

Space-borne 640-GHz SIS Receiver Based on 4-K Mechanical Cooler

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Highly sensitive submillimeter observations

for astronomical & atmospheric research (SMILES on ISS/JEM)

Space-borne 640-GHz SIS Receiver Based on 4-K Mechanical Cooler

640-GHz SIS Mixer

- Cooled at 4.5K
- Low noise temperature
- Broad IF bandwidth
- No mechanical tuner

HEMT Amplifier

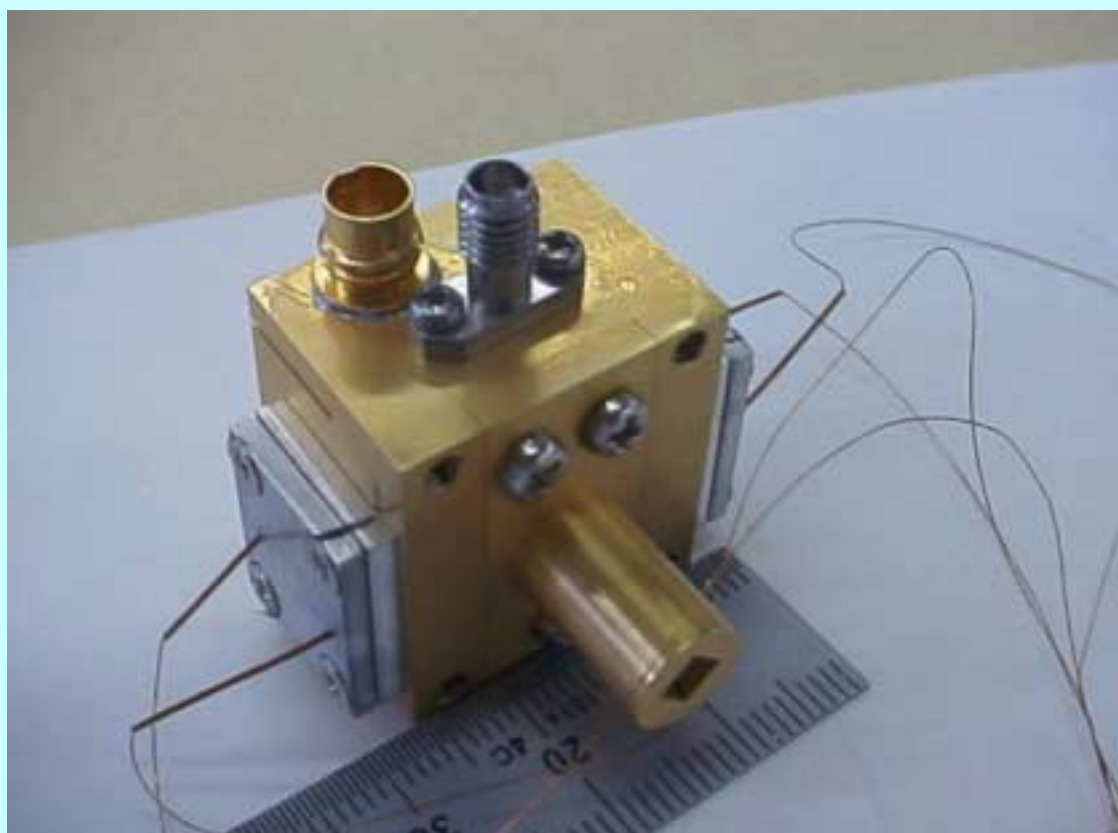
- Cooled at 20 K & 100 K
- Low noise temperature
- Broad bandwidth
- Small power dissipation

4-K Mechanical Cooler

- Two-stage Stirling & Joule-Thomson
- Low power consumption
- Vibration tests
- One-year running tests

