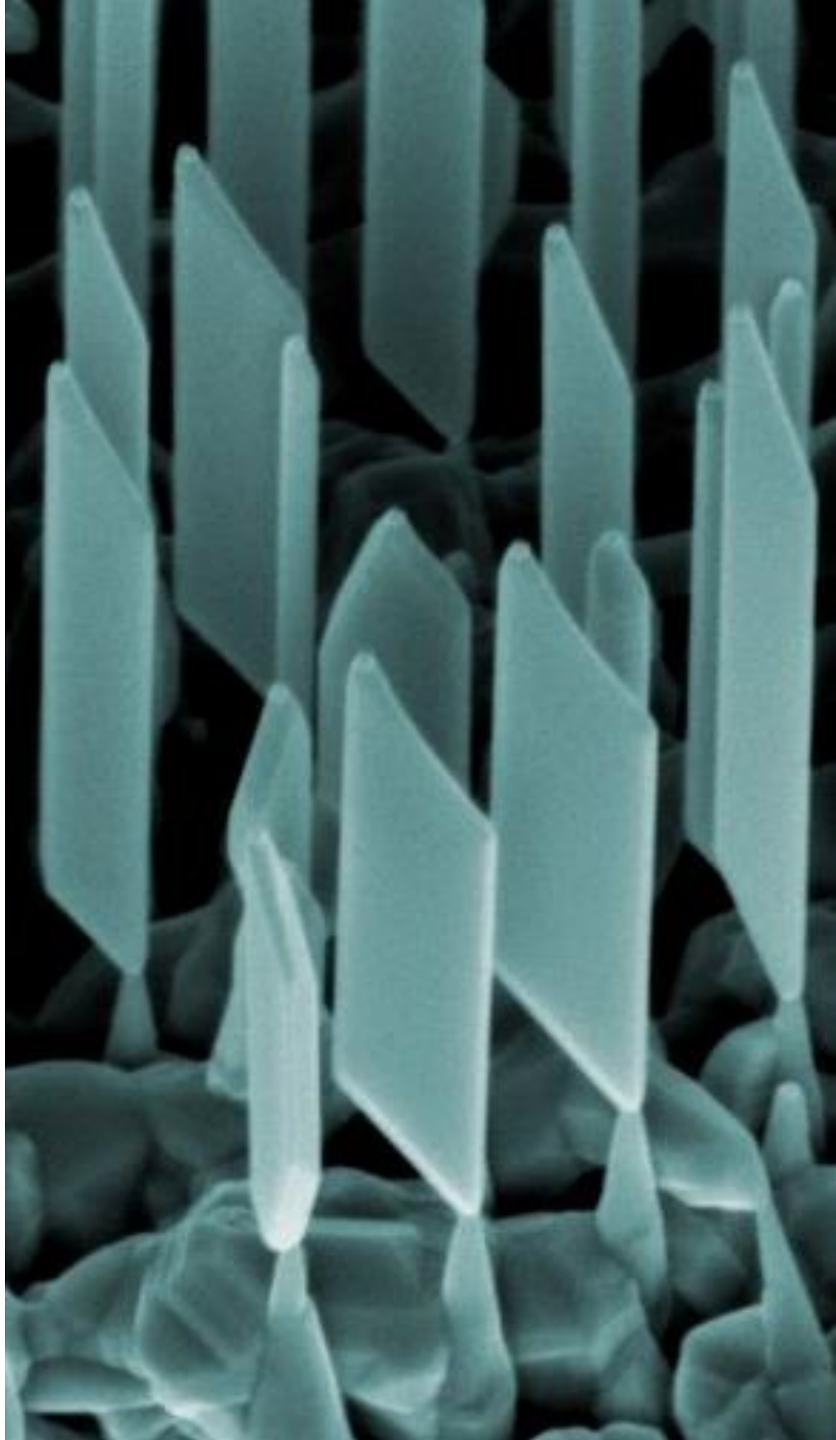
Josephson Diode Effect in High-Mobility InSb Nanoflags

