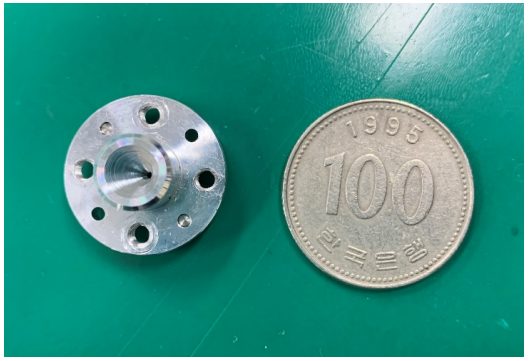


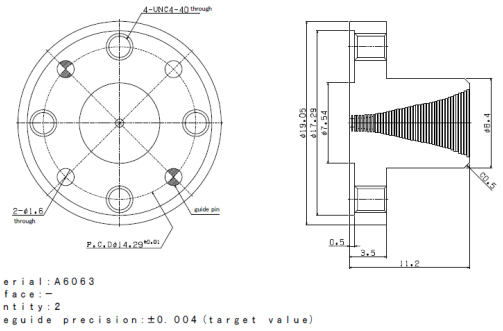
cartridge layout



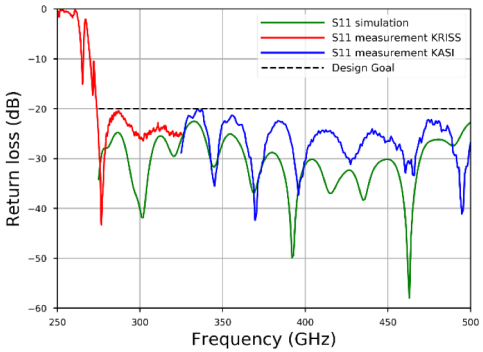


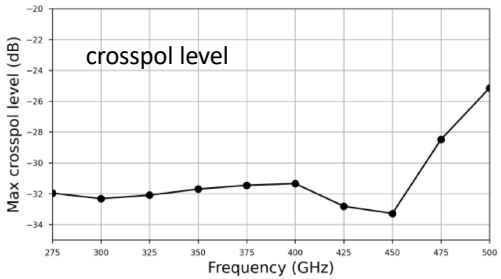
profiled corrugated horn (Bangwon Lee & Alvaro Gonzalez)

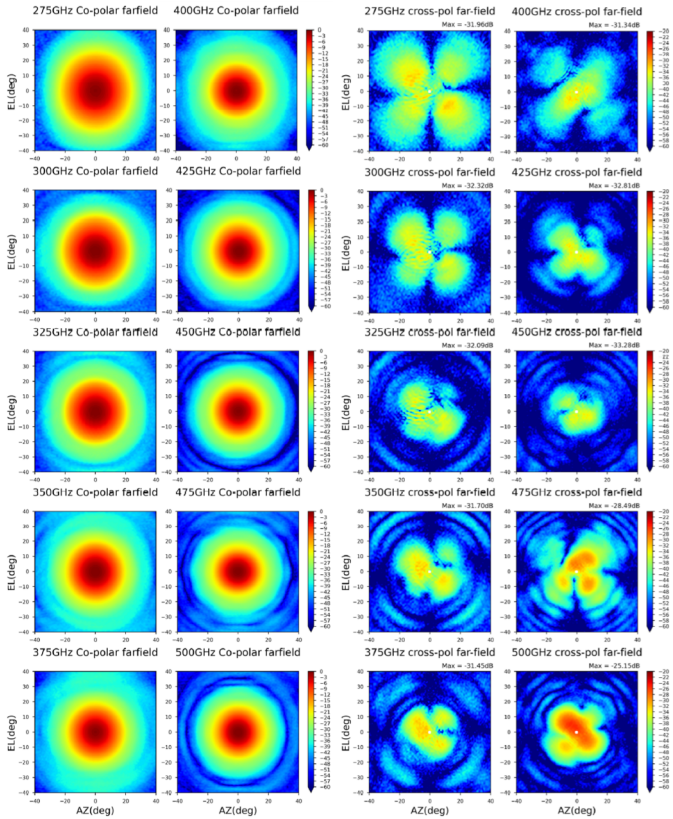




material : A6063
surface : –
quantity : 2
waveguide precision : ±0.004 (target value)



