Superconducting Integrated Spectrometer for TELIS

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

Institute of Radio Engineering and Electronics (IREE), Moscow, Russia

Pavel Yagoubov, Gert de Lange, Ruud Hoogeveen, and Wolfgang Wild

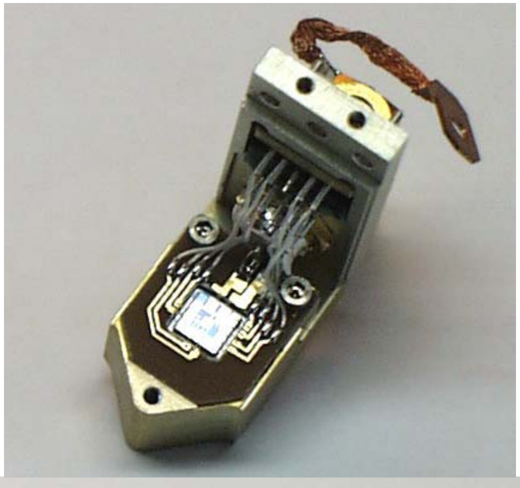
SRON Netherlands Institute for Space Research, the Netherlands

Superconducting Integrated Spectrometer for TELIS

Outline

- Superconducting Integrated Receiver (SIR);
- TErahertz LImb Sounder (TELIS) project;
- SIR channel design and SIR chip lauout;
- Nb-AlN-NbN SIR – first implementation;
- SIR channel performance:
  - Noise Temperature,
  - IF Performance,
  - Beam Pattern,
  - Spectral Resolution,
- Conclusion

Superconducting Integrated Receiver (SIR)



STATE OF THE ART

- Single chip Nb-AlOx-Nb SIS receivers with superconducting FFO have been studied at frequencies from 100 to 700 GHz;
- A DSB receiver noise temperature as low as 90 K has been achieved at 500 GHz;
- 9-pixel Imaging Array Receiver has been successfully tested;
- FFO Phase Locking (PLL) up to 700 GHz.

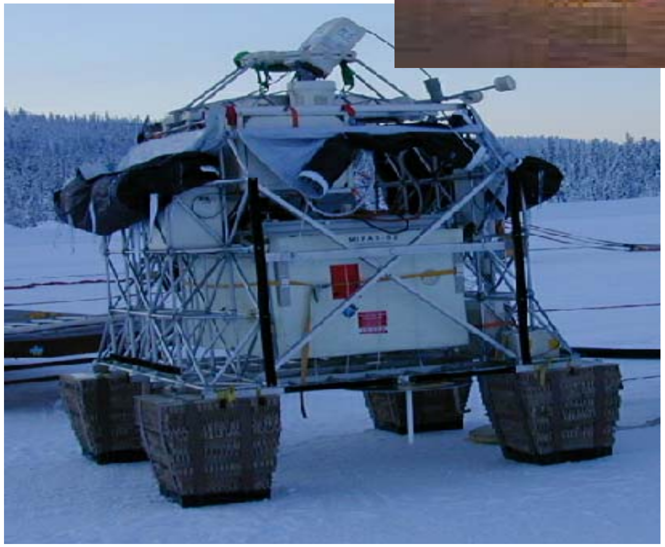
APPLICATIONS

- Airborne Receiver for Atmospheric Research and Environmental Monitoring; Radio Astronomy
- Focal Plane Array Receivers;
- Laboratory submm wave Spectrometers.

TELIS - TErahertz LImb Sounder

TELIS Objectives:

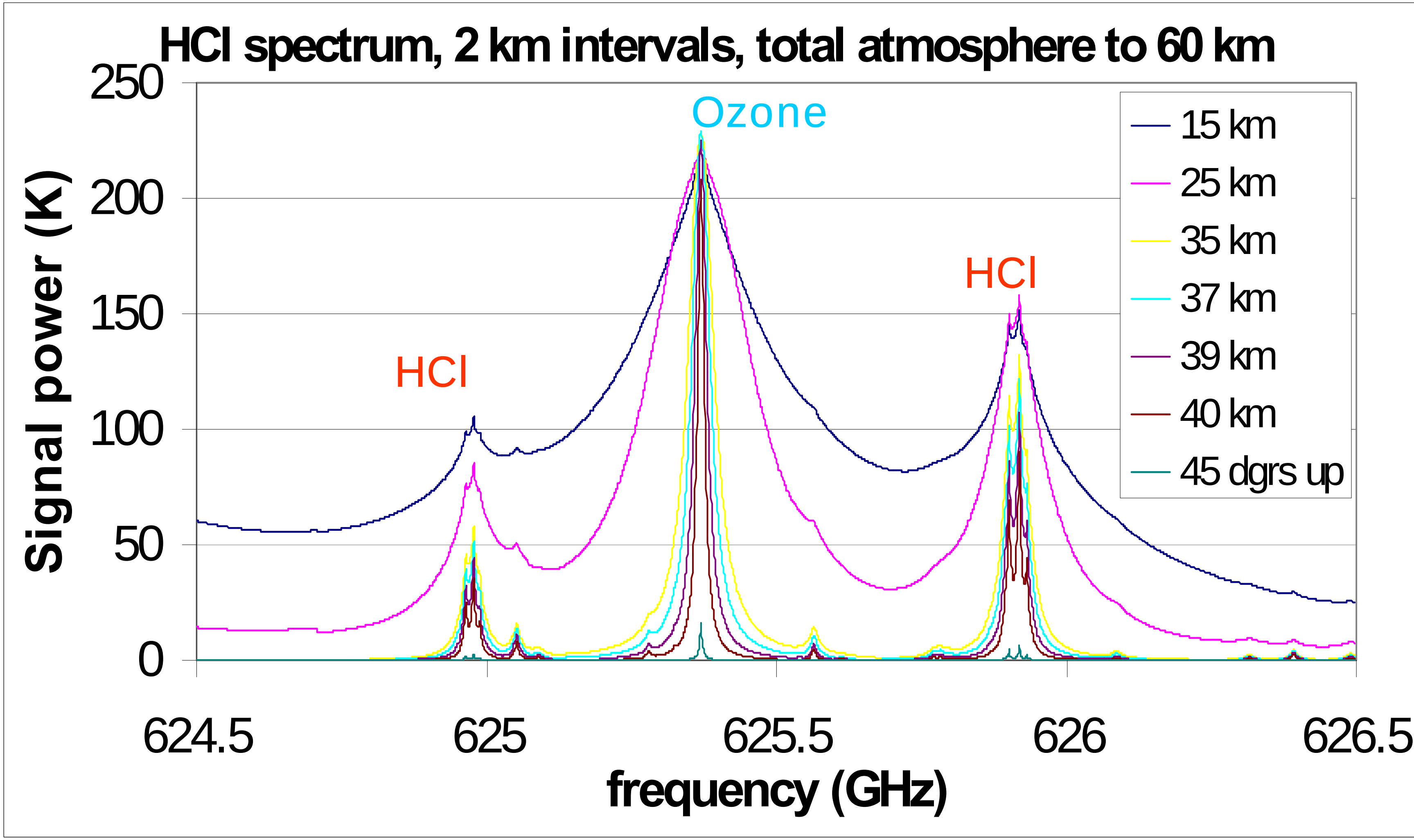
- Measure many species for atmospheric science (ClO, BrO, O_3, HCl, HOCl, etc);
  - Chemistry, Transport, Climate
- Serve as a test platform for new sensors
- Serve as validation tool for future satellite missions



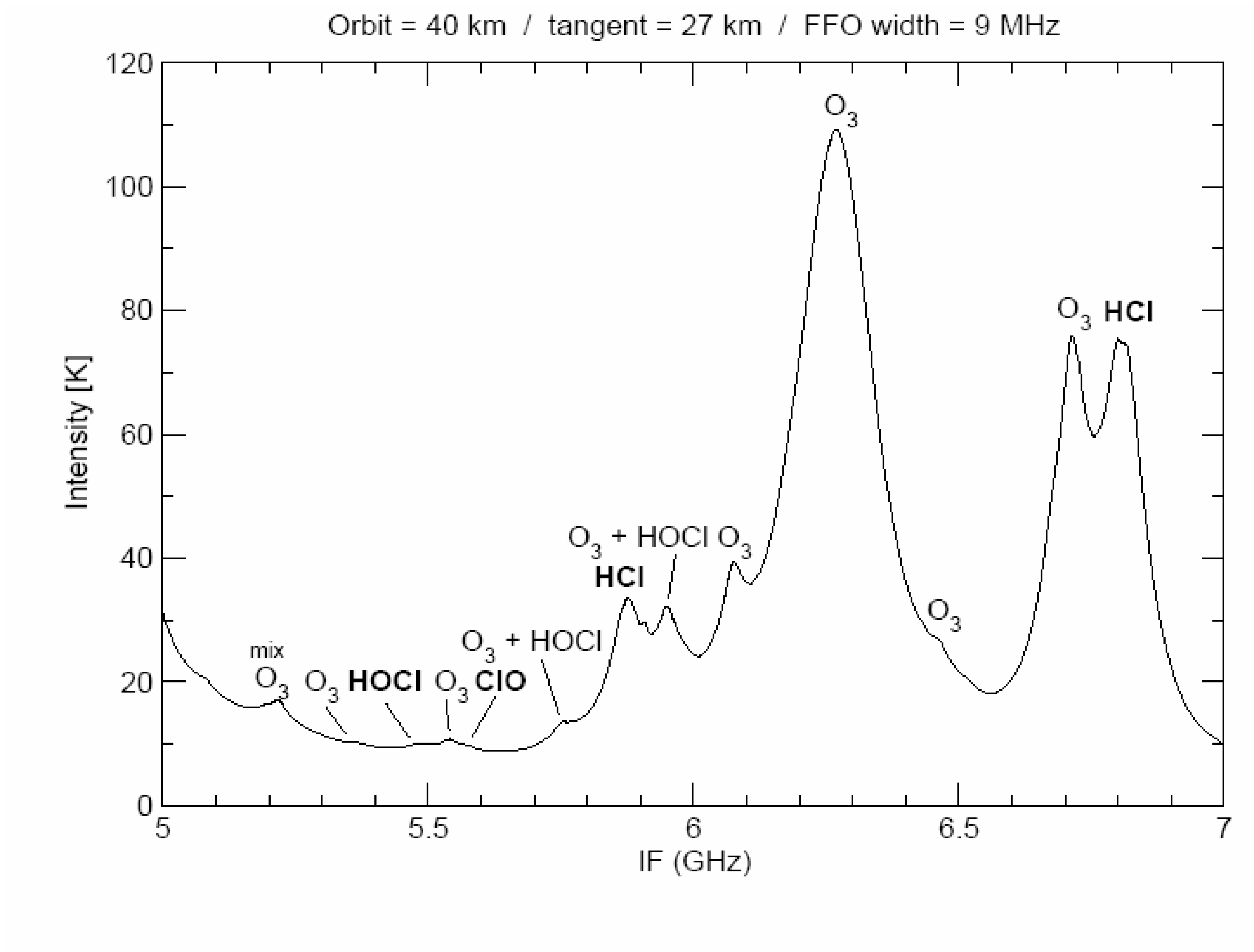
Three independent frequency channels, cryogenic heterodyne receivers:

- 500 GHz by RAL
- **600-650 GHz by SRON-IREE**
- 1.8 THz by DLR (PI)