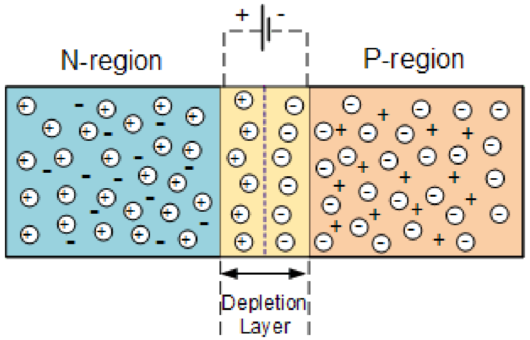
Bianca Turini

Supervised by
Prof. Stefan Heun
Prof. Lucia Sorba

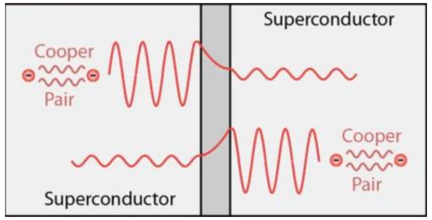


Revolutionary devices

The diode



The Josephson junction

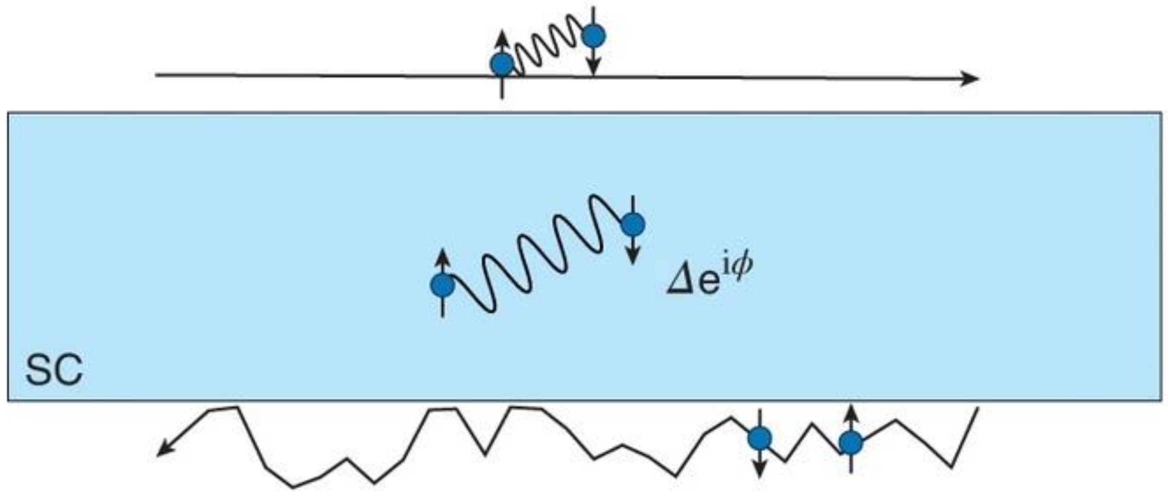


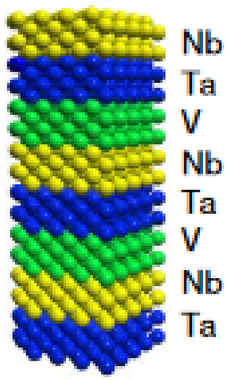
- Gate tunability
- Scalability

- Dissipation-less
- Fast switching

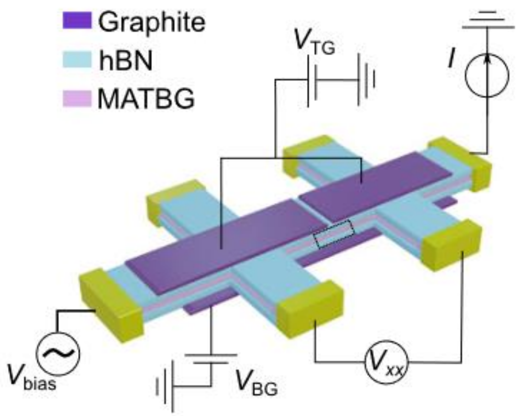
Superconducting diodes

Spin orbit coupling + superconductivity



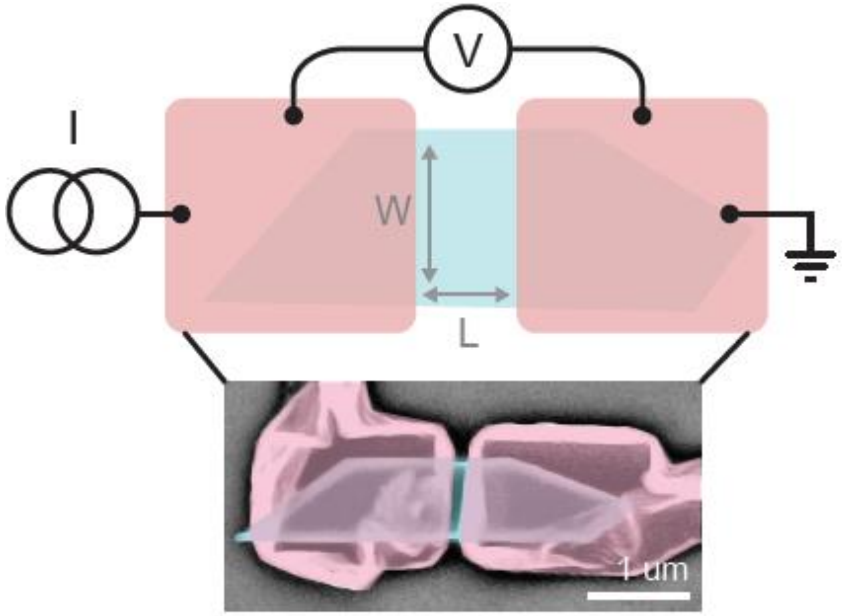


Ono's lab (2020)



Efetov's lab (2023)

Josephson Diode Effect in High-Mobility InSb Nanoflag(s)



III-V semiconductor/superconductor hybrid system

Single-junction Josephson diode

SCUOLA NORMALE SUPERIORE

CNRNANO PISA NEST

Heun Lab

Sorba Lab

Giazotto Lab

Josephson Diode Effect in High-Mobility InSb Nanoflags

- InSb Nanoflags
- NF-based Josephson junctions
- Observation of the JDE

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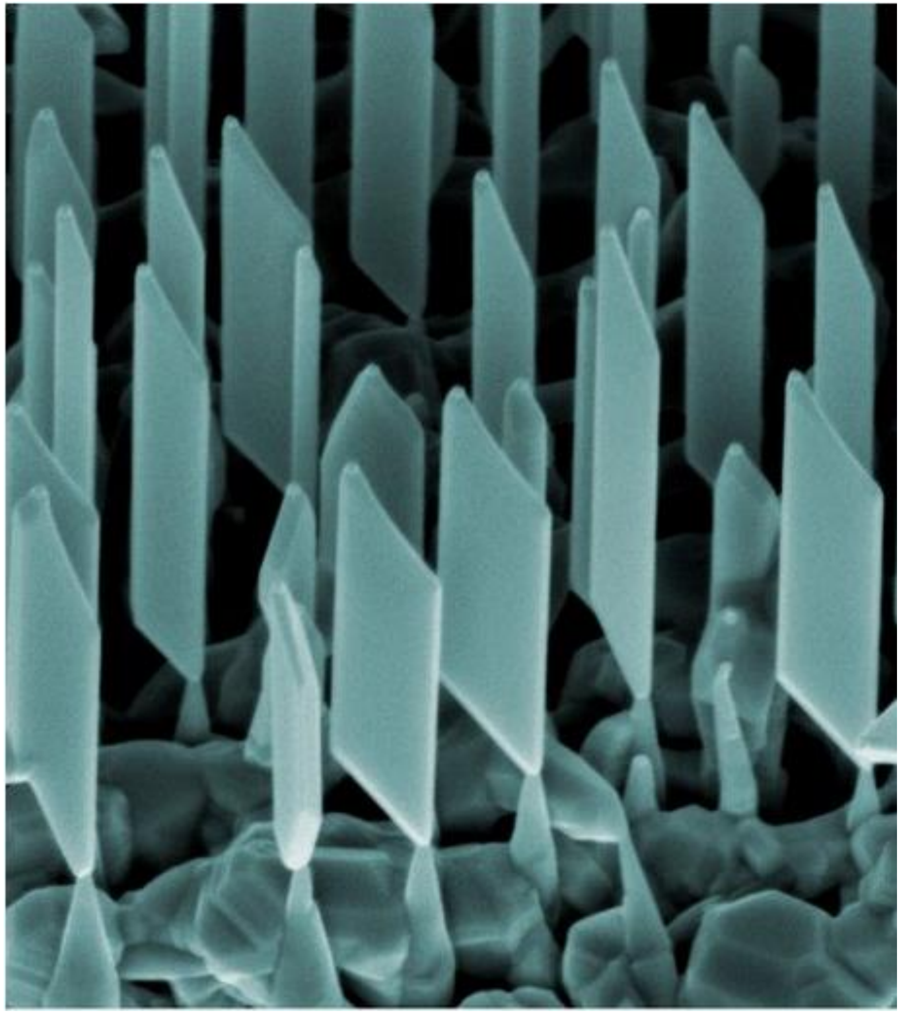
InSb is appealing for spintronics

