Low-noise THz-range SIS Receivers based on Nb tunnel junctions for Radio Astronomy

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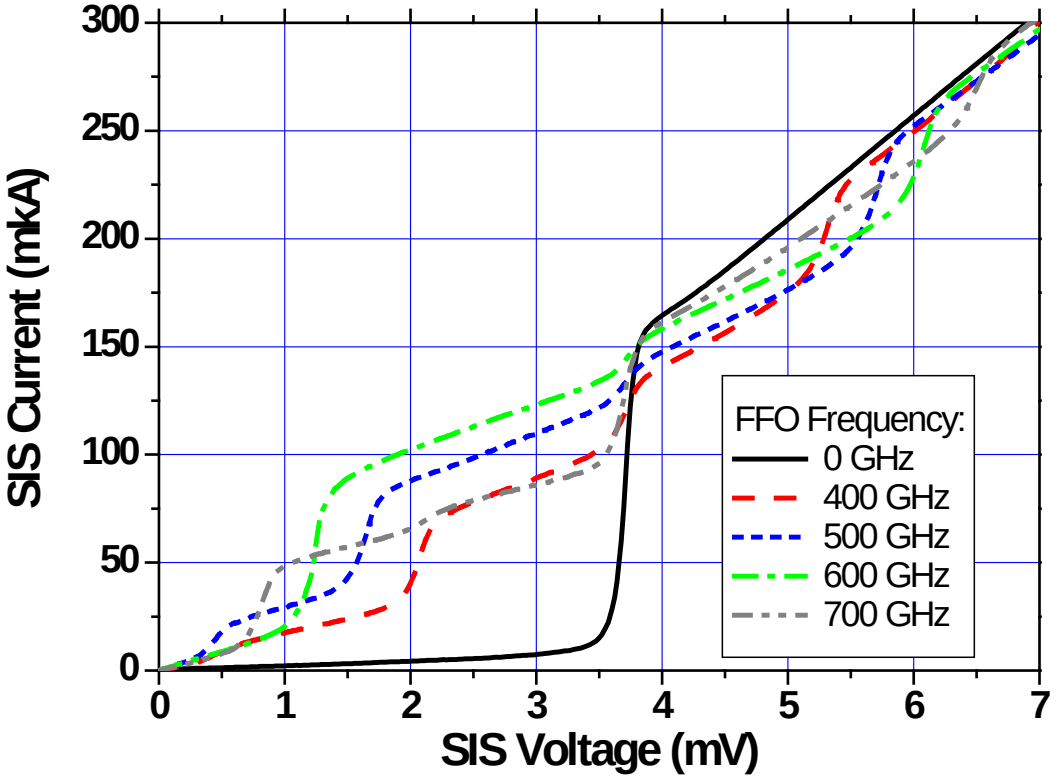
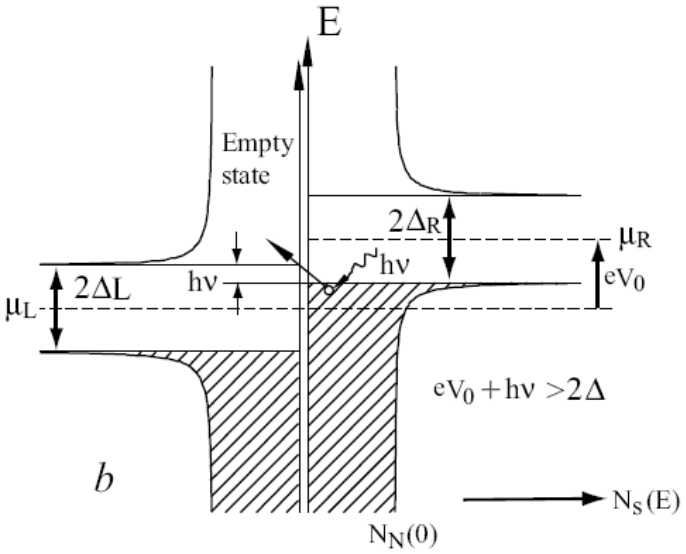
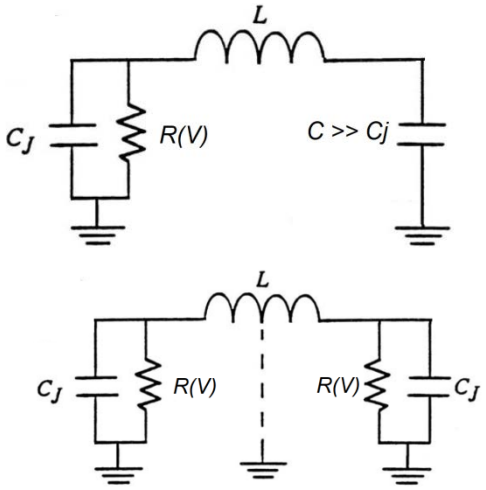
Quantum-limited coherent SIS-mixers;



Frequency range: 0.1 – 1.4 THz, Noise temperature down to hf/k_B





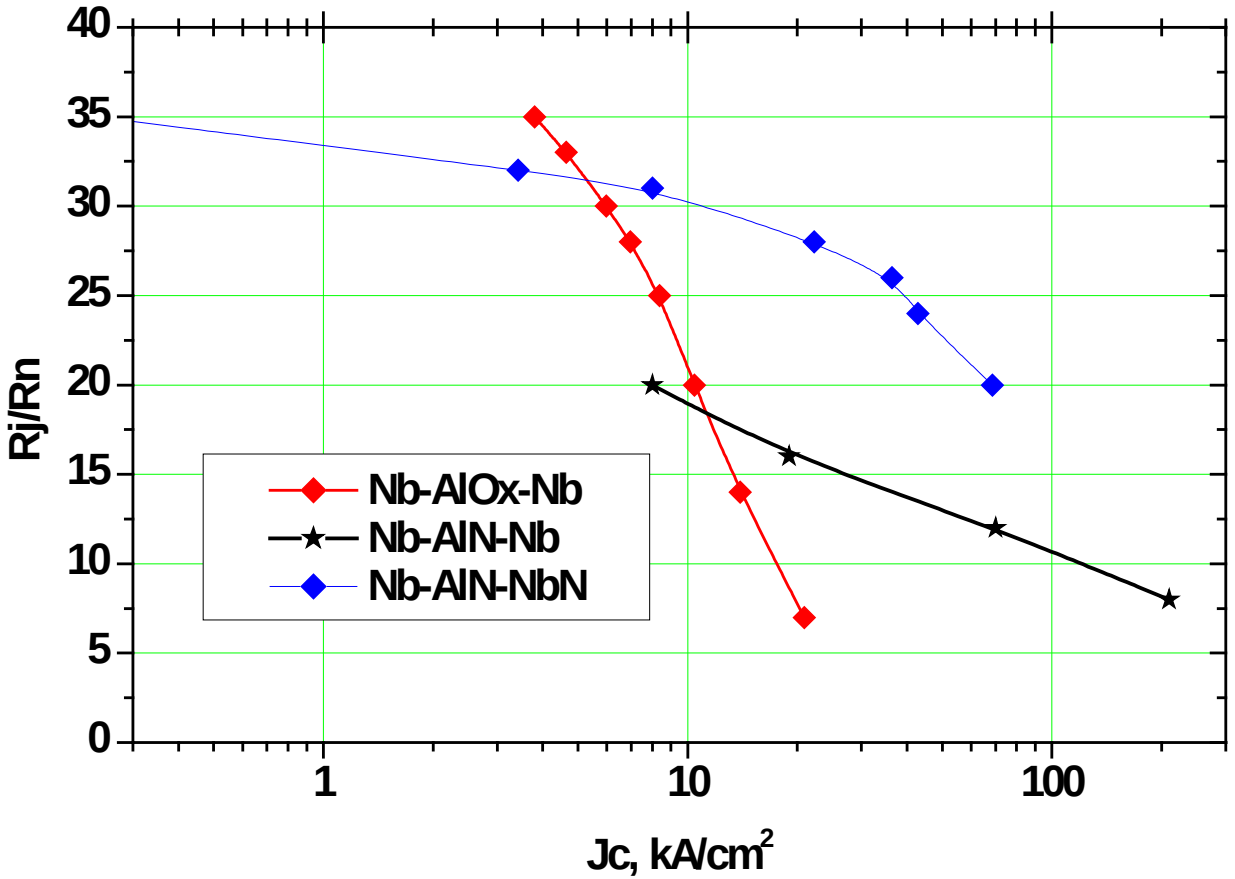
Nb-AlOx-Nb
Nb-AlN-Nb(N)
J_c = 5-30 kA/cm²

Rj/Rn > 20

SIS Junctions for THz mixers
Nb-AlN-NbN; Nb-AlOx-Nb;

