Supercurrent manipulation by Scanning Gate Microscopy in InSb nanoflag-based Josephson Junctions

Antonio Lombardi

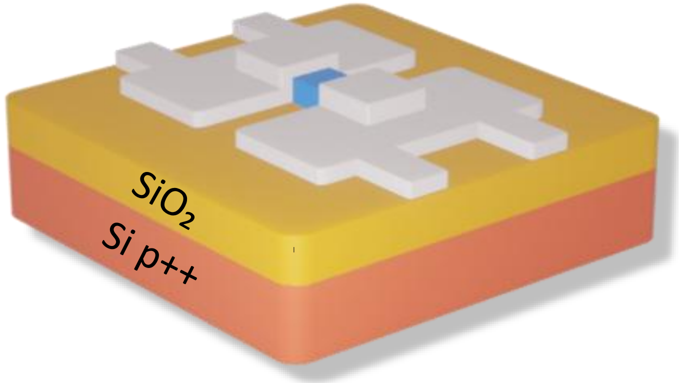
Supervisors: Prof. S. Heun and Prof. L. Sorba

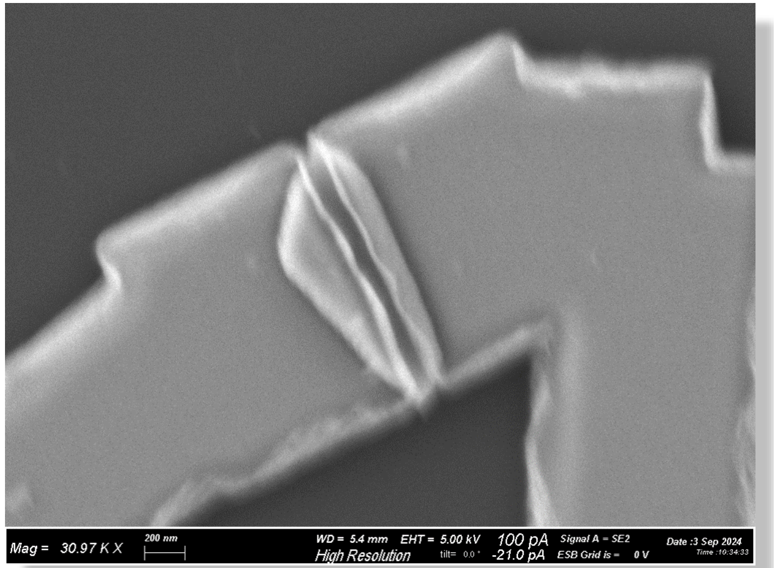
Outline

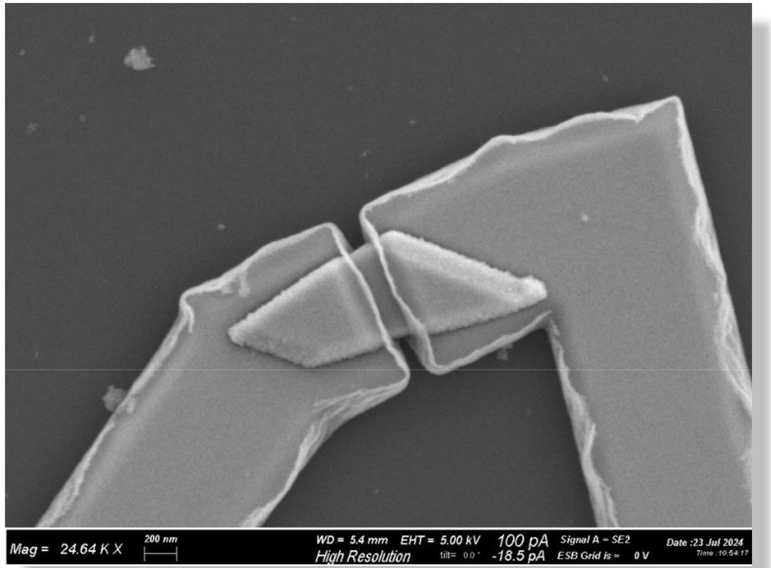
- First SGM maps of InSb nanoflag-based devices
- First measurements of tip-induced critical current modulation
- Observaton of high interface transparency for InSb nanoflag-based devices

Nanoflag-based device nanofabrication

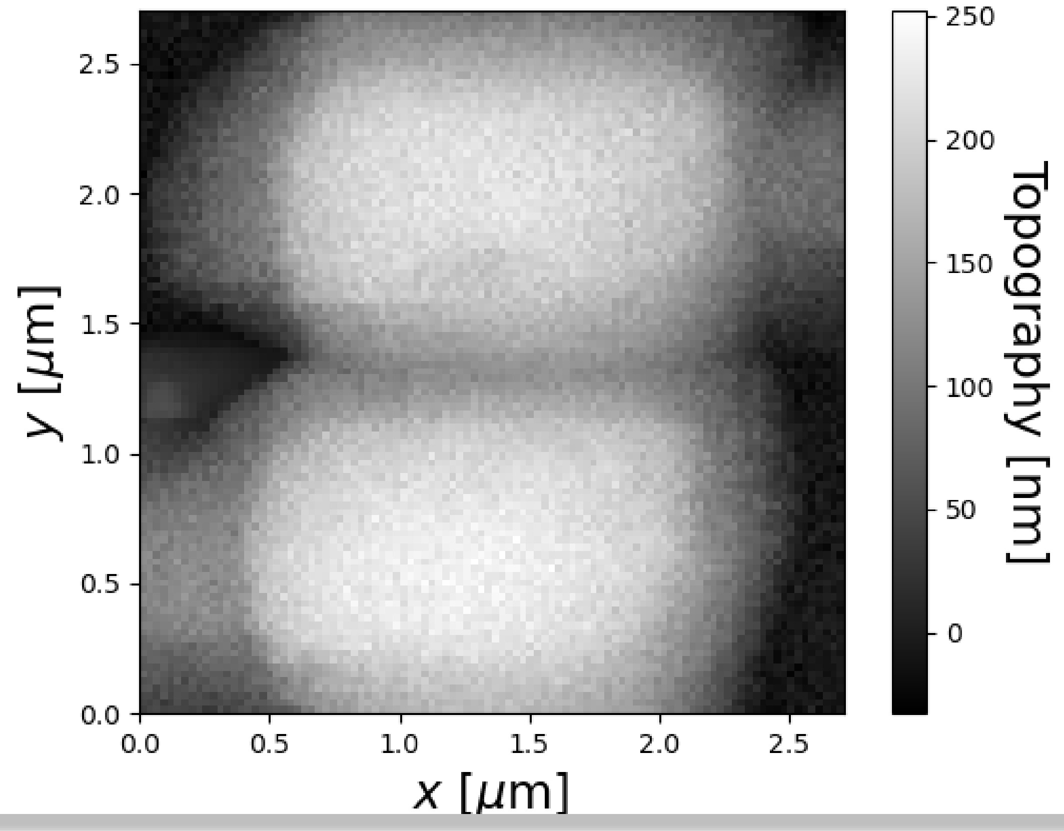
- Random drop-casting on pre-patterned Si(100) p++ substrate with 280 nm SiO_2 as dielectric
- Selected nanoflags position determined by SEM
- Leads patterning by Electron Beam Litography
- Surface passivation: 1 min in 1:9 $(NH_4)_2S_x$ at 40°C
- Metal deposition by sputtering (Nb)

