Cryogenic Phase Detector for Superconducting Integrated Receiver

Andrey Khudchenko, Valery Koshelets, Pavel Dmitriev
Andrey Ermakov

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

Pavel Yagoubov

SRON Netherlands Institute for Space Research, the Netherlands

in collaboration with Oleksandr Pylypenko

State Research Center of Superconducting Electronics "Iceberg", Kyiv, Ukraine

Superconducting Integrated Receiver (SIR)

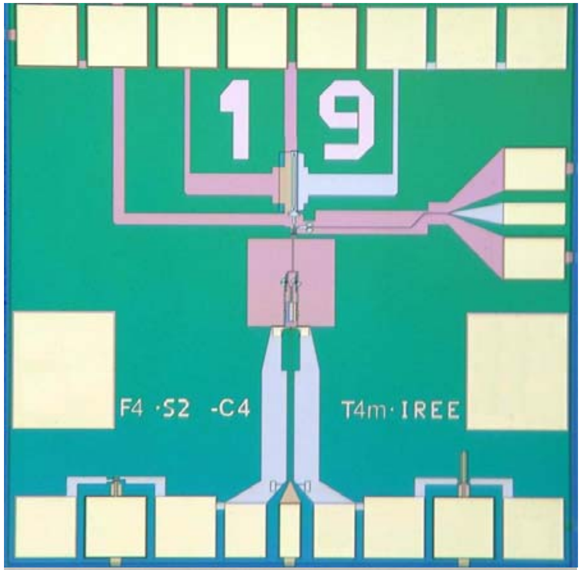
APPLICATIONS

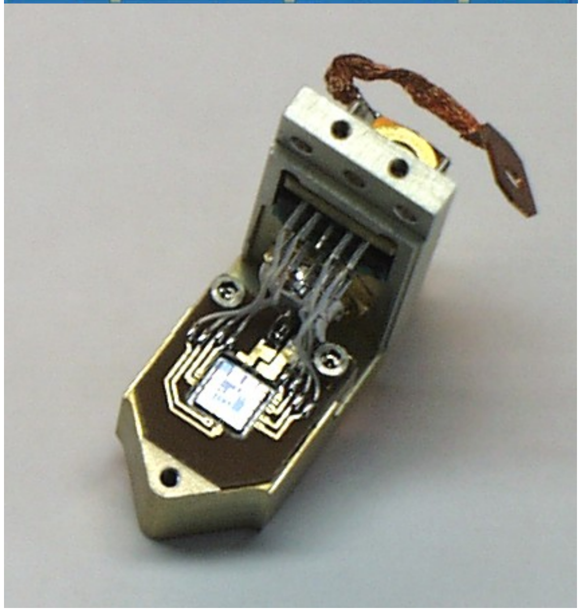
- **Airborne Receiver for Atmospheric Research and Environmental Monitoring; Radio Astronomy**
- **Large Imaging Array Receiver**
- **Laboratory MM & subMM Spectrometer**

STATE OF THE ART

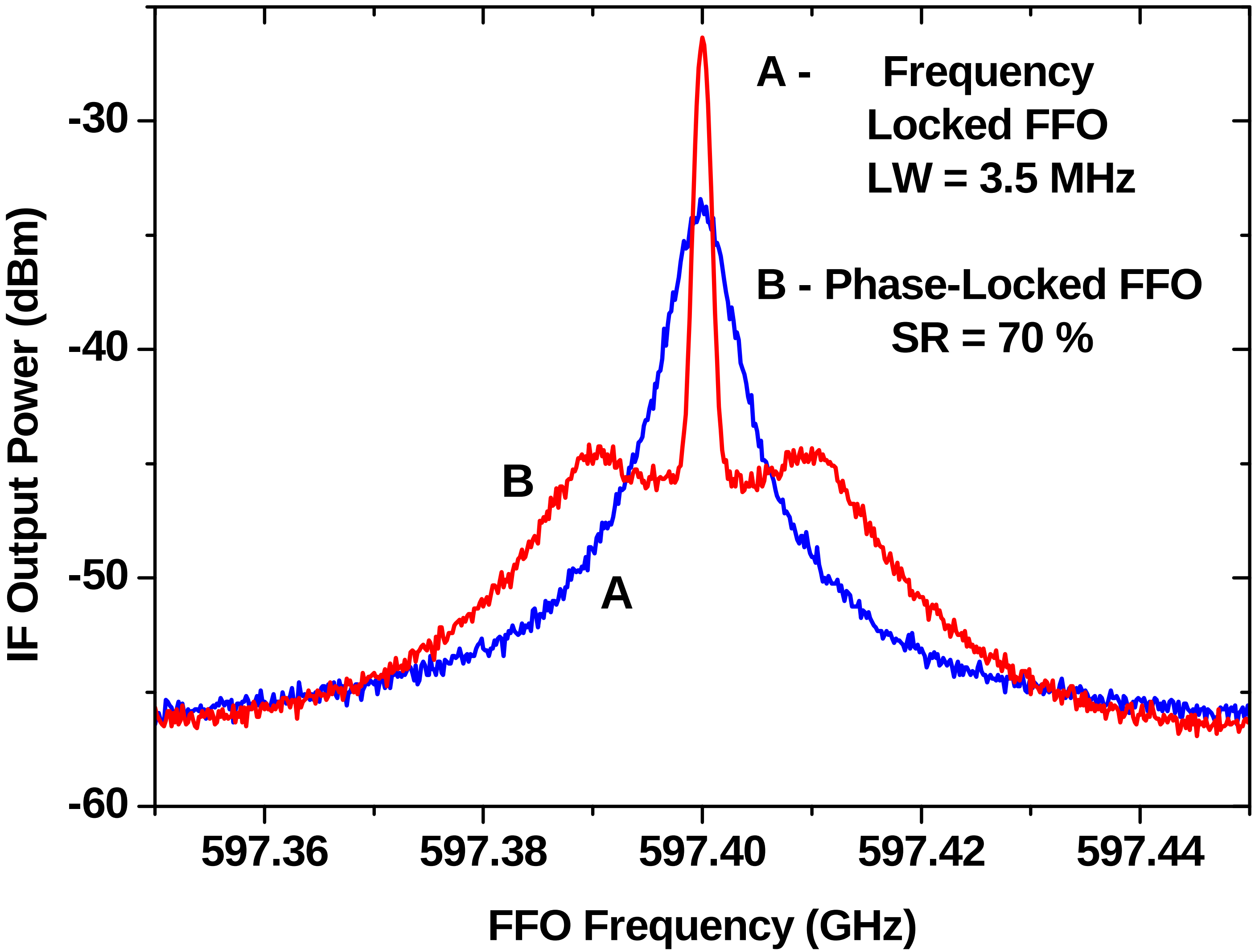
- **Single chip Nb-AlOx-Nb SIS receivers with superconducting FFO has been studied at frequencies from 100 to 700 GHz**
- **A DSB receiver noise temperature as low as 100 K has been achieved at 500 GHz**
- **9-pixel Imaging Array Receiver has been successfully tested**
- **Phase Locked operation from 550 to 700 GHz**
- **TELIS - balloon-borne spectrometer, the qualification flight is foreseen in 2007**