J_c = 1 - 100 kA/cm^2; S = 0.1 – 1000 mkm^2

Vg as high as 3.7 mV for Nb-AlN-NbN



Nb/Al-AlN/NbN SIS junctions for THz mixer

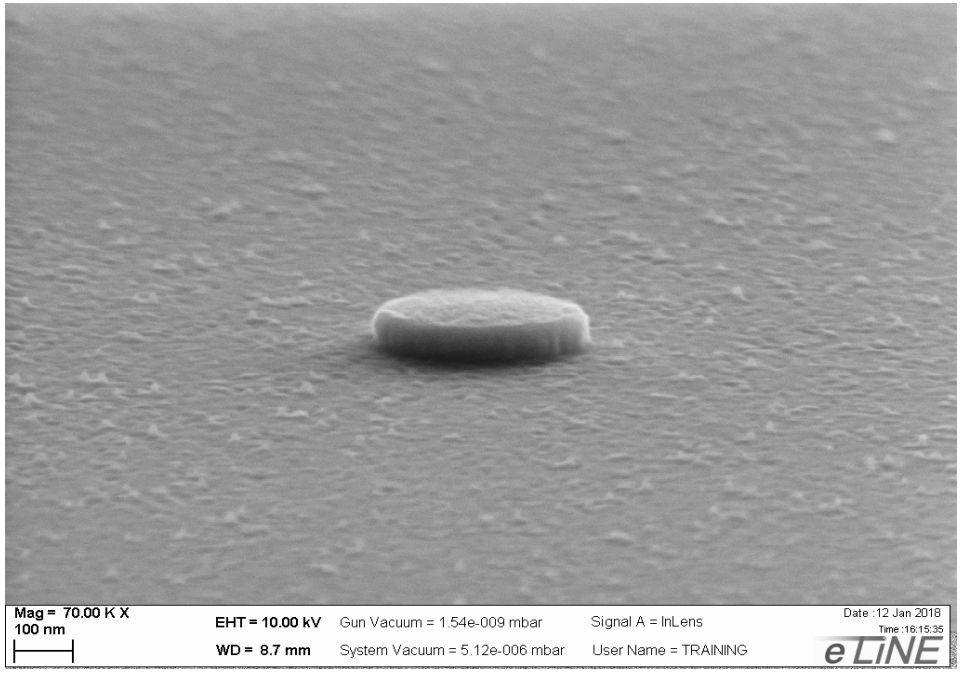
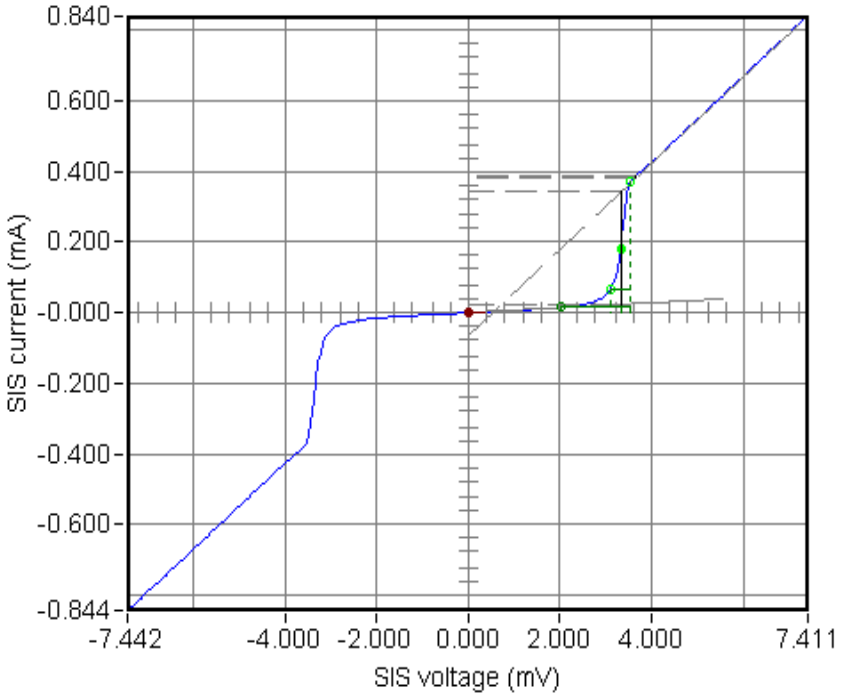
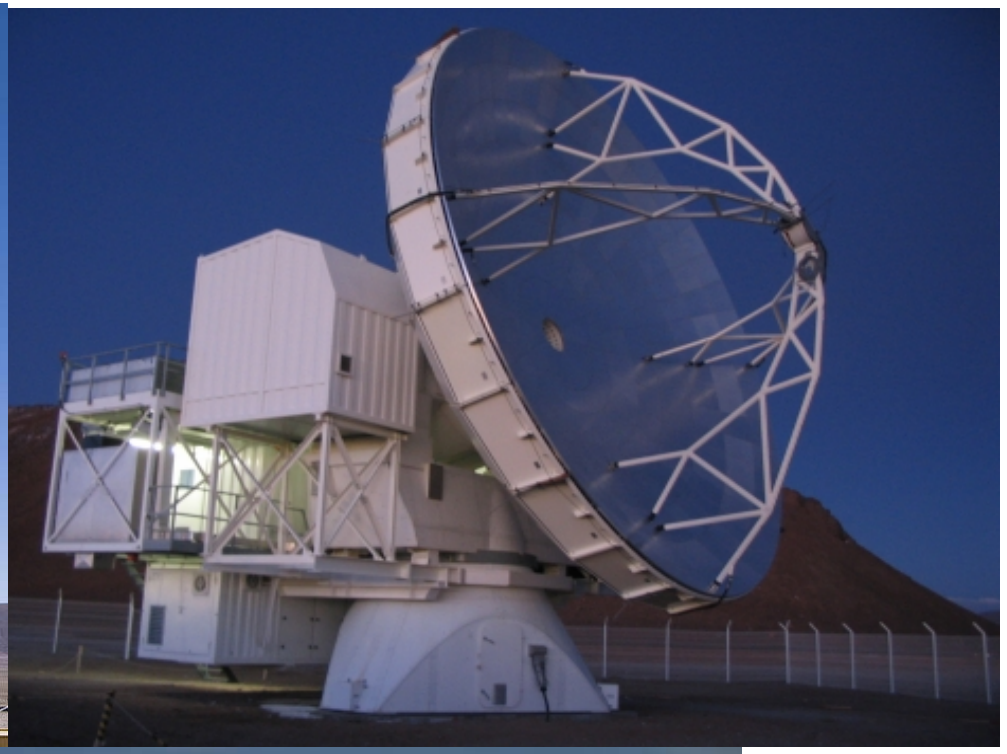


Photo of the Nb/Al-AlN/NbN junction after RIE (without SiO_2 layer)
SIS junction area = 0.1 μm^2



IVC of the Nb/Al-AlN/NbN junction
(junction area = 0.7 μm^2)
Vg = 3.33 mV; Rn= 8.2 Ω; Rj/Rn = 18

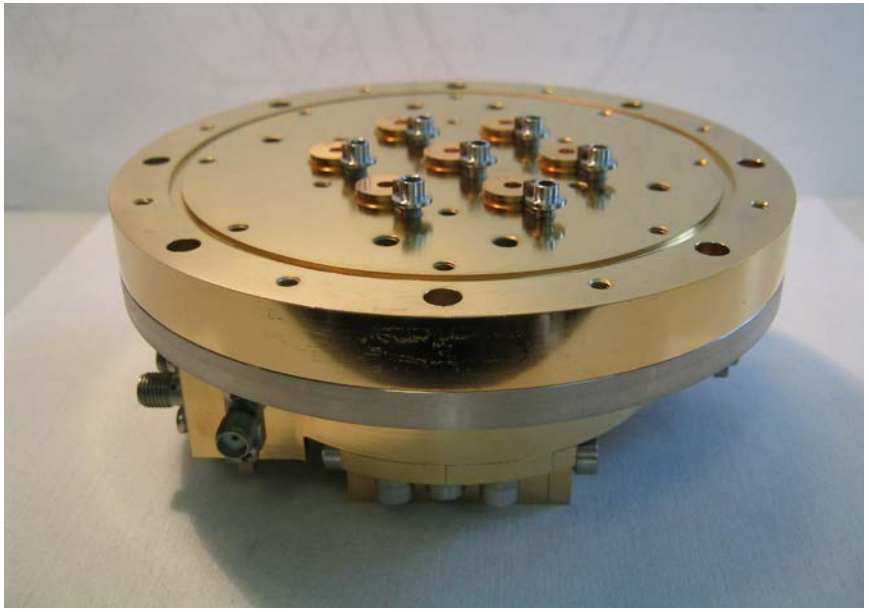
CHAMP+ at APEX (Chile, 5105 m, 12m dish)



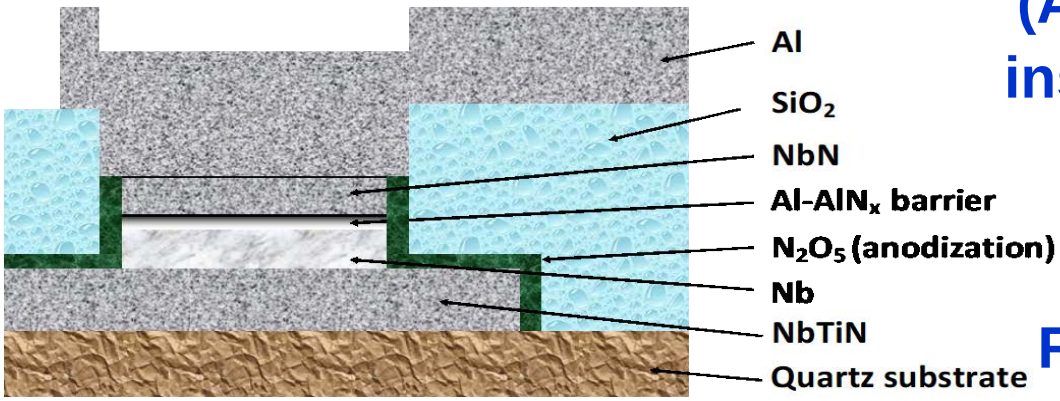
Atacama Pathfinder EXperiment (APEX)