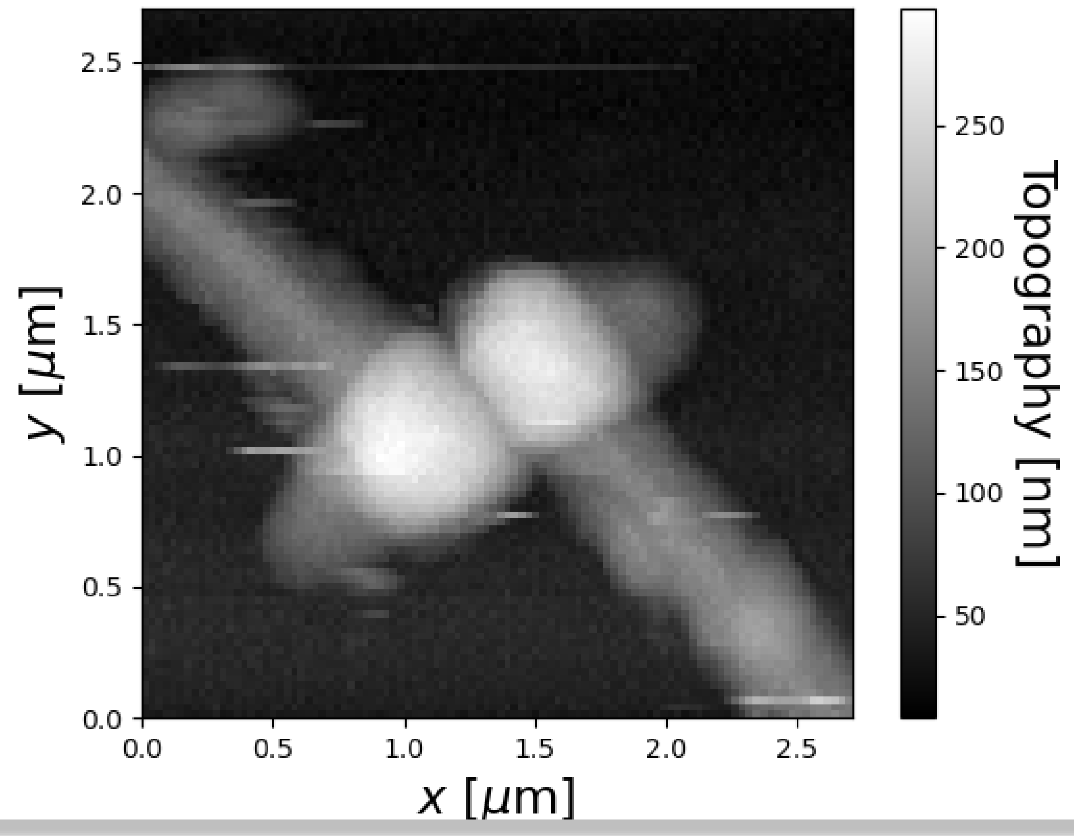




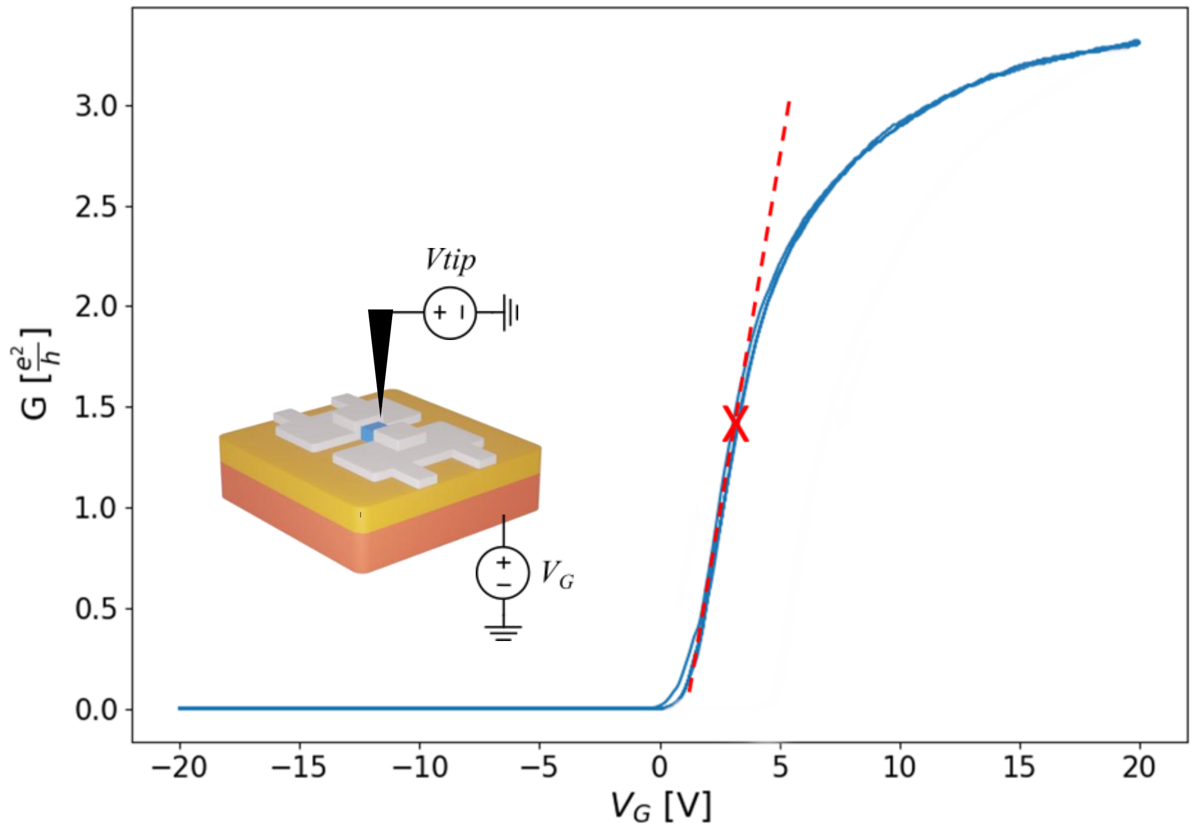


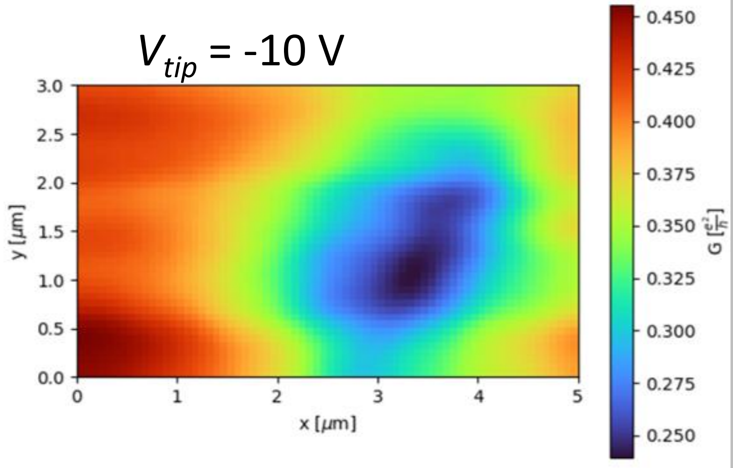
Room temperature topography maps

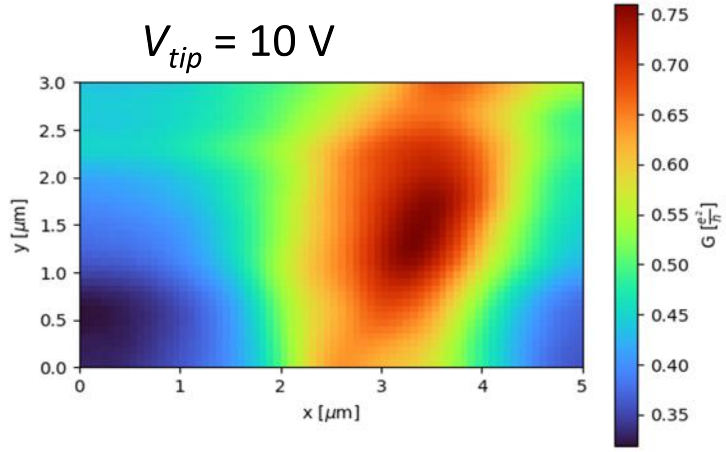




Scanning Gate Microscopy 77K





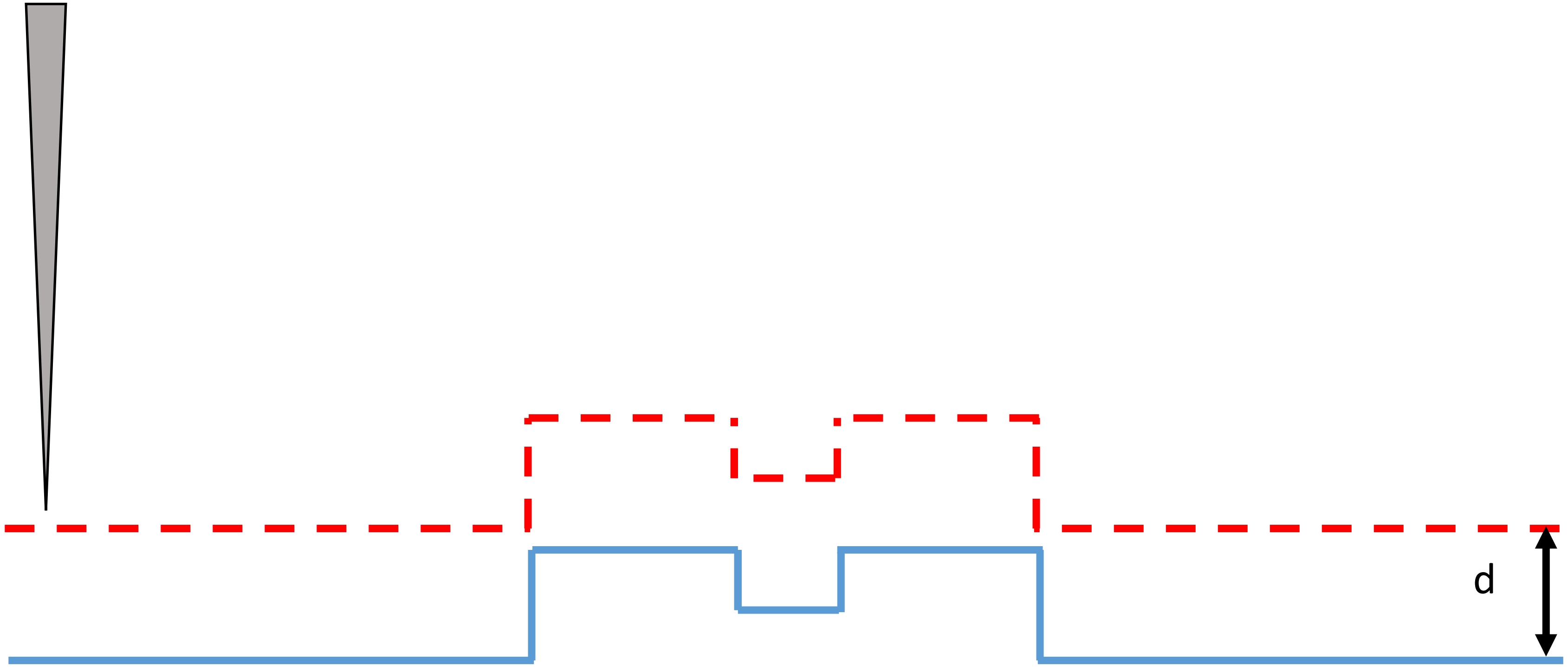


CNRNANO PISA NEST

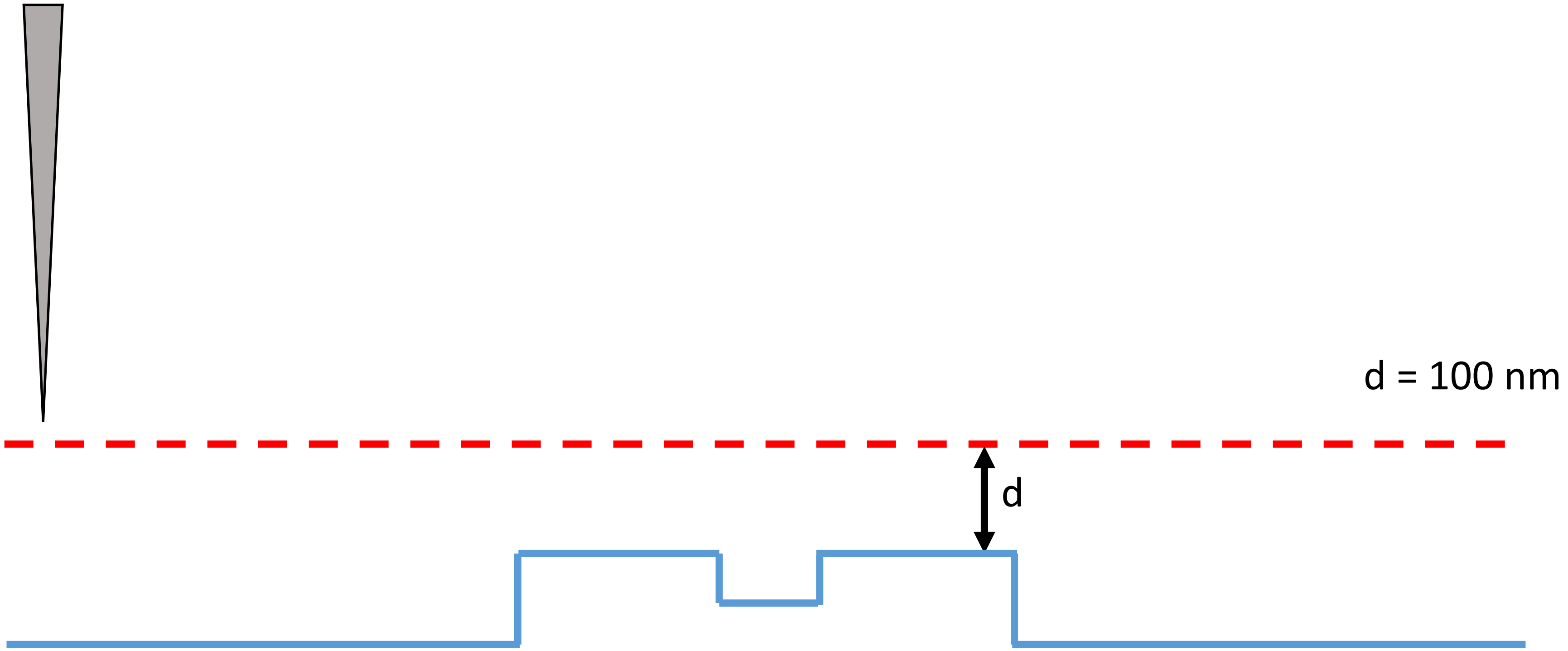
IN SUPREMÆ DIGNITATIS 1343

SCUOLA NORMALE SUPERIORE

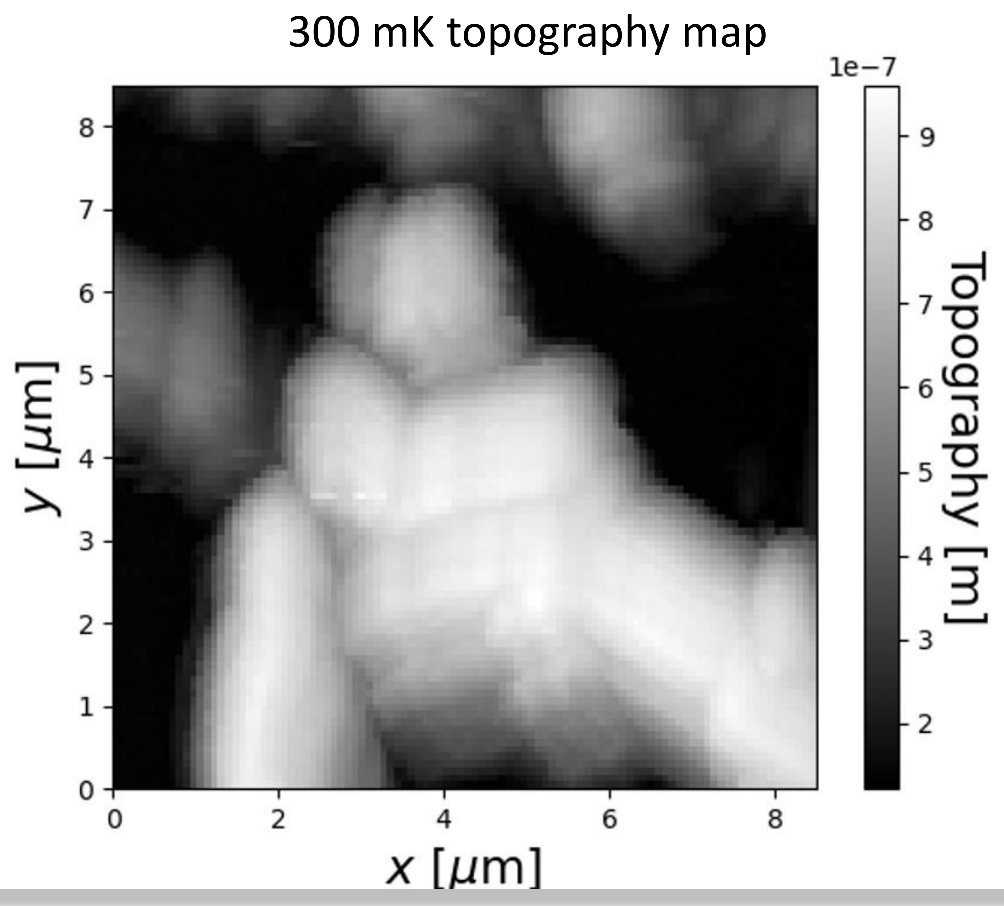
Dual Pass Mode

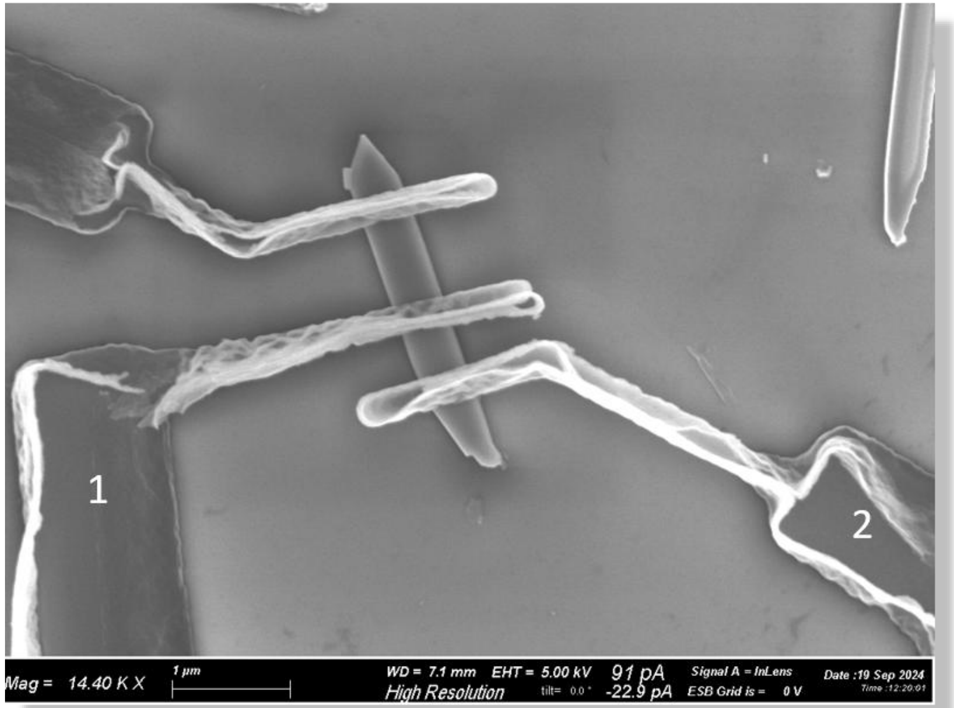


Flying Mode



