Status of the SIR Program for SR&T (Extension to 1 THz)

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List of participants

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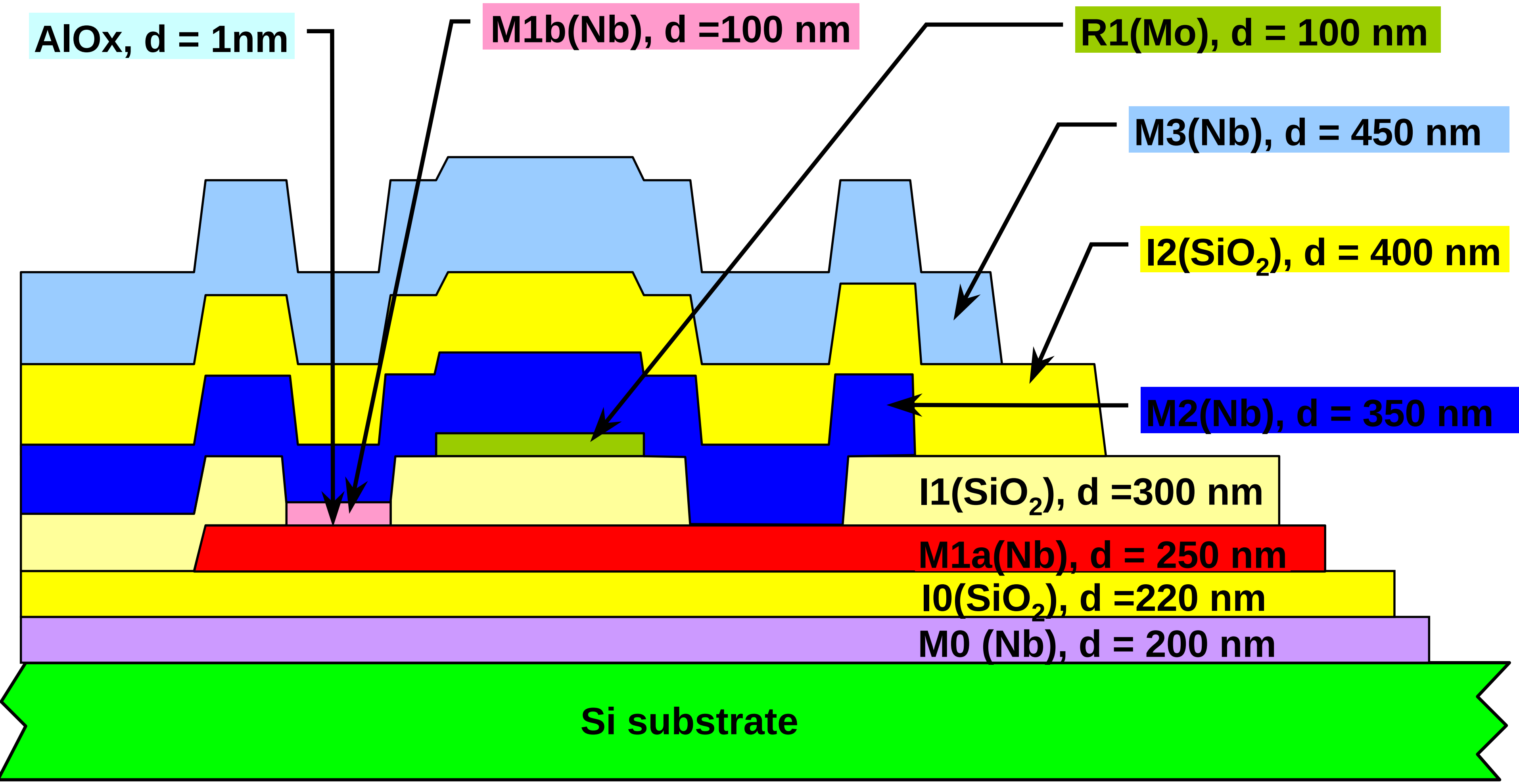
Status of the SIR Program for SR&T (Extension to 1 THz)

Outline

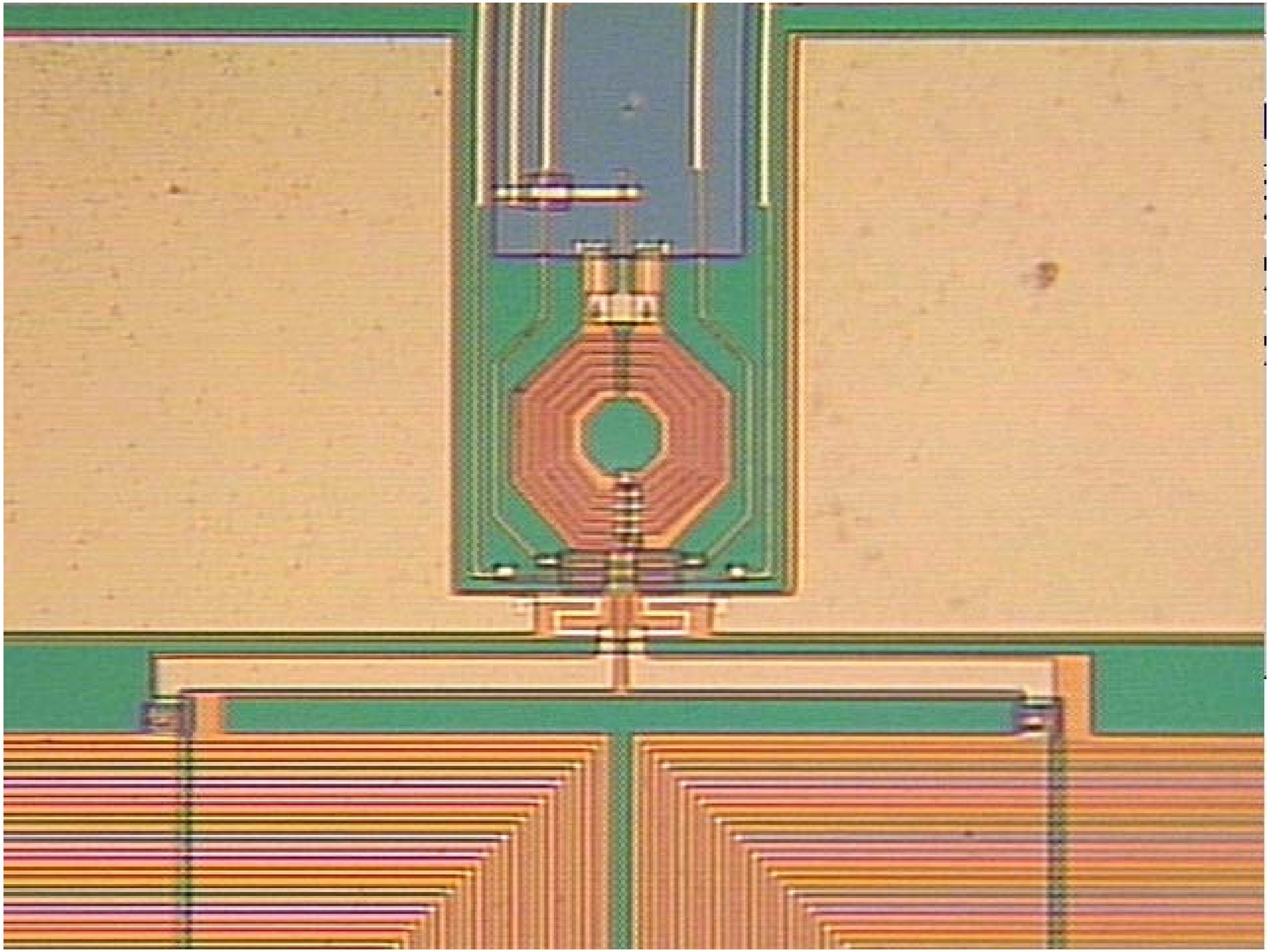
- IREE Technological Facilities
- Tunnel Junctions with AlN barriers
- Sub-micron SIS Junctions
- Tunnel Junctions with NbN electrodes
- Test of the FFO with NbN electrodes
- Cryogenic PLL; SQA
- Towards 1 THz SIR
- Conclusion

IREE Technological Facilities

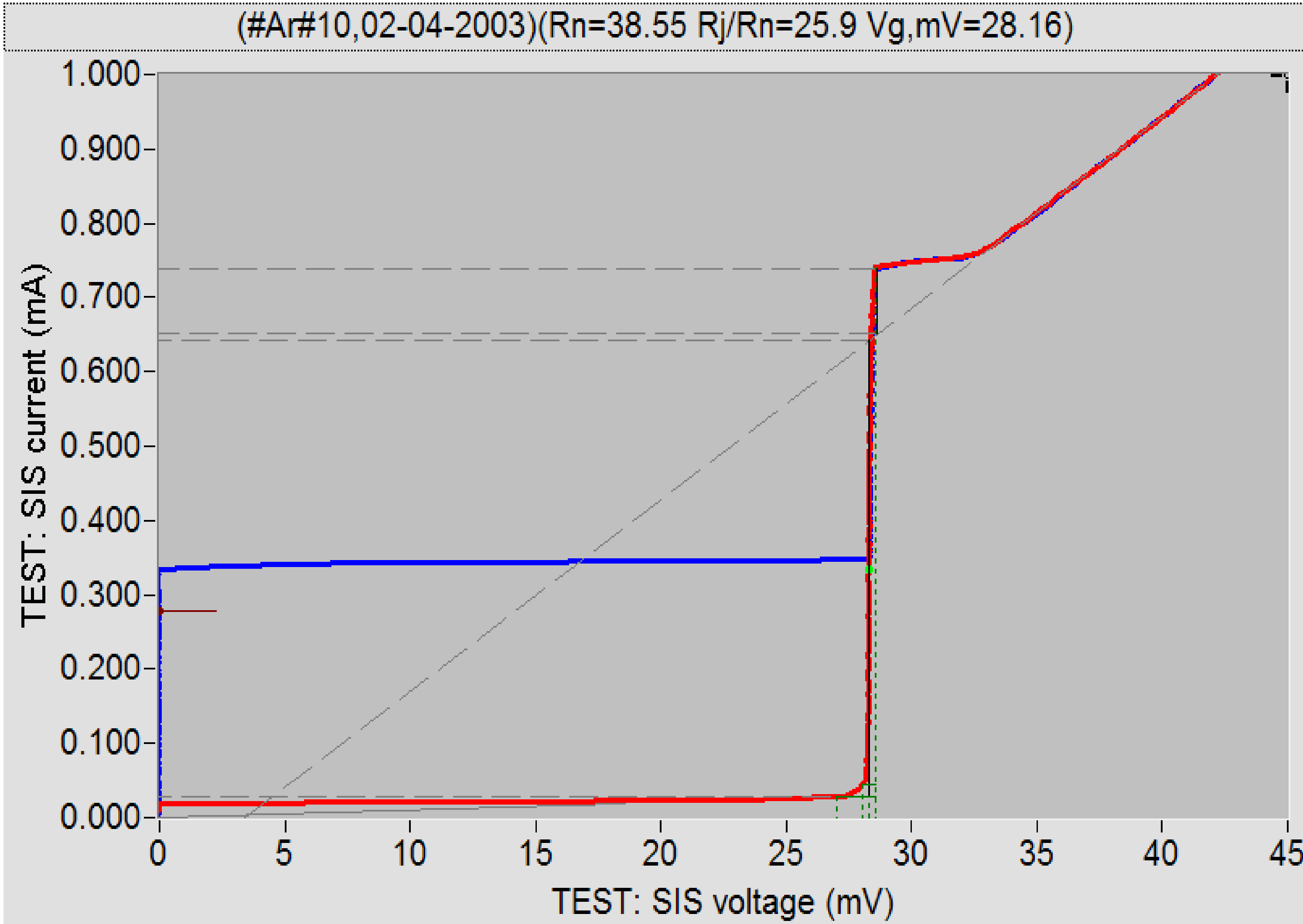
Cross-section of an Integrated Superconducting Microcircuit