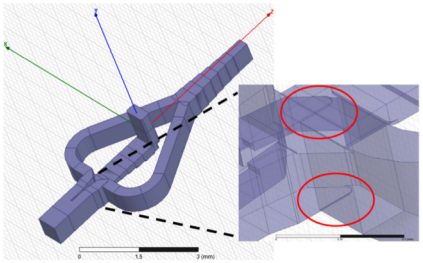


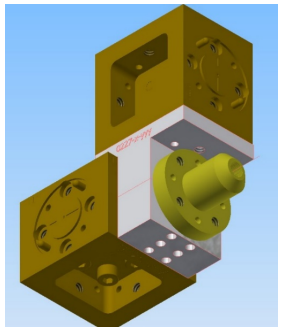


Far field beams converted from near-field measurements

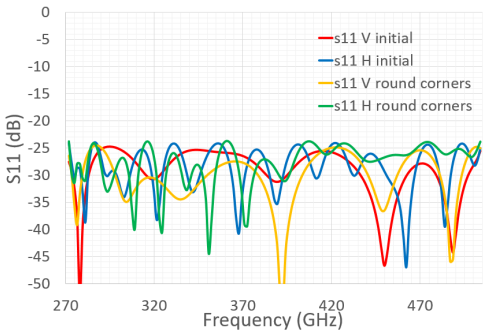
wideband OMT prototype

A. Gonzalez et al., IEEE TST, no. 3., 2021

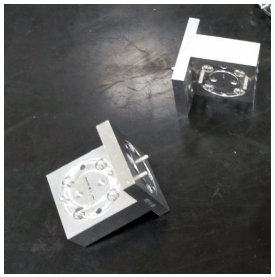




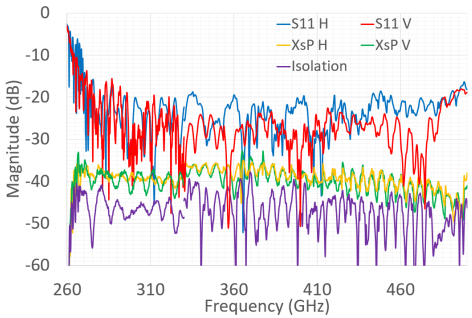
Assembly Horn + OMT + 2SB units



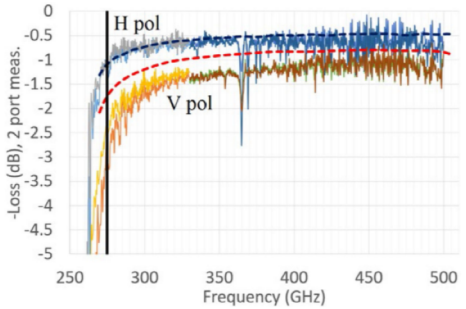
simulated return loss



UG387 flange

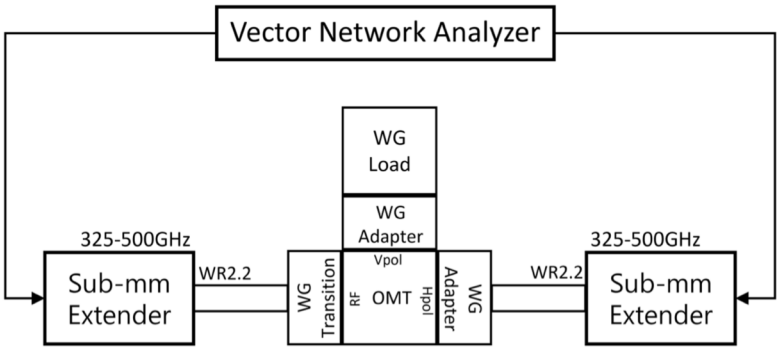


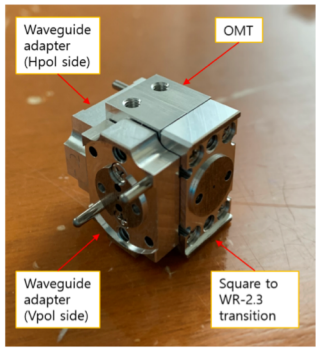
measured reflection/crosspol leakage/isolation

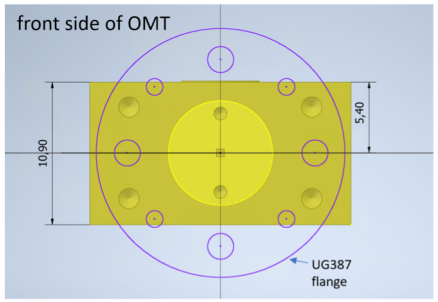


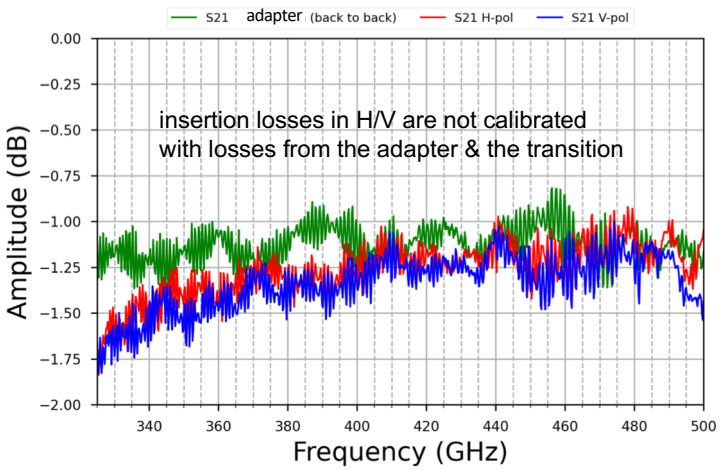
measured insertion loss with simulated ones