→ ***Tuesday, August 29, 4:00pm; Report 2EY01***

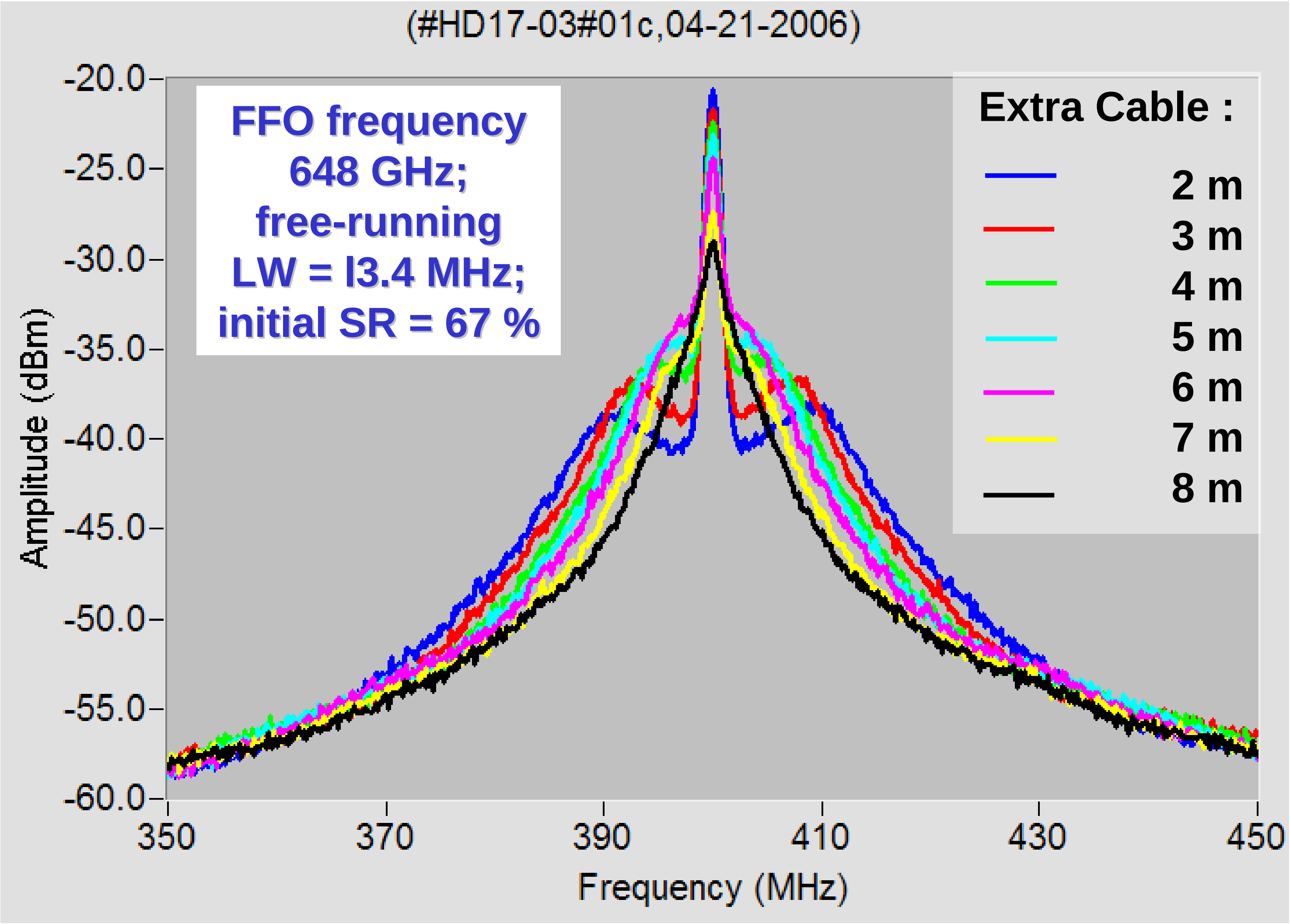




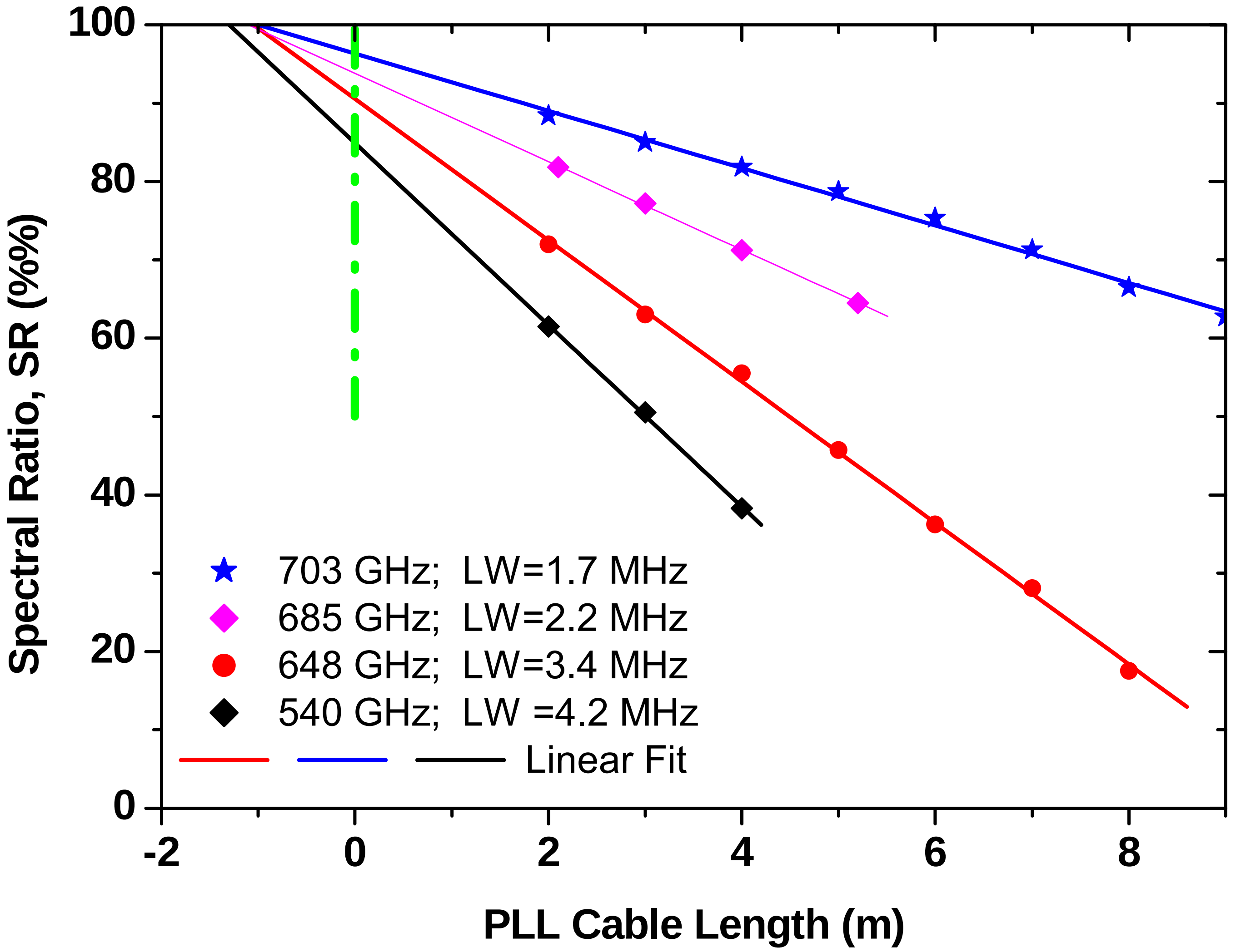
Spectra of the Frequency and Phase Locked FFO



