Superconducting Integrated Receiver
(Development and Implementation)

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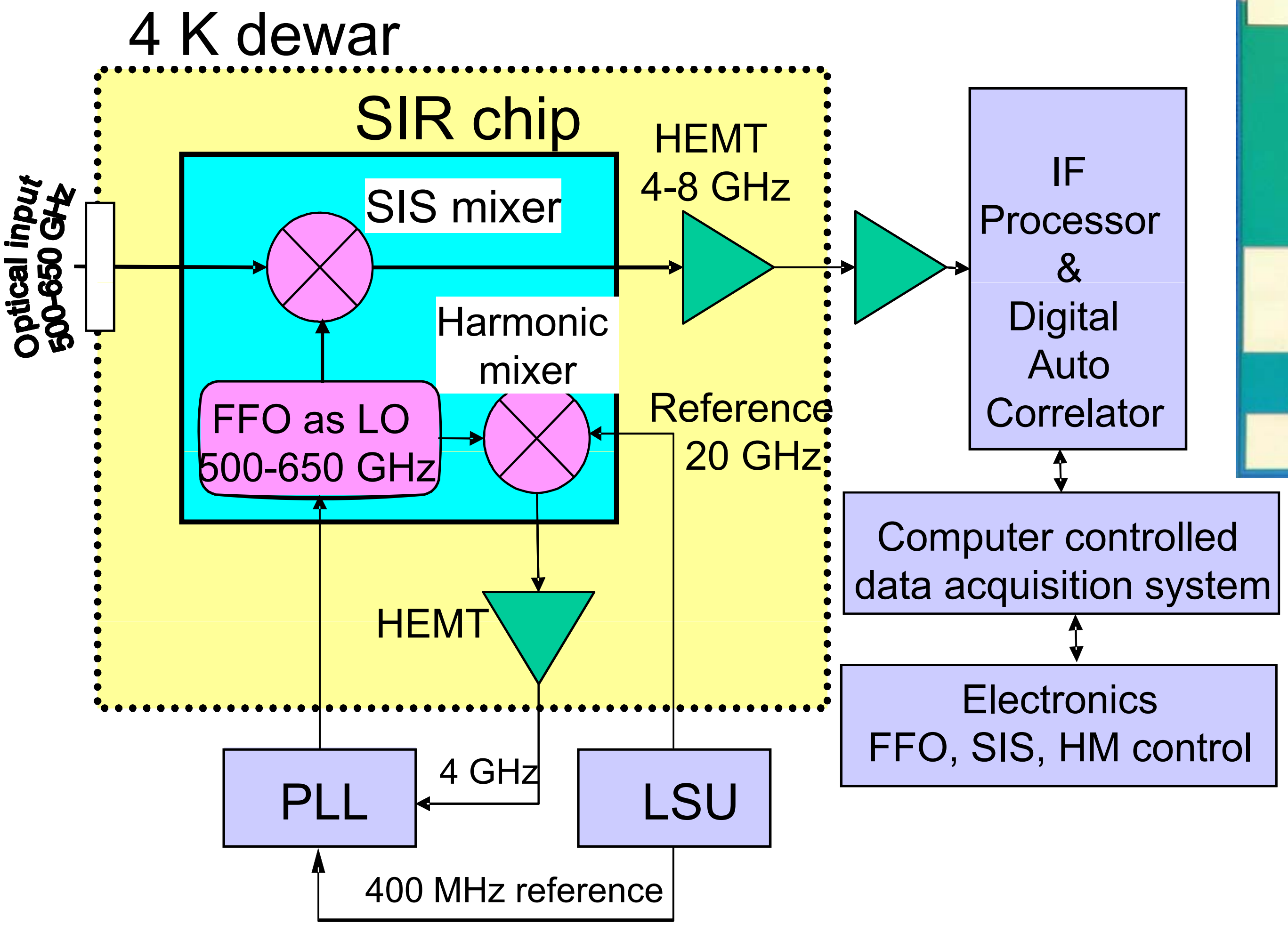
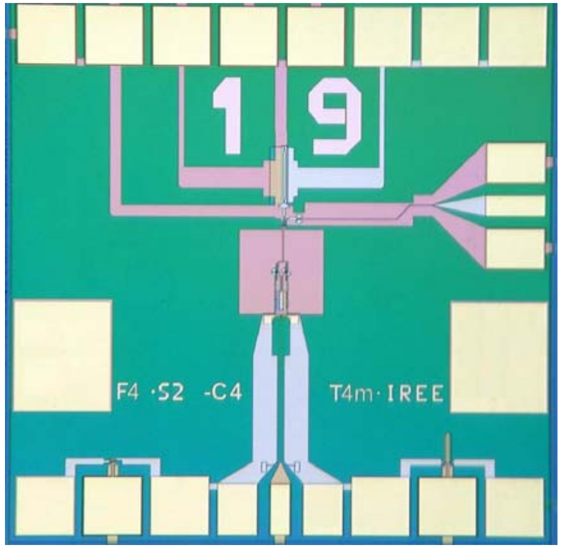
in collaboration with

SRON Netherlands Institute for Space Research, the Netherlands

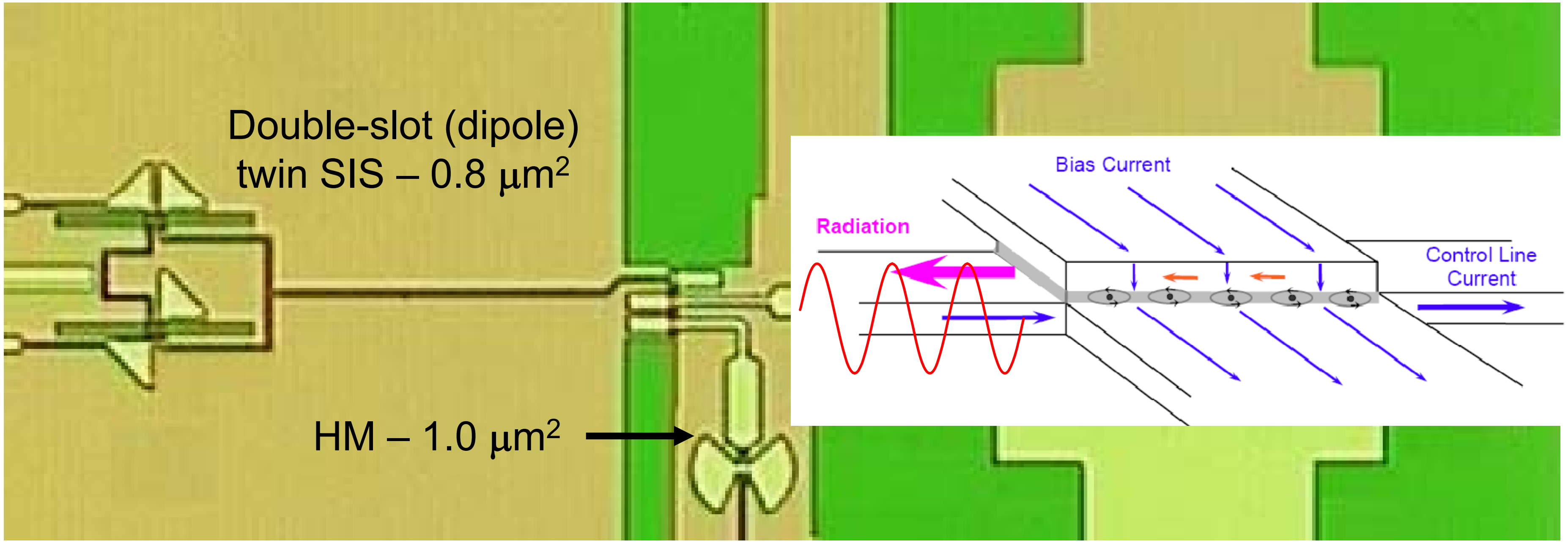
Superconducting Integrated Receiver (SIR) with phase-locked FFO