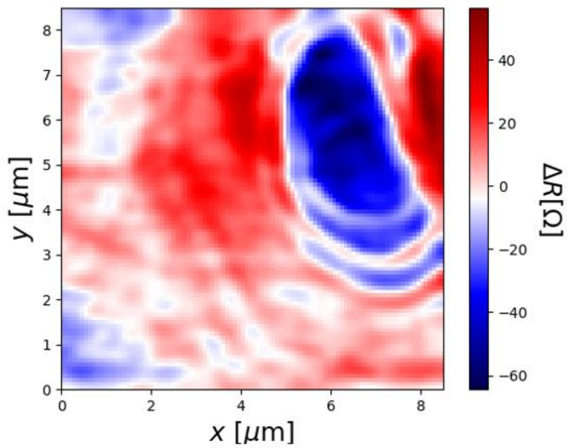
Device SC7 @300 mK



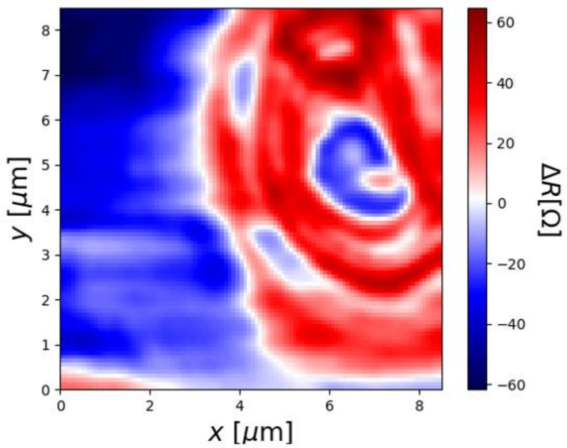


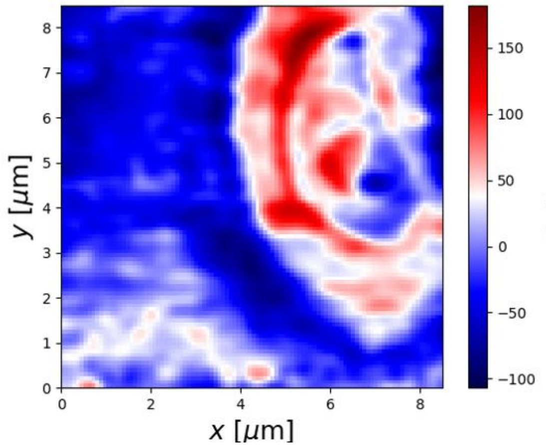
Coulomb blockade imaging by SGM

10V backgate voltage

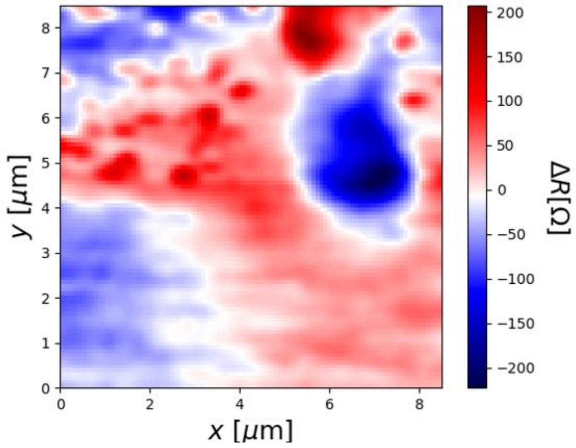


8V backgate voltage





6V backgate voltage



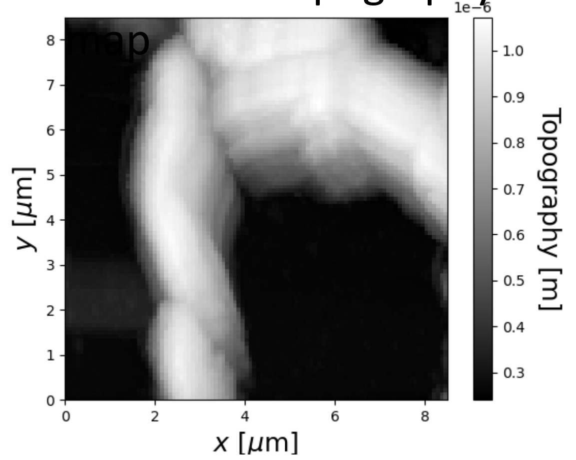
4V backgate voltage

-10V on the tip

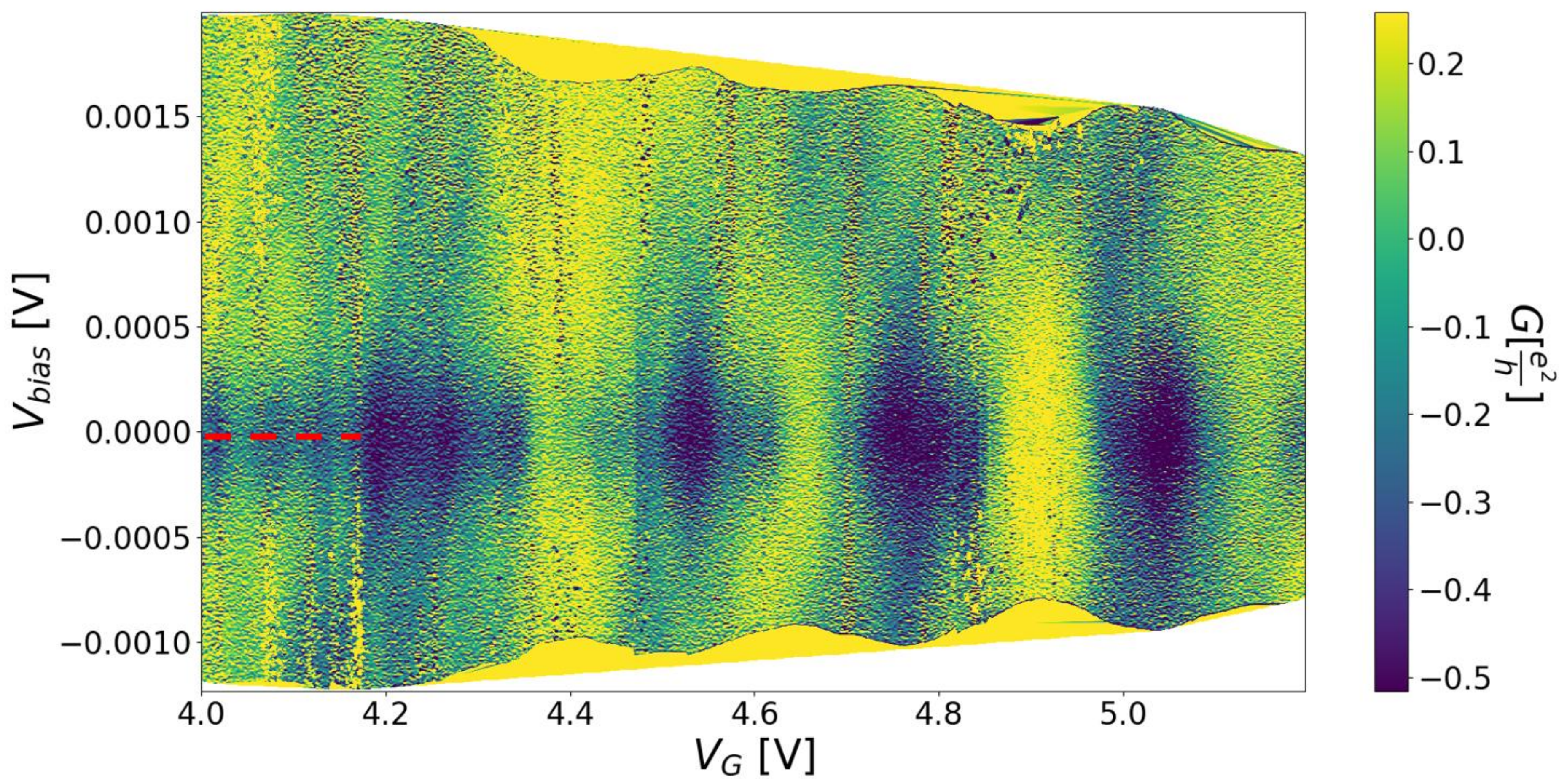
Disorder induced quantum dots

Rings-like features corresponding to Coulomb blockade transitions

Reference topography map



Hints of Coulomb diamonds