640-GHz SIS Mixer

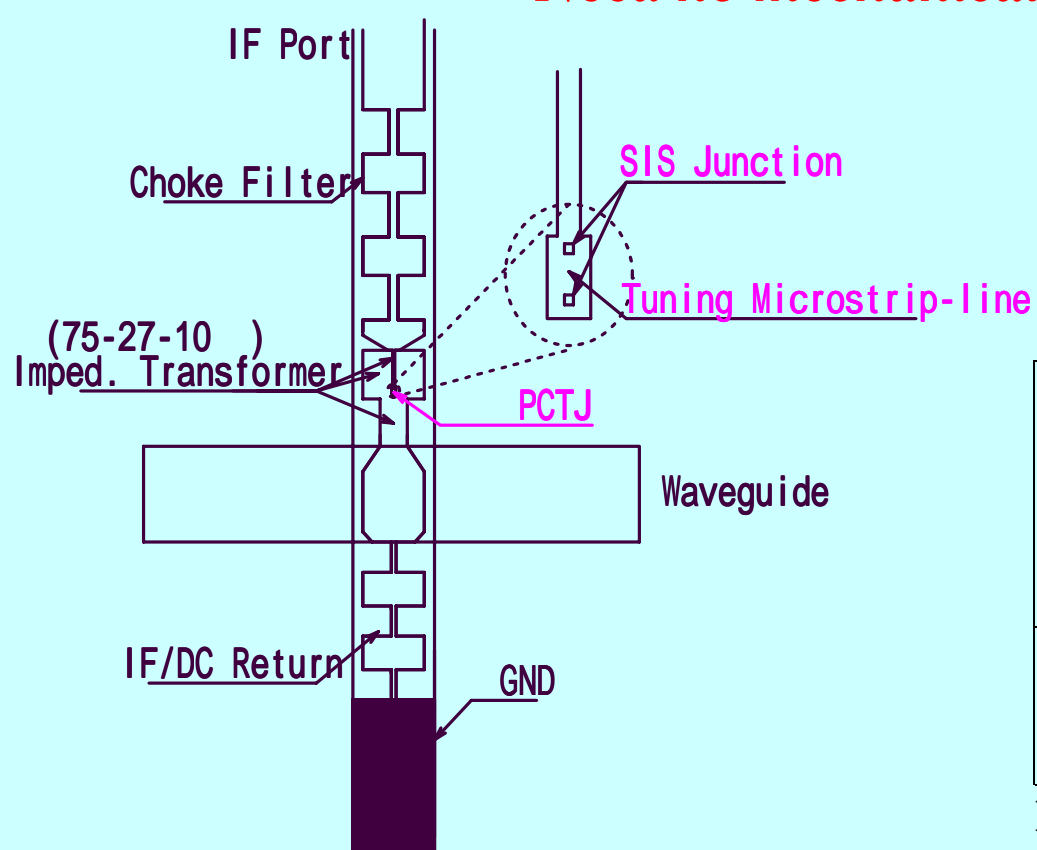
- Low noise temperature
- No mechanical tuner
- Broad IF bandwidth



640-GHz SIS Device

- Nb/AlO_x/Nb device
- PCTJ(parallel-connected-twin-junction)type.

Need no mechanical tuners in the mixer mount.



SIS device	Device size (mm)	2 x 0.13 x 0.065
	Junction size (μm)	1.25 x 1.25
	Current density	5.5 kA/cm ²
	Normal resistance	10.6 Ω
	$\omega R_n C_j$ at 640 GHz	8
Mixer mount	Device slot (mm)	0.14 x 0.14
	Waveguide (mm)	0.4 x 0.14
	Backshort (mm)	0.03

