Superconducting Integrated Submm Wave Receiver for Atmosphere Monitoring

Valery Koshelets, Pavel Dmitriev, Andrey Ermakov, Lyudmila Filippenko, Andrey Khudchenko, Nickolay Kinev, Oleg Kiselev, Alexander Sobolev, Mikhail Torgashin,

Kotel'nikov Institute of Radio Engineering and Electronics, Moscow, Russia

in collaboration with

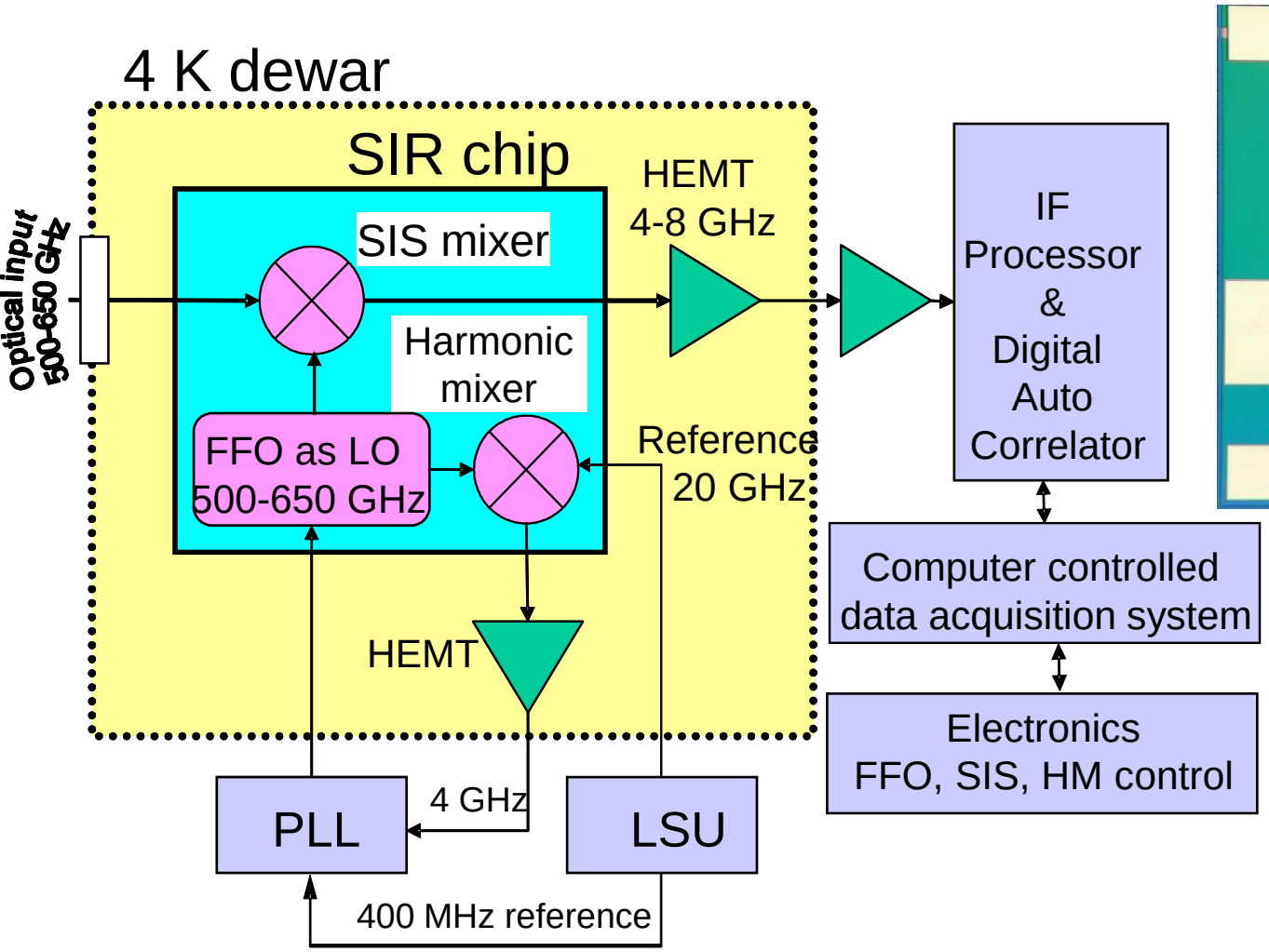
SRON Netherlands Institute for Space Research, the Netherlands

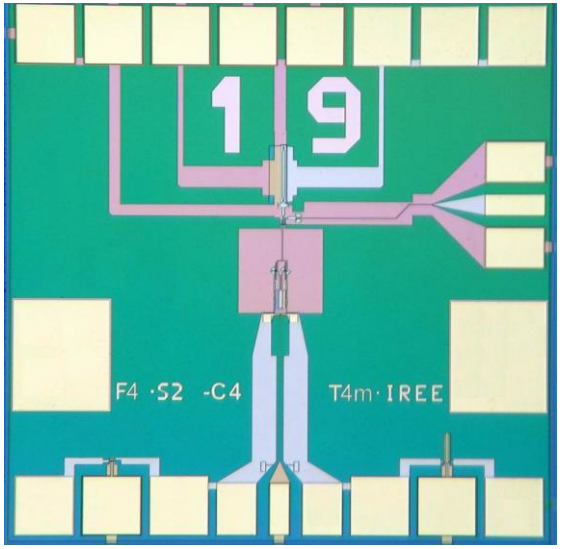
Superconducting Integrated Submm Wave Receiver for Atmosphere Monitoring

Outline

- Superconducting Integrated Receiver (SIR)
- Flux Flow Oscillator (FFO) for the SIR
- TErahertz LImb Sounder (TELIS) project
- TELIS SIR channel: design and performance
- First TELIS flight
- Future SIR applications
- Conclusion

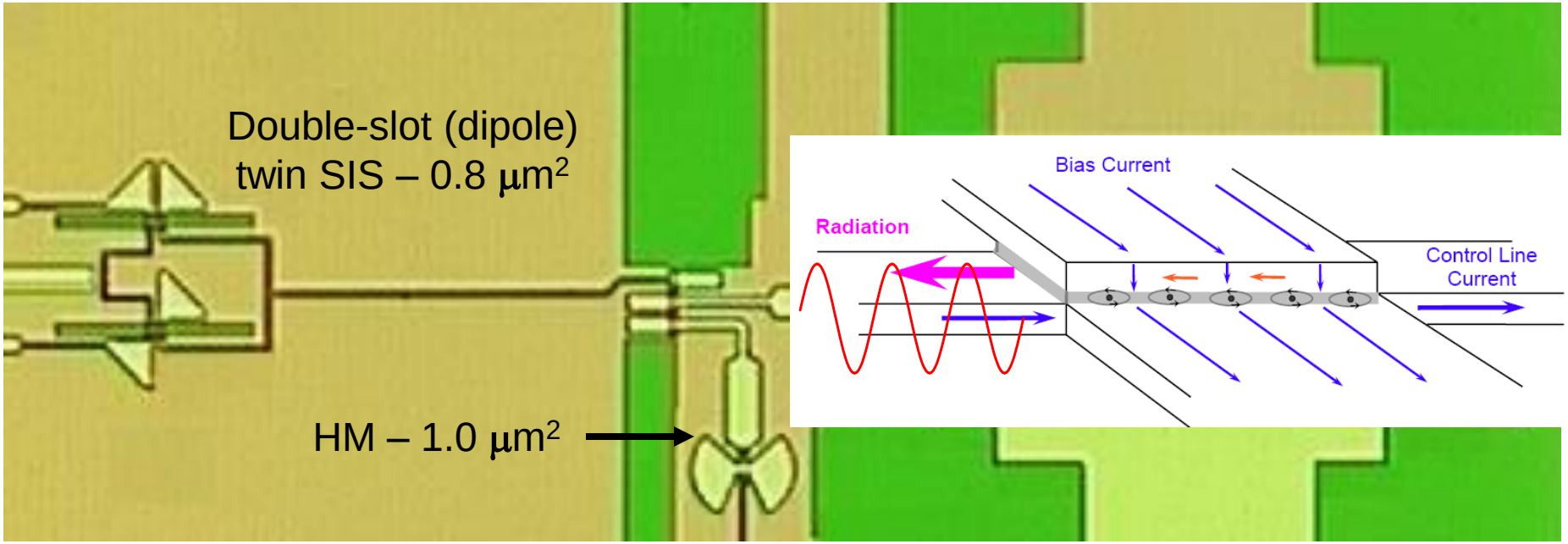
Superconducting Integrated Receiver (SIR) with phase-locked FFO