CHAMP+

- 7 SIS mixers
  600 - 720 GHz
- 7 SIS mixers
  780 - 950 GHz
- IF: 4 - 8 GHz

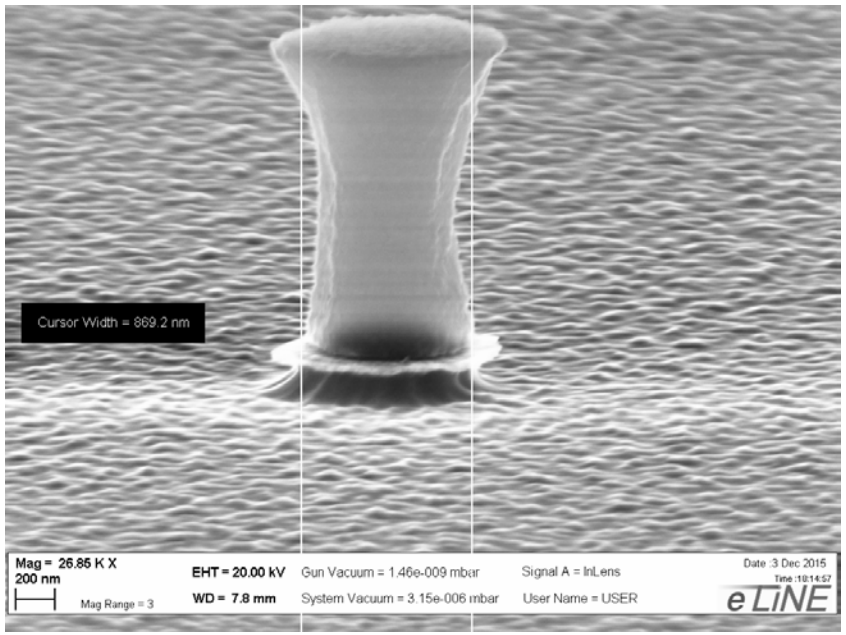


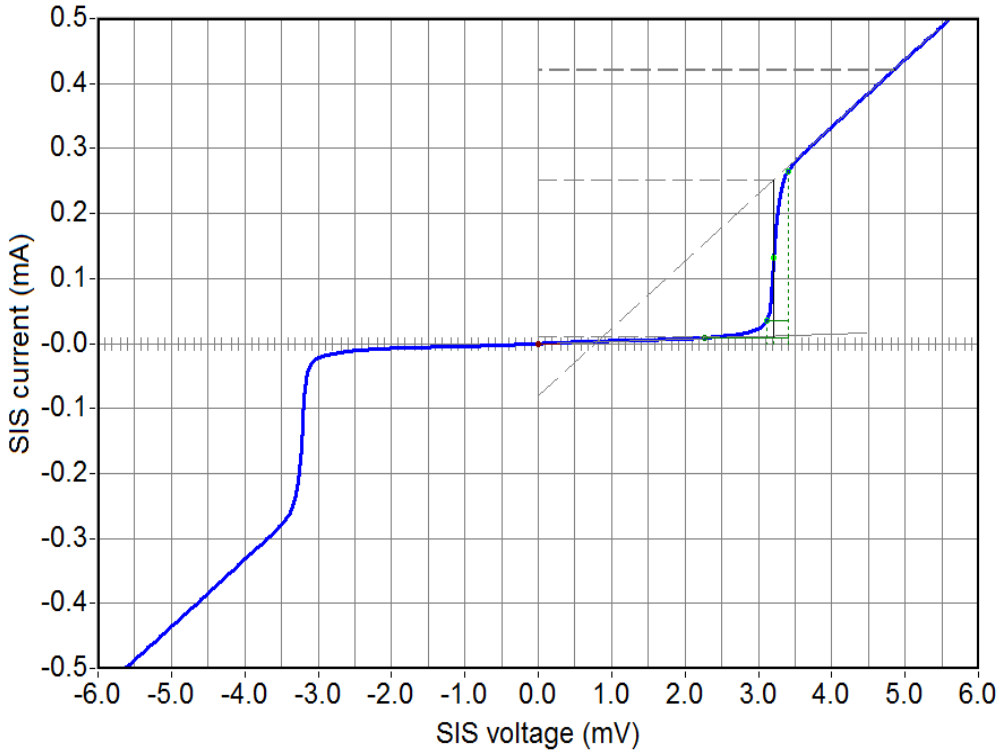
THz SIS circuits for APEX



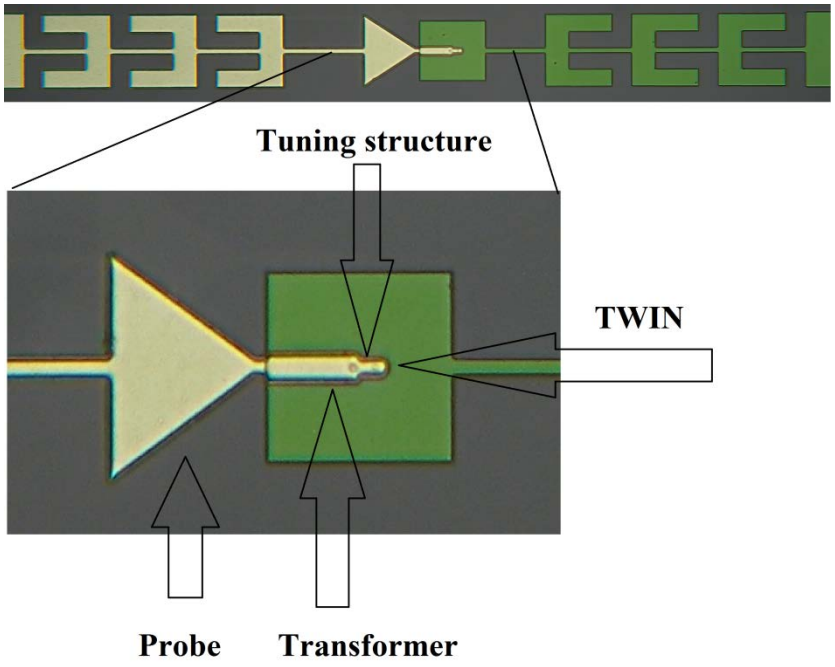
Nb/Al-AlN_x/NbN SIS
(A = 0.5 μm² ; Jc ~ 30 кА/см²)
inserted in the microstrip line:
base electrode – NbTiN,
top - Al

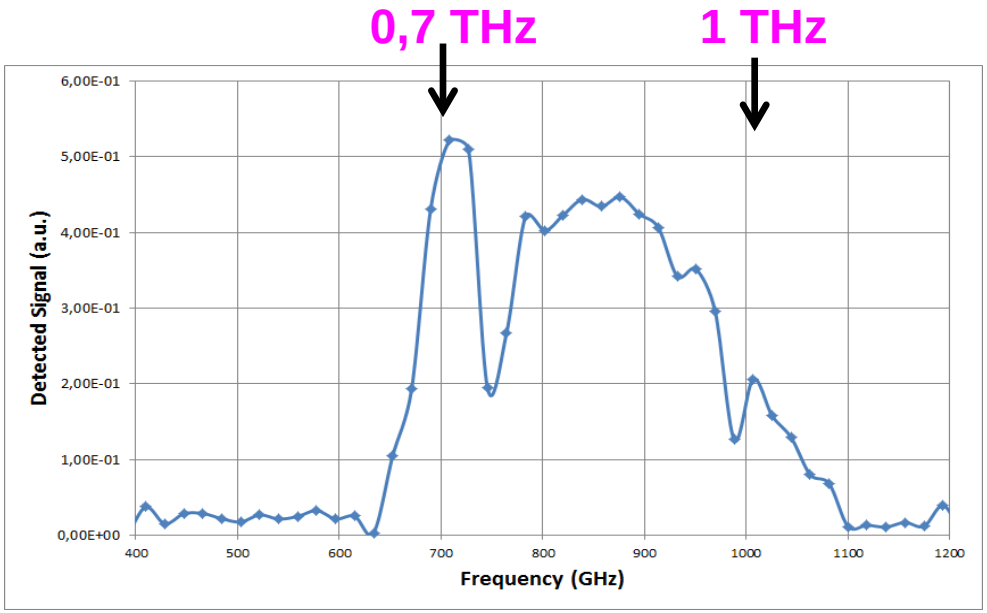
Rn = 9.67 Ohm; Rj/Rn = 29.9
Jc = 34 kA/cm²; Vg = 3.22 mV