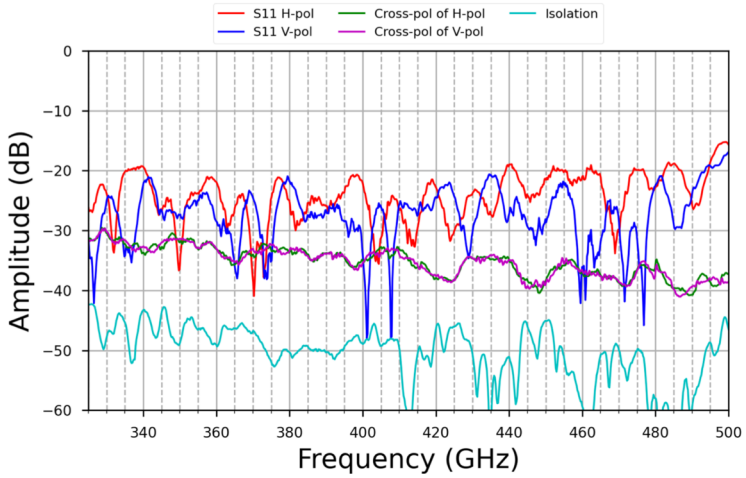
OMT with compact flanges





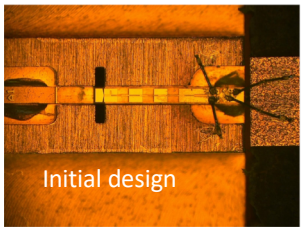


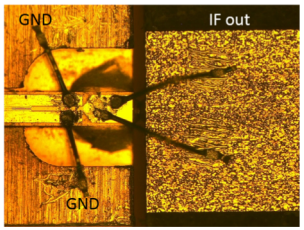


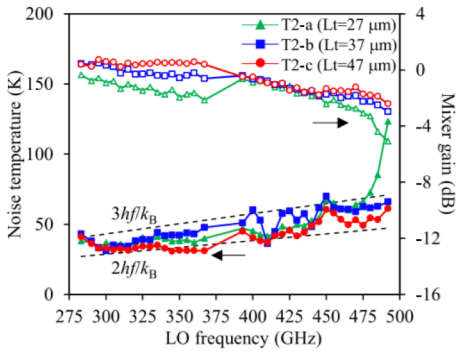


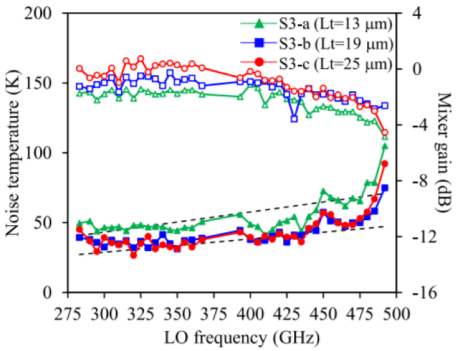
NAOJ B7+8 mixer

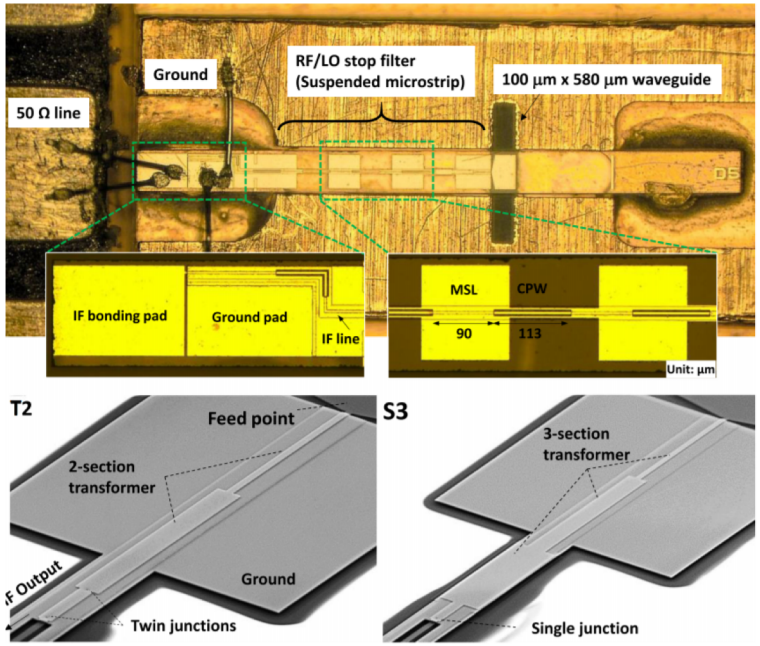
AlN high jc (30kA/cm2) junctions
T. Kojima et al., IEEE TST, 2018











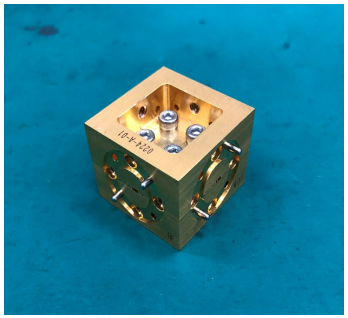
2-section transformer+ twin junctions (T2)
3-section transformer + single junction (S3)

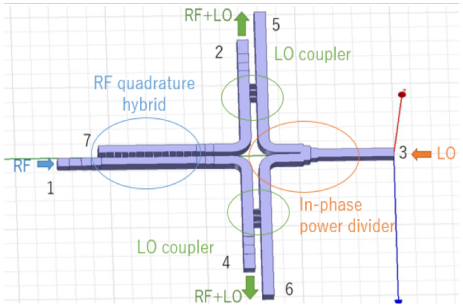
best DSB mixer performance : T2-c/S3-b, given measured T_IF as 7 K

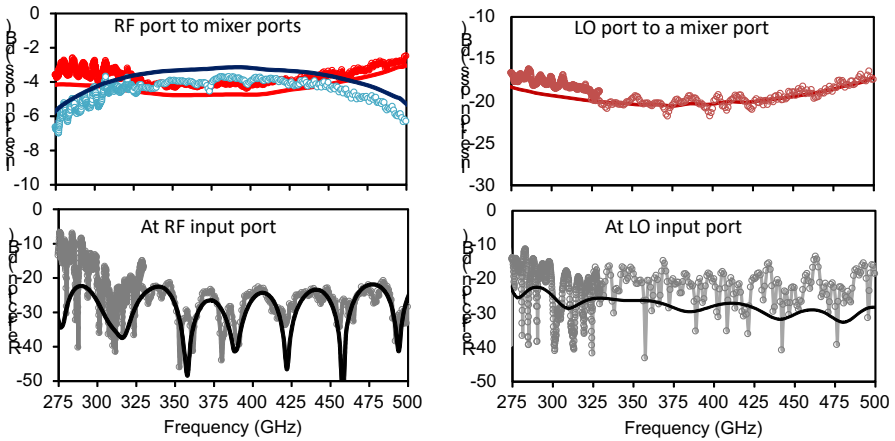
- Gmix= -2.5~+ 0.5 dB
- Tmix(DSB) = 1.5-2 quantum limit

prototype 2SB unit

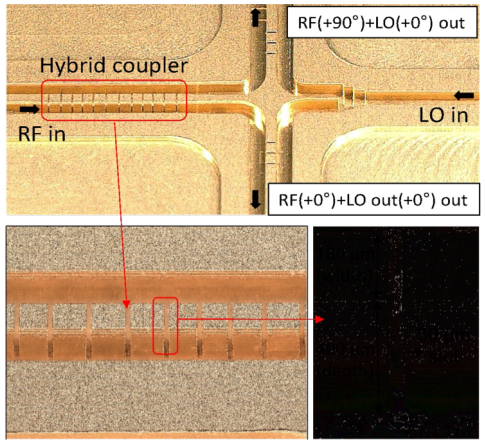
T. Kojima et al.