SIR microcircuit

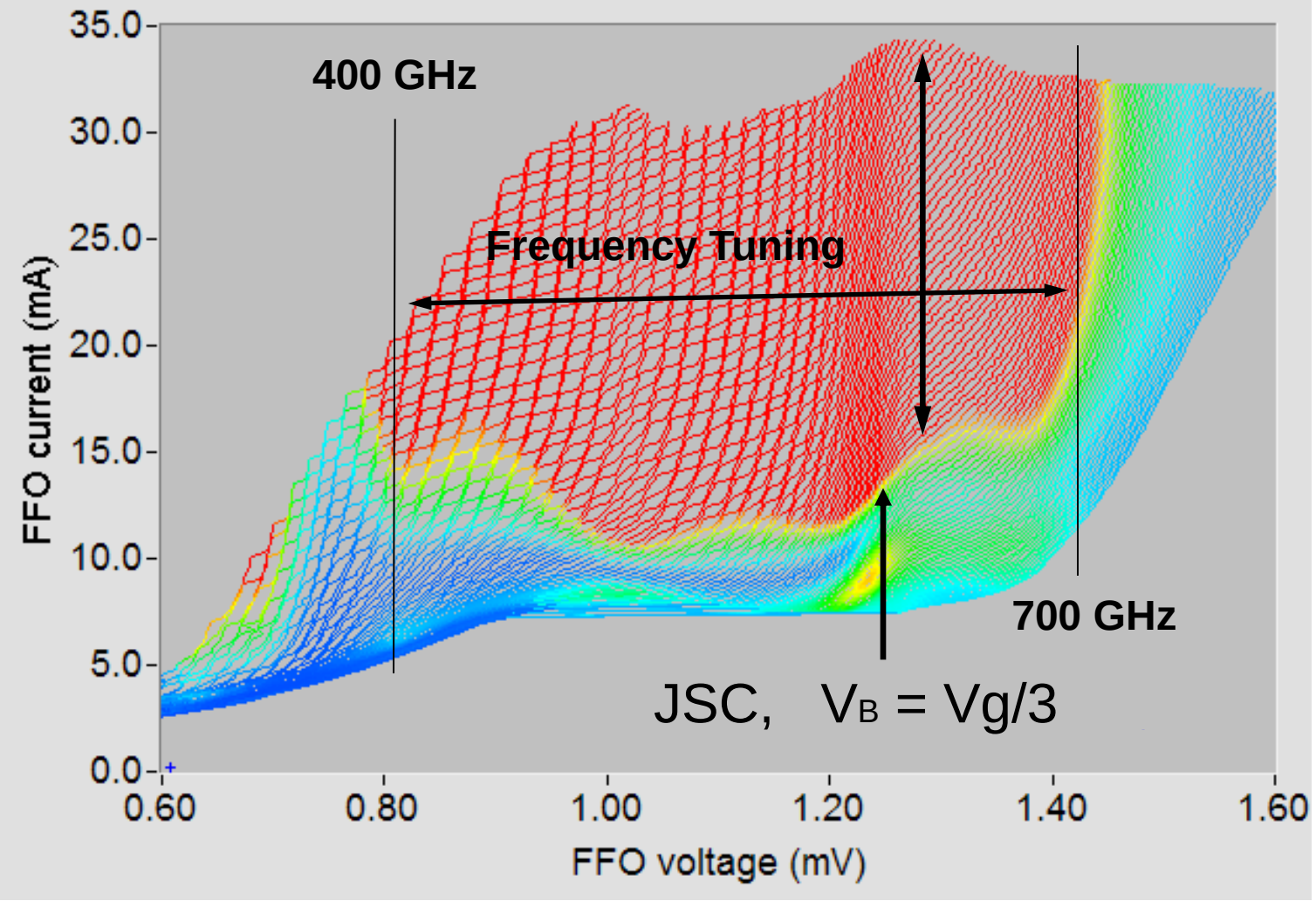
Internal part of the SIR Microcircuit



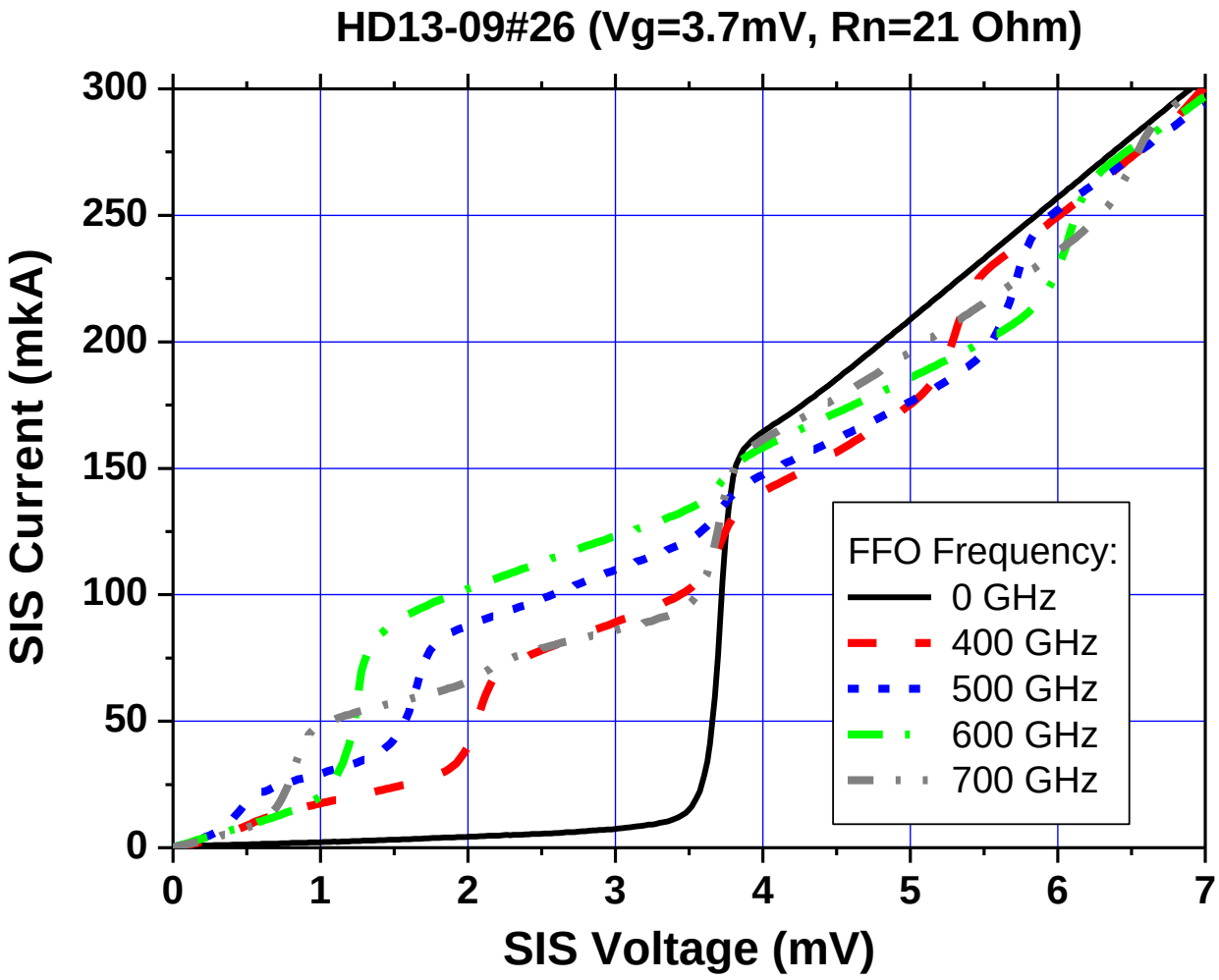
Nb-AlOx-Nb, Nb-AlN-NbN; Jc = 5 - 10 kA/cm²

Optionally: SIS – Jc = 8 kA/cm²; FFO + HM = 4 kA/cm²

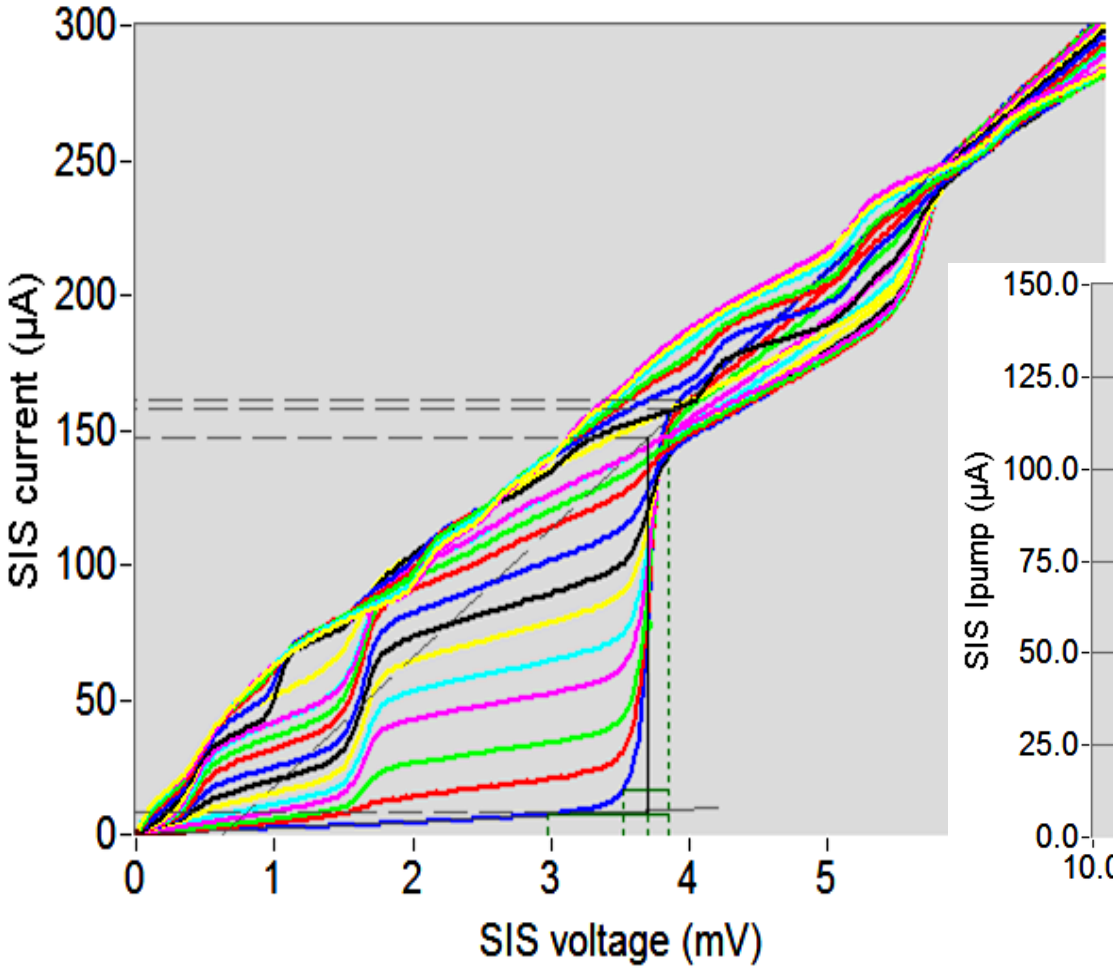
Nb-AlOx-Nb and Nb-AlN-NbN FFO for SIR

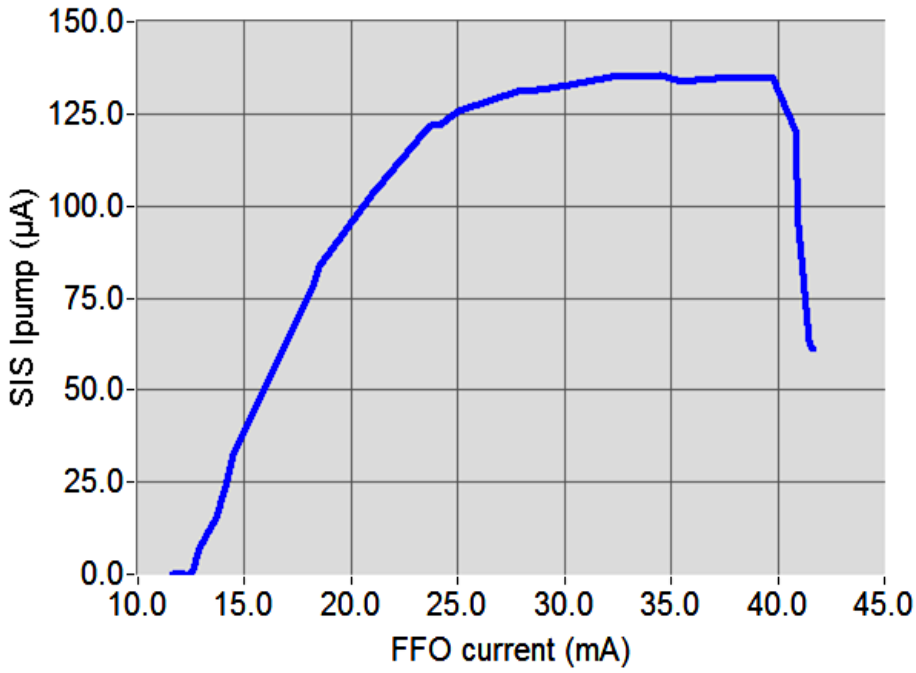


Nb-AlN-NbN SIS pumped by FFO; FFO frequency tuning

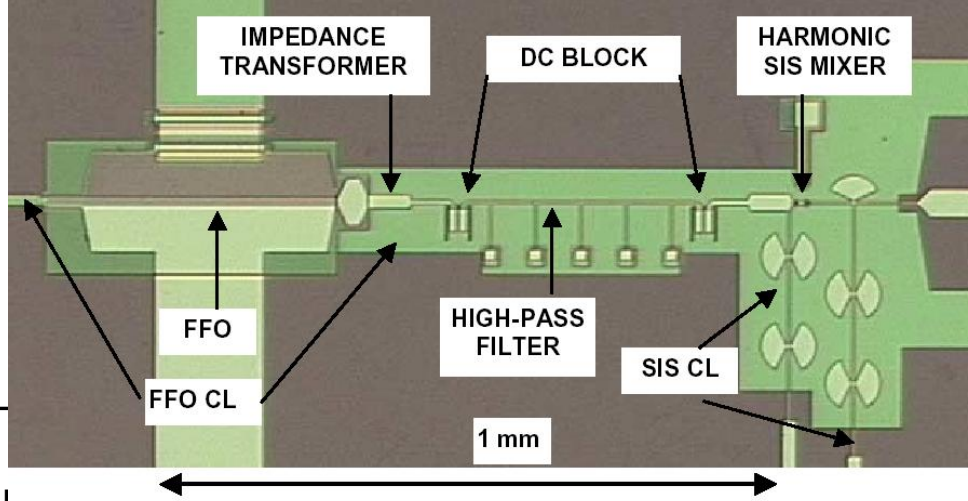


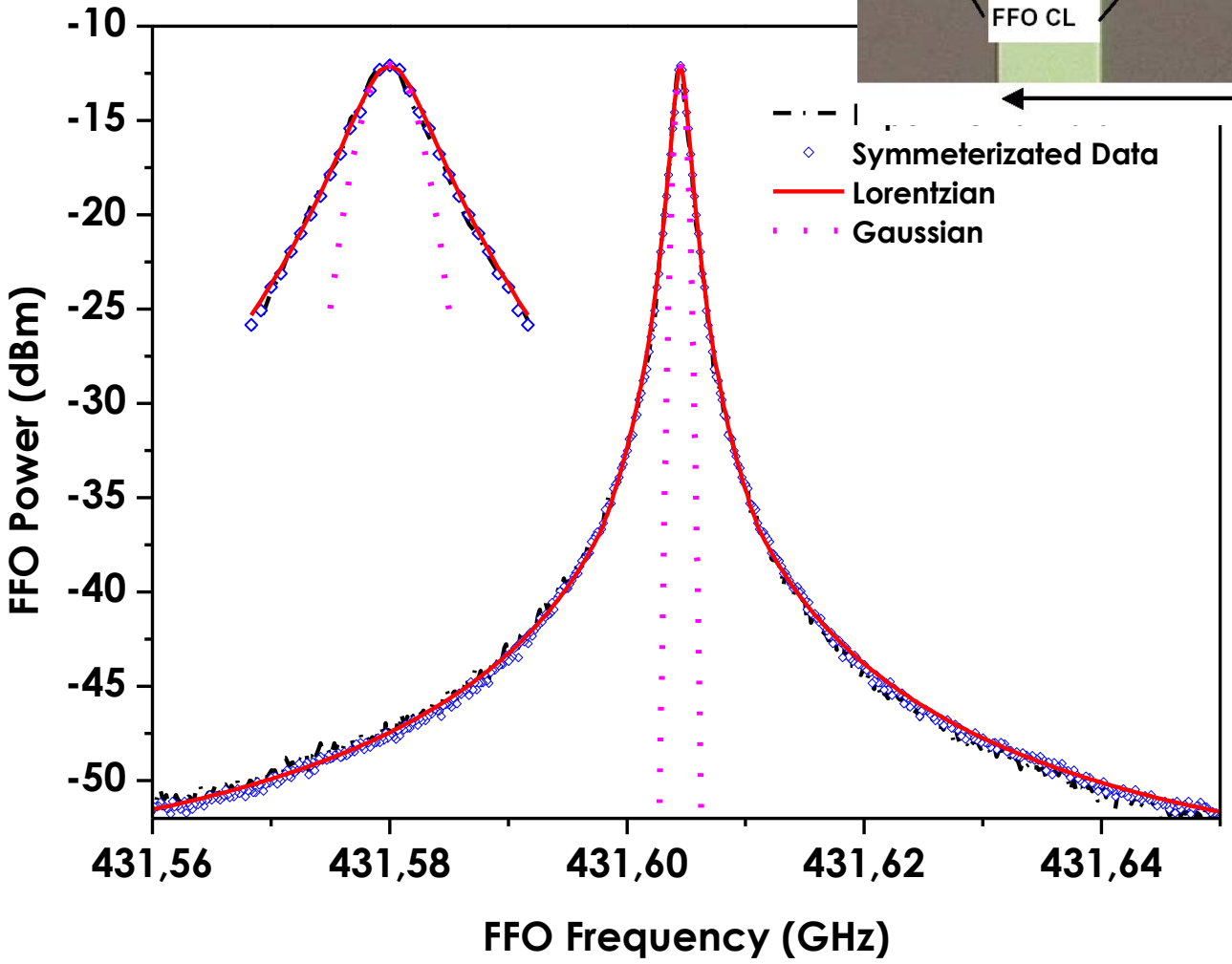
Nb-AlN-NbN SIS pumped by FFO; FFO power tuning (f = 500 GHz)