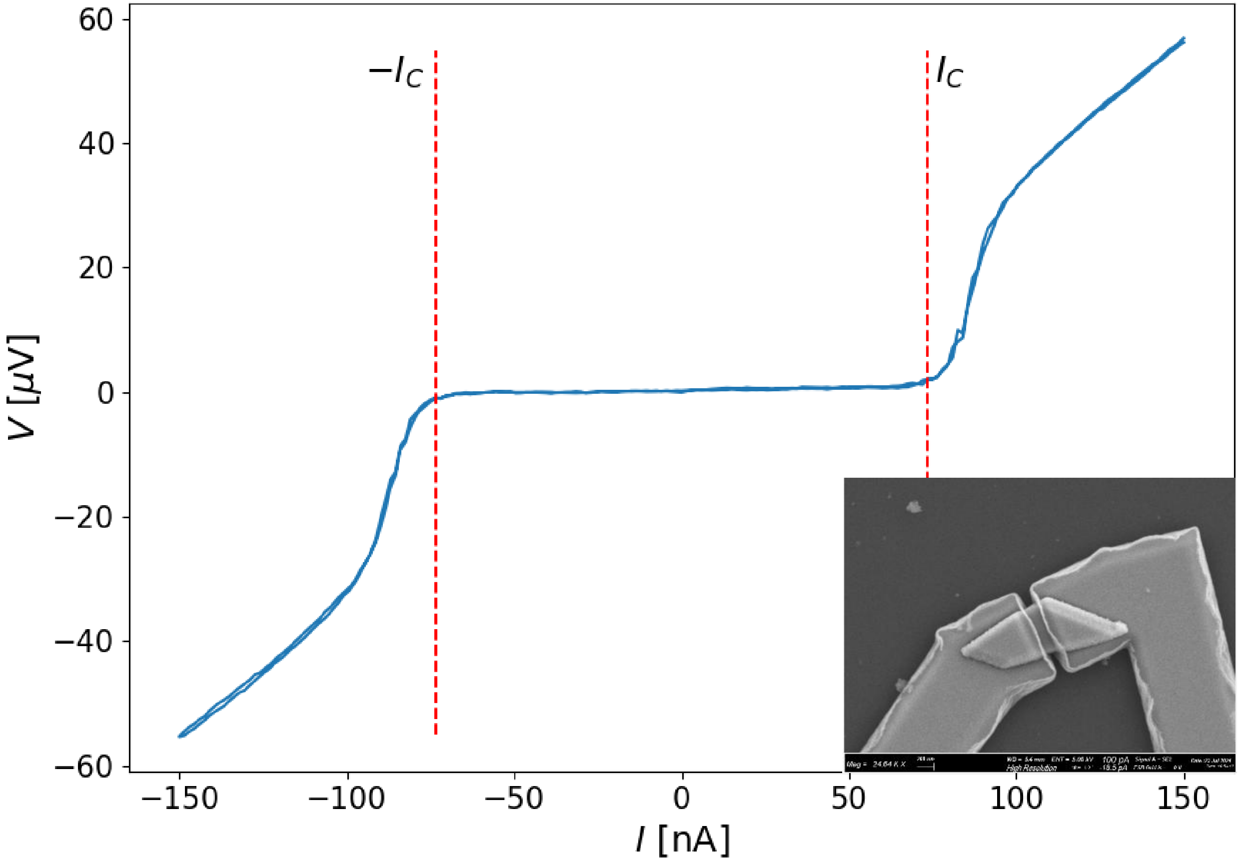


InSb nanoflag-based Josephson Junction

T = 300 mK

I_C = 73 nA

V_G = 40 V



A new generation of devices

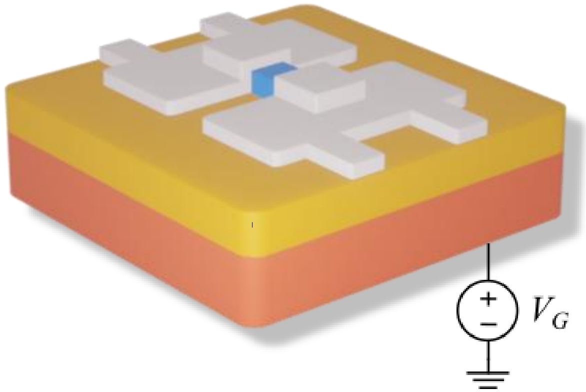
	device	L [nm]	W [nm]	I_C [nA] at $V_G = 40\,V$
	SGM1 D8D1	180 ± 10	1530 ± 30	90 ± 10
SGM devices	SGM1 D8D2	130 ± 10	610 ± 10	80 ± 20
	SGM3 H4D2	190 ± 10	1420 ± 30	35 ± 5
	SGM3 H5D1	190 ± 10	1500 ± 30	700 ± 50
Older generation devices	SC10 [10]	200	700	50
	SC20 F6 [121]	250 ± 10	540 ± 10	50
	SC20 F7 [121]	110 ± 10	530 ± 10	17