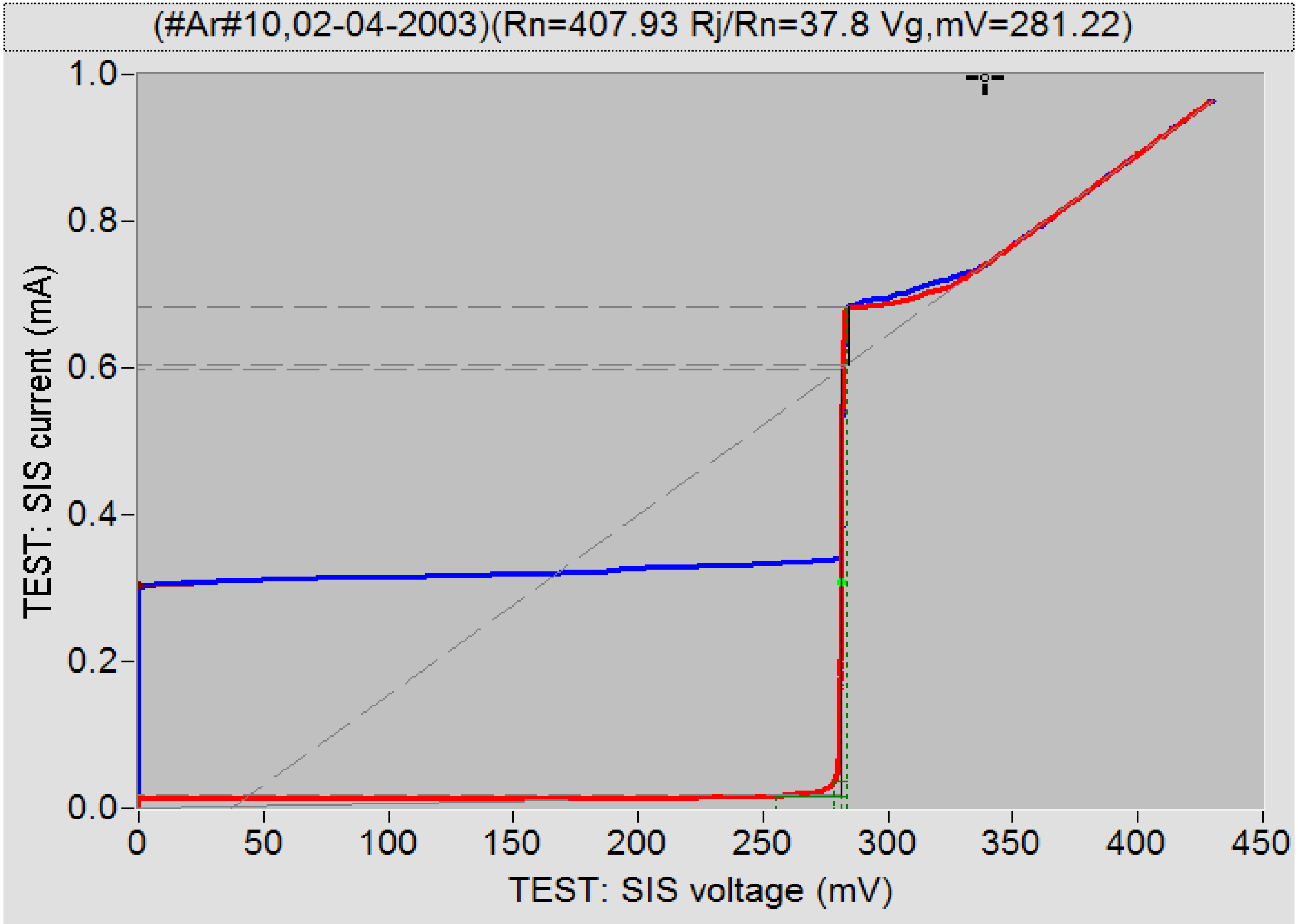
SQUID Sensor



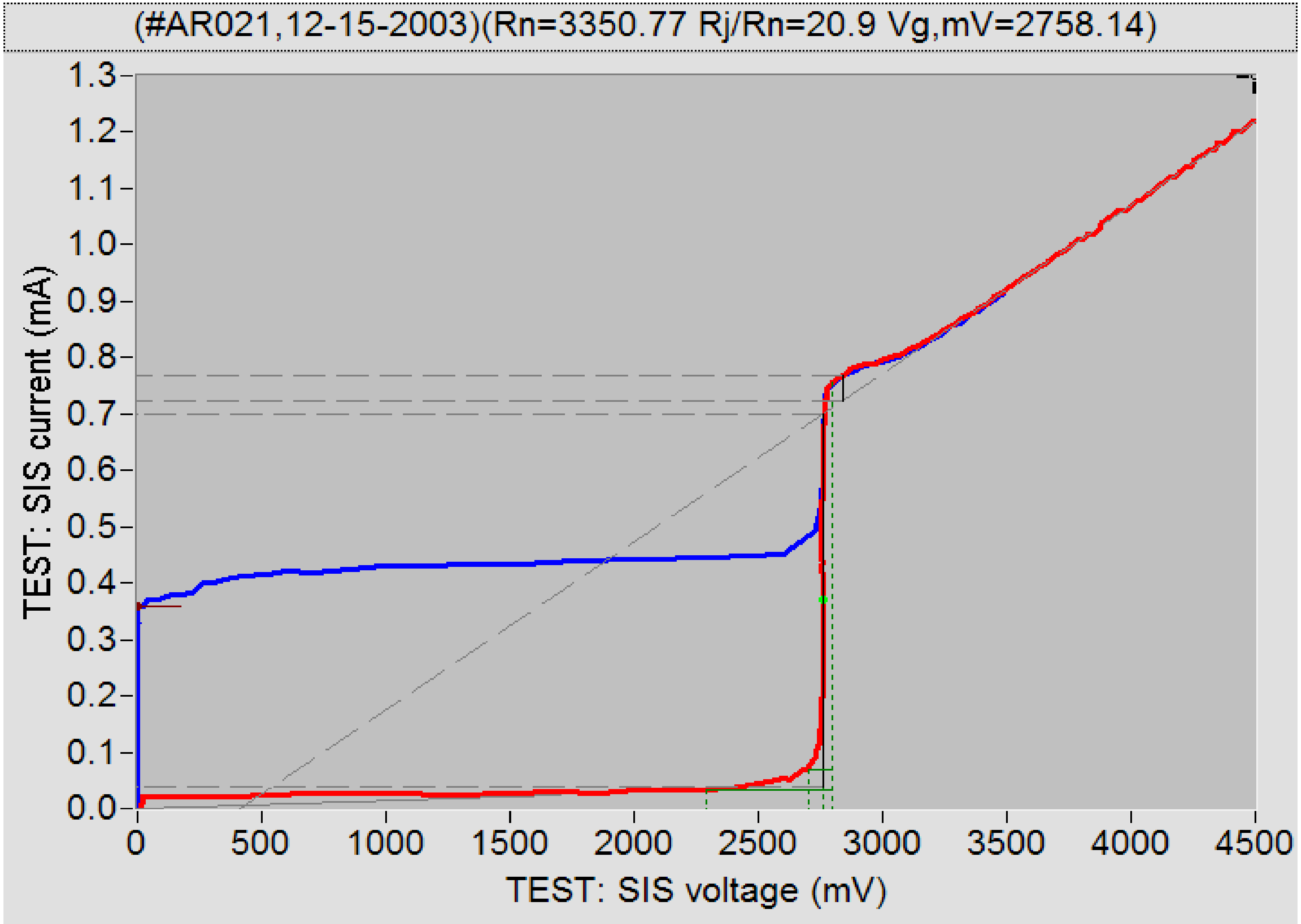
10 SIS Array (8 μm^2; Jc = 5 kA*cm^2)



100 SIS Array (8 μm^2; Jc = 5 kA*cm^2)



1000 SIS Array (8 μm²; Jc = 5 kA*cm²)



Quality vs Jc for Nb-AlOx-Nb Technology

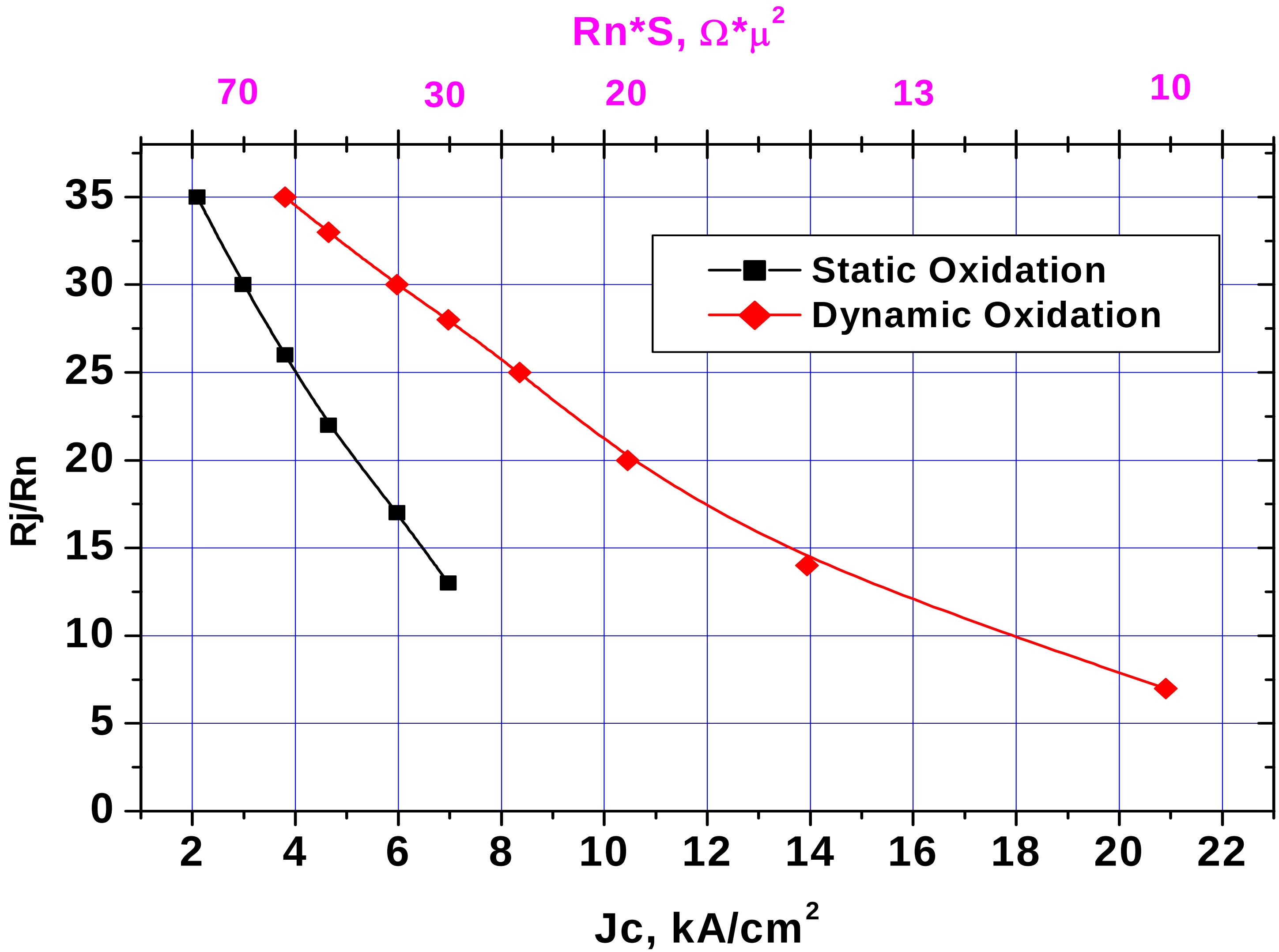
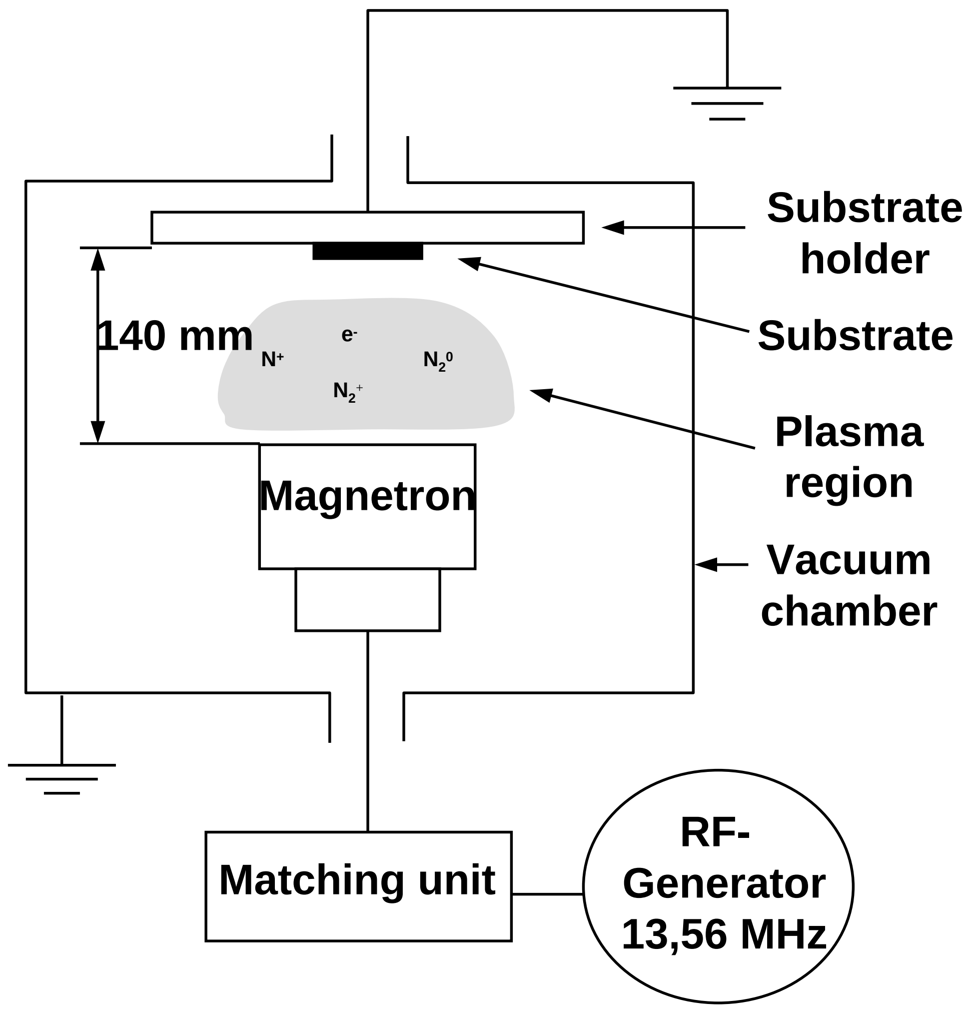
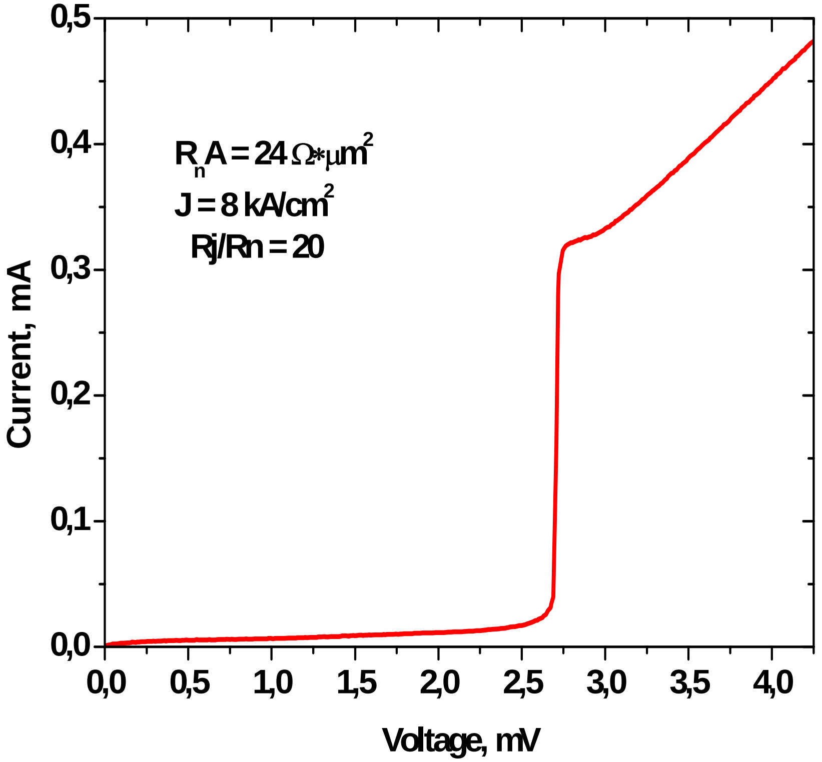
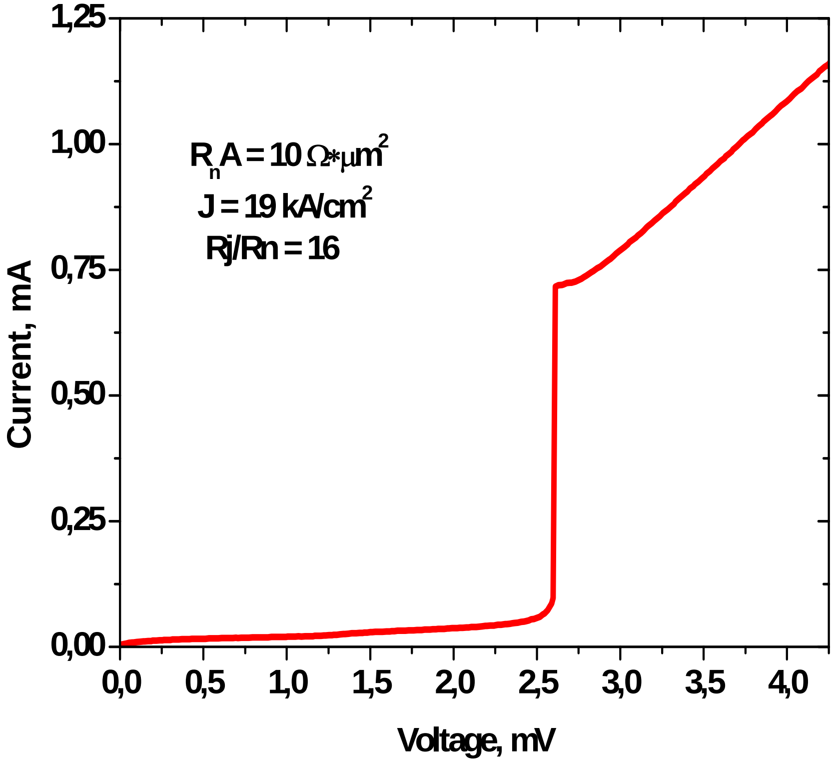


Diagram of the nitridation process

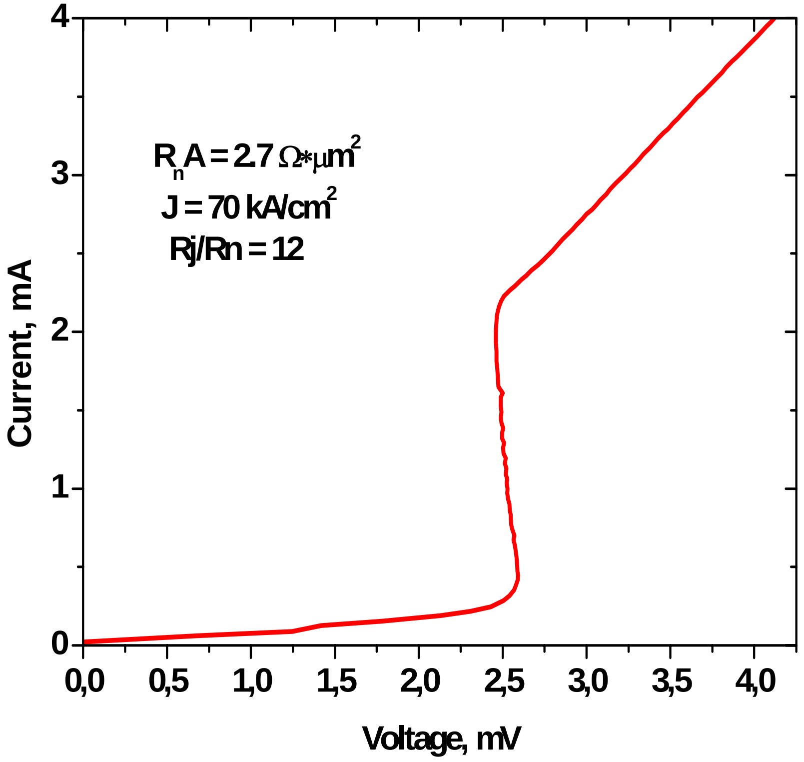


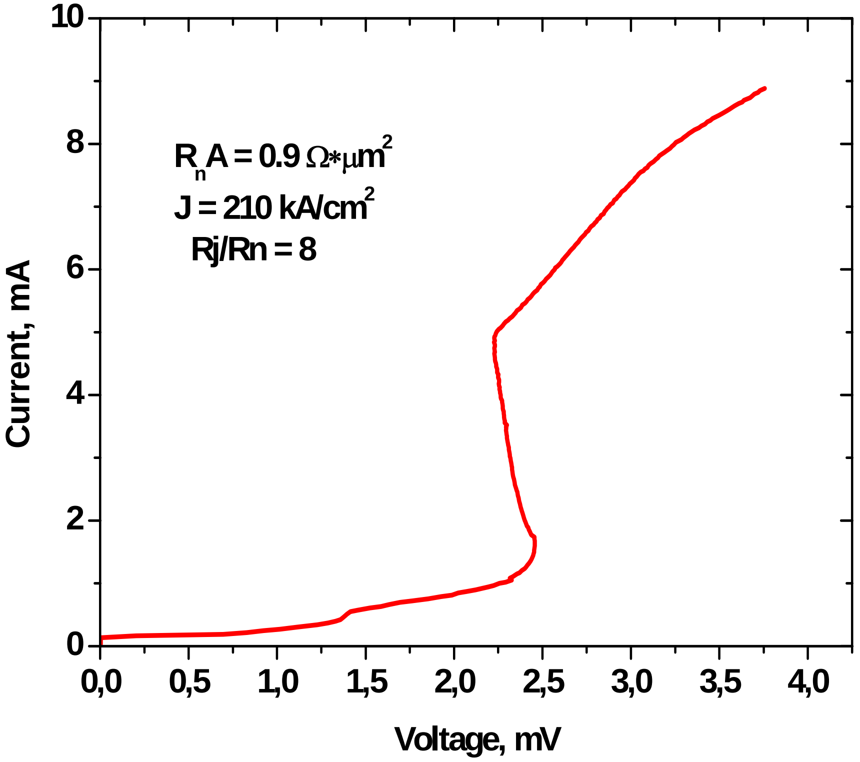
Nb-AlN-Nb Junctions for THz SIR: Jc = 8 and 19 kA/cm^2