SIR microcircuit

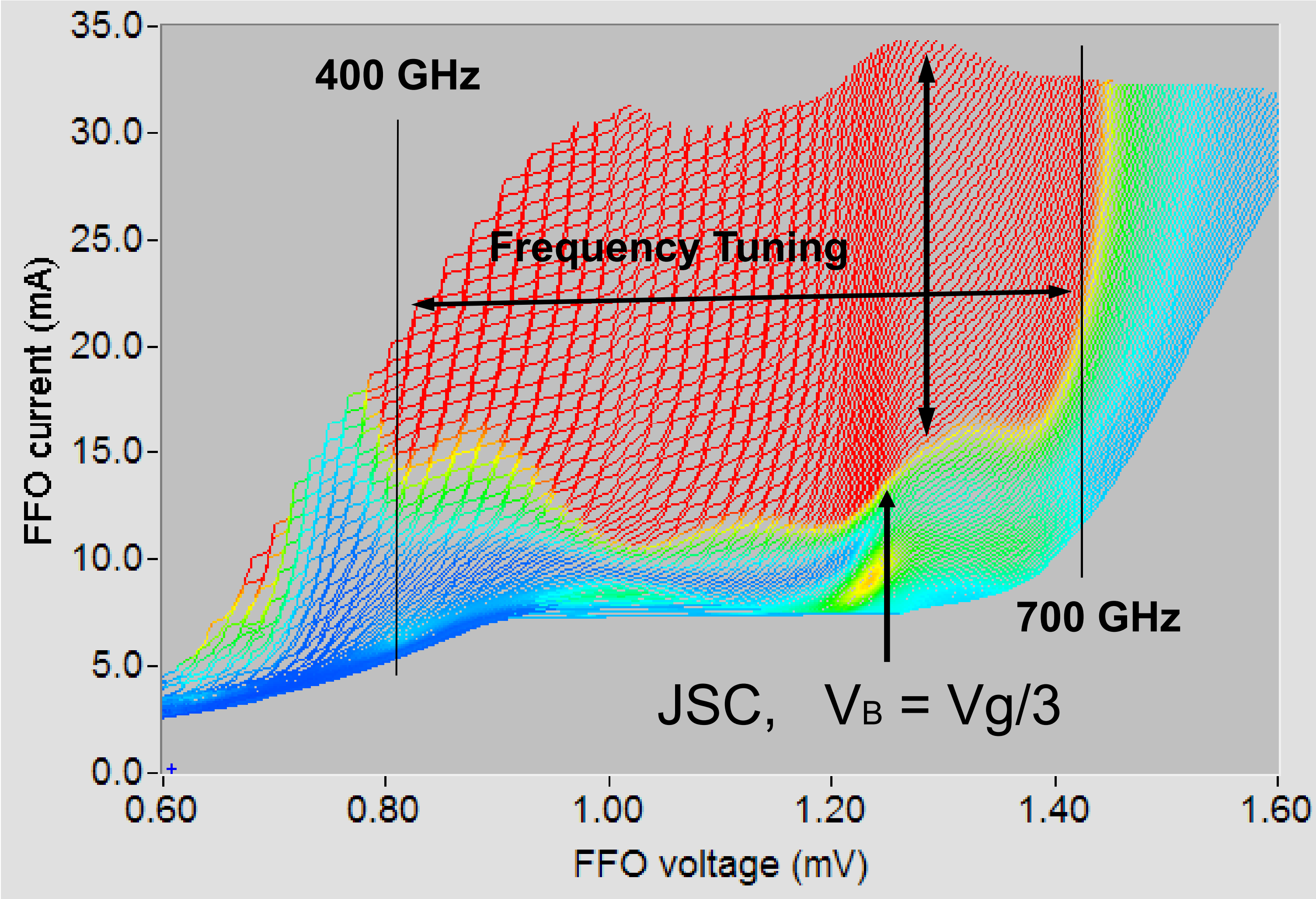
Internal part of the SIR Microcircuit



Nb-AlOx-Nb, Nb-AlN-NbN; Jc = 5 - 10 kA/cm^2

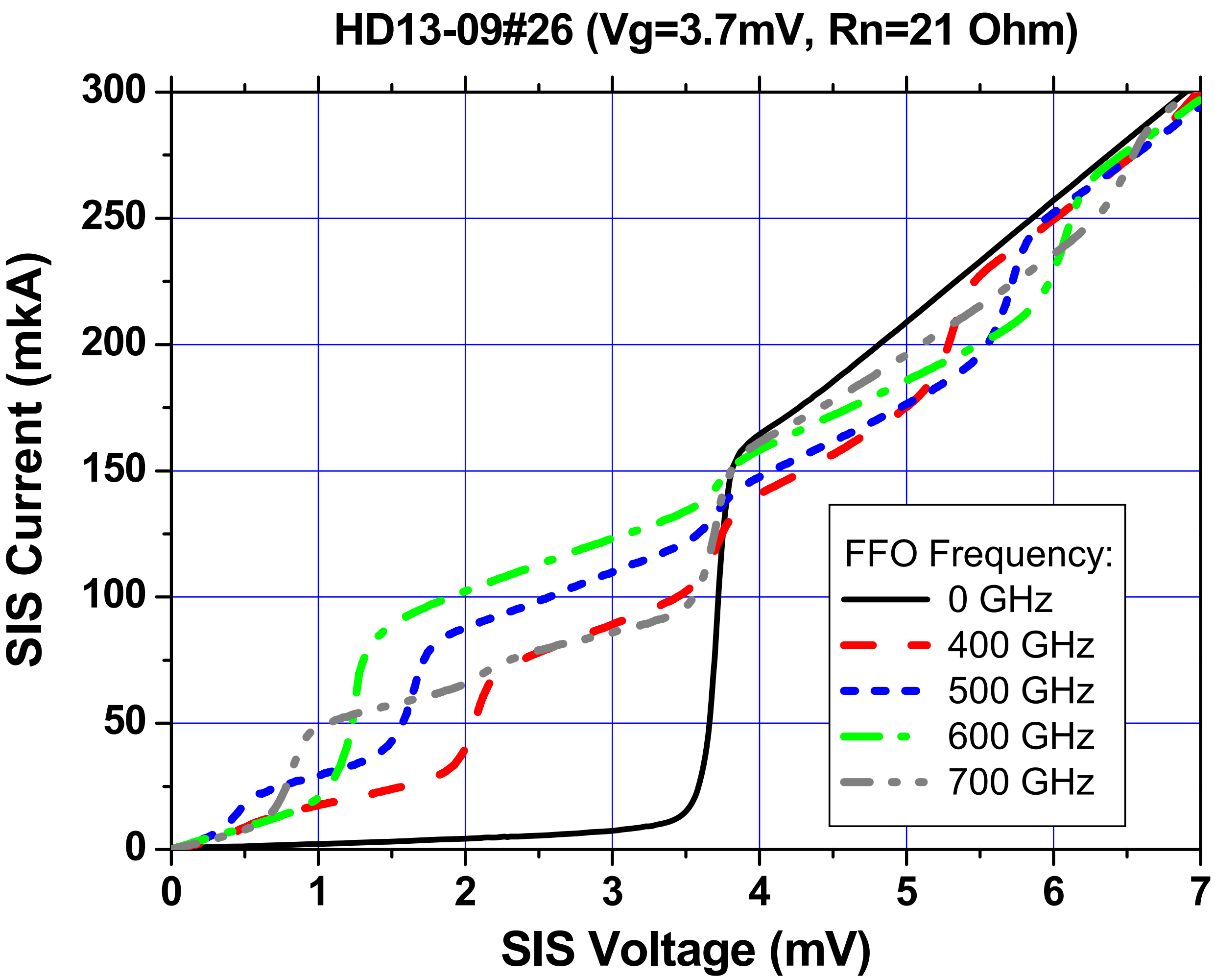
Optionally: SIS – Jc = 8 kA/cm^2; FFO + HM = 4 kA/cm^2

Nb-AlOx-Nb and Nb-AlN-NbN FFO for SIR

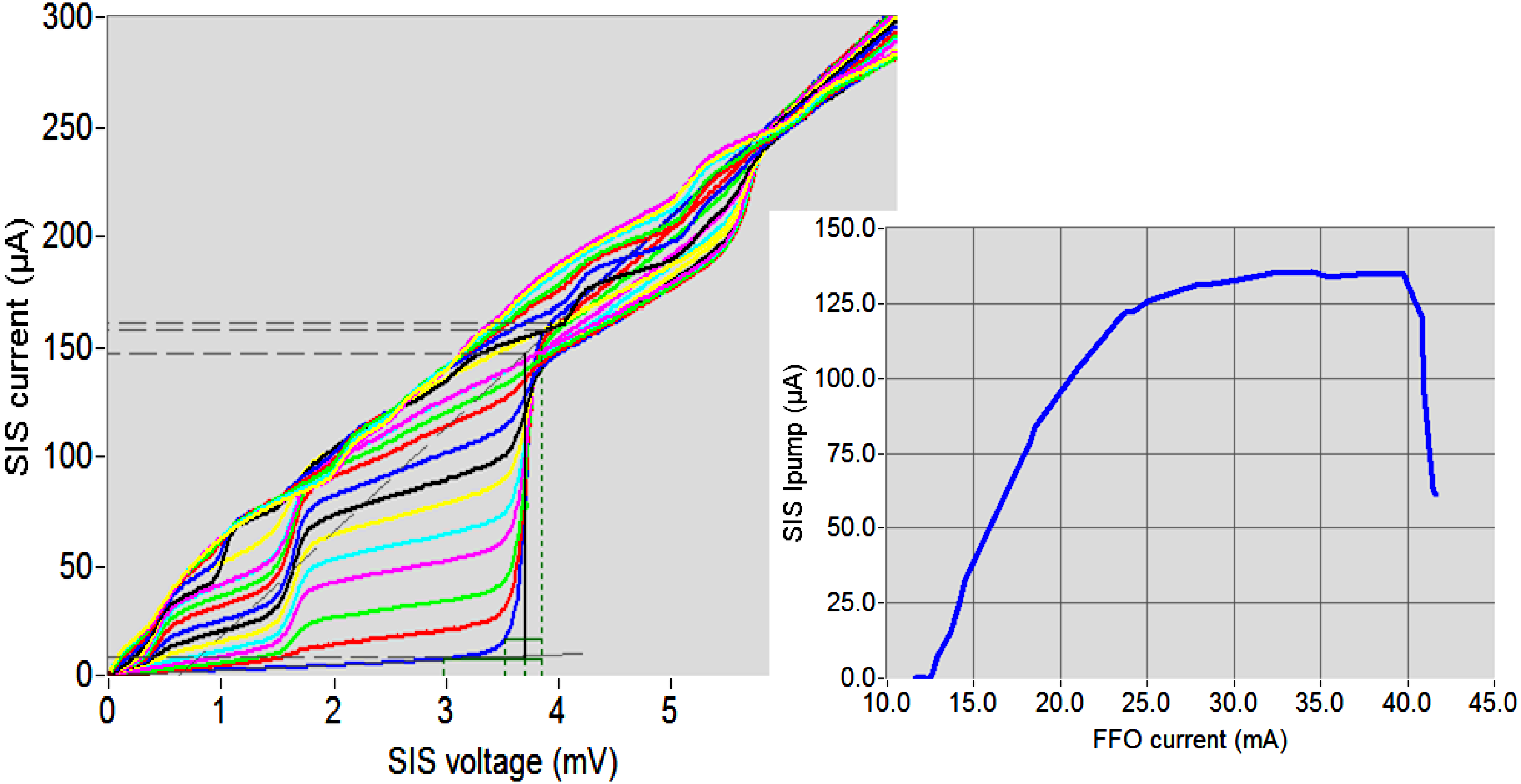


V.P. Koshelets, et al, Phys. Rev. B, vol. **56**, pp 5572-5577, (1997)

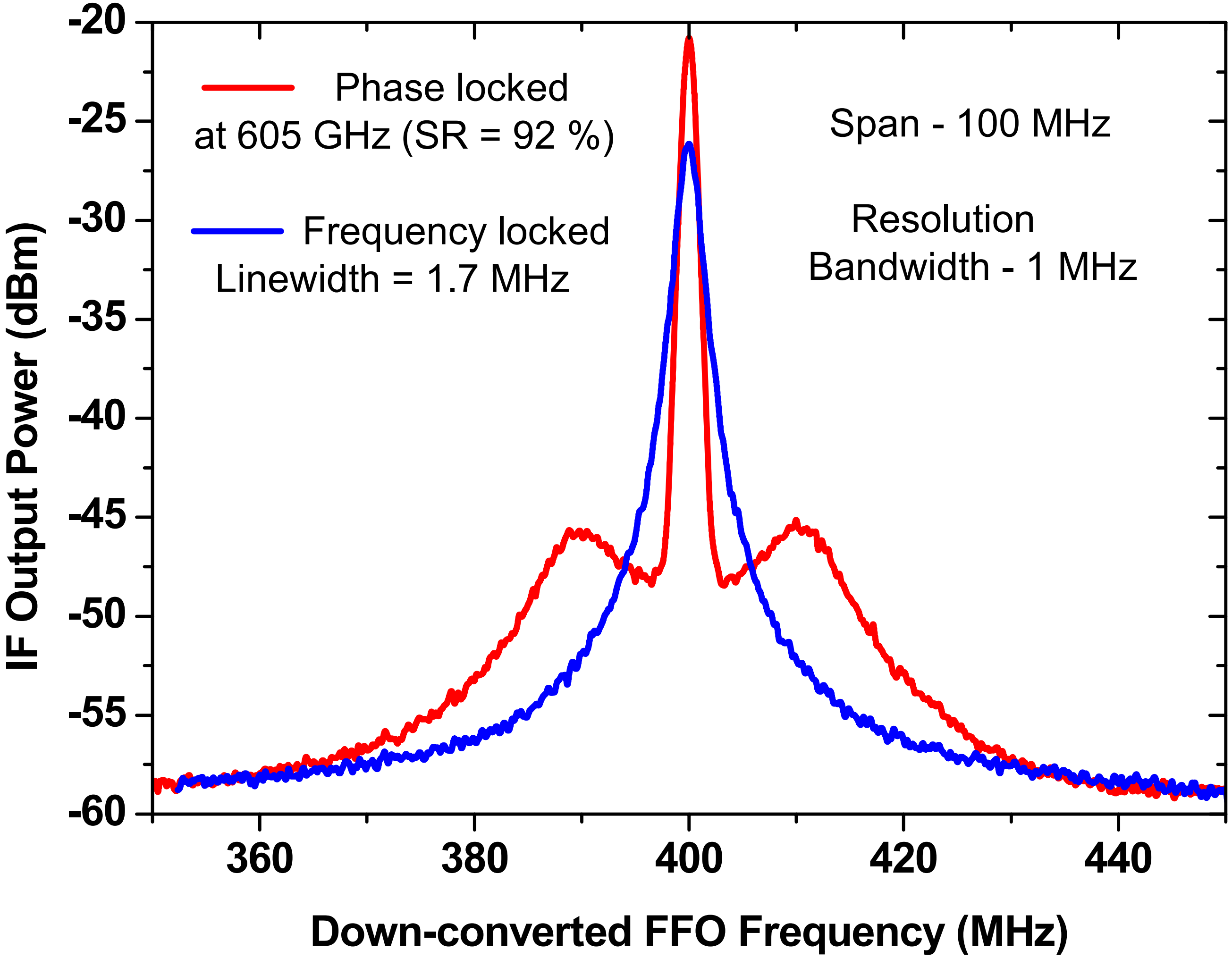
Nb-AlN-NbN SIS pumped by FFO; FFO frequency tuning