Dimensions of the 640-GHz SIS mixer device

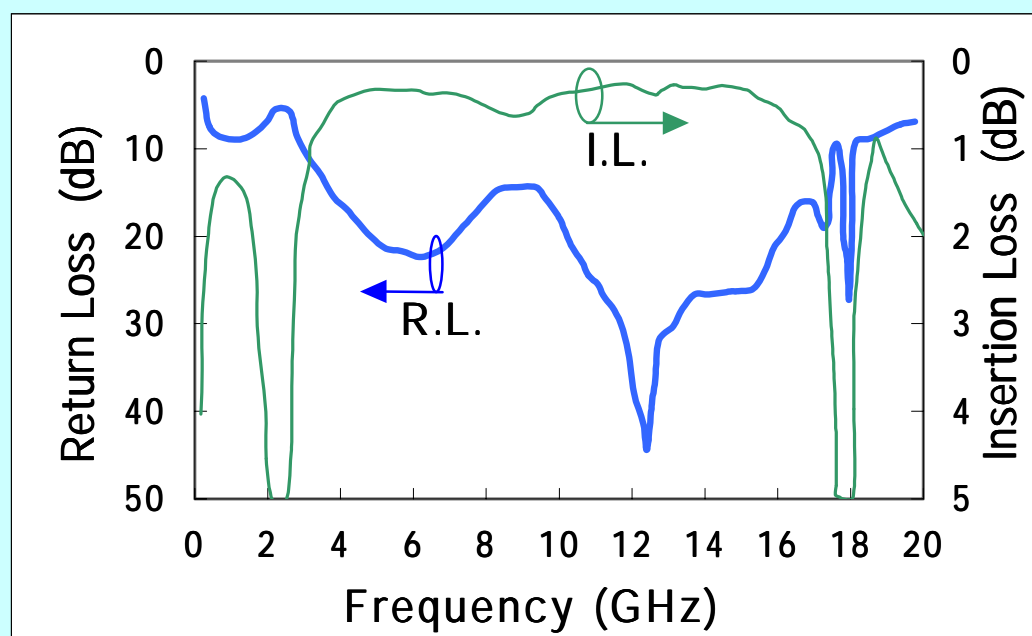
640-GHz SIS mixer device for SMILES

DC-bias Circuit

- Integrated in the mixer mount
- Broad bandwidth



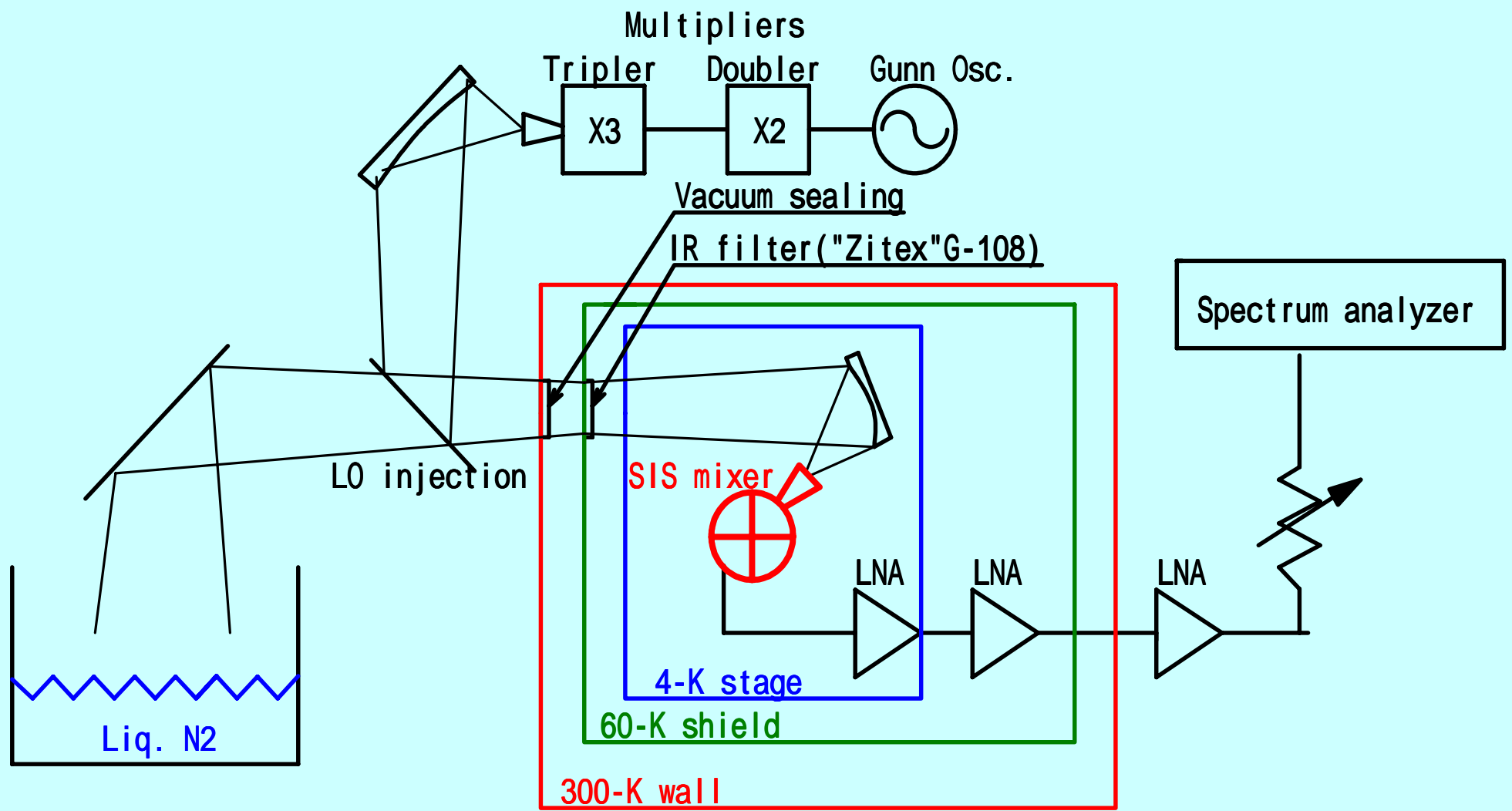
Inside of 640-GHz SIS mixer. DC-bias circuit is shown.