Simulated spectra for Ozone and HCl at 625 GHz



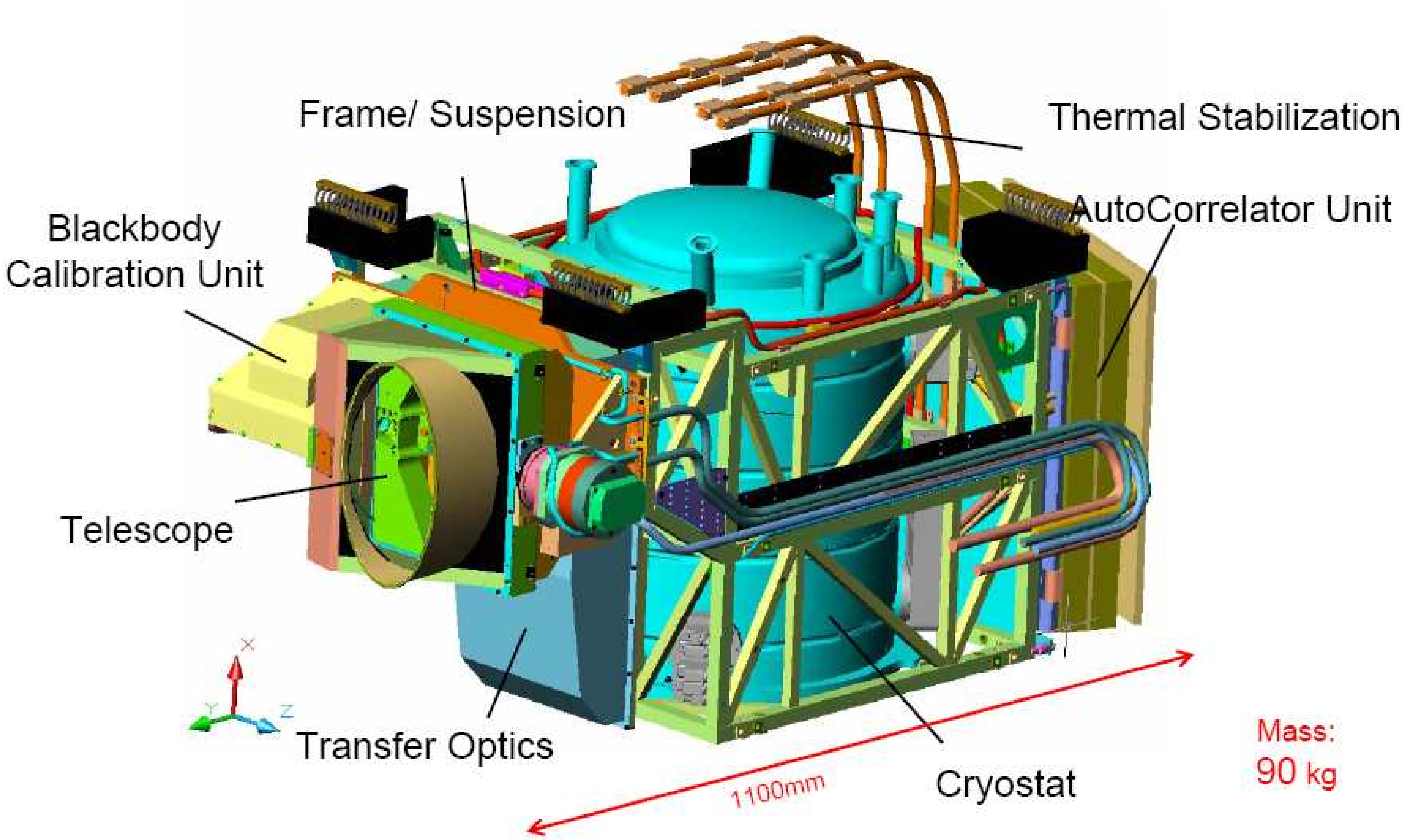
Simulated atmospheric spectra (DSB) at 619 GHz



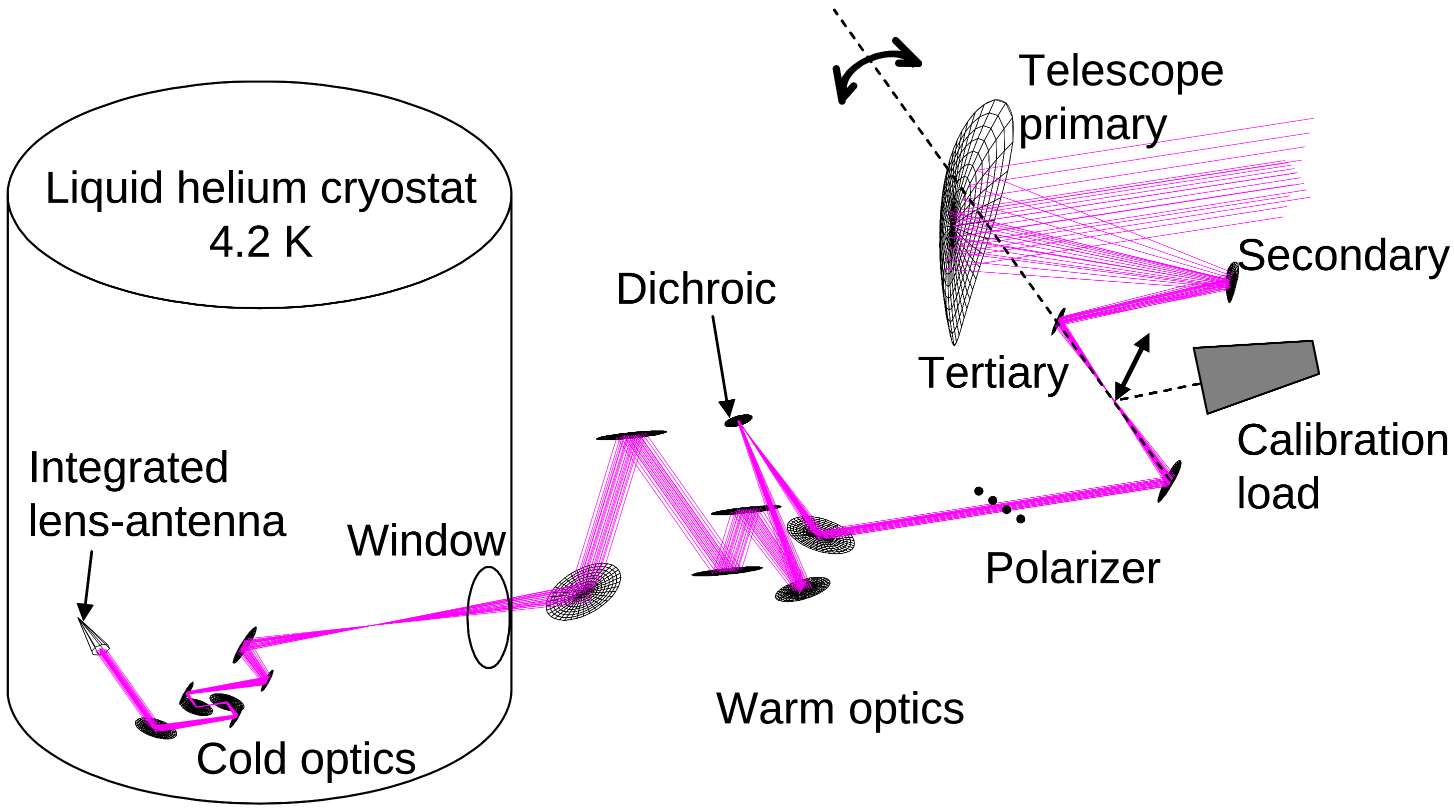
TELIS-SIR Main Parameters

##	Description	Value (Spec)
1	Input frequency range, GHz	500 – 650 (550 – 650)
2	Minimum noise temperature in the range (DSB), K	150 (250)
3	Output IF range, GHz	4 - 8 (5 - 7)
4	Spectral resolution (width of the spectral channel), MHz	< 1 (2)
5	LO frequency net, MHz	< 300
6	Dissipated power at 4.2 K stage (including IF amplifiers chain), mW	100
7	Operation temperature, K	< 4.5

TELIS – Instrument Model



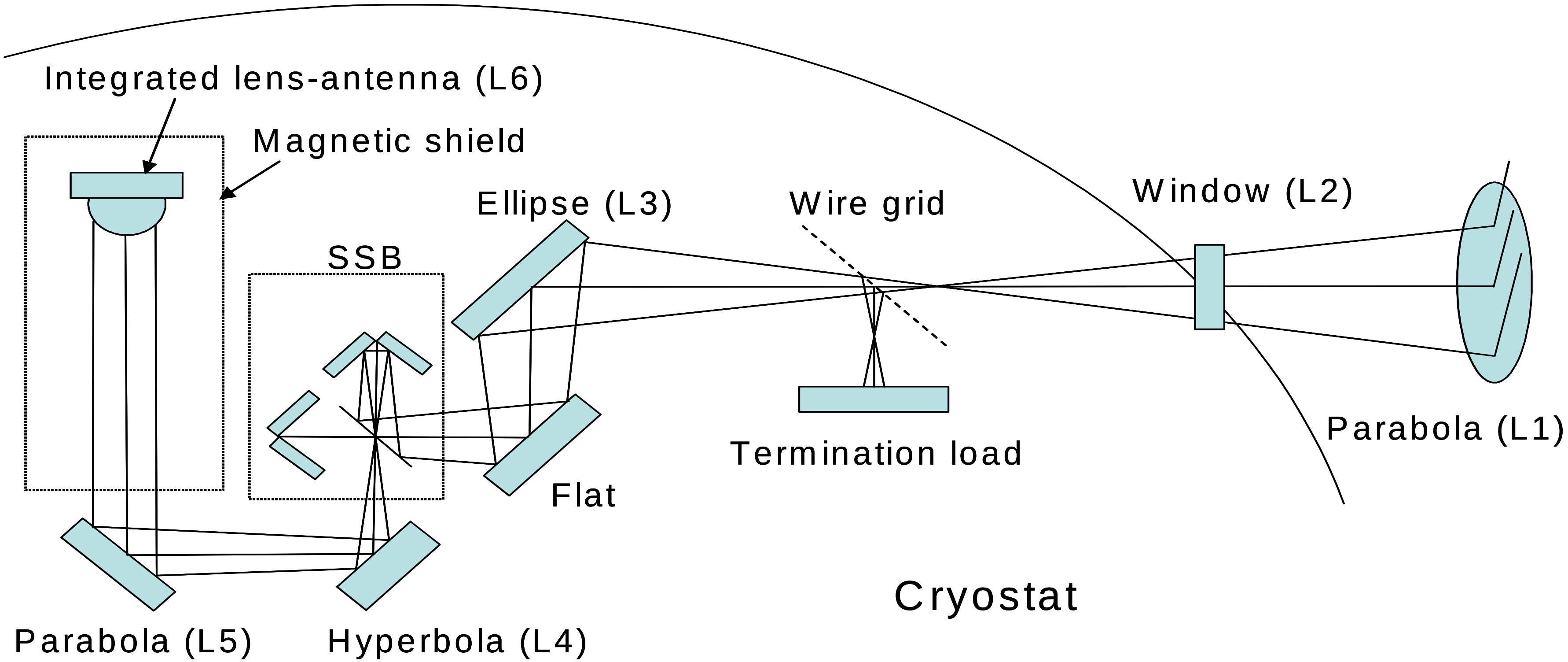
Schematics of the 550-650 GHz channel optics



Wire grid polarizer and dichroic plate are used to separate this receiver from the two other frequency channels (not shown). The cold optics and mixer element are located inside the cryostat at the ambient temperature 4.2 K