Small bandgap E_g=0.23 eV

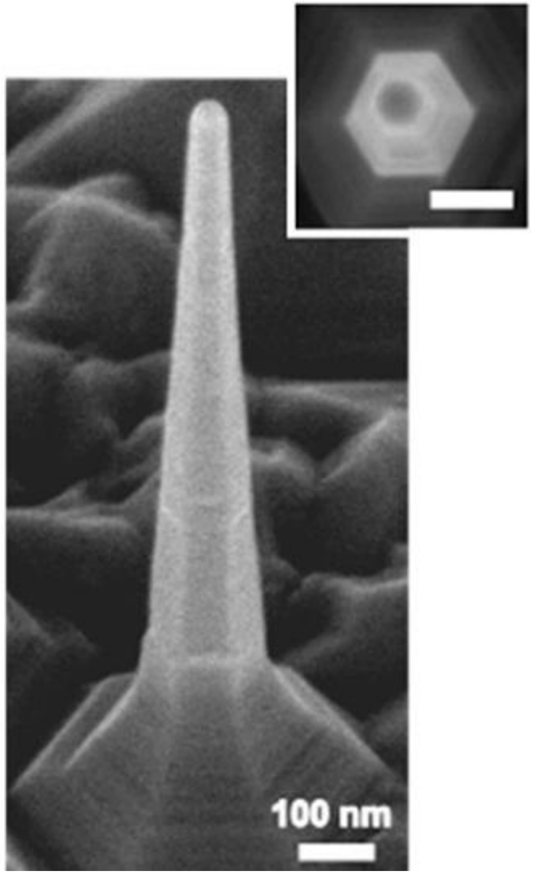
Low effective mass m/m_0 = 0.018

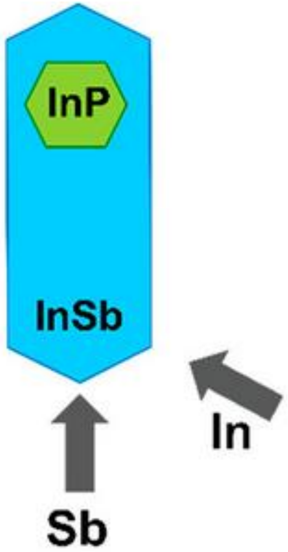
Strong SOC E_{SOC} ~ 200 μeV

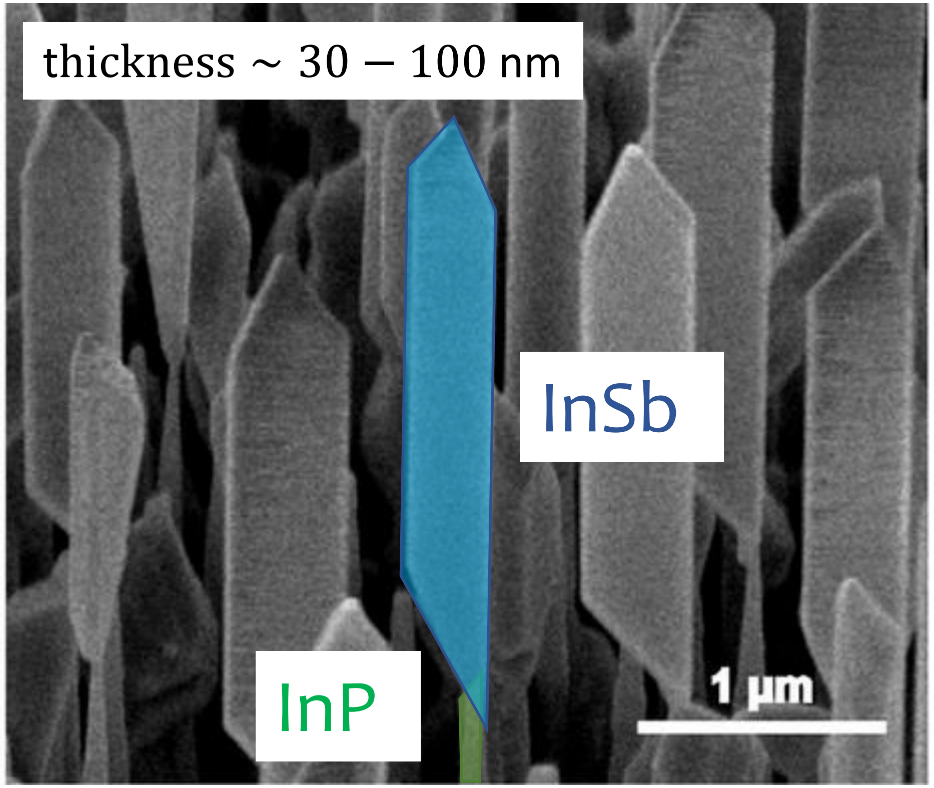


Nanoflags are grown via Chemical Beam Epitaxy

Dr. I. Verma



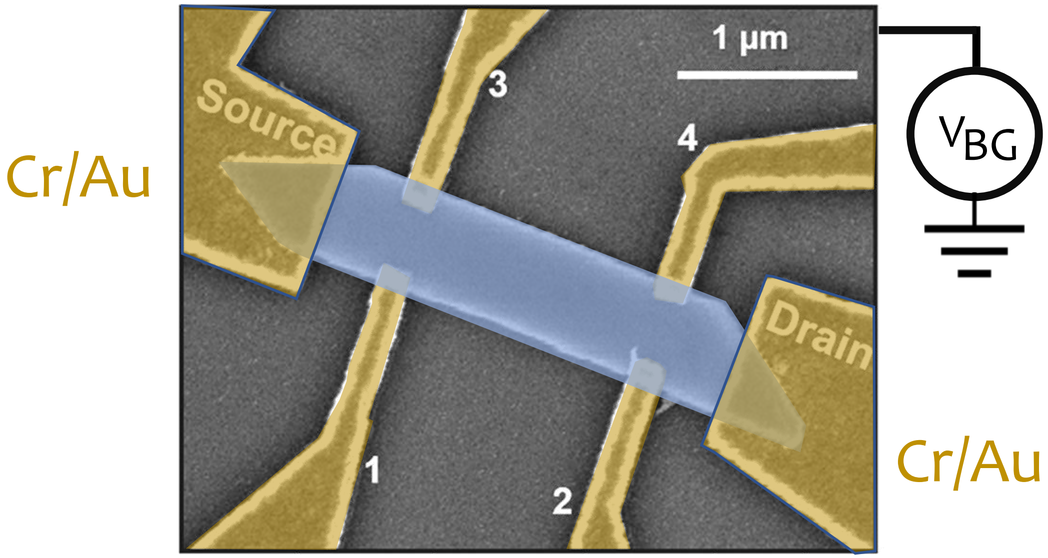


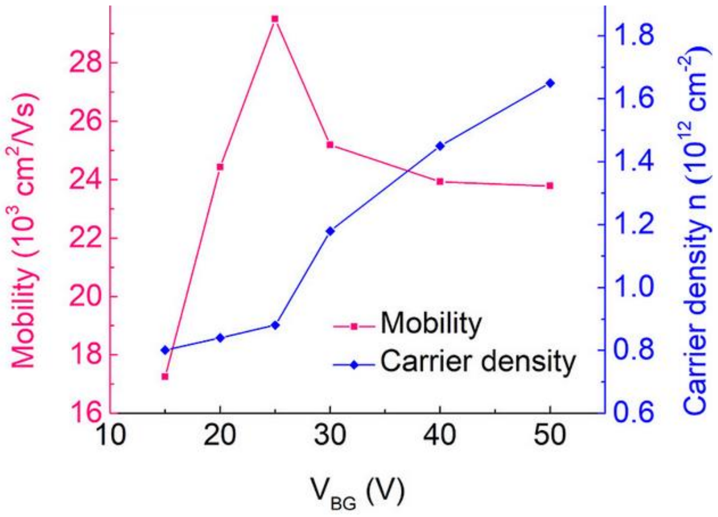