Measured insertion and return losses of the DC-bias circuit

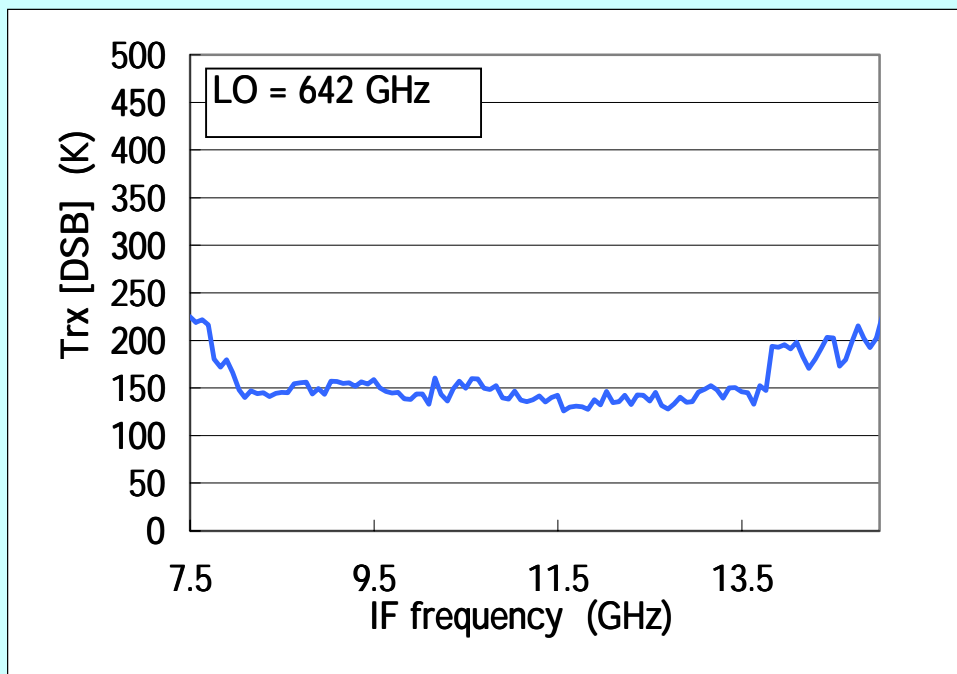
Measurement Setup for SIS Mixer

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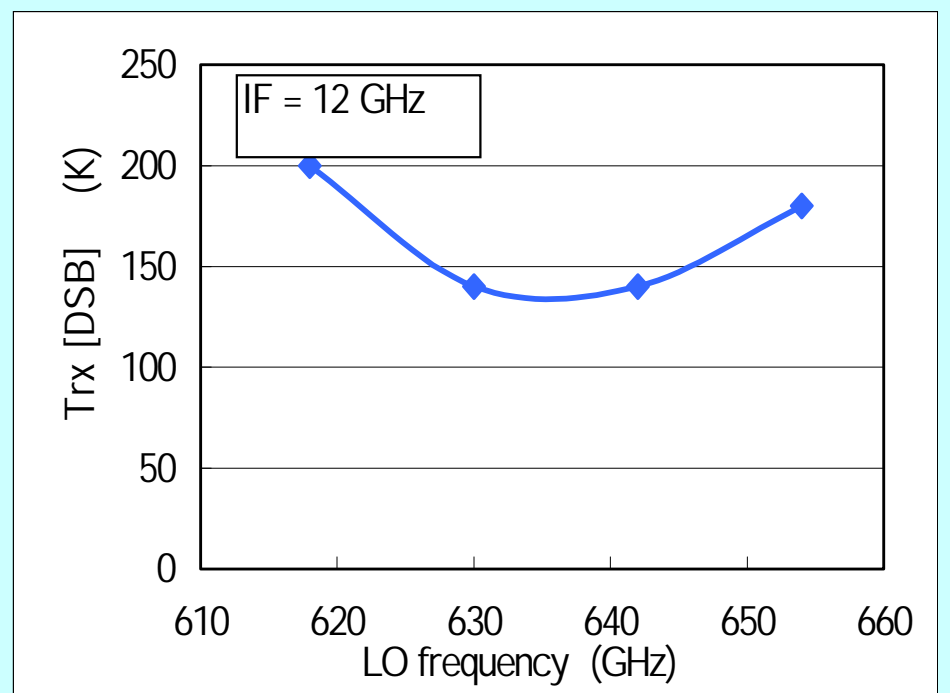


Measurement Results

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Measured T_{rx} of the 640-GHz SIS mixer as a function of IF frequency.