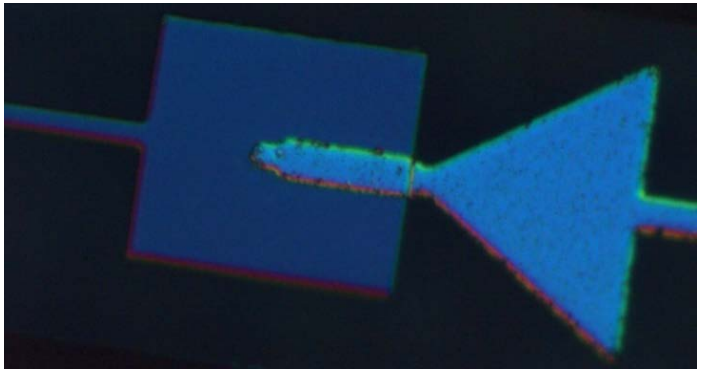


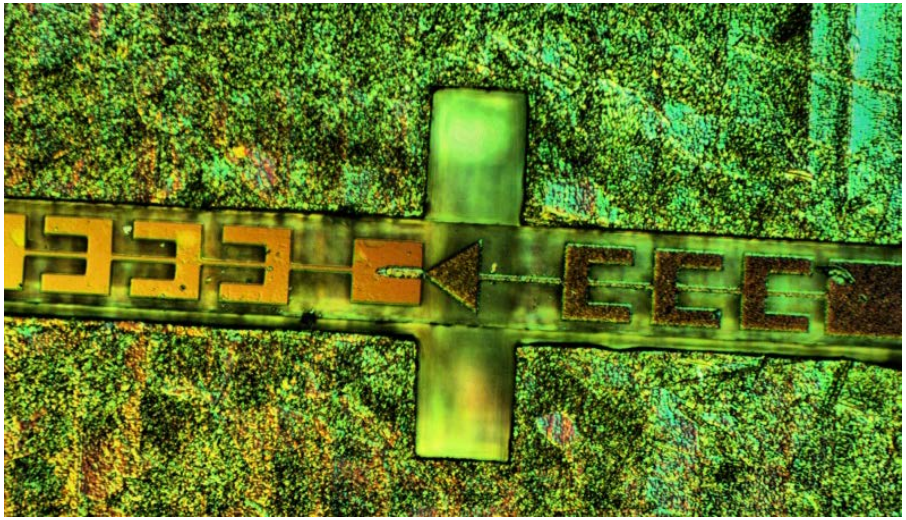


THz SIS Receiver for APEX

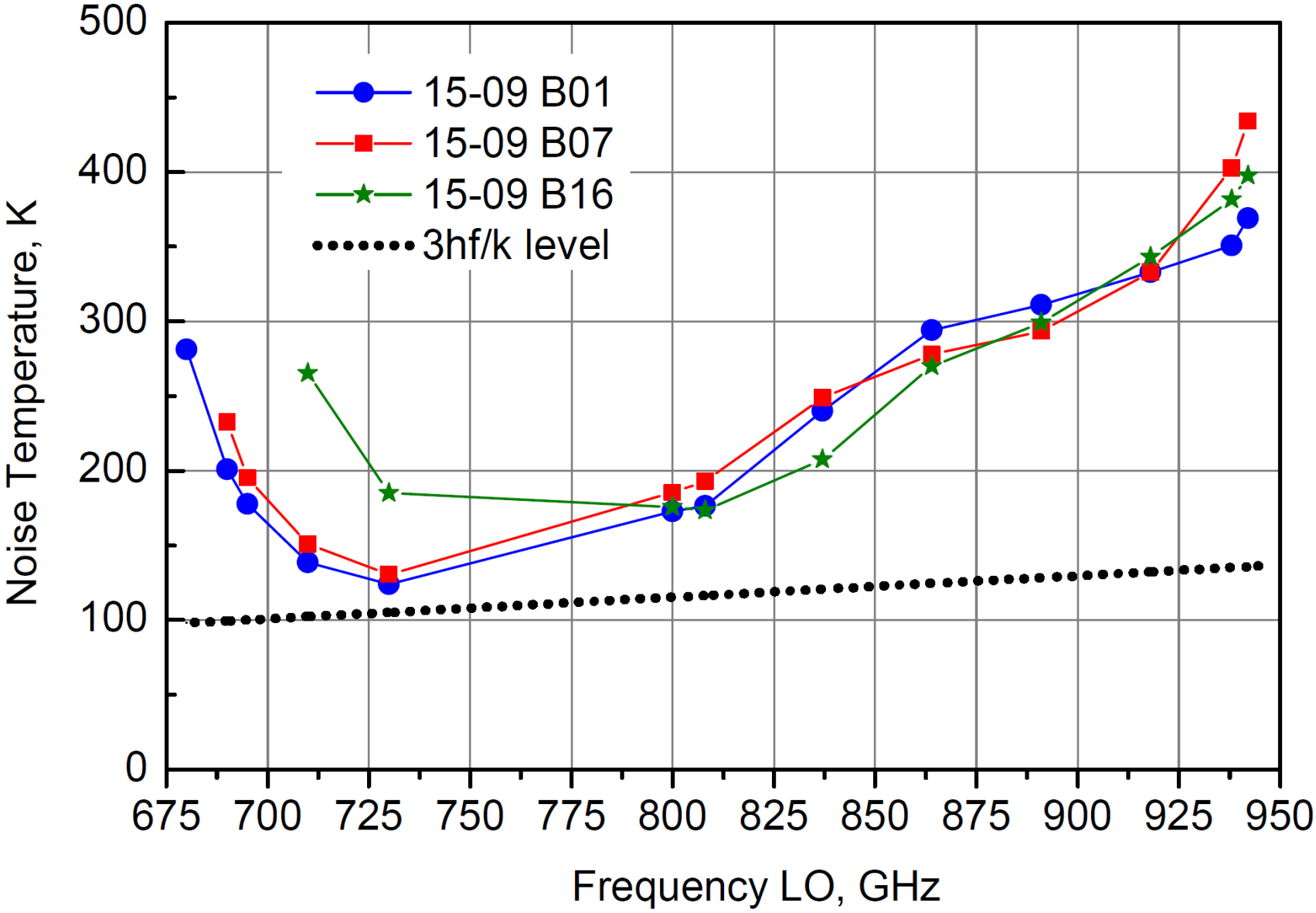




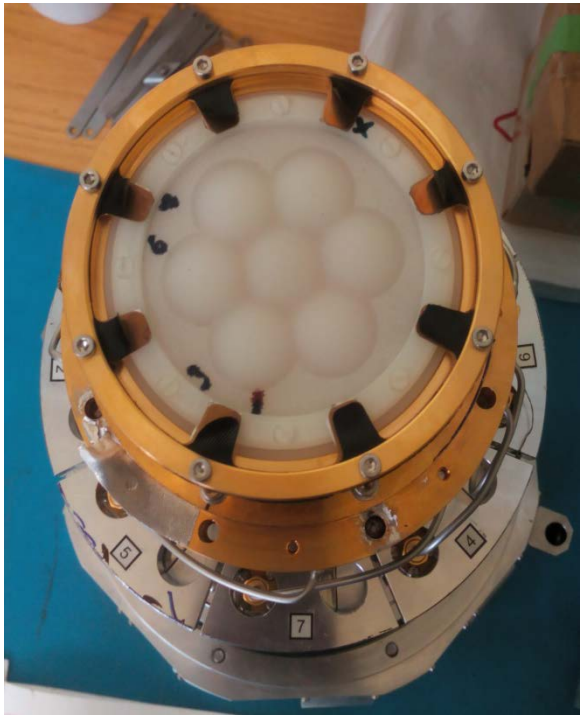


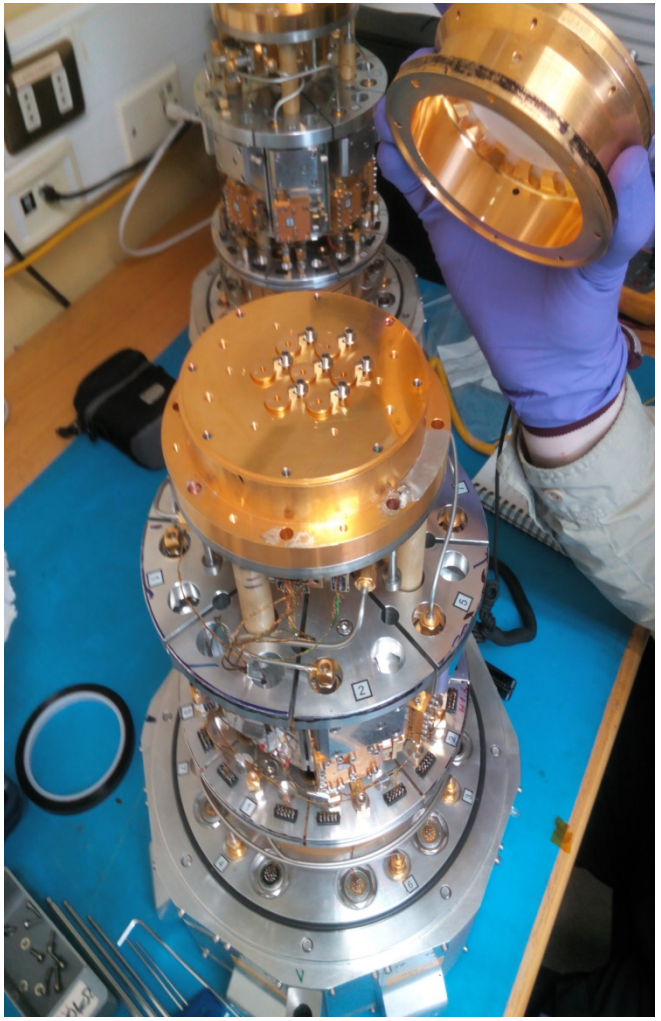


Receiver Noise Temperature

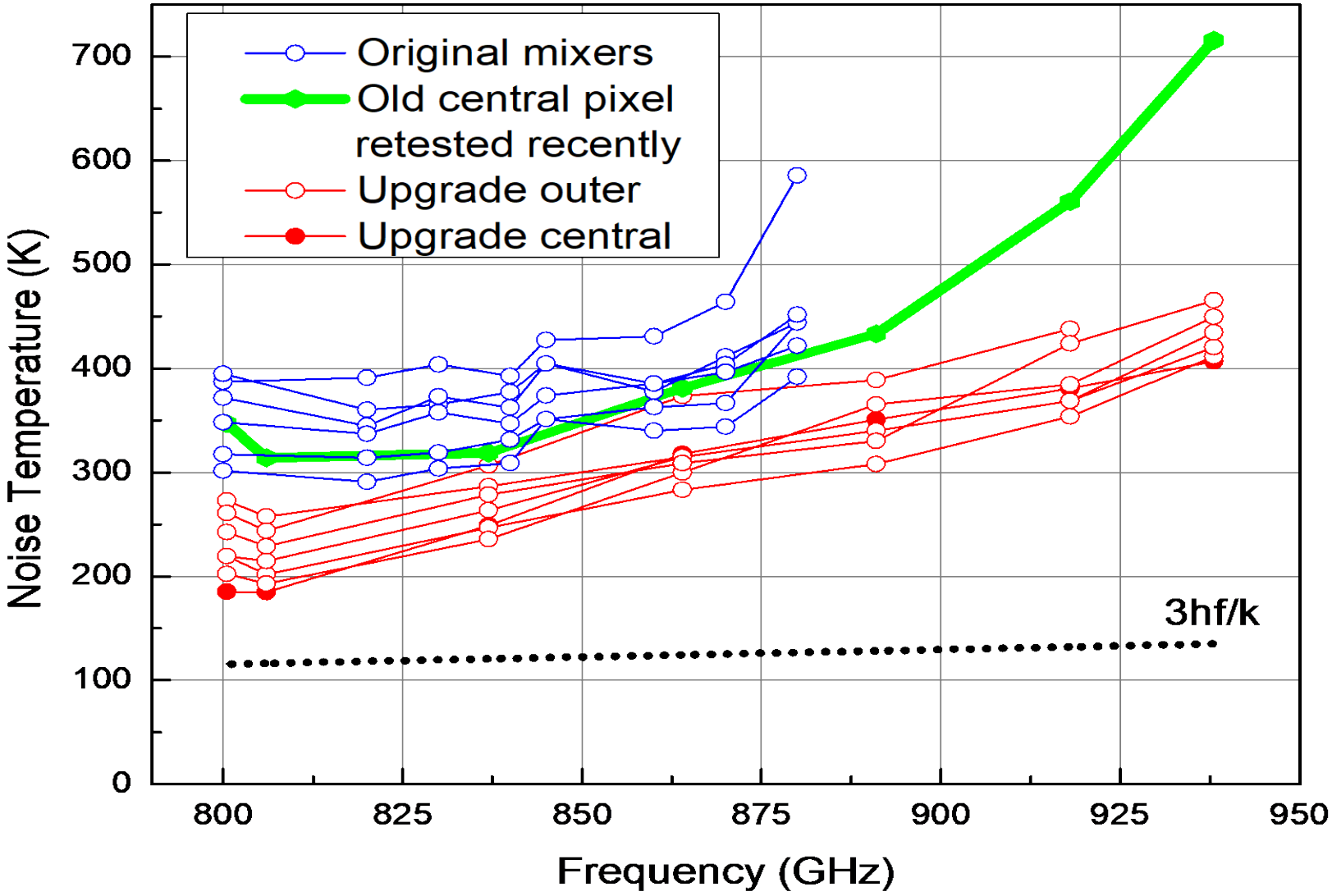


Lens array at the top of the cartridge body; opened horns with the mixers & single pixel