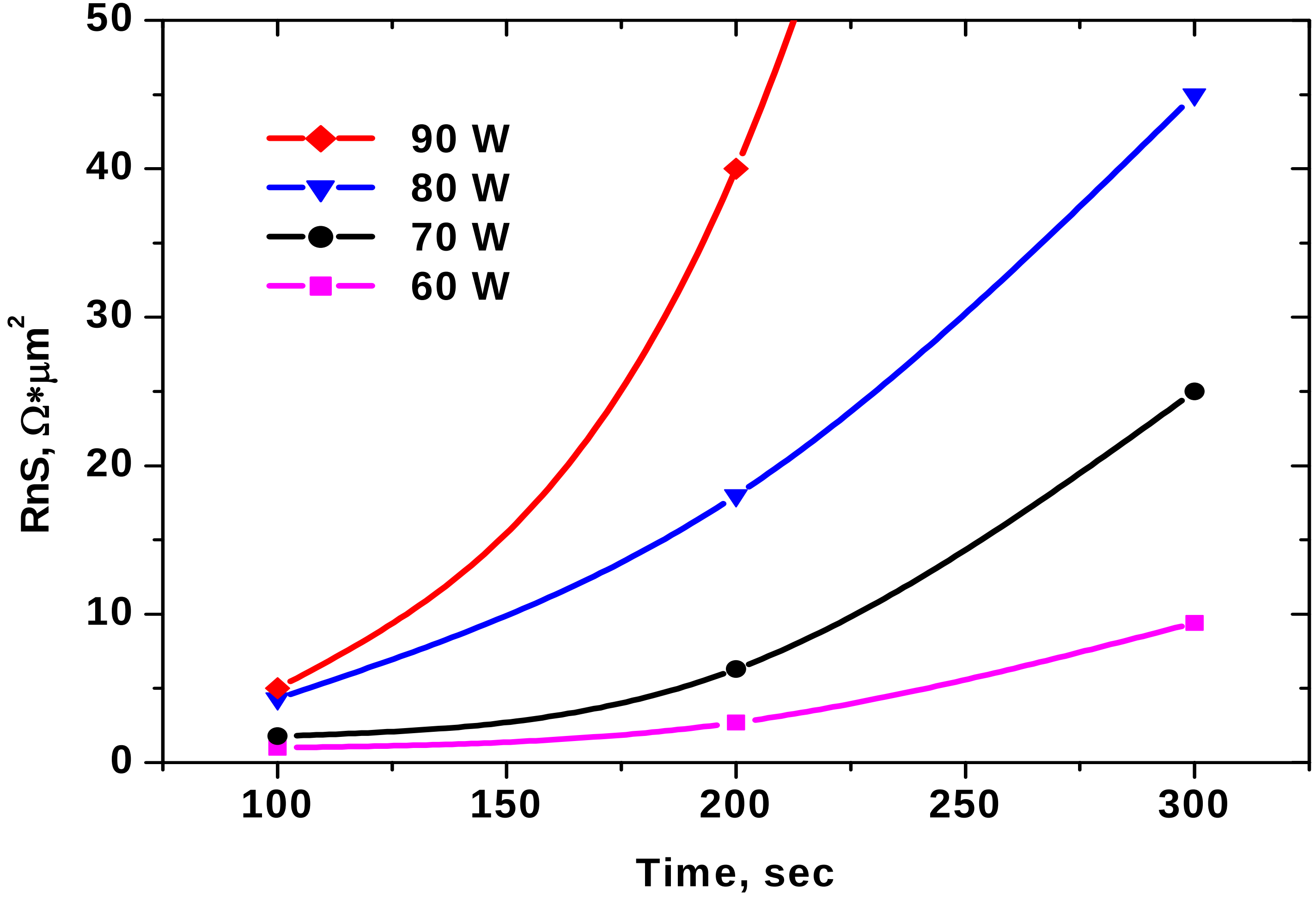


Nb-AlN-Nb Junctions for THz SIR: Jc = 70 and 210 kA/cm²

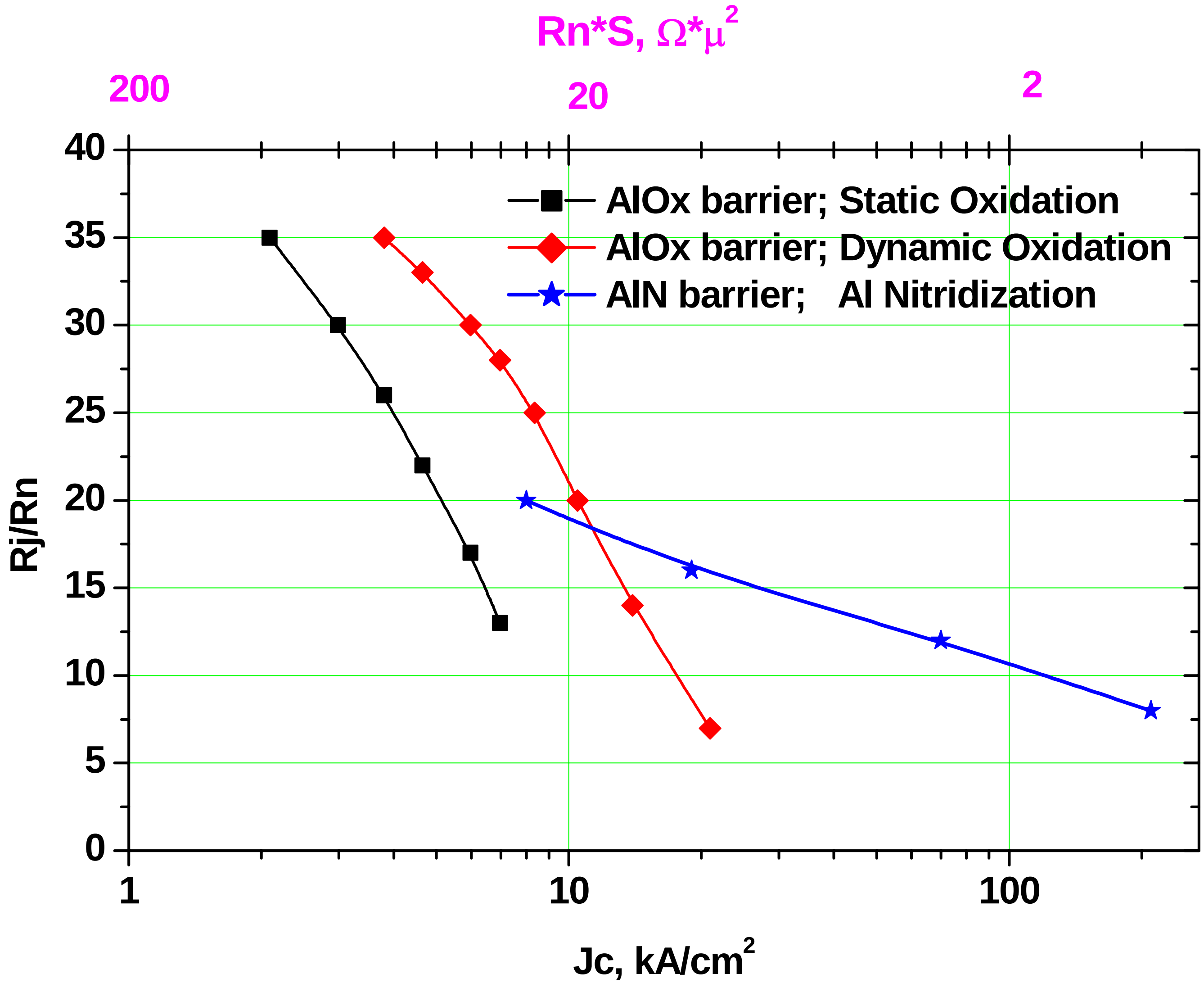




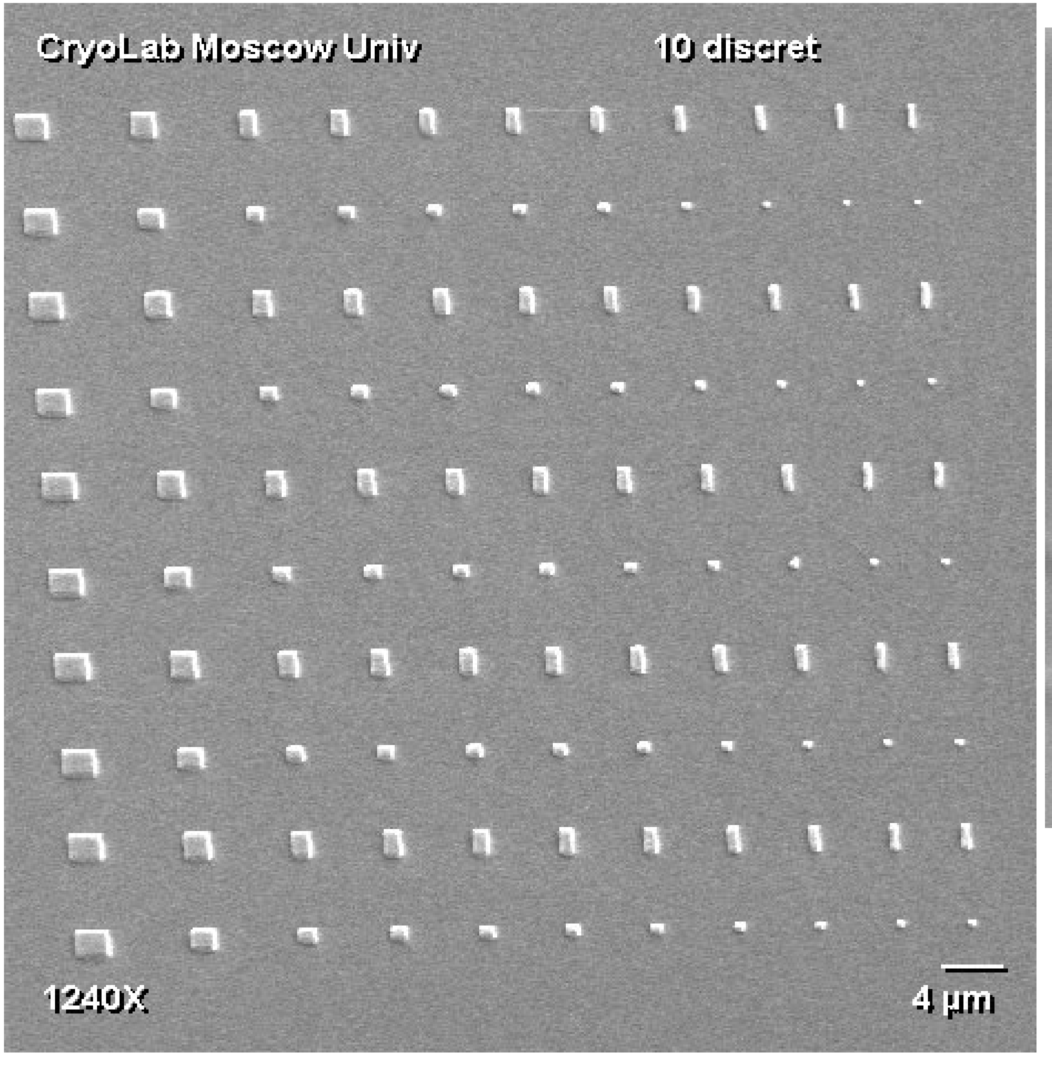
Rn*S of Nb-AlN-Nb SIS vs nitridation parameters

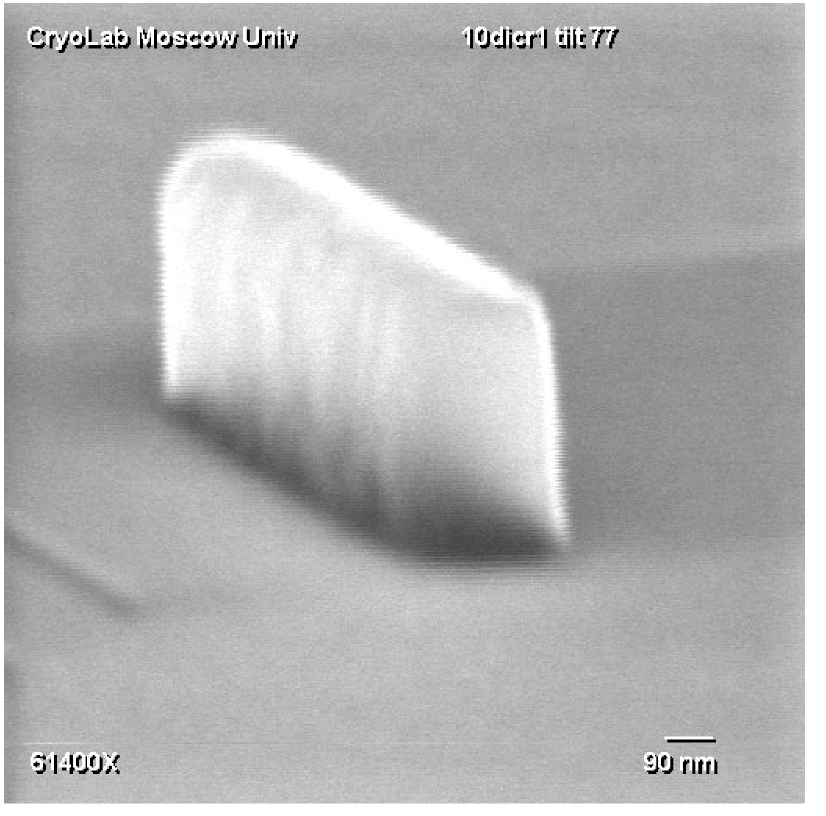


Quality vs Jc (AlOx and AlN barriers)