Spectra of the phase-locked FFO for different length of the PL loop

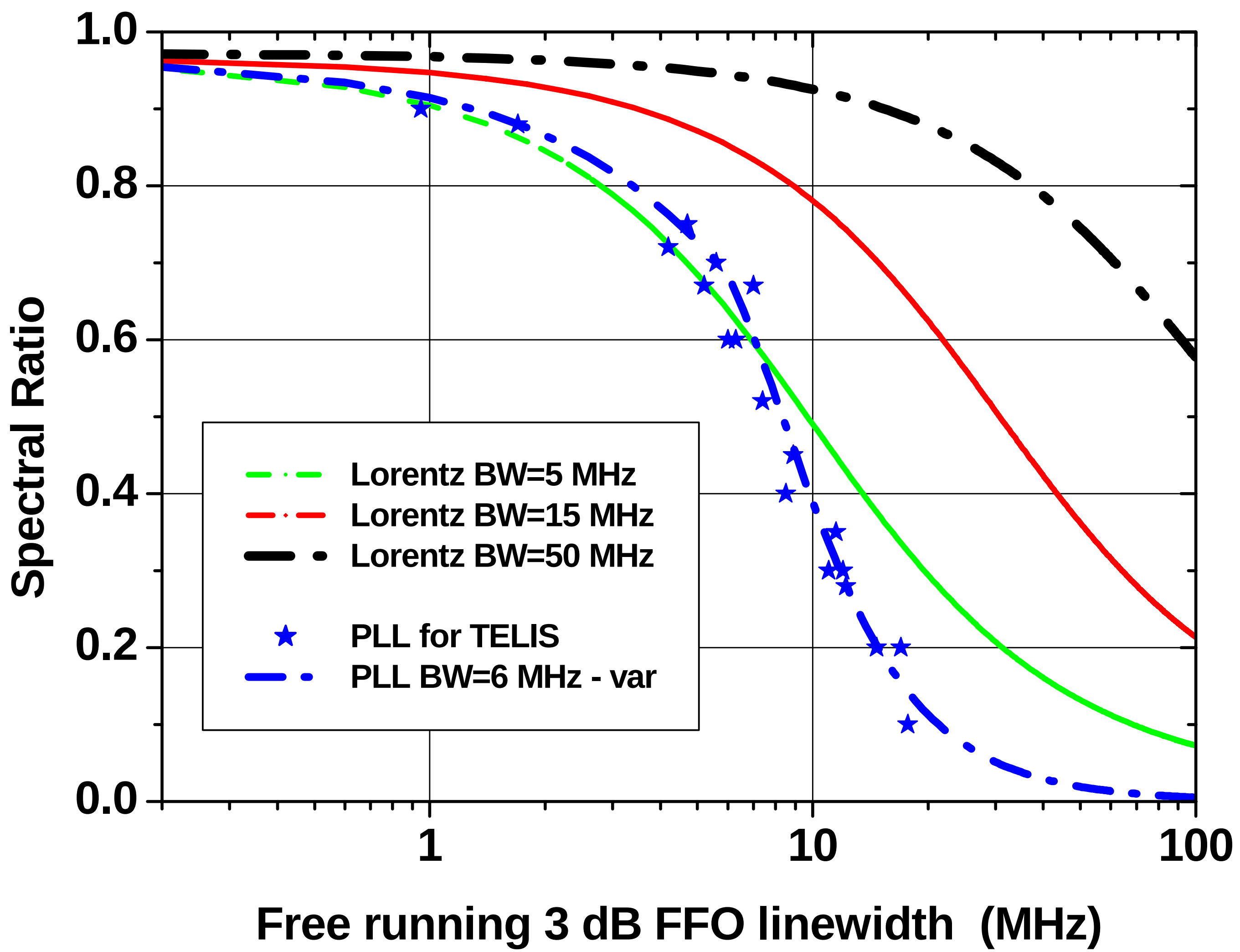


SR value on the length of the extra cable added to the PL loop