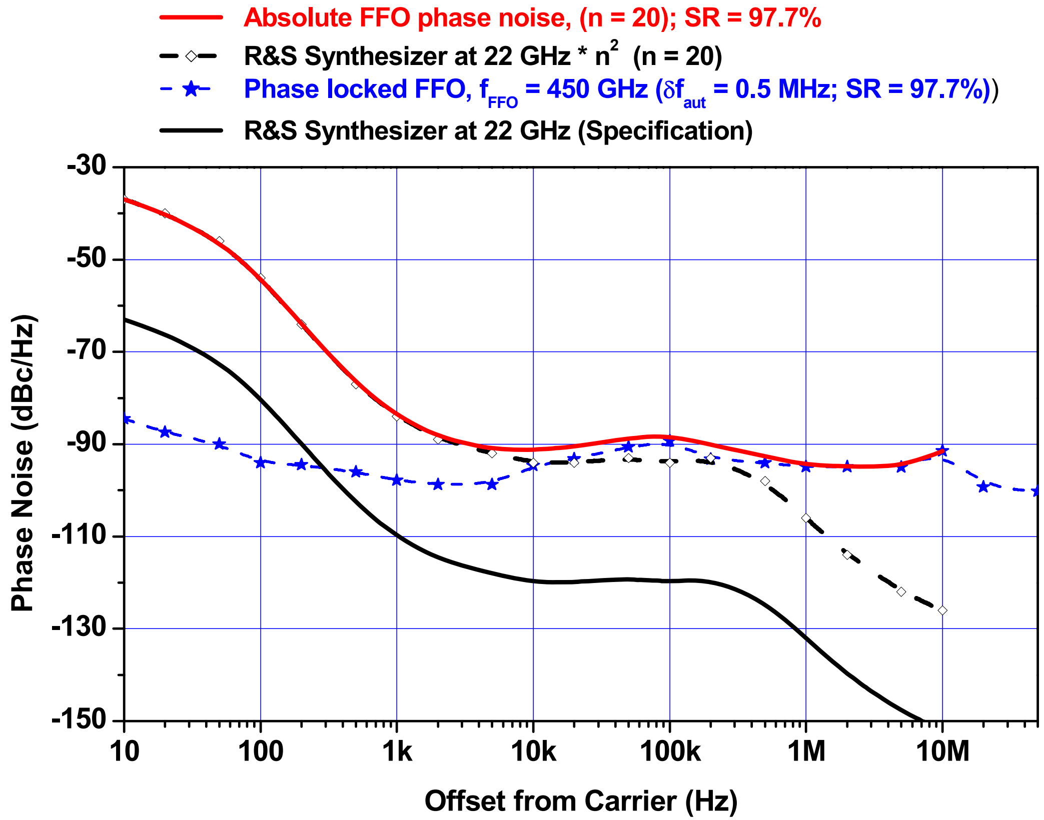
Nb-AlN-NbN SIS pumped by FFO; FFO power tuning (f = 500 GHz)

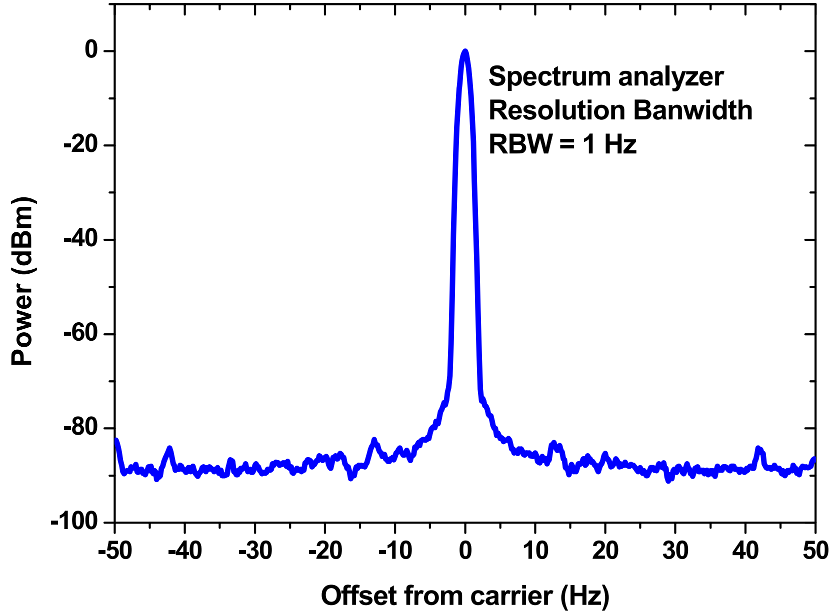


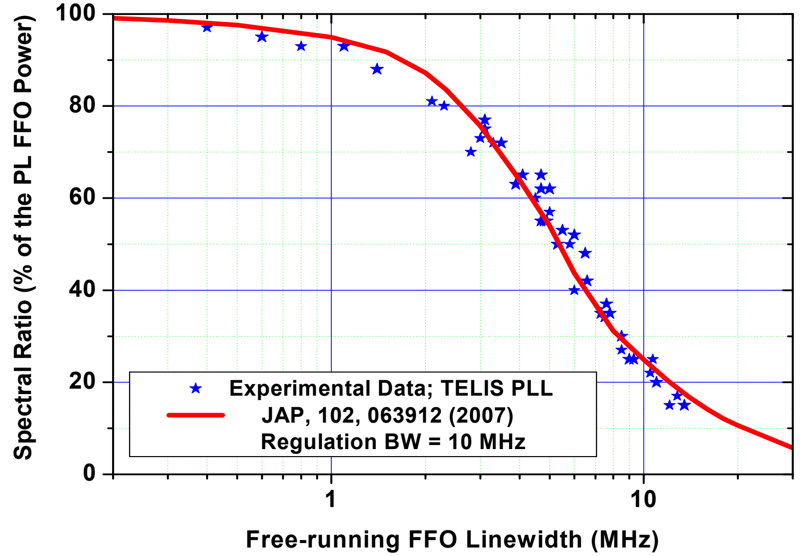
FL and PL spectra of the Nb-AlN-NbN FFO : frequency 605 GHz; LW = 1.7 MHz; SR = 92 %



Phase Noise of the PL FFO







Development of the Integrated Spectrometer for TELIS

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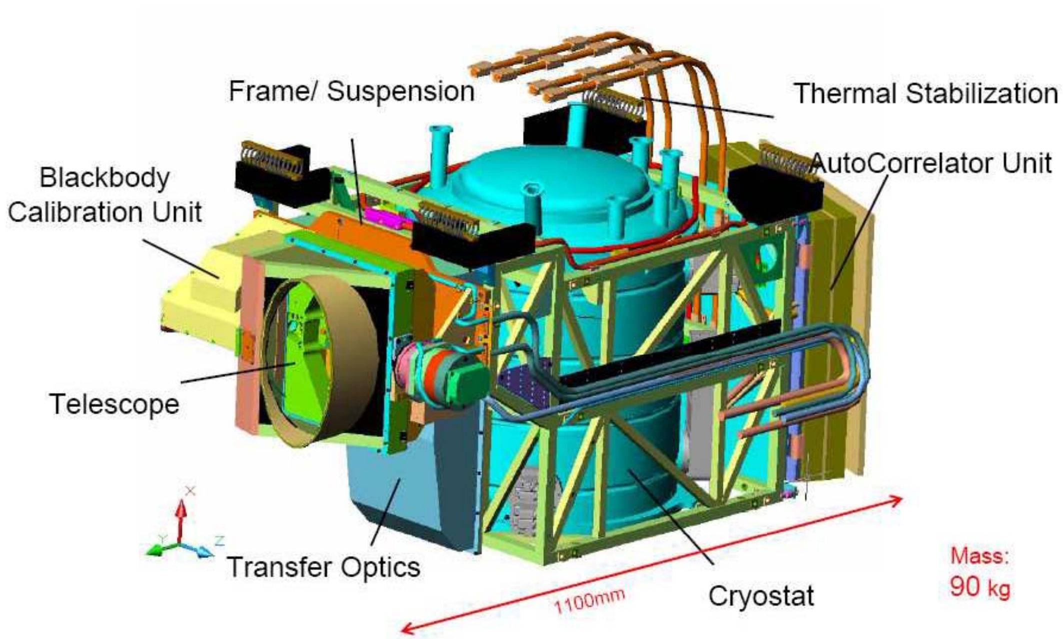
Institute for Remote Sensing Technology, DLR, Germany

TELIS (Terahertz Limb Sounder)