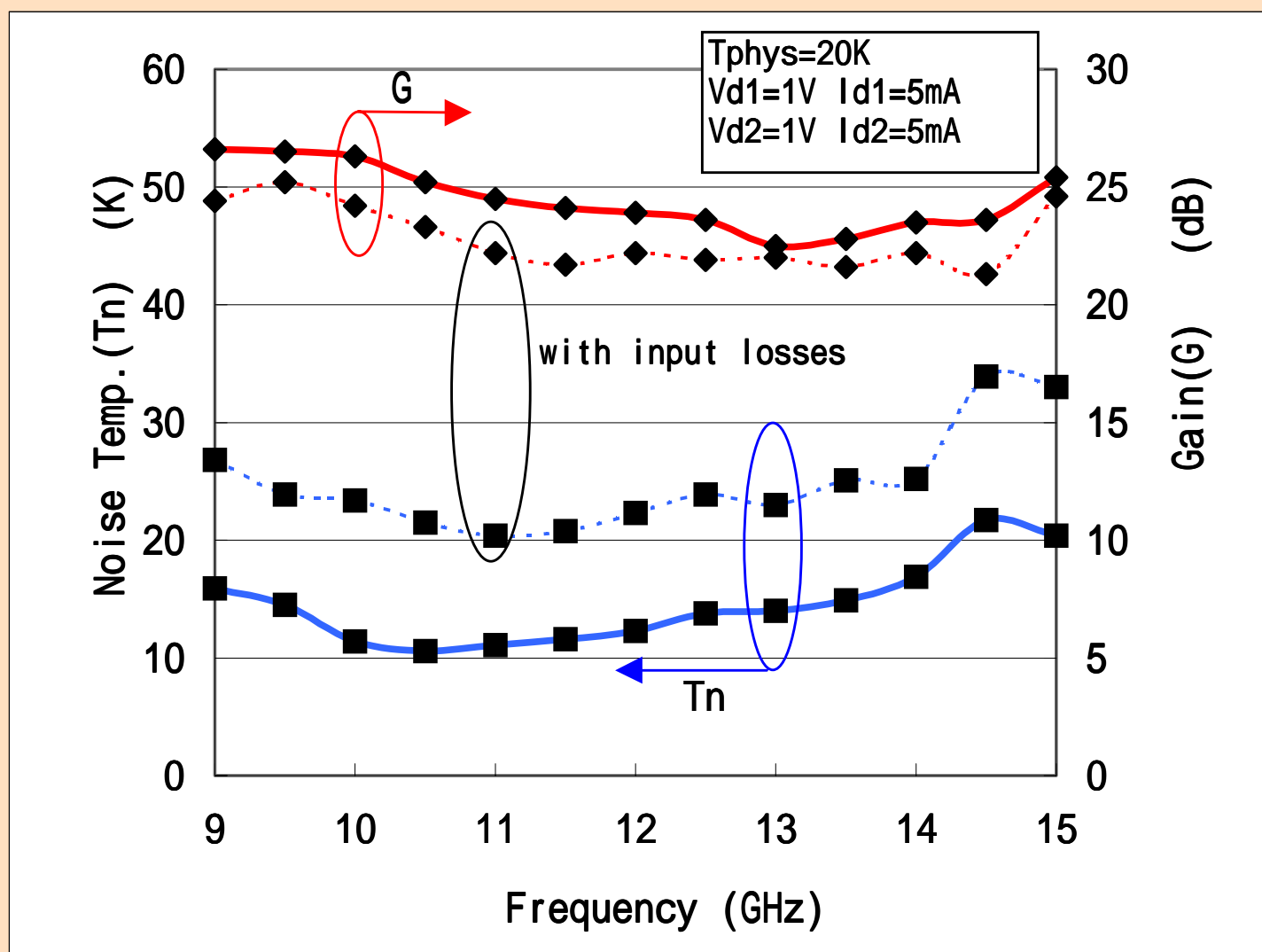
Measured T_{rx} of the 640-GHz SIS mixer as a function of LO frequency.

Low-Noise HEMT Amplifiers

- Low noise.
- High gain.
- Broad bandwidth.
- Small power dissipation.

	20-K HEMT amplifier	100-K HEMT amplifier
Operating temperature	20 - 25 K	100 - 110 K
Number of HEMT device	2	3
Bandwidth	Over 9-14 GHz	Over 9-14 GHz
Gain	>23 dB	>30 dB
Noise temperature	<17 K	<27 K
Power dissipation	10mW	15mW

Brief specification of HEMT amplifiers.



Measured performance of the 20-K HEMT amplifier with a heat dissipation of 10 mW. Solid lines show the performance of the 20-K amplifier alone. Dotted lines show its performance including losses due to the cable and isolator between SIS mixer and the 20-K amplifier.