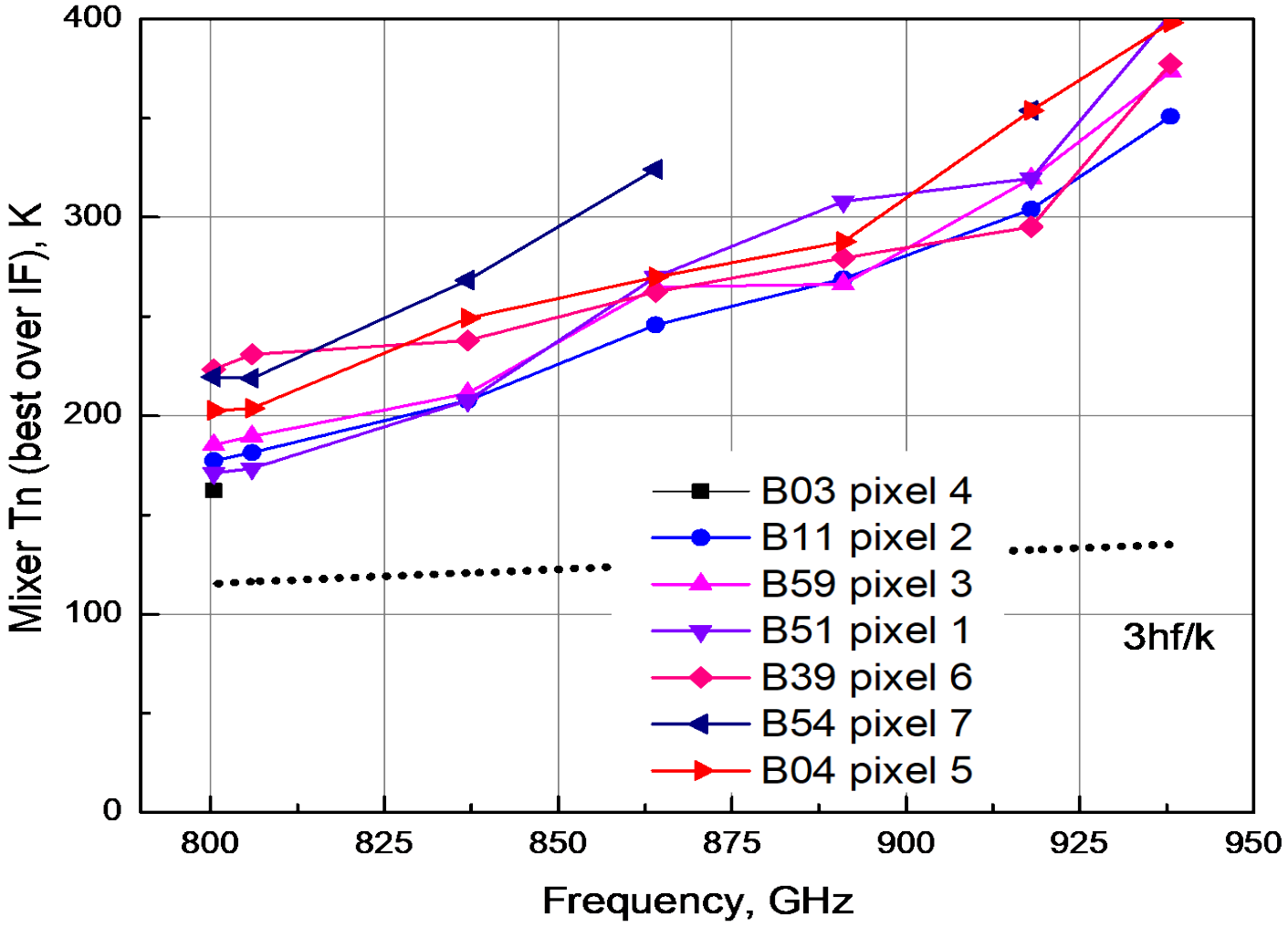




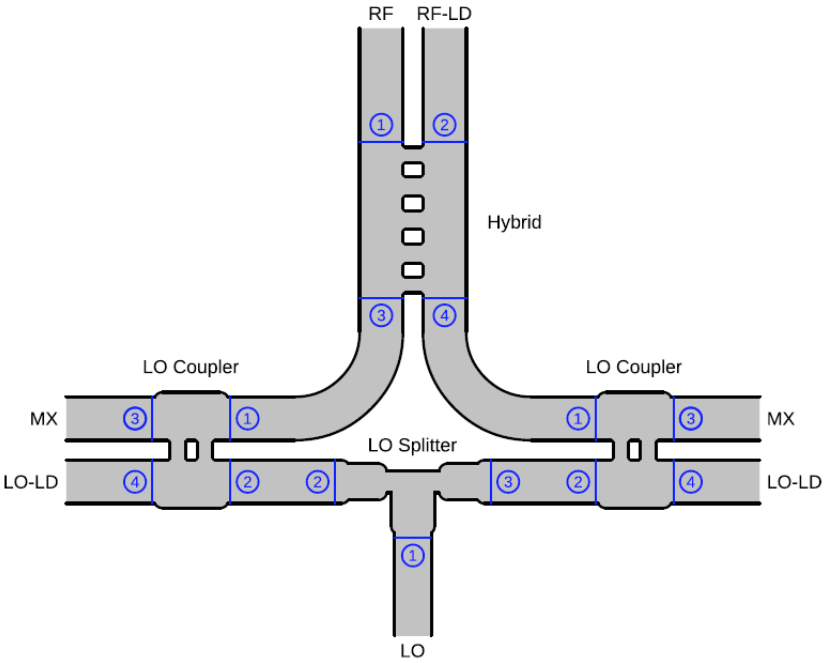
DSB mixer noise temperature for the entire 4-12 GHz IF band vs. LO frequency

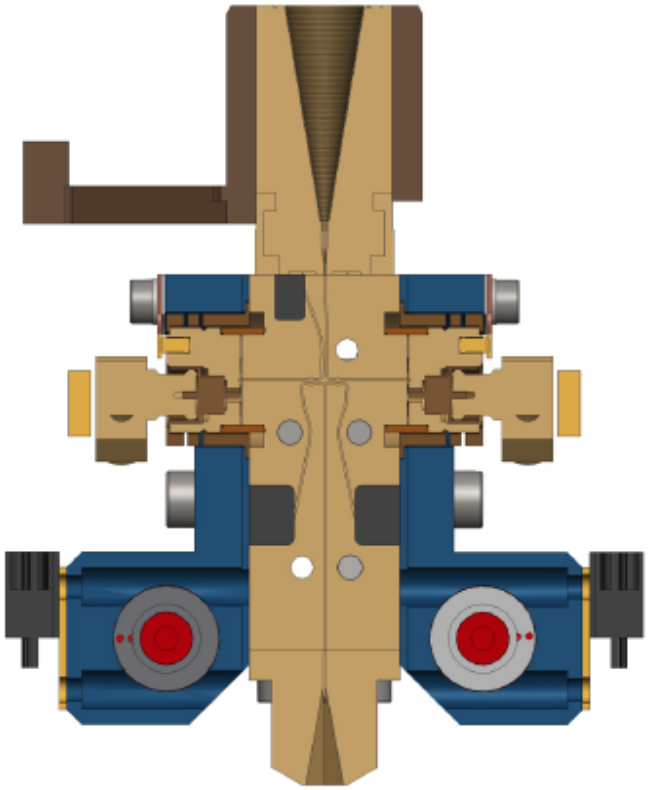


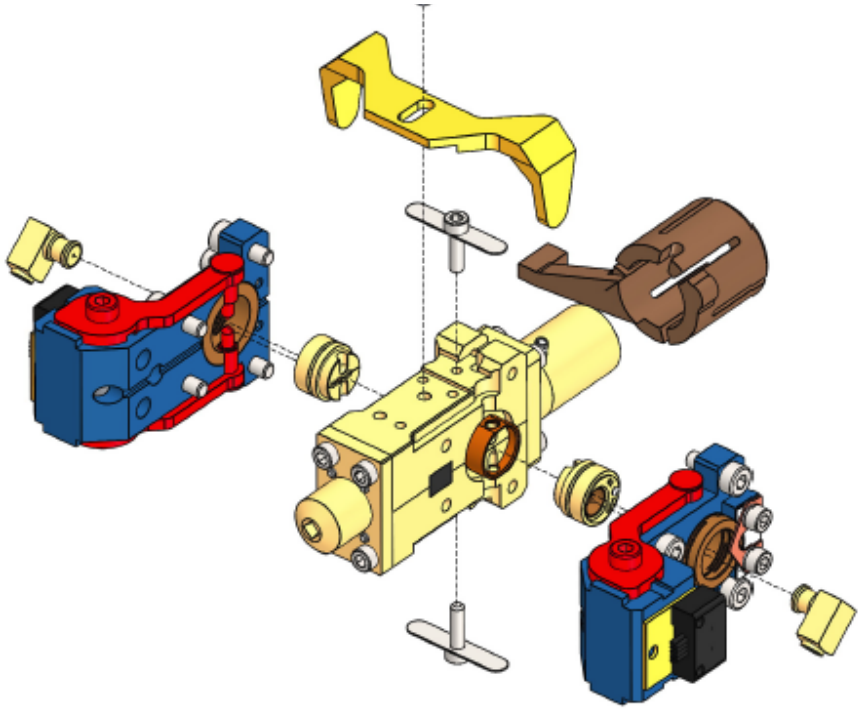
Tn at the best IF point vs LO frequency (corrected for a beam splitter contribution)