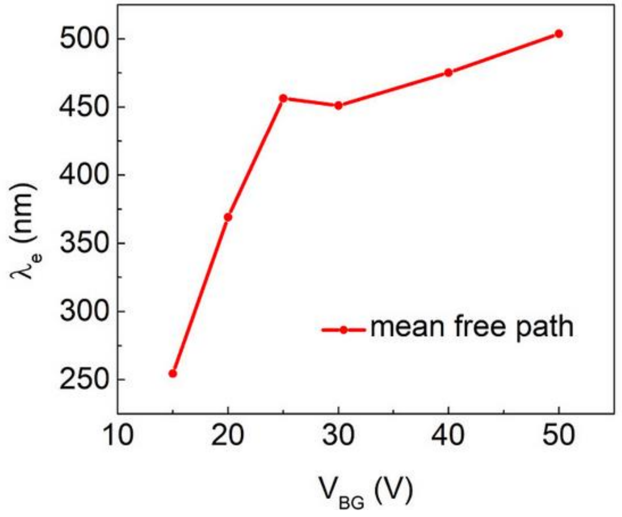
NFs show high mobility

Dr. S. Salimian

@ T = 4.2 K



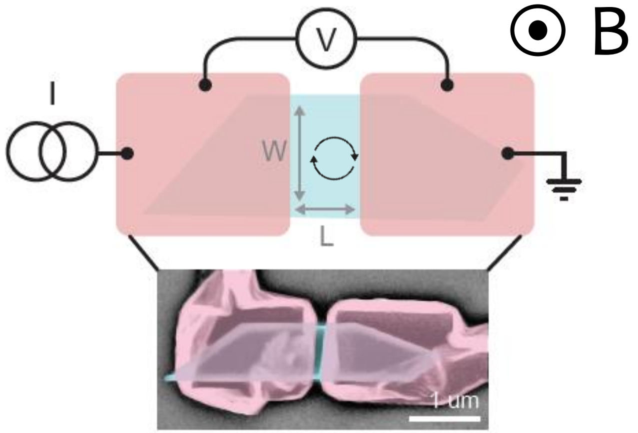




$\mu_e \sim 29500\ \mathrm{cm^2/Vs}$

$\lambda_{mfp} \sim 500\ \mathrm{nm}$

NFs are characterized via magneto-transport

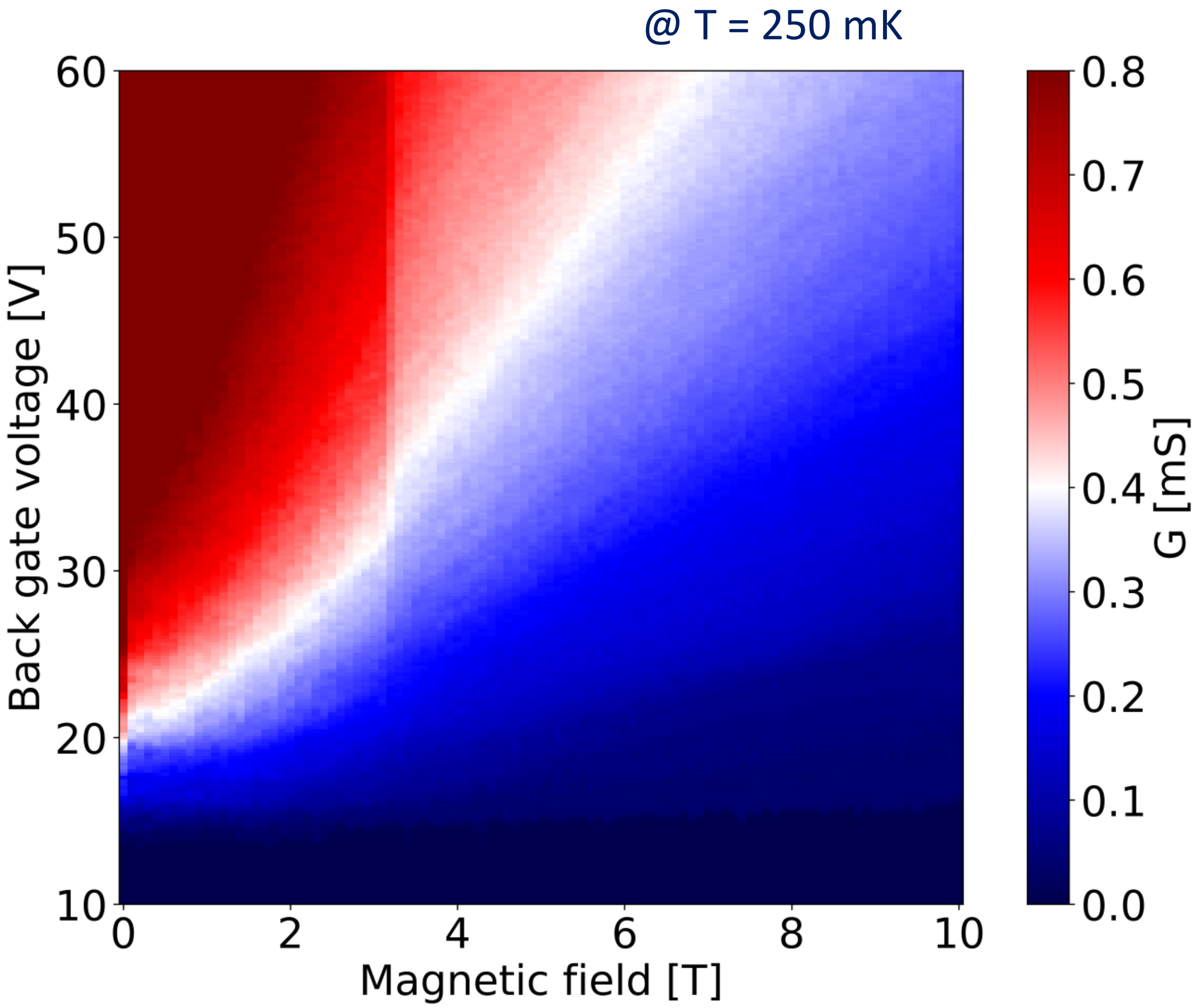


Quantum Hall effect:

$$G_{xy} = G_0 \nu$$

Conductance quantum

Filling factor



NFs have a large effective g-factor

Zeeman energy

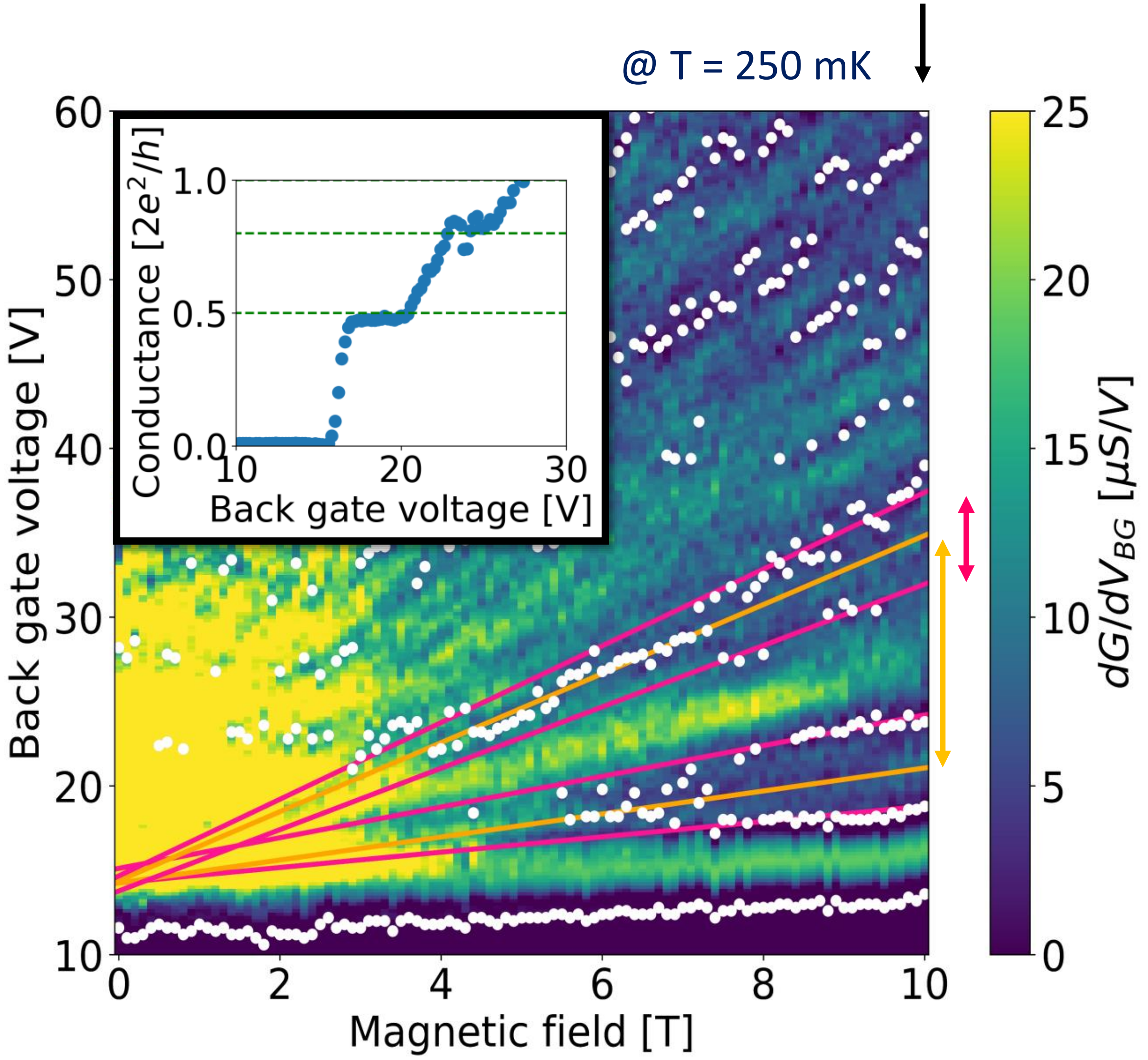
$$\delta E_z = g^* \mu_B B$$

Landau energy

$$\delta E_L = \hbar eB/m^*$$

Effective coupling

$$g^* = \frac{\delta E_Z}{\delta E_L}\frac{\hbar e}{\mu_B m^*} = 44$$



Josephson Diode Effect in High-Mobility InSb Nanoflags