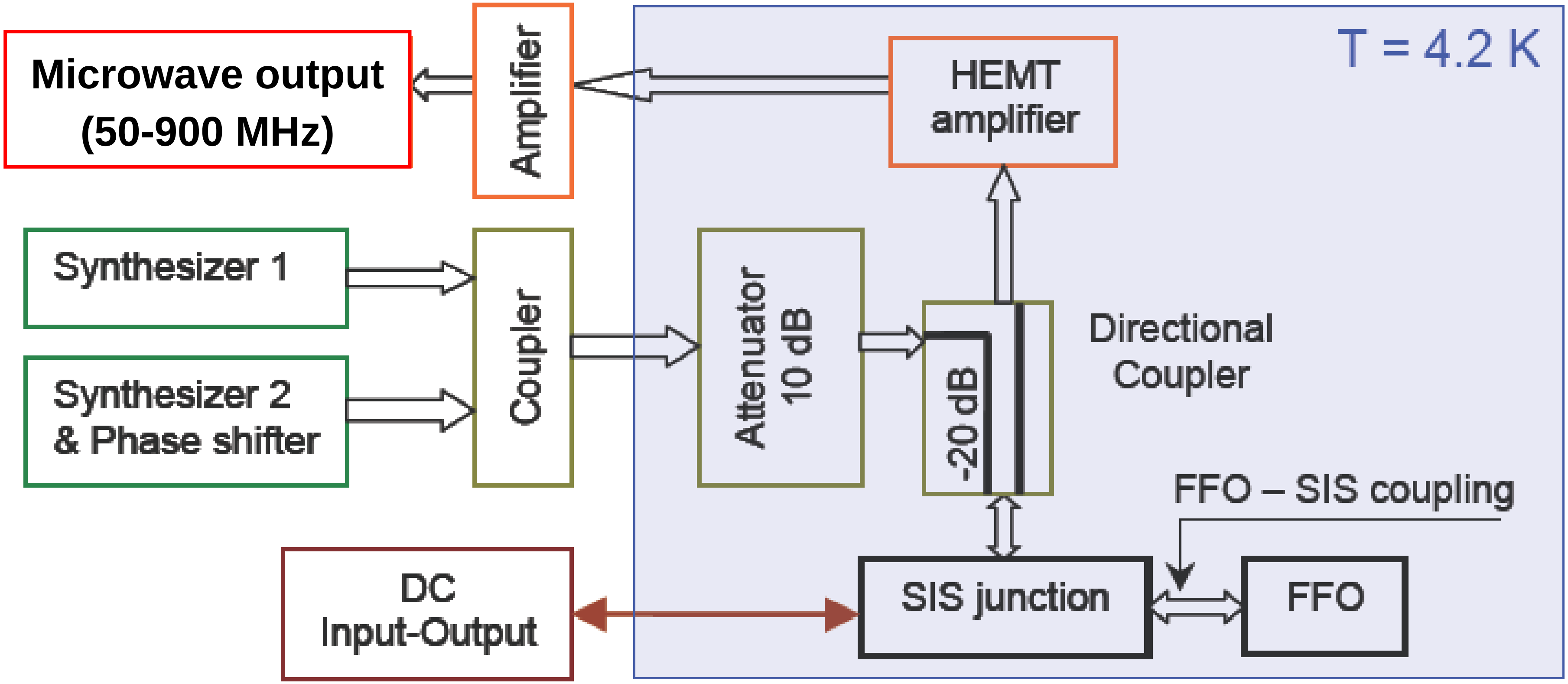
Min PLL cable length is 2 m

Ratio of PL and total FFO power (SR) on FFO LW



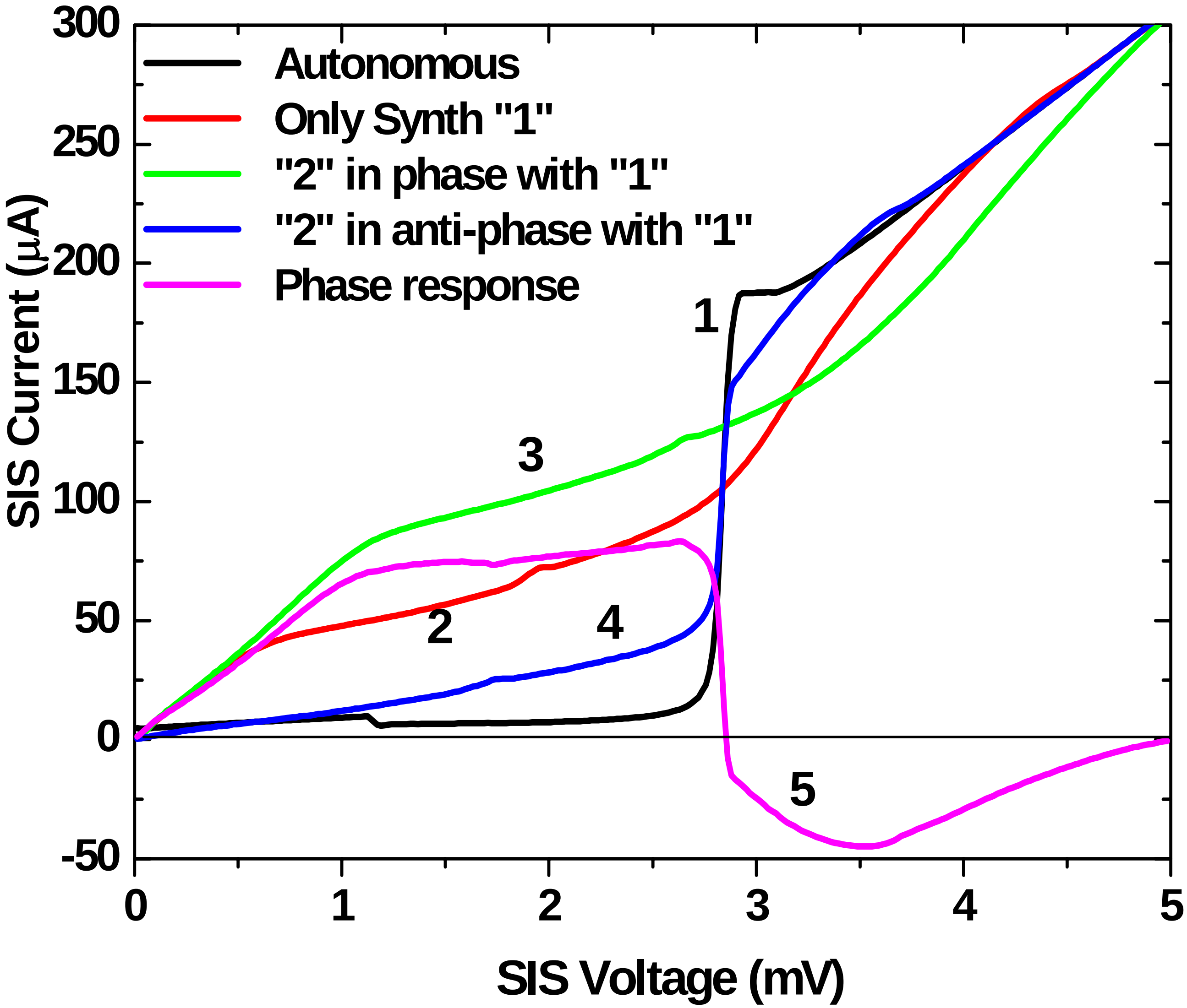
Block-diagram
for the Cryogenic Phase Detector Tests