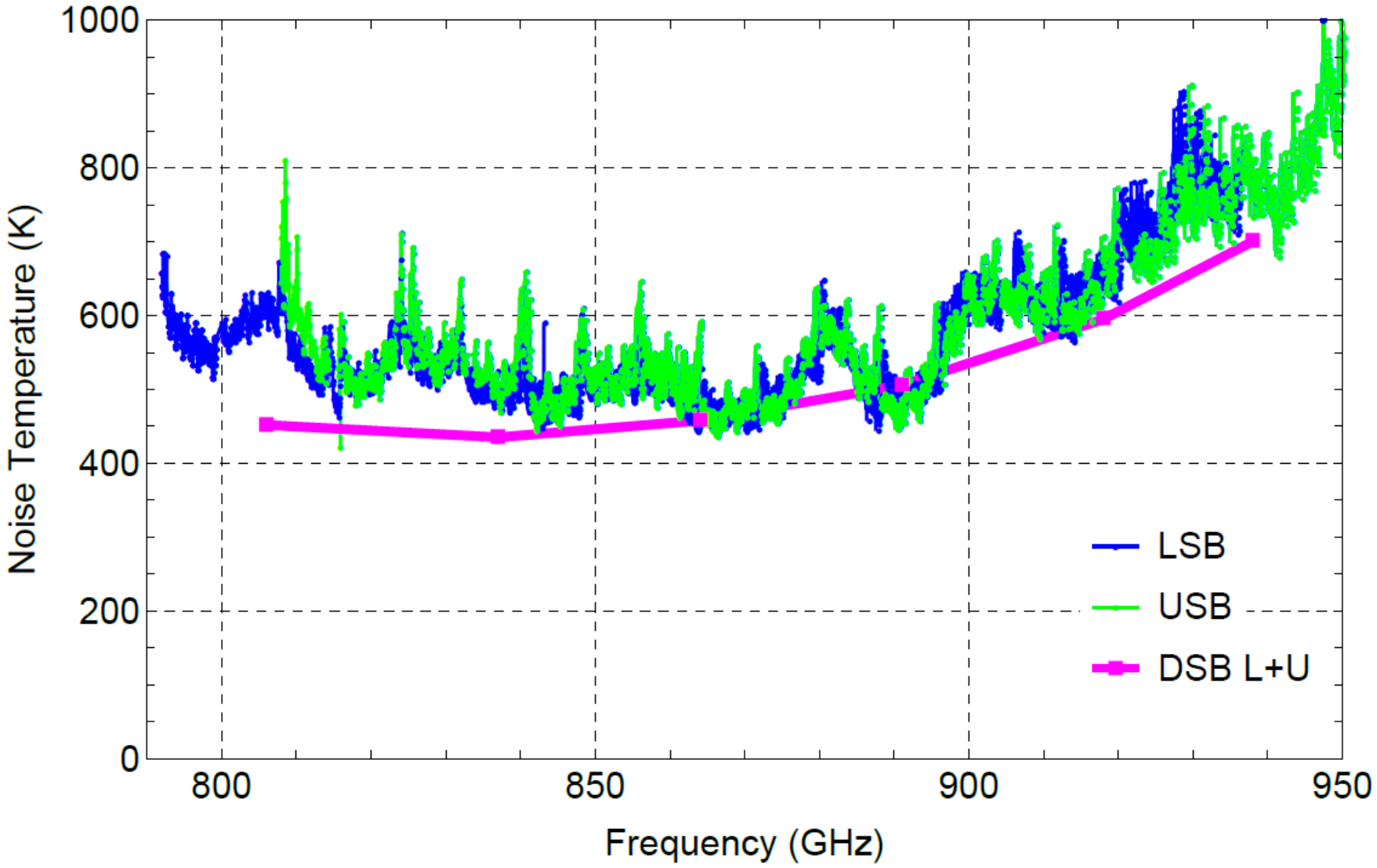
FLASH
790-950 GHz 2SB Mixer





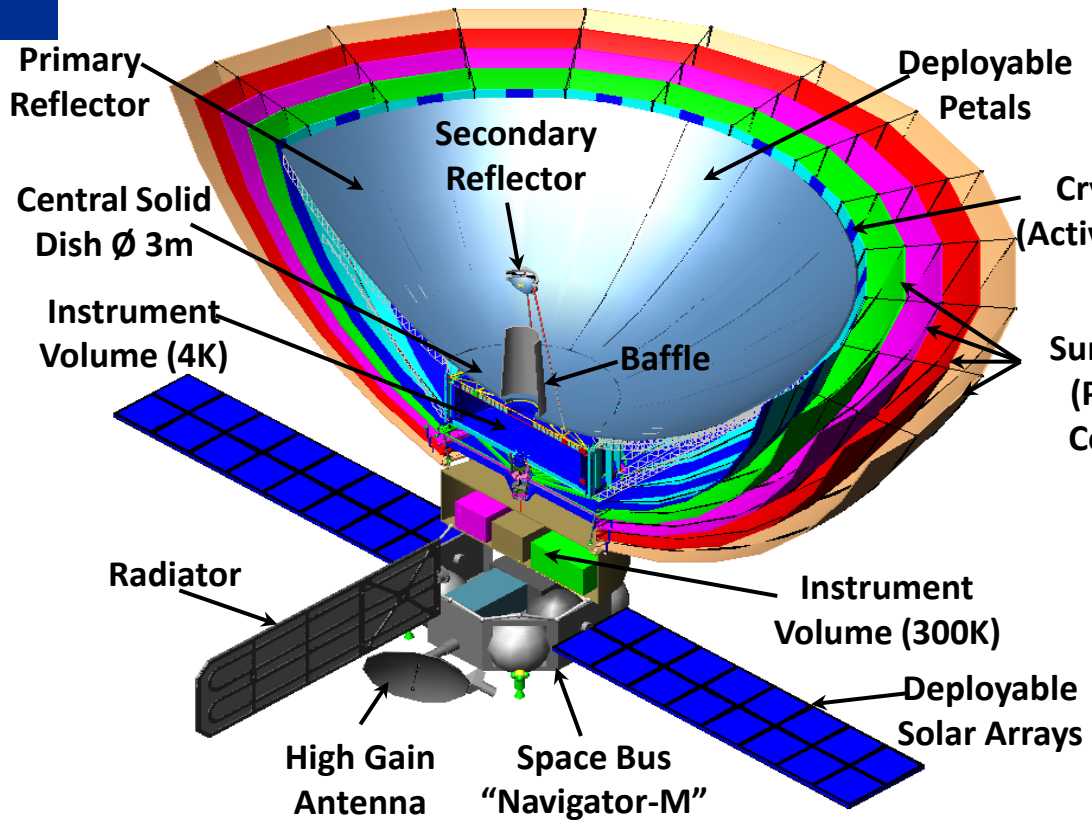


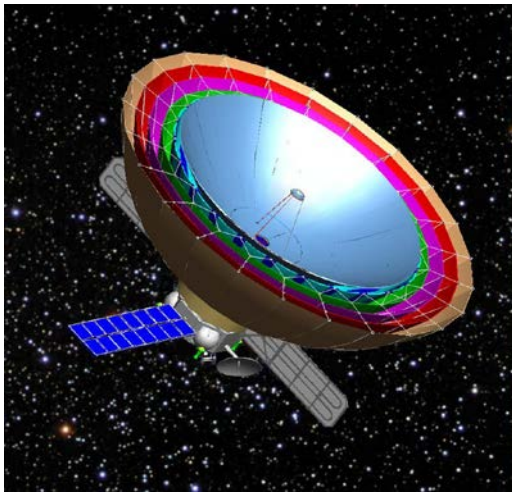
Sideband Separating (2SB) SIS Mixer



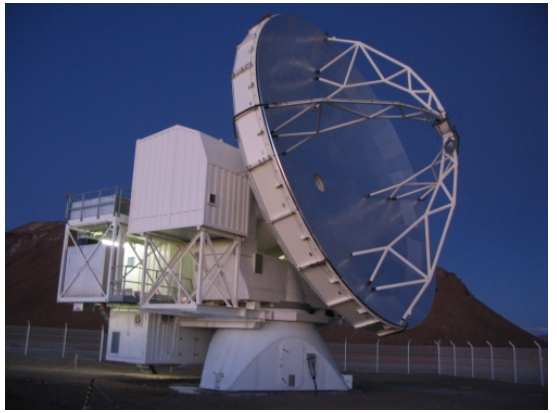
“Millimetron” – Russian Space Agency
10 m cryogenic mirror; λ = 0,01- 20 mm.