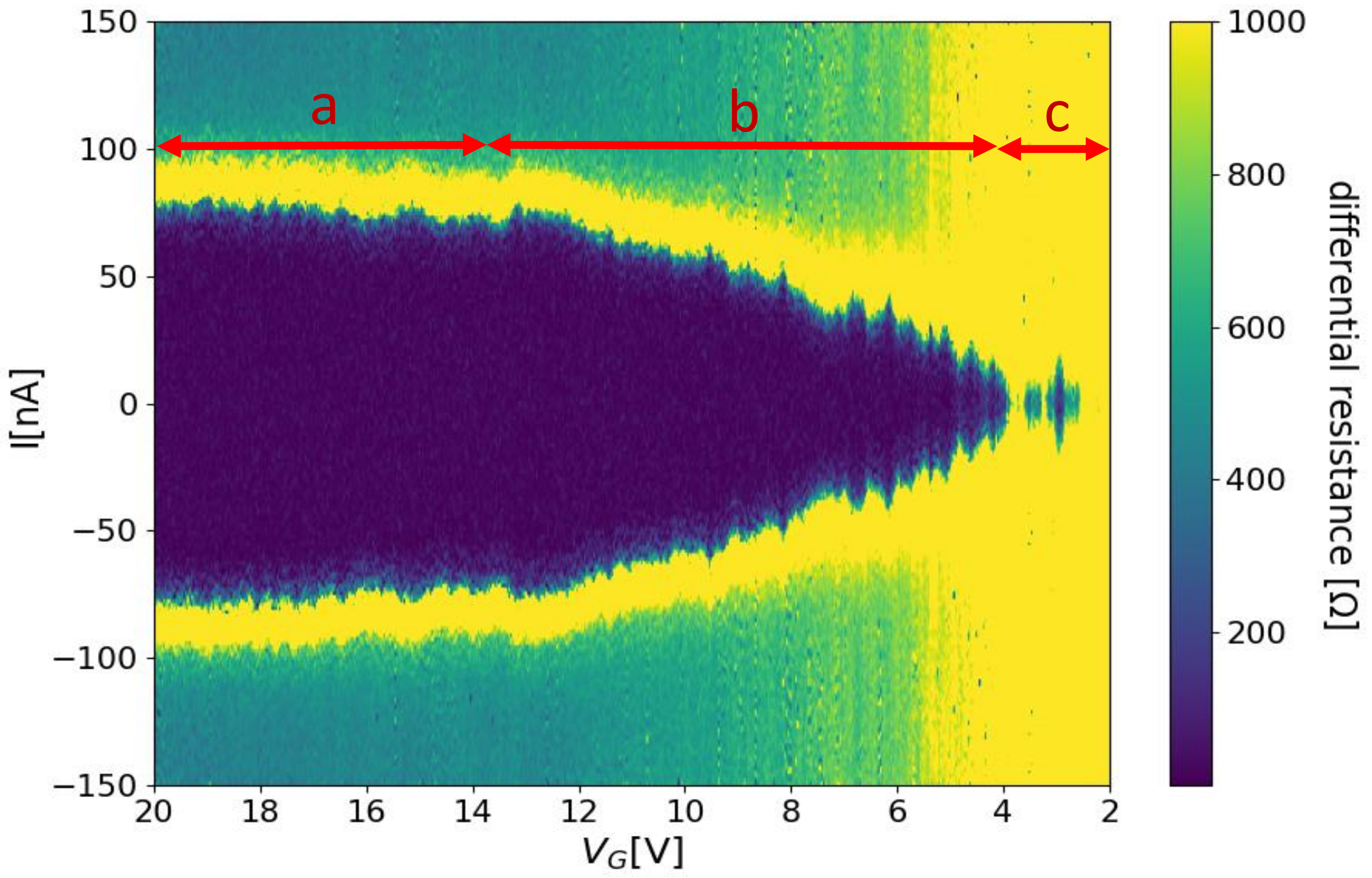
Gate tunable supercurrent: JoFET

a = saturation regime

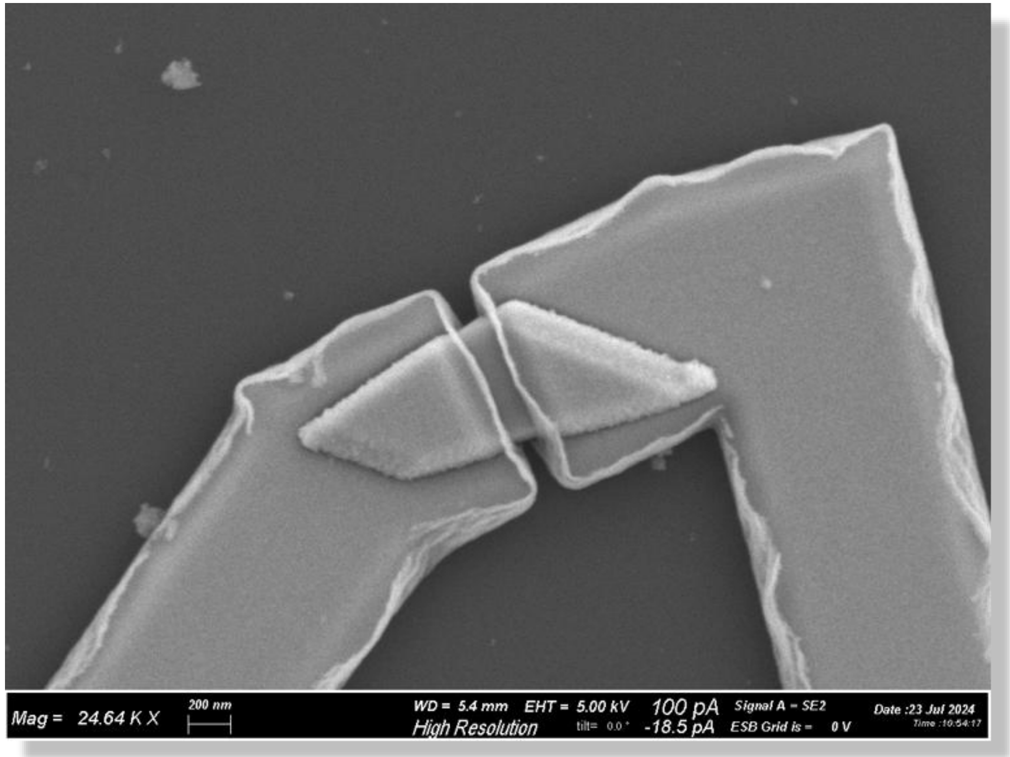
b = modulation regime

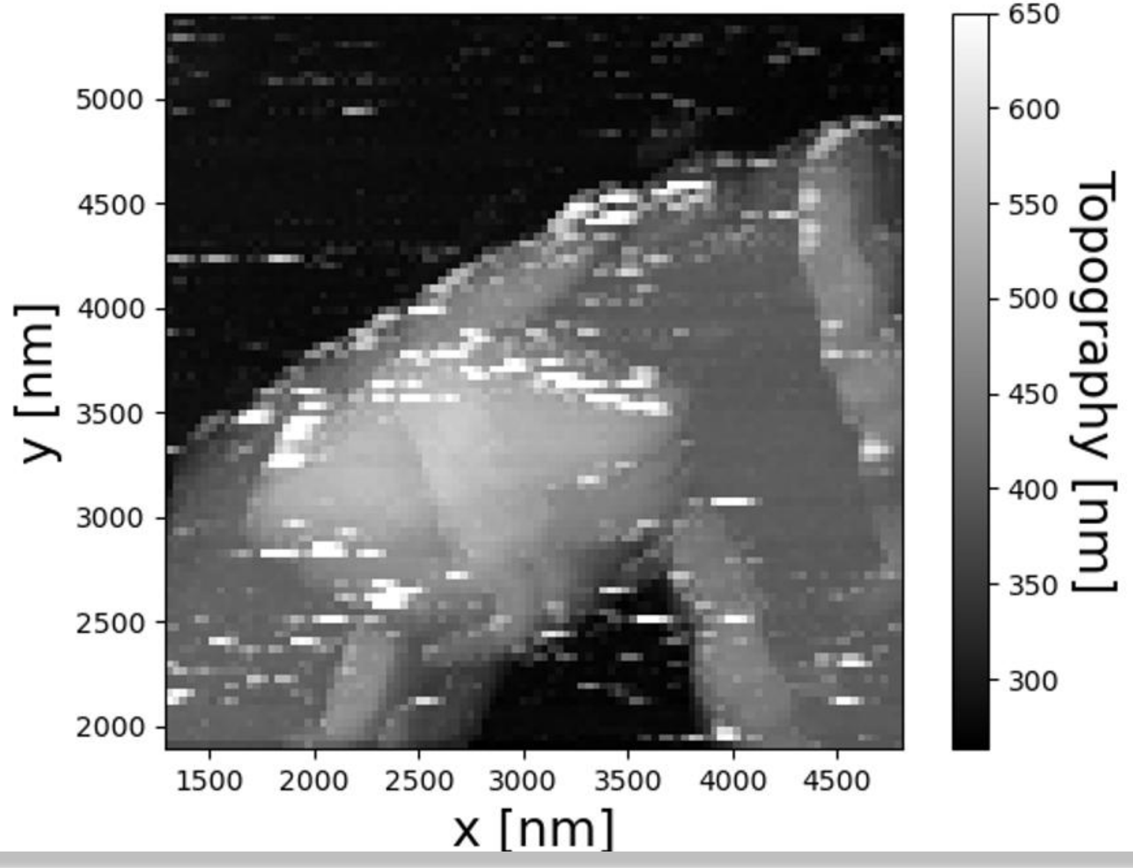
c = pinch-off regime





300 mK topography maps



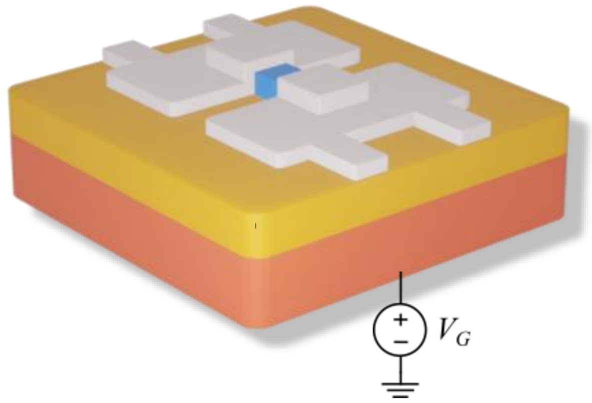


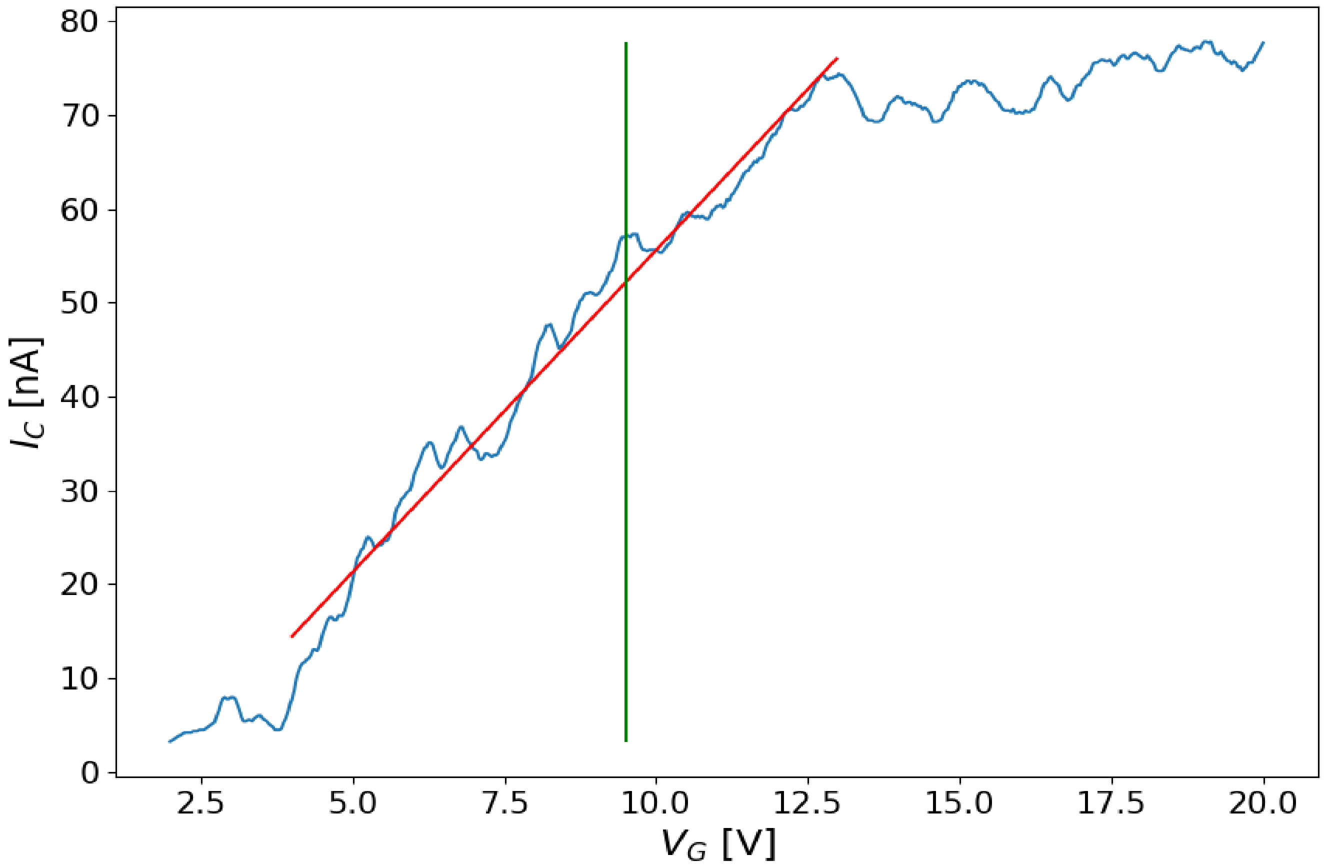
Working point

Best fit with linear model:

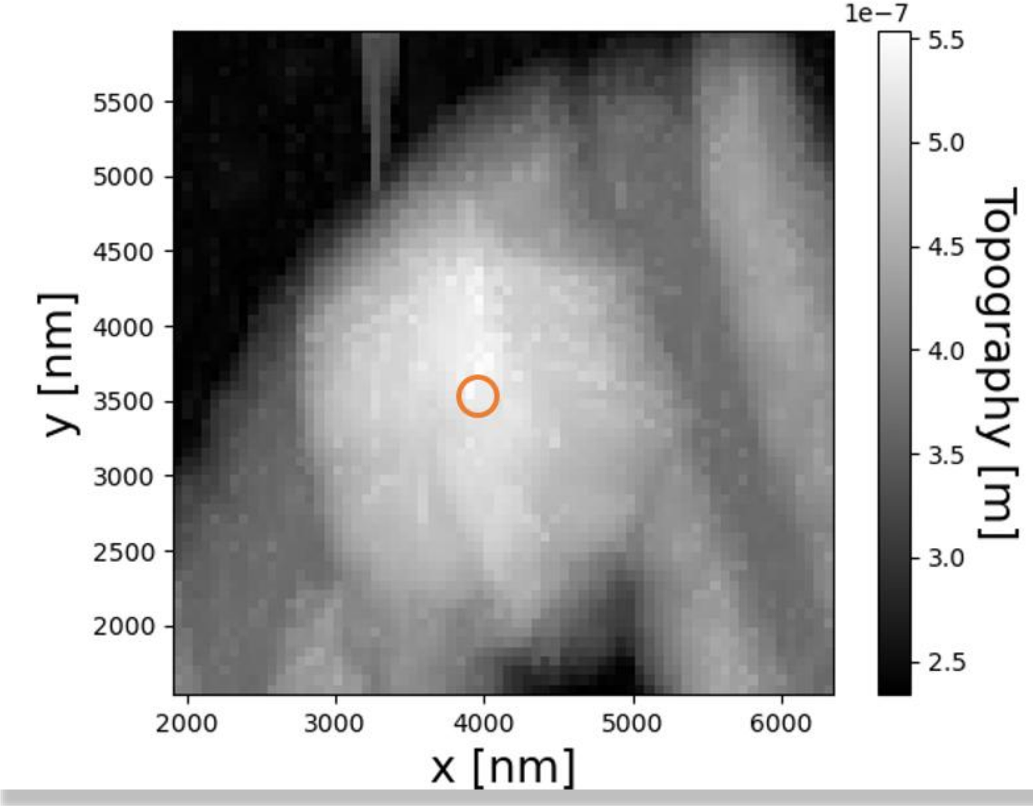
$$I_C = \alpha_G V_G + b$$

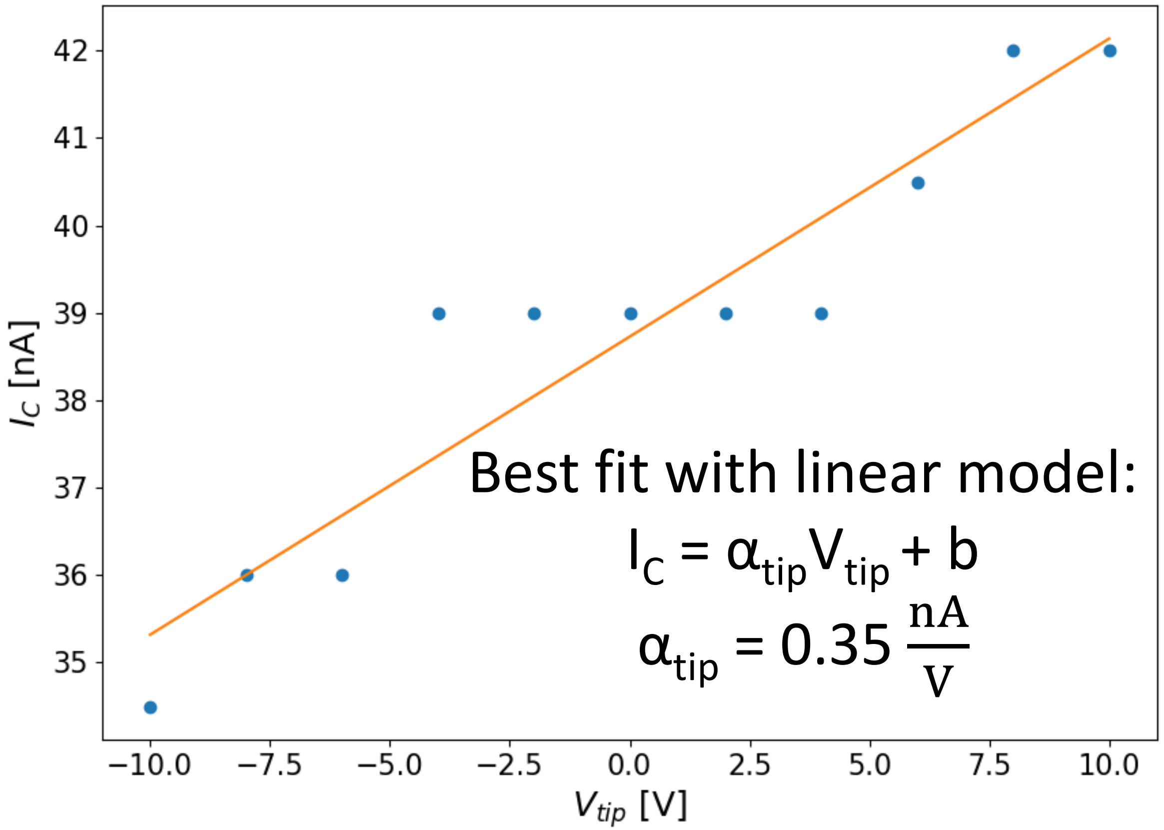
$$\alpha_G = 6.5\,\frac{\mathrm{nA}}{\mathrm{V}}$$