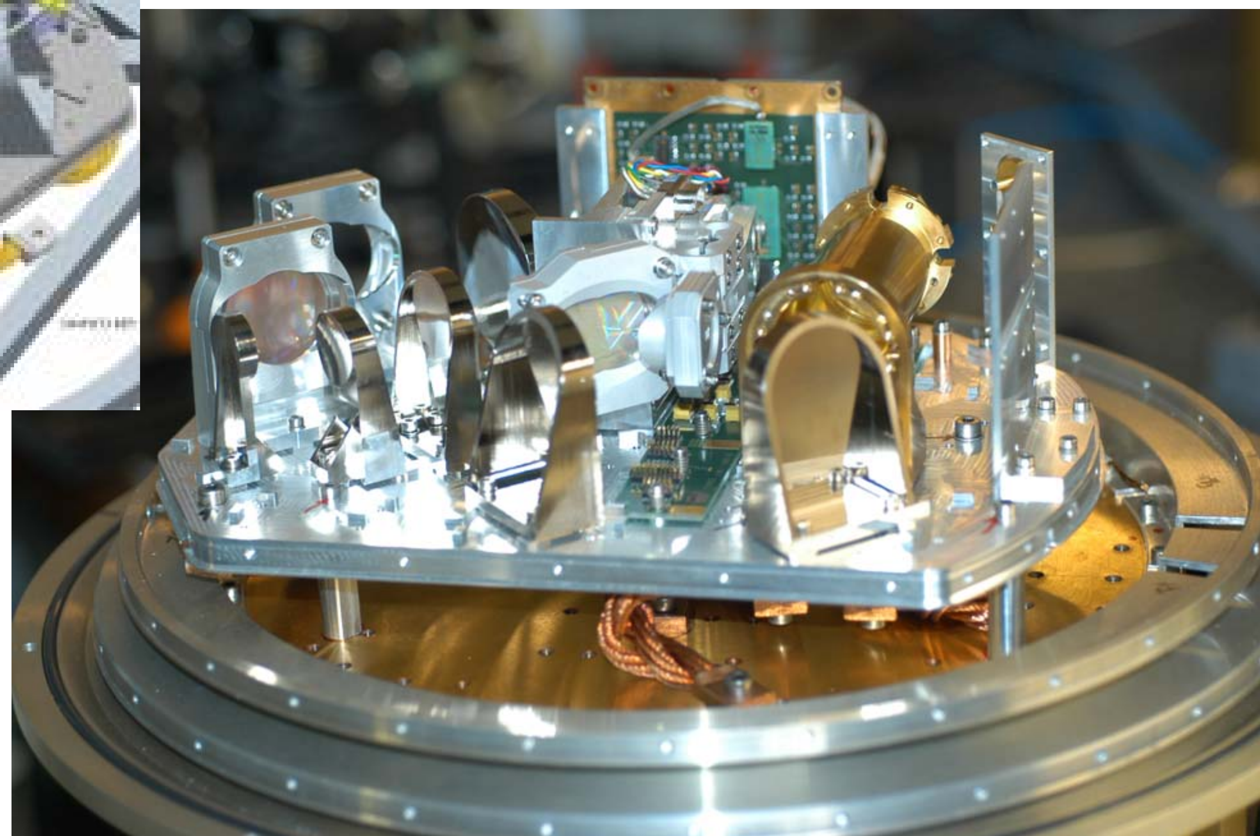
➡ ***Thursday, March 22,   P. Yagoubov;   Report 7-5***

Layout of SIR cold channel

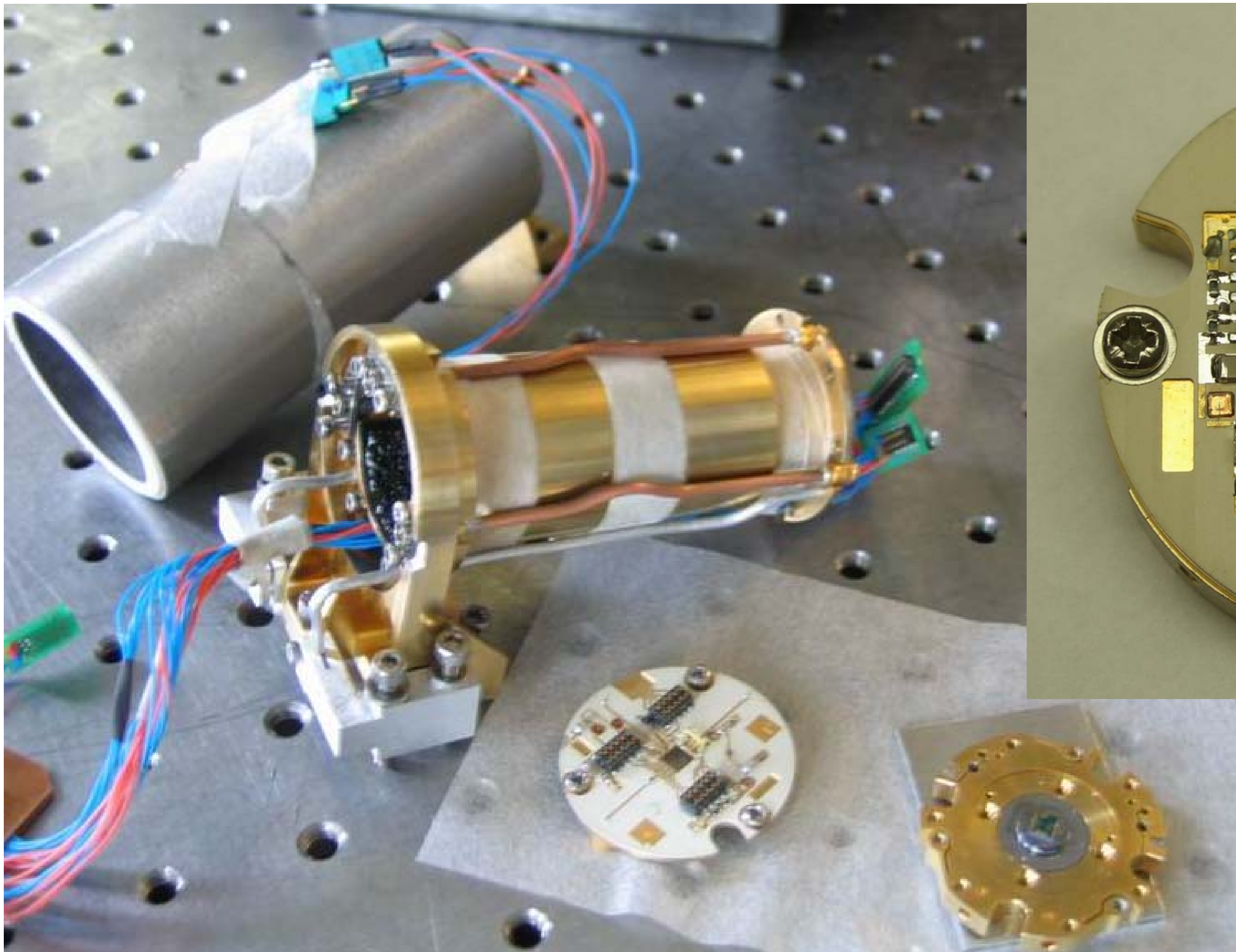


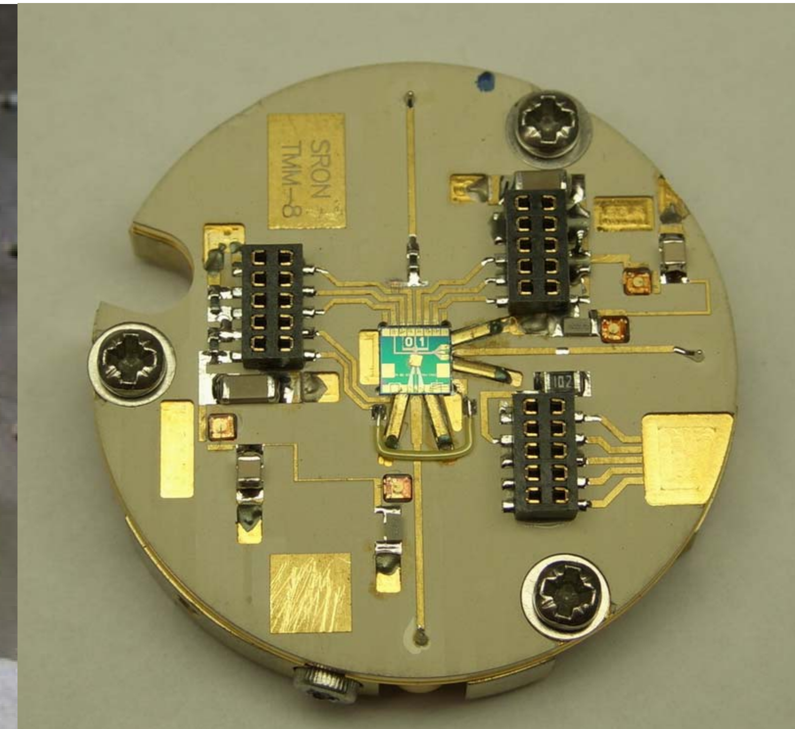
➡ ***Thursday, March 22, P. Yagoubov; Report 7-5***