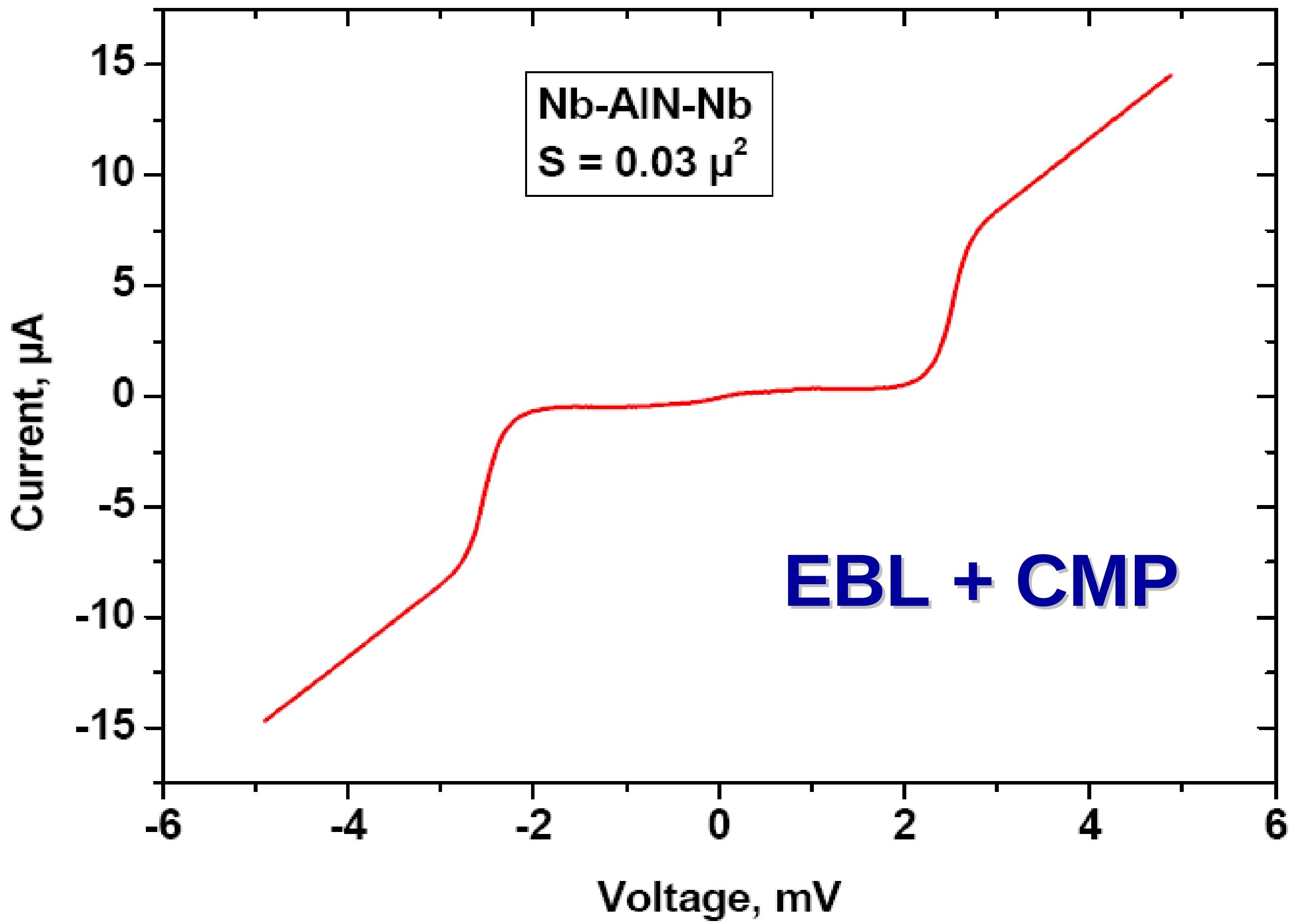


Electron Beam Lithography (with MSU)

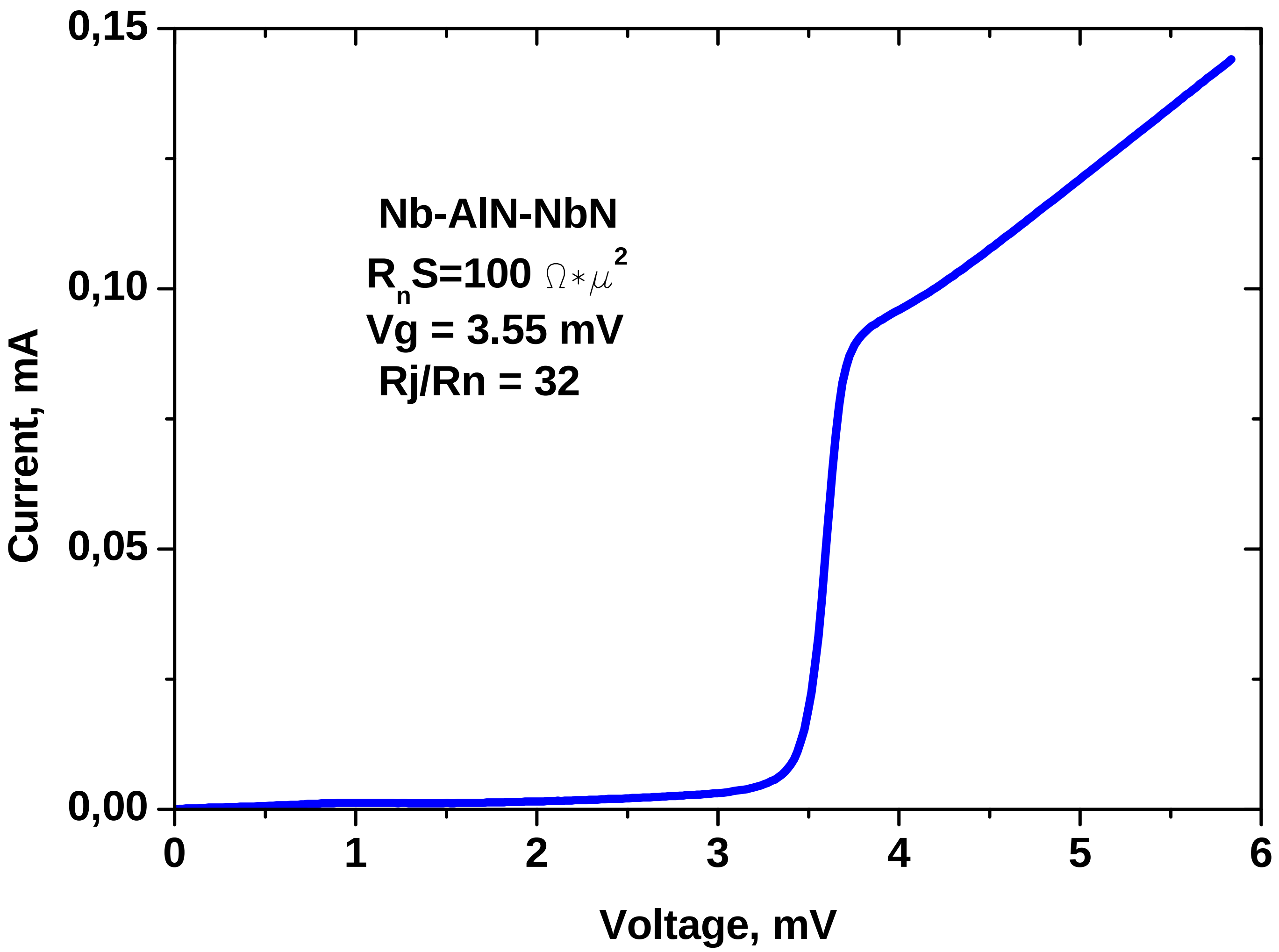




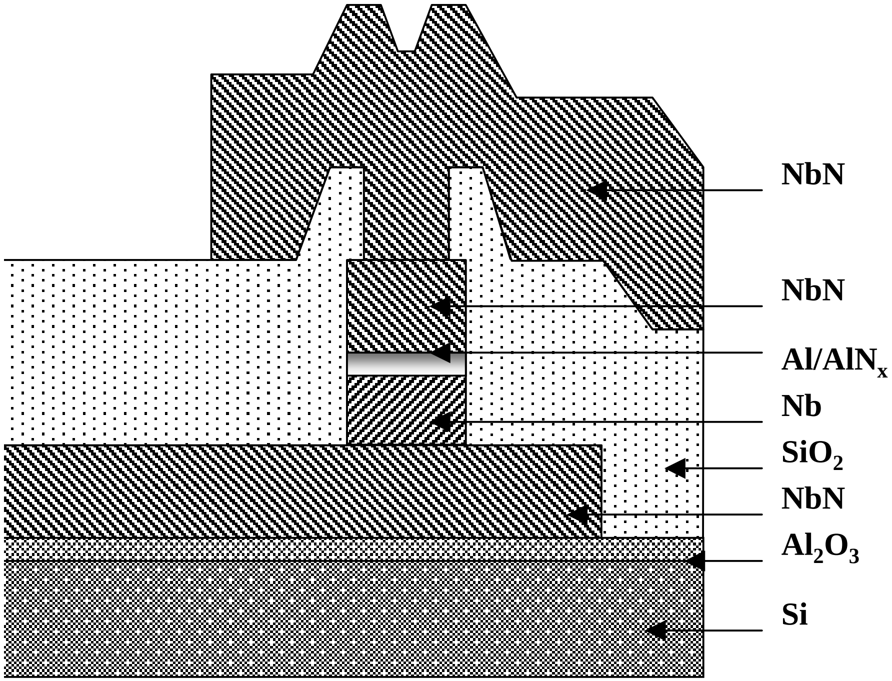
Sub-micron Nb-AlN-Nb junction: S = 0.03 μ^2; Jc = 21 kA/cm^2; Rj/Rn = 14