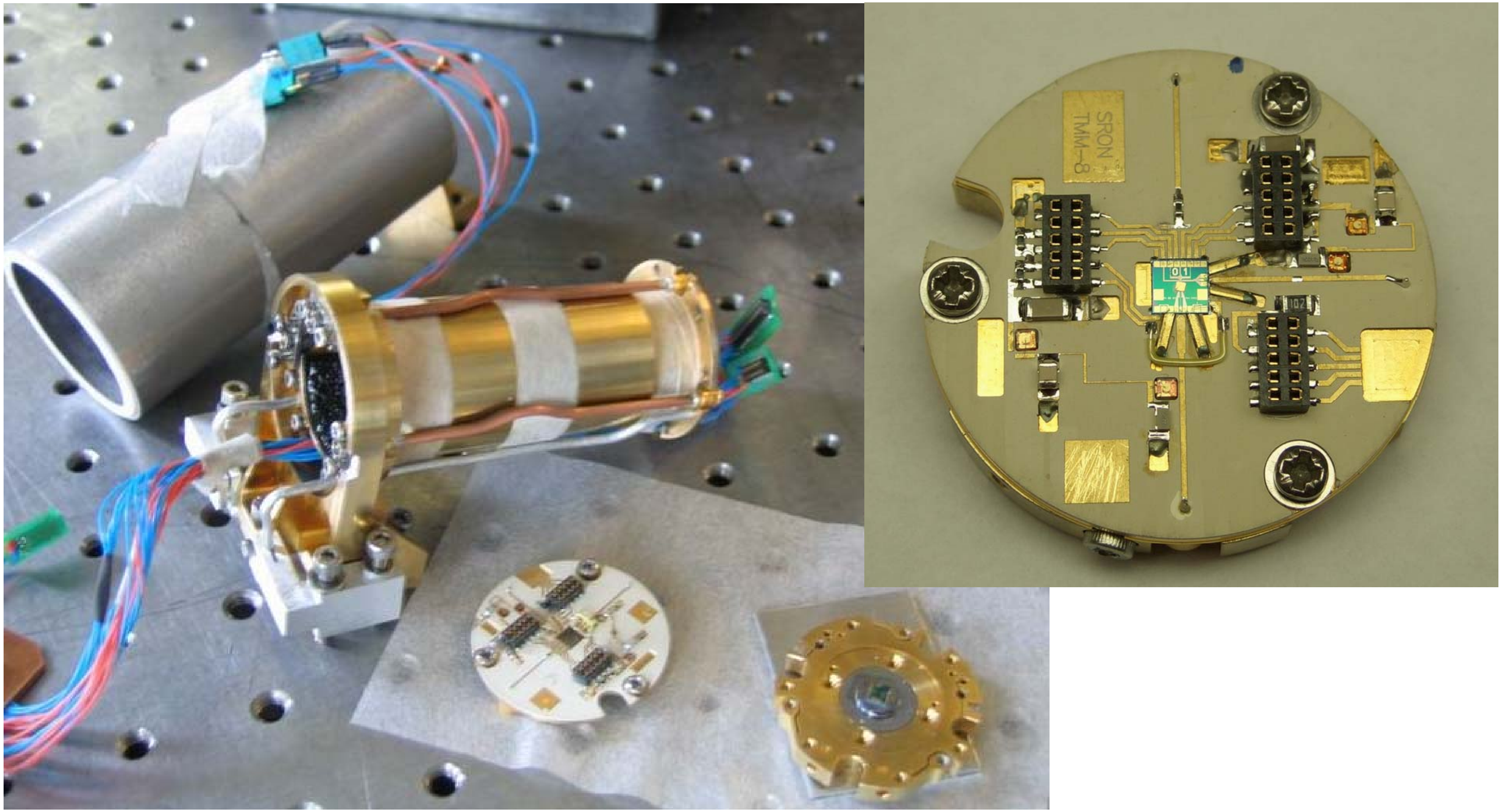


TELIS Instruments

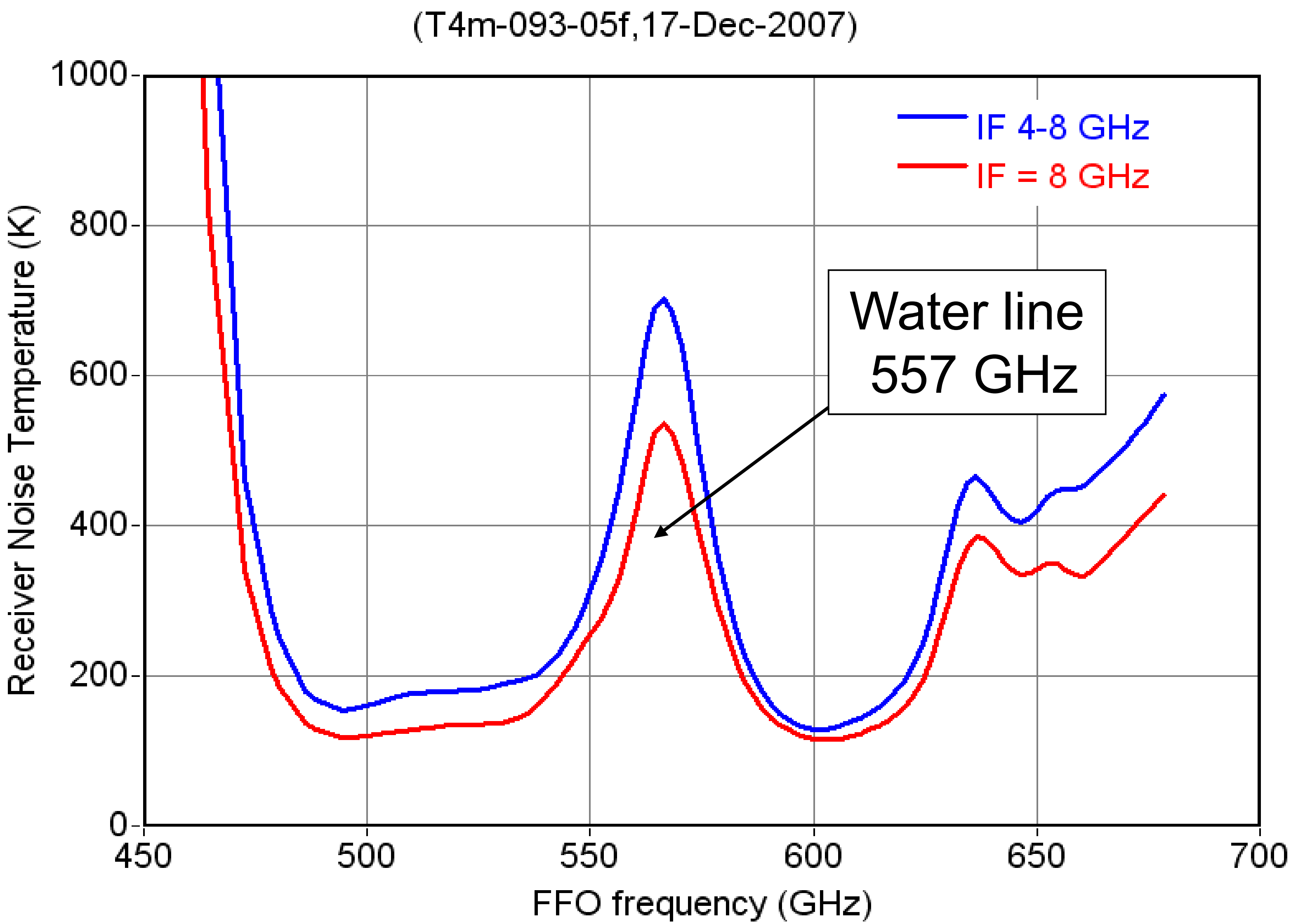
TELIS Objectives:

- Measure many species for atmospheric science:
  ClO, BrO, O_3, HCl, HOCl, etc;
  - Chemistry, Transport, Climate
- Serve as a test platform for new sensors
- Serve as validation tool for future satellite missions
- Three independent frequency channels, cryogenic heterodyne receivers:
  - 500 GHz by RAL
  - **500-650 GHz by SRON-IREE**
  - 1.8 THz by DLR (PI)

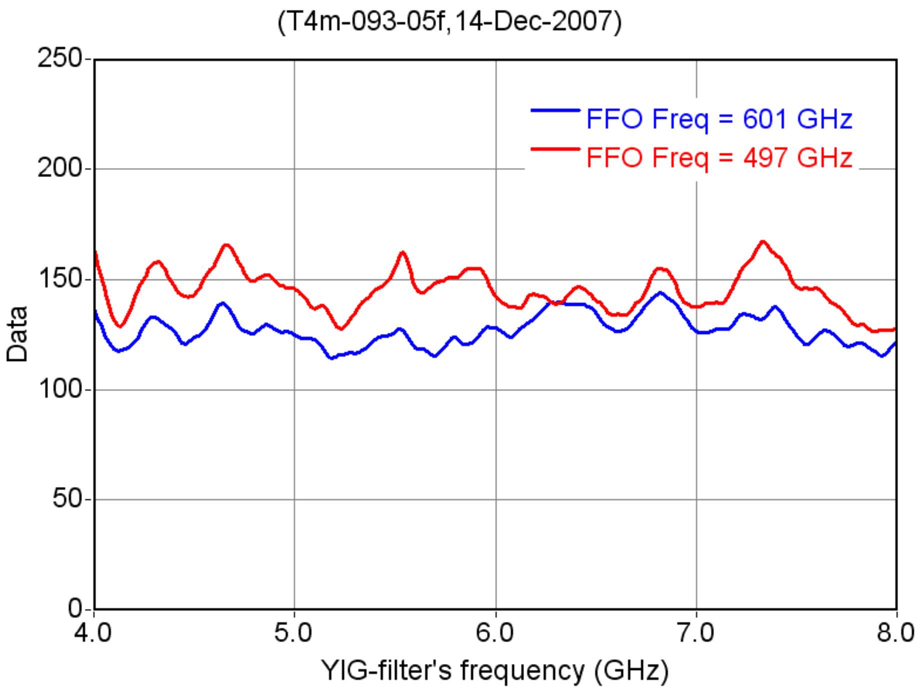
SIR Mixer Block with Shields

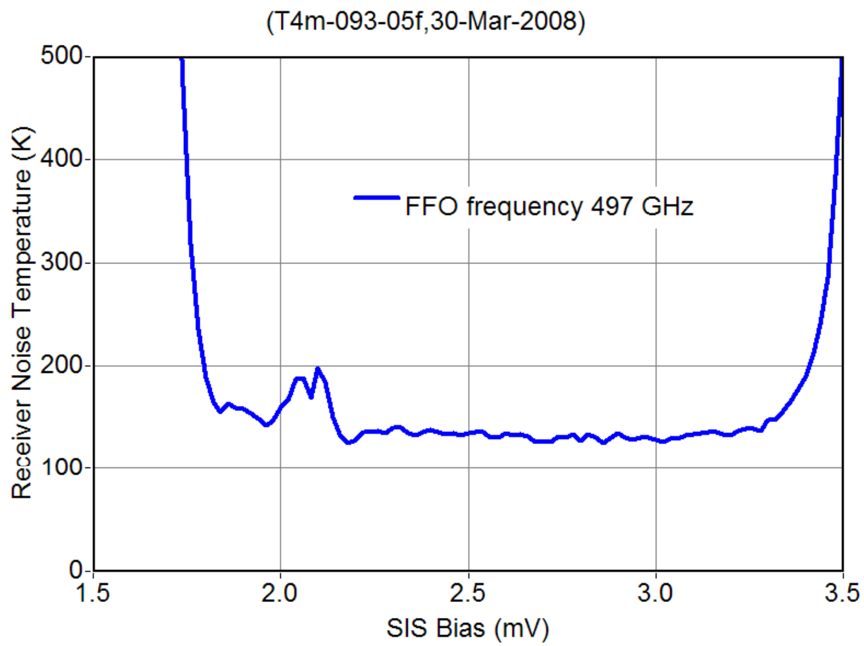


Noise Temperature of the Flight SIR (DSB)

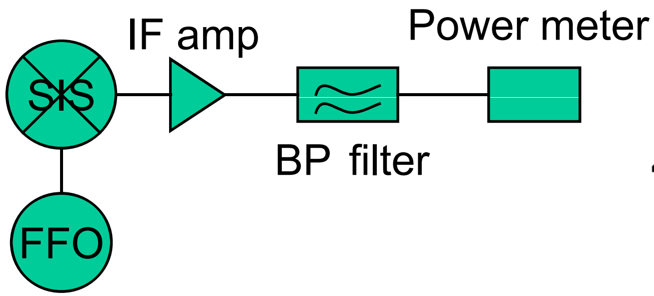


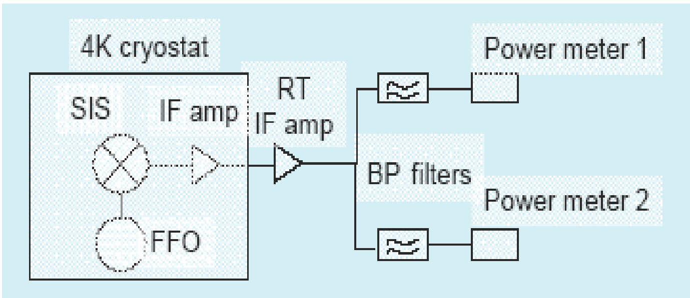
SIR Noise Temperature on Intermediate Frequency and SIS Bias