Photo of the SIR-TELIS channel



SIR Mixer Block with Shields





Schematics of PLL SIR

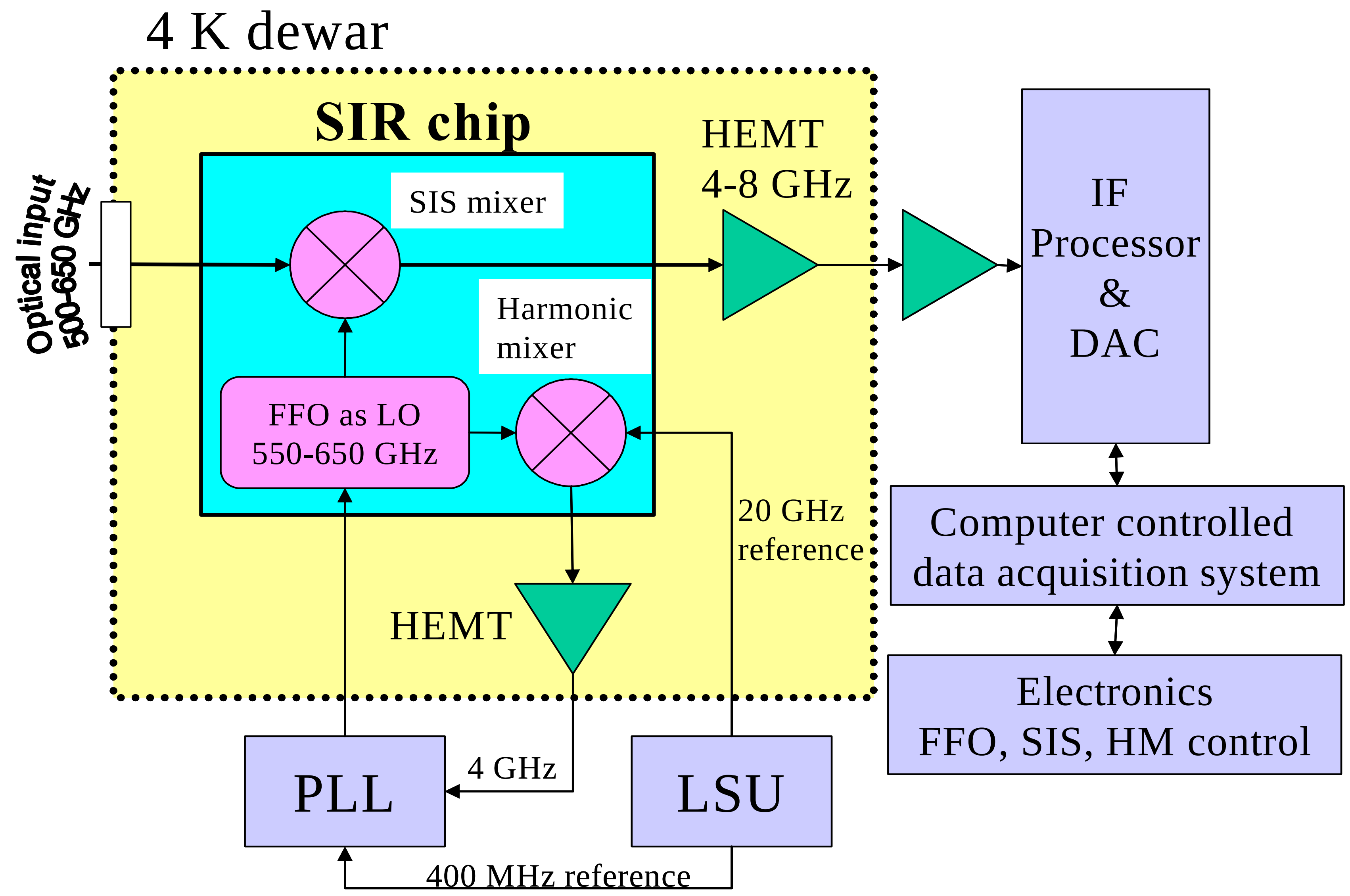


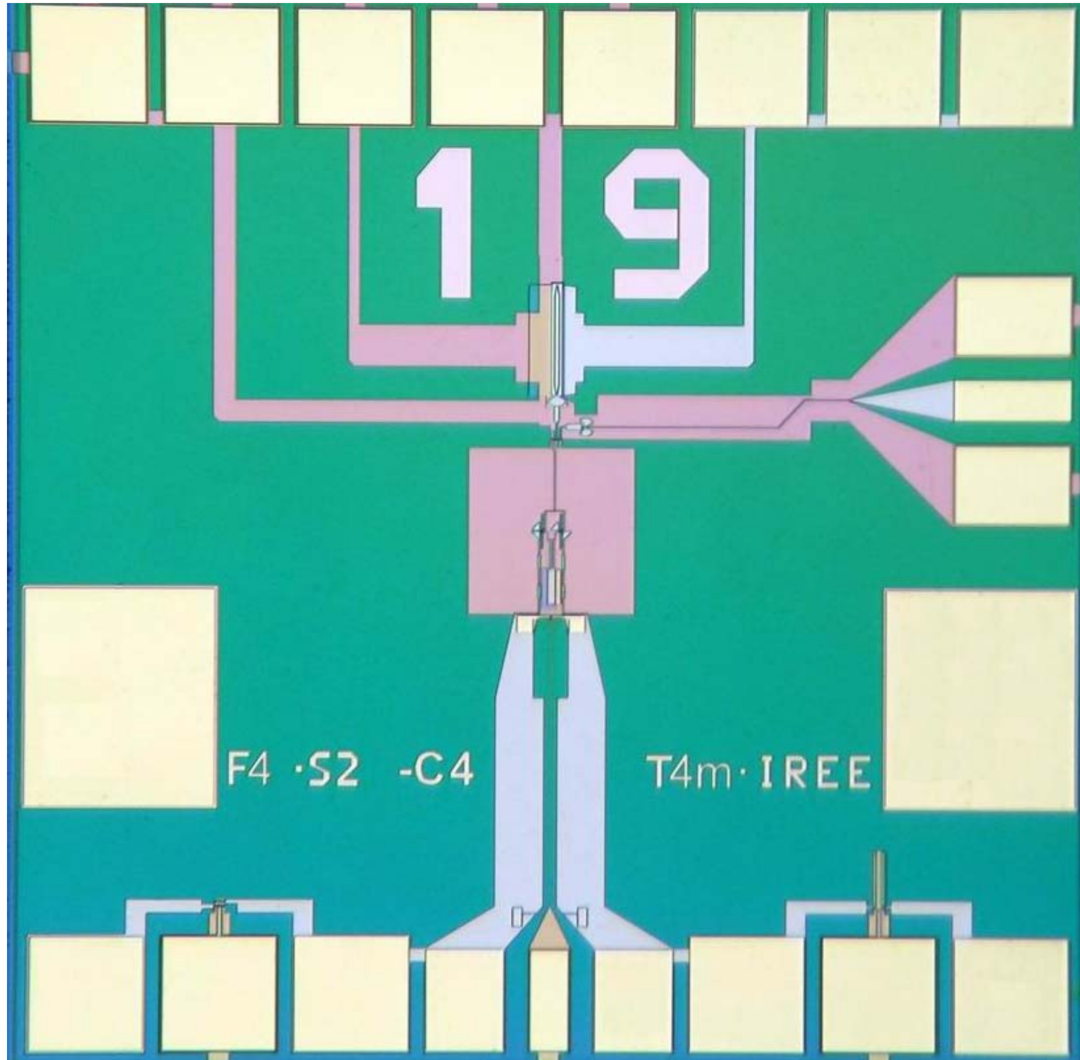
Photo of the T4m SIR chip

Silicon (Si);

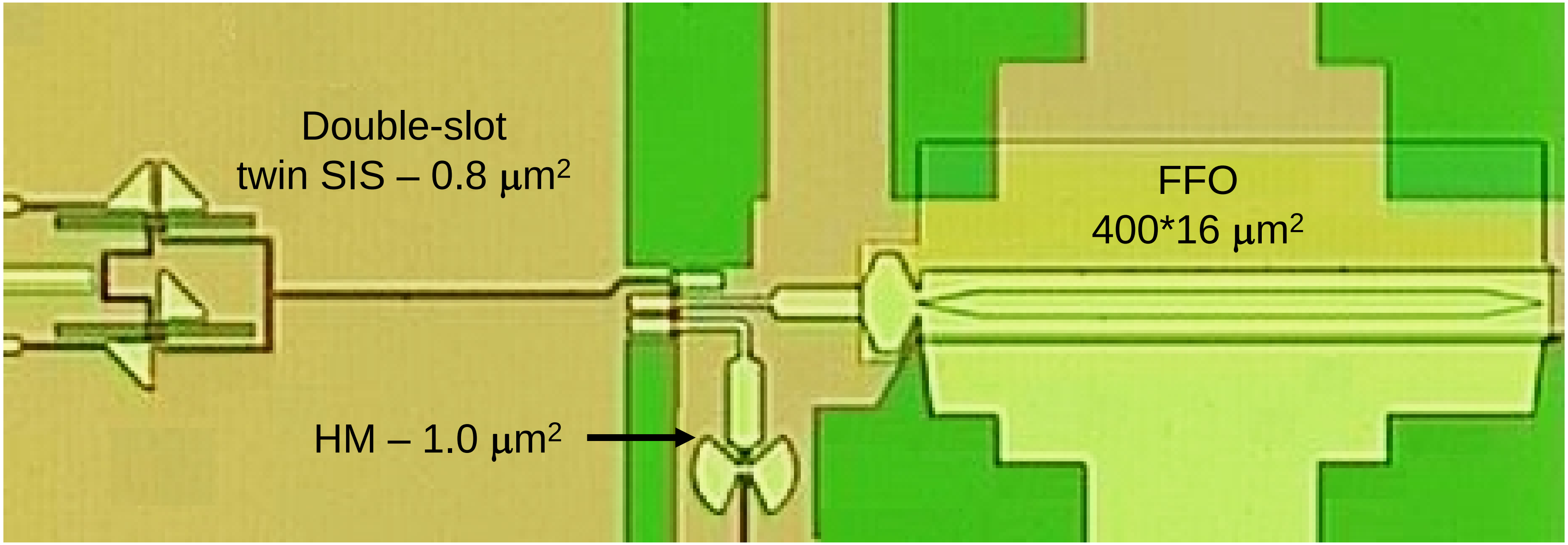
4 x 4 x 0.5 mm^3

Nb-AlOx-Nb or

Nb-AlN-NbN;