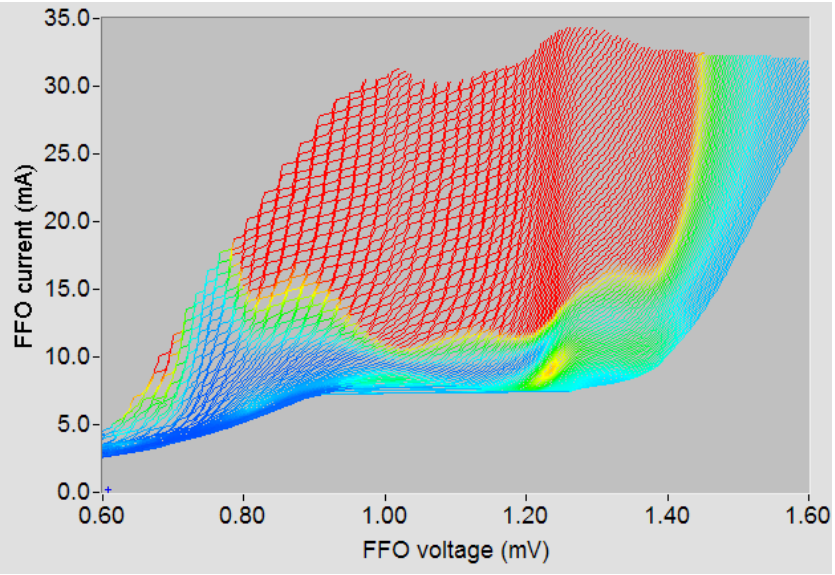


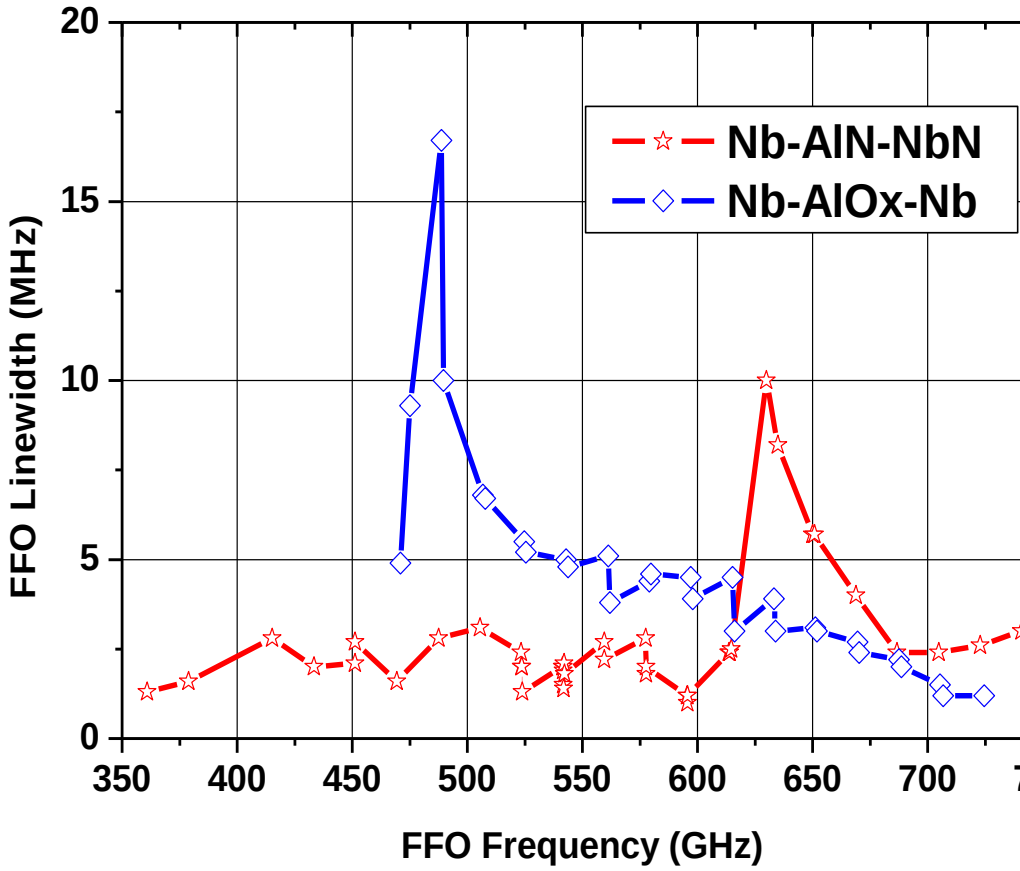
FFO Spectrum



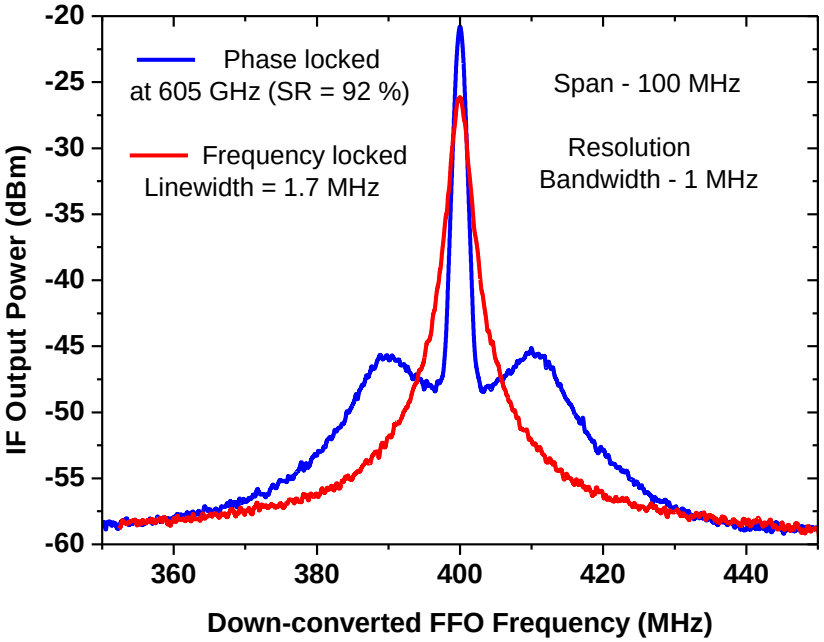


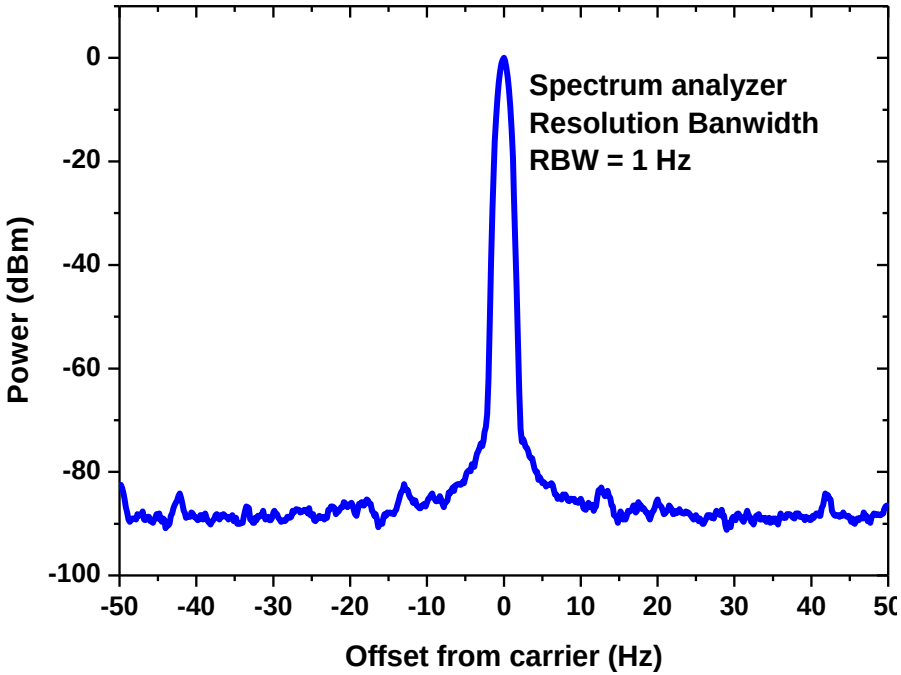
Frequency dependence of the FFO: Nb-AlOx-Nb and Nb-AlN-NbN circuits



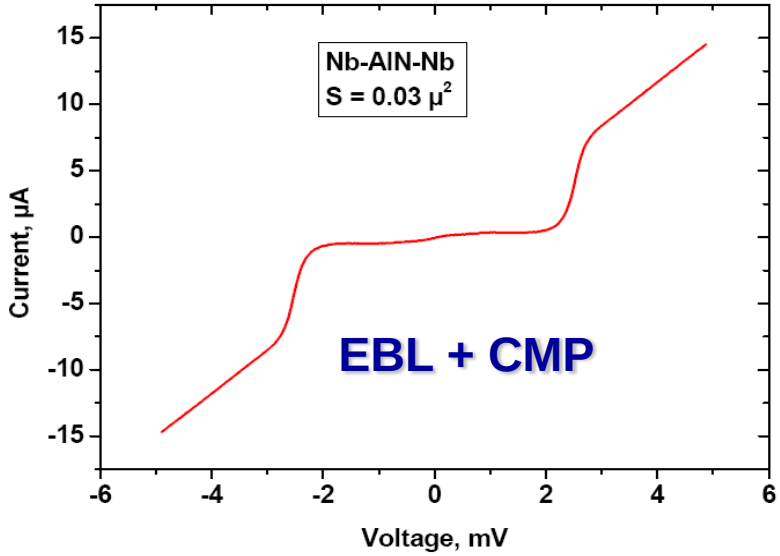


FL and PL spectra of the FFO :
frequency 605 GHz; LW = 1.7 MHz; SR = 92 %





Laboratory of Superconducting Devices for Signal Detection and Processing

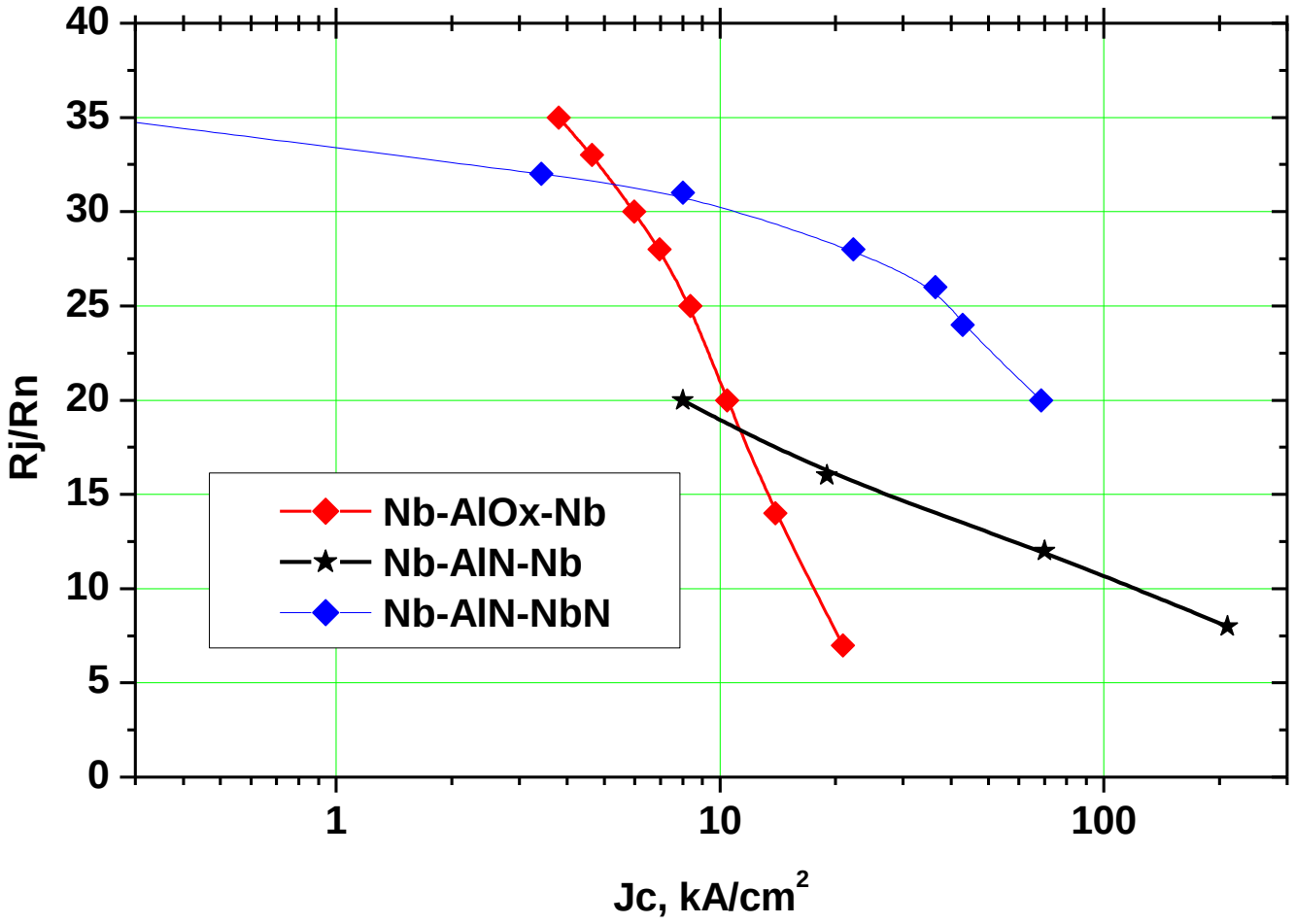


Nb-AlN-NbN
Nb-AlOx-Nb;