4-K Mechanical Cooler

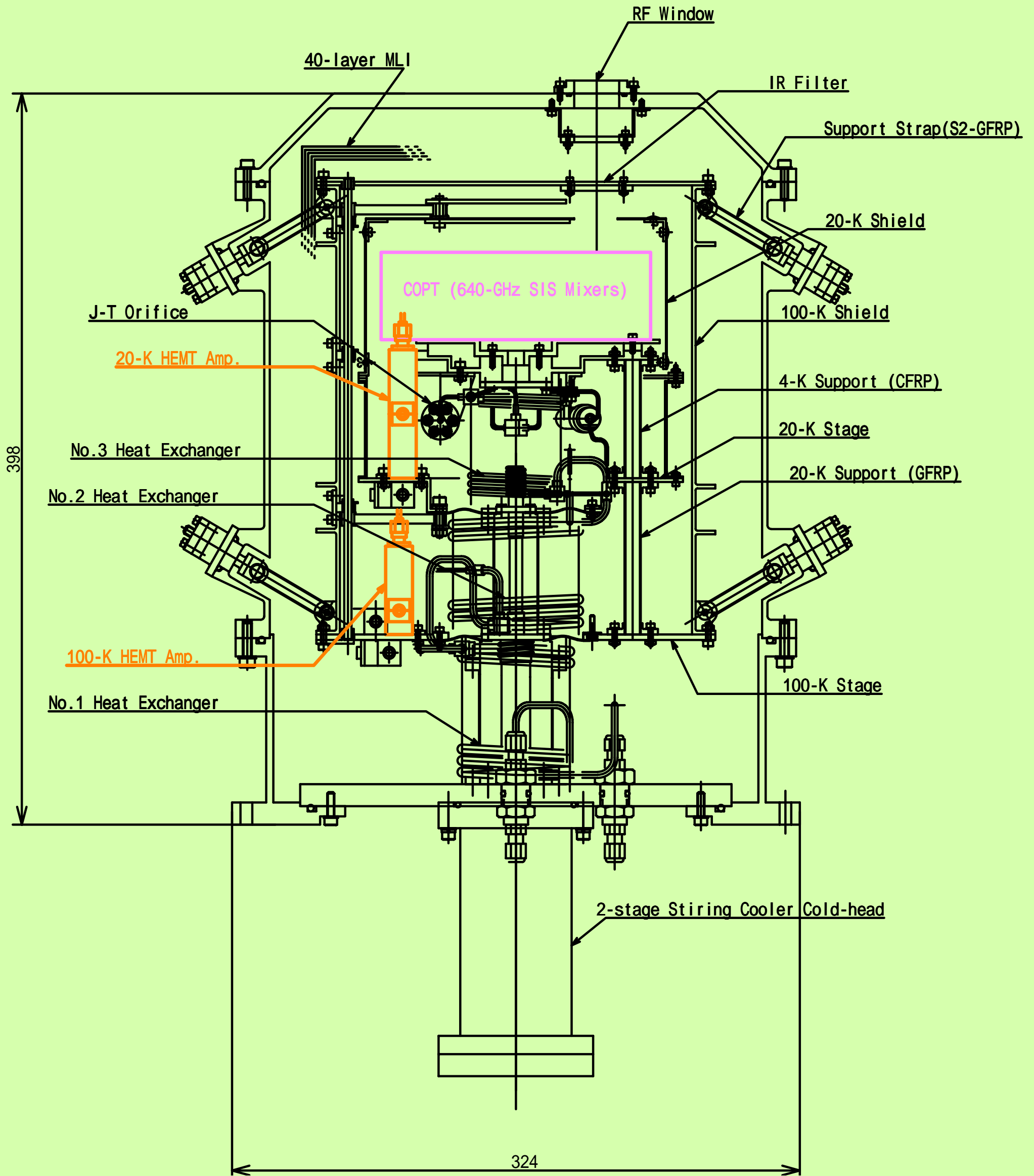


- Requirements
 - SIS Mixers & Cooled Optics @ **4.5 K**
 - HEMT Amplifiers @ **22 K & 100 K**
- Mechanical Cooler
 - Two-Stage Stirling & Joule-Thomson
 - **Small** Power Consumption:
- Tests
 - Random vibration test: **15.1 Grms**
 - Running test: **over one year**

Thermal Balance

Items	Types	Heat load at each stage (mW)		
		100-K stage	20-K stage	4-K stage
RF input window	radiation	150	3	2.4
Walls (with MLI)	radiation	370	19	0.1
Supporting structures	conduction	230	47	2.4
IF cables	conduction	49	22	7.9
DC bias cables	conduction	28	5	0.6
Bias current	heat source	9	3	1
Monitor cables	conduction	11	4	0.6
HEMT amplifiers	heat source	30	20	-
J-T gas cooling	heat source	170	87	-
Total load		1050	210	15
Temperature		100 K	22K	4.5 K
Refrigerator		Two-stage Stirling		J-T
Power consumption	at AC driver	110 W (15 Hz)		80W (30 Hz)
	at DC power supply	260 W (120 V)		