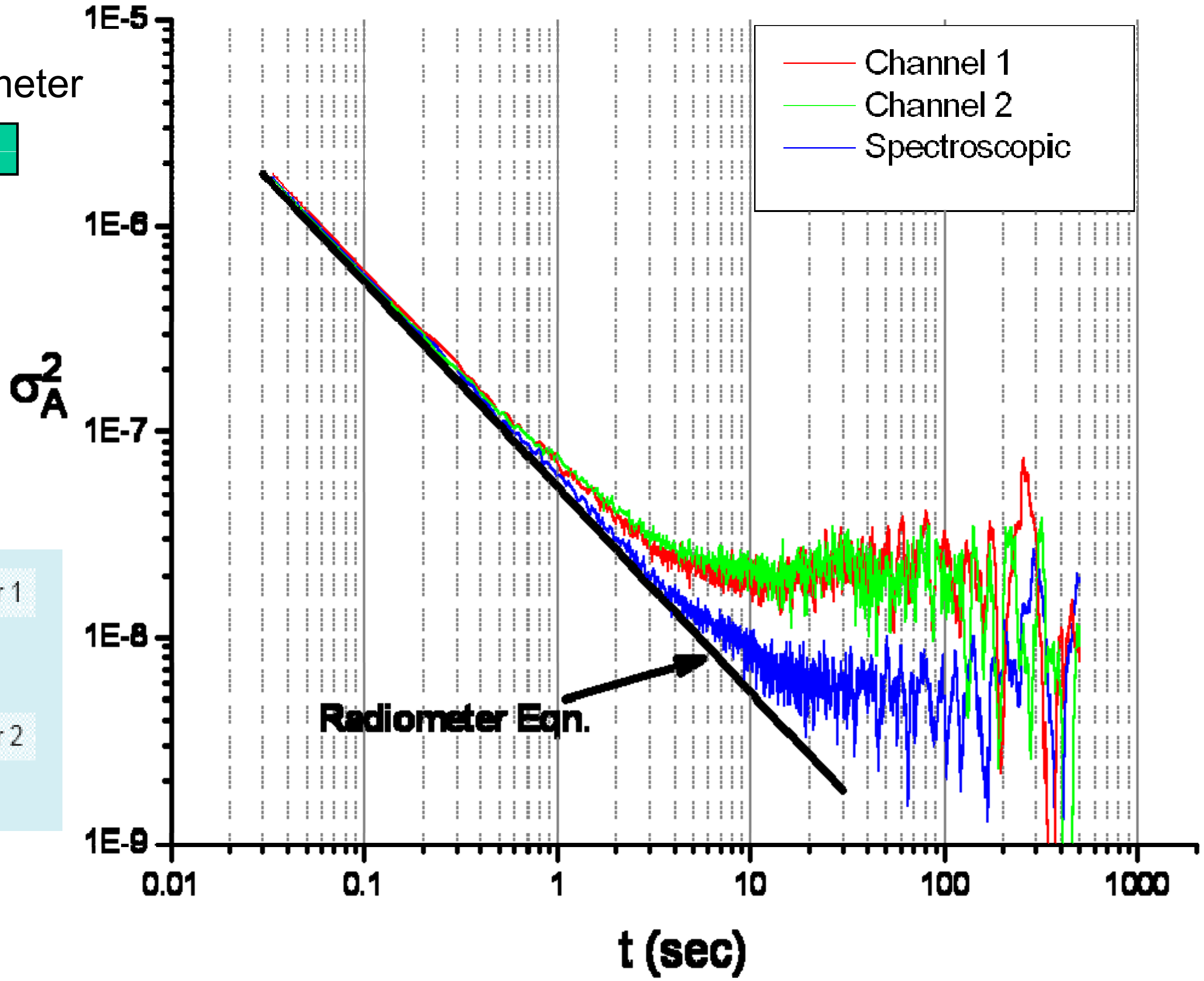




SIR Stability: Allan variance test

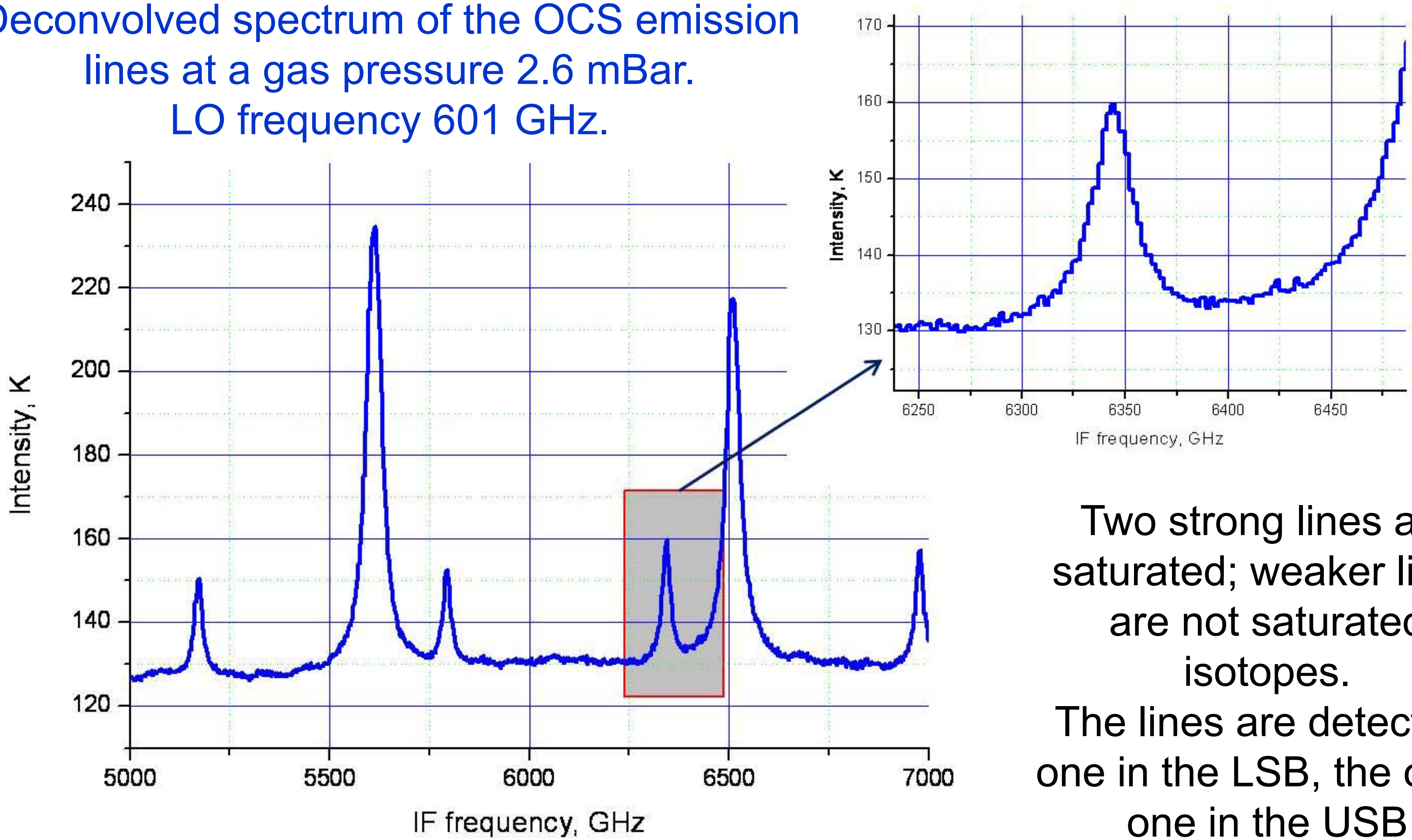






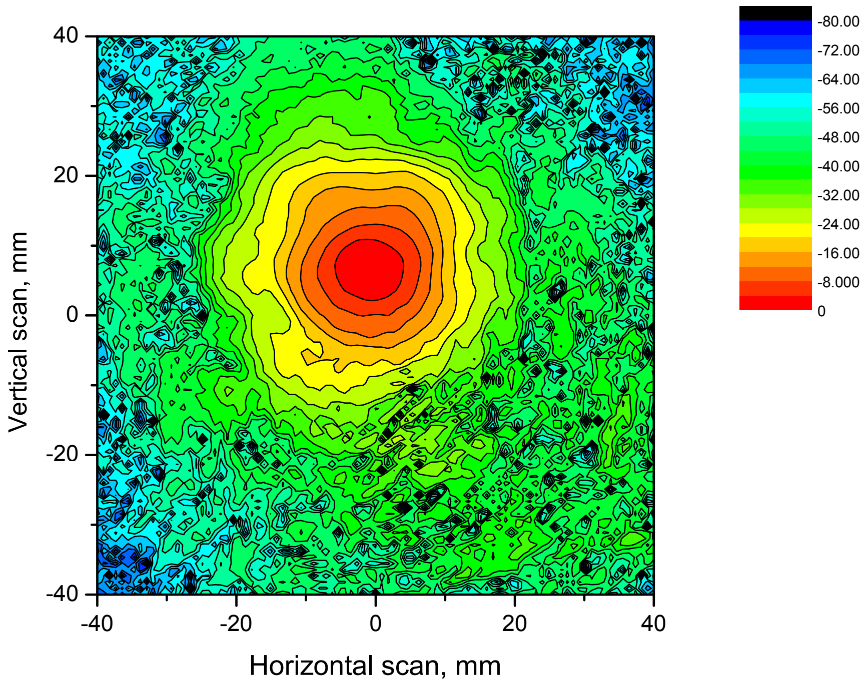
SIR Spectral Resolution

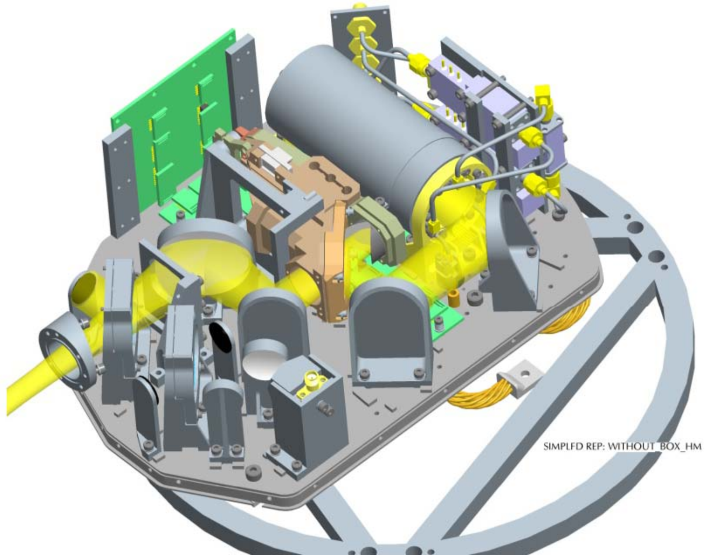
Deconvolved spectrum of the OCS emission lines at a gas pressure 2.6 mBar.
LO frequency 601 GHz.



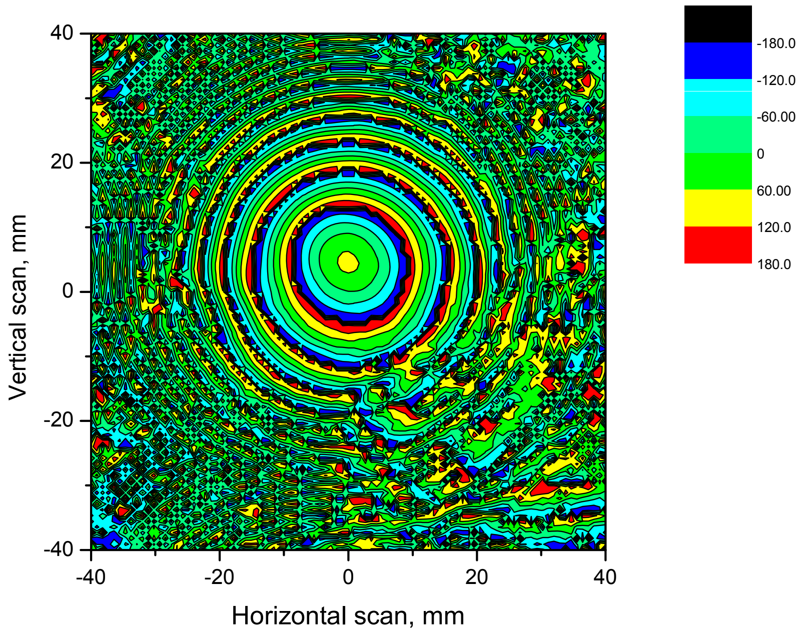
Two strong lines are saturated; weaker lines are not saturated isotopes.
The lines are detected, one in the LSB, the other one in the USB

