Superconducting Integrated THz Receivers: Development and Applications

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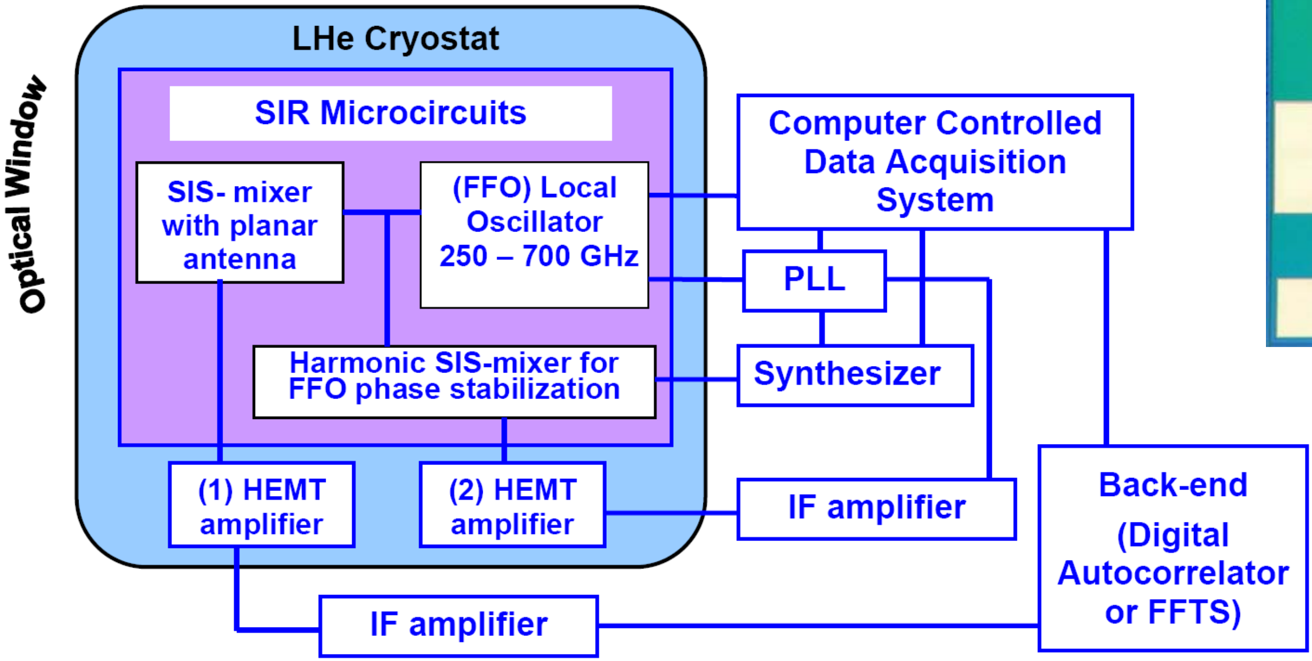
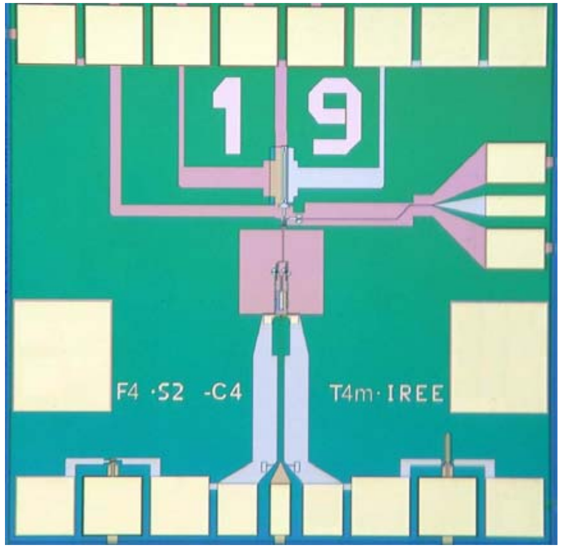
Superconducting Integrated THz Receivers: Development and Applications

Outline

- Superconducting Integrated Receiver (SIR)
- Flux Flow Oscillator (FFO) for the SIR
- TErahertz LImb Sounder (TELIS) project
- Results of the TELIS flights
- Future SIR applications
- Conclusion

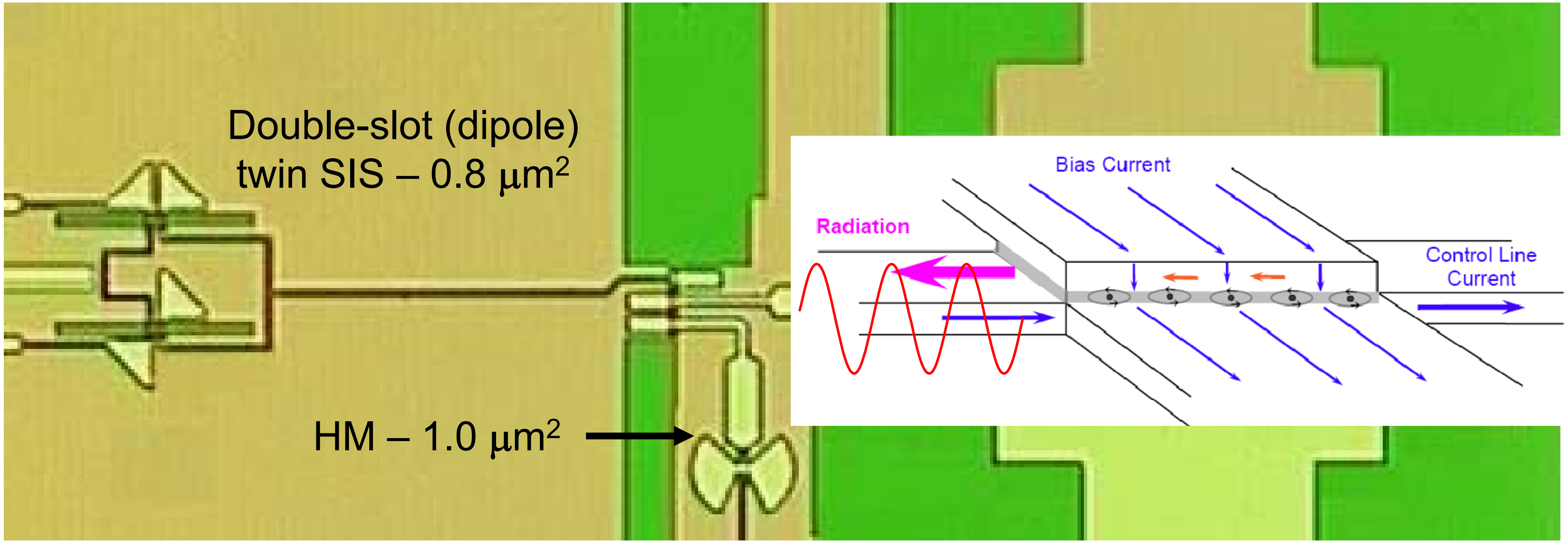
Superconducting Integrated Receiver (SIR) with phase-locked FFO