Structure of the Cryostat



Receiver Integration

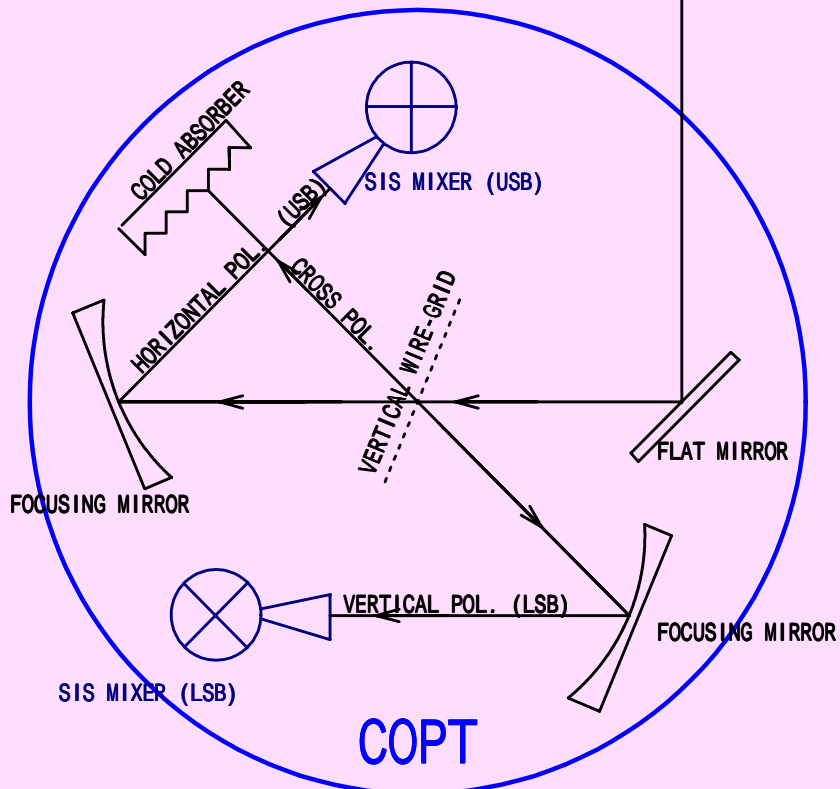
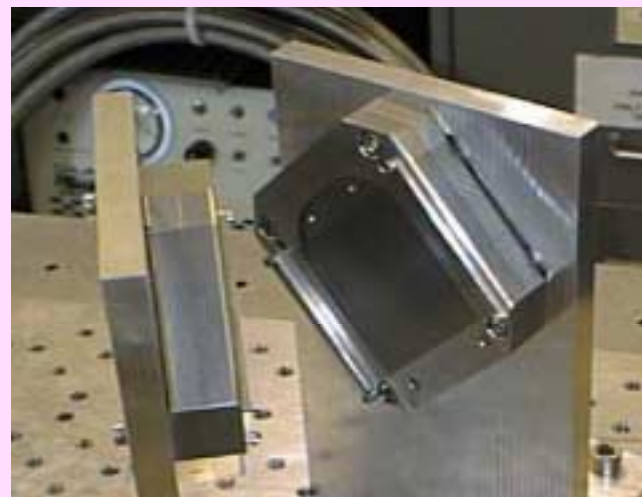
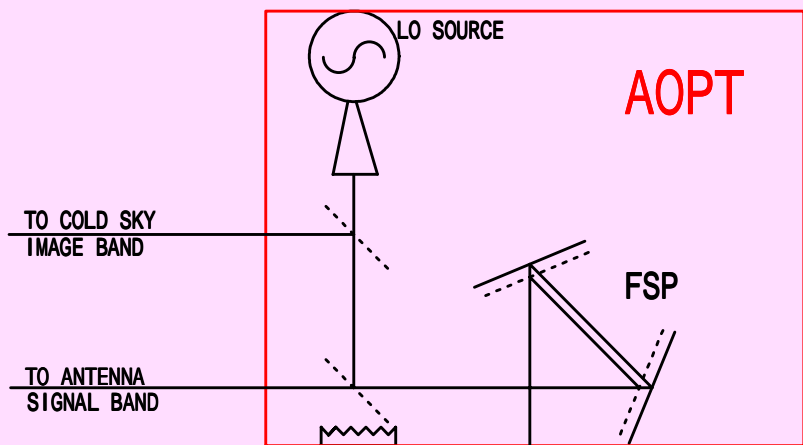


- Optics
- Measurement result
- Noise breakdown

Submillimeter Optics of the SMILES Receiver

AOPT (Ambient-Temperature Optics)

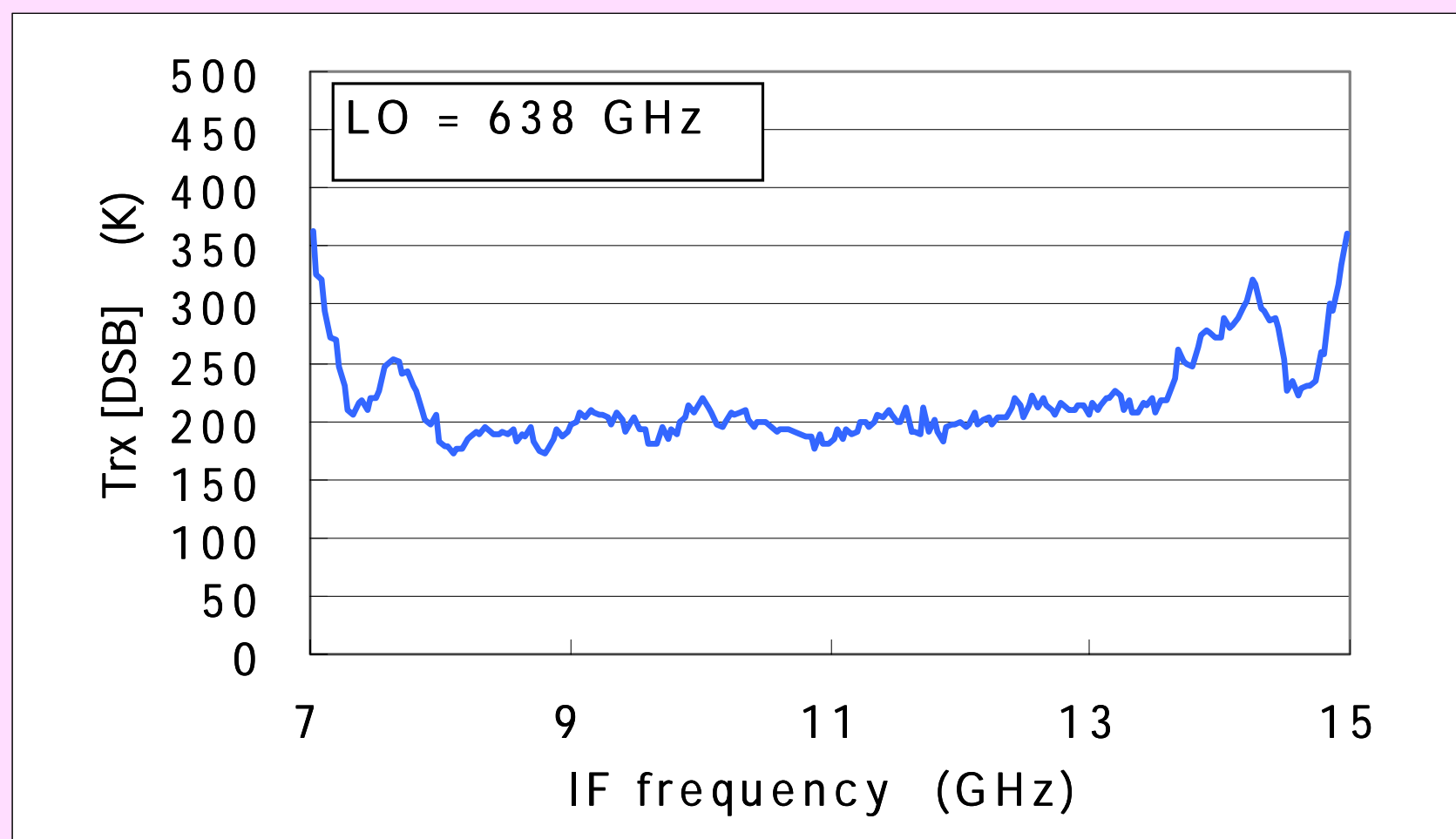
- LO source
- SSB Filter: Frequency-Selective-Polarizer (FSP)