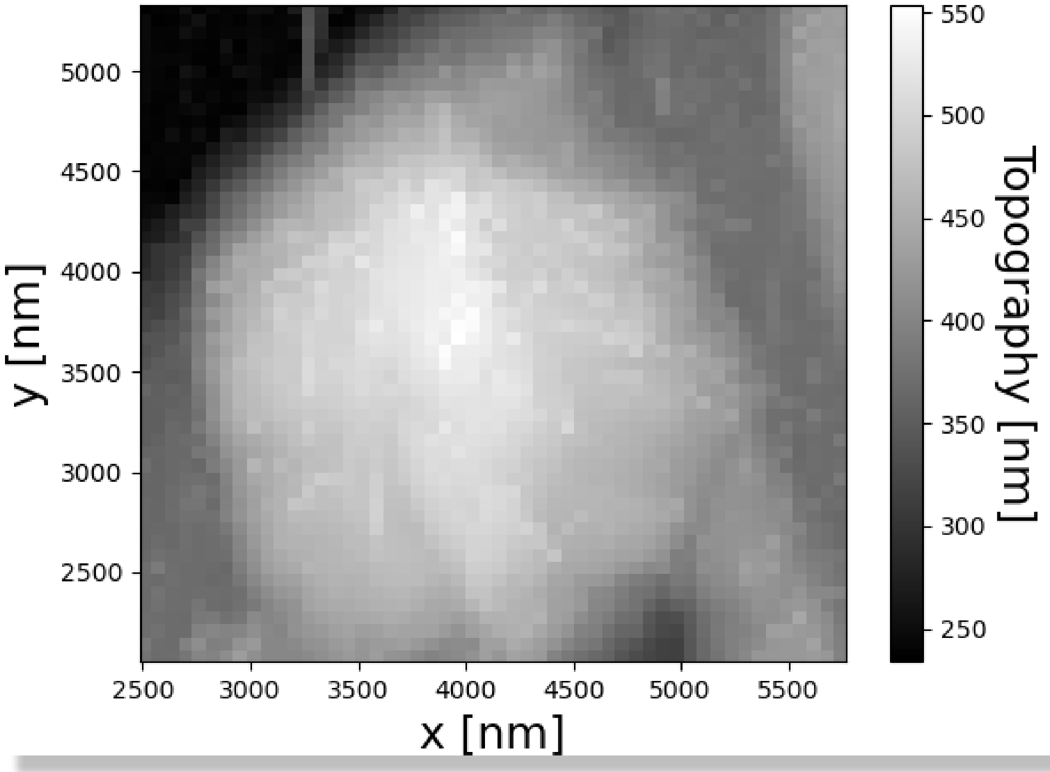


Tip-induced critical current modulation

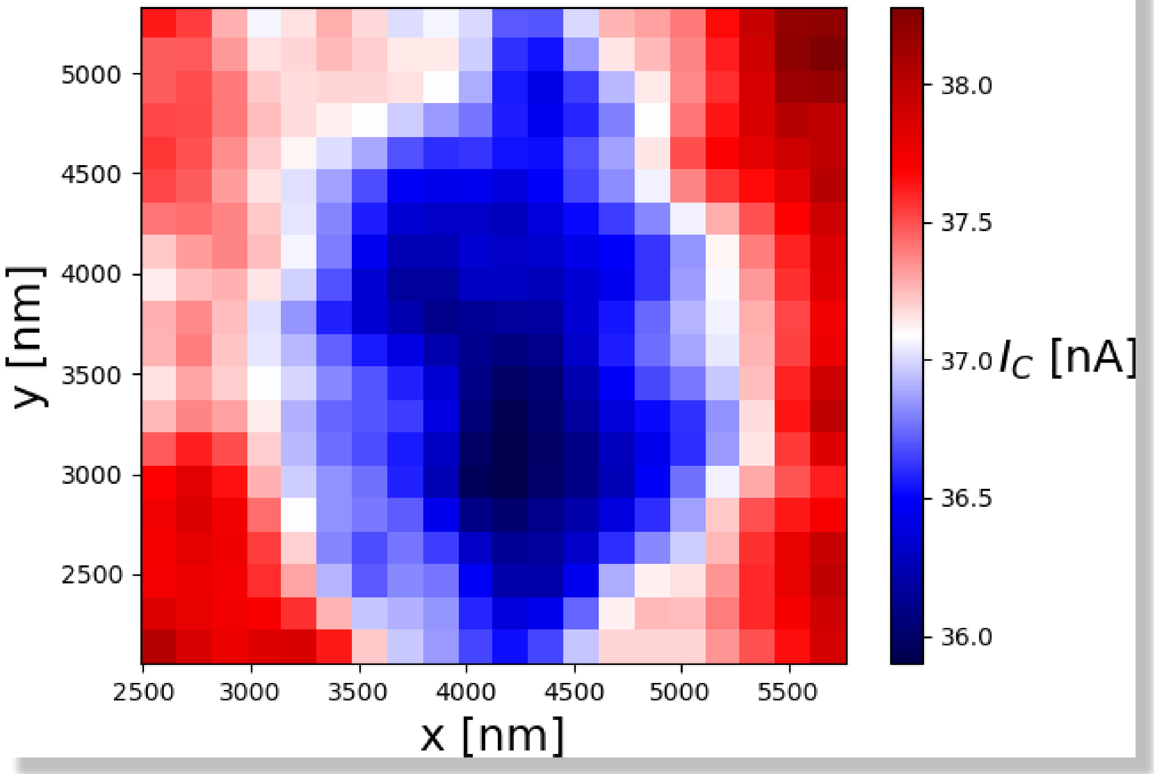




Critical current modulation by SGM

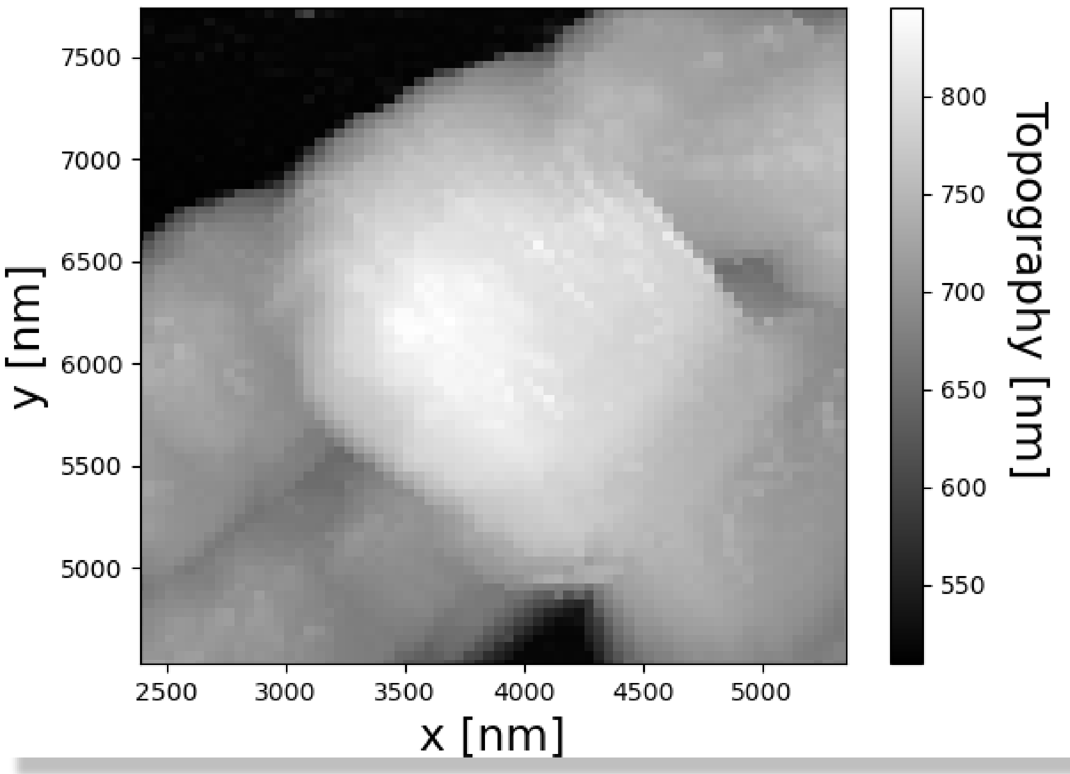


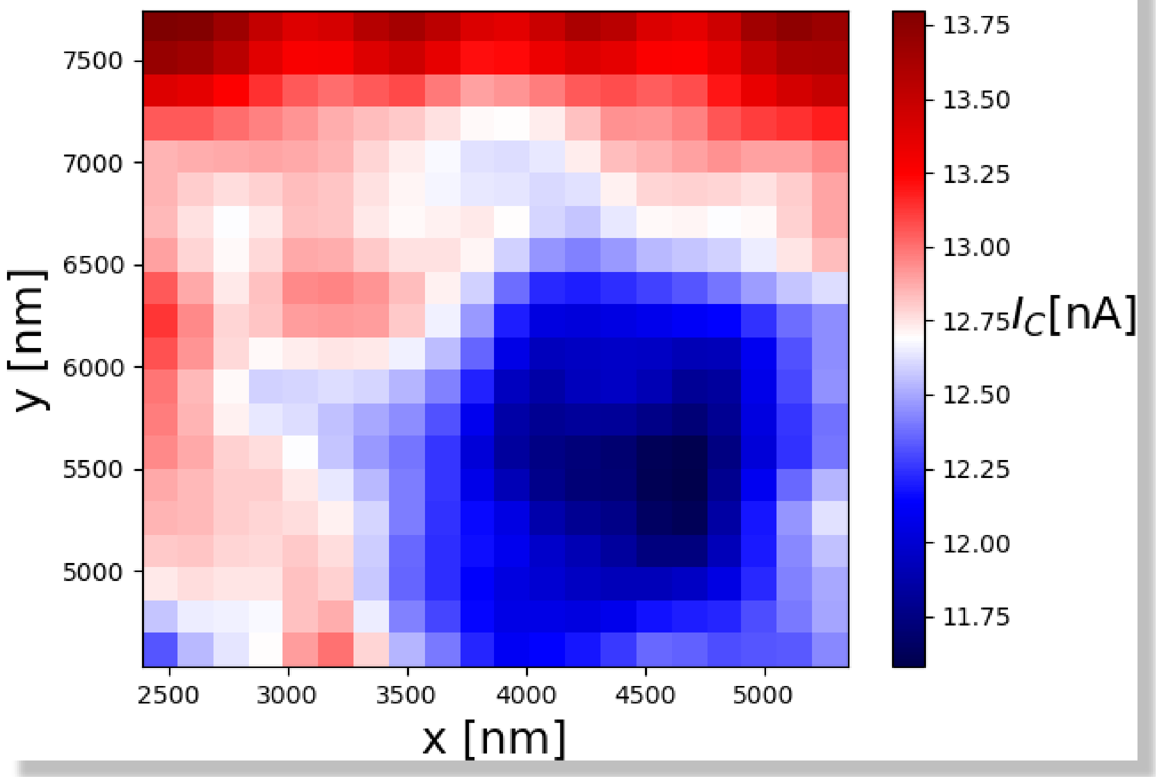
V_{tip} = -10 V V_G = 9.5V



Reproducibility: device SGM3 H4D2

V_{tip} = -10 V V_G = 6V





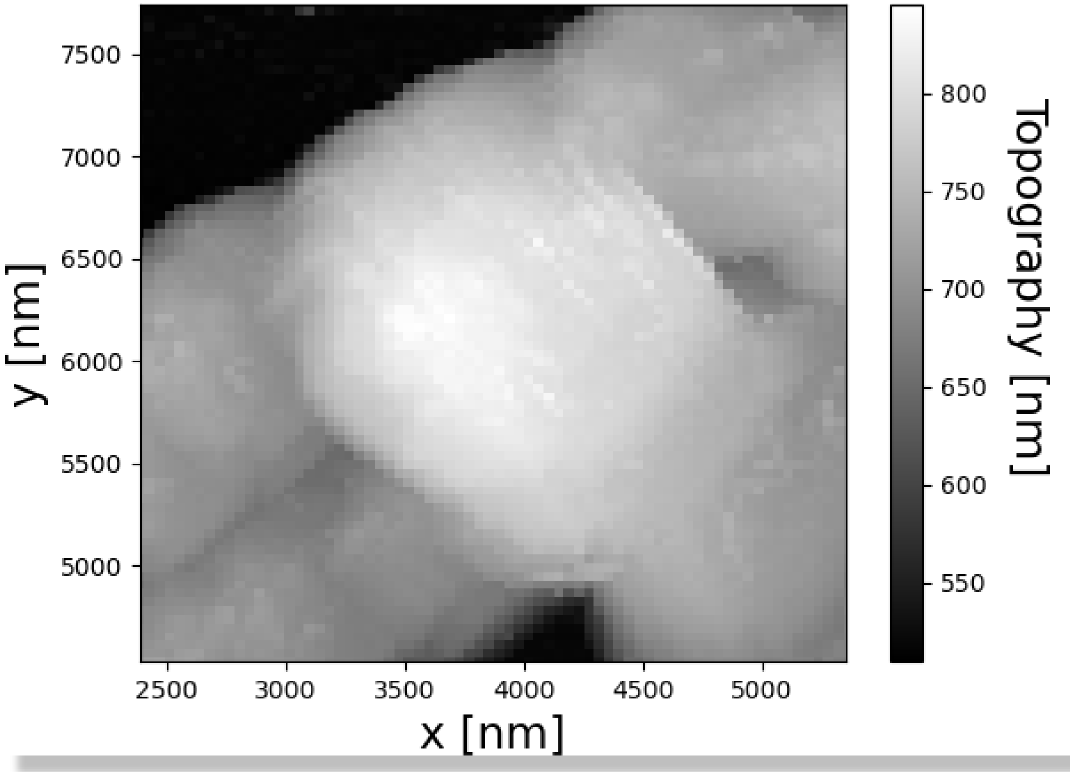
CNRNANO PISA NEST

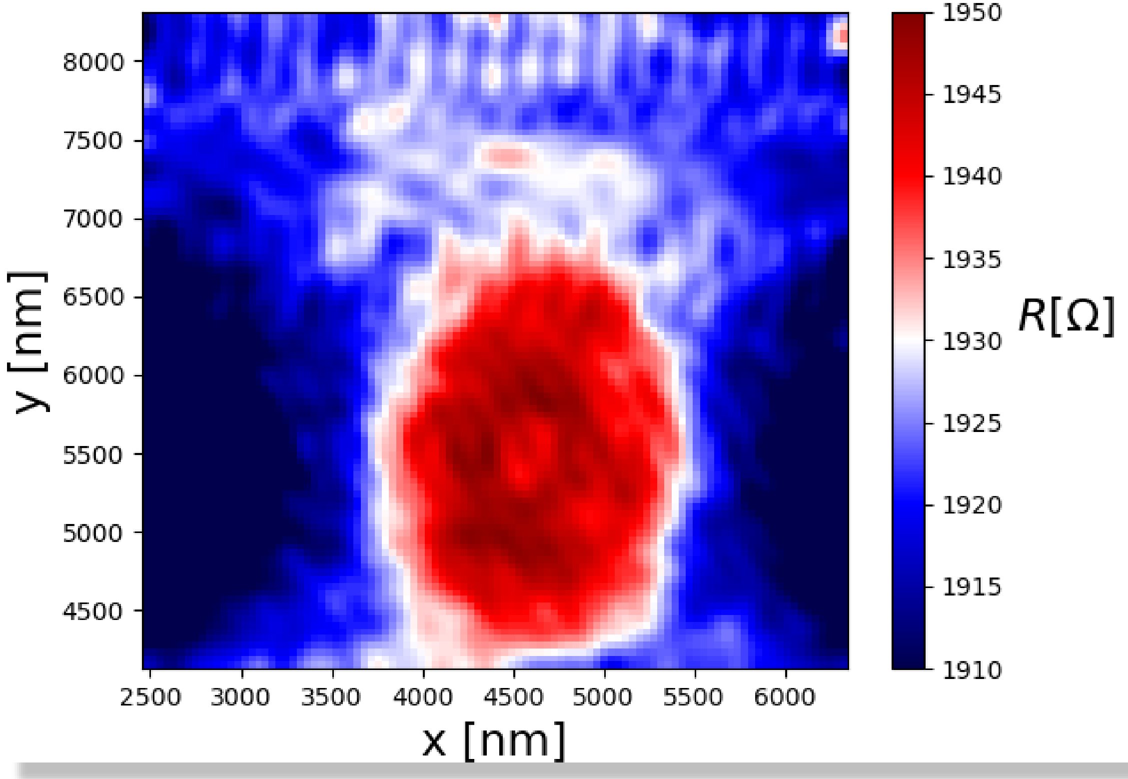
IN SUPREMÆ DIGNITATIS 1343

SCUOLA NORMALE SUPERIORE