SIR microcircuit

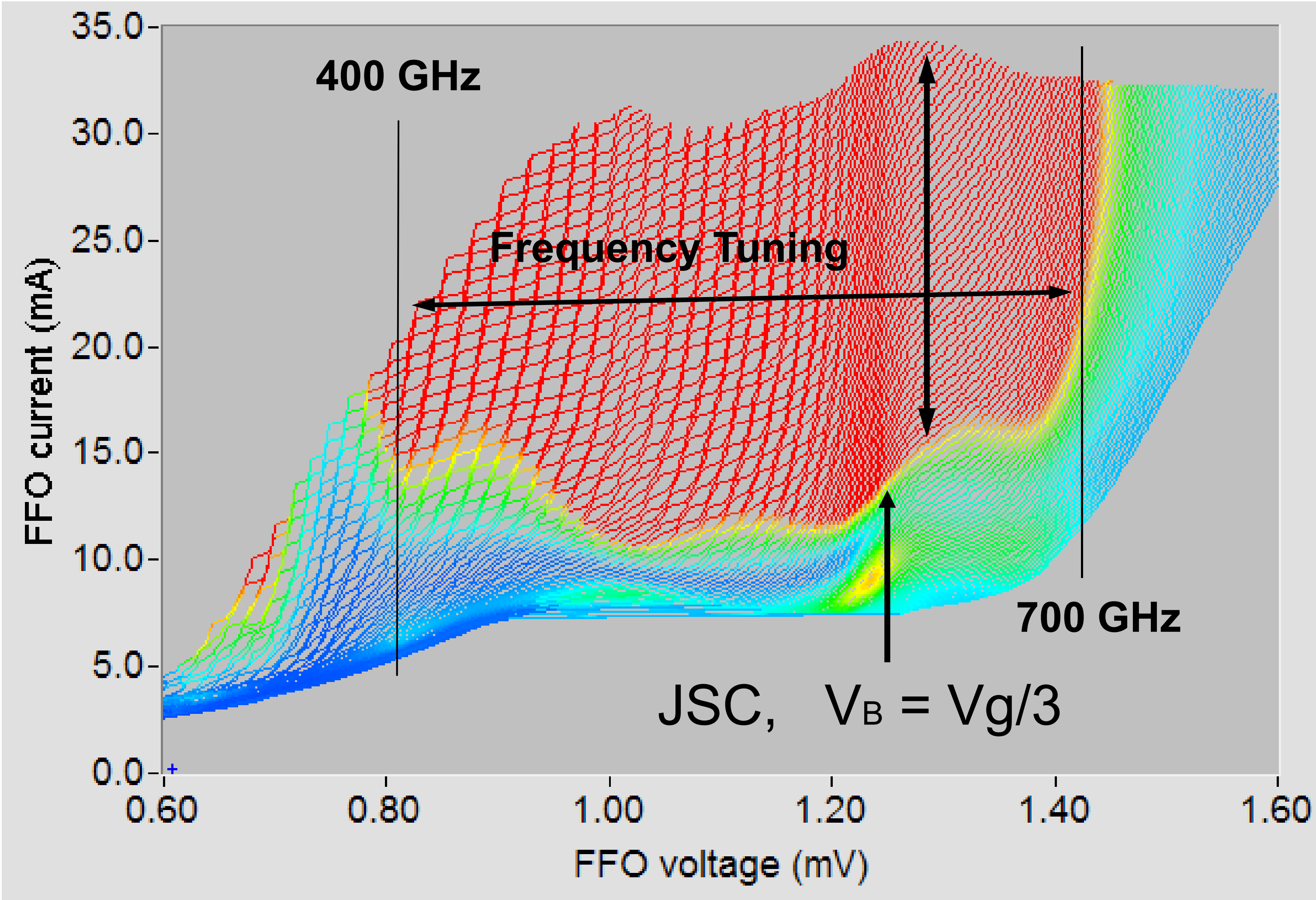
Internal part of the SIR Microcircuit



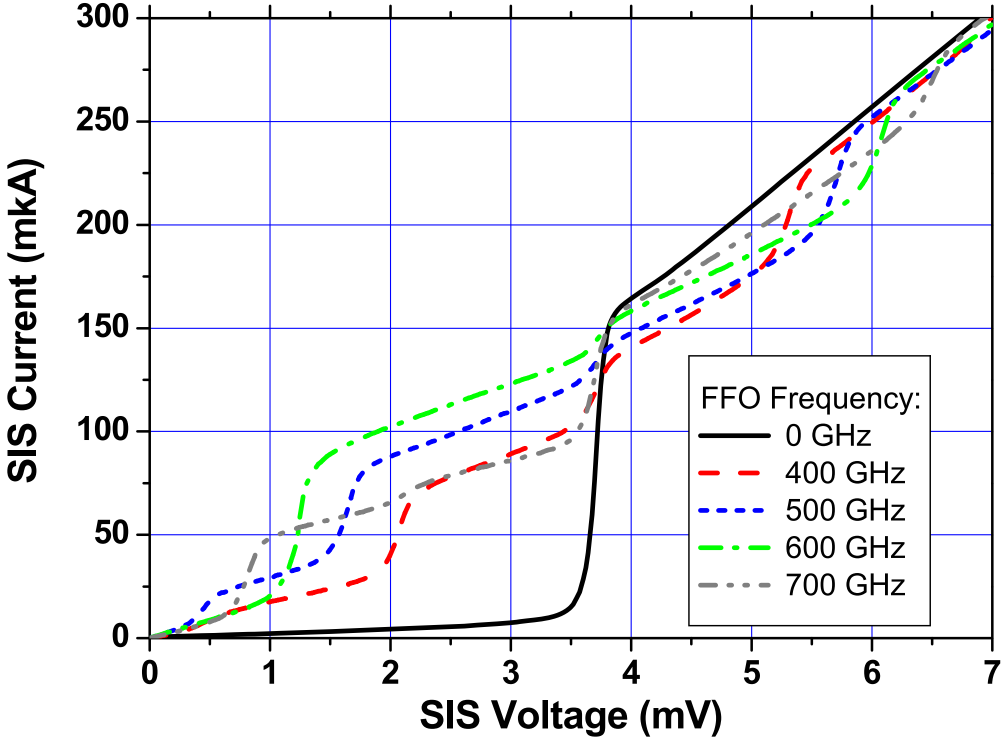
Nb-AlOx-Nb, Nb-AlN-NbN; Jc = 5 - 10 kA/cm²

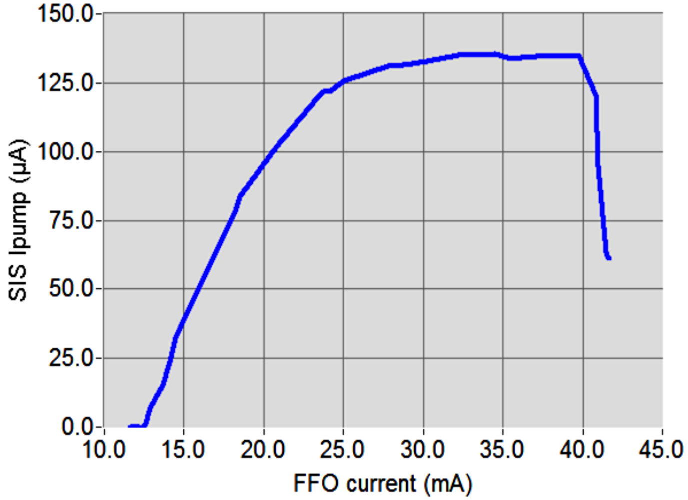
Optionally: SIS – Jc = 8 kA/cm²; FFO + HM = 4 kA/cm²