InSb Nanoflags

I. Verma *et al.*, *ACS ANM* (2021)

gate-tunability
high-mobility
giant g*-factor

NF-based Josephson junctions

Observation of the JDE

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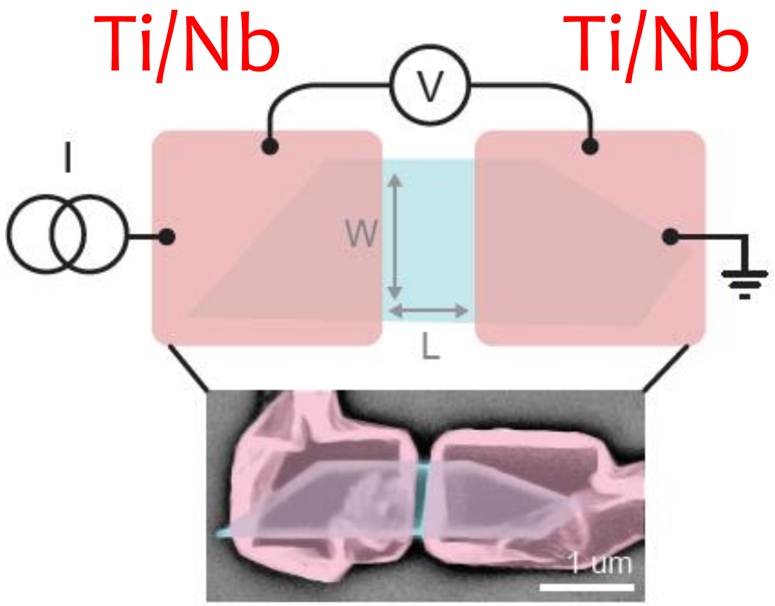
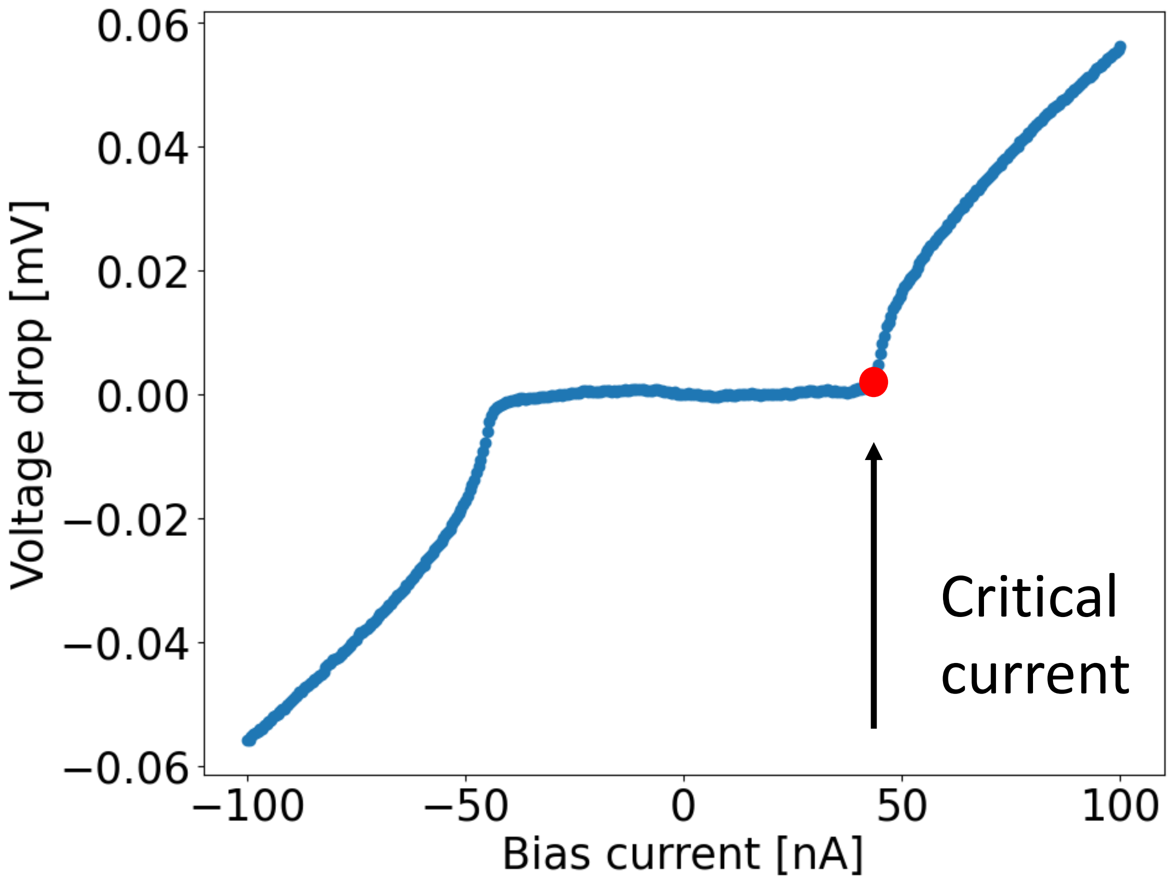
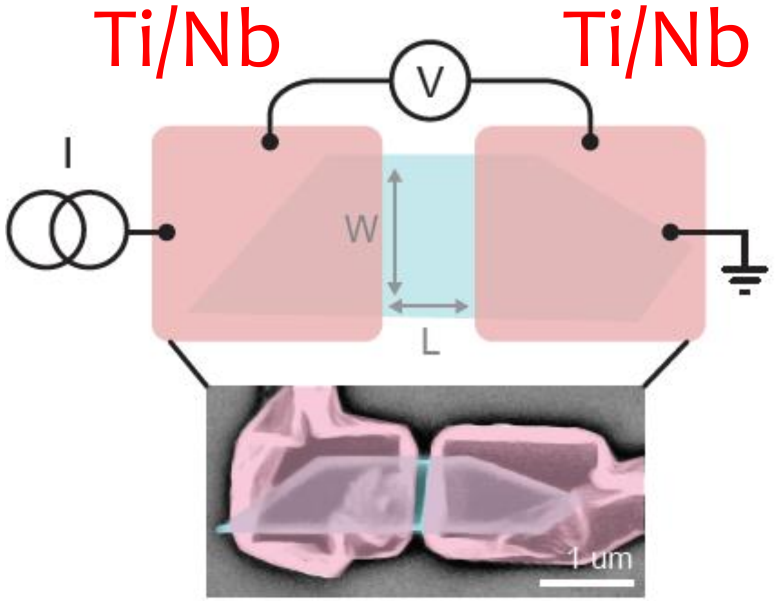
The device shows supercurrent