ASC LPI



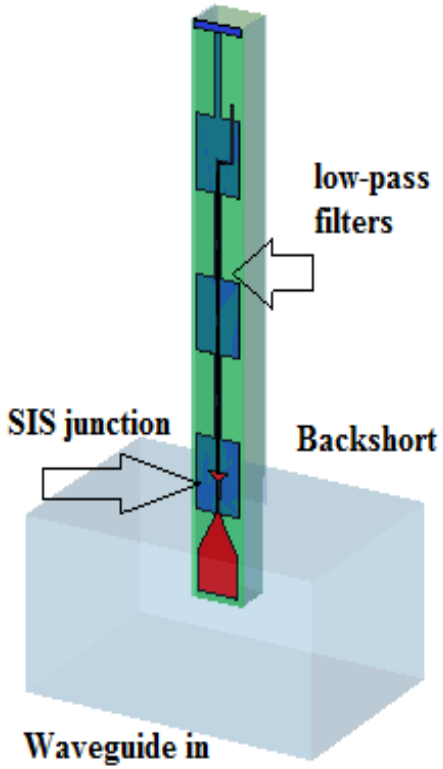


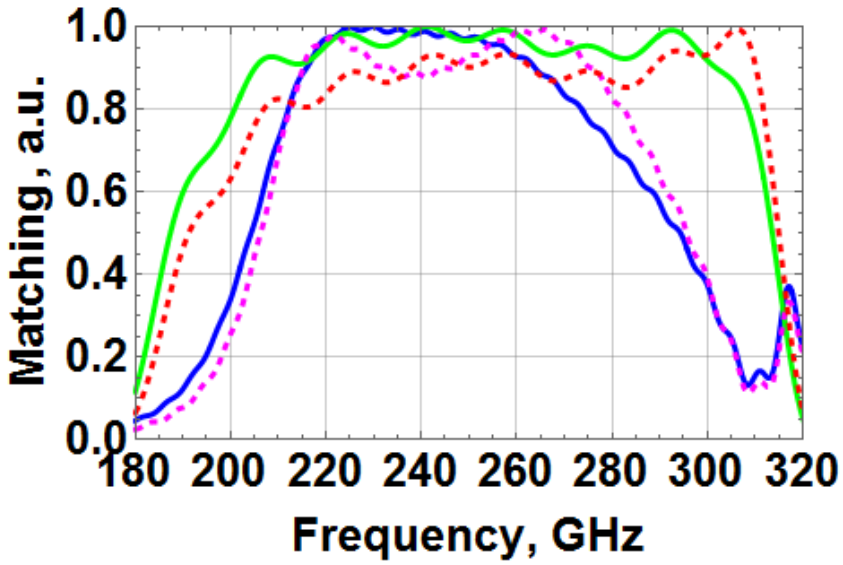
Earths-space interferometer



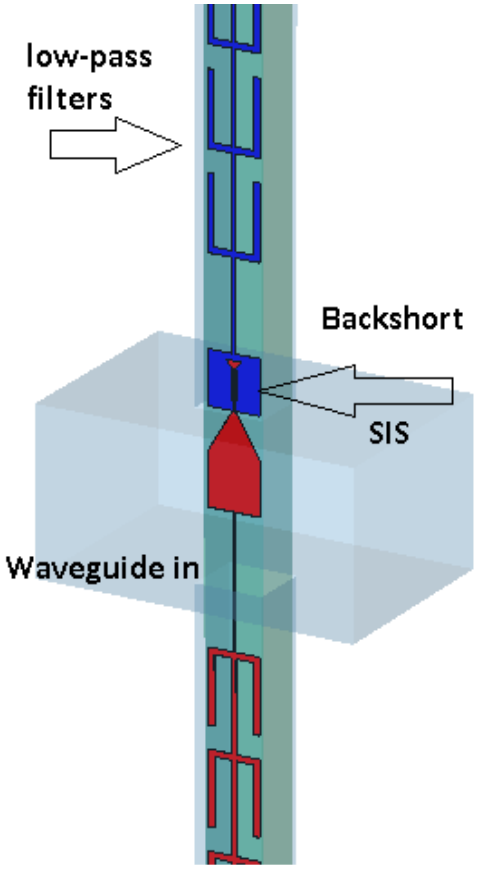
Earth-Space VLBI receivers
Band 3 (ALMA 6) : 211-275 GHz
SSB Noise Temperature < 80 K

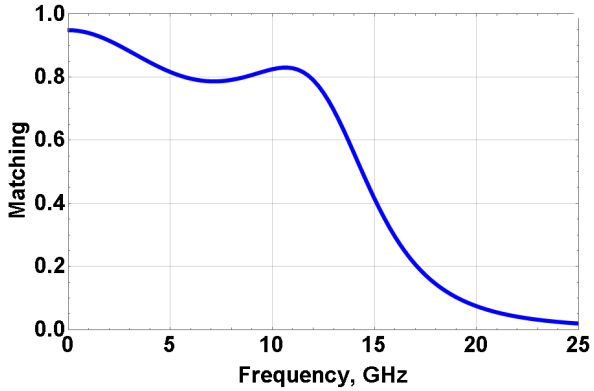
3D CST model for 211-275 GHz mixer





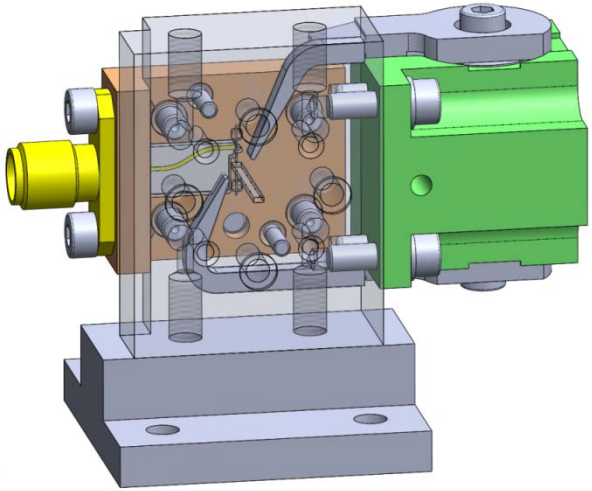
Power matchings between
a SIS junction and a waveguide
for different SIS junction`s parameters

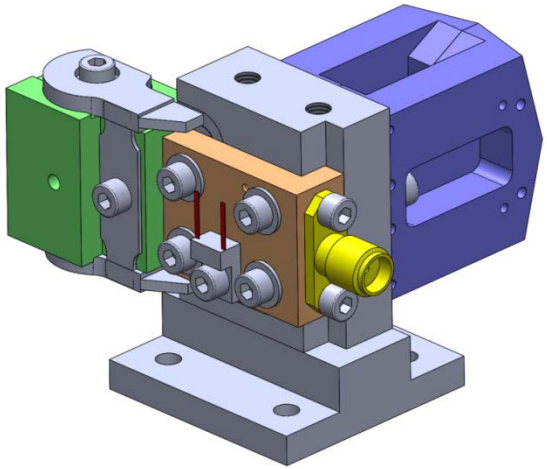


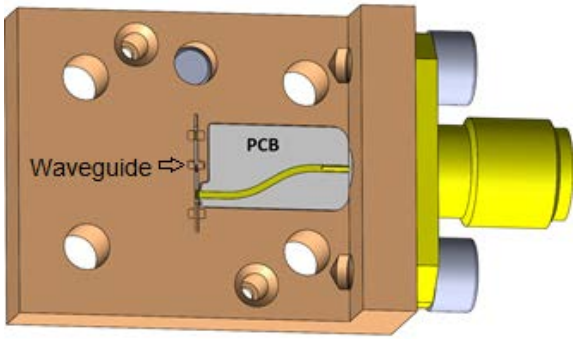


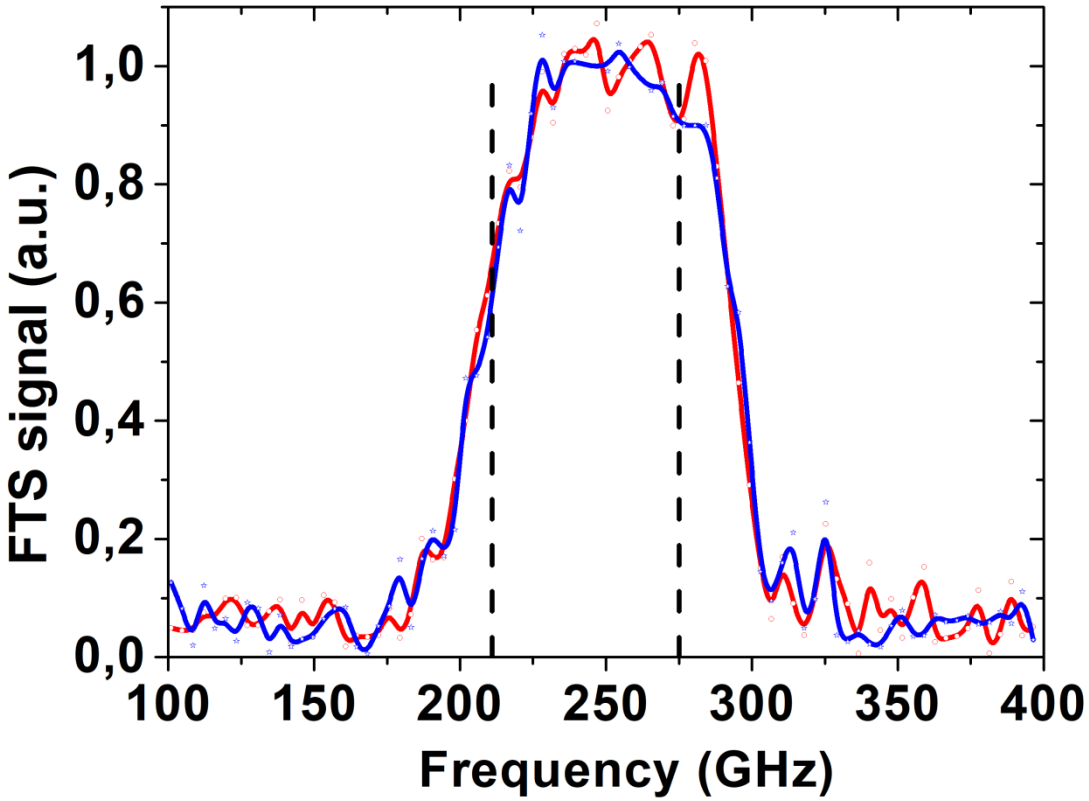
Power matchings at IF (intermediate frequency) for a single SIS junction design