J_c = 1 - 100 kA/cm²

S = 0.1 – 1000 mkm²

Quality of the AlOx and AlN tunnel barriers on the current density



Development of the Integrated Spectrometer for TELIS (TErahertz LImb Sounder)

Valery Koshelets, Lyudmila Filippenko, Pavel Dmitriev, Andrey Ermakov, Andrey Khudchenko, Nickolay Kinev, Oleg Kiselev, Alexander Sobolev, Mikhail Torgashin,

Kotel'nikov Institute of Radio Engineering and Electronics, Moscow, Russia

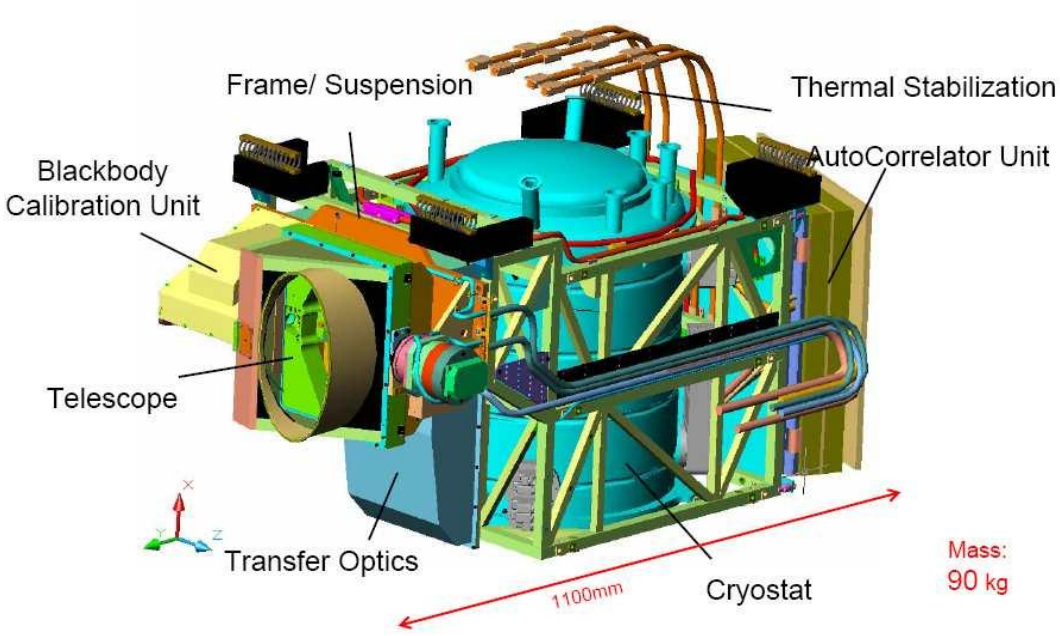
Pavel Yagoubov, Gert de Lange, Hans Golstein, Leo de Jong, Arno de Lange, Bart van Kuik, Ed de Vries, Johaness Dercksen, Ruud Hoogeveen, Avri Seleg

SRON Netherlands Institute for Space Research, the Netherlands

Nopporn Suttiwong, Georg Wagner, Manfred Birk (PI)

Institute for Remote Sensing Technology, DLR, Germany

TELIS (Terahertz Limb Sounder)

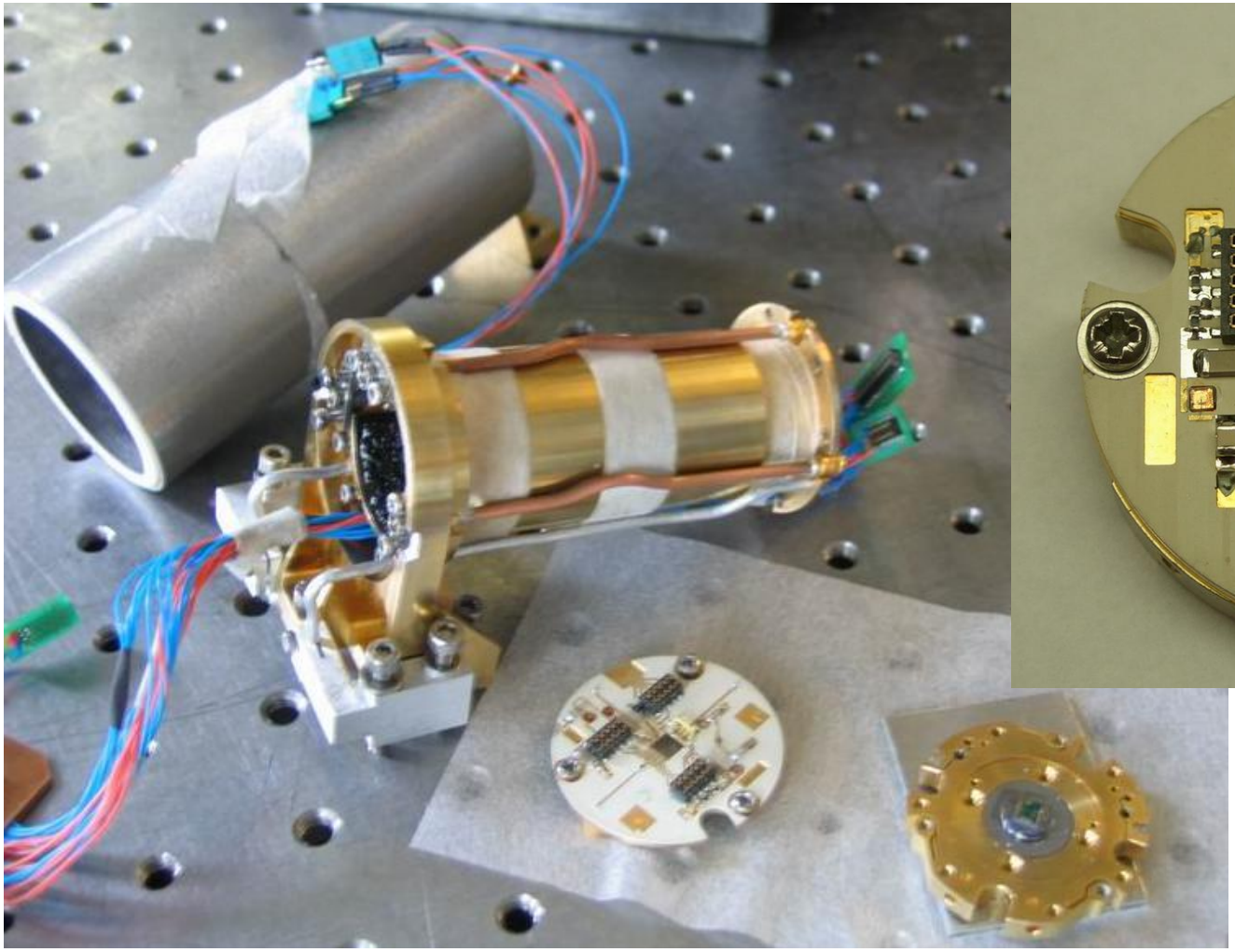


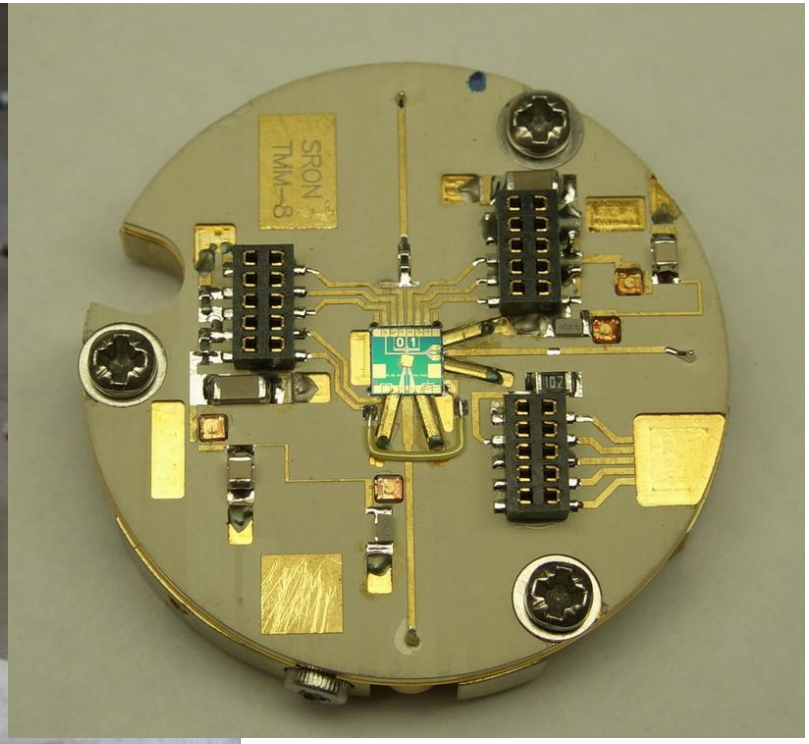
Balloon-Borne TELIS Instrument

TELIS Objectives:

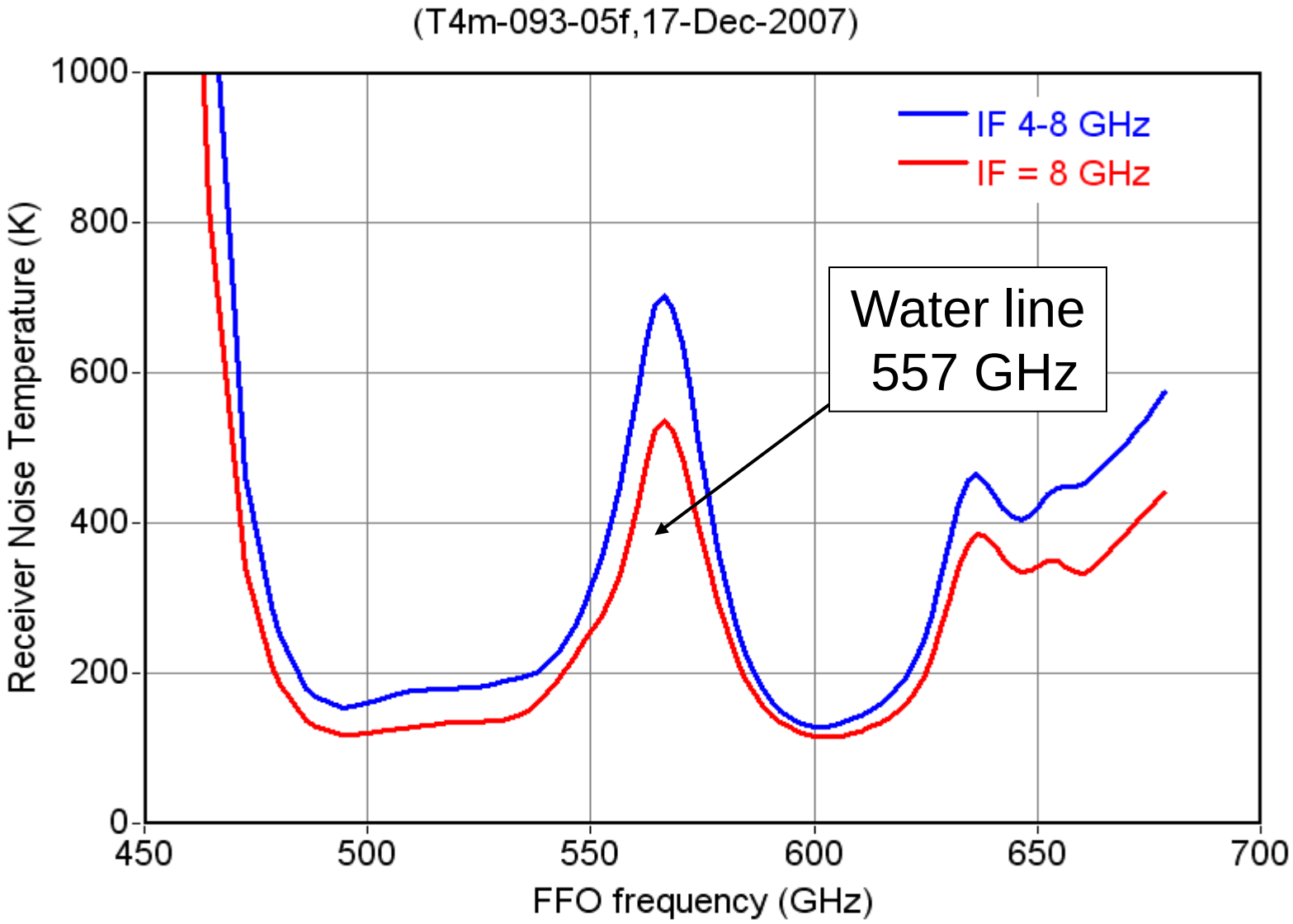
- Measure many species for atmospheric science:
  ClO, BrO, O_3, HCl, HOCl, etc;
  - Chemistry, Transport, Climate
- Serve as a test platform for new sensors
- Serve as validation tool for future satellite missions
- Three independent frequency channels, cryogenic heterodyne receivers:
  - 500 GHz by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