Amplitude and phase APB of the SIR with cold optics



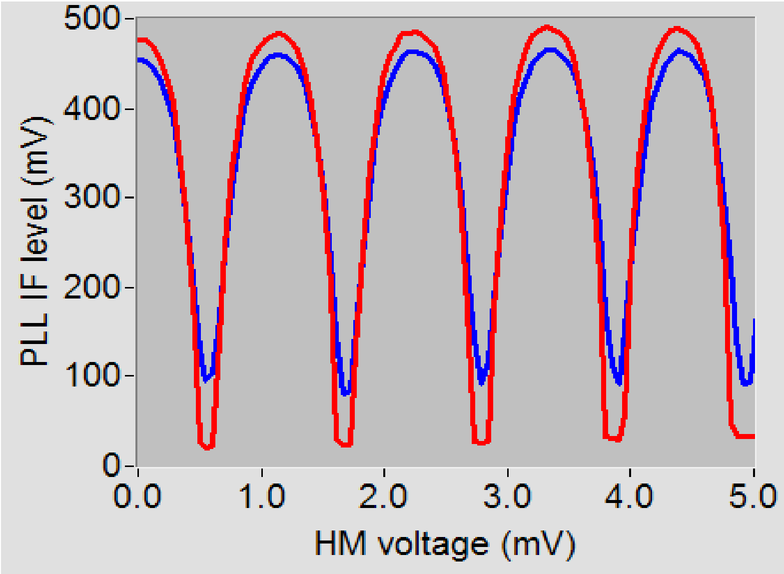


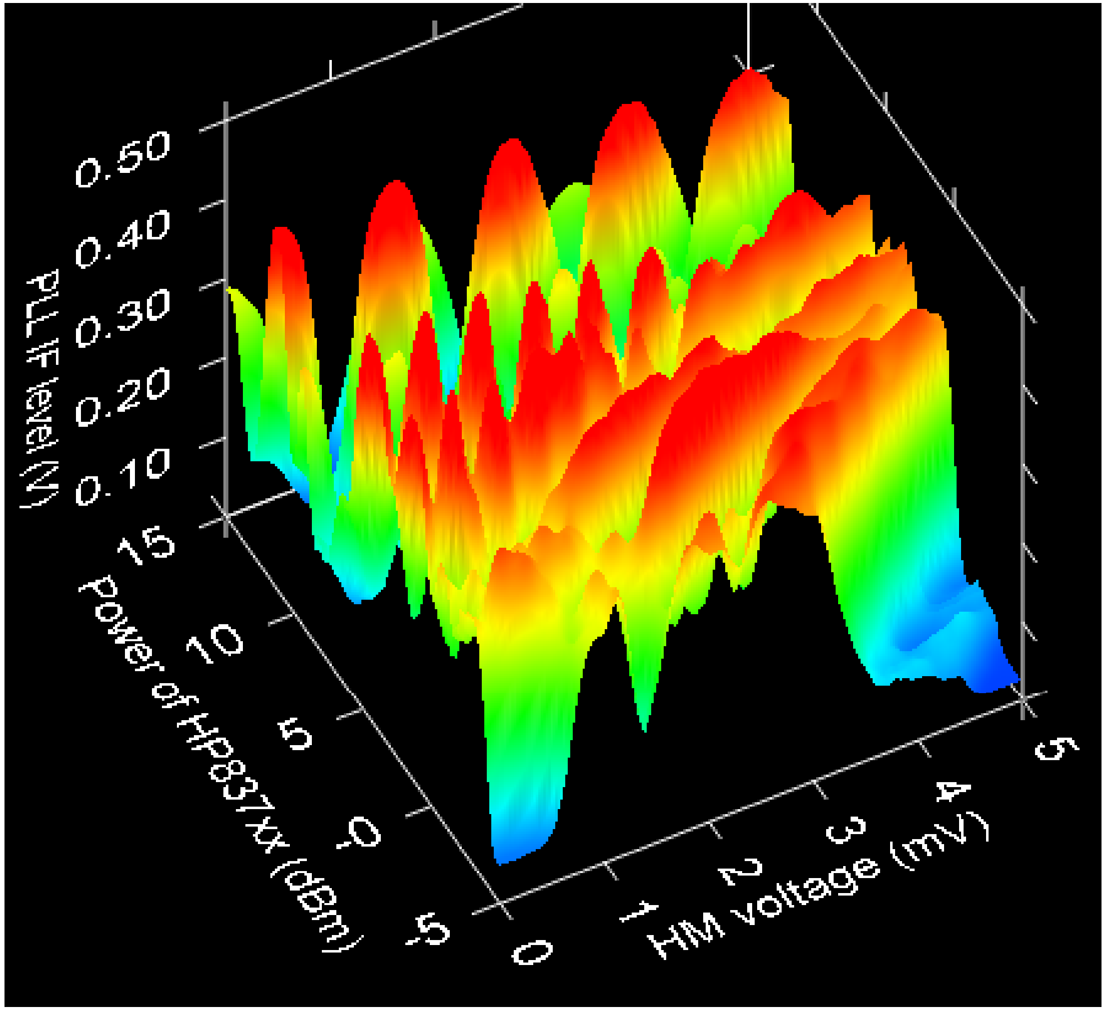
Amplitude

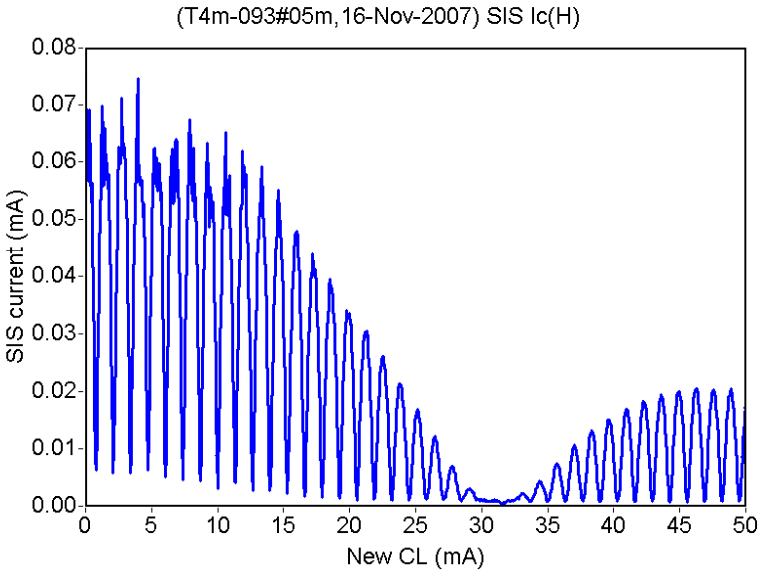


Phase

SIR for TELIS – remote operation







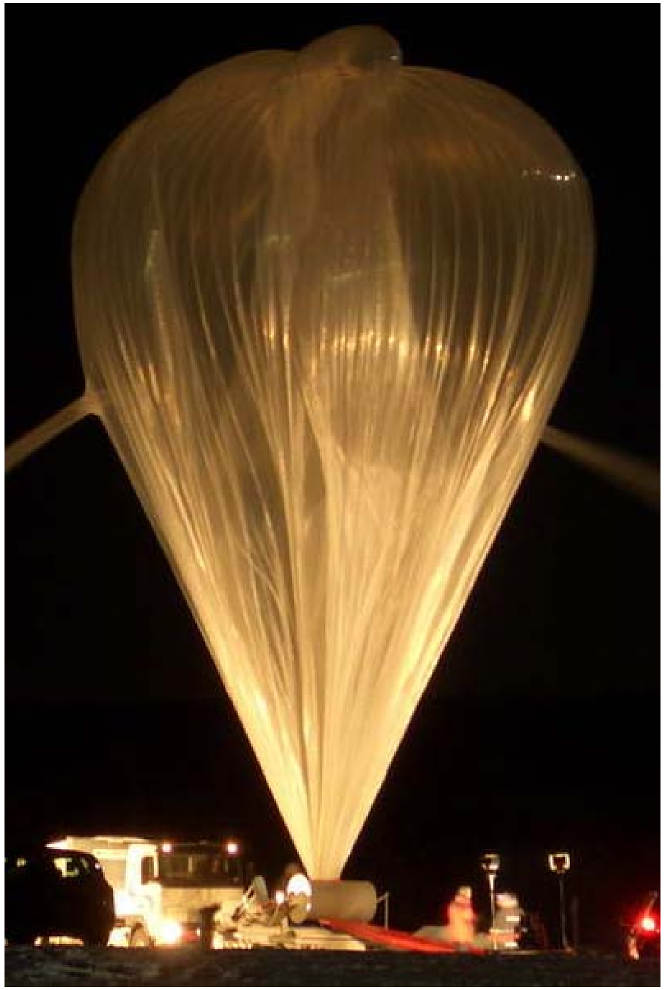
TELIS-SIR Main Parameters

(parameters determined by digital correlator are in parentheses)

Input frequency range, GHz	500 – 650 ГГц
Minimum noise temperature in the range (DSB), K	120 К
Output IF range, GHz	4-8 (5-7) ГГц
Spectral resolution, MHz	< 1 (2) МГц
LO frequency net, MHz	< 300 МГц
Dissipated power at 4.2 K stage, mW	< 30 мВт
Operation temperature, K	< 4.5 К

Esrange Space Center , Kiruna, Sweden, 67.5^{o}N, 21.1^{o}E; March 2009

TELIS (Terahertz Limb Sounder)

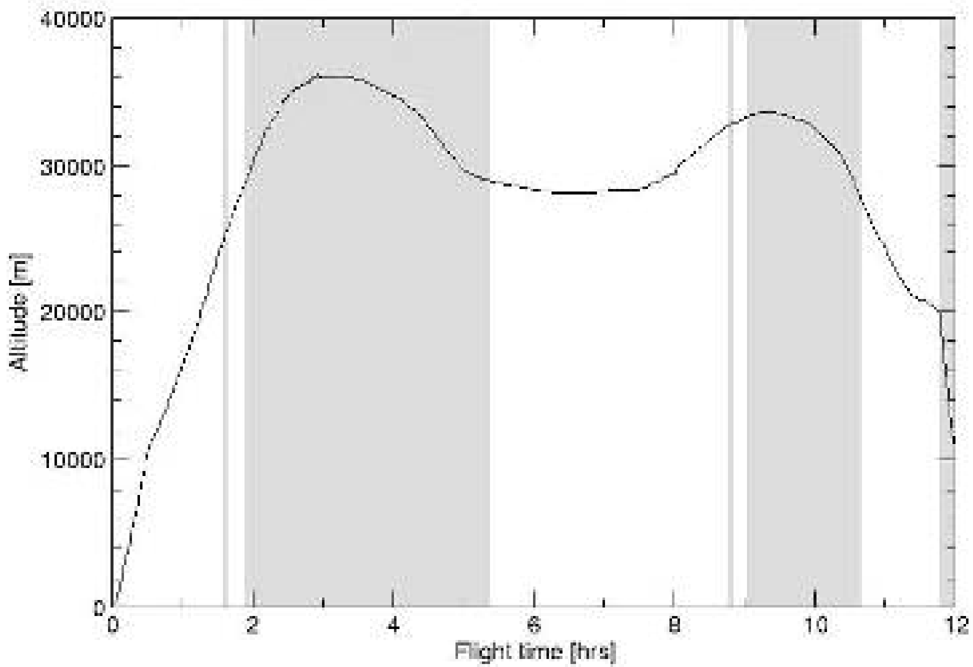


TELIS-MIPAS at Esrange, Sweden; March 2009

Balloon size: 400 000 m3; Payload weight: 1 200 kg

Flight trajectory (predicted)

Flight profile (actual)



Frequencies and substances selected for the first TELIS flight

##	FFO Frequency, GHz	Substances (High priority)
1	495.04	H_2-^{18}O
2	496.88	HDO
3	505.6	BrO (ΔT = 0.3 K !!)
4	507.28	ClO
5	515.25	O_2 /pointing /pressure
6	519.25	BrO (ΔT = 0.3 K !!)
7	607.78	O_3 isotopes
8	619.1	HCl (HOCl, ClO)