λ_{mfp}	500 nm
L	200 nm
ξ_S	750 nm



The device shows gate-tunable supercurrent



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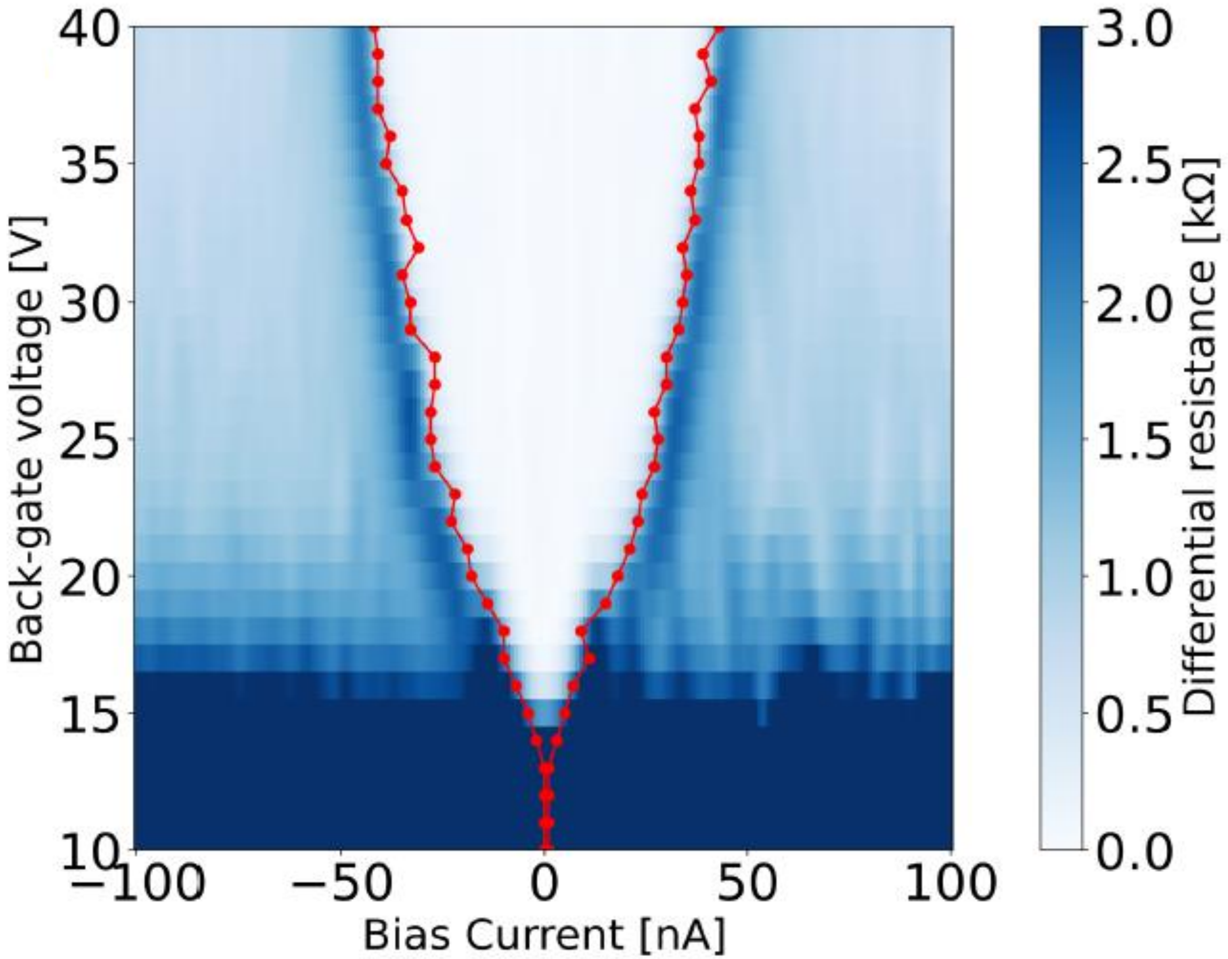
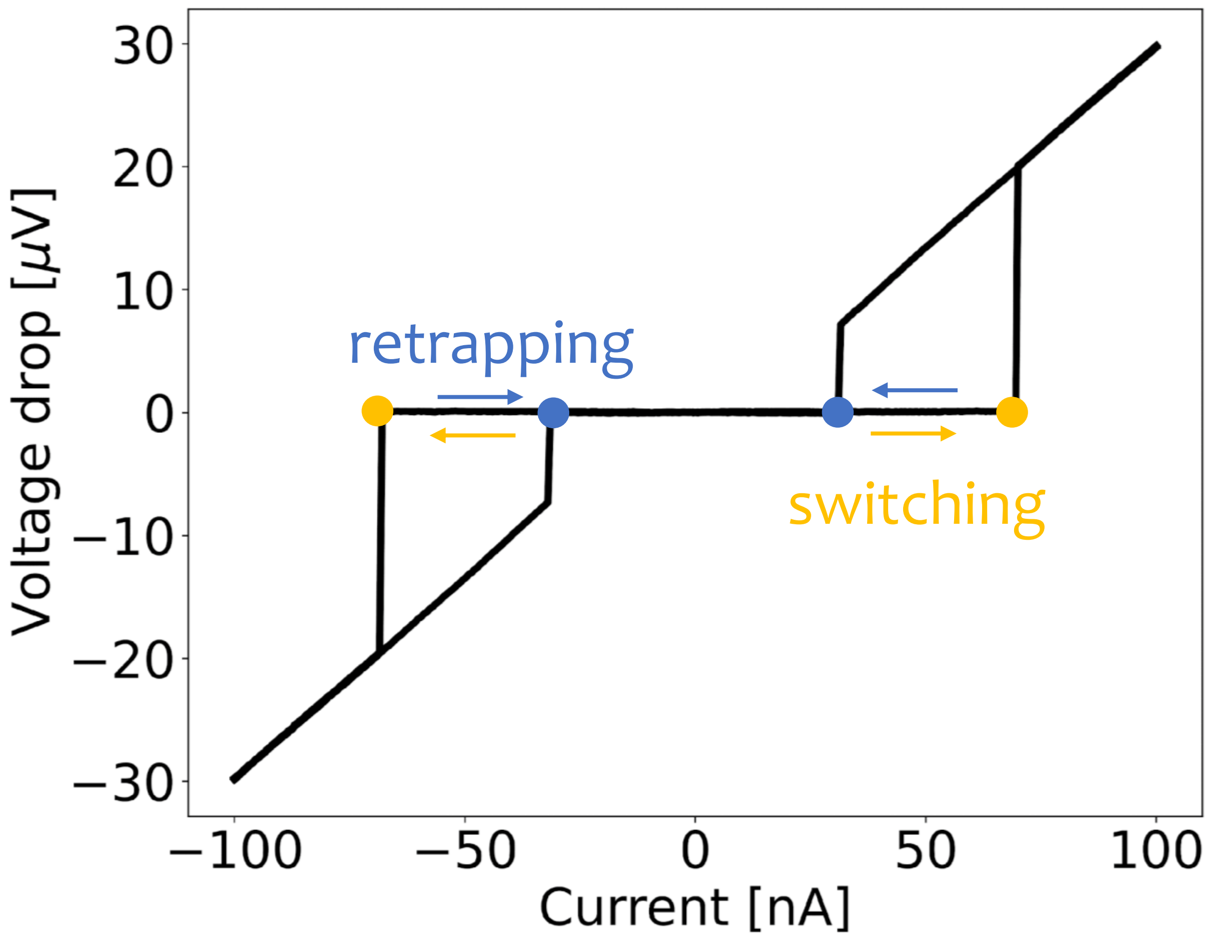