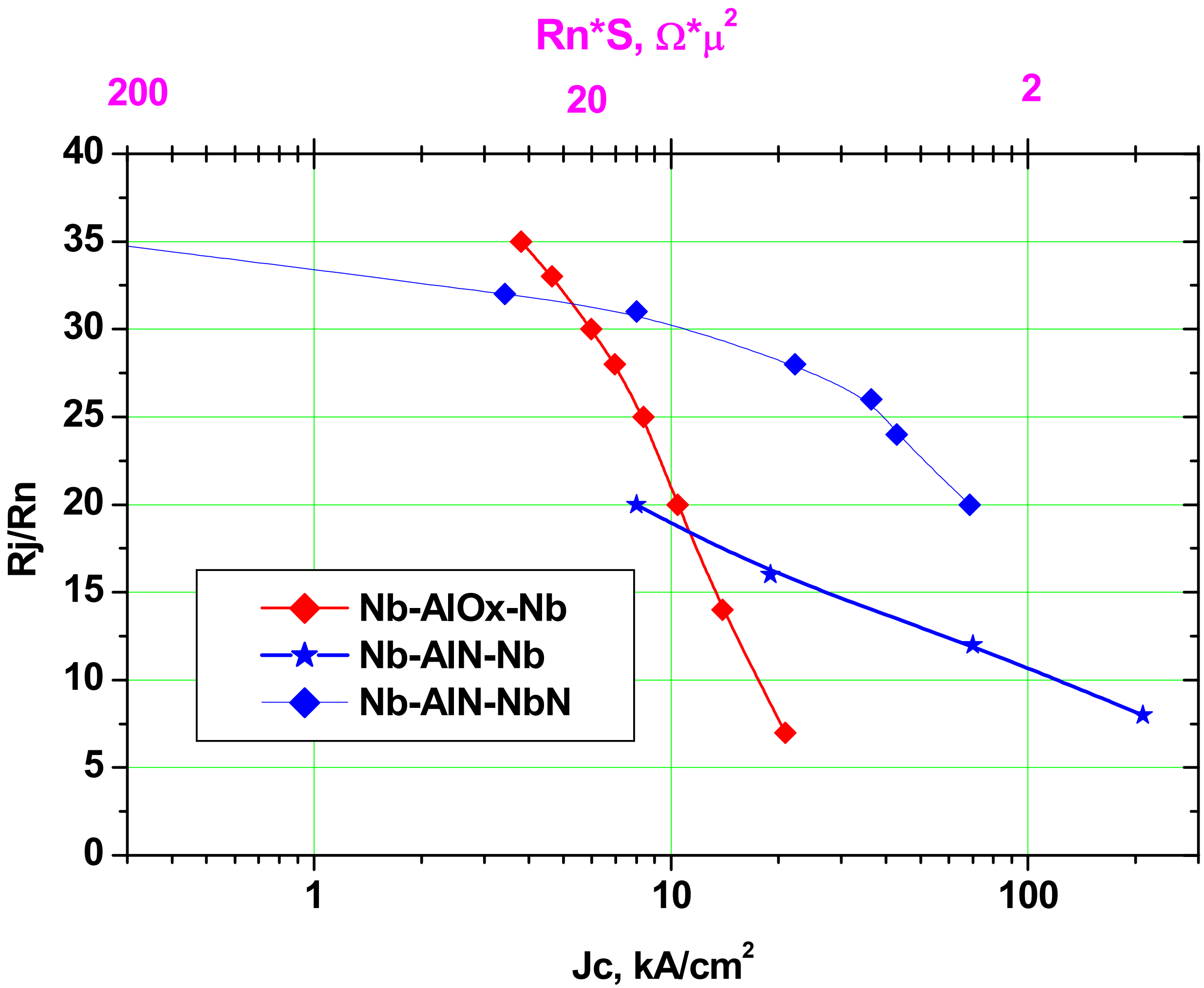
SIR Microcircuit for TELIS



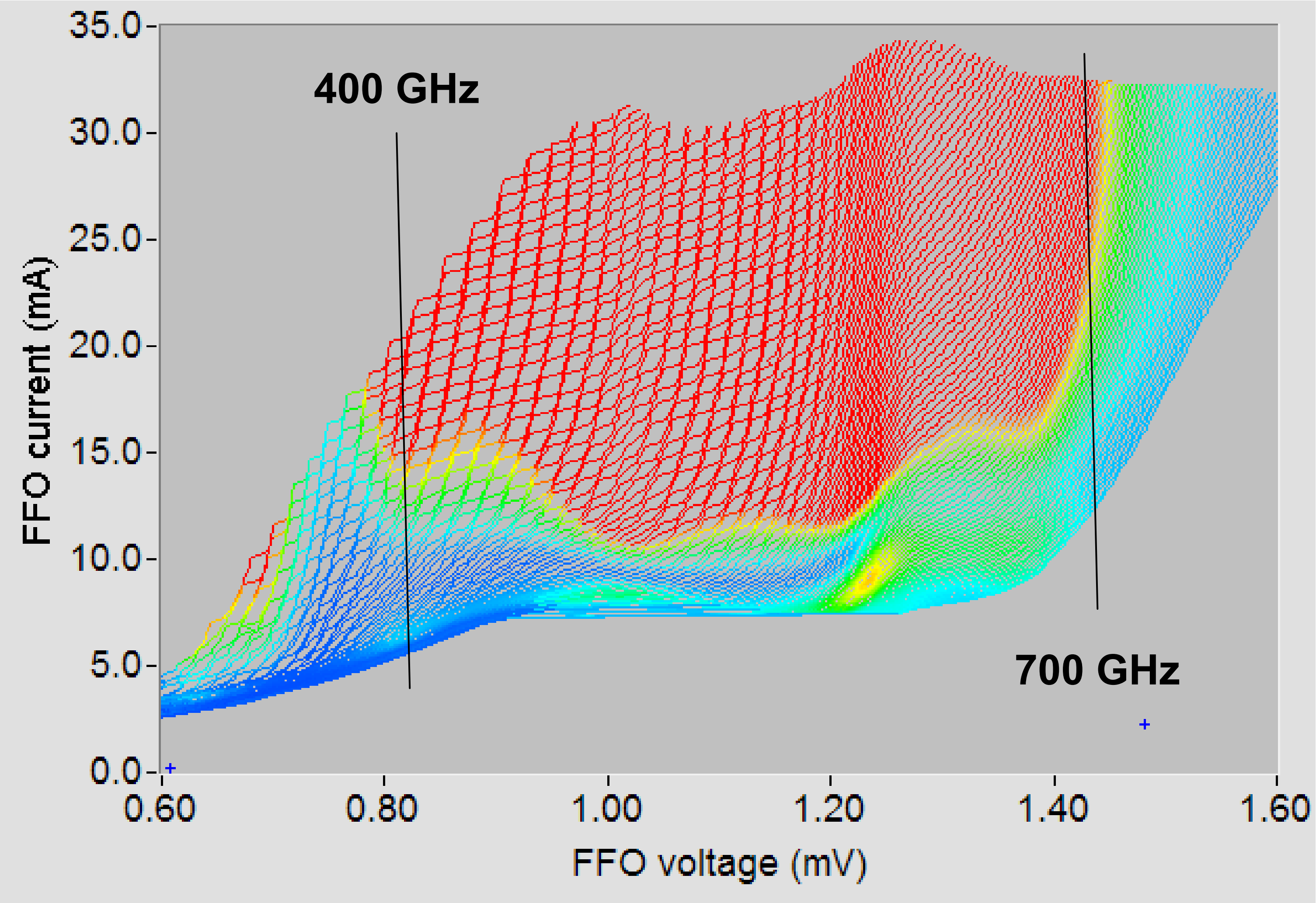
Nb-AlN-NbN or Nb-AlOx-Nb; Jc = 5 - 10 kA/cm^2

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

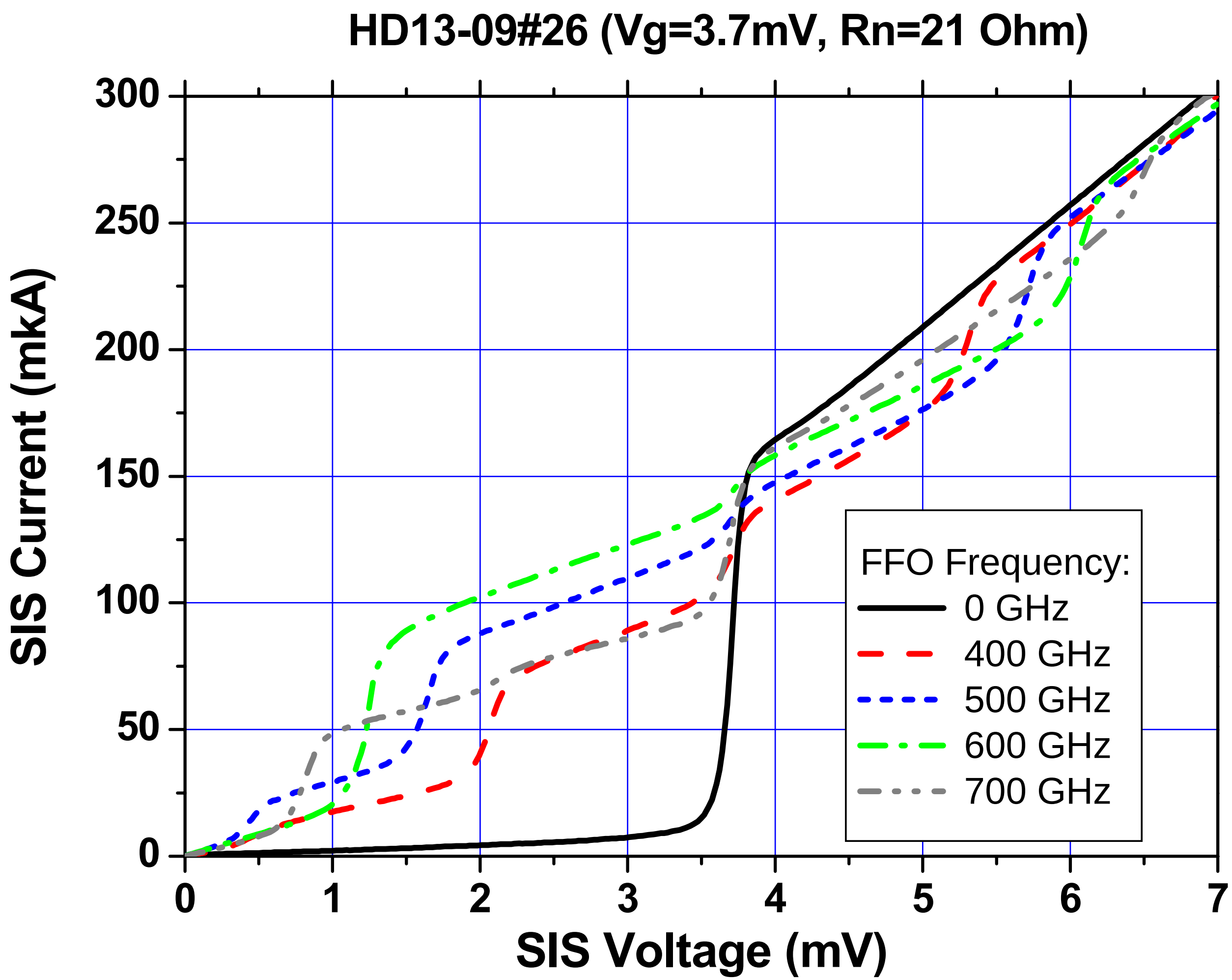
Quality of the AlOx and AlN tunnel barriers on the current density