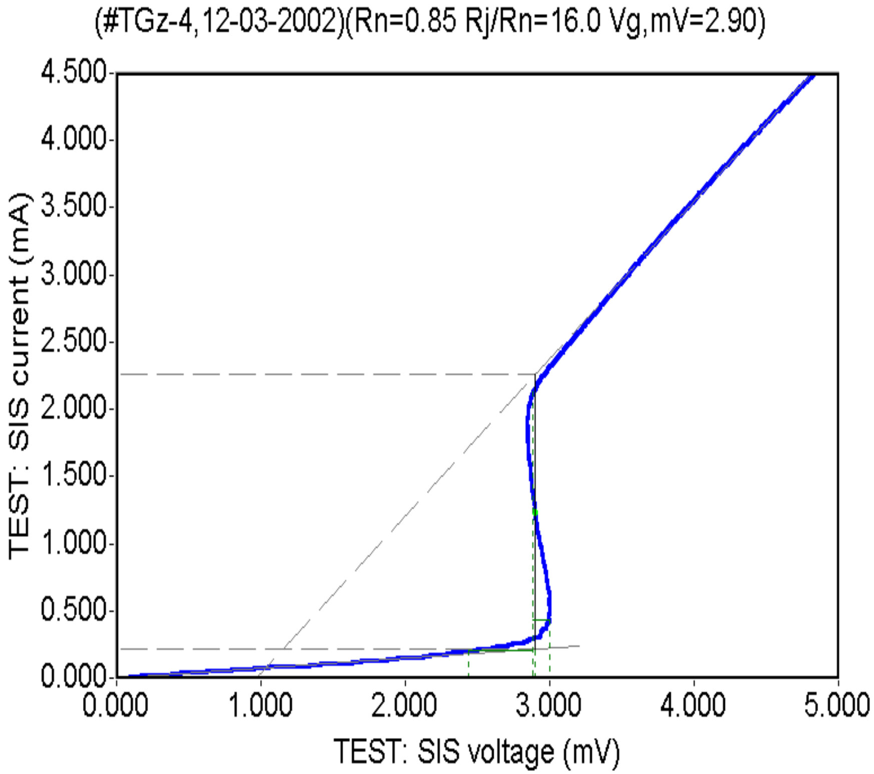


Nb-AlN-NbN Junctions



A THz SIS Mixer incorporated in NbN microstrip line

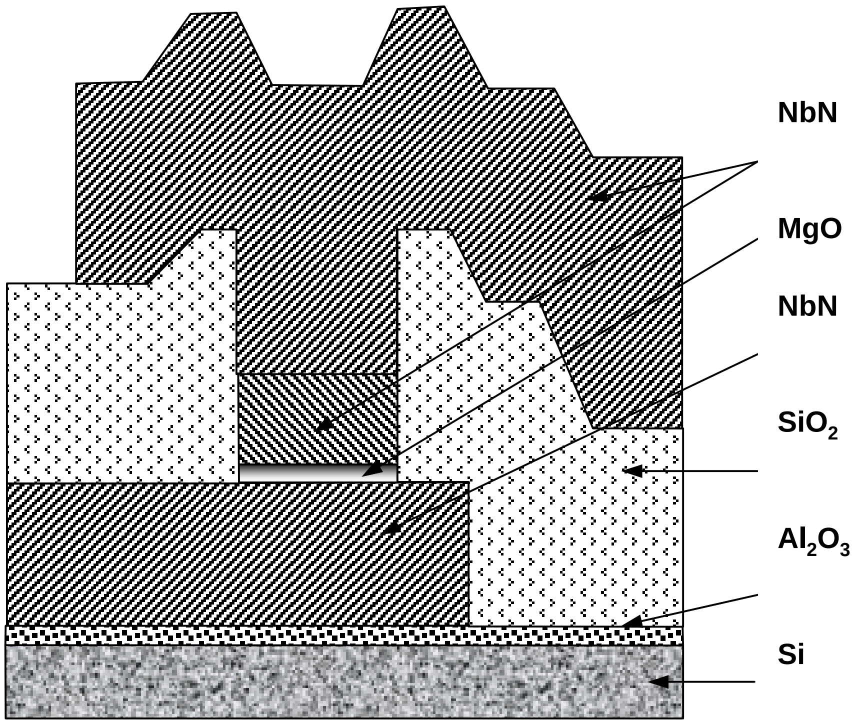


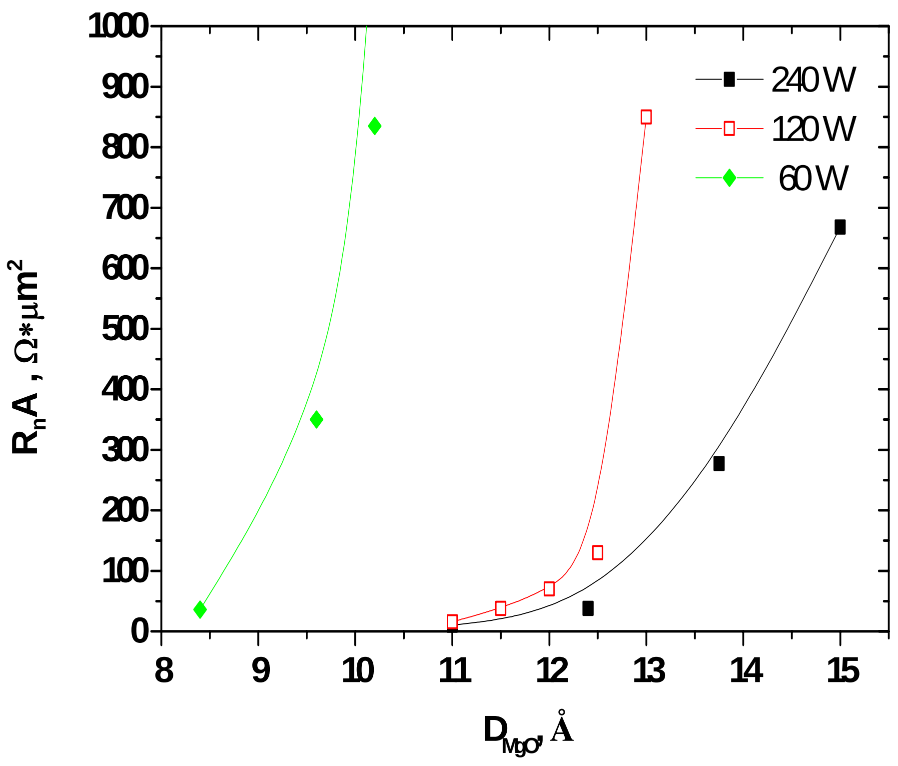


NbN-MgO-NbN SIS junctions

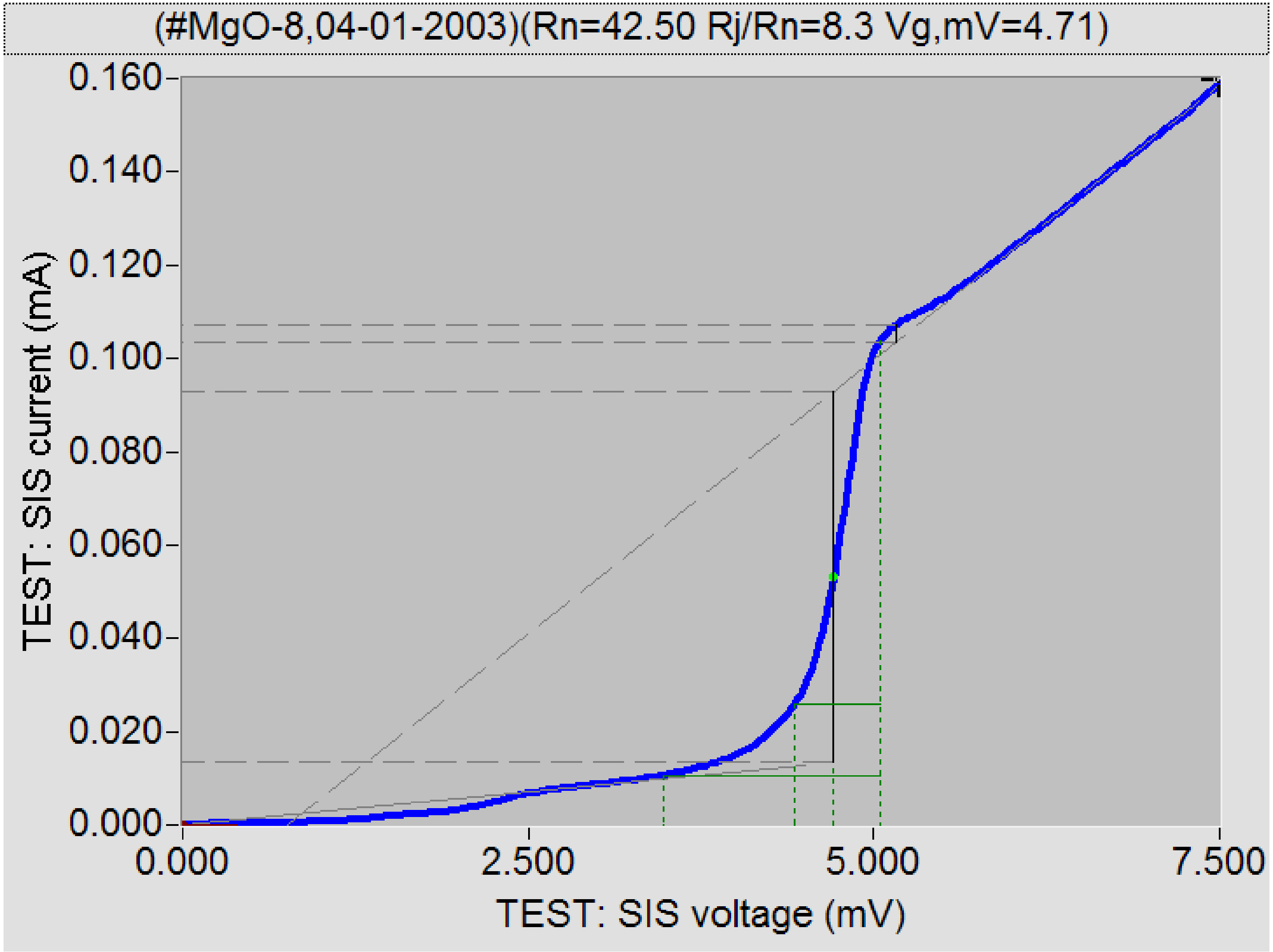
NbN - ρ^{300} = 160 $\mu\Omega$*cm

$T_c \sim 15.7$ K; $(\rho^{300}/\rho^{20}) \sim 0.9$

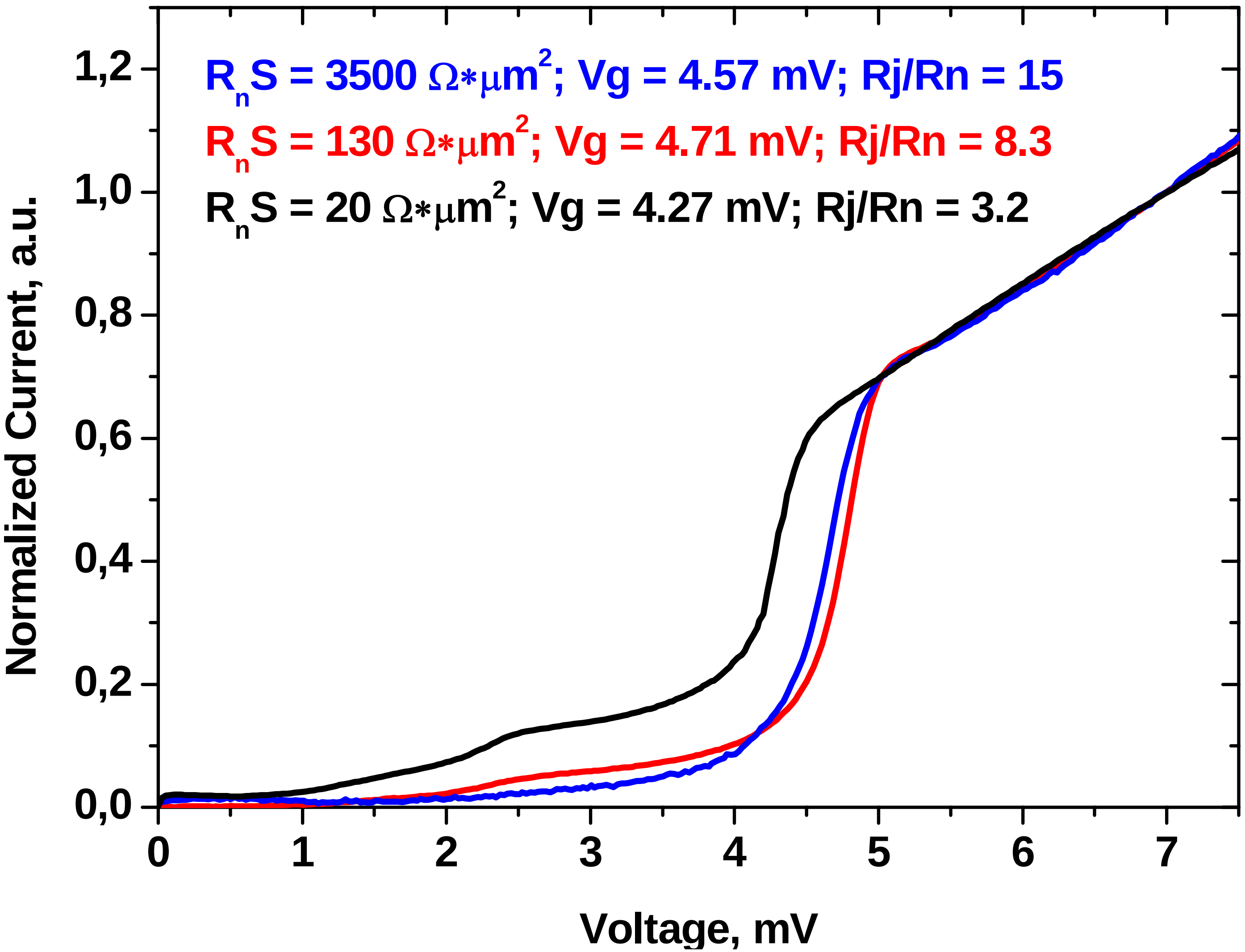




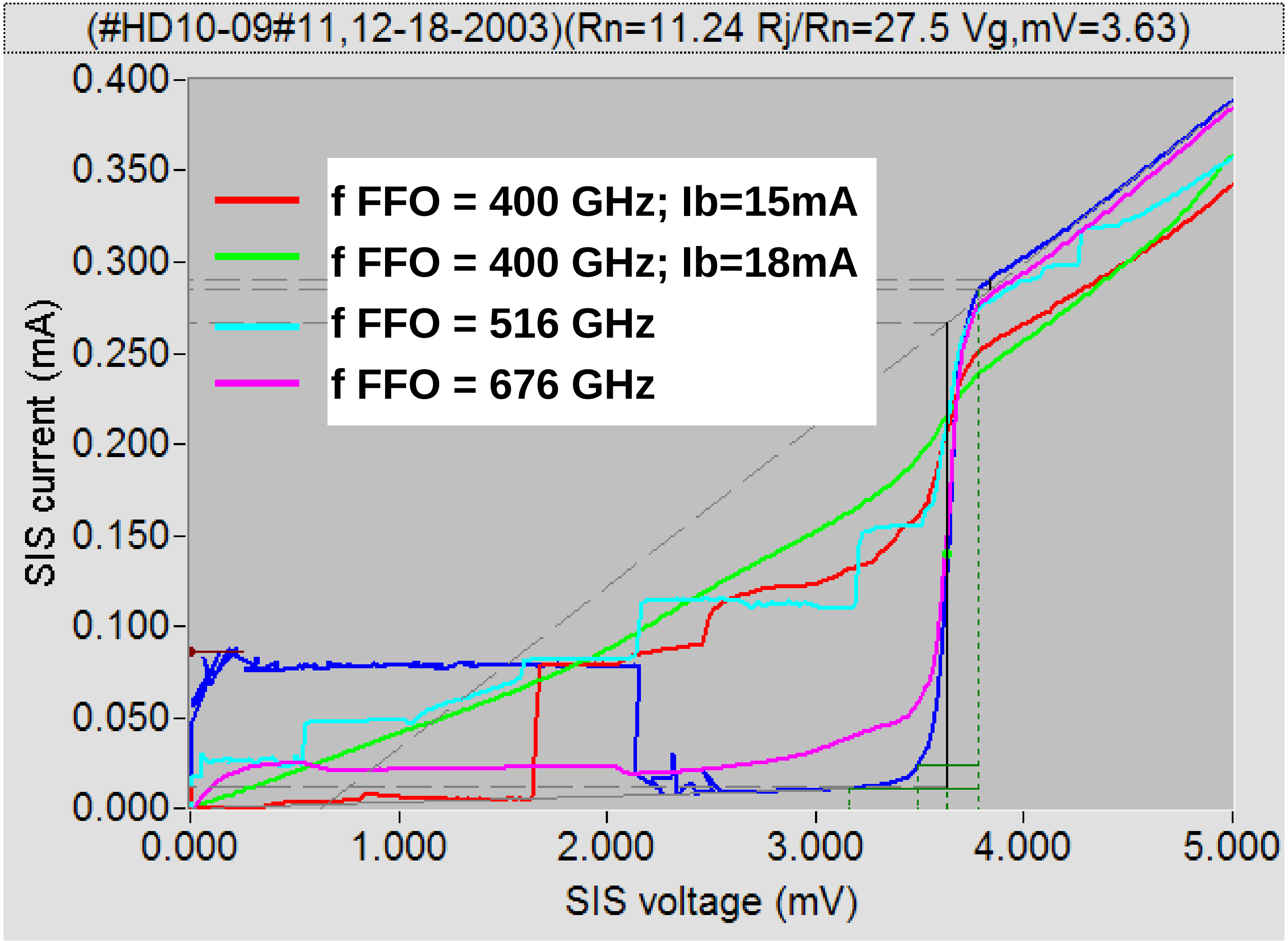
NbN-MgO-NbN SIS junctions



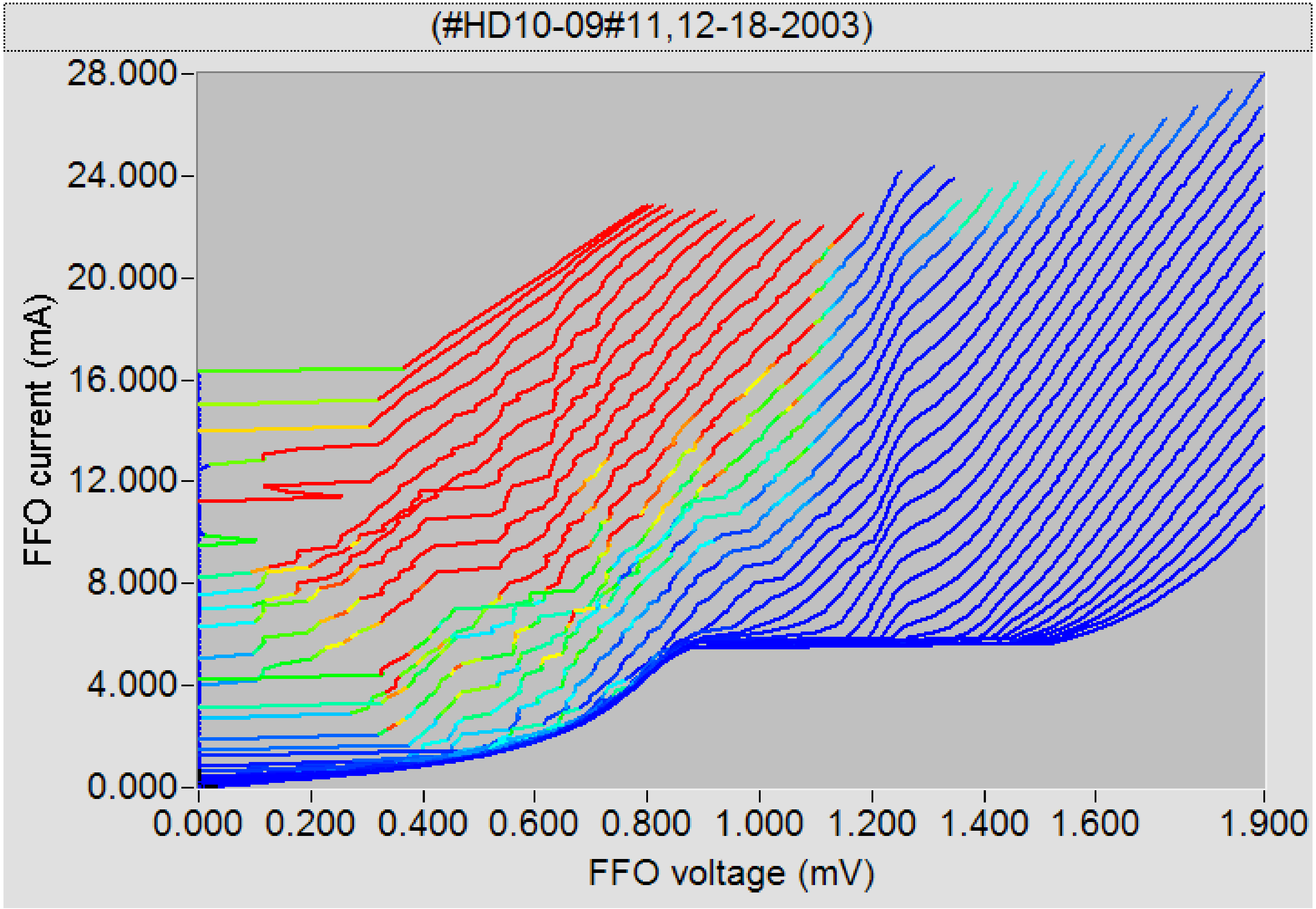
NbN-MgO-NbN SIS junctions



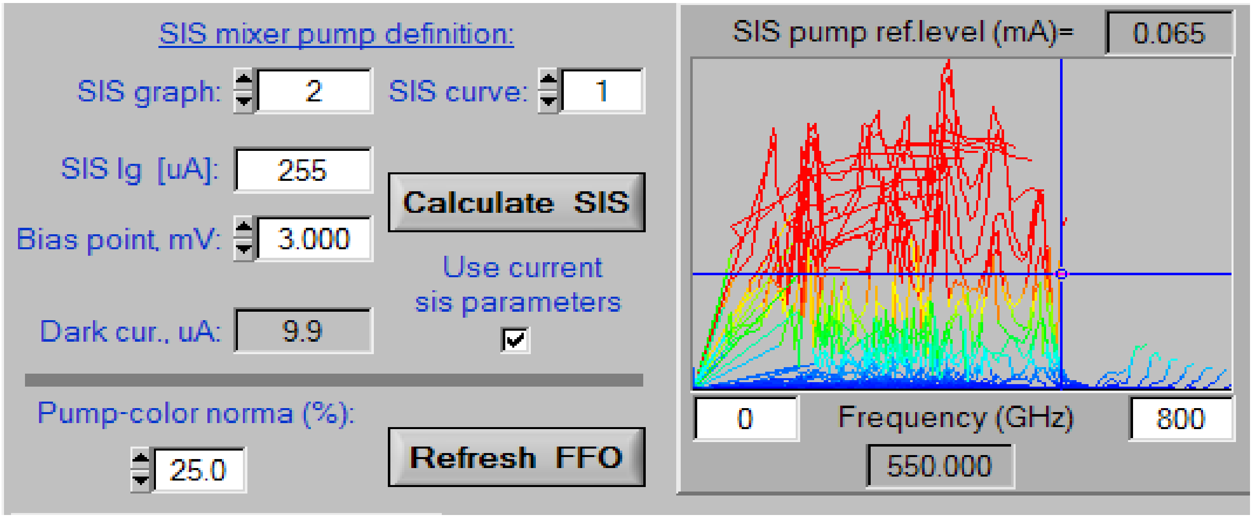
IVCs of the Nb-AlN-NbN SIS pumped by FFO