SIR Mixer Block with Shields

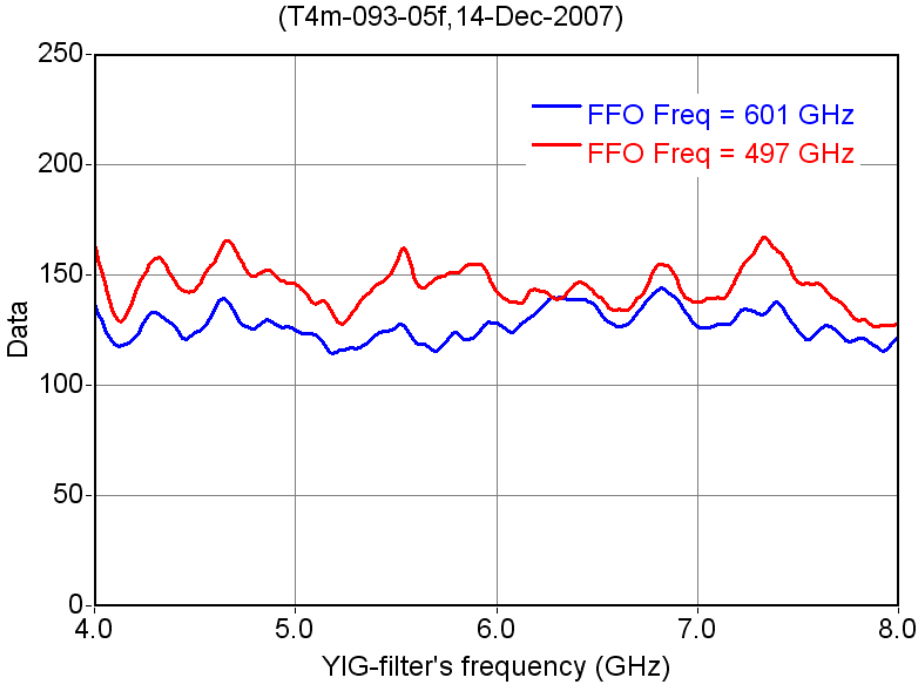


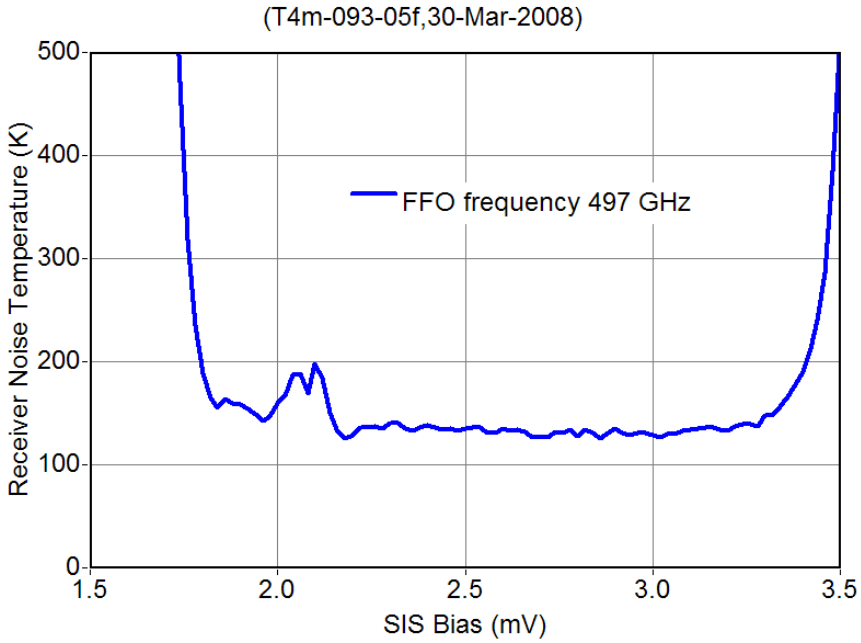


Noise Temperature of the Flight SIR (DSB)



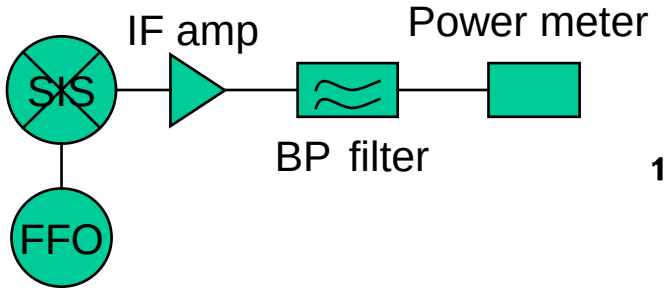
SIR Noise Temperature on Intermediate Frequency and SIS Bias