Conventional normal state SGM

V_{tip} = -10 V V_G = 1.5V

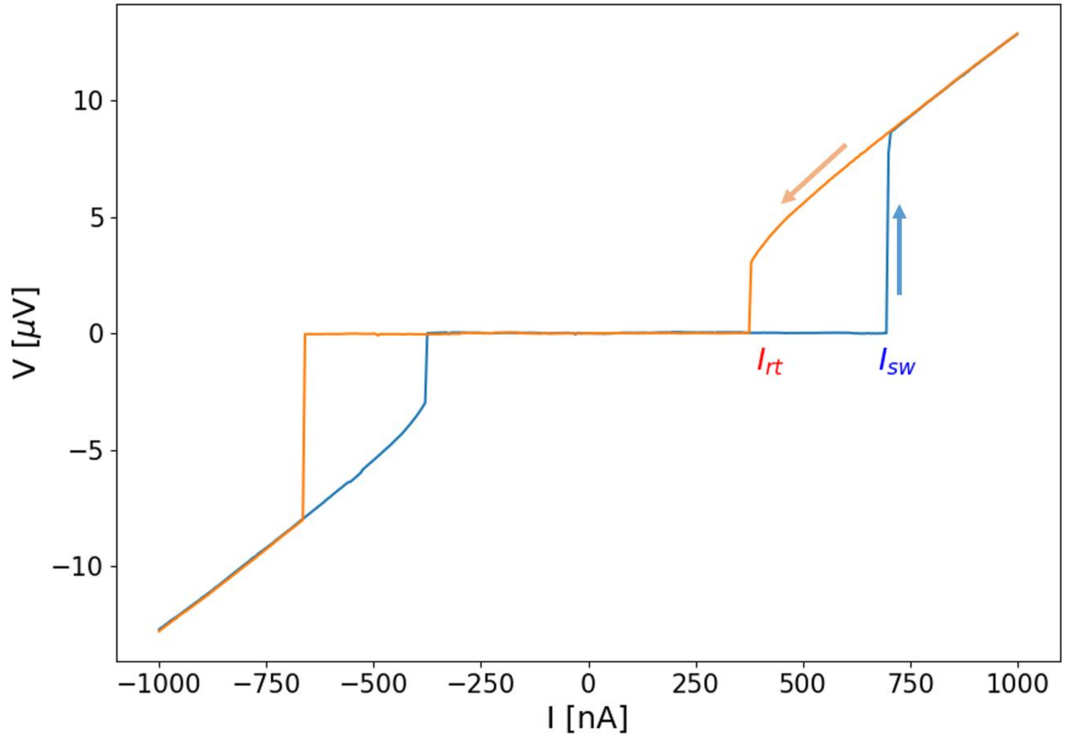


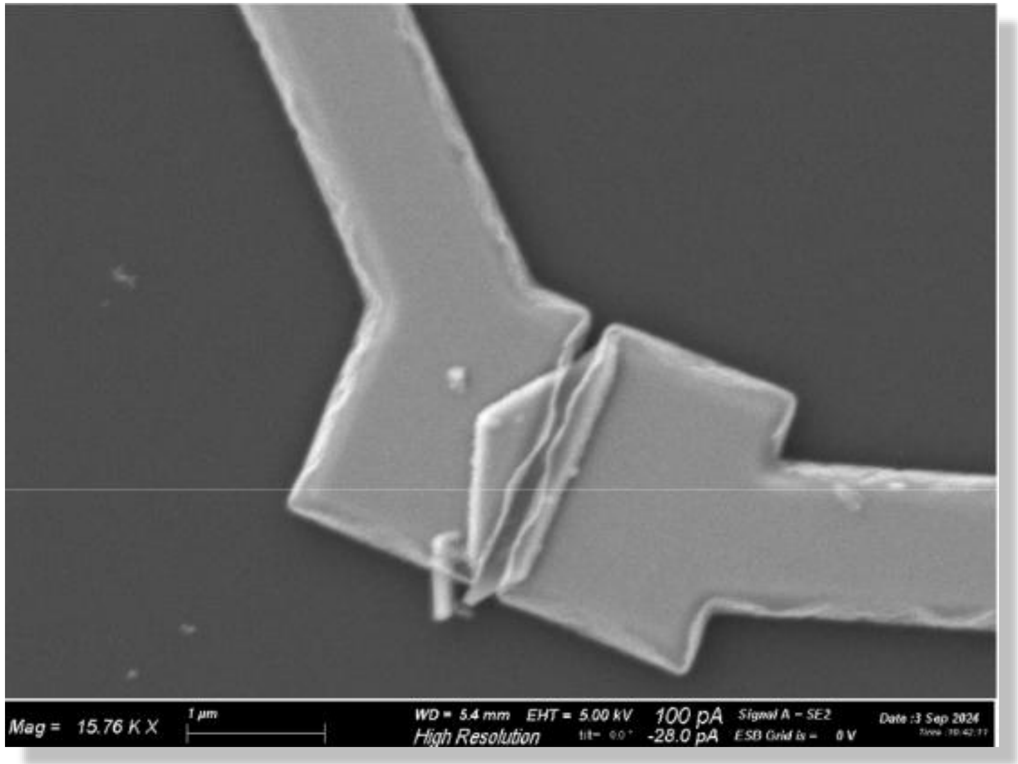


Device SGM H5D1

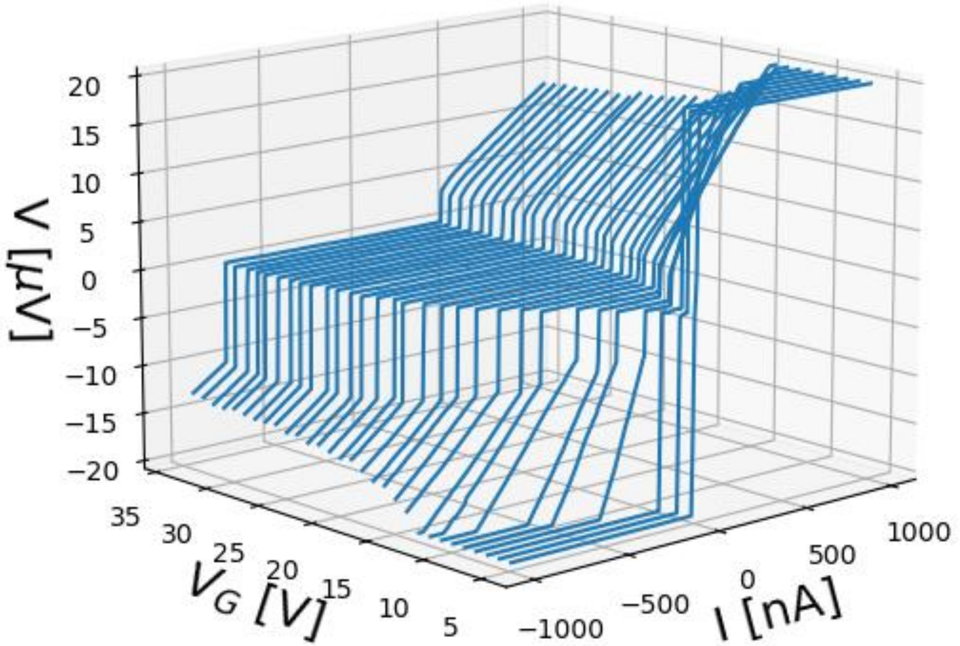
device	L [nm]	W [nm]	I_C [nA] at $V_G = 40\,V$
SGM1 D8D1	180 ± 10	1530 ± 30	90 ± 10
SGM1 D8D2	130 ± 10	610 ± 10	80 ± 20
SGM3 H4D2	190 ± 10	1420 ± 30	35 ± 5
SGM3 H5D1	190 ± 10	1500 ± 30	700 ± 50
SC10 [10]	200	700	50
SC20 F6 [121]	250 ± 10	540 ± 10	50
SC20 F7 [121]	110 ± 10	530 ± 10	17