COPT (Cooled Optics)

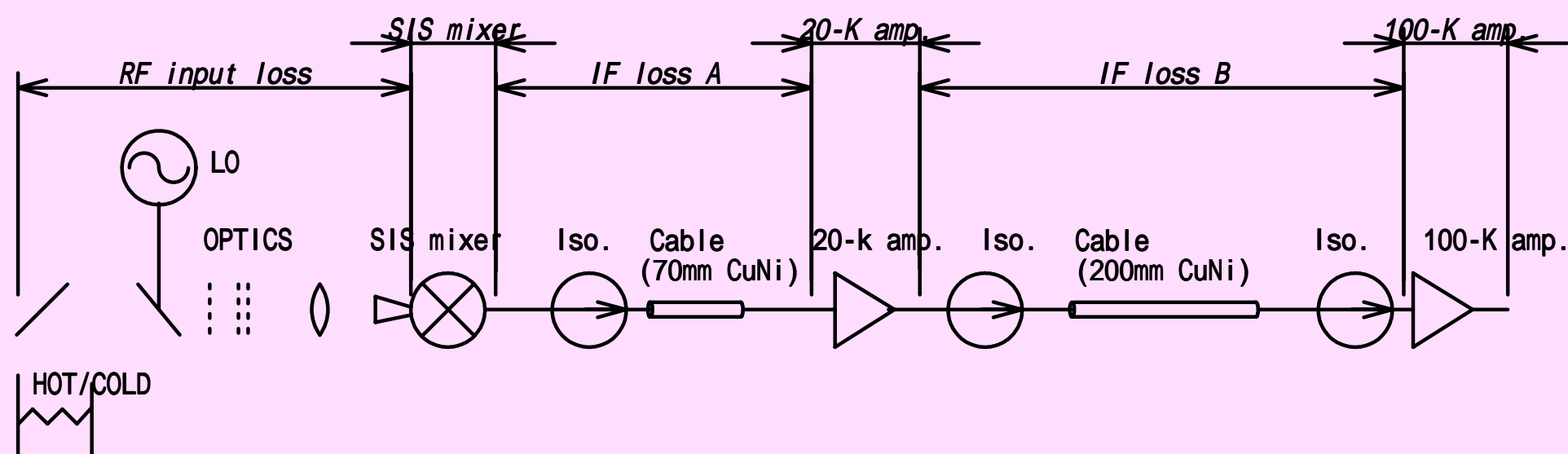
- Cooled at 4.5 K
- Two SIS mixers (USB,LSB)

SMILES Receiver Measurement



Measured T_{rx} of SMILES receiver as a function of IF frequency.

Noise Breakdown



	RF input loss	SIS mixer	IF loss A	20-K amp.	IF loss B	100-K amp.	
Gain (dB)	-1.0	-5.0	-1.2	23.9	-3.0	33.9	
Phys. Temp. (K)	290	4.5	12	22	60	100	
T_n (K)	80	30.2	3.8	12.3	11.9	20.8	T_{rx} (K)
ΔT_{rx} (K)	80	38.5	15.1	65.3	0.2	0.9	200.0

Measured values

Assumed values

Calculated values