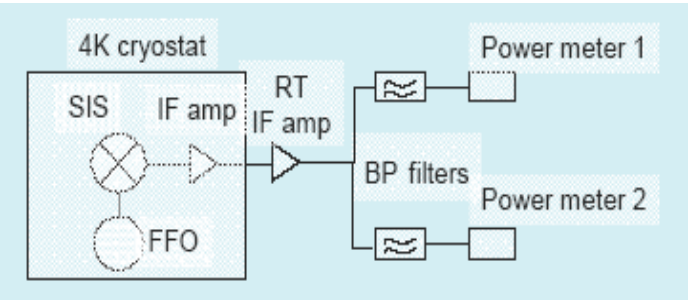


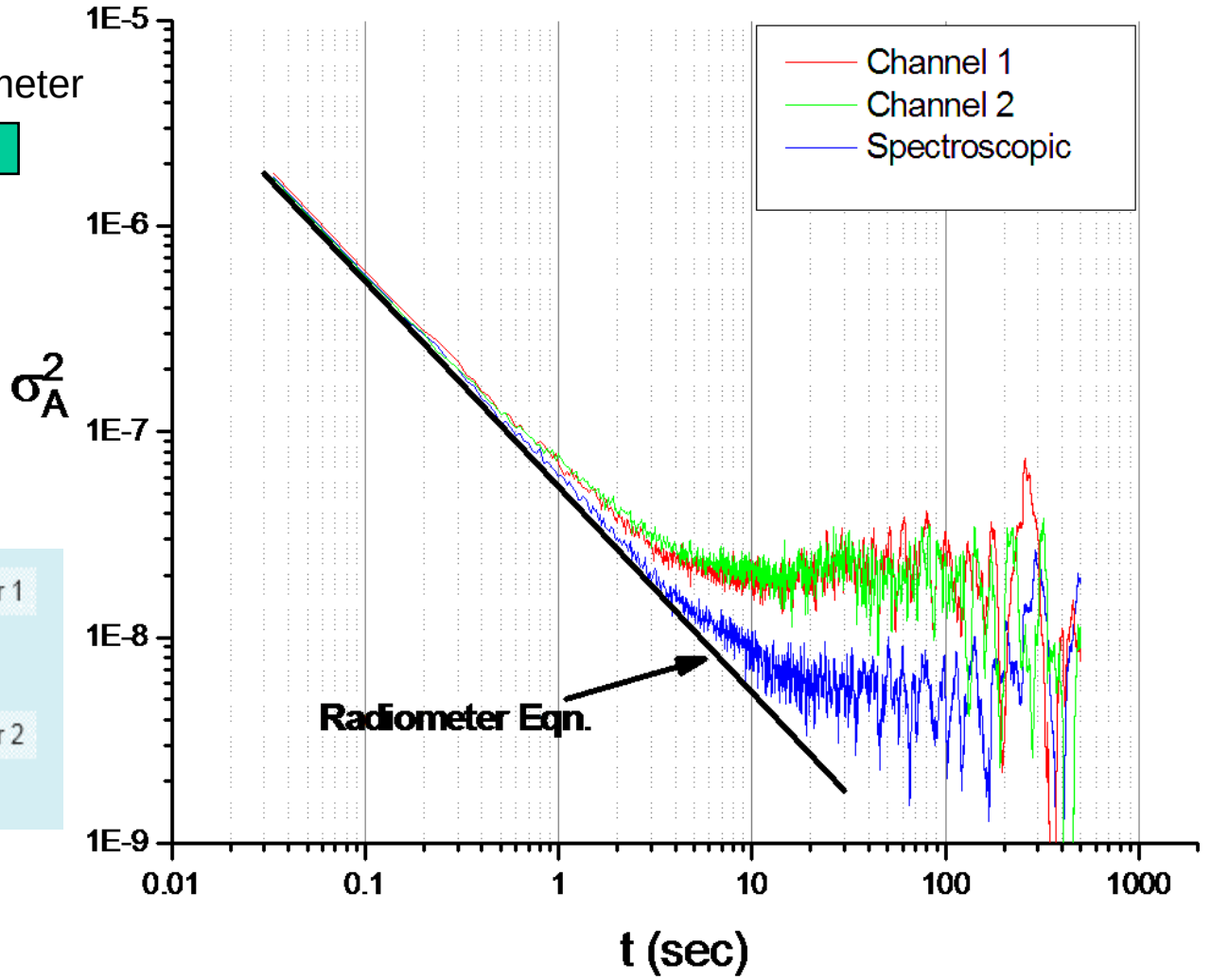


SIR Stability: Allan variance test

SRON
Netherlands Institute for Space Research

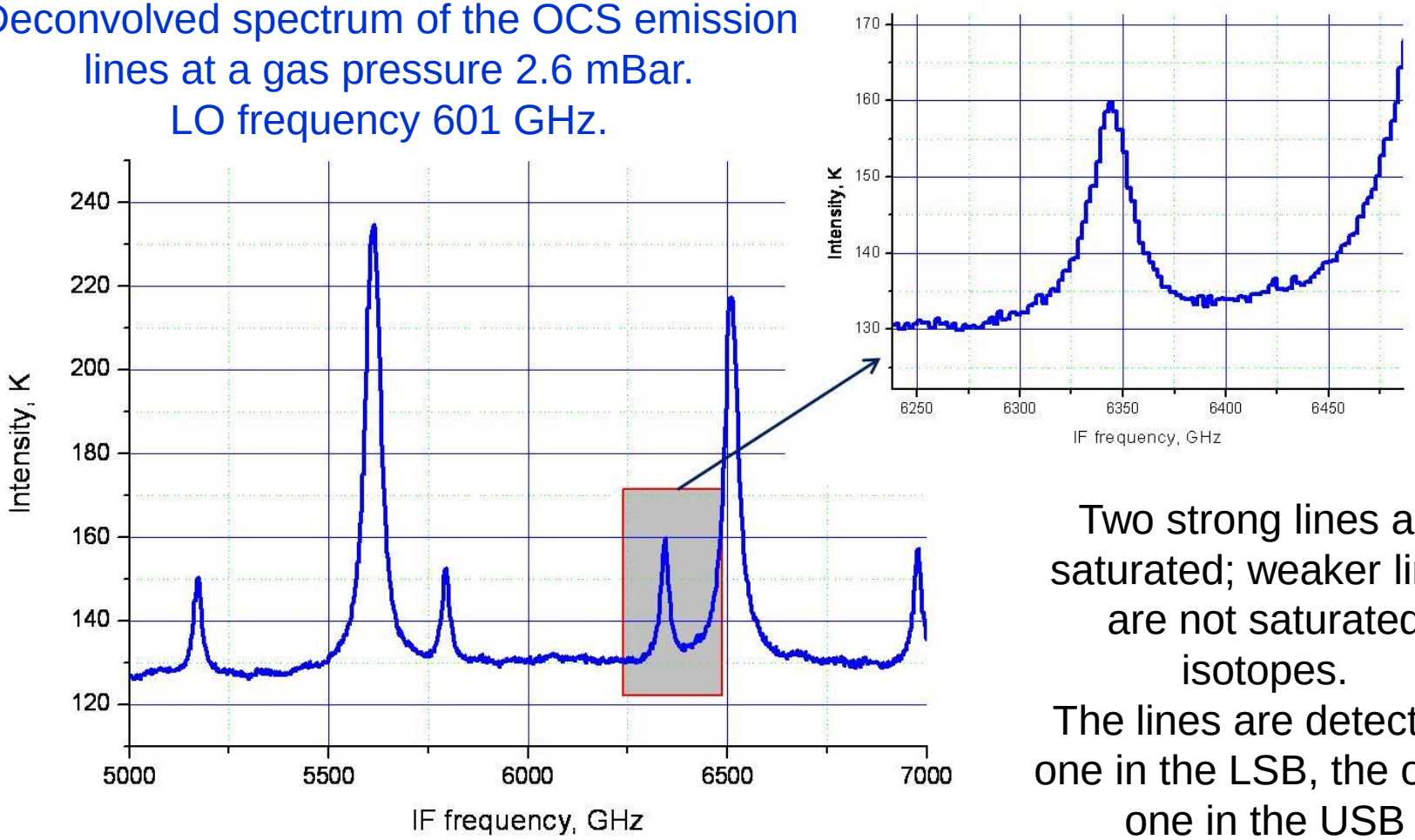






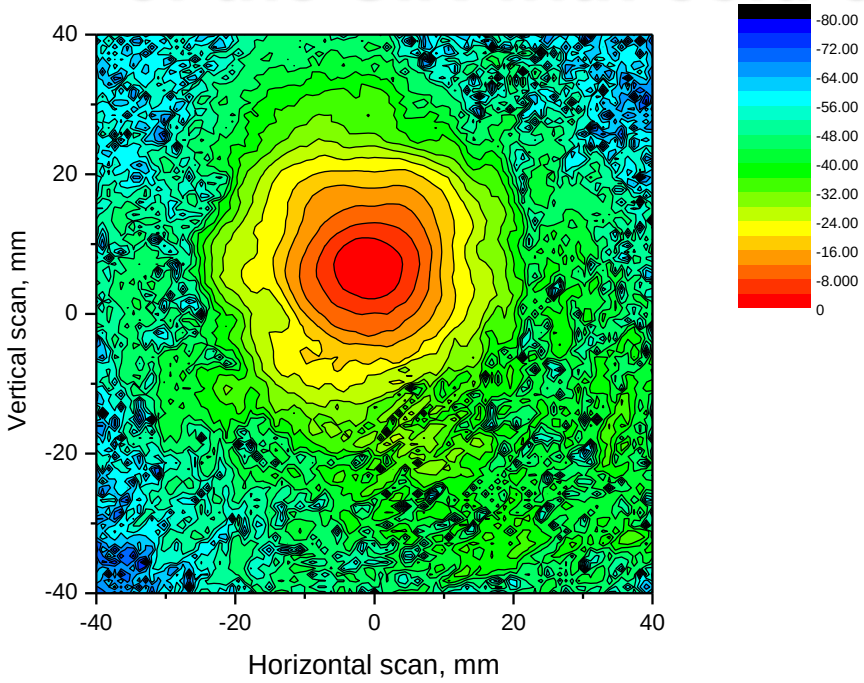
SIR Spectral Resolution

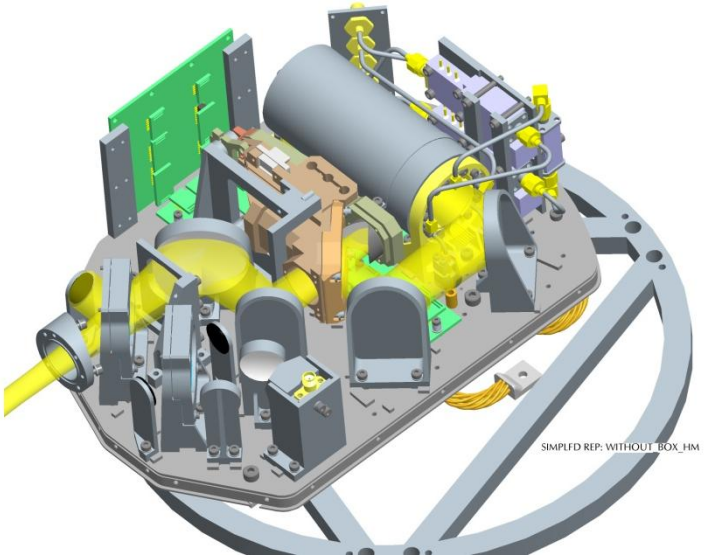
Deconvolved spectrum of the OCS emission lines at a gas pressure 2.6 mBar.
LO frequency 601 GHz.



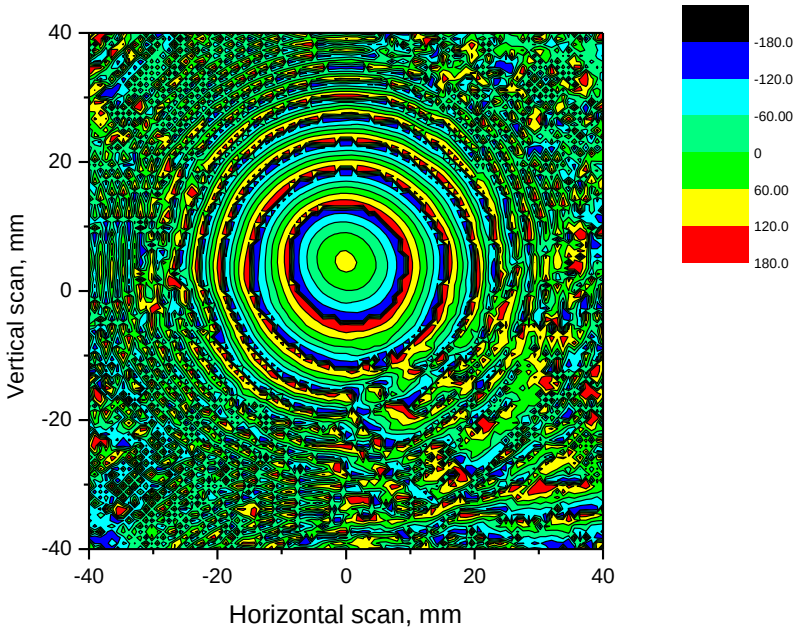
Two strong lines are saturated; weaker lines are not saturated isotopes.
The lines are detected, one in the LSB, the other one in the USB

Amplitude and phase APB of the SIR with cold optics





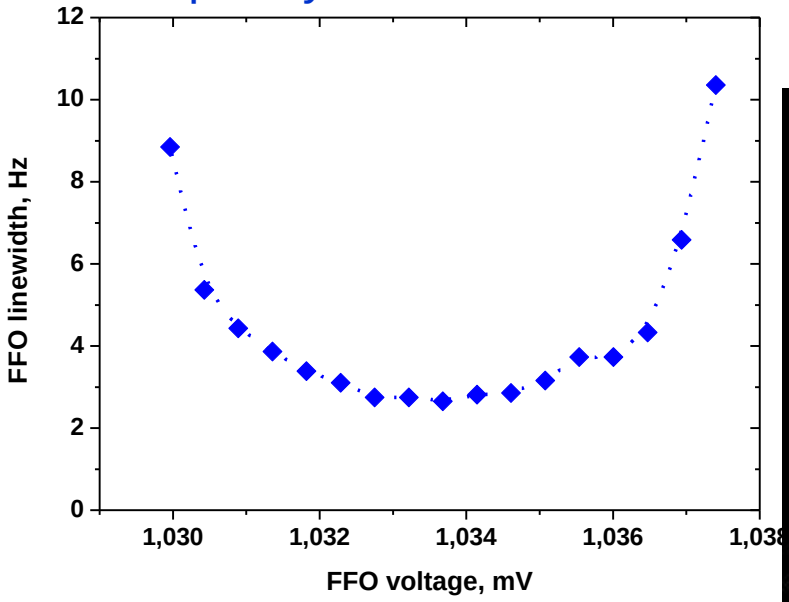
Amplitude

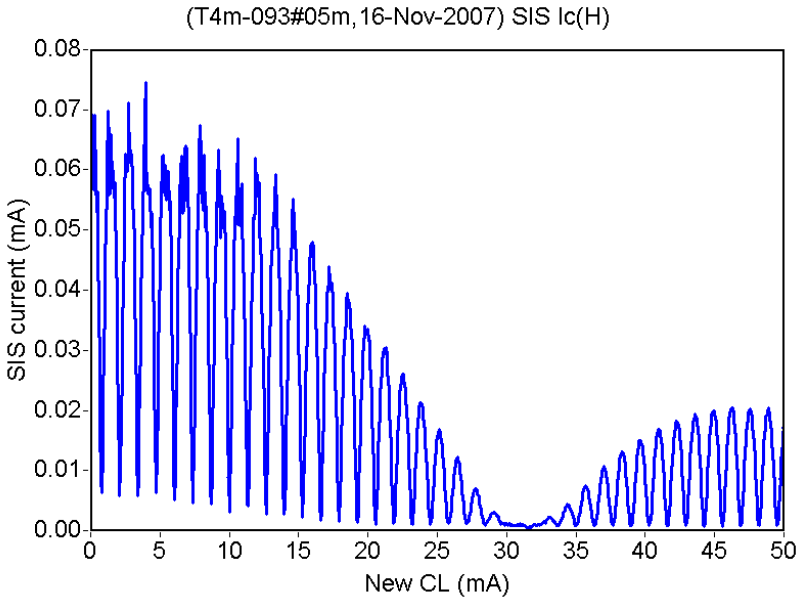


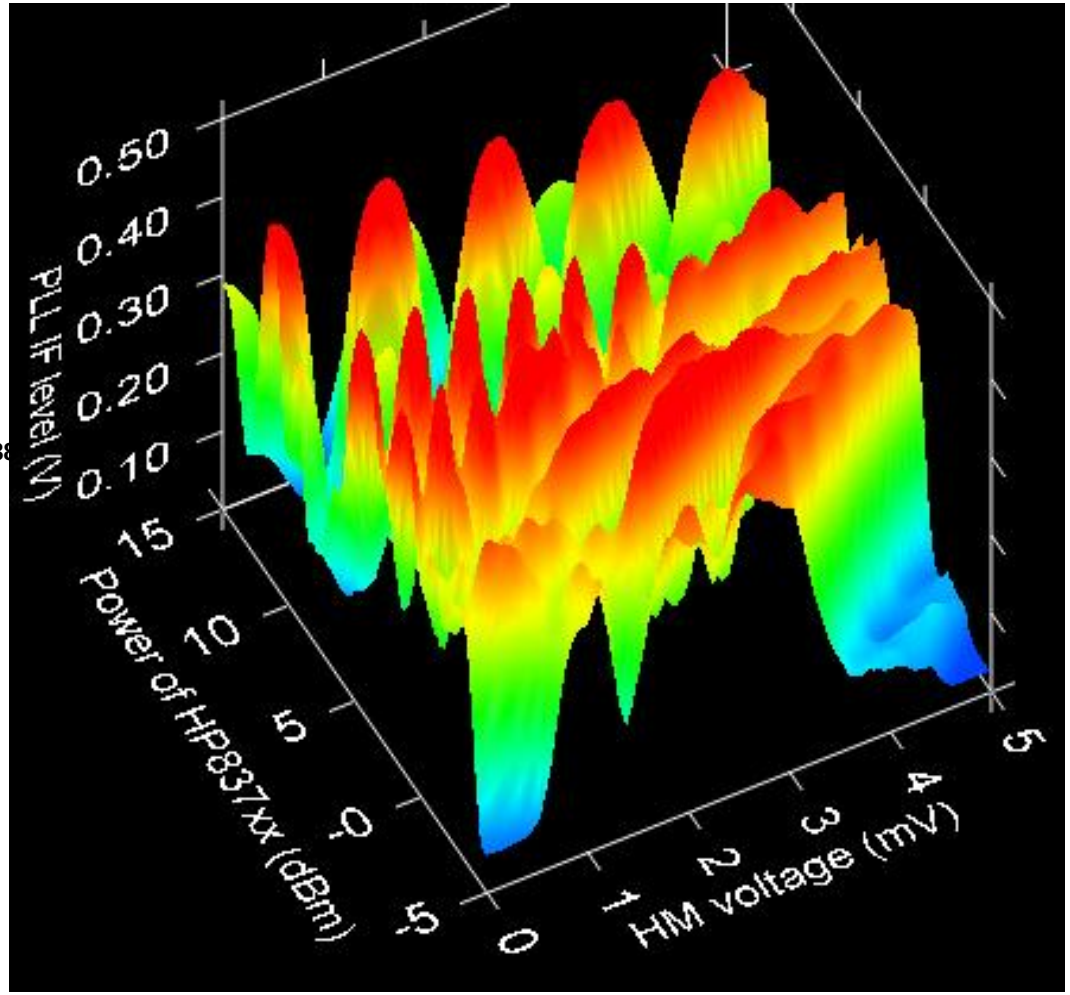
Phase

SIR for TELIS – remote operation

FFO frequency of about 500 GHz





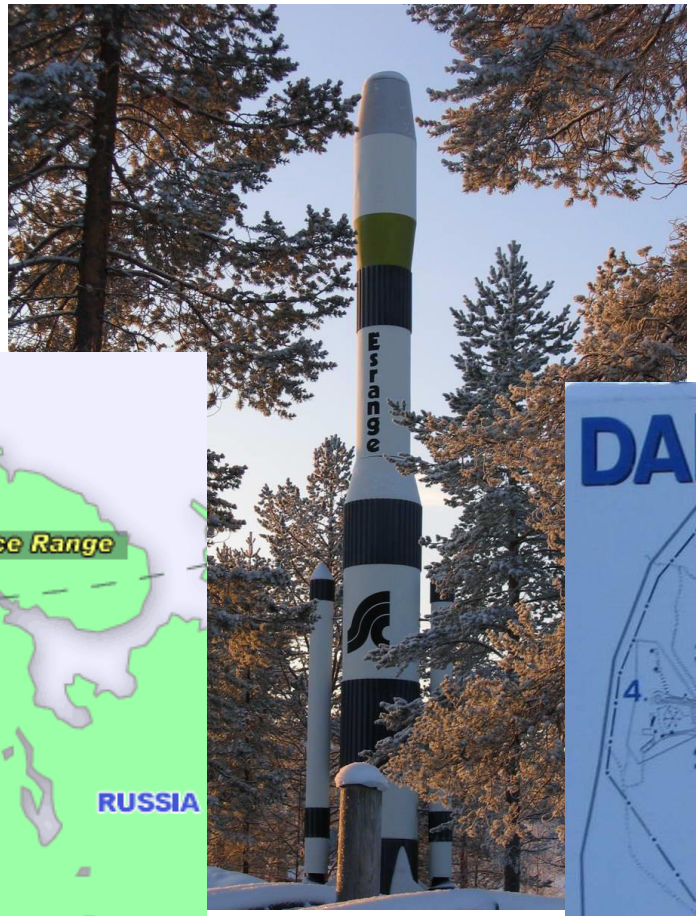


TELIS-SIR Main Parameters

(parameters determined by digital correlator are in parentheses)