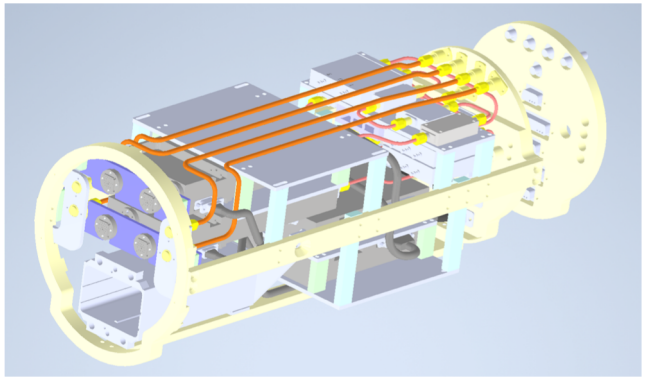
Comparison of the performance between the simulation (solid line) and measurement (circles)

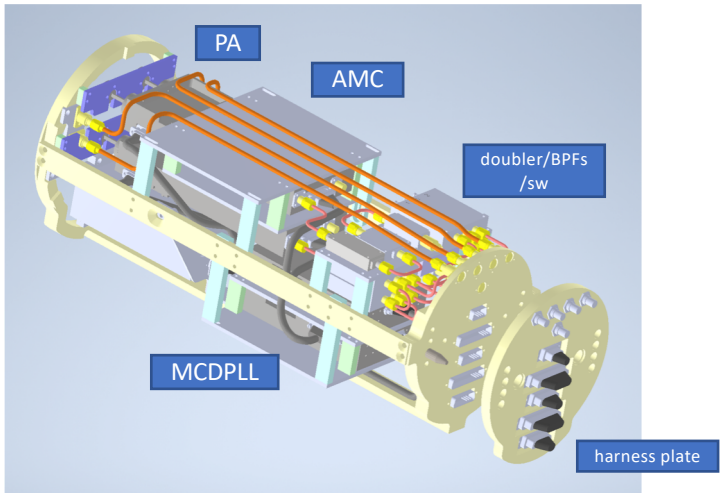


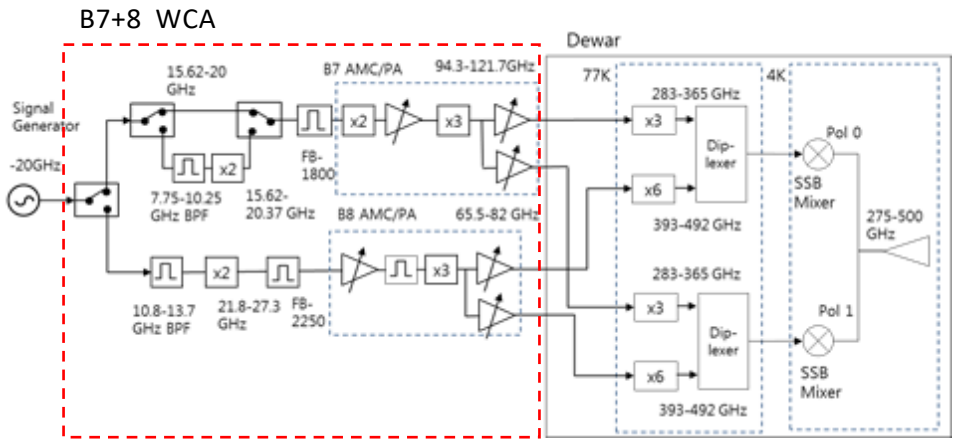
Revised units are under fabrication for tighter tolerances (<3 um) esp. in slot width (amplitude imbalance <2 dB)

combined WCA

(Do-Heung Je)





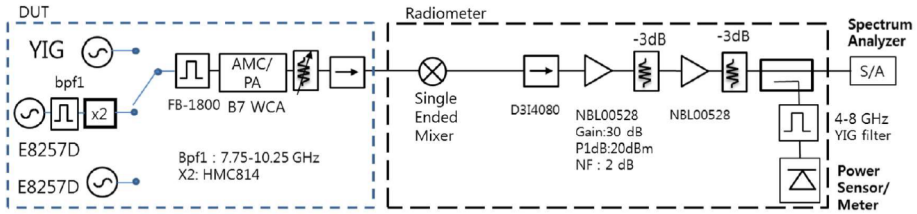


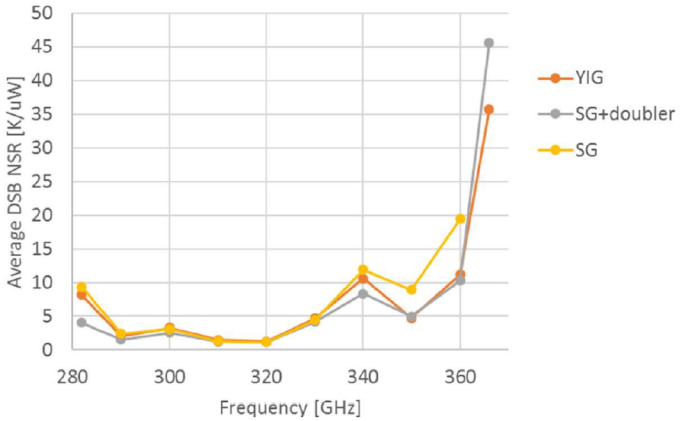
- base oscillator : a COTS signal generator (Agilent E8257D)
- switches, BPFs and doublers are necessary to cover the bandwidth and to ensure low AM noise from the signal generator