f1, f2 = 0.5 ÷ 5 GHz



Nb-AlOx-Nb; $S_{SIS} = 1 \div 2\ \mu m^2$

SIS IVCs at difference settings of two synthesizers

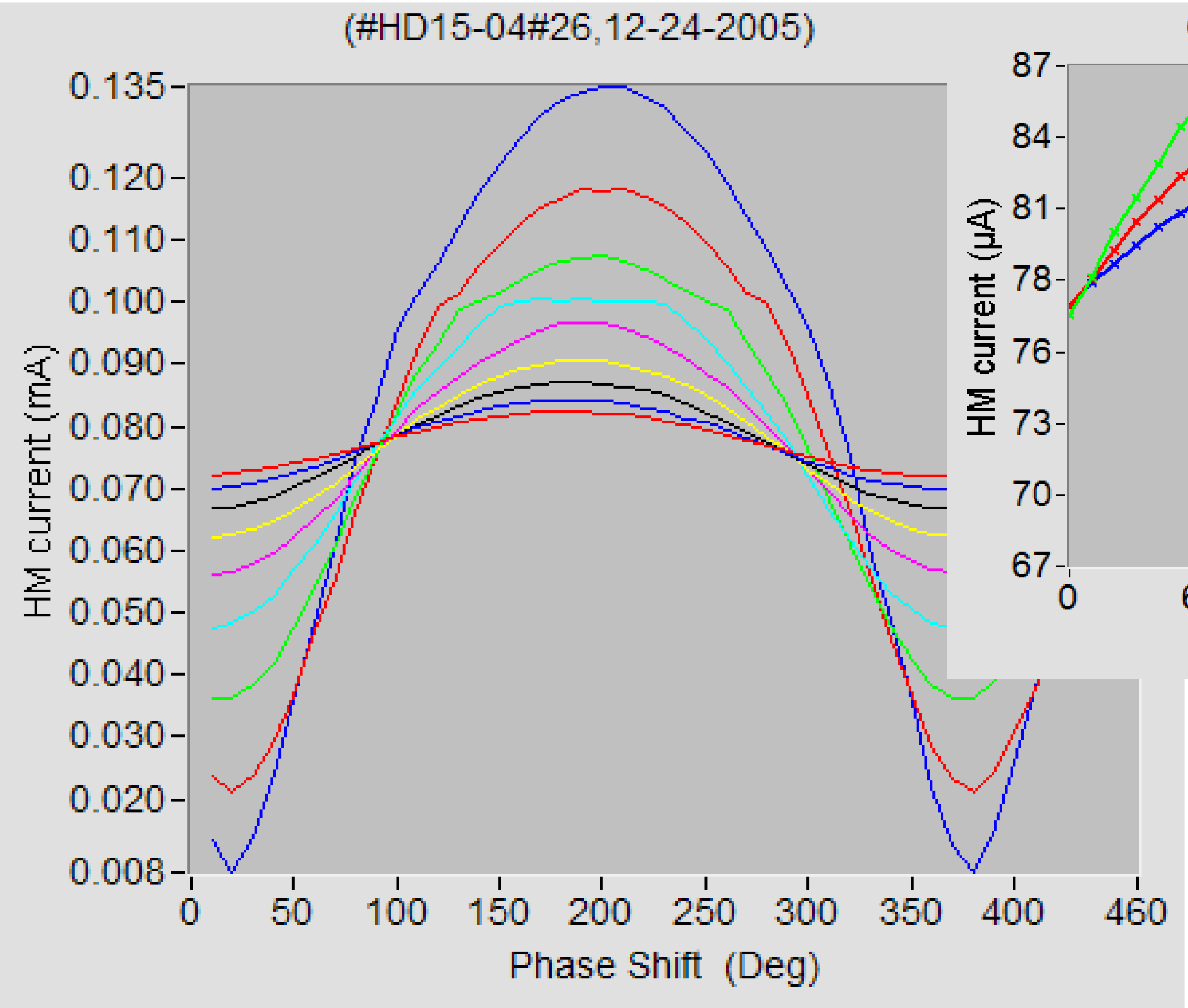


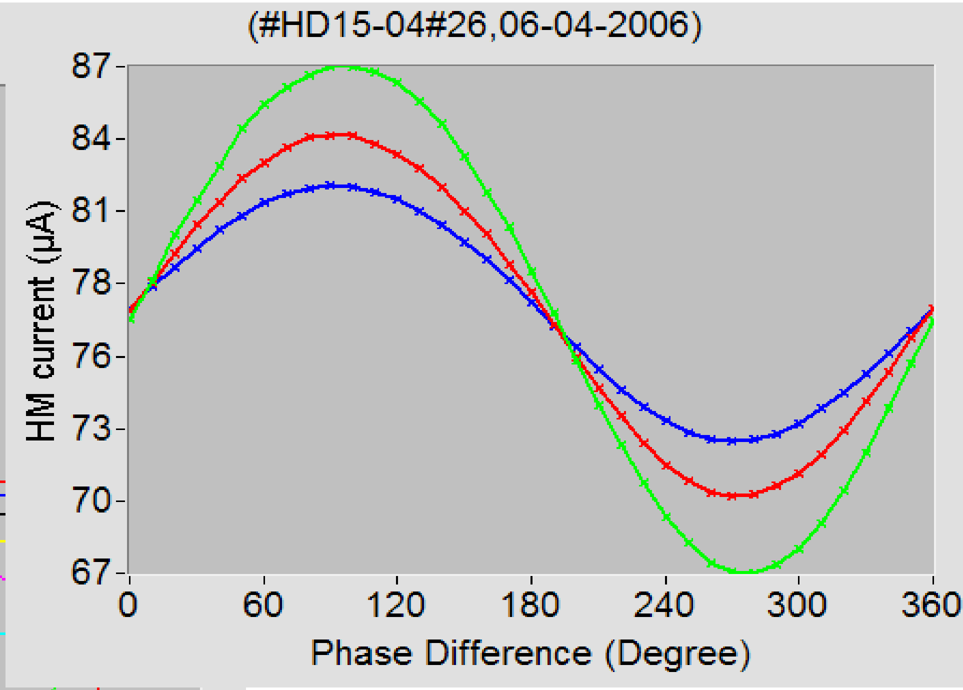
SIS $I_C = 0$

Frequency
5 GHz

P1 = 0.3 μ W
P2 = 0.1 μ W

Dependence of SIS current on the phase difference between two 5 GHz signals



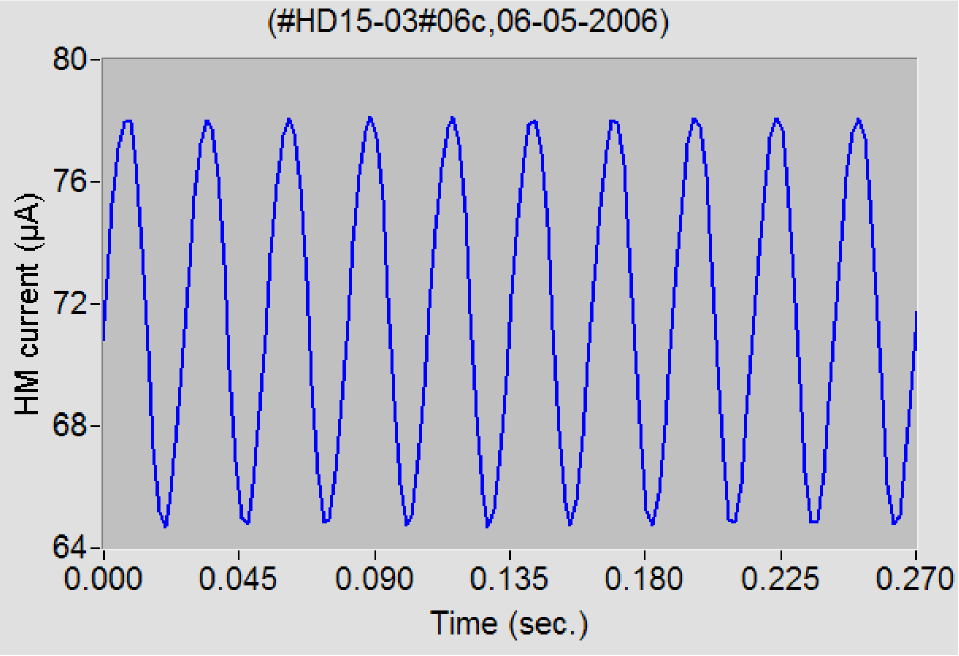


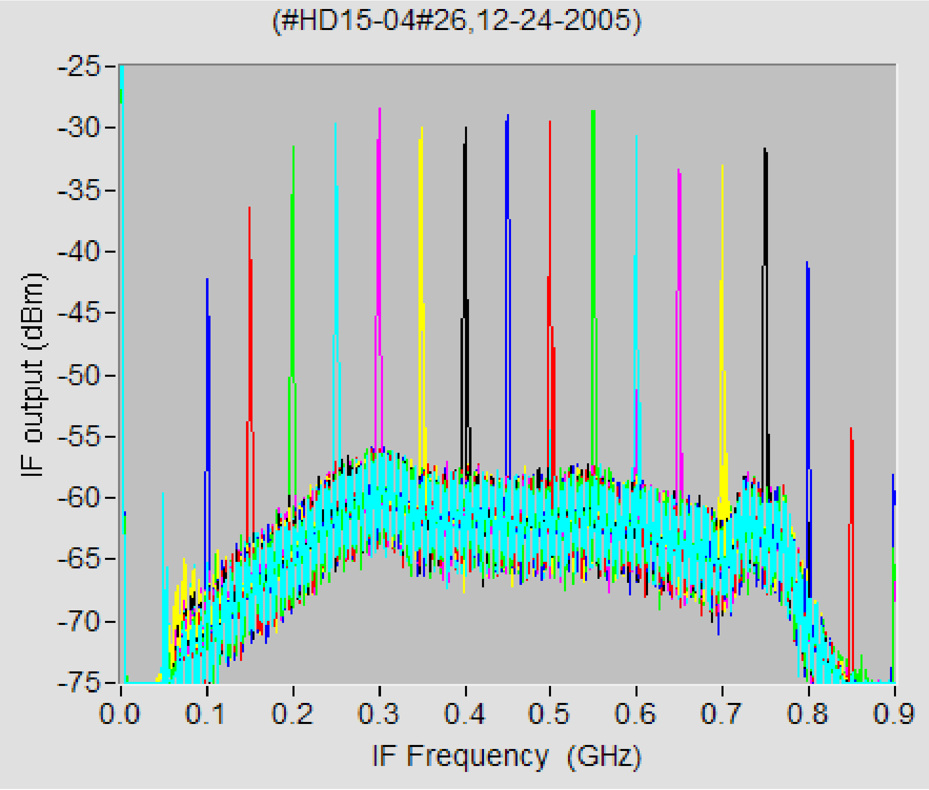
Vsis = 2.55 mV
Ig = 0.15 mA

SIS Phase Detector output at DC and IF; two different frequencies applied

f1 = 5 GHz; f1 - f2 = 37 Hz

f1 - f2 = 0 ÷ 1000 MHz





Vsis = 2.55 mV

SIS current vs. applied power

Total power P applied to the SIS is a coherent combination of incident signals:

$$P = P1 + P2 + 2\sqrt{P1P2}\cos\varphi,$$

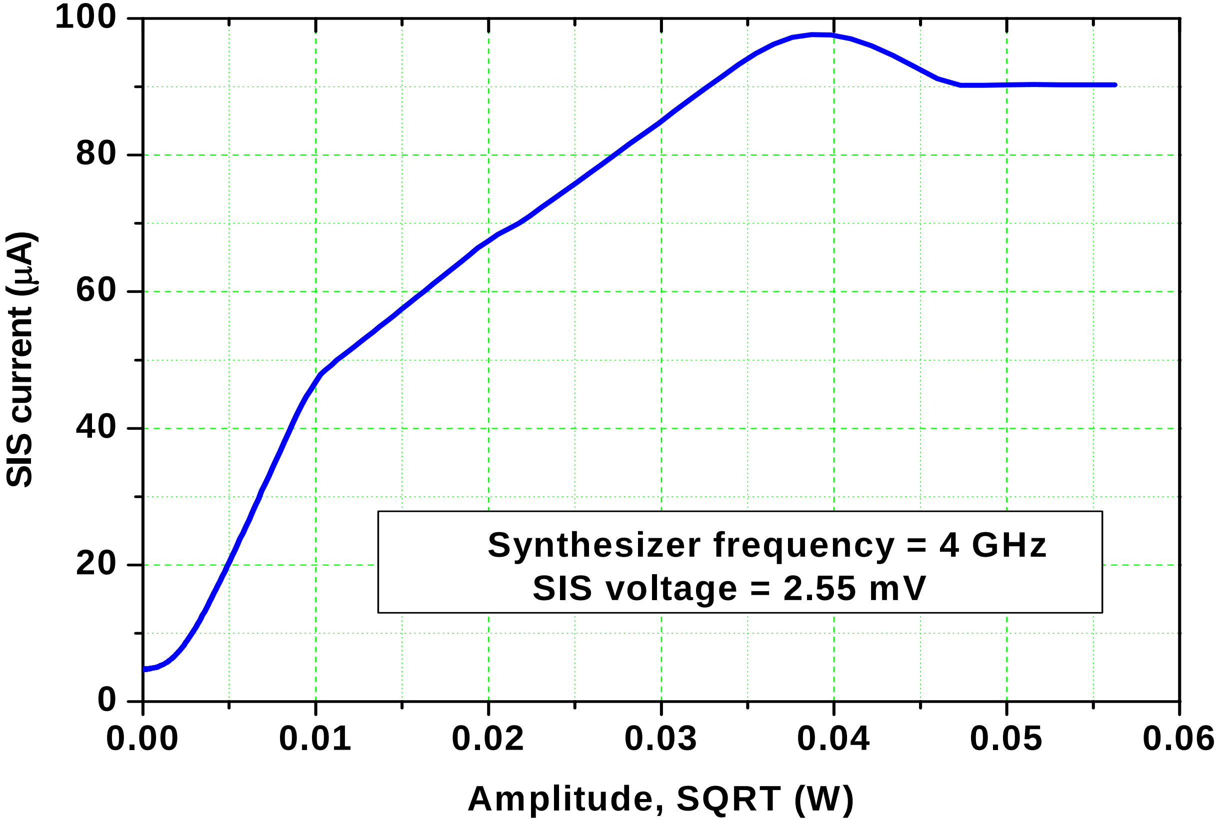
φ – phase difference between two signals

In-phase:

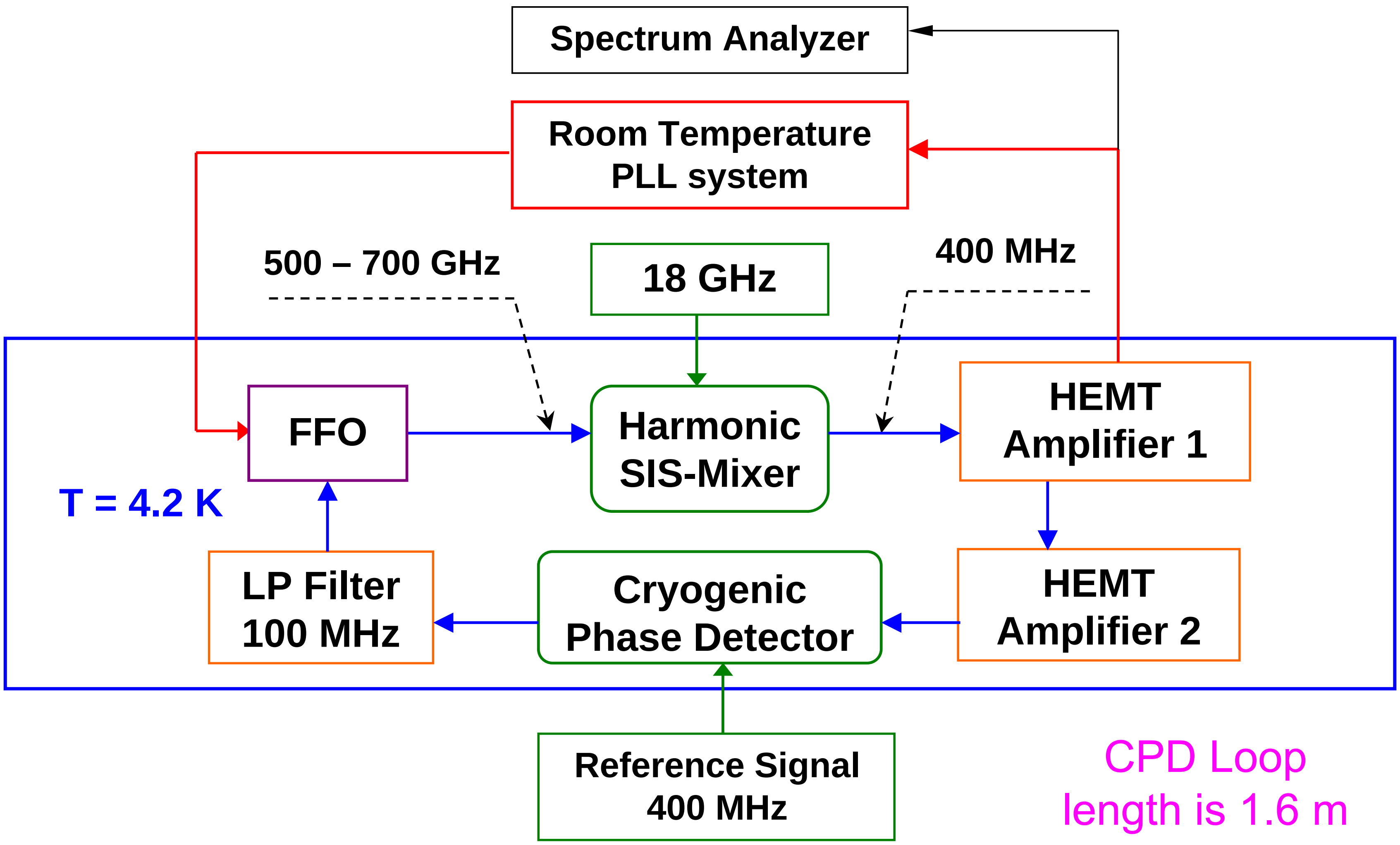
$$\sqrt{P(\varphi=0)} = \sqrt{P1} + \sqrt{P2}$$

In anti-phase:

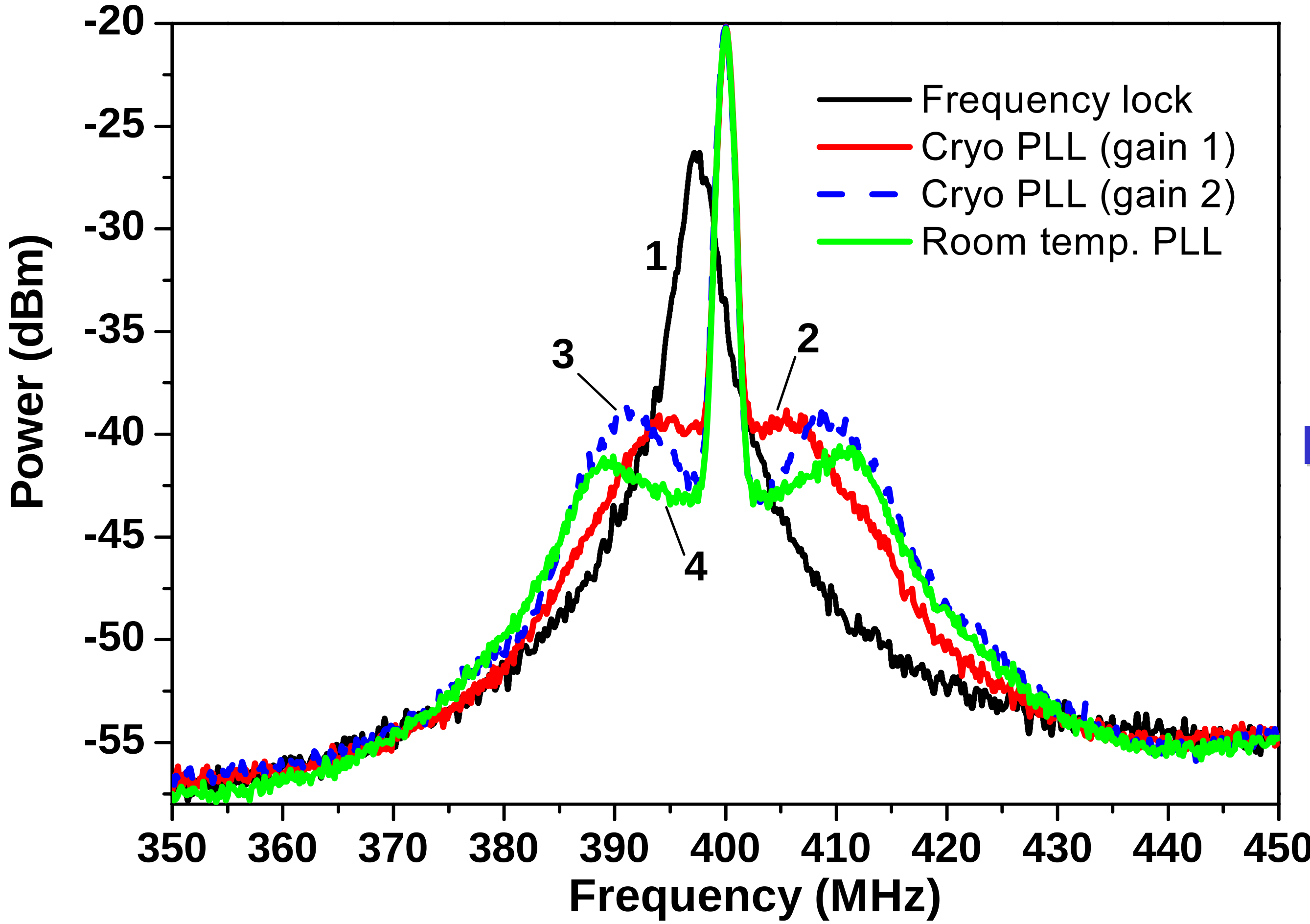
$$\sqrt{P(\varphi=180^\circ)} = \sqrt{P1} - \sqrt{P2}$$



Block diagram of the setup for CPD/FFO test



Down-converted spectra of the FFO operating at 600 GHz and locked by CPD and RT PLL



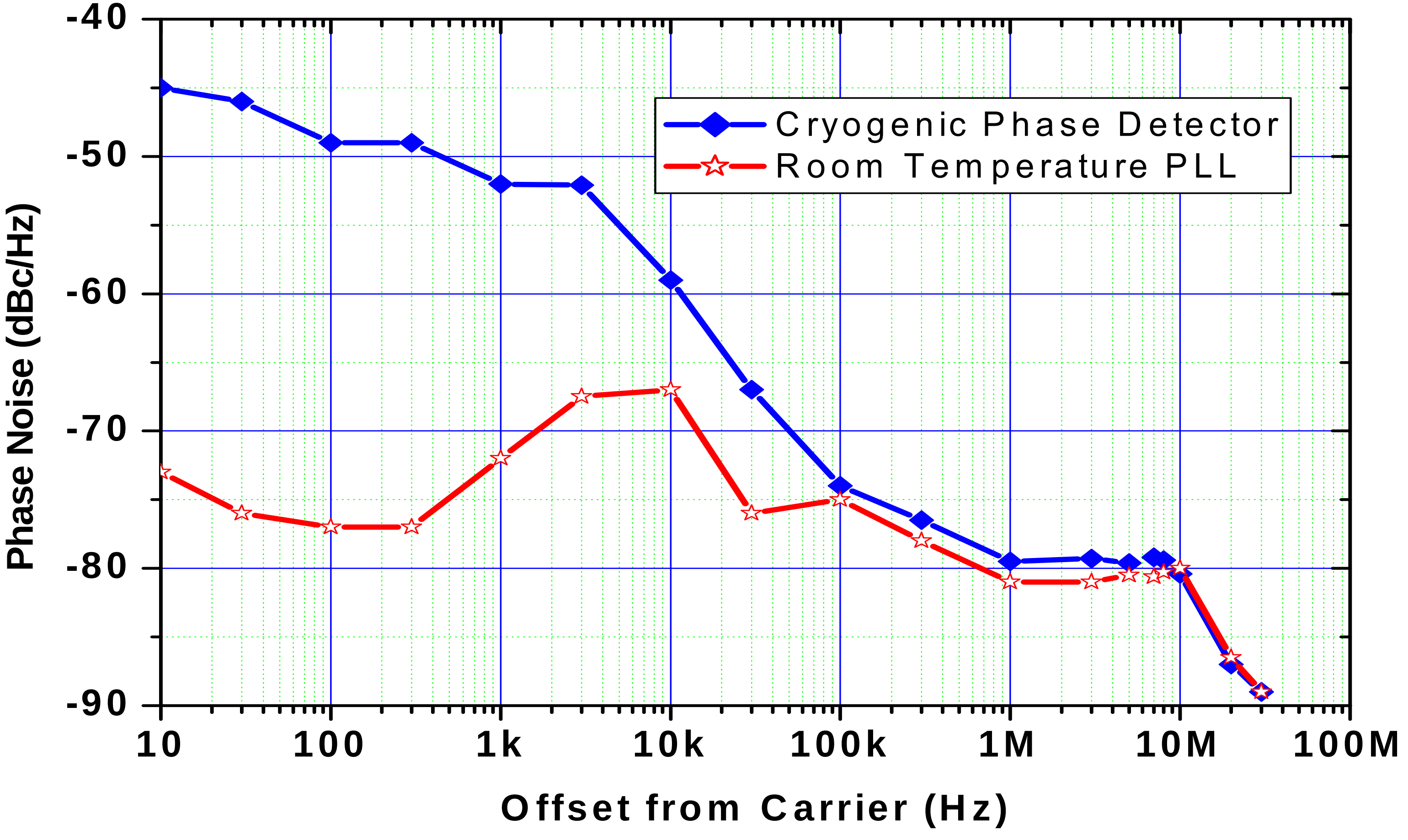
curve “1” – frequency locked,

FFO LW = 2.6 MHz

“2”, “3” – phase locked by CPD, SR = 80%;