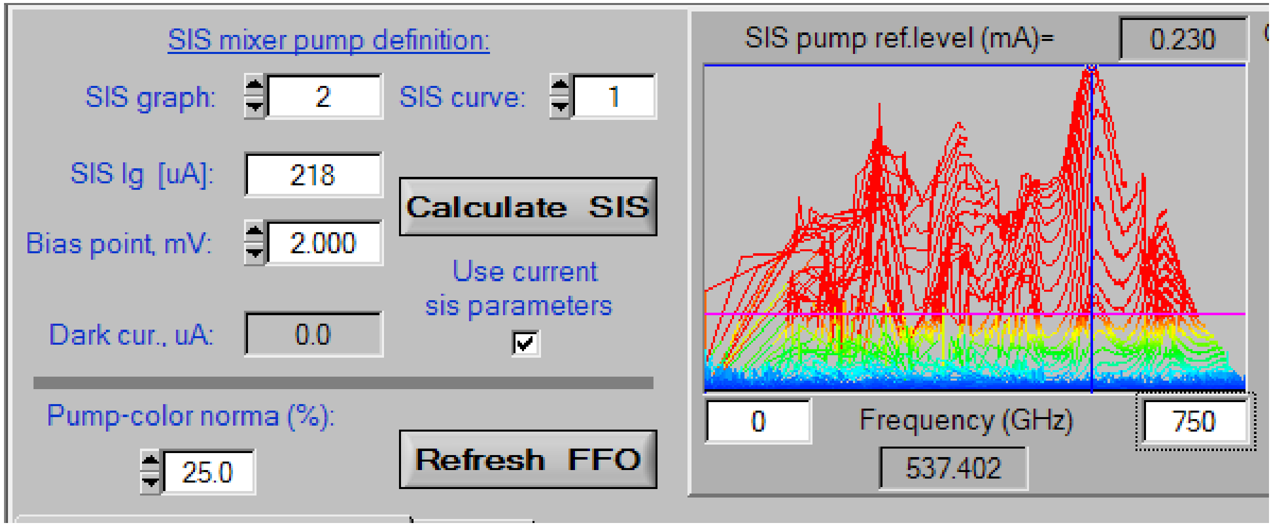
IVCs of the Nb-AlN-NbN FFO, measured at different magnetic fields



Experimental FFO power coupling to SIS



NbN



Nb

Calculations of the FFO power coupling
------ Nb electrode ------ NbN electrode

TEST_DCB = 0

HD11-1JJ_HM

$d1SiO_2$ = 200 nm,

$d2SiO_2$ = 140 nm,

ε = 4.2,

λ_{L1} = 85 nm

λ_{L2} = 300 nm

RnS = 10,

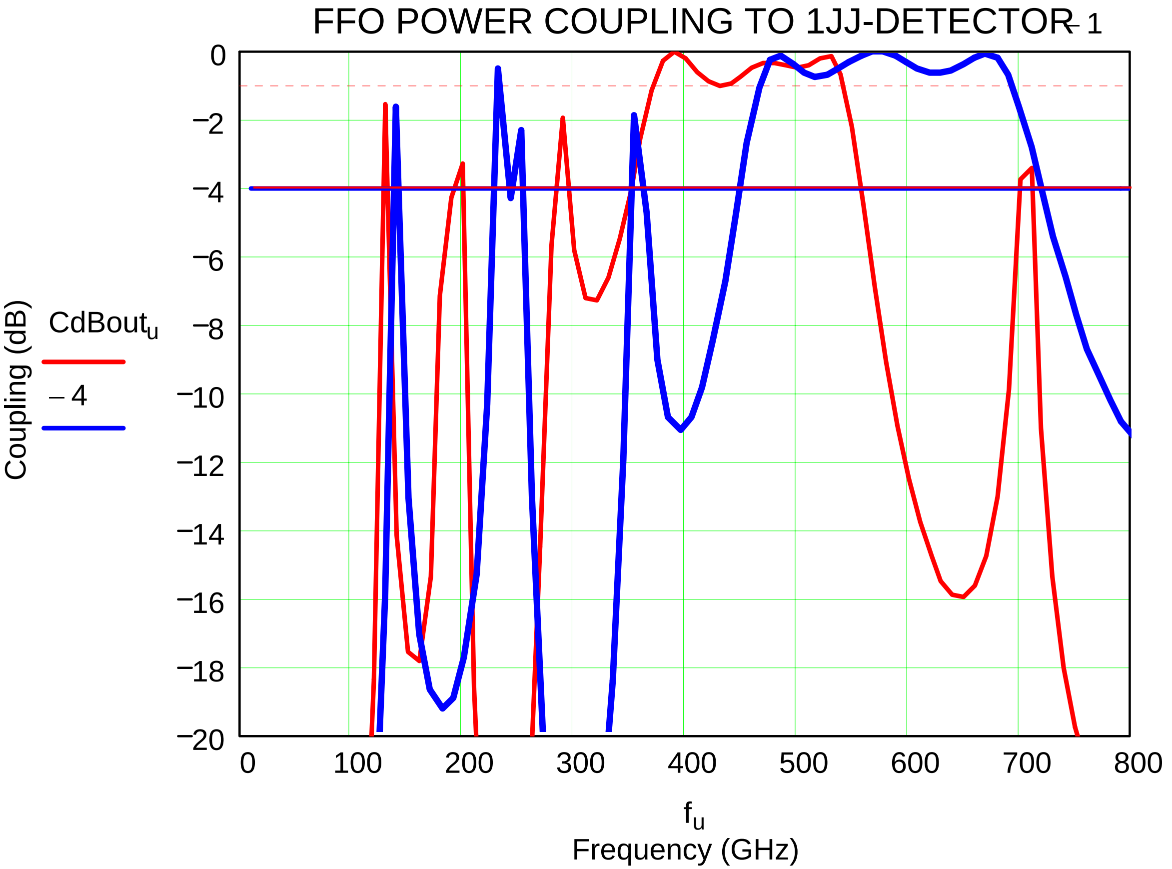
C = 0.09 pF/um^2

S = 2.0 mkm^2

Ltuner = 5 mkm

WE_{FFO}=1.0 mkm

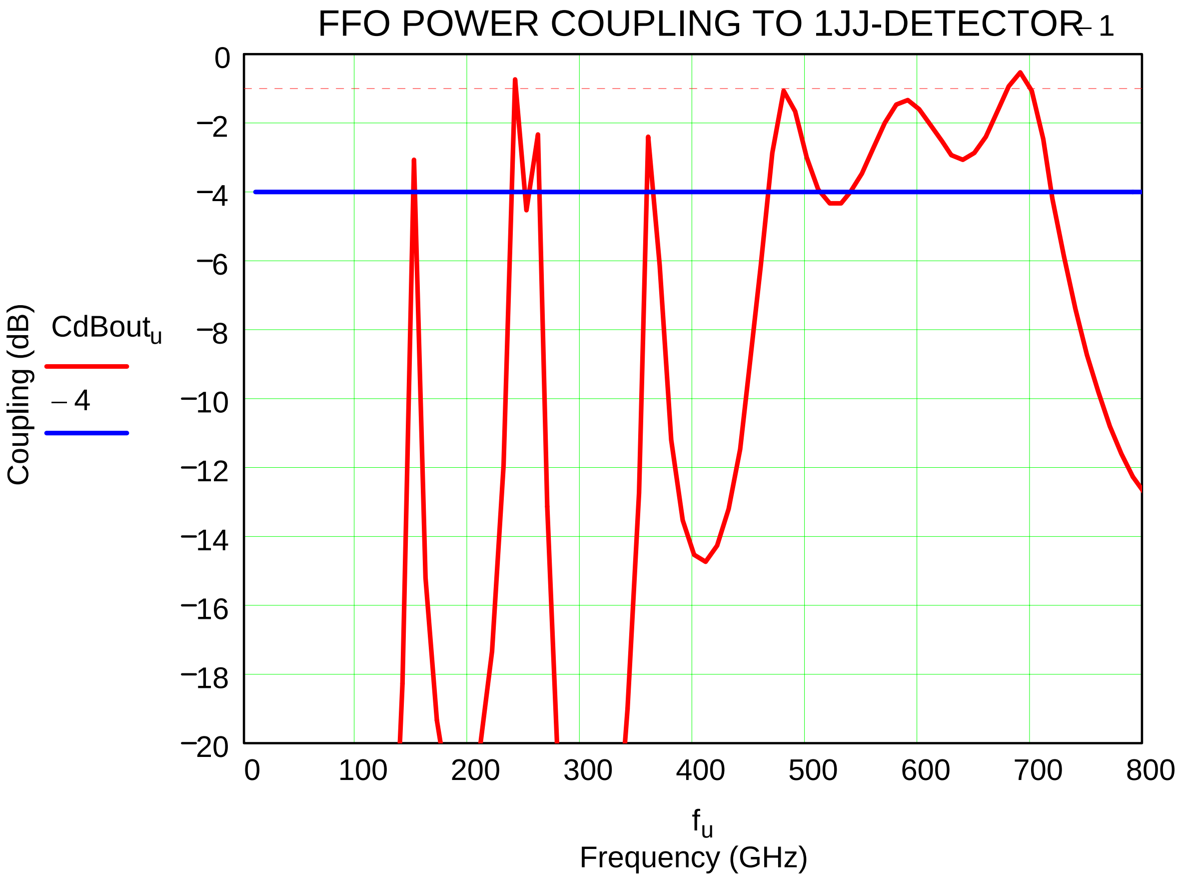
Widle = 4 mkm



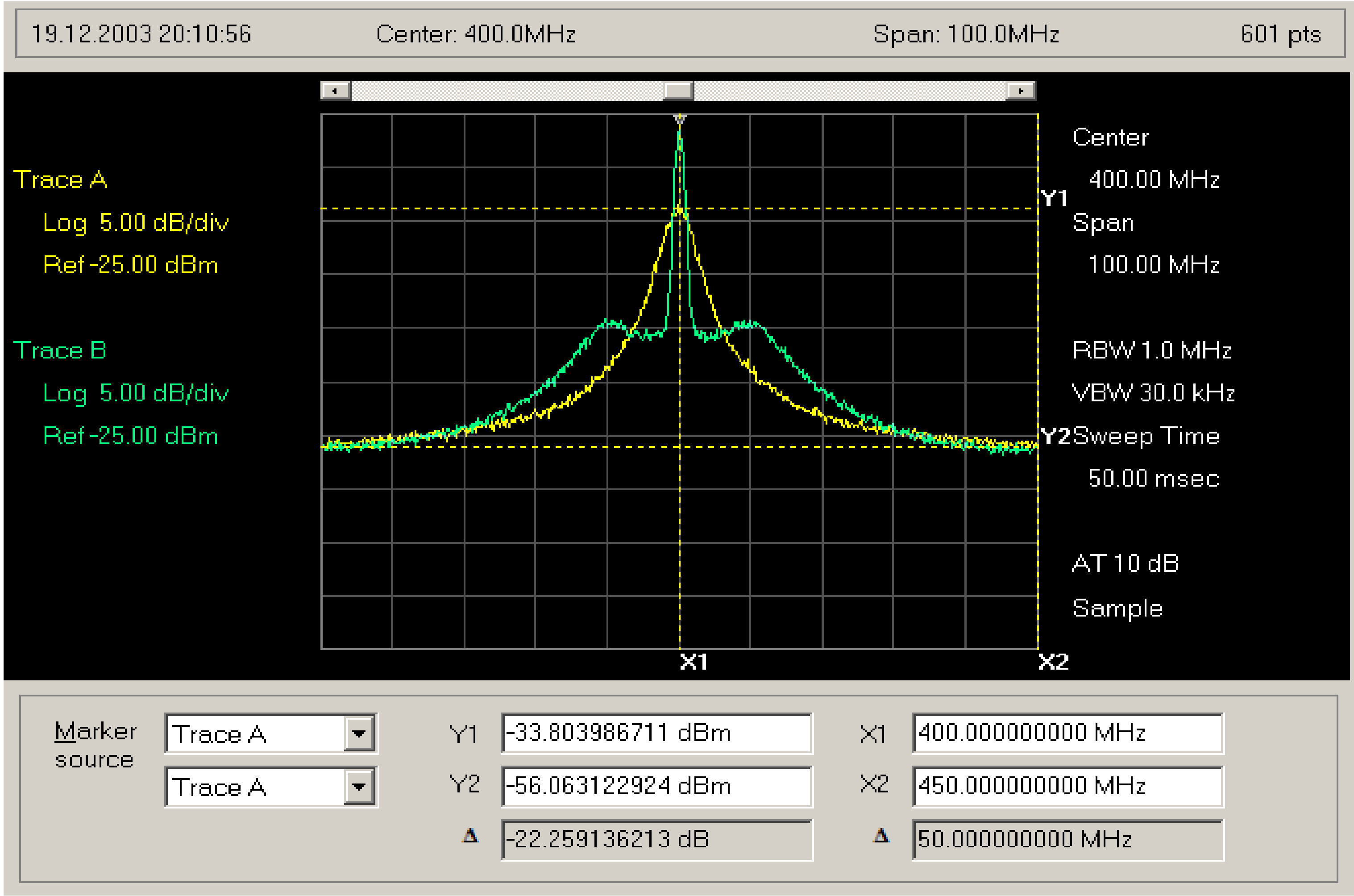
Nb-AlN-NbN circuit – optimized design

TEST_DCB = 0

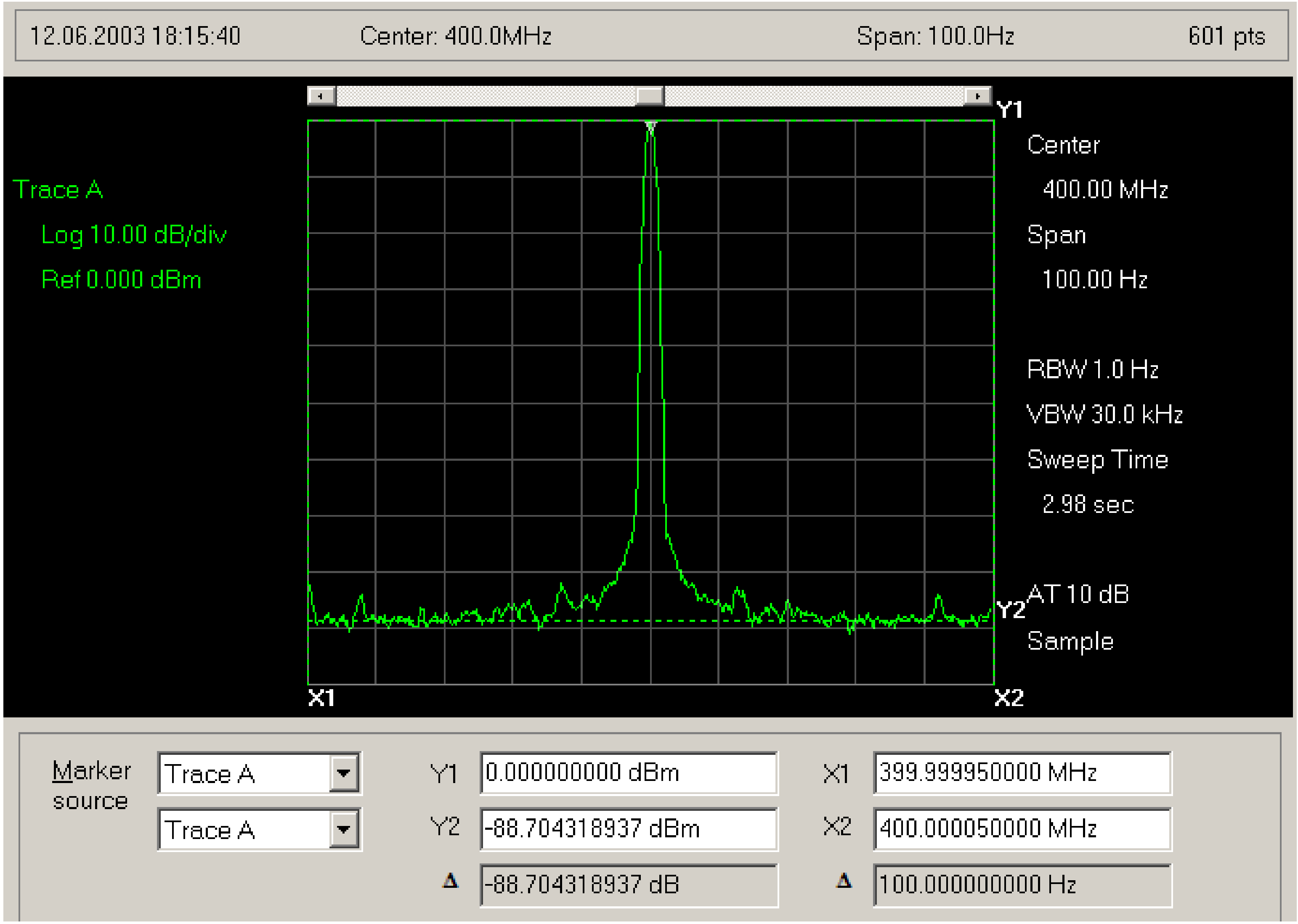
HD11-1JJ_HM (without BPF and DCB2)
$d1SiO_2$ = 280 nm,
$d2SiO_2$ = 140 nm,
ε = 4.2,
λ_{L1} = 85 nm
λ_{L2} = 85 nm
RnS = 40,
C = 0.082 pF/um^2
S = 2.0 mkm^2
Ltuner = 5 mkm
WE_{FFO}=1.0 mkm
Widle = 4 mkm