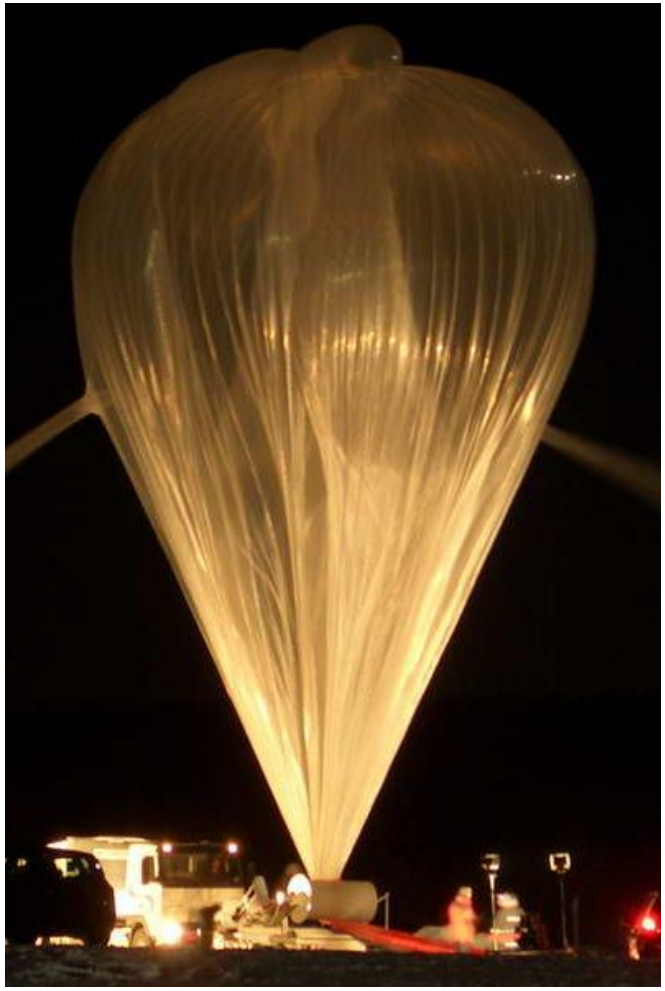
Input frequency range, GHz	**500 – 650 ГГц**
Minimum noise temperature in the range (DSB), K	**120 К**
Output IF range, GHz	**4-8 (5-7) ГГц**
Spectral resolution, MHz	**< 1 (2) МГц**
LO frequency net, MHz	**< 300 МГц**
Dissipated power at 4.2 K stage, mW	**< 30 мВт**
Operation temperature, K	**< 4.5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

Esrange Space Center , Kiruna, Sweden, 67.5°N, 21.1°E; March 2009



Swedish Space Corporation

TELIS (Terahertz Limb Sounder)



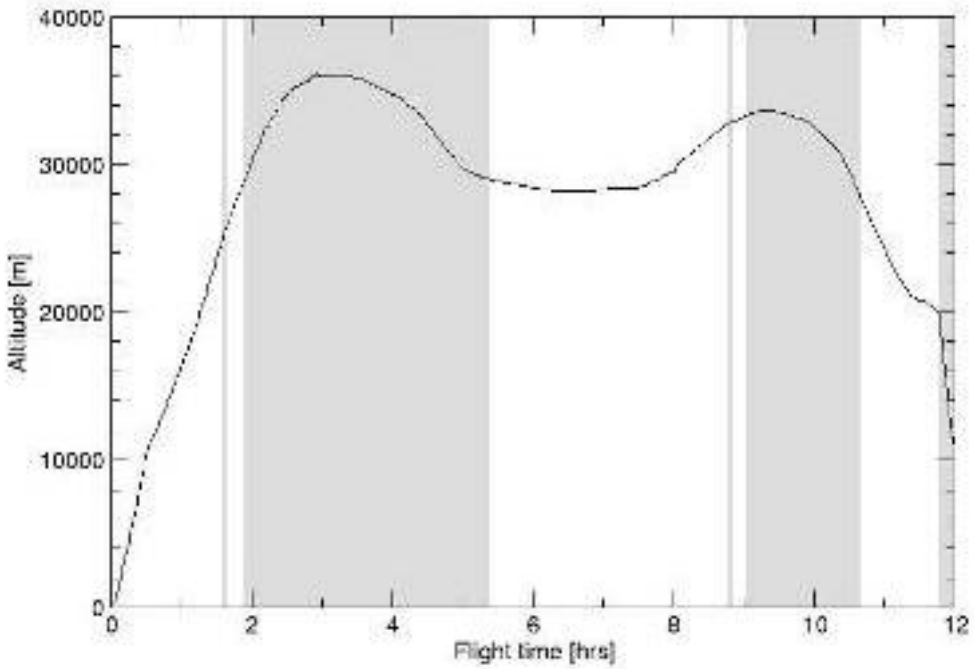
TELIS-MIPAS at Esrange, Sweden; March 2009

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

Altitude: 40 km (max); Duration: 12 hours

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

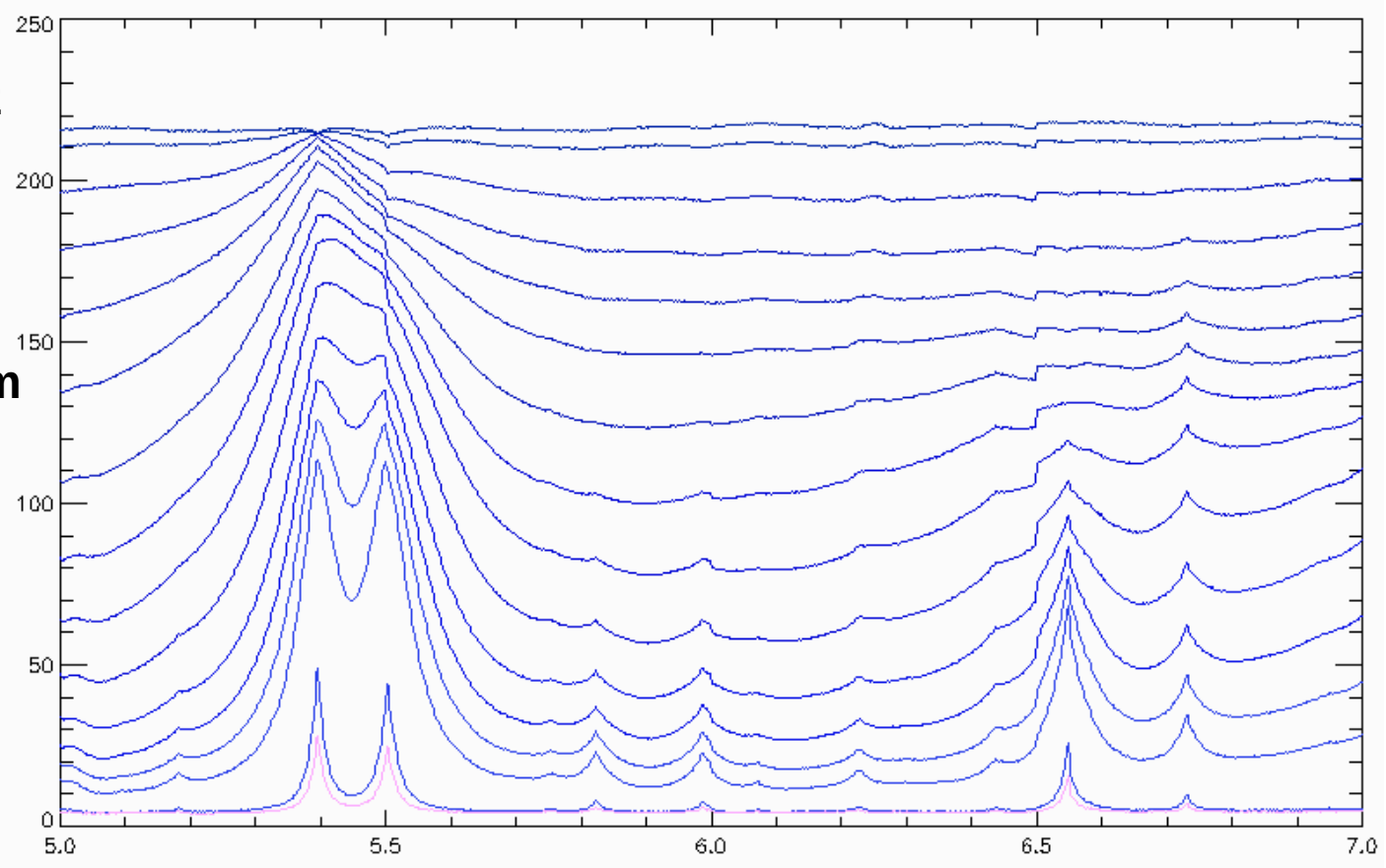
FFO Freq = 495 GHz

Orbit – 30 km;