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

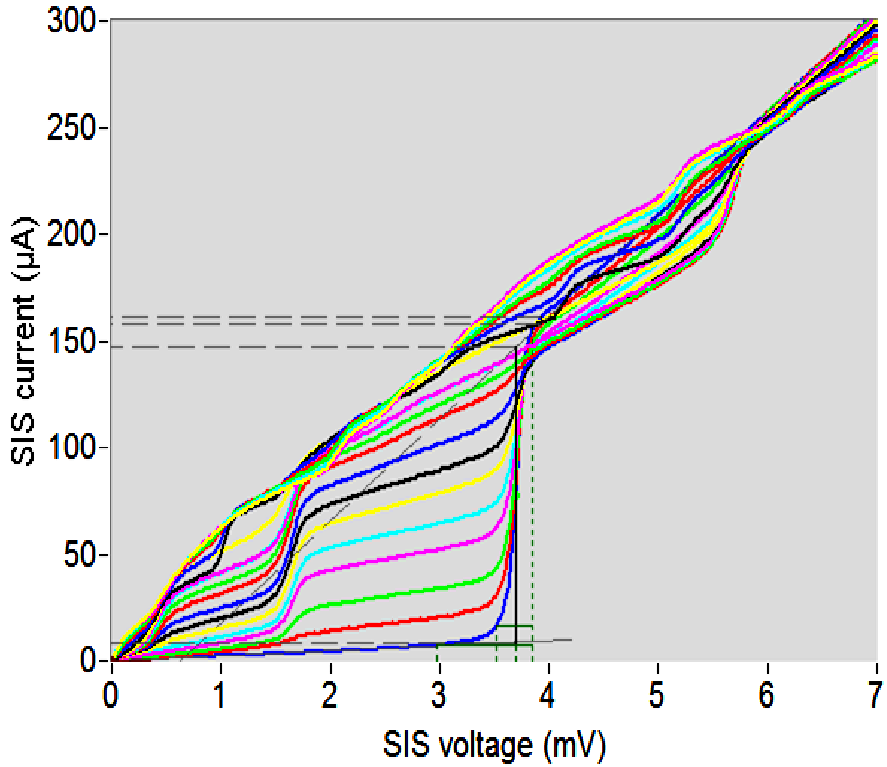


FFO frequency and power tuning



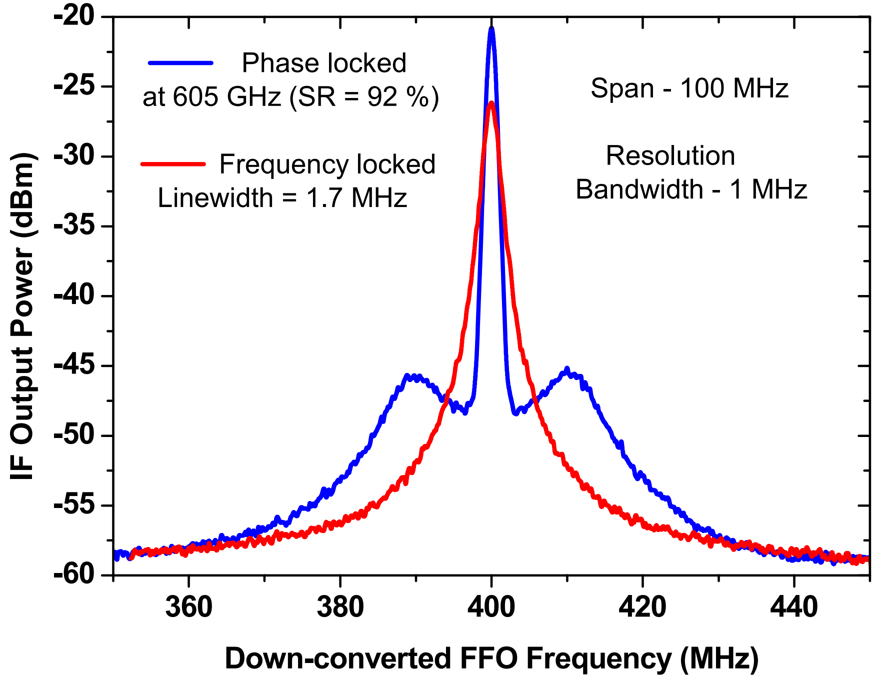


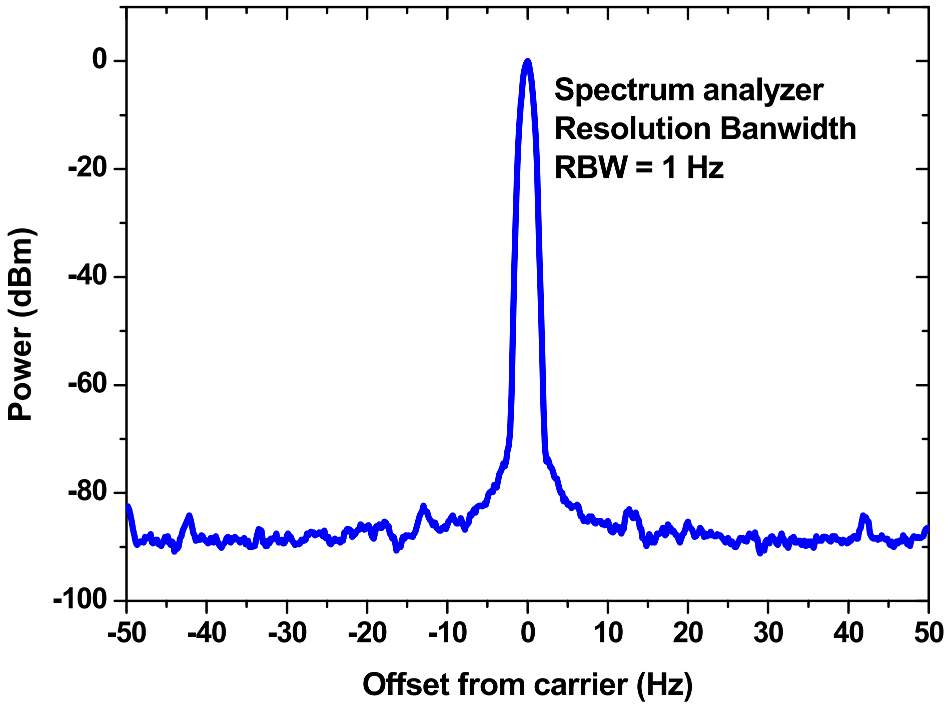
FFO frequency = 500 GHz



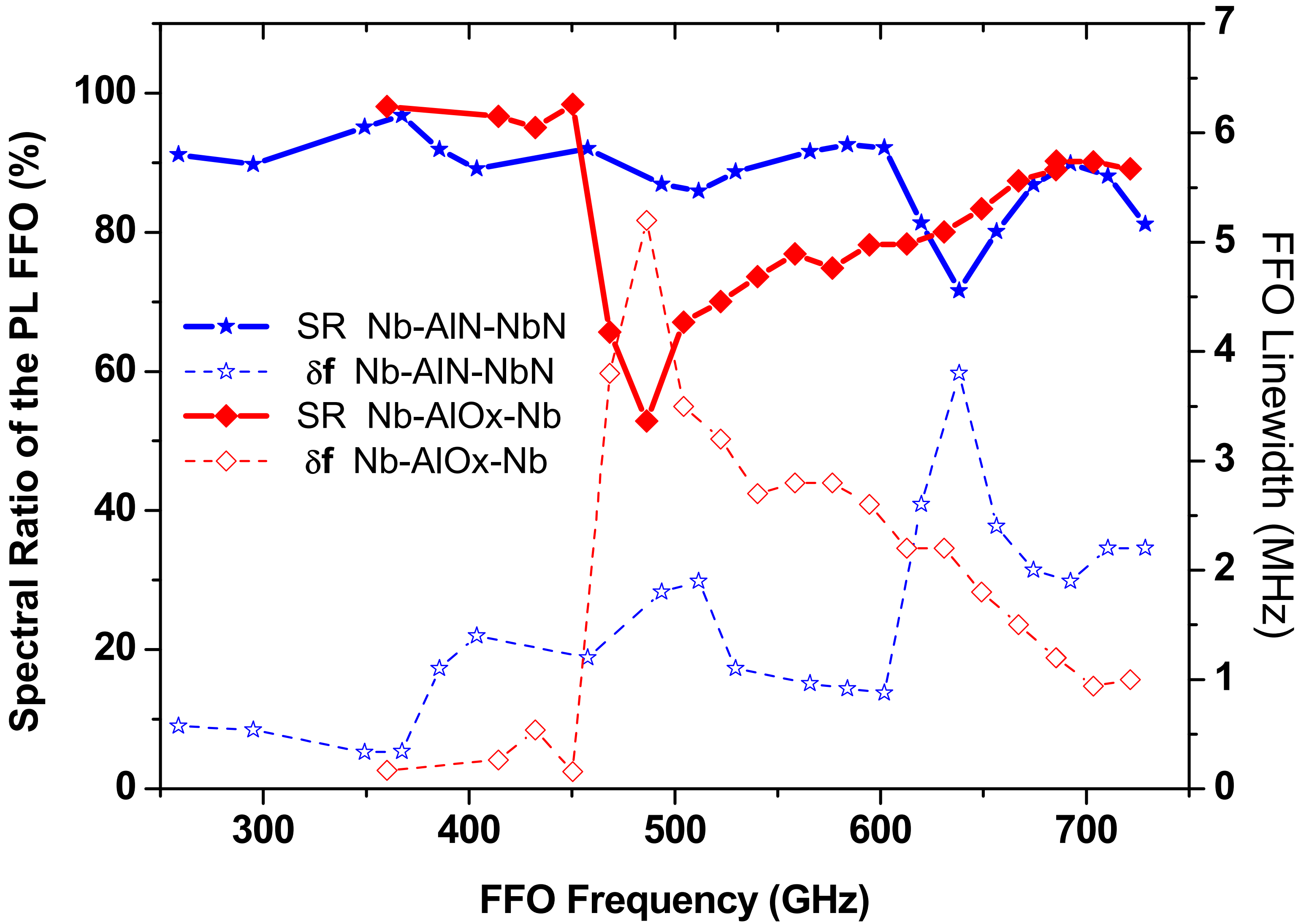