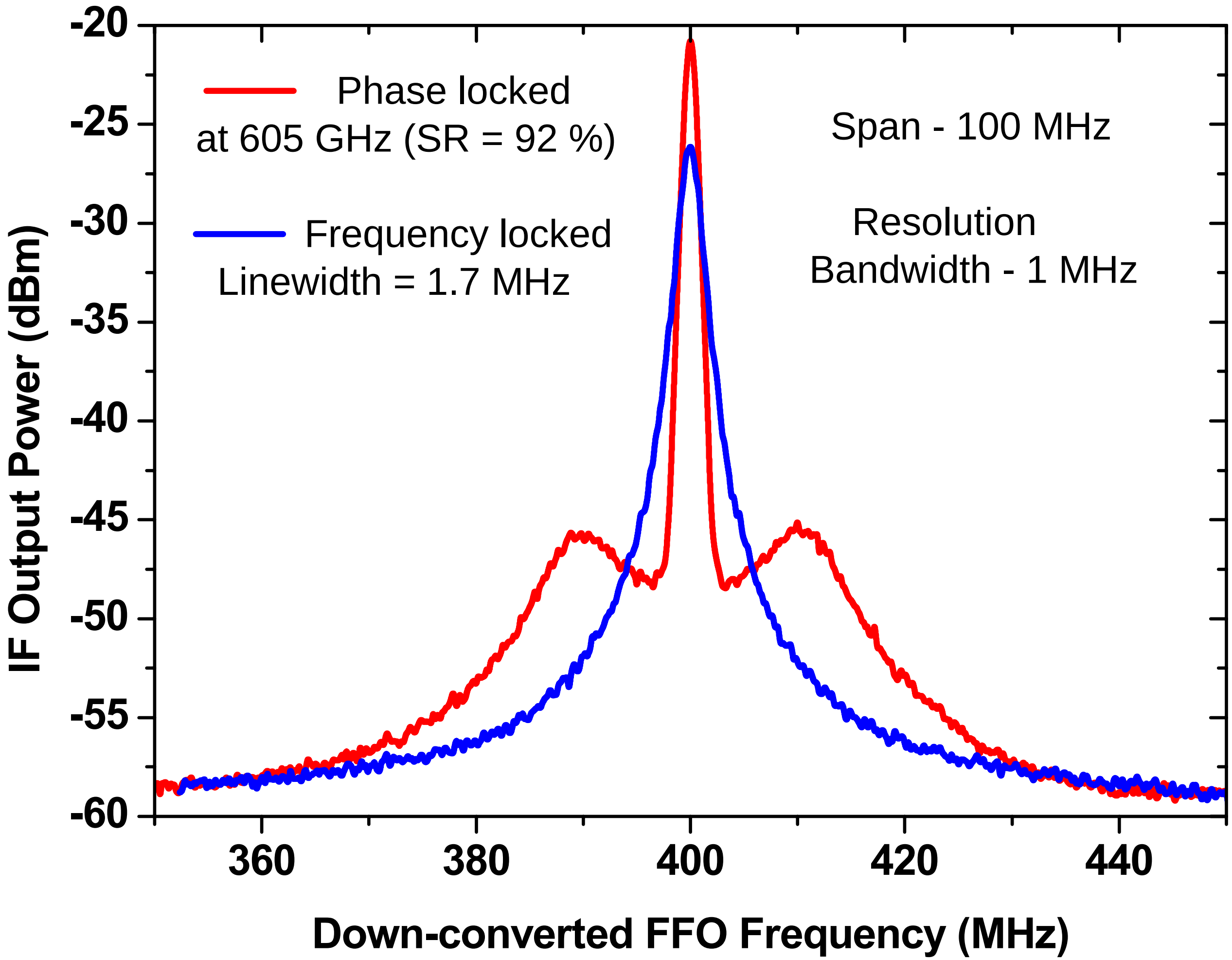
Nb-AlN-NbN SIR – new features



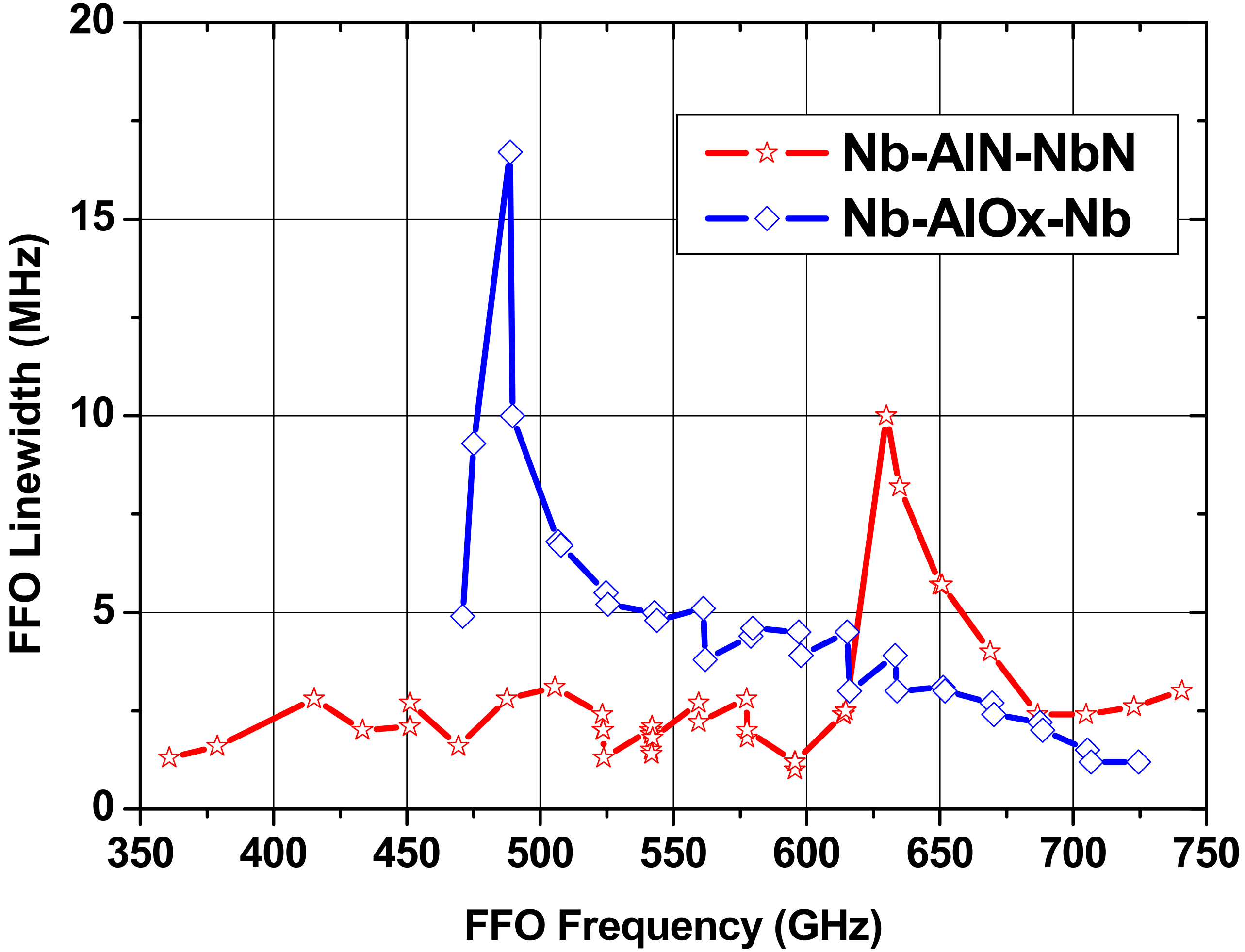
Nb-AlN-NbN SIS pumped by FFO; FFO frequency tuning



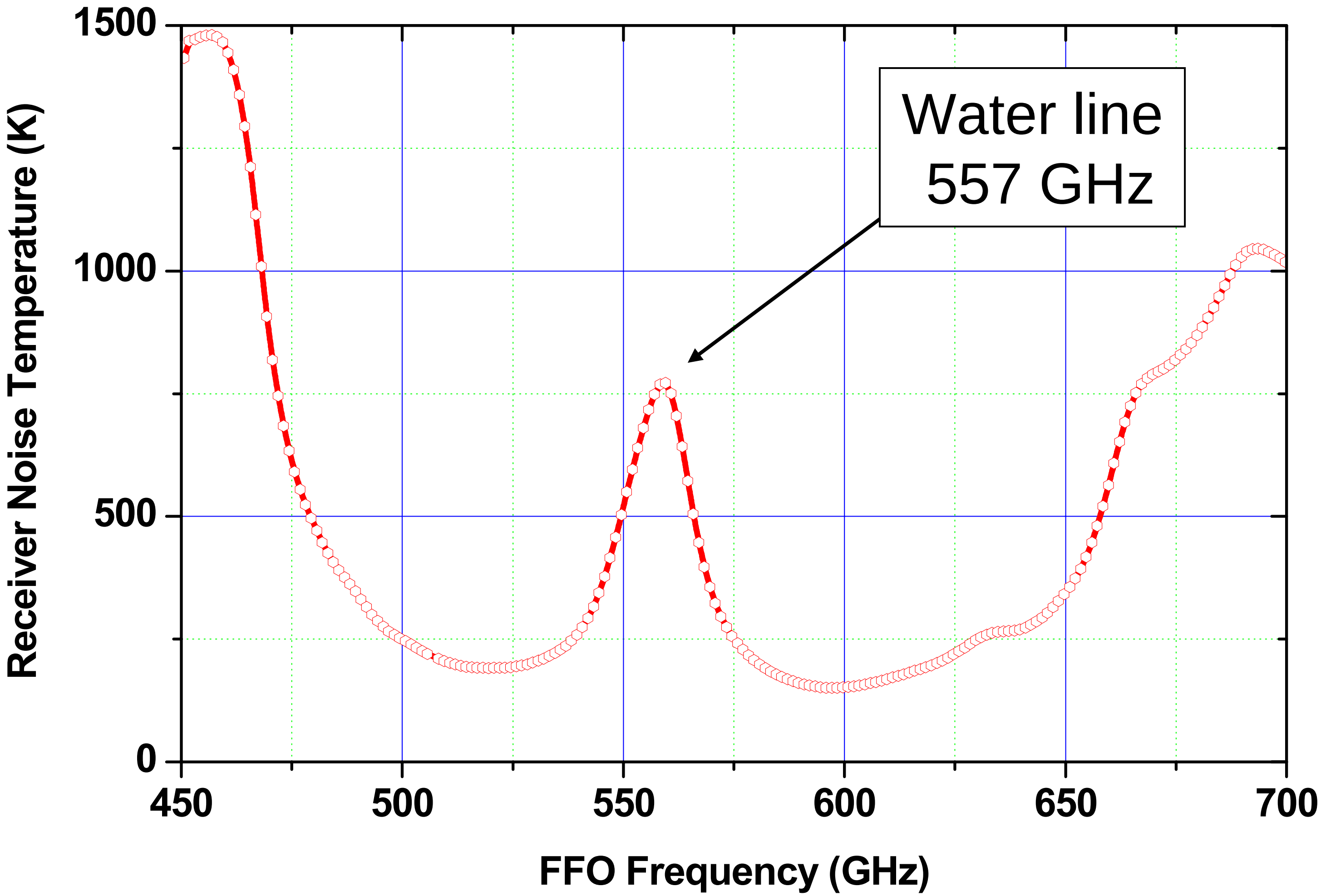
FL and PL spectra of the Nb-AlN-NbN FFO : frequency 605 GHz; LW = 1.7 MГц; SR = 92 %



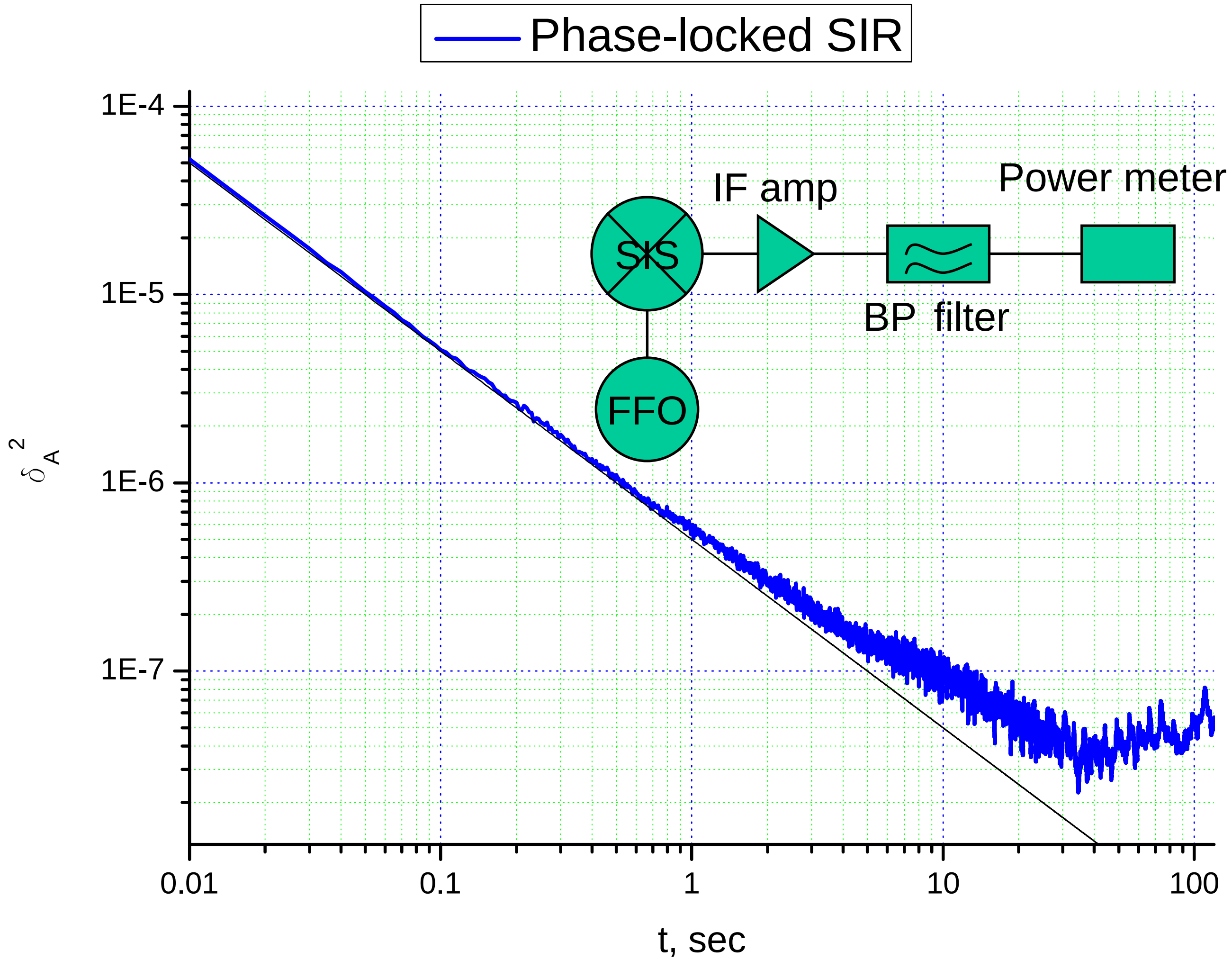
Frequency dependence of the FFO: Nb-AlOx-Nb and Nb-AlN-NbN circuits



Uncorrected Receiver Noise Temperature (DSB)