combined WCA: AM noise

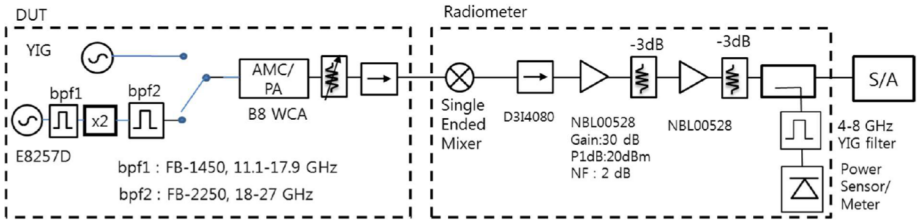
Do-Heung Je

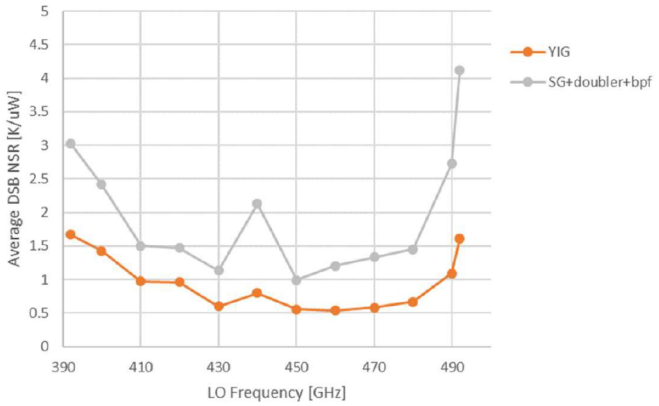
band 7





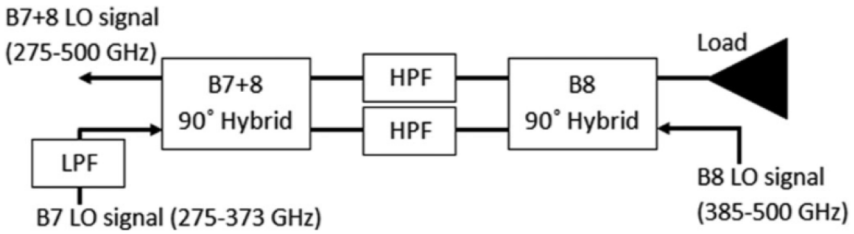
band 8

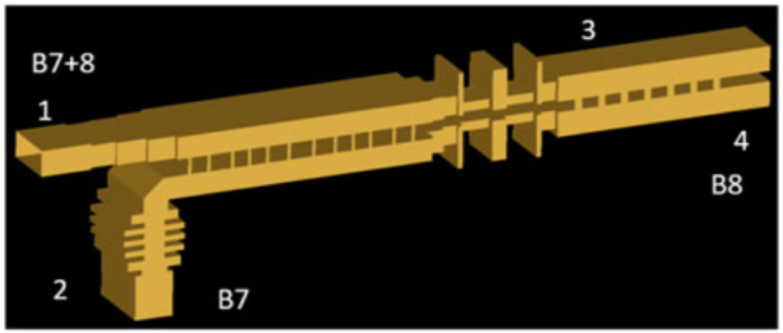


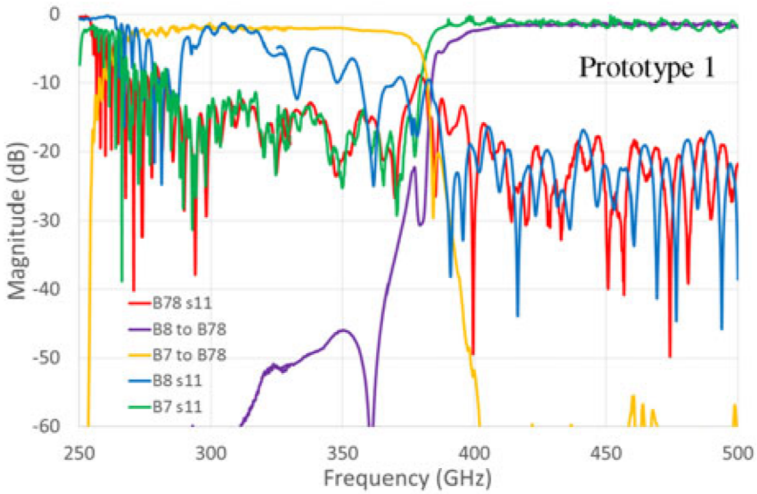


LO diplexer

A. Gonzalez et al., IEEE TST, 2017



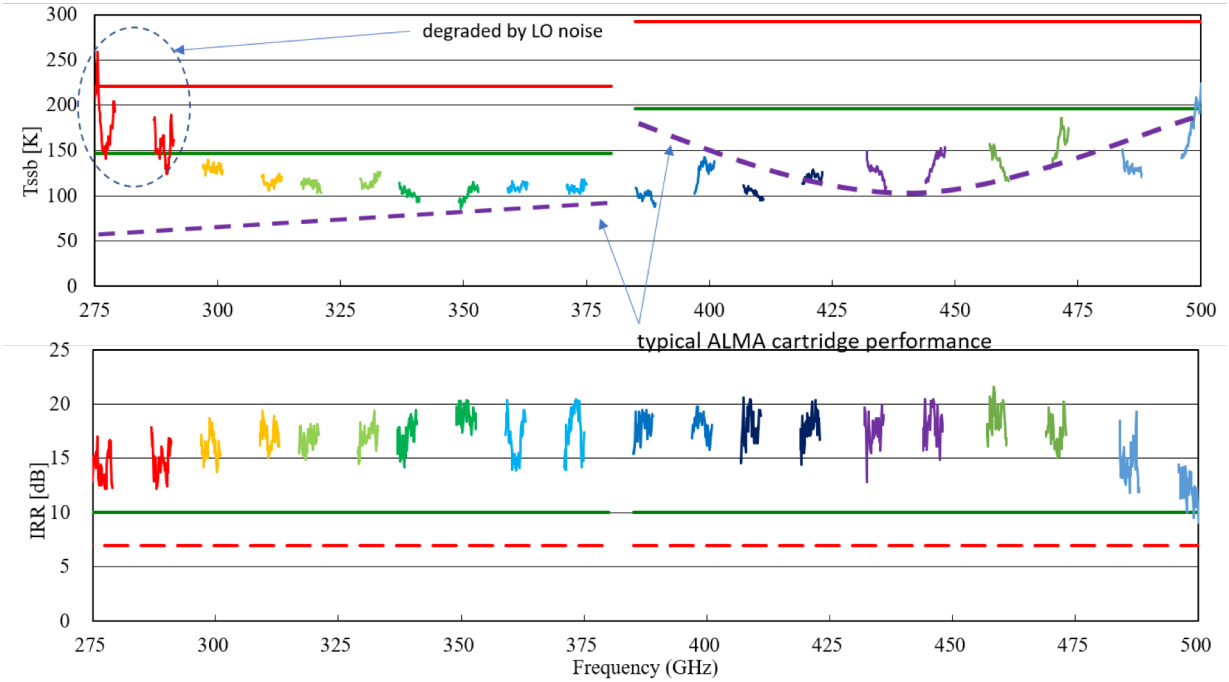




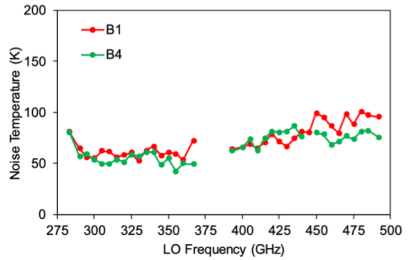