2011, September 22

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

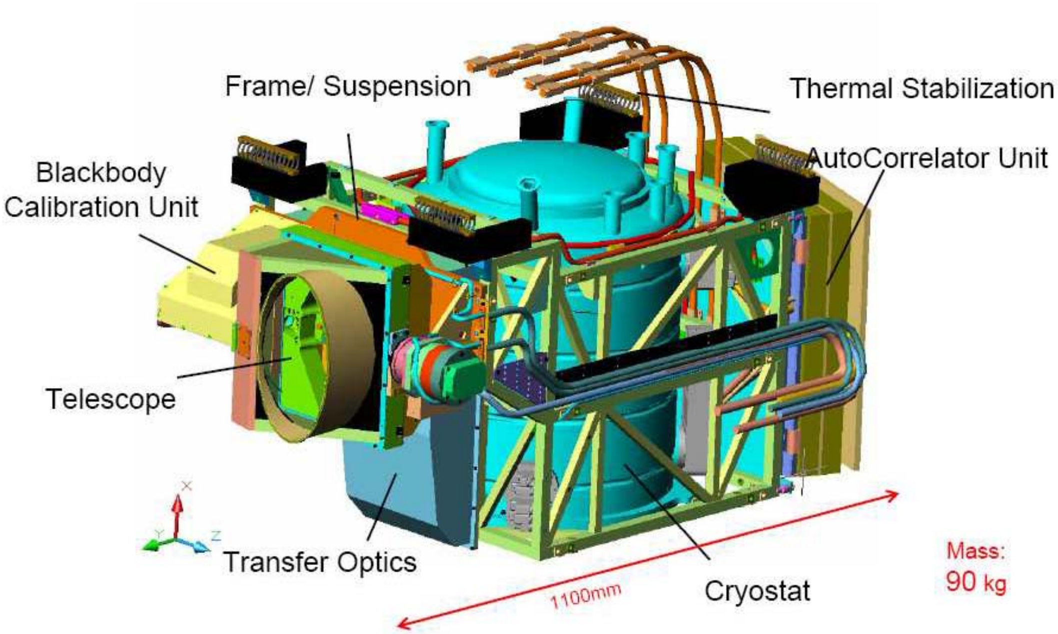




Linewidth and Spectral Ratio on the FFO frequency



TELIS (Terahertz Limb Sounder)



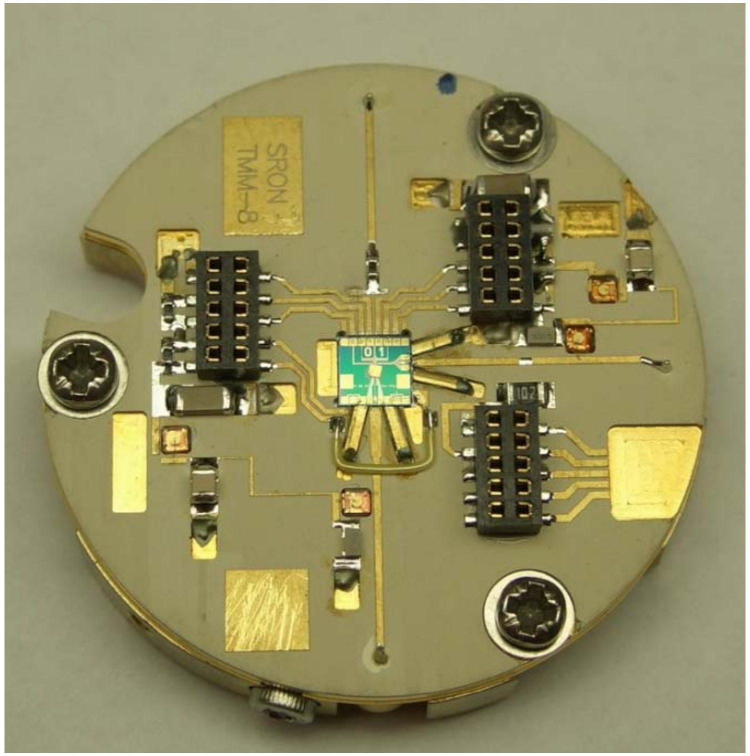
Balloon-Borne TELIS Instrument

TELIS Objectives:

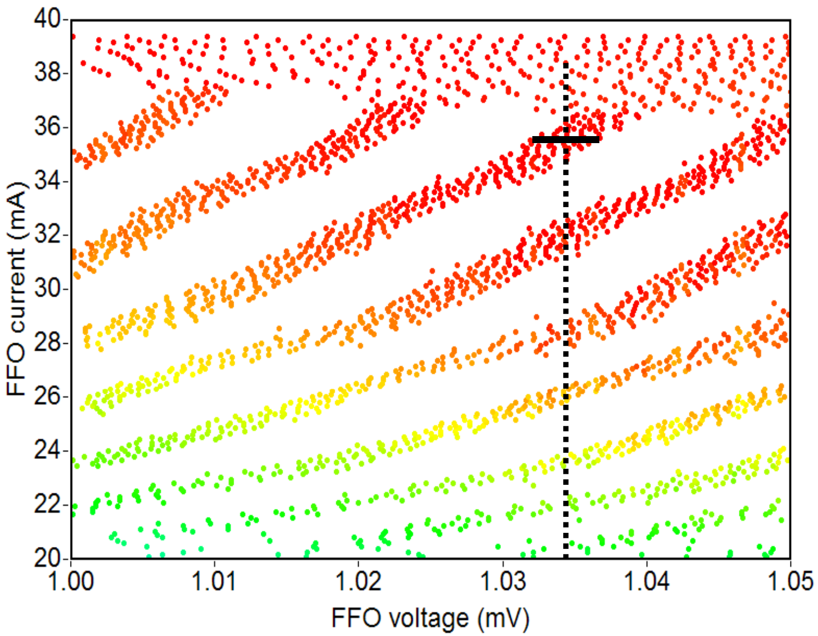
- Measure many species for atmospheric science:
  ClO, BrO, O_3, HCl, HOCl, etc;
  - Chemistry, Transport, Climate
- Serve as a test platform for new sensors
- Serve as validation tool for future satellite missions
- Three independent frequency channels, cryogenic heterodyne receivers:
  - 500 GHz by RAL
  - **490-630 GHz by SRON-IREE**
  - 1.8 THz by DLR (PI)

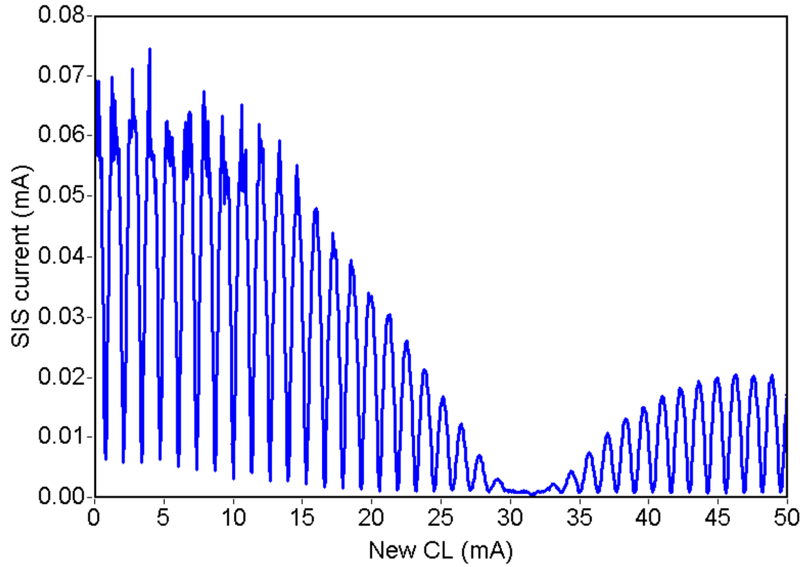
TELIS-SIR Main Parameters

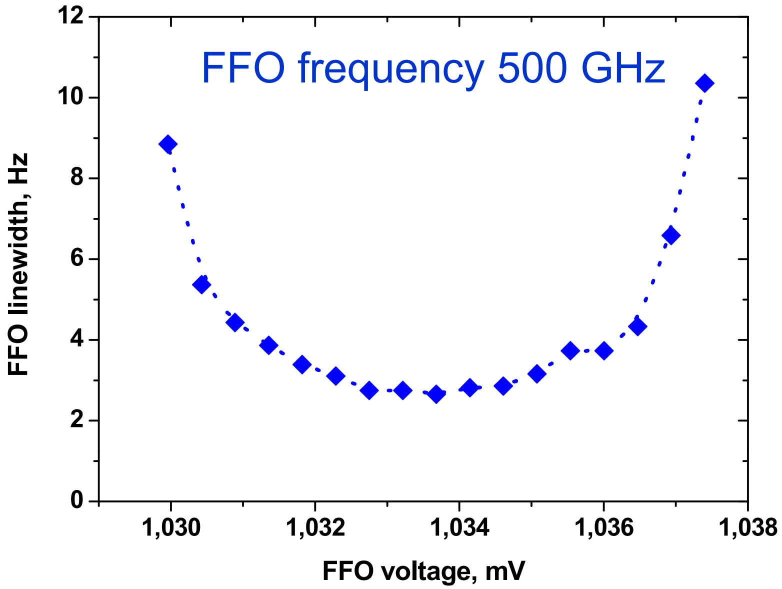
Input frequency range	470 – 670 GHz
Minimum DSB noise temperature in the range	< 120 K
Output IF range	4 - 8 GHz
Spectral resolution	< 1 MHz
System stability (Allan variance)	20 s
Dissipated power (at 4.2 K stage)	< 30 mW
Operation temperature	< 4.5 K

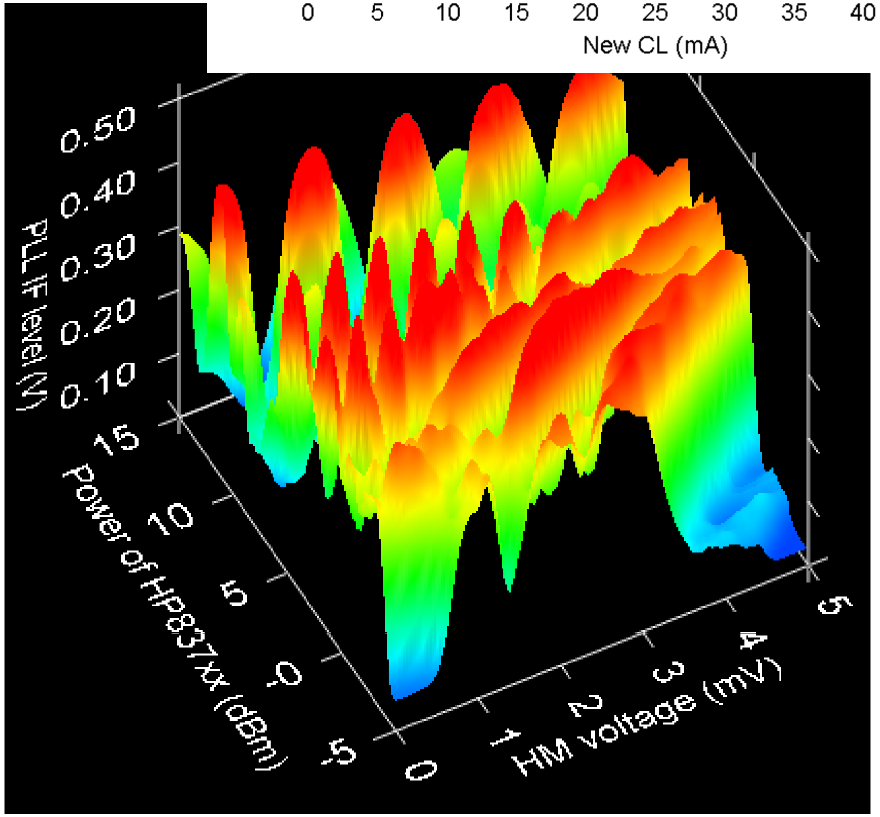


SIR for TELIS – remote operation









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)