Spectra of the Nb-AlN-NbN FFO at 597 GHz, δf = 3.5 MHz; SR = 70%



Spectrum of the PL Nb-AlN-NbN FFO (–90 dBc)



Concept of cryogenic PLL

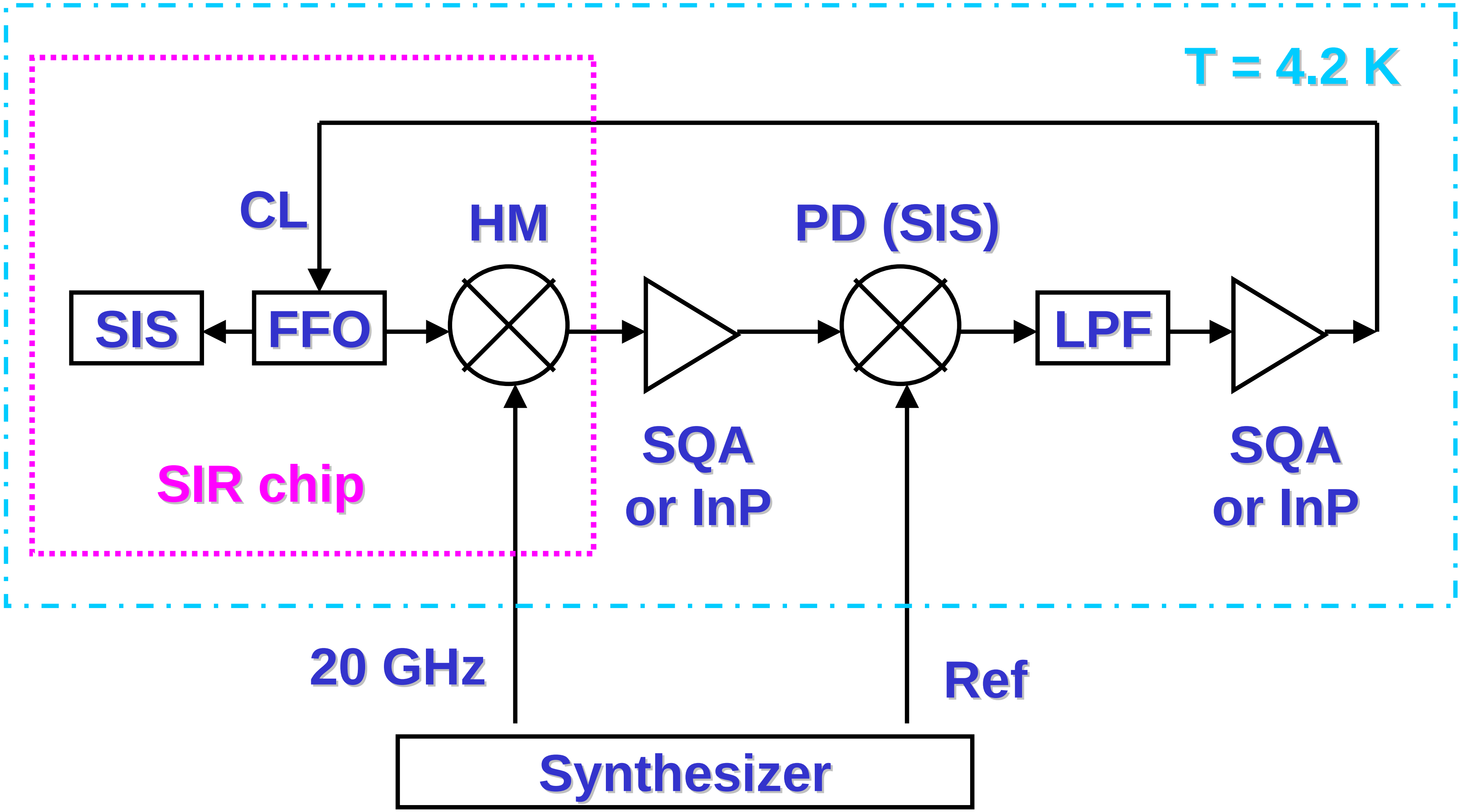
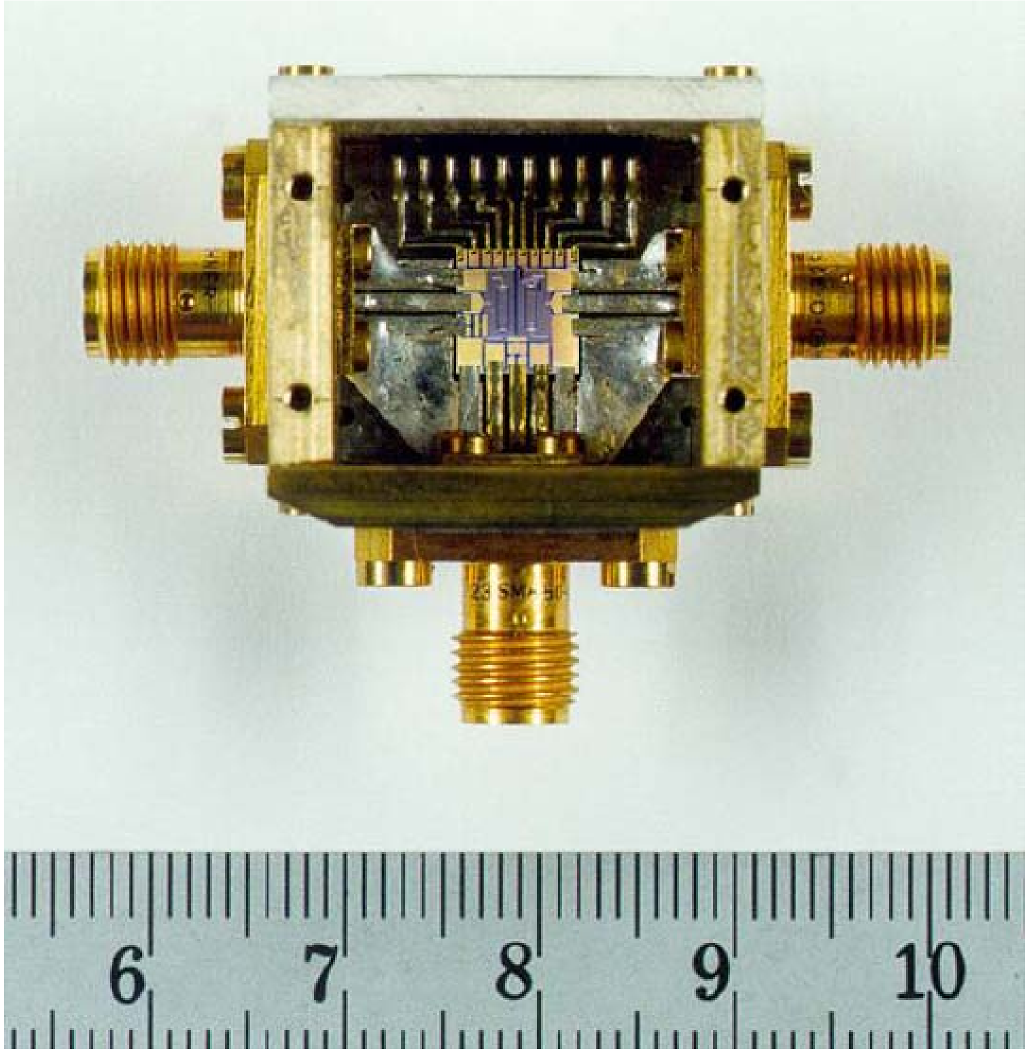
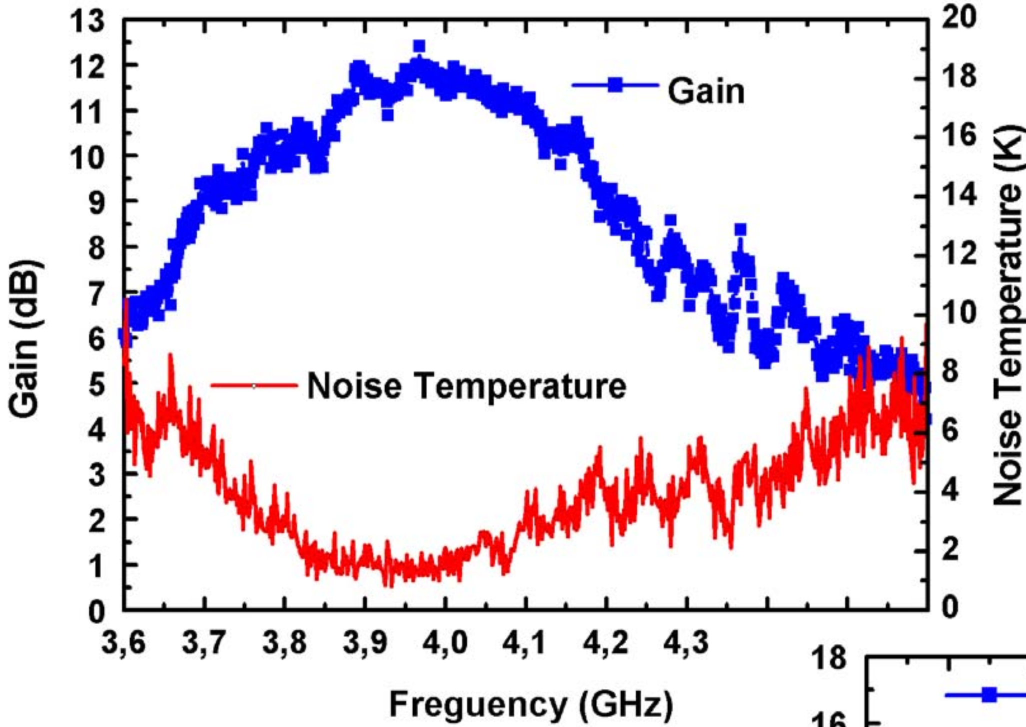
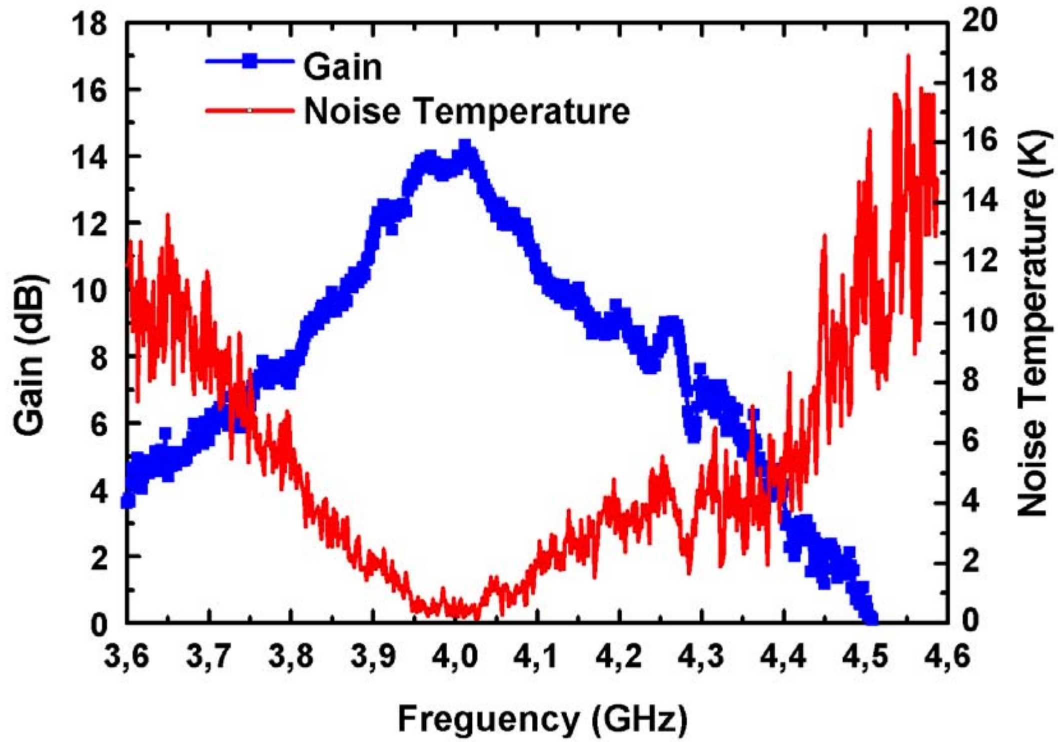


Photo of SQA test unit with two-stage SQA chip





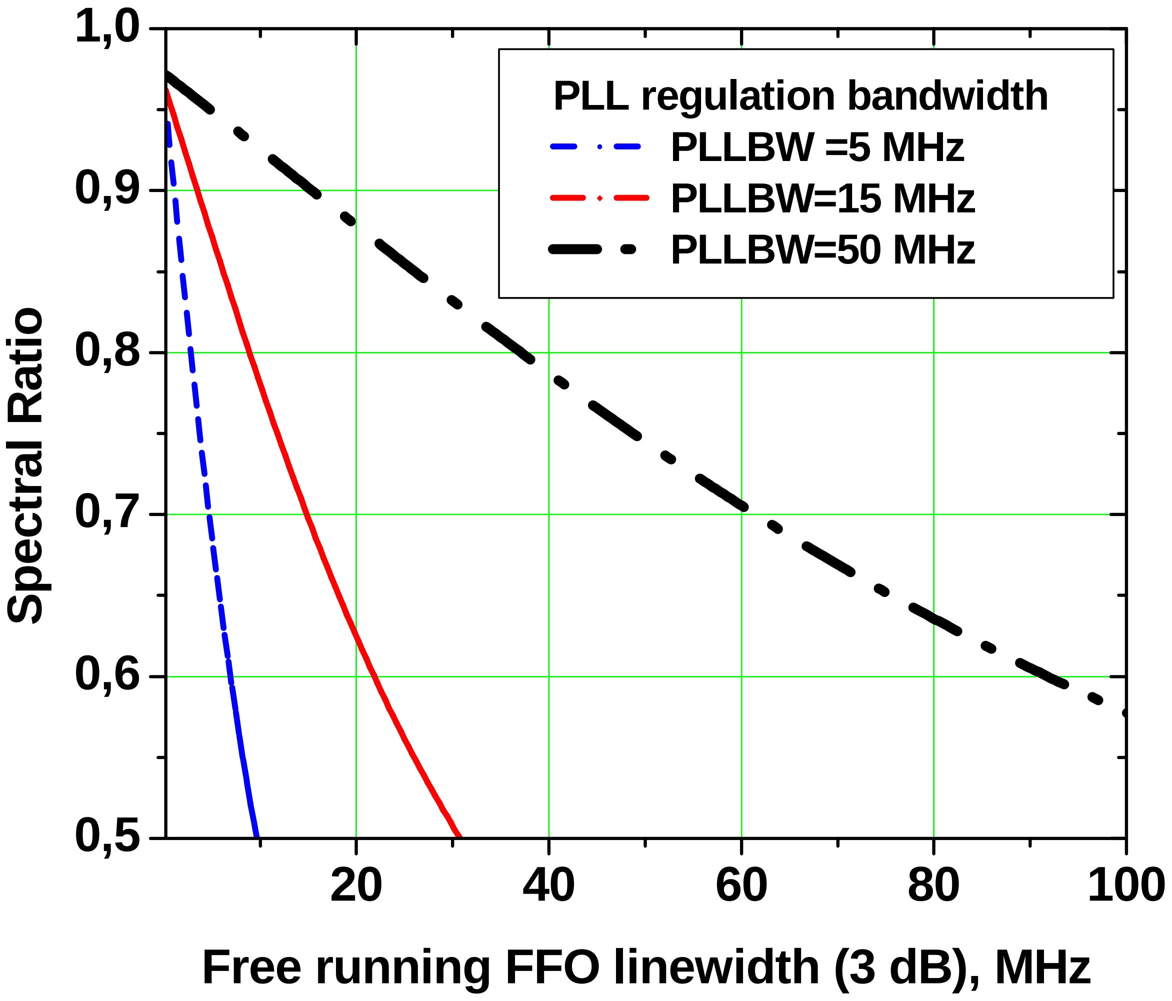
Gain and noise of SQA at 4.2 K (balanced and non-balanced)