3D design of the mixer block & first FTSs

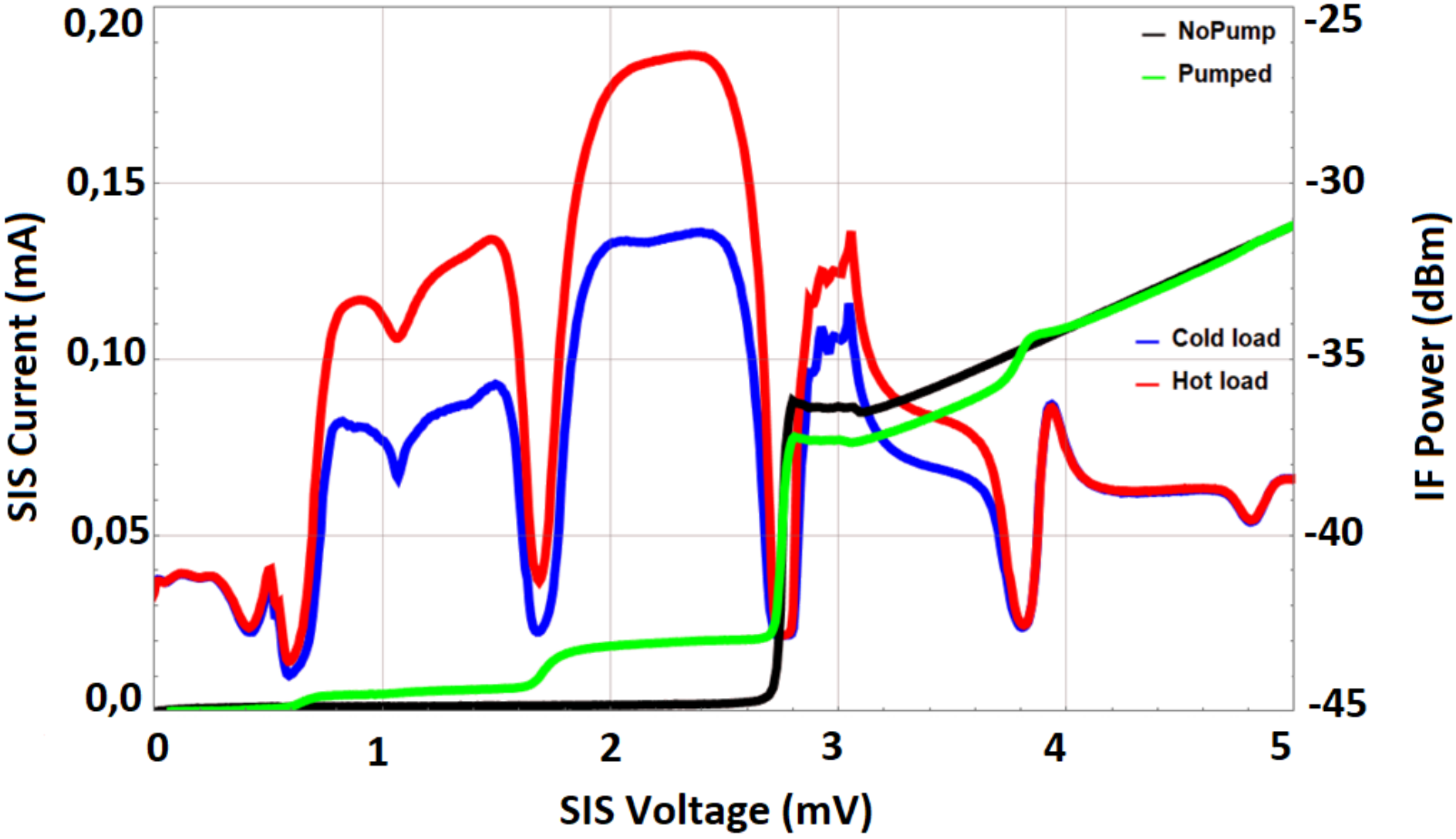




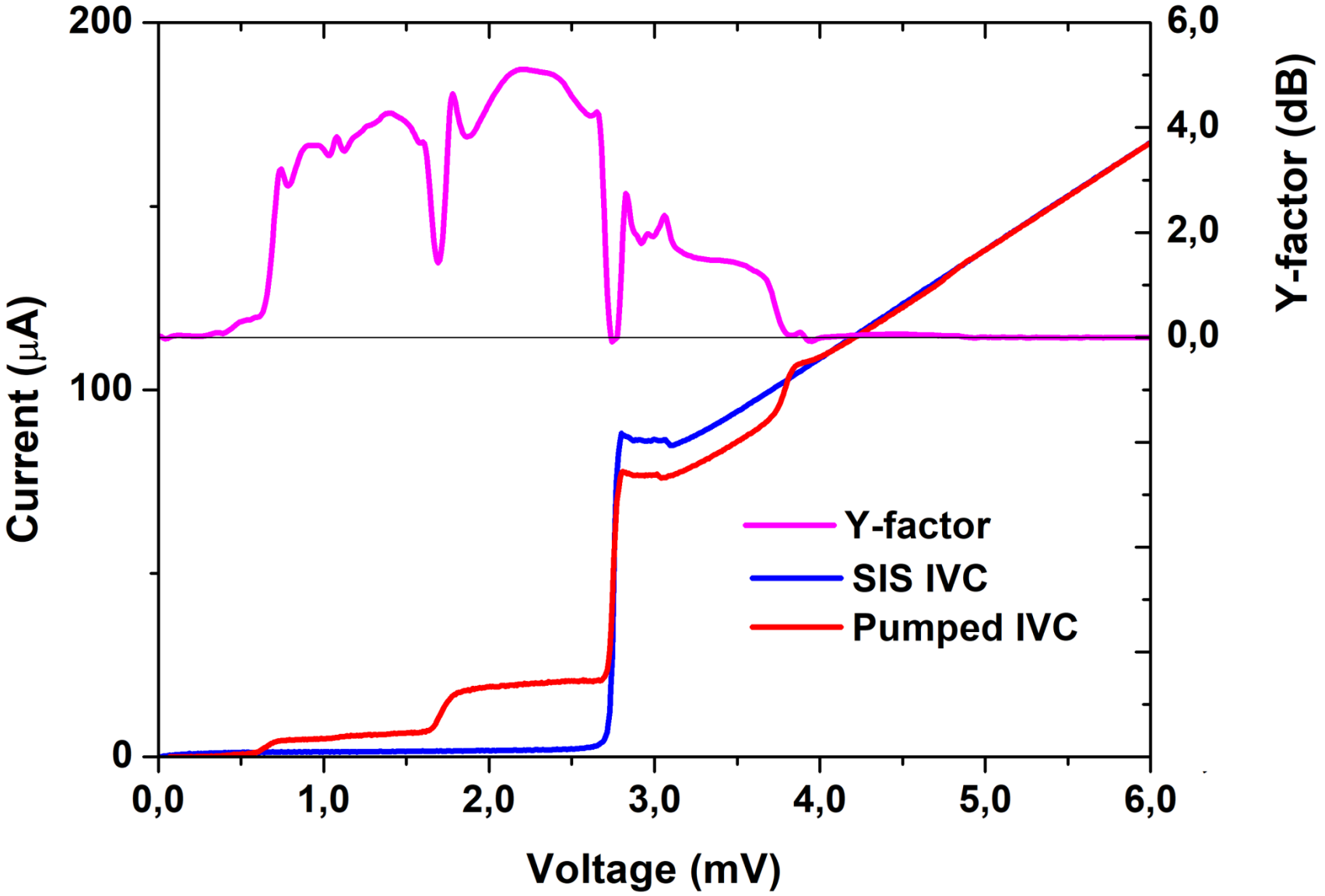




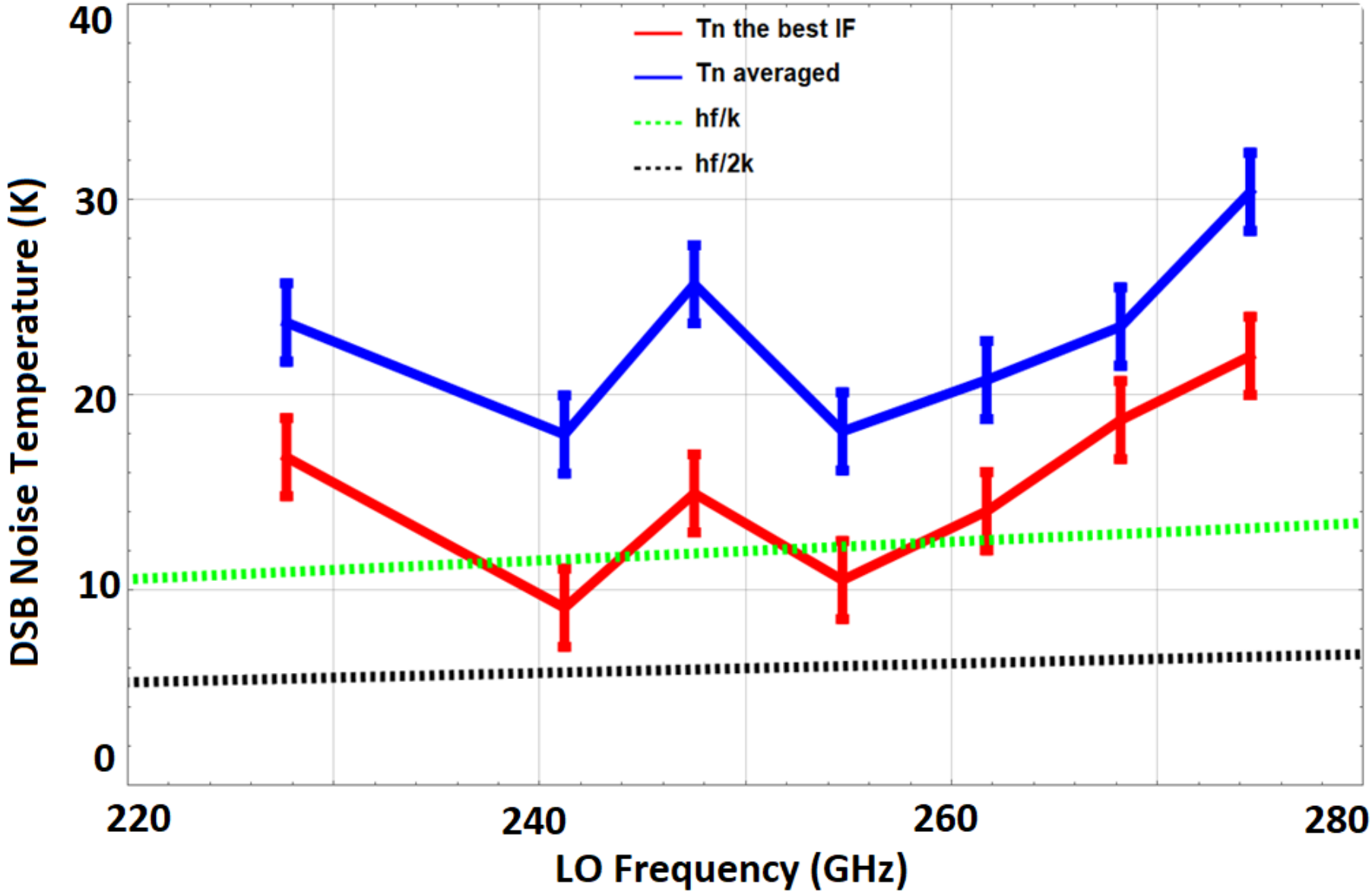
IVCs and IF signal at 6.5 GHz; LO = 261 GHz



IVCs & Y-factor; LO = 265 GHz, IF = 6.5 GHz



Uncorrected DSB receiver noise temperature



Conclusion

- Technology for fabrication of high-quality tunnel junctions (current density up to 70 kA/cm^2) and THz integrated circuits have been developed.
- SIS mixers based on Nb/AlN/NbN twin tunnel junctions incorporated in a NbTiN/Al microstrip line have been developed. The best noise temperature as low as 120 K has been achieved at 725 GHz, that is of about 3 hf/k_B.
- SIS mixer for frequency range 211 – 275 GHz based on Nb tunnel junctions have been designed and tested. DSB noise temperature below 30 K has been realized; Tn as low as 10 K has been measured for the LO = 241 GHz at the best IF point.
- The SIS fabrication technology developed at Kotel'nikov IREE is mature enough for current radio-astronomy projects and future ground-based and space missions.

Thank you for your attention !