- Such a component allows us to use dedicated AMC chains in each band.

2SB mixer performance

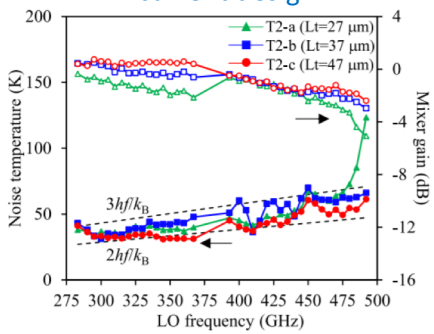
(Takafumi Kojima)



initial design

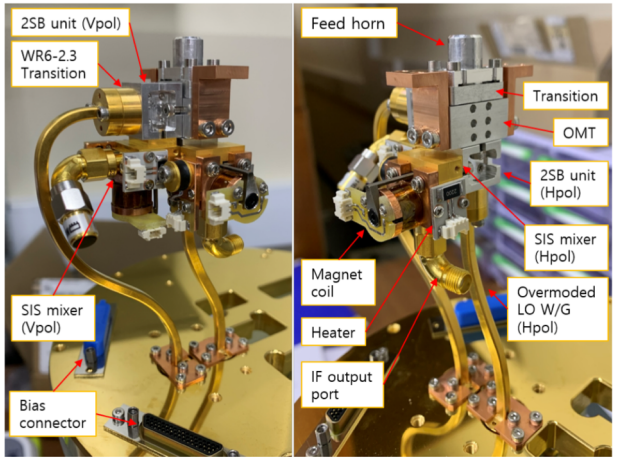


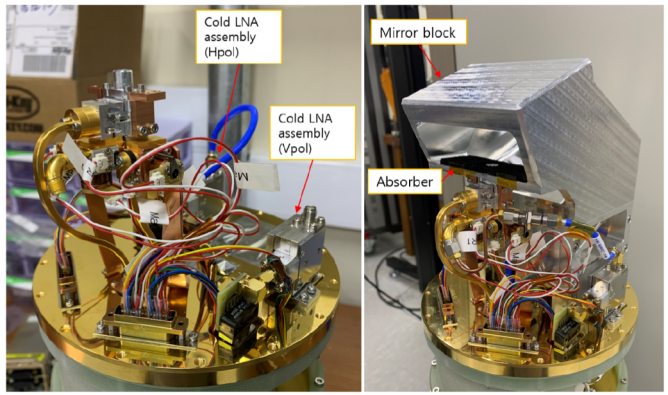
current design

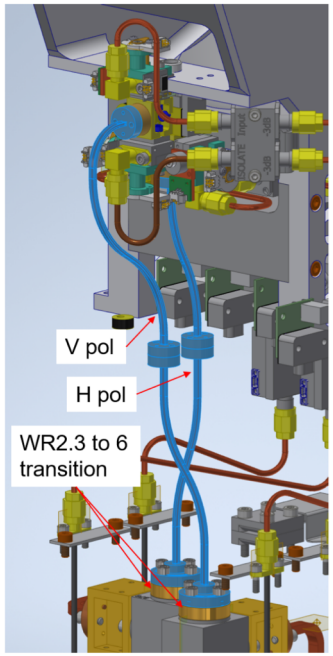


- measured with 1st gen. b7+8 mixers; without OMT
- expect to follow Band 7 noise performance with mixer chips of the multi-section transformer