Gain >10 dB
Tn ≤ 1 K @ 4 GHz at 4.2 K

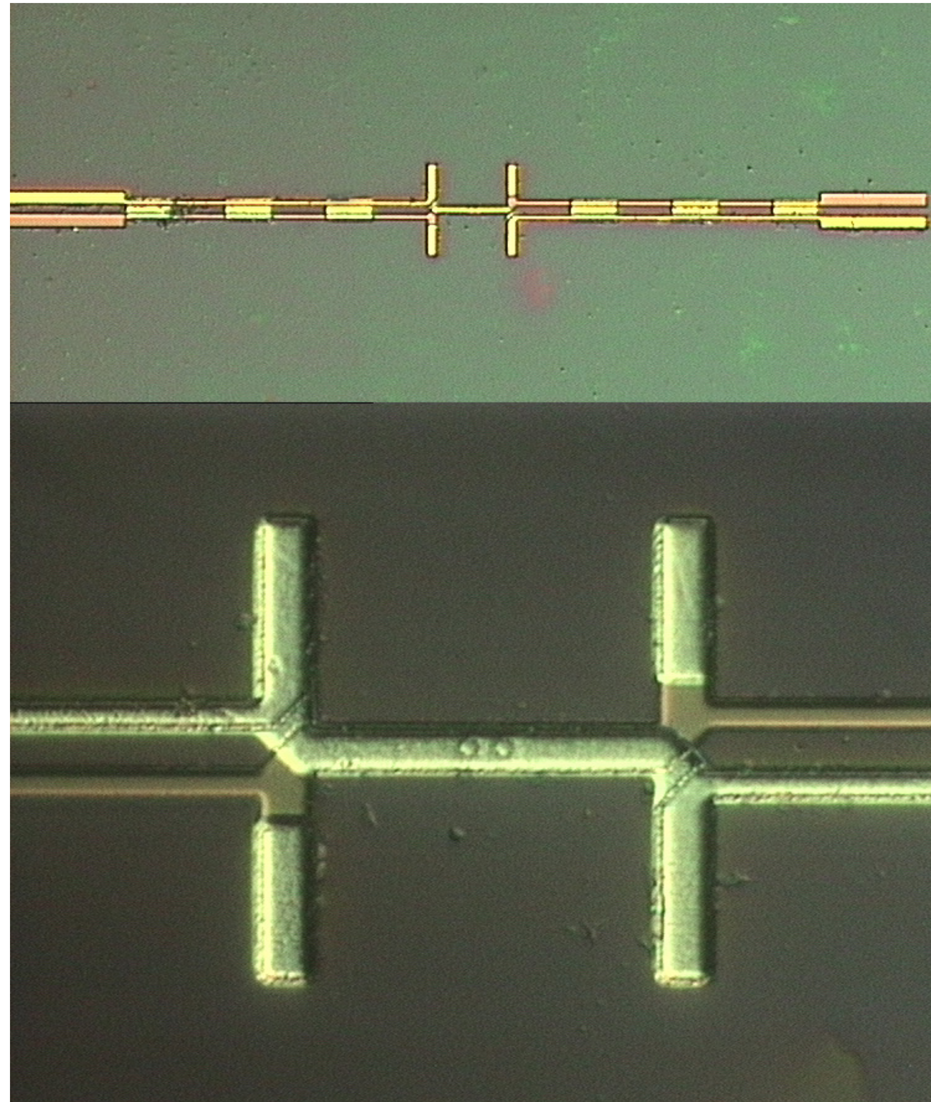
3-dB BW ≈ 10%

Spectral Ratio vs FFO LW for different PLLBW

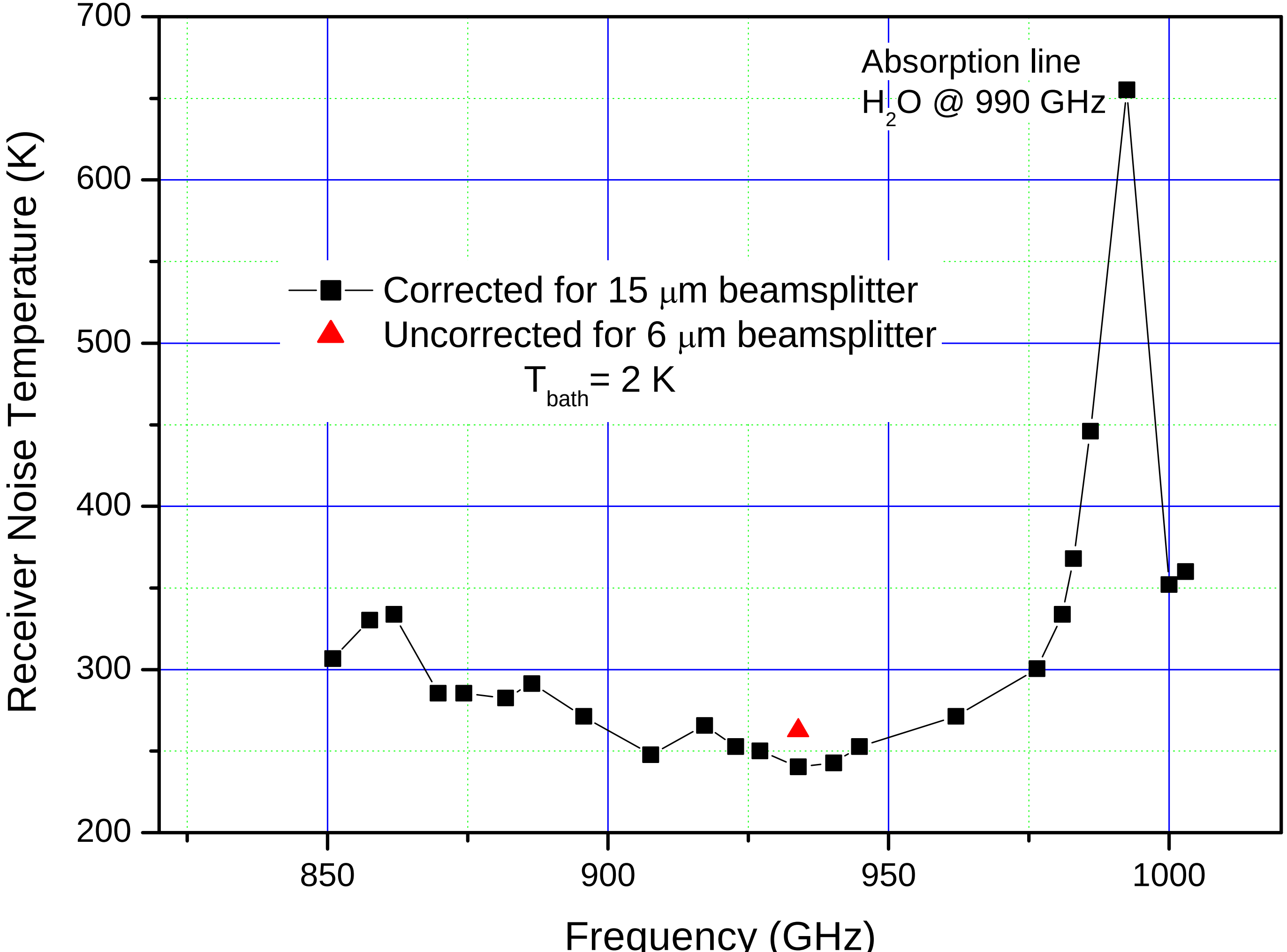


1 THz SIS-mixer (SRON - IREE)

1 THz
Nb-AlOx-Nb
SIS-mixer with
Double-dipole
Antenna and
$NbTiN/SiO_2/Al$
Tuning
Microstrip

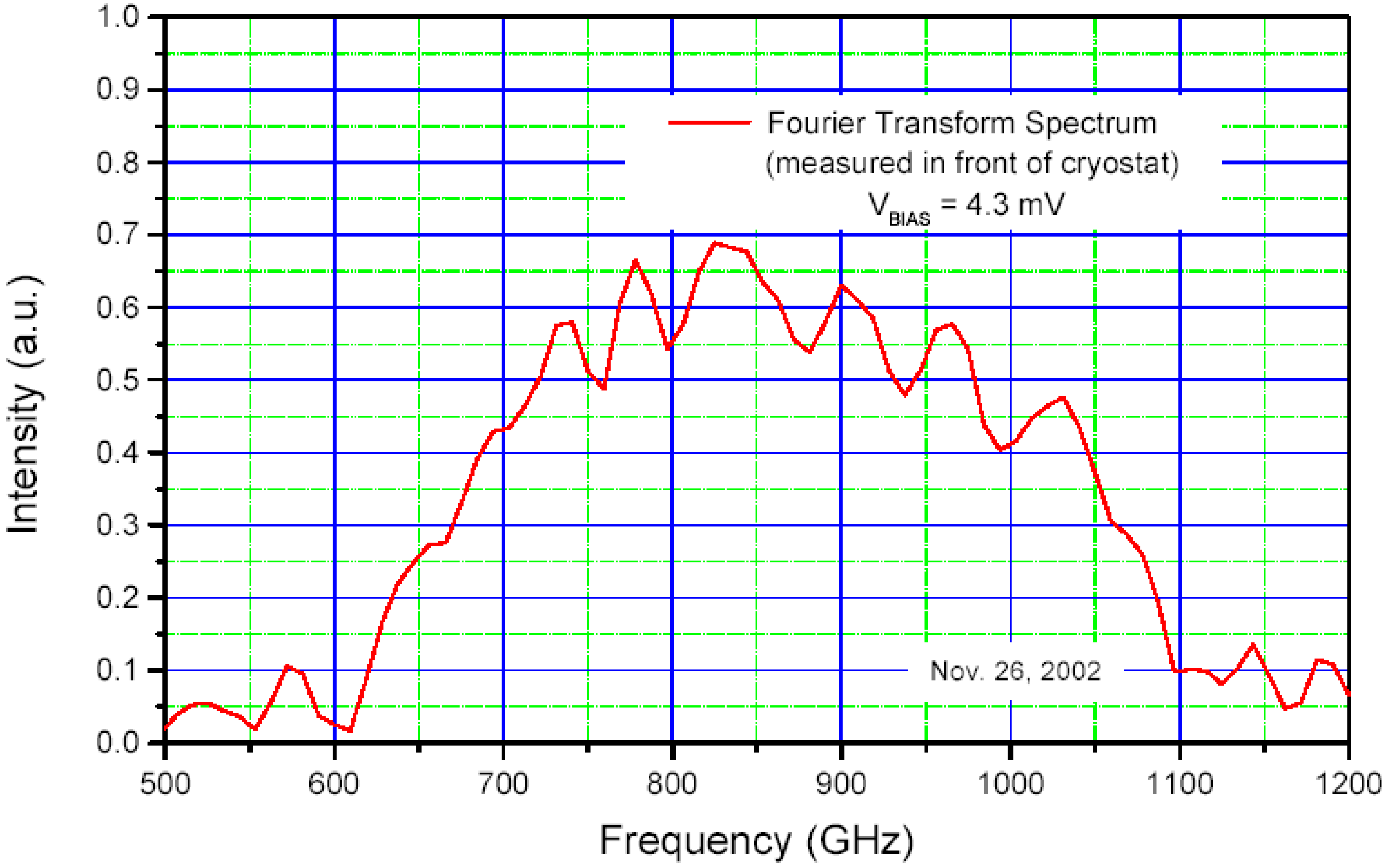


1 THz SIS-mixer with NbTiN/Al Tuner (SRON - IREE)

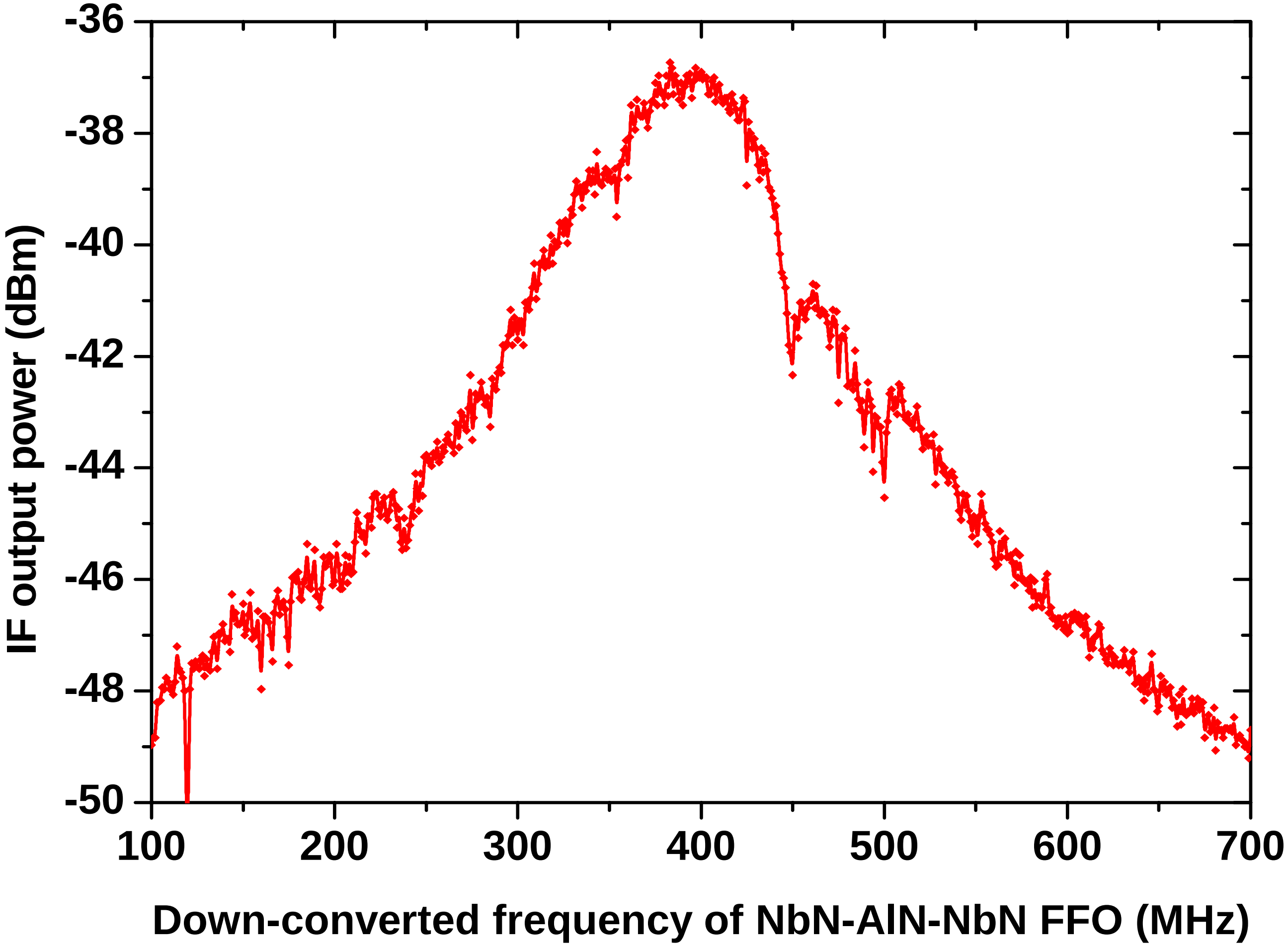


May 20, 2000 by S.V.Shitov

All NbN SIR: FTS (AIST – IREE - SRON)



All NbN SIR: LW (AIST – IREE - SRON)



THz SIR – Possible Implementations

FFO	Mixer
• **NbN-MgO/(AlN)-NbN**	**NbN-MgO/(AlN)-NbN**
Vg up to 6 mV (1.5 THz)	$P_{LO} \sim \omega^2$ **(~ 1 μW at 1 THz)**
• **NbN-MgO/(AlN)-NbN**	**Phonon Cooled NbN HEB**
	P_{LO} **< 0.1 μW (ω independent)**
	T_R **~ 700 K at 1.5 THz**
• **Stacked NbN-MgO-NbN**	**Phonon Cooled NbN HEB**
frequency up to 3 THz	

Conclusion

- **High quality Nb-AlOx-Nb SIS; Jc up to 20 kA/cm^2**
- **AlN barriers; Jc up to 200 kA/cm^2**
- **Sub-micron SIS (EBL + CMP); S = 0.03 μ^2**
- **SIS junctions with NbN electrode; Vg = 3.6 mV**
- **PL Nb-AlN-NbN FFO for TELIS ?**
- **NbN- MgO(AlN)-NbN junctions and circuits – additional study required (tech + calc + exp)**
- **?? Integration of a FFO and NbN HEB ??**
- **A special project to develop an array of PL SIRs is required**