Spectra measured at limb-sounding

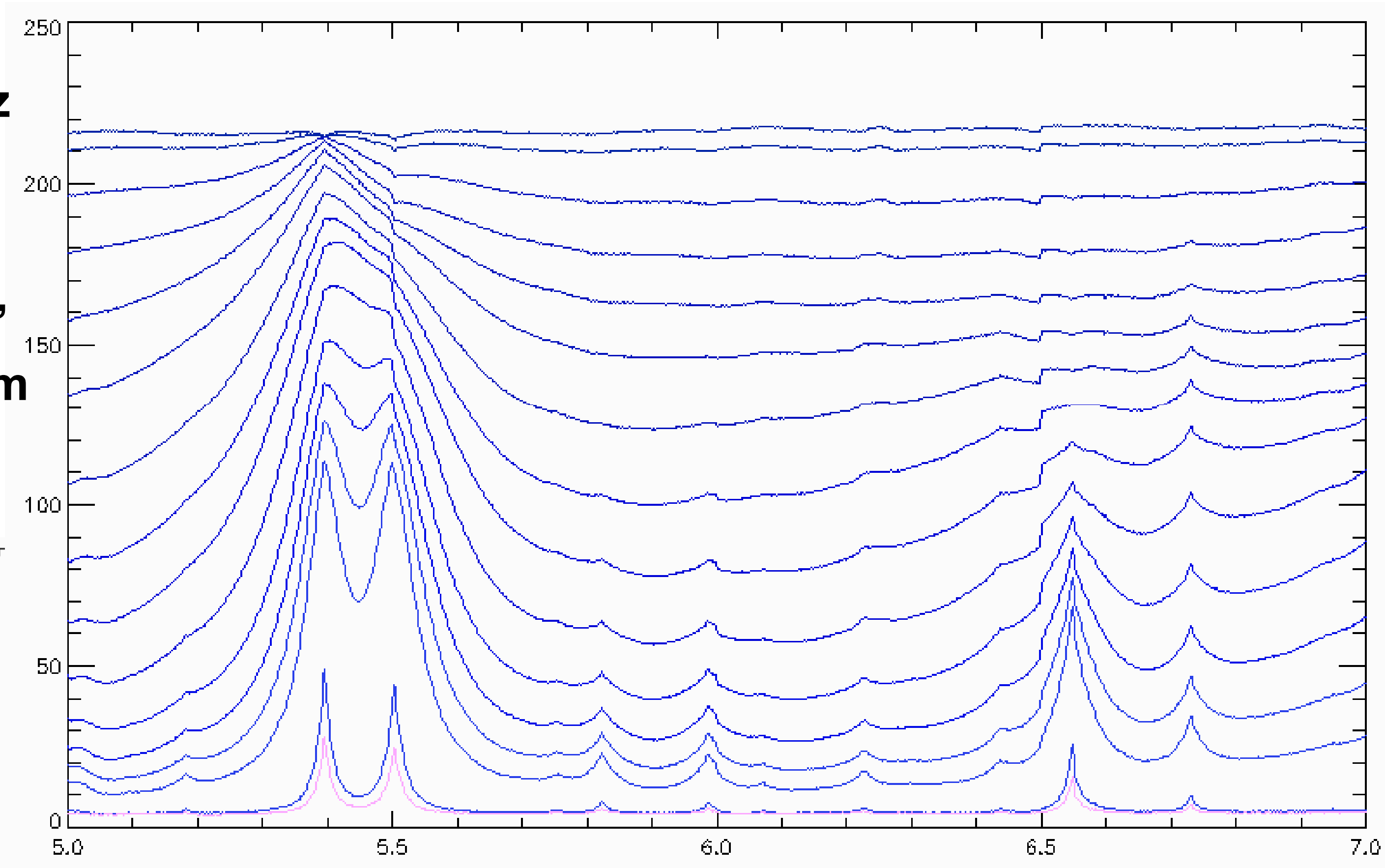
FFO Freq = 495 GHz

Orbit – 30 km;

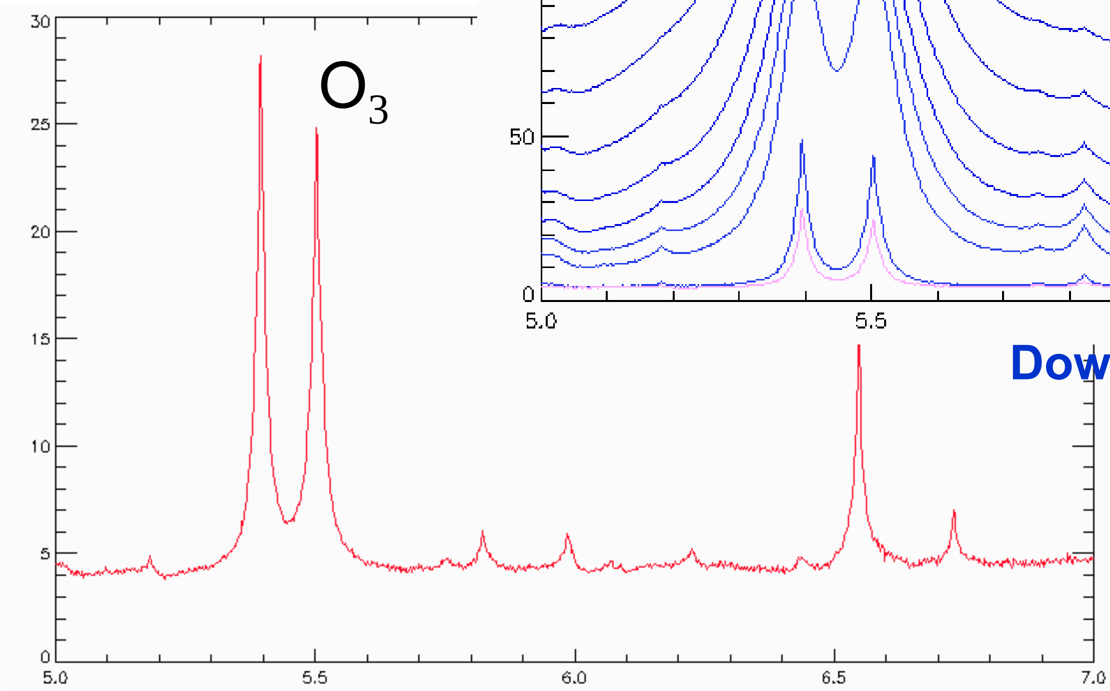
Increment – 1.5 km,

Tangent: 10.5 – 30 km

45 degrees up

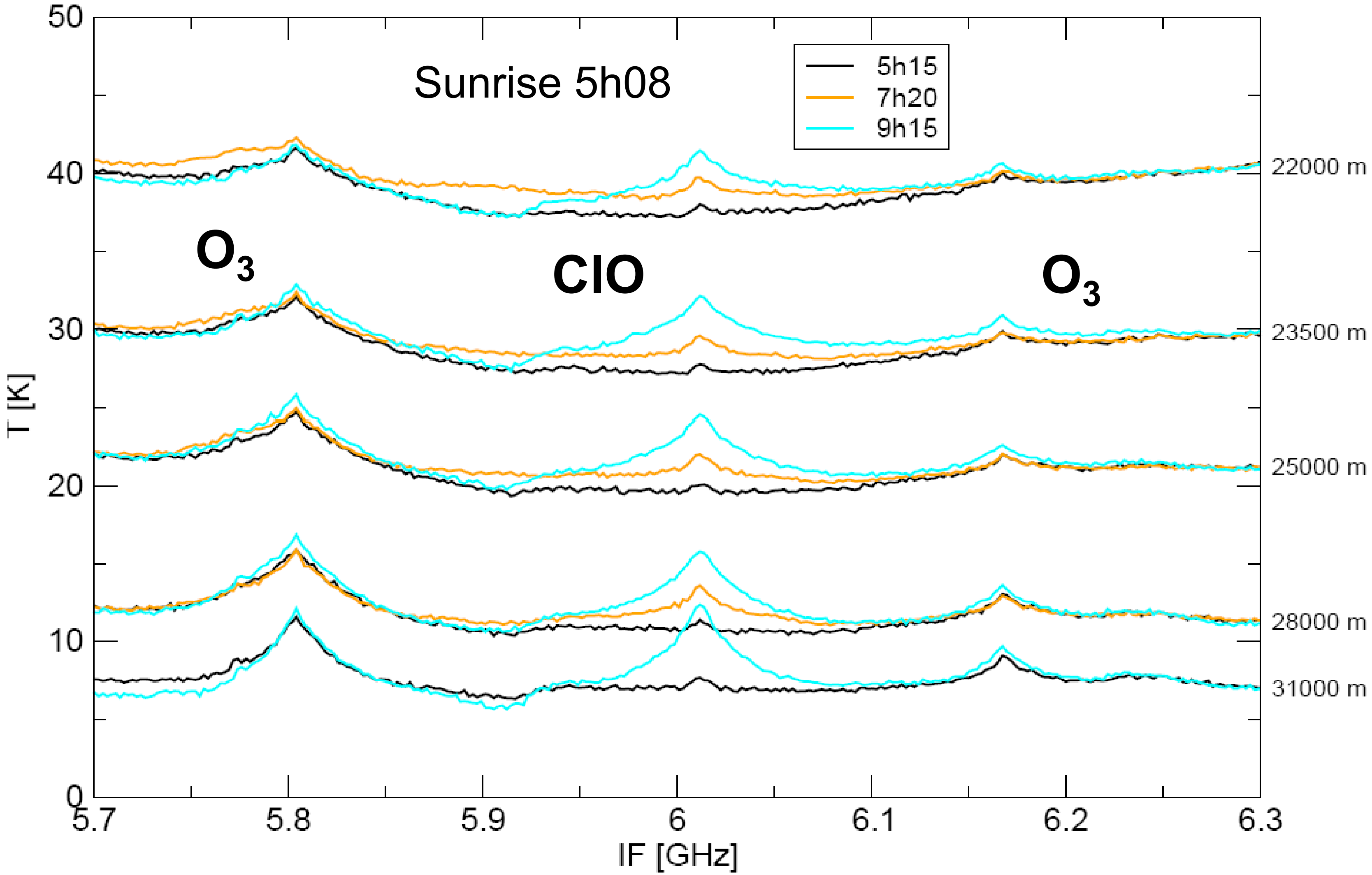


Down-converted Frequency, GHz



Down-converted Frequency, GHz

ClO line over time (FFO = 495 GHz)



Back to the Earth…

30-cm POrtable Submillimeter Telescope (POST)

Purple Mountain Observatory; Nanjing.

Site: Delingha of Qinghai province *(altitude ~3200 m)*

Frequency - 345 GHz
Tr (DSB) < 100 K
Spectral resolution < 1 MHz

2-stage GM type;
cooling capacity
– 0.1 W;

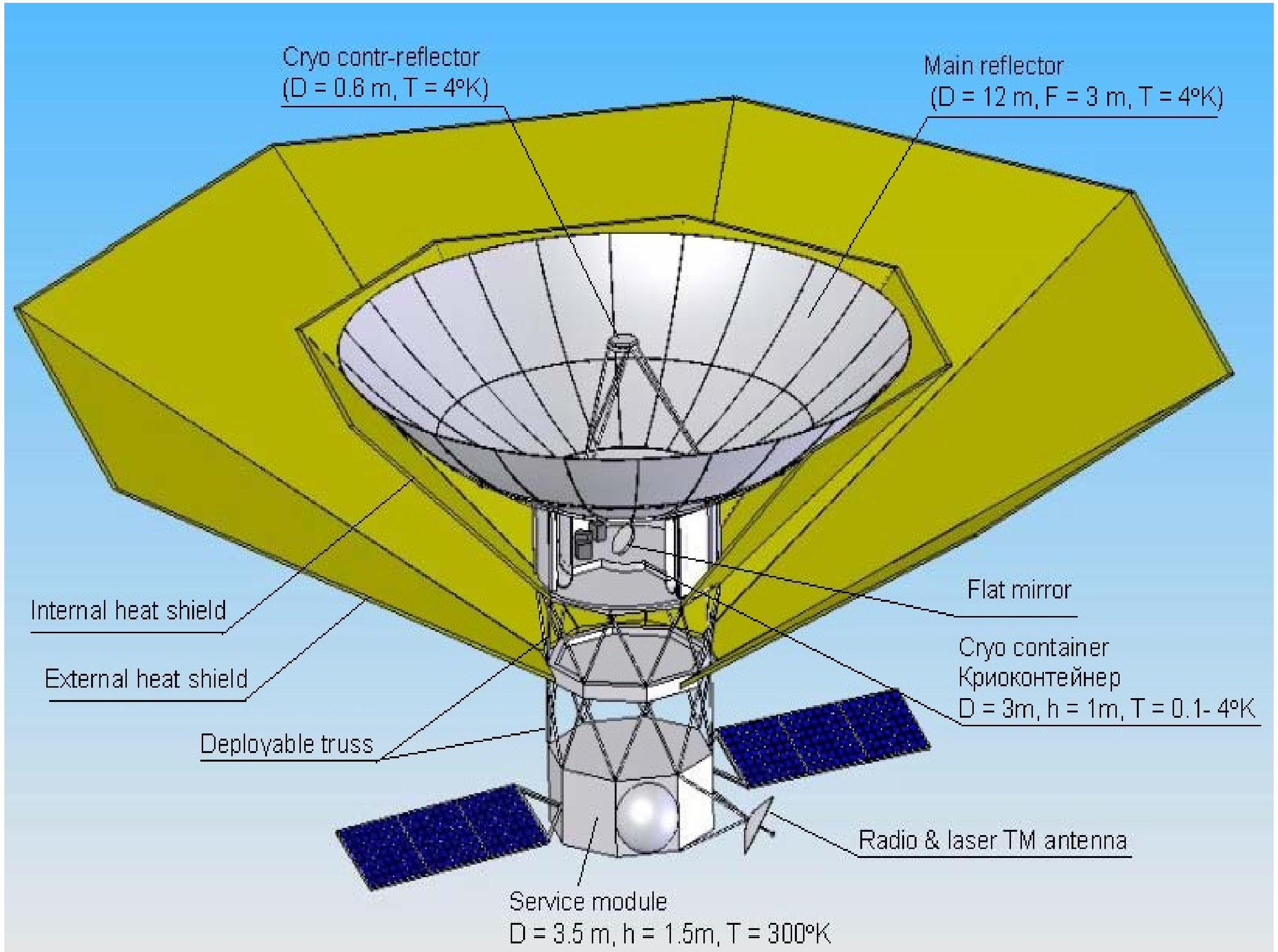
compressor – 42 kg;
power consumption
- 1.2 kW

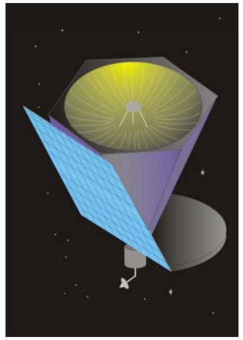
ESPRIT – Exploratory Submm Space Radio-Interferometric Telescope

The six elements of ESPRIT in an Ariane 5

- Telescope sizes ~ 3.5 meter ; off-axis
- Number of elements N = 6 (15 baselines)
- Projected baselines 200 - 1000 meter
- Frequencies:
  Spots in the range 0.5 – 6 THz
- Front Ends - (0.5 – 1.5 THz):
  SIS mixers, multiplier LO /
  SIR = FFO + SIS + HM
  (1.5 – 6 THz) HEB mixers, QCL as LO
- System temperature < 1000 K
- IF bandwidth > 4 GHz (goal 8 GHz)

“Millimetron” – Russian Space Agency (> 2017)
12 m cryogenic mirror; λ = 0,01- 20 mm.