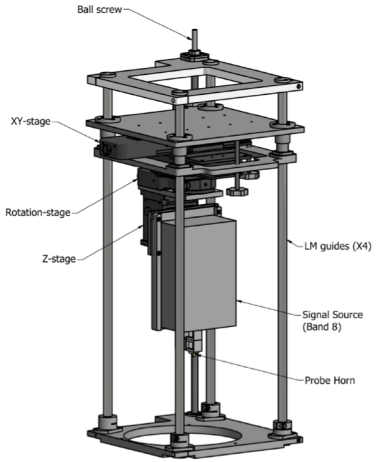
cold beam measurement



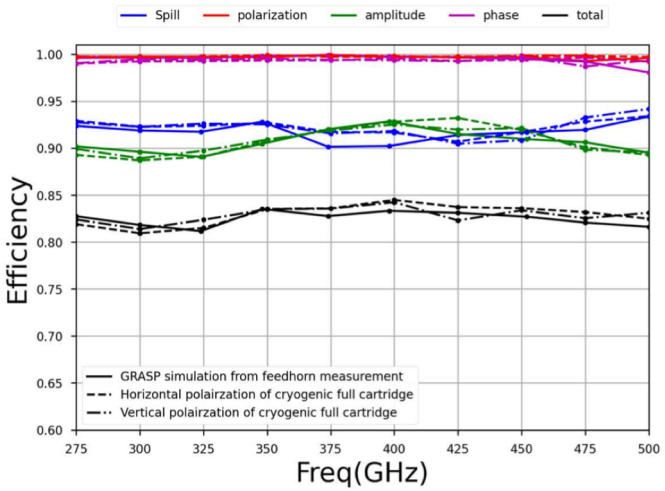




overmoded waveguide chains

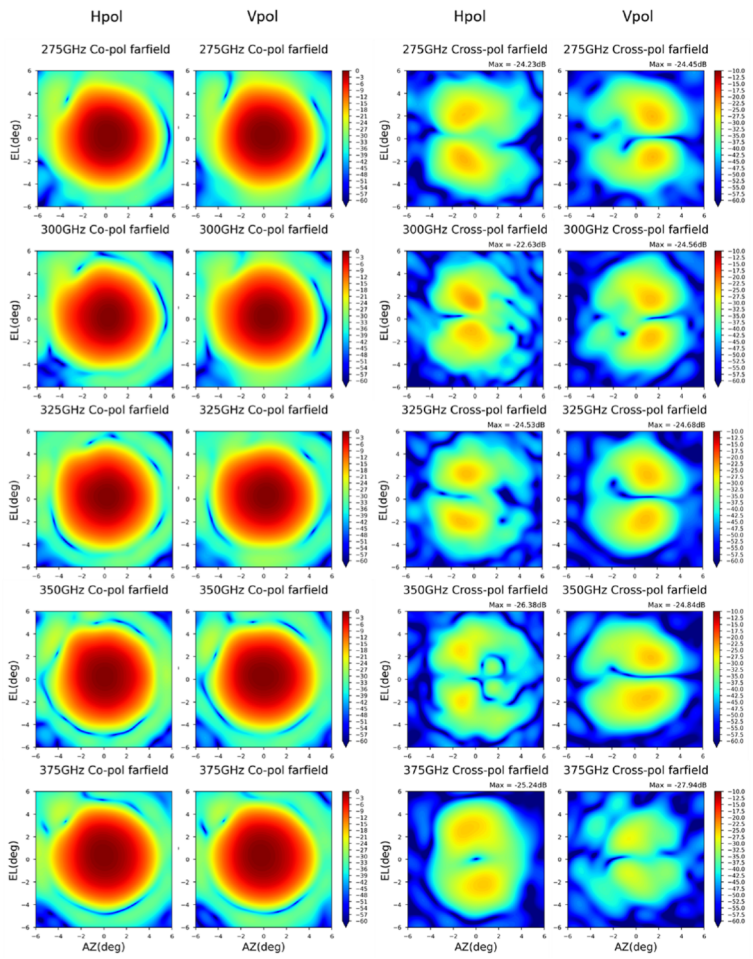


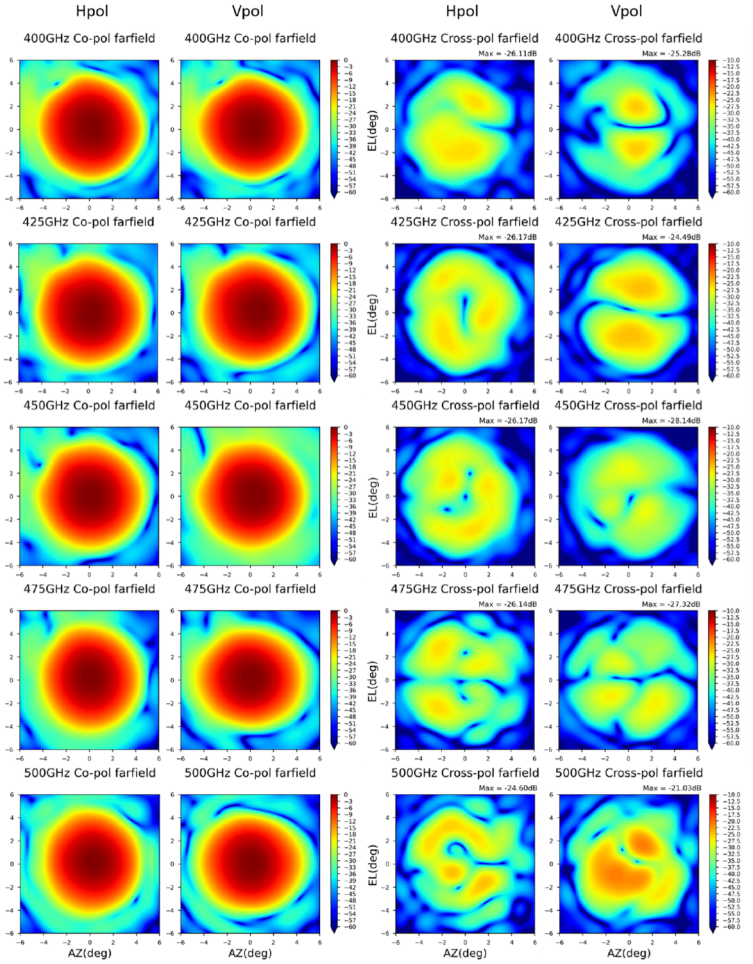
beam scanner on top of the cartridge test dewar