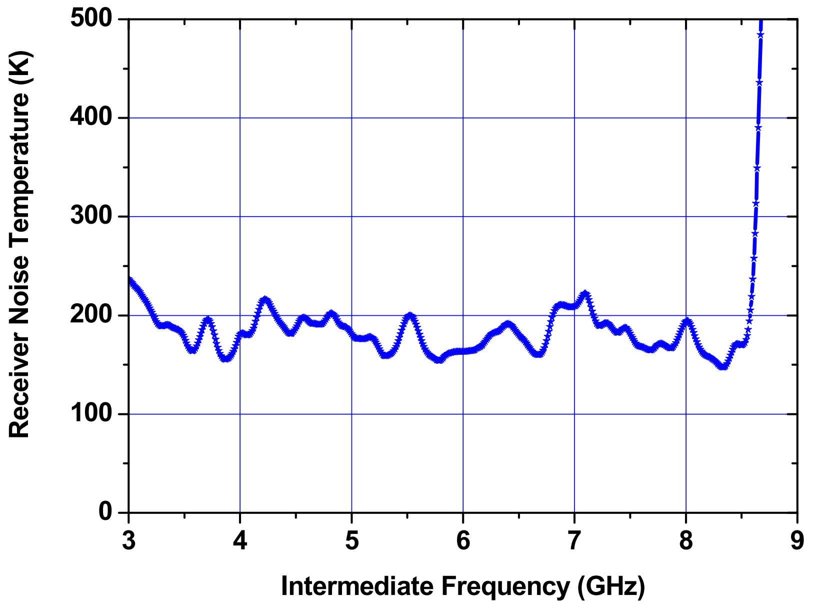


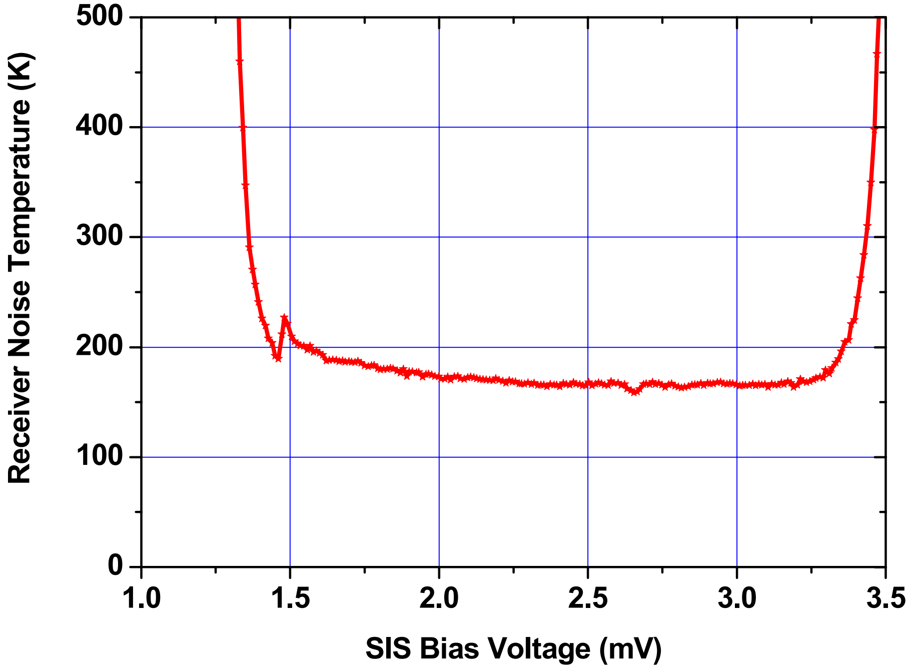
SIR Stability: Allan variance test



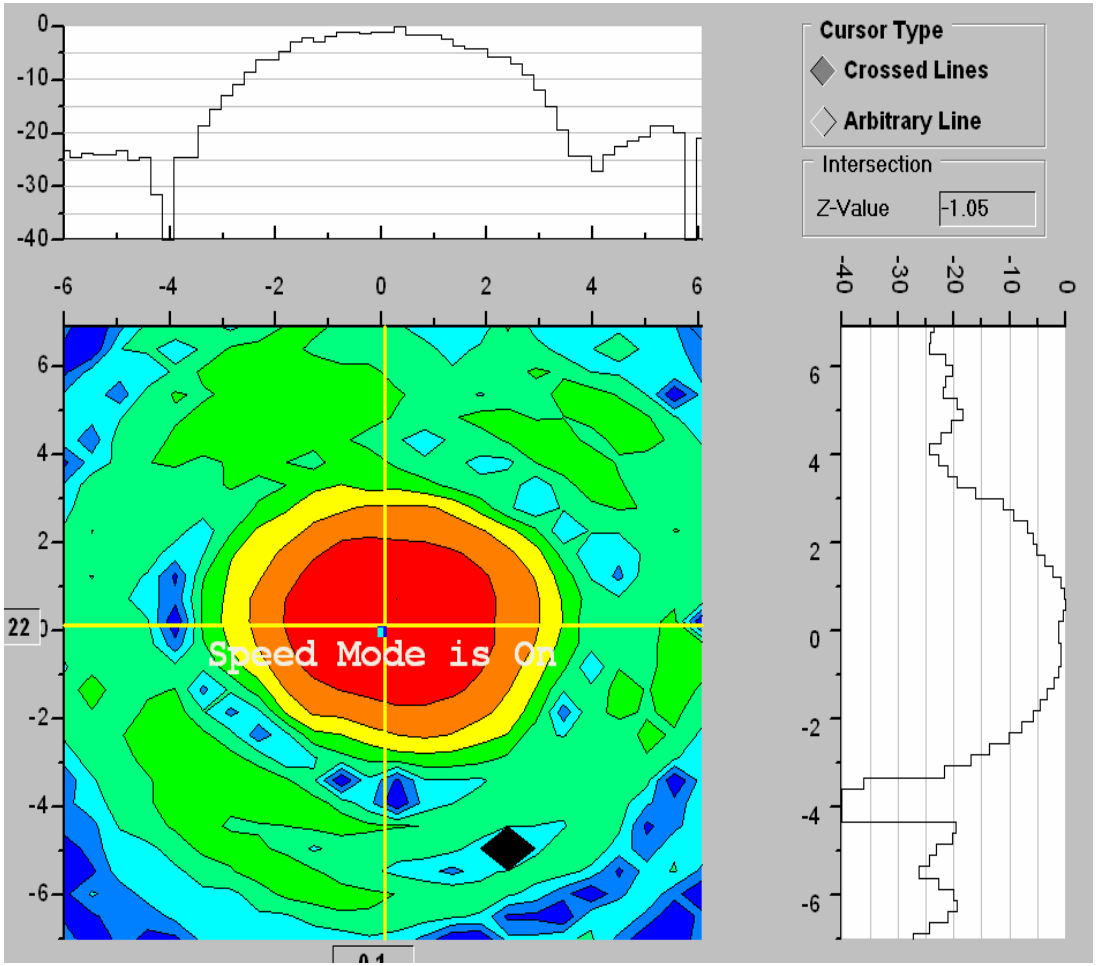
Wednesday, March 21, P. Yagoubov; Report P-7

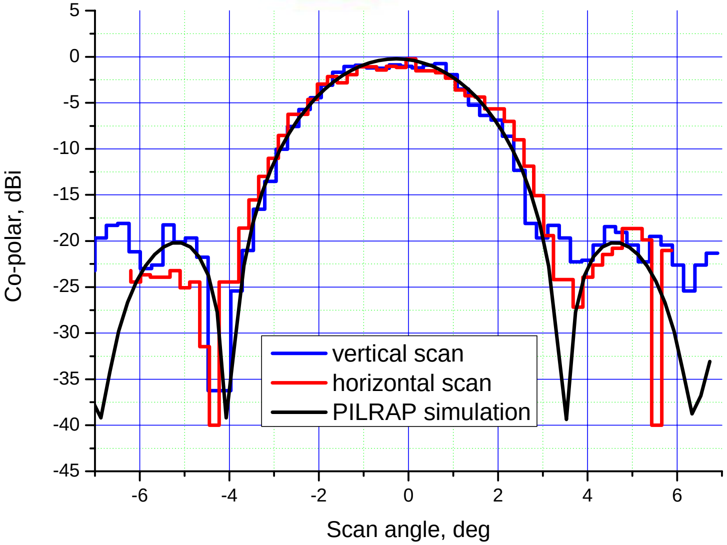
SIR Noise Temperature on Intermediate Frequency and SIS Bias





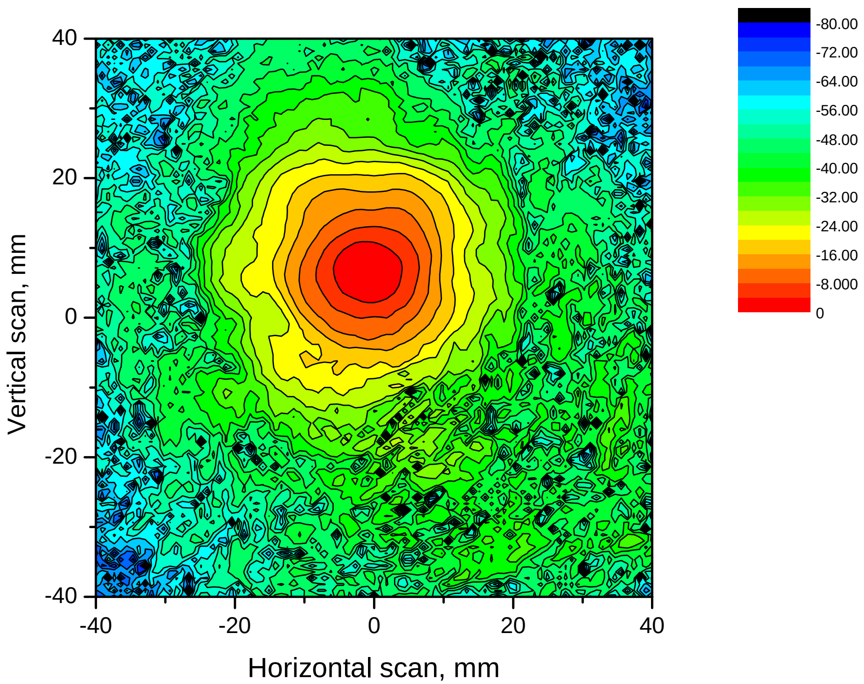
Antenna-Lens Beam Pattern of the SIR at 625 GHz