Ground-space interferometer

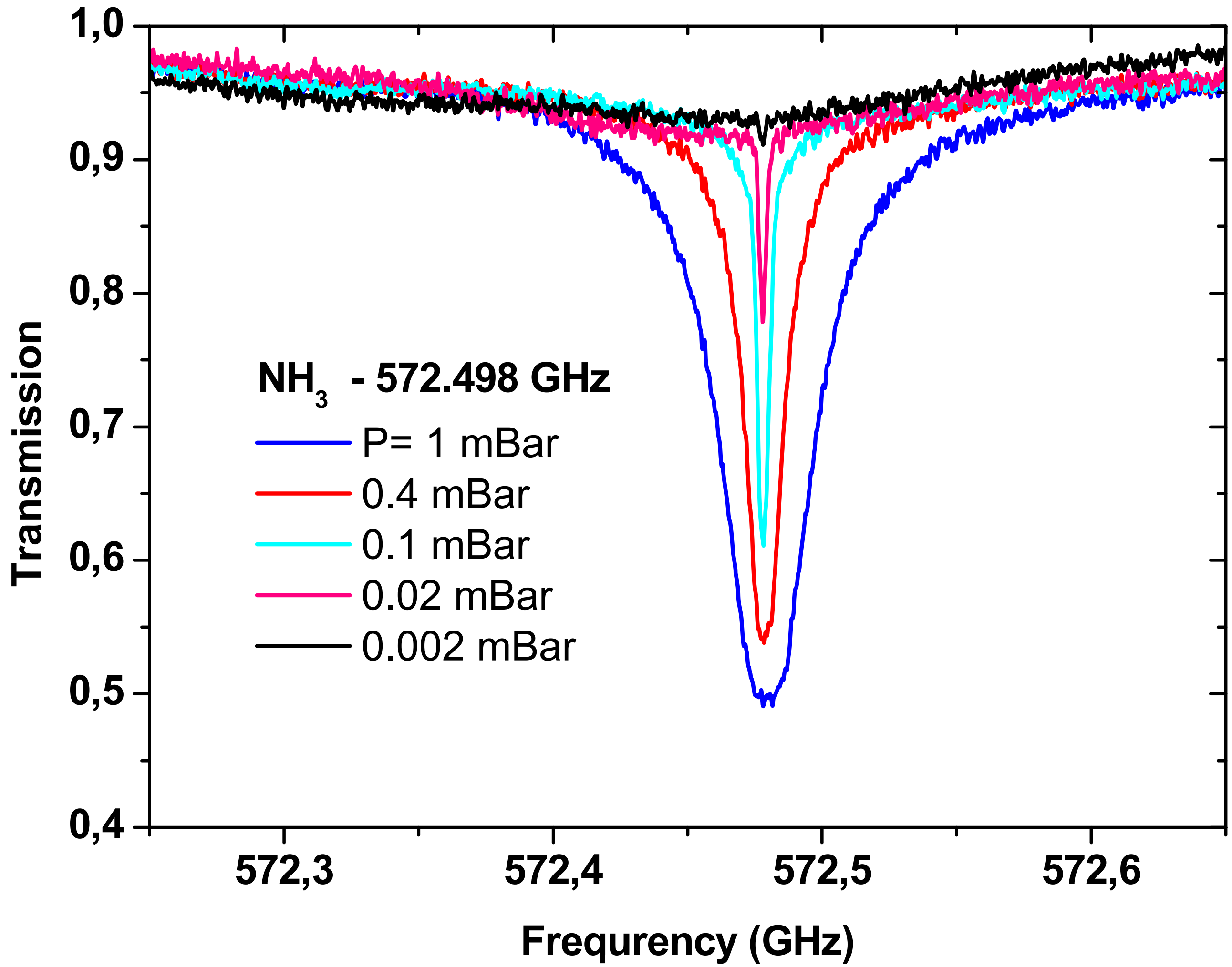
Medical applications

Non-invasive medical diagnostics based on analysis of exhaled air

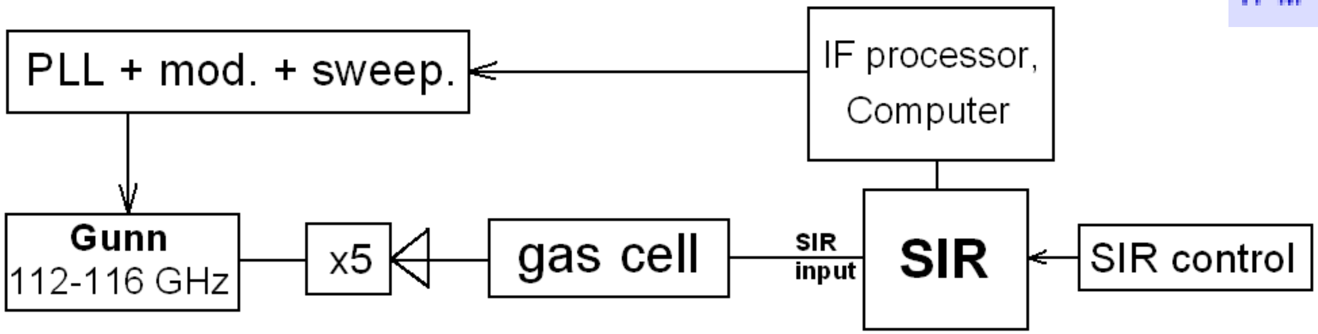
- human exhalation contains up to 600 volatile compounds
- some of them can be used as **markers of diseases**

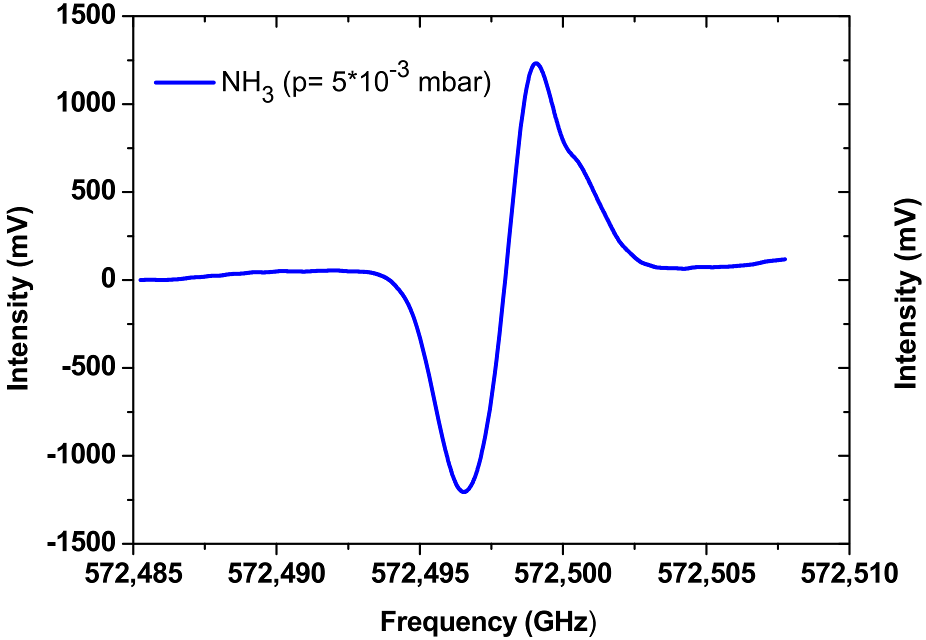
CO Blood disease, asthma, oxidative stress
NO Diseases of respiratory tract, oncology
NH_3 Diseases of gastro-enteric tract, liver, kidney
CH_4 Malabsorption of hydrocarbons
CS_2 Markers of coronary arteries diseases, schizophrenia
H_2O_2 Radiation injury, asthma

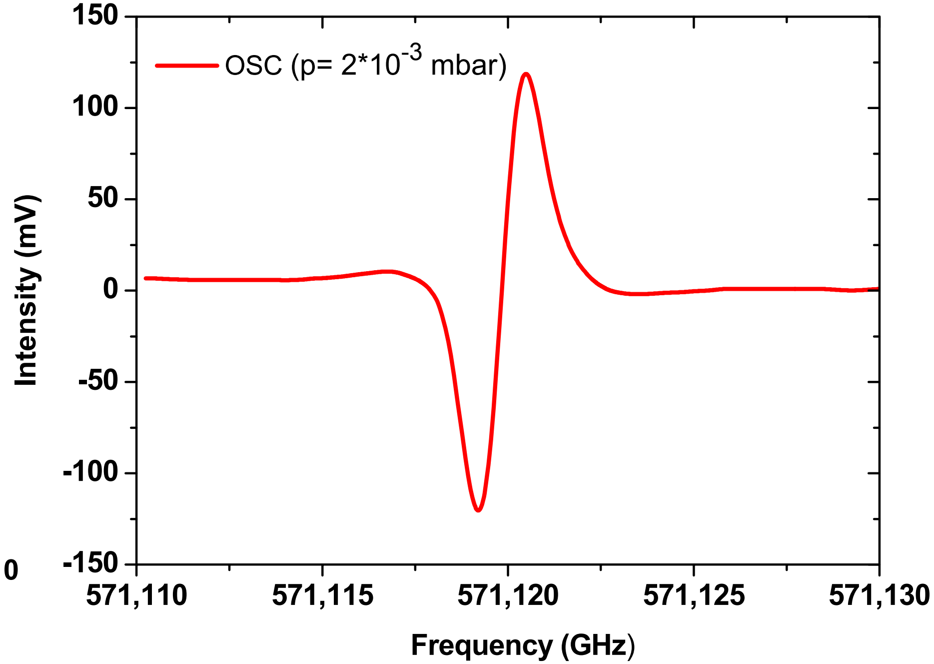
Gas Spectra Detection by FFTS



Gas Spectra Detection - 2







Conclusion

- Concept of the Phase-locked SIR is developed and proven.
- Nb-AlN-NbN FFOs and SIRs have been successfully implemented.
- New generation of the SIR with PL FFO for TELIS has been developed showing a possibility to achieve all TELIS requirements:
  Frequency range 500 – 650 GHz; Noise temperature < 150 K;
  IF bandwidth 4 - 8 GHz; Spectral resolution better 1 MHz;
  Beam Pattern - FWHM = 3 deg, with sidelobes < - 17 dB.
- Procedure for remote SIR operation has been developed and experimentally proven.
- TELIS flight has been completed in March 2009 (Kiruna, Sweden).
- Future space and ground-base missions are under consideration.
- SIR Technology is mature enough for both future space missions and non-invasive medical diagnostic.