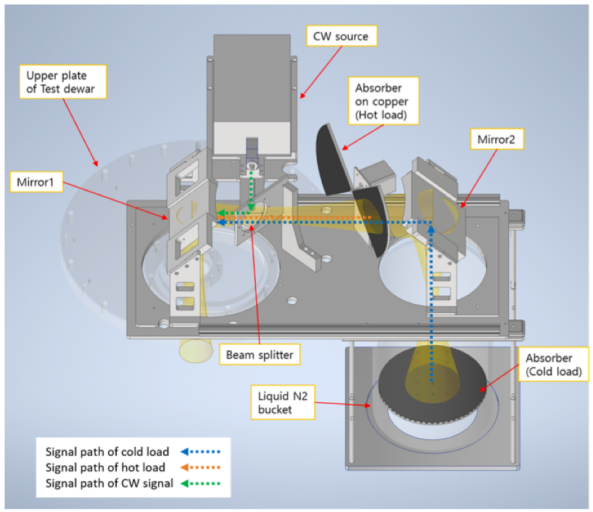
aperture efficiency estimate from cold beam measurement

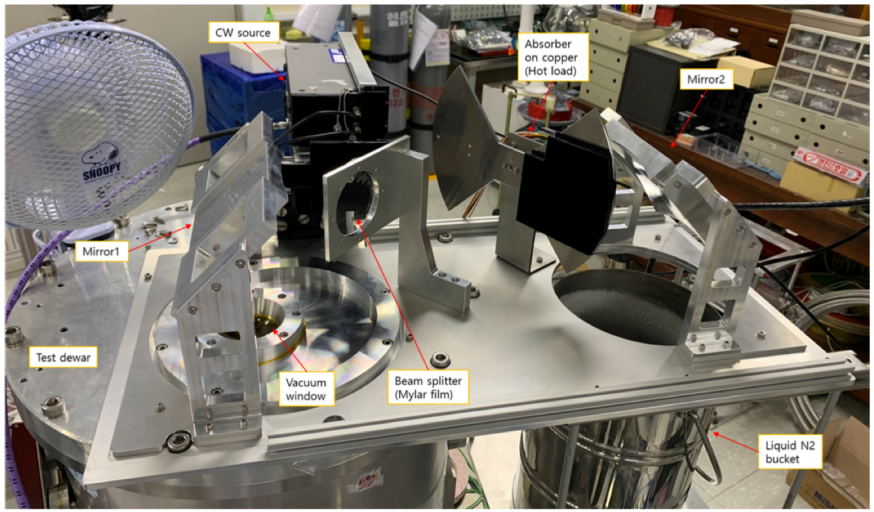
cold beam measurement: far-field patterns

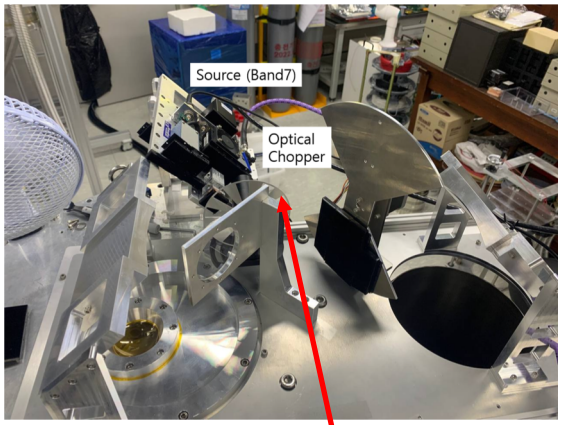




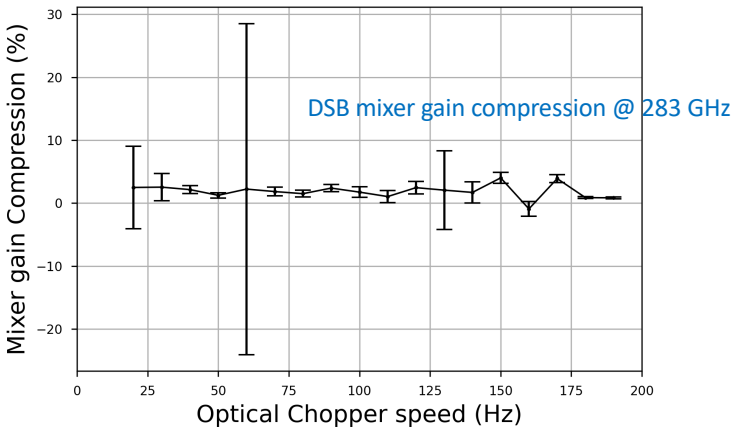
2SB/gain compression measurement







optical chopper added in front of
CW source for incremental gain change

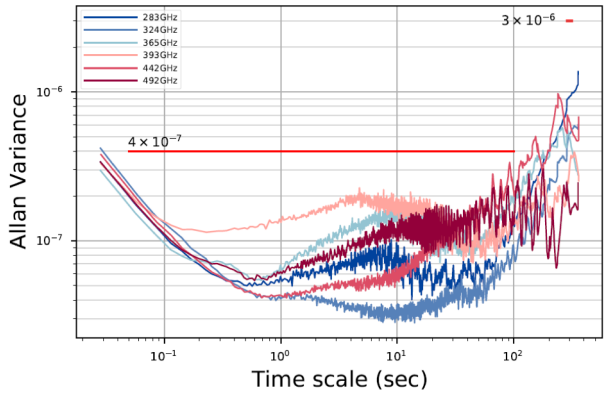


Summary & outlook

- Various receiver components working for band 7+8 frequency range were developed successfully.
- New 2SB unit fabrication: fabrication will be finished around mid-October

→ Tests are expected to start from late October after re-assembly.

→ Measurement of the whole cartridge performances will be completed within this December.



gain stability of a B7+8 DSB mixer in the cartridge