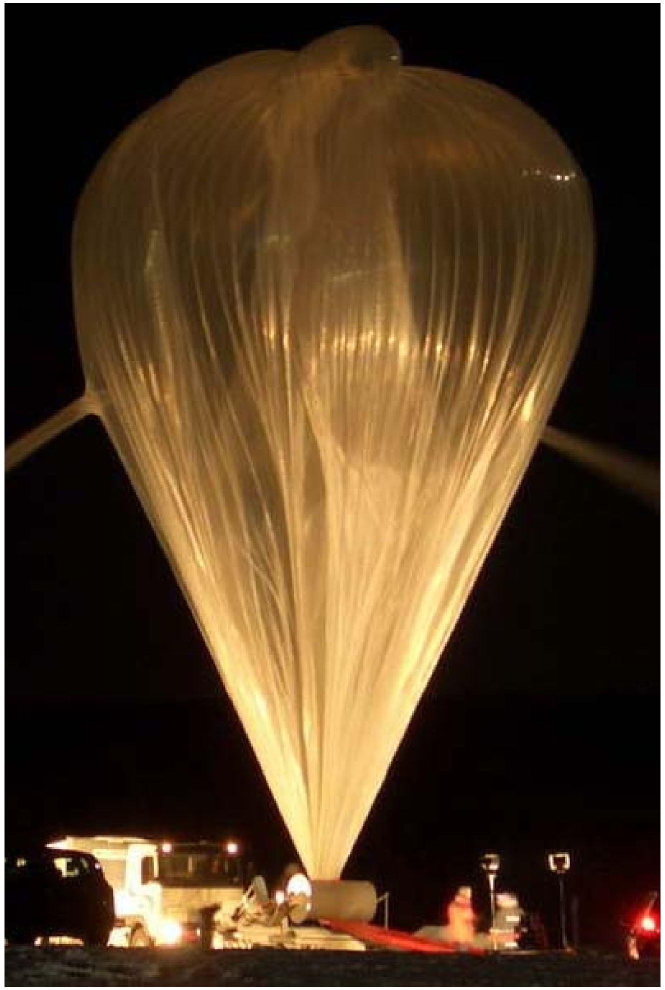
TELIS (Terahertz Limb Sounder)

TELIS-MIPAS at Esrange, Sweden;

March 2009; January 2010; March 2011

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

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



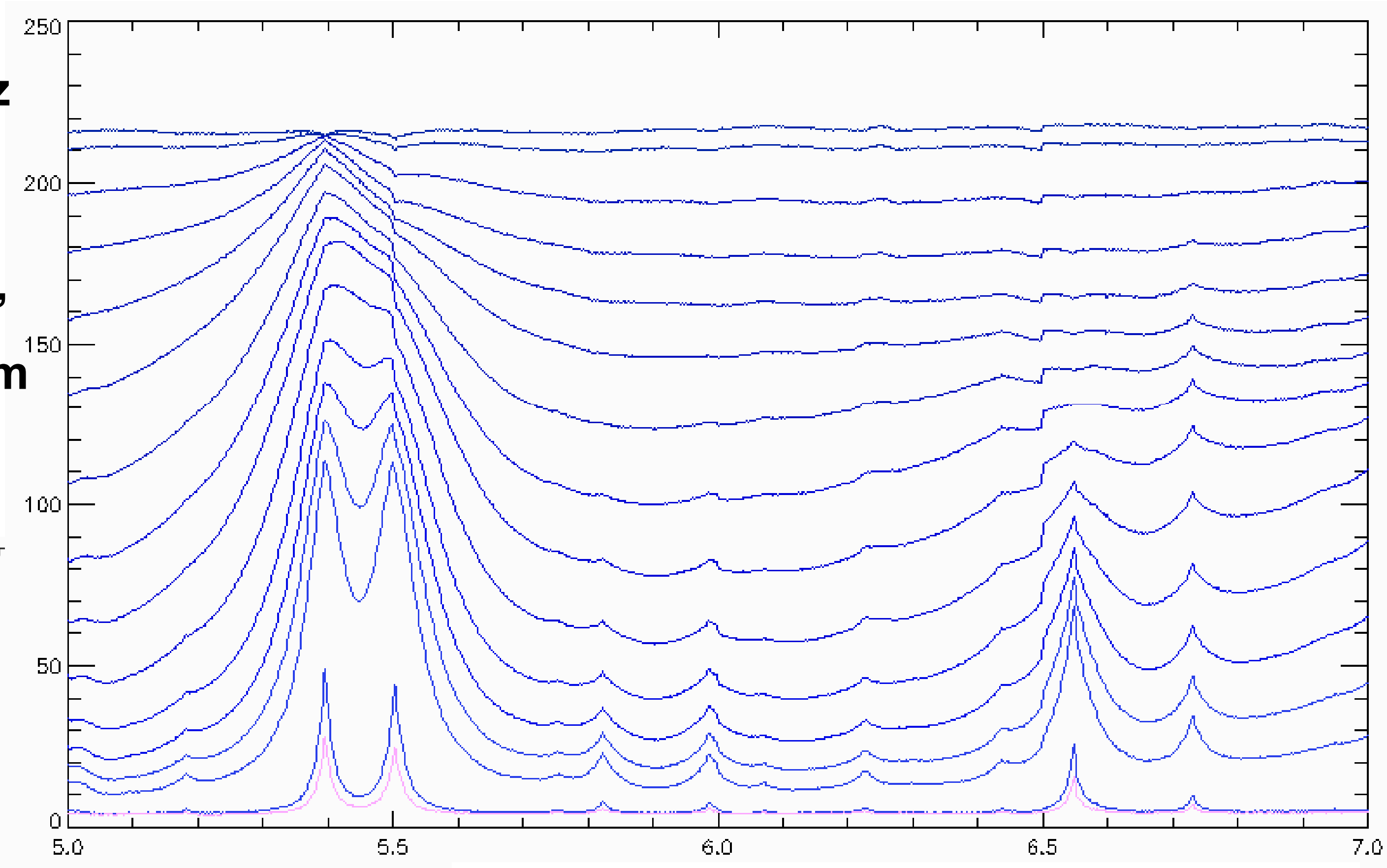
Spectra measured at limb-sounding

FFO Freq = 495 GHz

Orbit – 30 km;