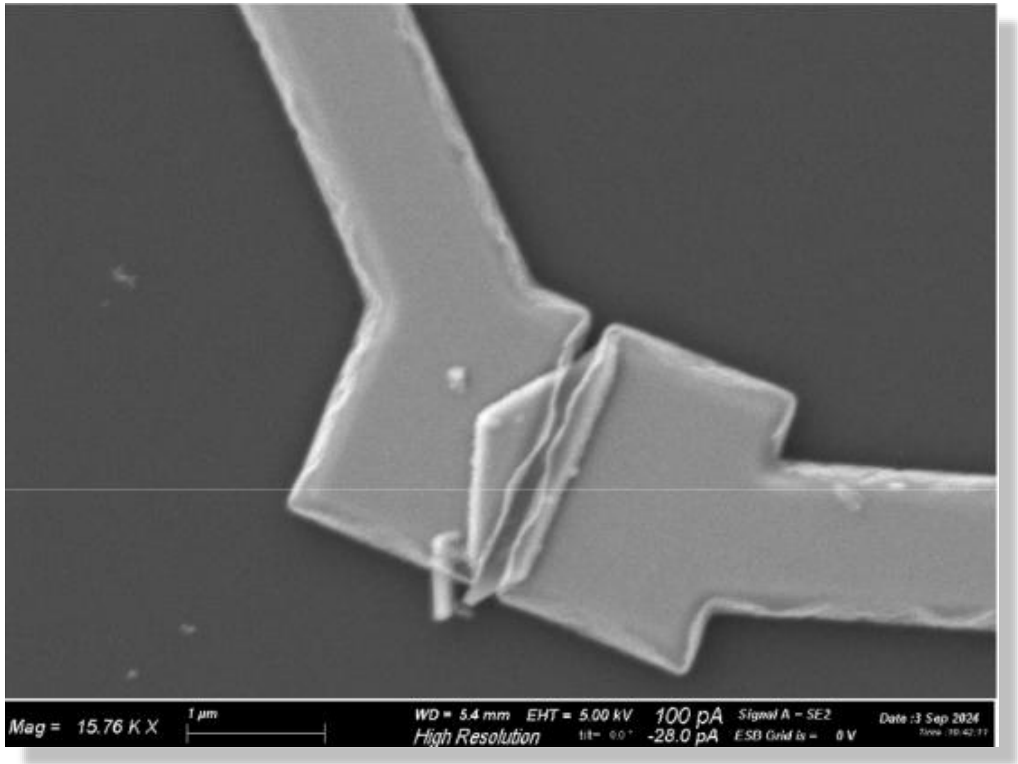
An interesting outlier





An interesting outlier

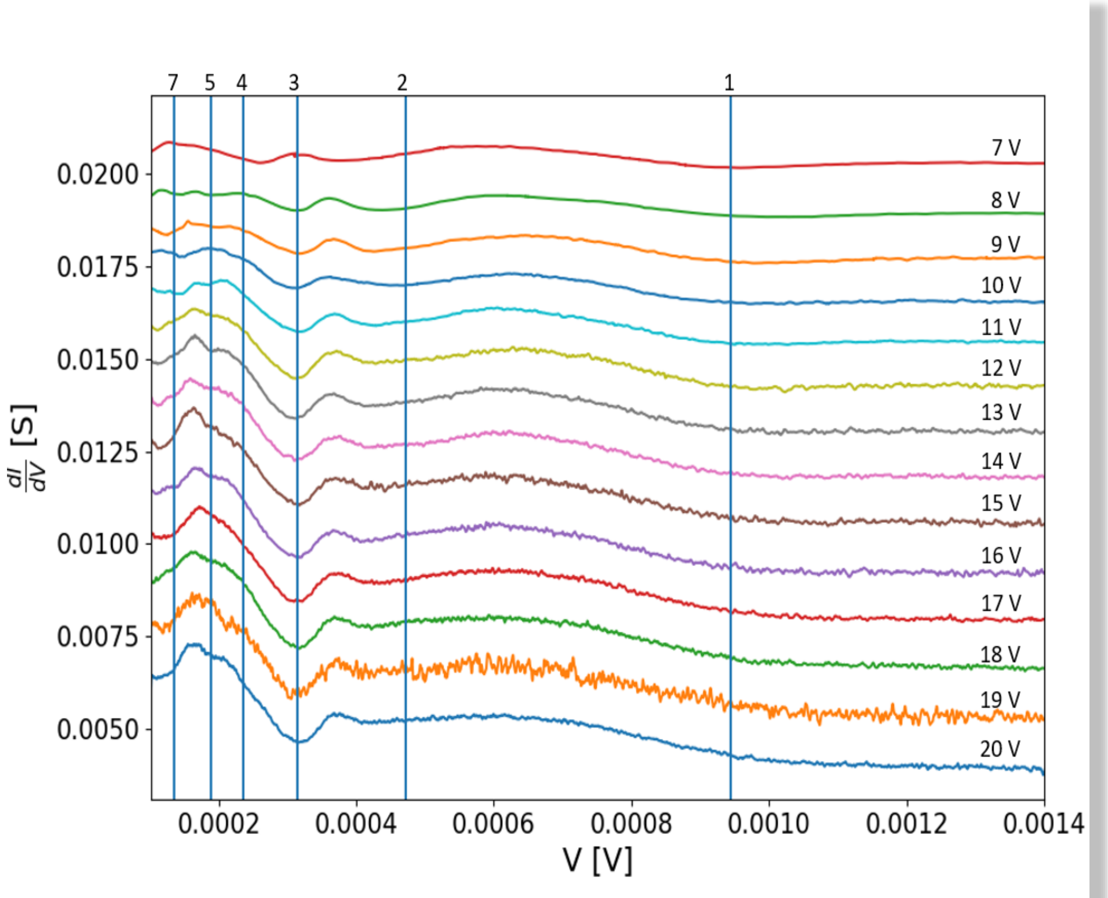


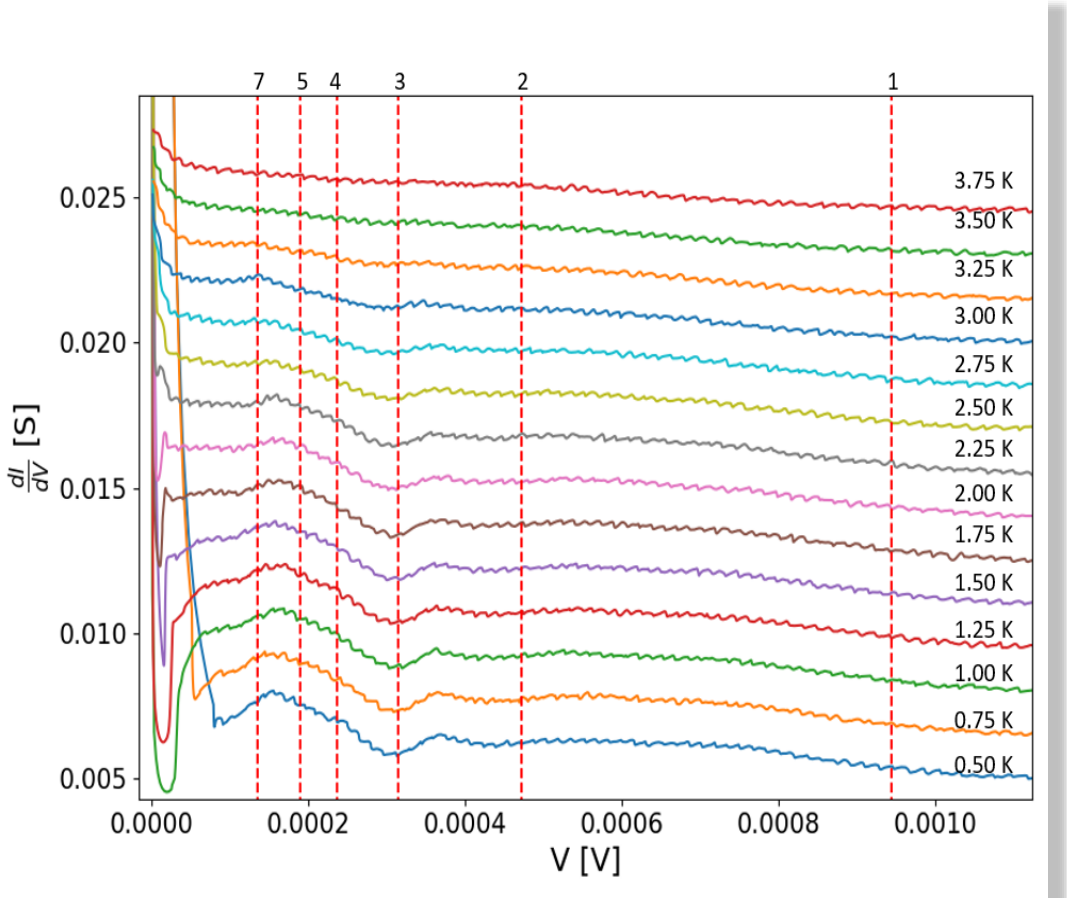


Multiple Andreev reflections

Δ' = 460 μeV (from third AR)
Corresponding γ_B= 3.28

$$\Delta^\star(T) = \frac{\Delta(T)}{1 + \frac{\gamma_B}{\pi T_C}\sqrt{\Delta^2(T) - \Delta^{\star 2}(T)}}$$





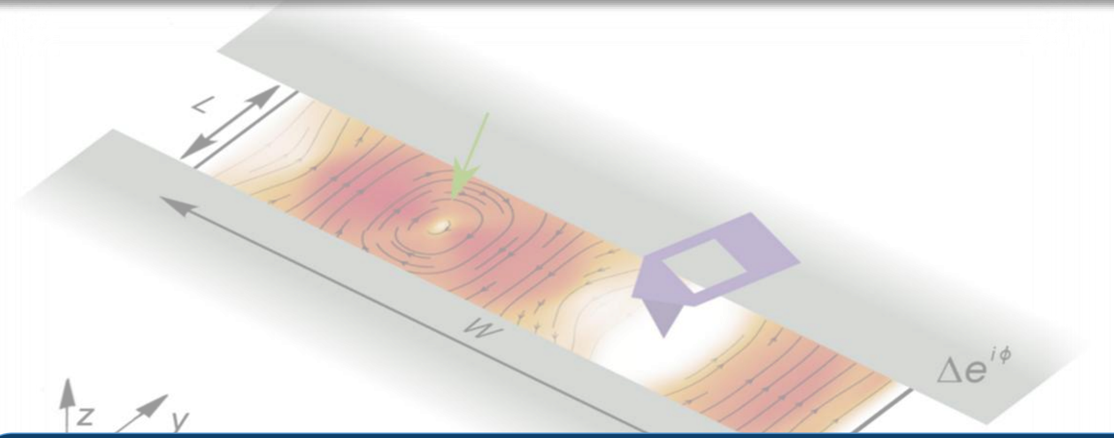
Sum up

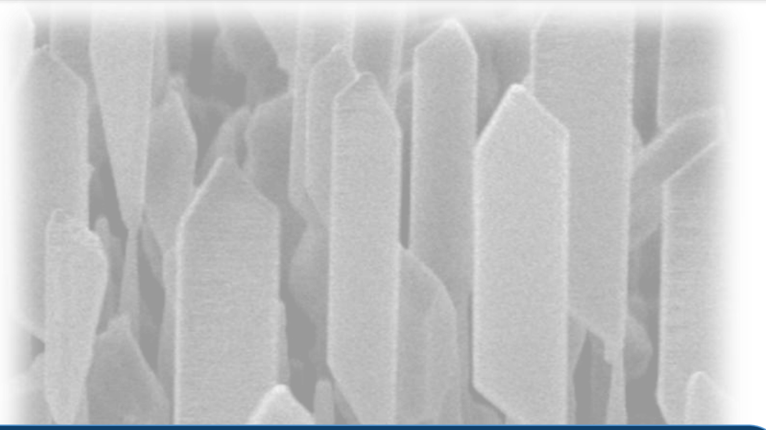
- First SGM maps of InSb nanoflag-based devices
- First measurements of tip-induced critical current modulation
- Observaton of high interface transparency for InSb nanoflag-based devices

Current goals

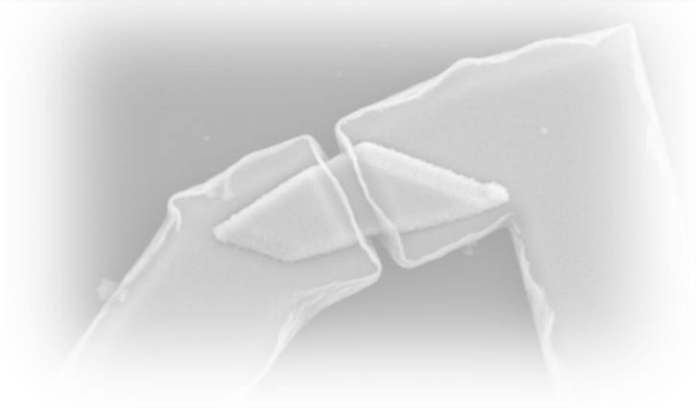
- Increase spatial resolution and signal to noise ratio
- Reduce tip-device distance
- Overcome tip-to-device discharge issues
- Investigate devices with higher switching currents by SGM

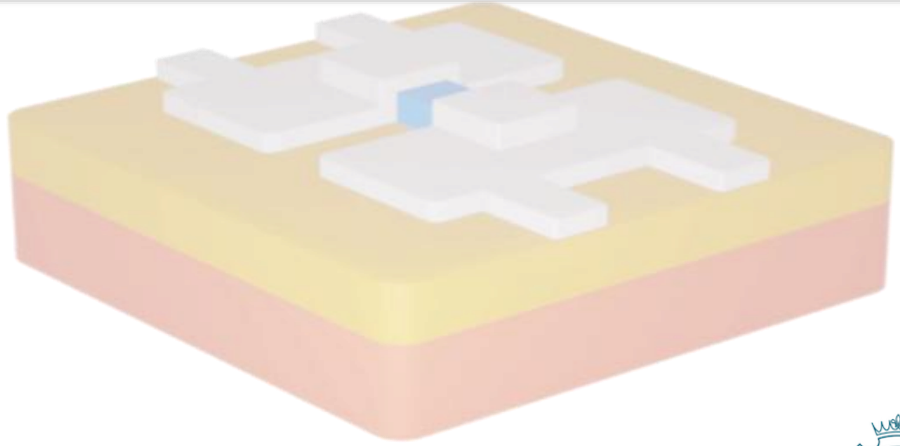
We are currently experimenting on depositing thin layers of high performance dielectric (HfO_2) on the region of interest





Thank you!





CNRNANO PISA NEST

IN SUPREMÆ DIGNITATIS 1343

SCUOLA NORMALE SUPERIORE