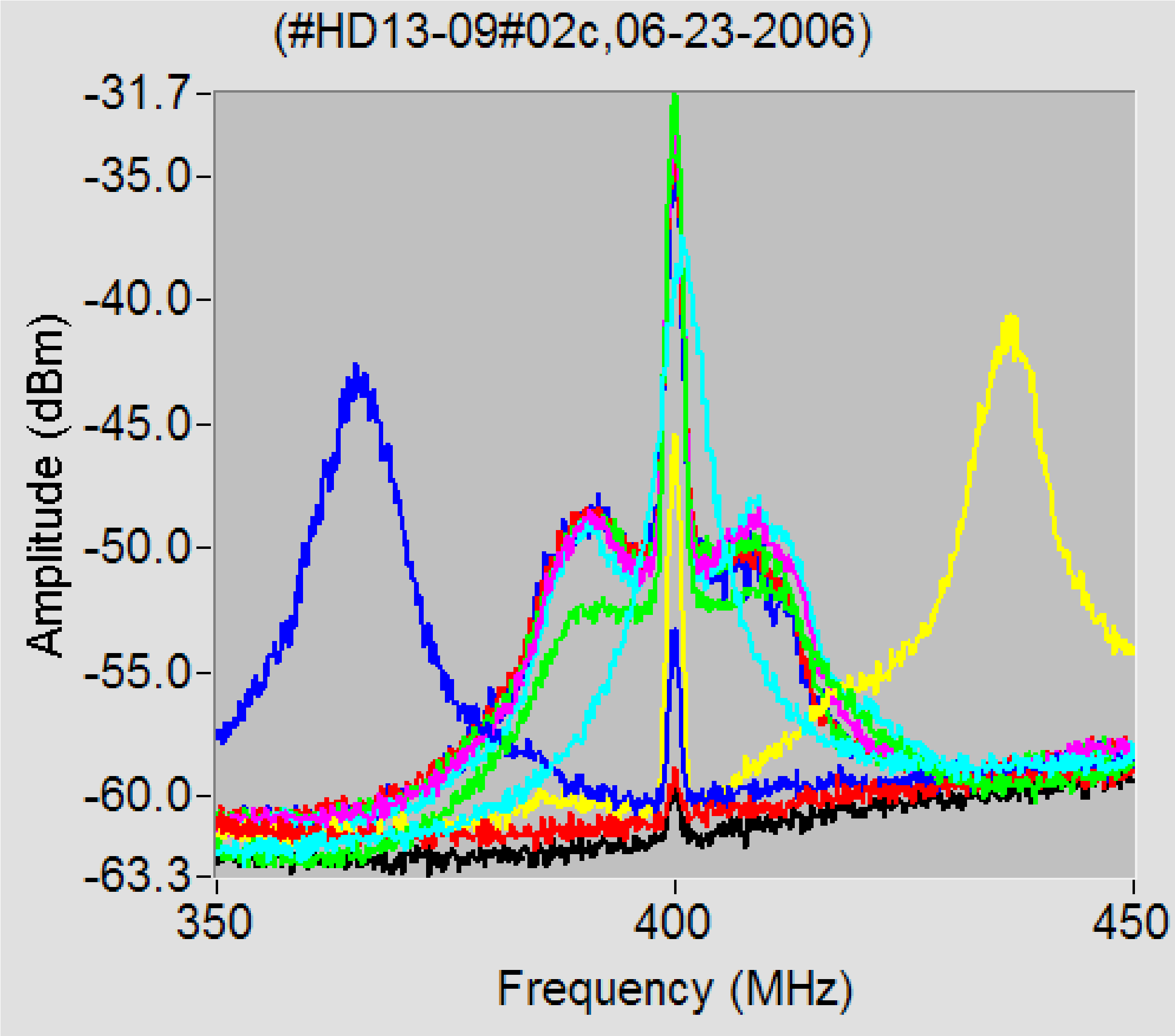
“4” - – phase locked by room temperature PLL, SR = 83.5%

Phase noise of the FFO operating at 600 GHz (free-running linewidth = 2.6 MHz)

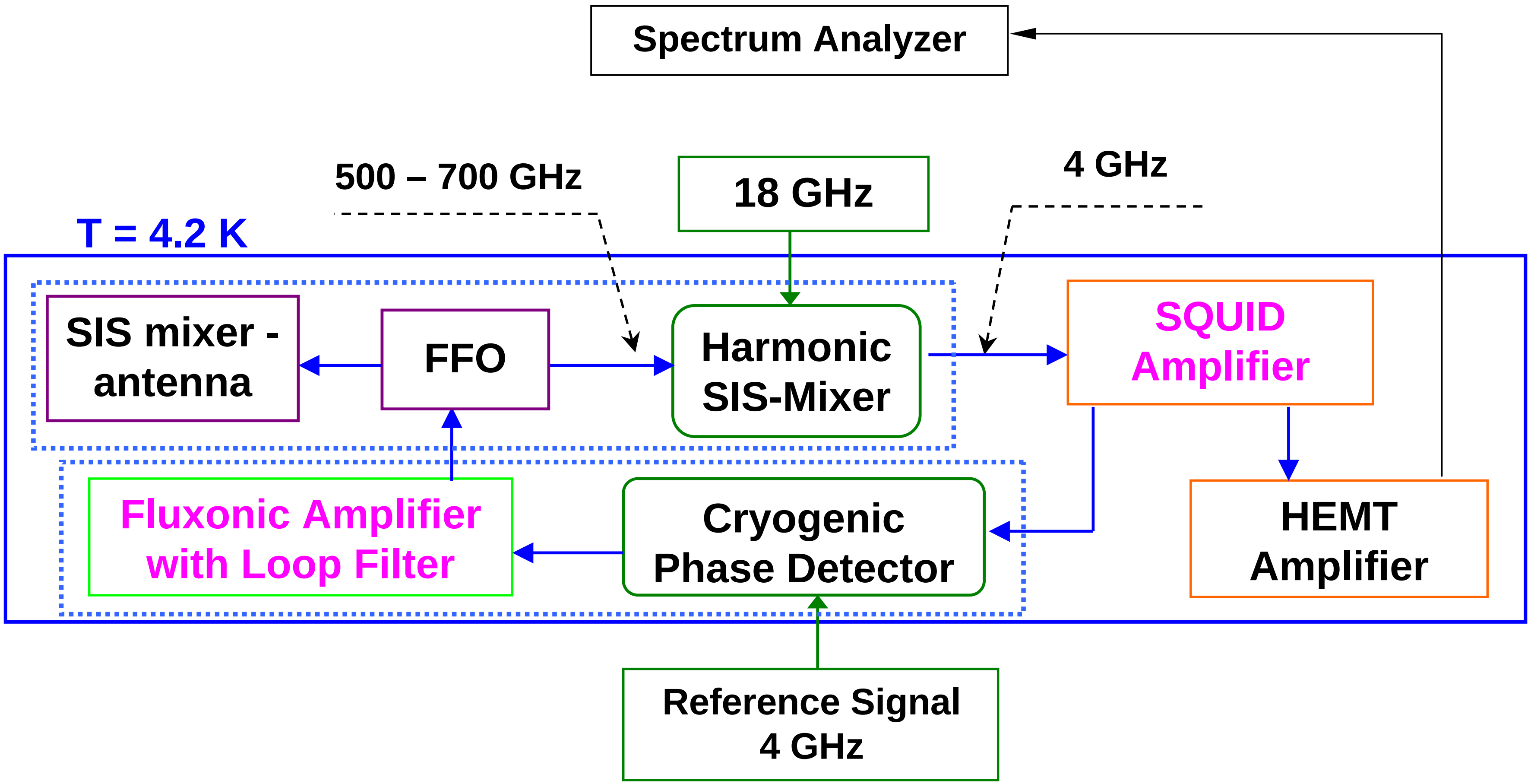


Loop Filter and DC-100 MHz amplifier between CPD and FFO are needed

Down-converted spectra of the FFO phase-locked by CPD only



Block diagram of "fully" superconducting integrated receiver with CPD



Conclusion

- New superconducting element, a cryogenic phase detector (CPD) has been proposed and successfully tested.
- SIS junction can operate as a phase detector with reasonably large output current
- Sinusoidal response of the CPD has been measured at the variation of the phase shift between the input signals
- Obtained data demonstrate that CPD intrinsically could operate with effective bandwidth more than 100 MHz
- Phase locking of an FFO by CPD with spectral ratio as high as 80 % has been demonstrated in the preliminary experiments
- Practical application of the CPD looks especially promising for the development of SIR arrays