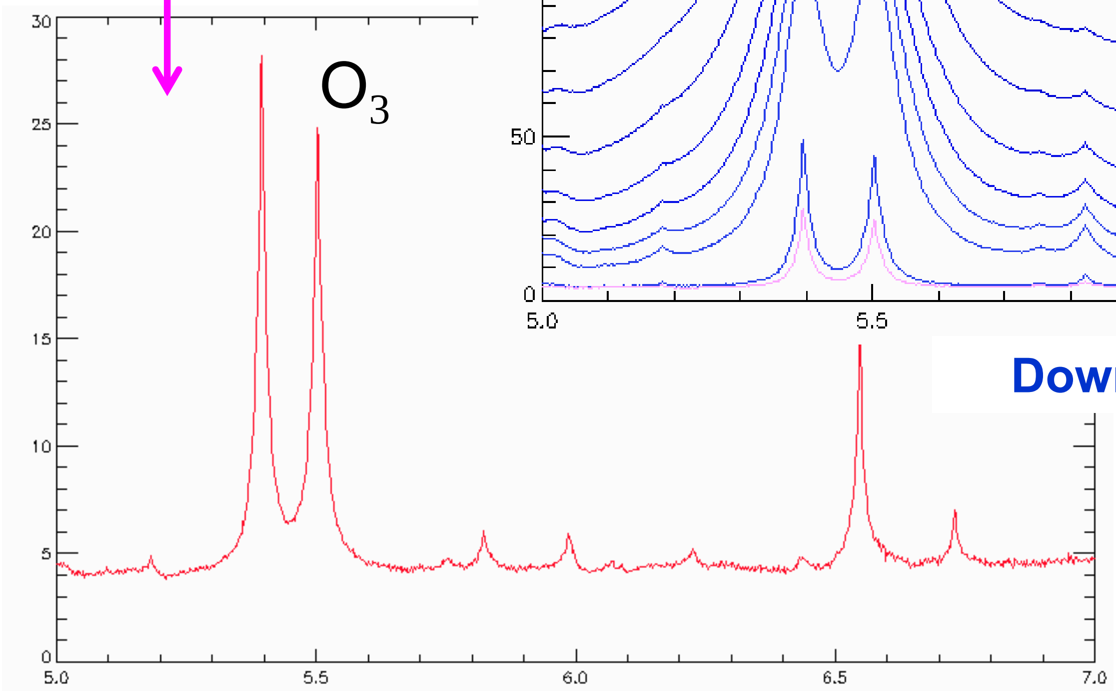
Increment – 1.5 km,

Tangent: 10.5 – 30 km



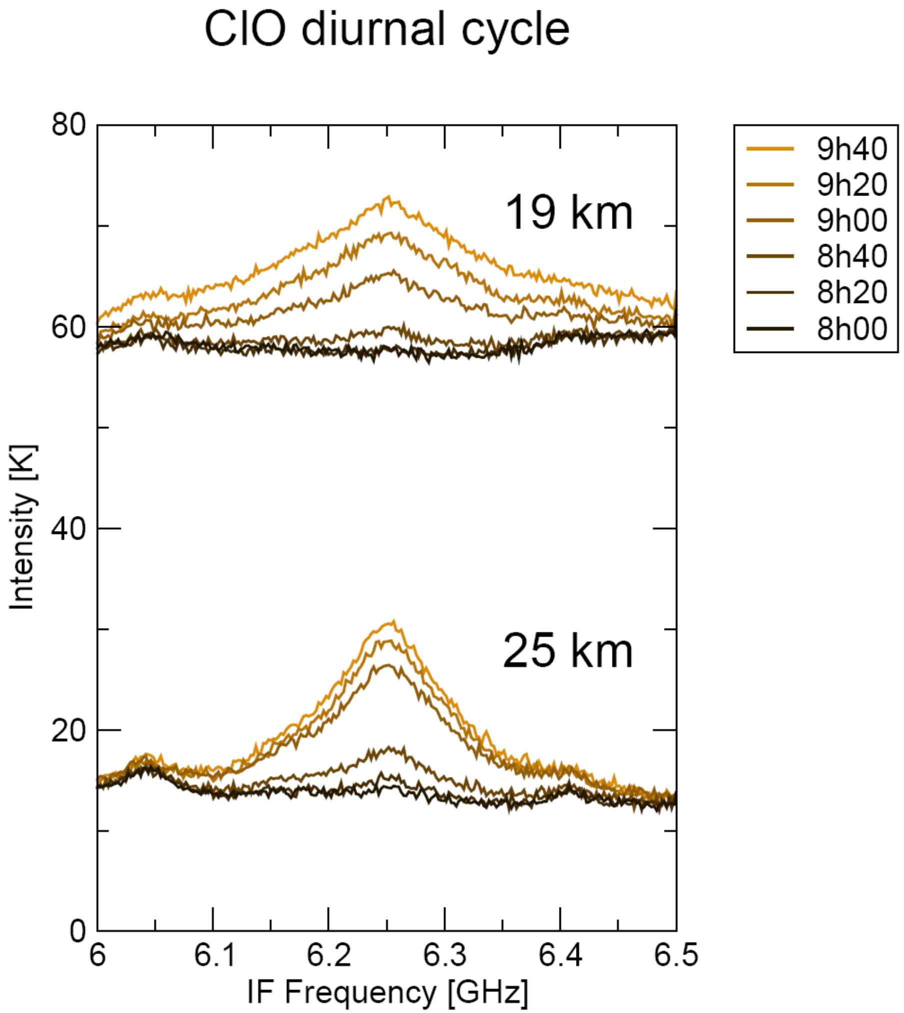
Down-converted Frequency, GHz

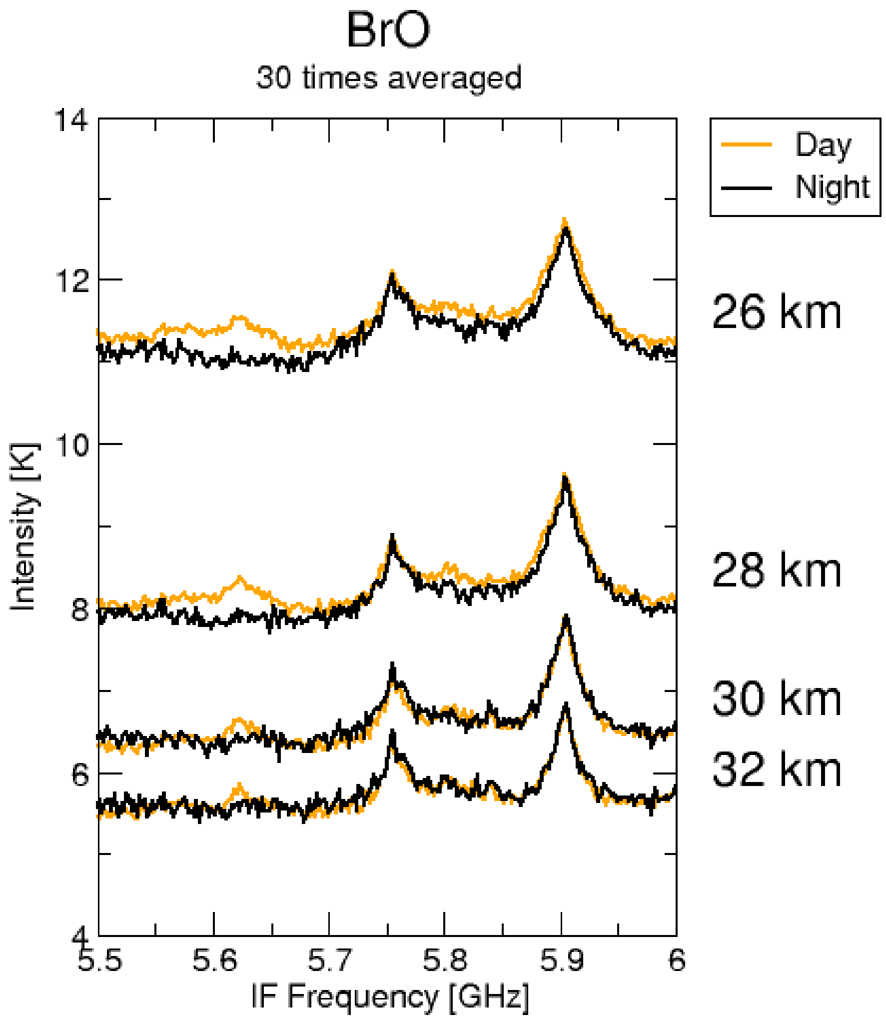
45 degrees up



Down-converted Frequency, GHz

Second TELIS flight
January 2010; Esrange, Sweden



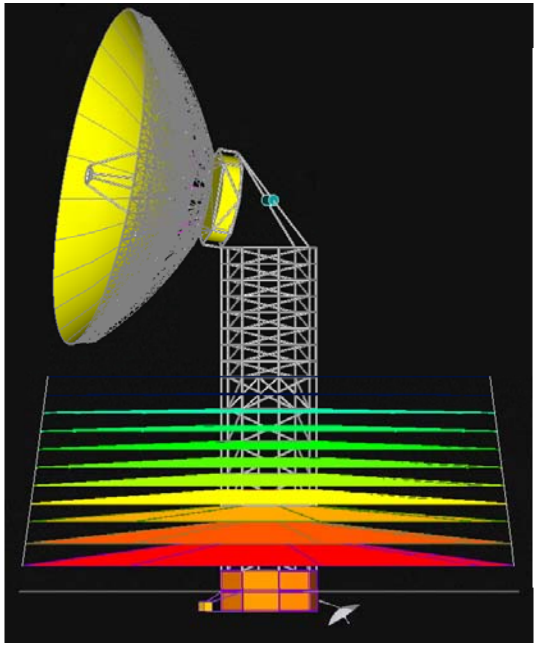


Future SIR applications

New balloon missions

High-altitude airplanes

Space project “Millimetron”



Ground-space interferometer

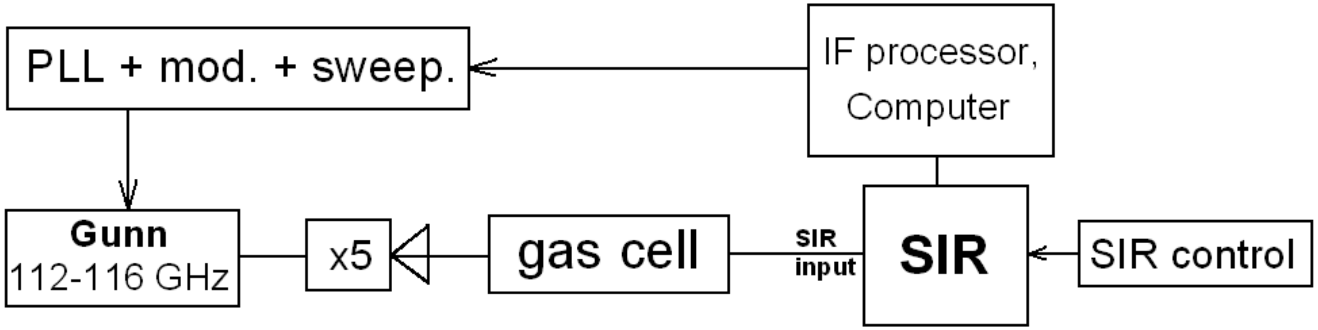
Medical applications

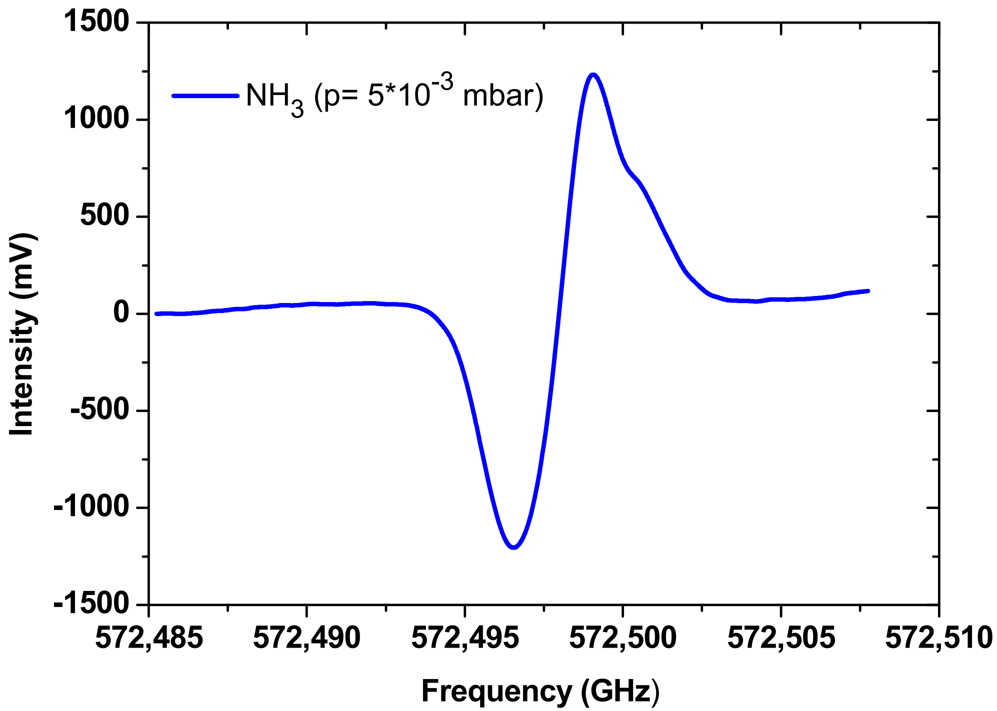
Non-invasive medical diagnostics based on analysis of exhaled air

- 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





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:
  Frequency range 470 – 670 GHz; Noise temperature < 120 K;
  IF bandwidth 4 - 8 GHz; Spectral resolution better 1 MHz;
  System stability (spectroscopic Allan variance) 20 sec;
  Beam Pattern - FWHM = 3 deg, with sidelobes < - 17 dB.
- Procedure for remote SIR operation has been developed and experimentally proven.
- 3 successful TELIS flights have been completed in March 2009, January 2010 and March 2011 at Esrange (Kiruna, Sweden).
- Future space and ground-base missions are under consideration.
- SIR Technology is mature enough for future space missions, non-invasive medical diagnostic, and security applications.