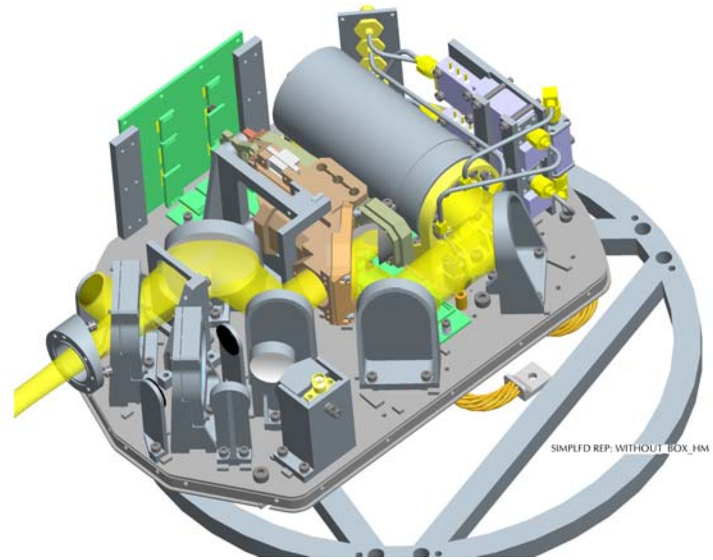


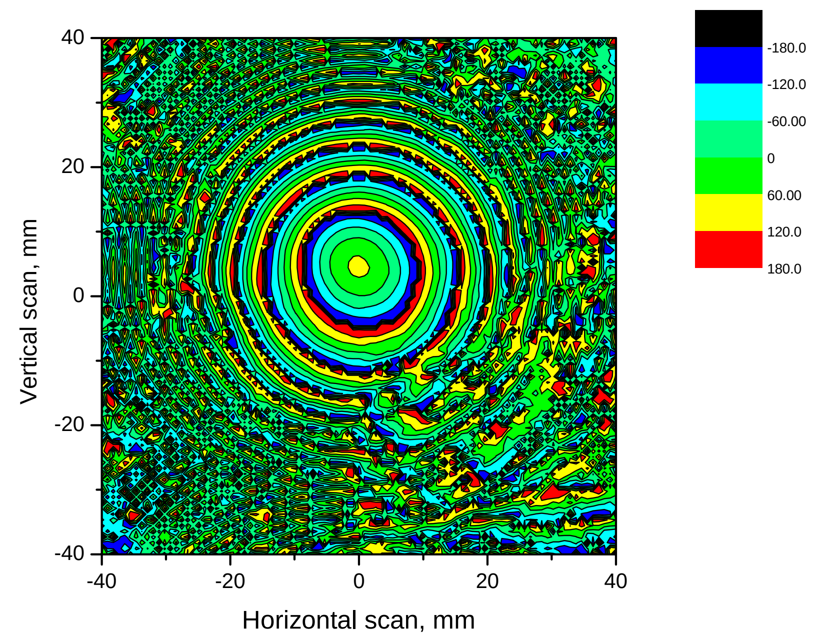


Wednesday, March 21, P. Yagoubov; Report P-7

Amplitude and phase APB of the SIR with cold optics



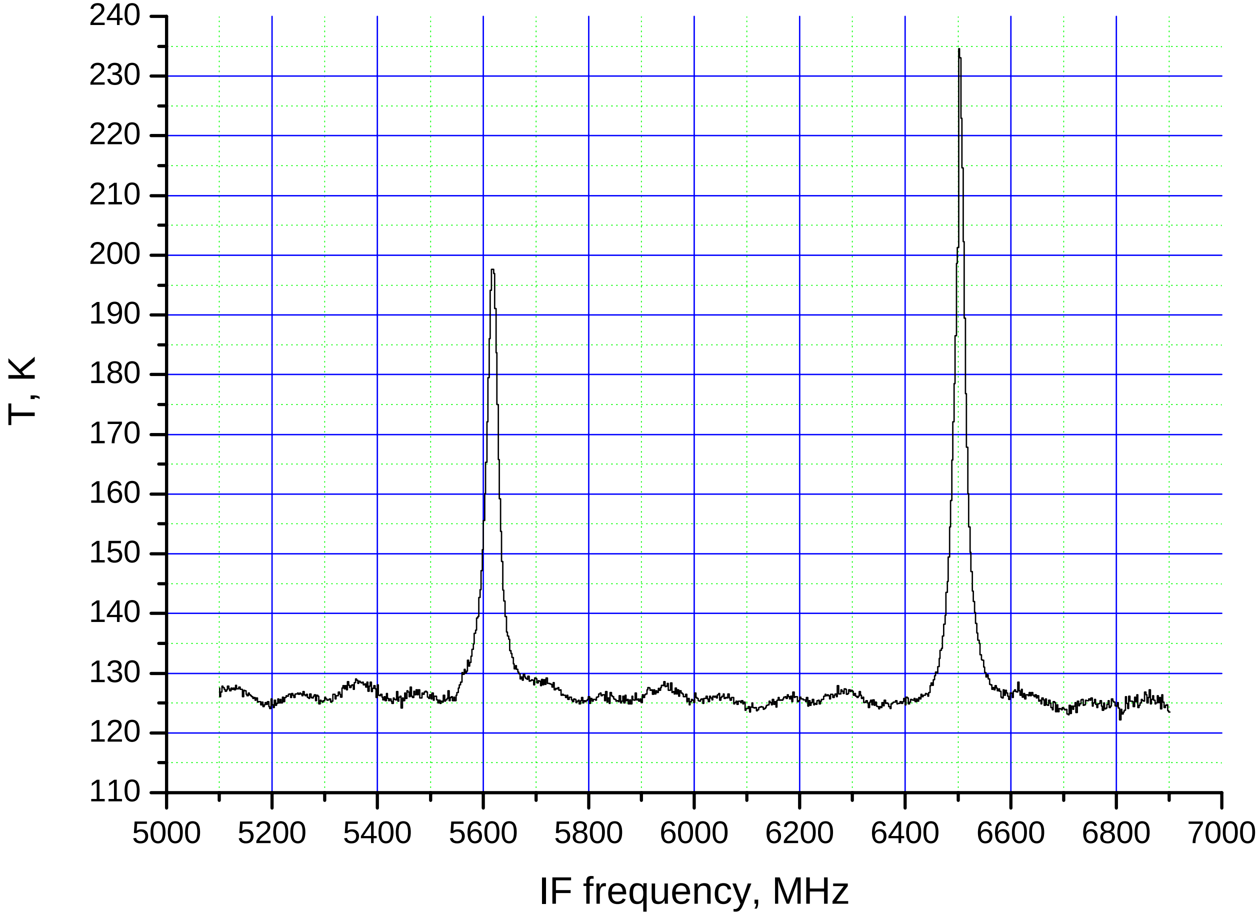




Wednesday, March 21,

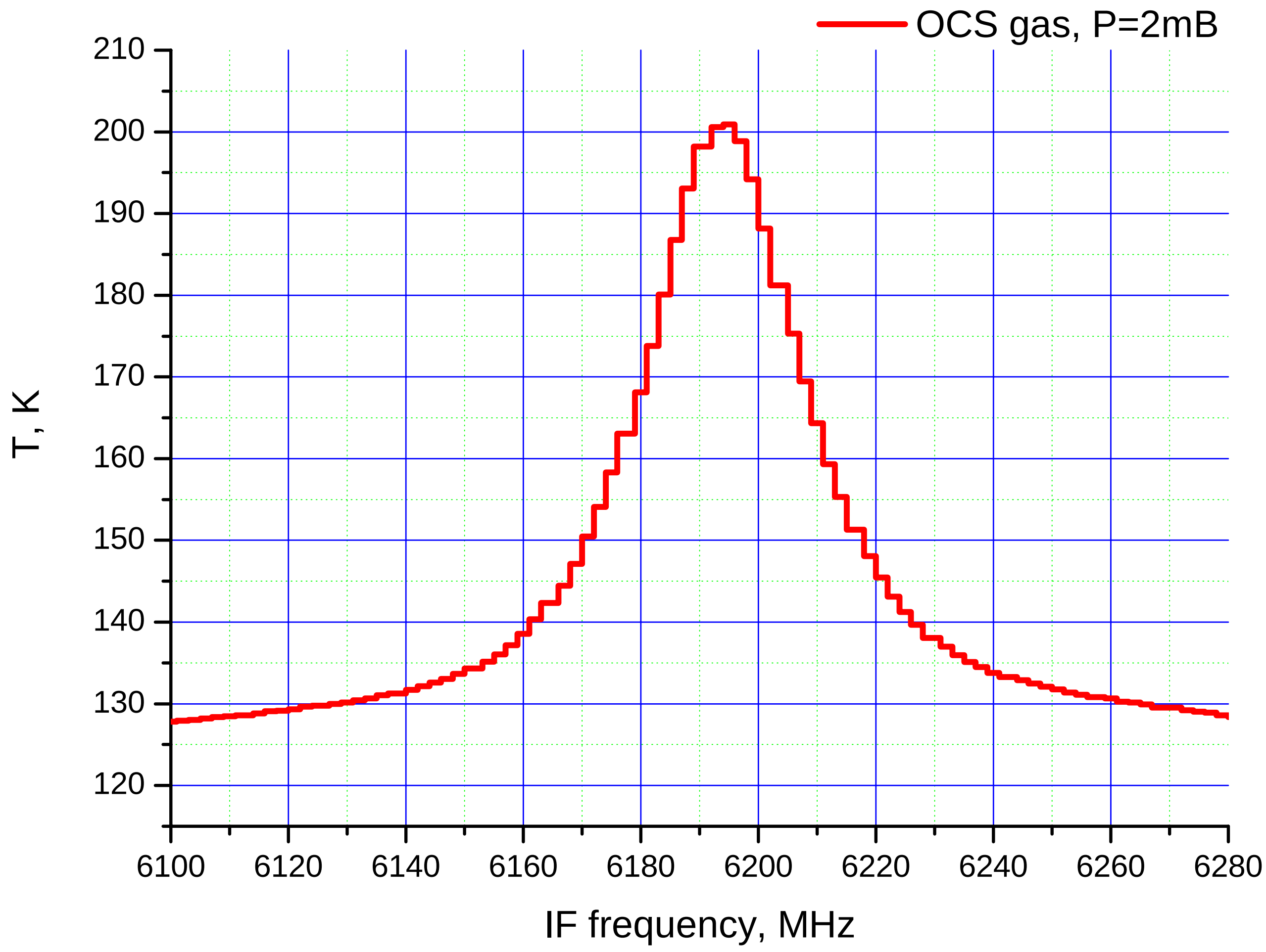
P. Yagoubov; Report P-7

Deconvolved spectrum of two OCS emission lines (gas pressure 1.2 mBar; FFO frequency 625.24 GHz)



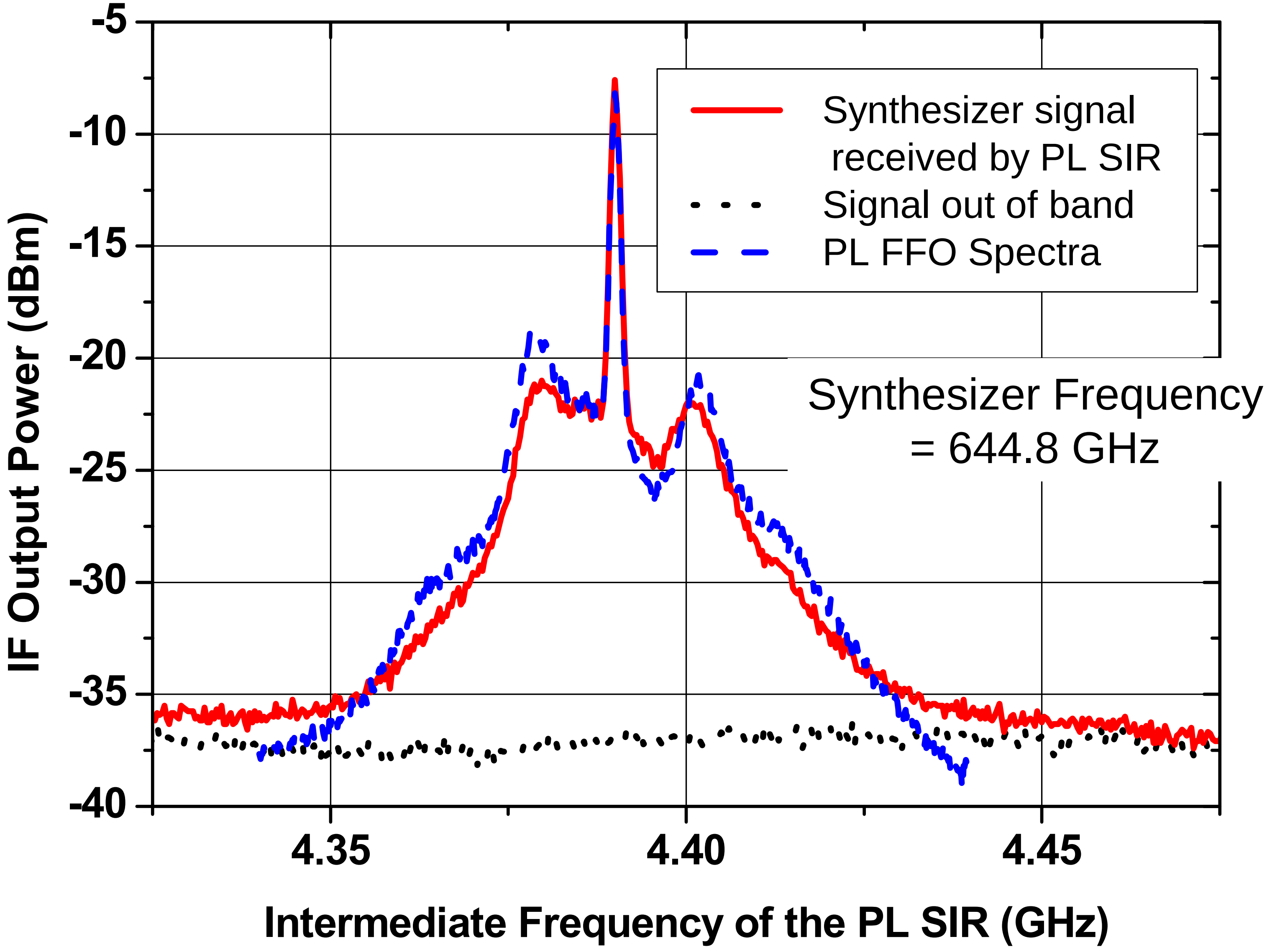
Wednesday, March 21, P. Yagoubov; Report P-7

Gas cell measurements; resolution determined by DAC



➡ ***Wednesday, March 21, P. Yagoubov; Report P-7***

Phase locked FFO; spectral resolution < 1 MHz



Conclusion

- Concept of the Phase-locked SIR is developed and tested.
- Nb-AlN-NbN FFO and SIR have been successfully tested.
- Improved design of the FFO for TELIS has been developed and optimized; free-running linewidth from 2 to 10 MHz recorded in the frequency range 350 – 740 GHz that allows to phase lock from 35 up to 90 % of FFO power.
- 3-rd generation of the PL SIR for TELIS has been developed showing a possibility to realize TELIS requirements:
  Frequency range 500 – 650 ГГц;
  Noise Temperature 150 К (DSB, min);
  IF bandwidth 4 - 8 ГГц;
  Beam Pattern - FWHM = 3 deg, with sidelobes < - 17 dB;
  Spectral resolution better 1 МГц.
- Procedure for remote optimization of the PL SIR operation has been developed and experimentally proven.
- First TELIS flight is scheduled on November 2007