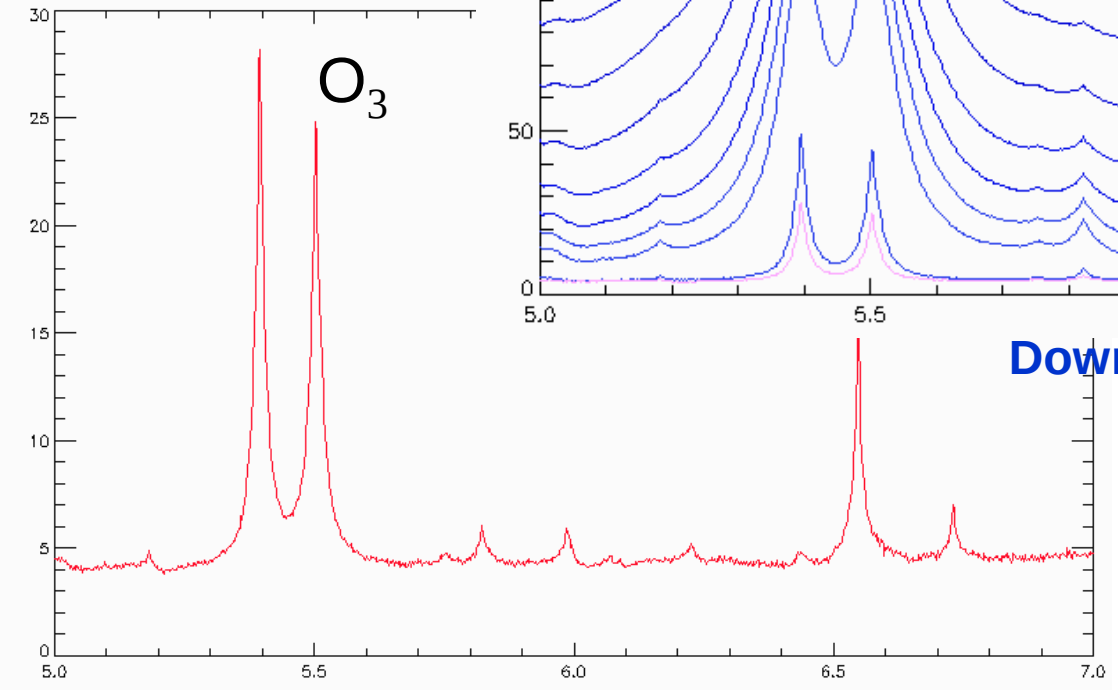
Increment – 1.5 km,

Tangent: 10.5 – 30 km

45 degrees up

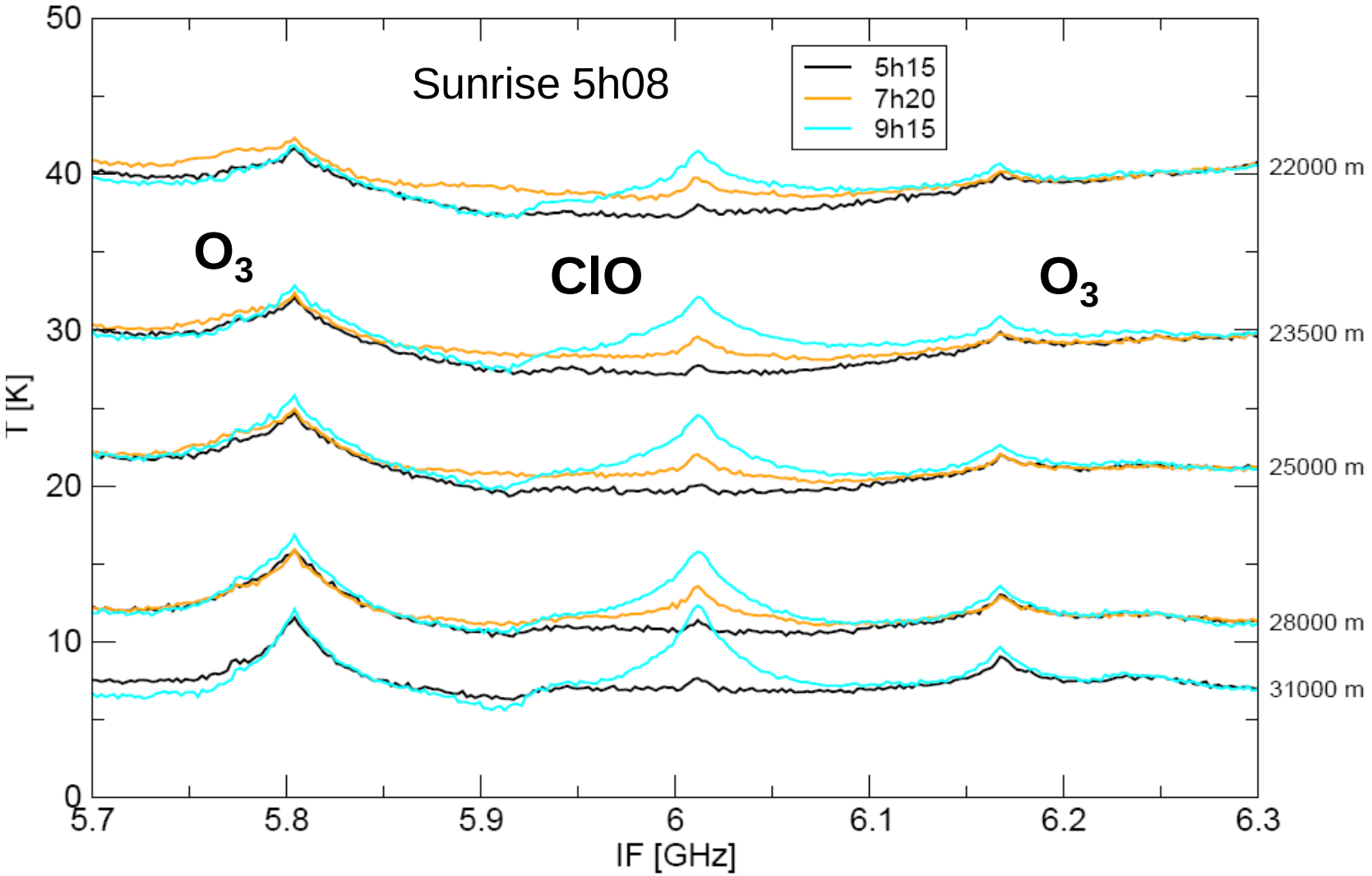


Down-converted Frequency, GHz



Down-converted Frequency, GHz

ClO line over time (FFO = 495 GHz)



Back to the Earth…

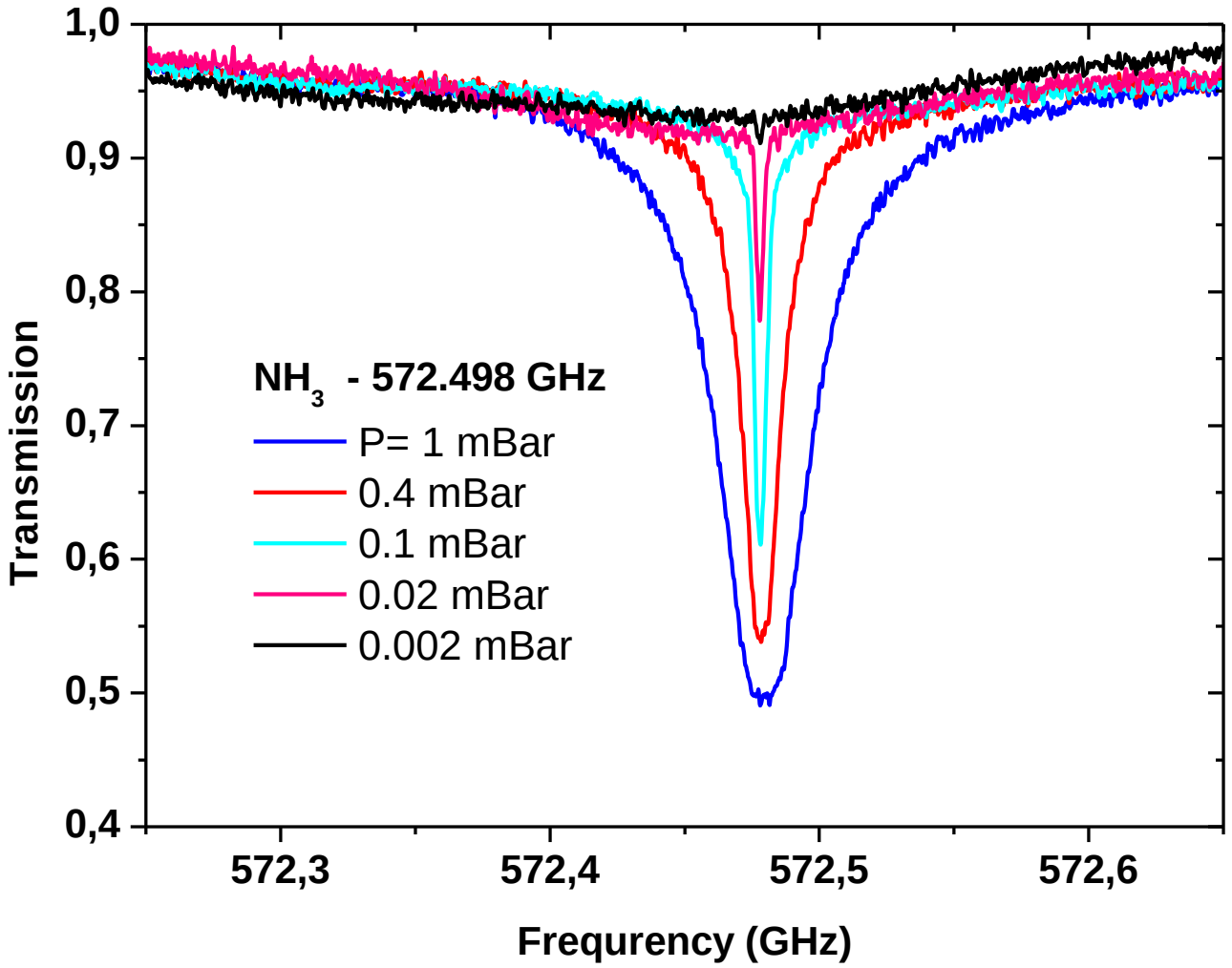
Medical applications

Non-invasive medical diagnostics based on analysis of exhaled air

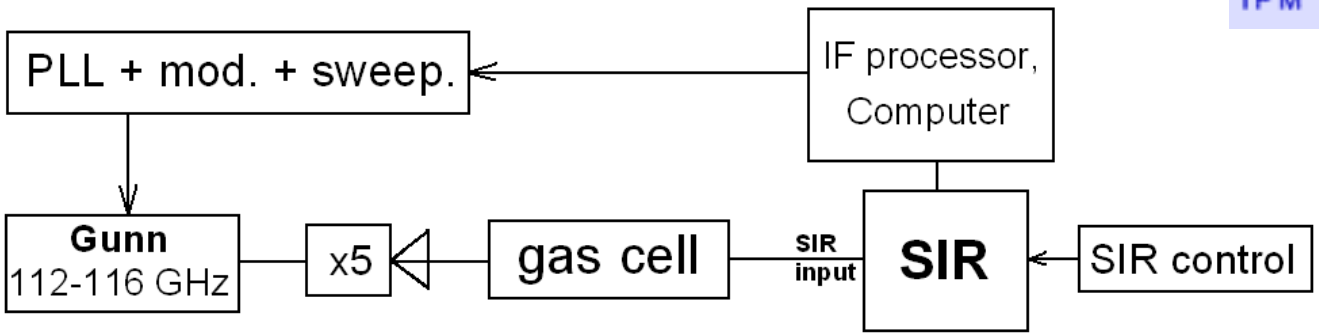
- human exhalation contains up to 600 volatile compounds
- some of them can be used as **markers of diseases**

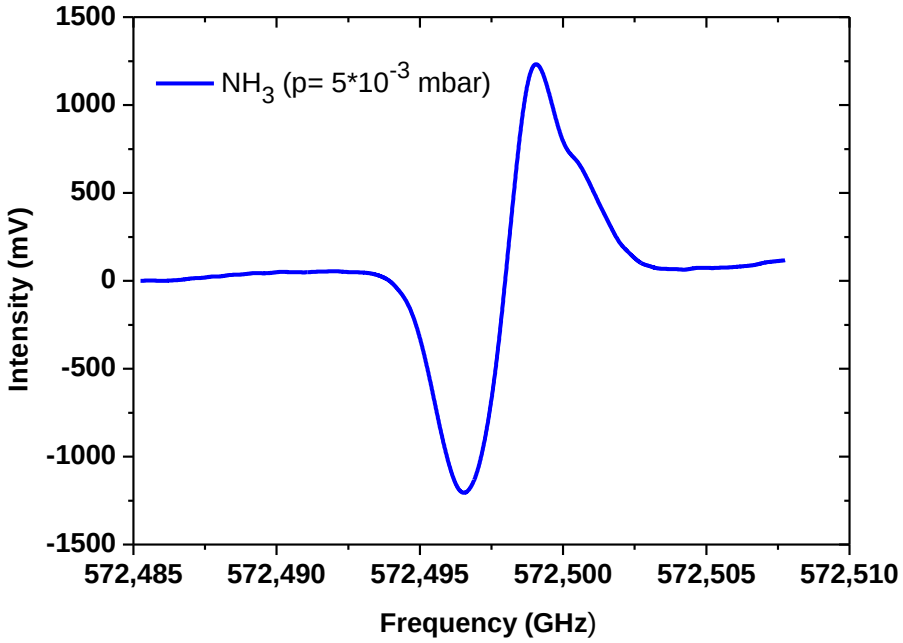
CO	Blood disease, asthma, oxidative stress
NO	Diseases of respiratory tract, oncology
NH_3	Diseases of gastro-enteric tract, liver, kidney
CH_4	Malabsorption of hydrocarbons
CS_2	Markers of coronary arteries diseases, schizophrenia
H_2O_2	Radiation injury, asthma

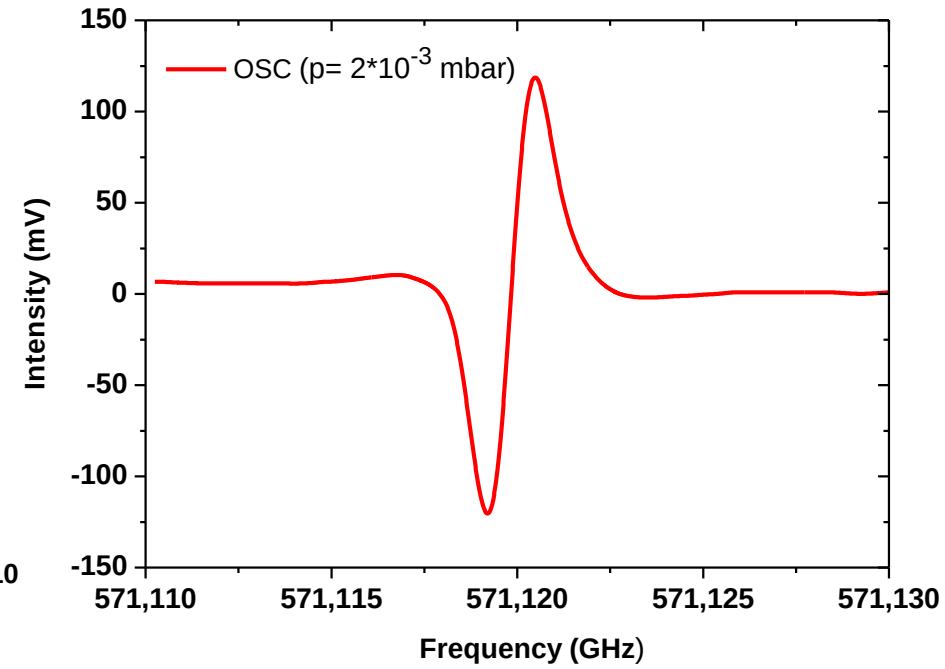
Gas Spectra Detection by FFTS



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 real applications:
  atmosphere monitoring, non-invasive medical diagnostic, etc.