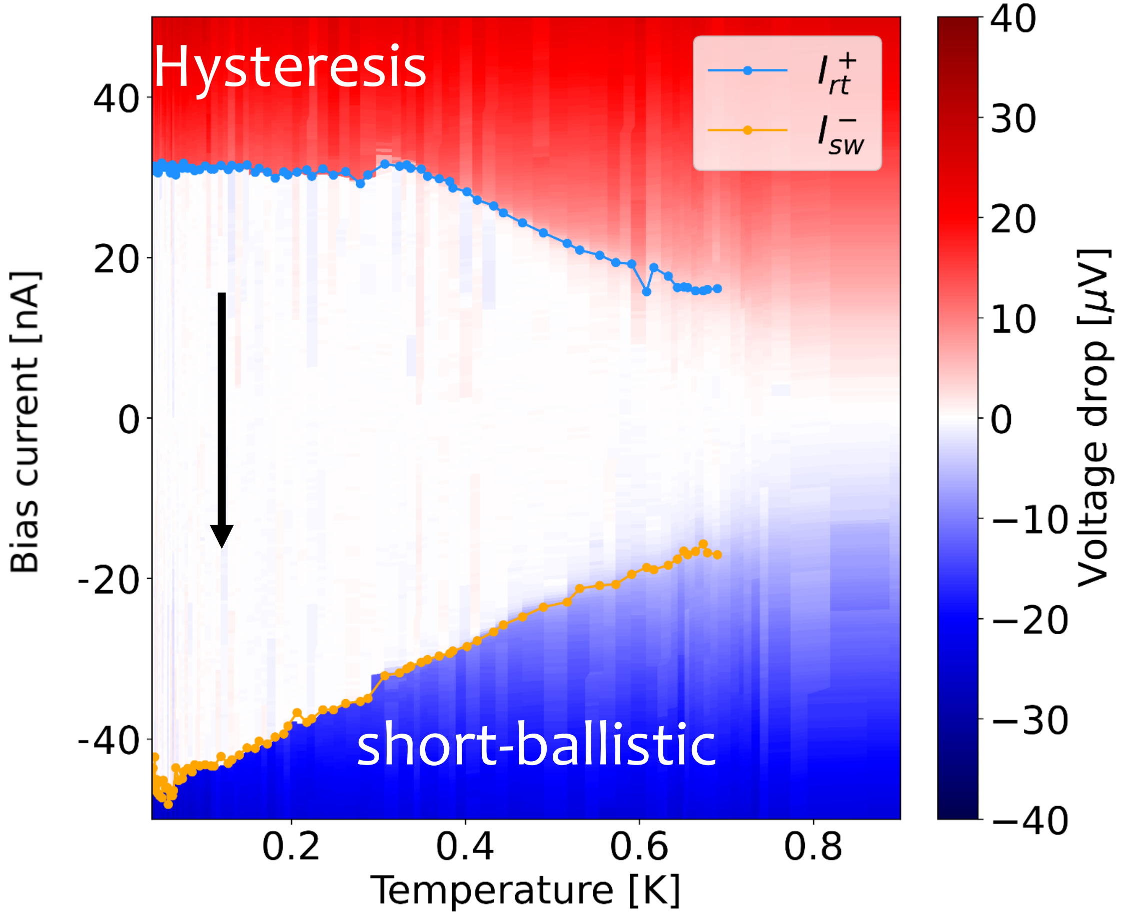
The junction works in the short-ballistic regime

Induced gap
Δ* =160 μeV

(Golubov & Kupriyanov, 2005)

@ T = 30 mK





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  S. Salimian *et al.*, APL (2021)

  short-ballistic
  $\Delta_S \sim E_{SOC}$

- Observation of the JDE

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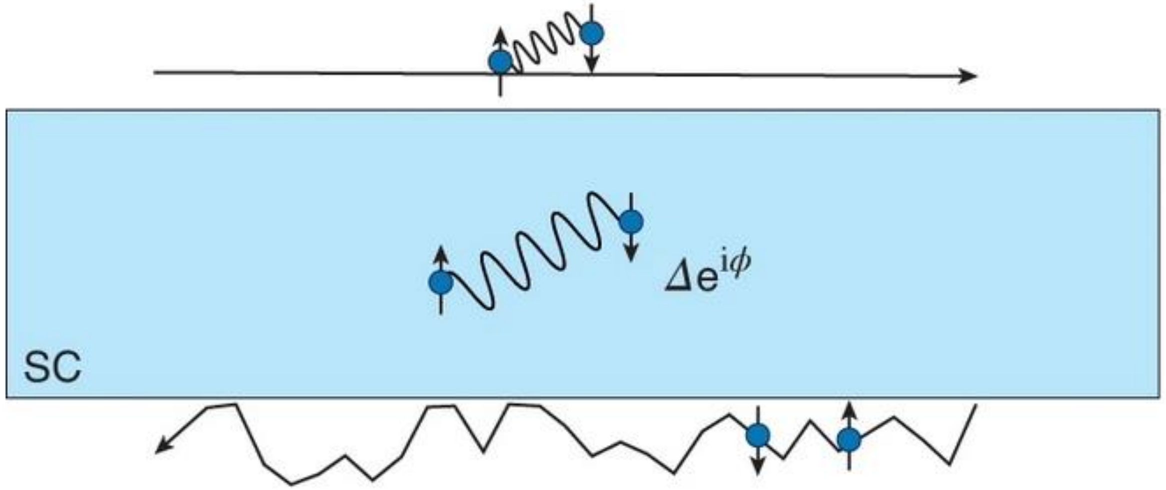
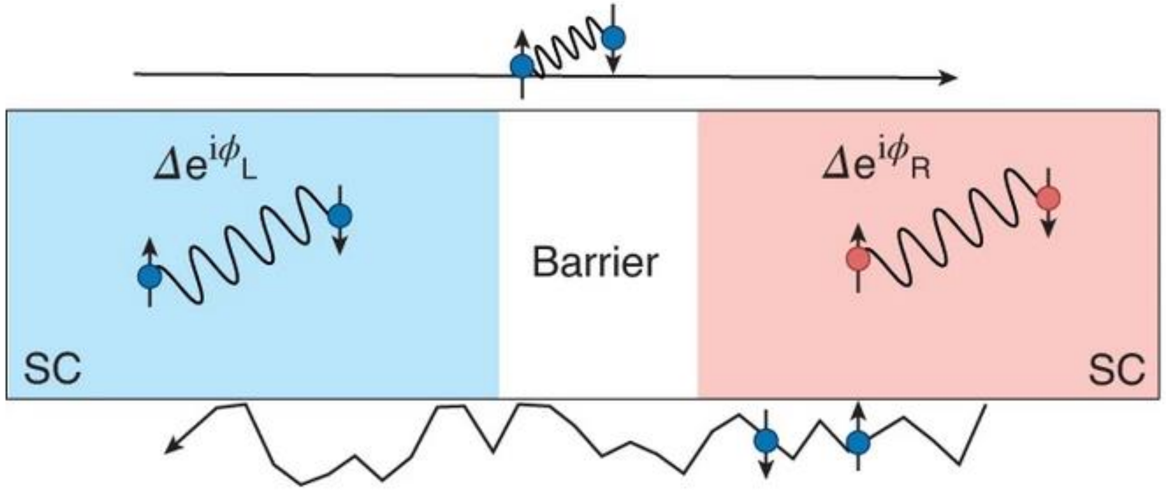
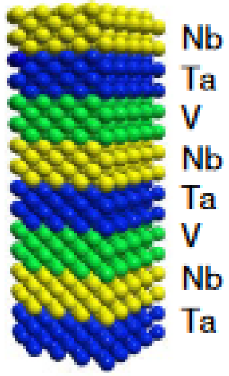
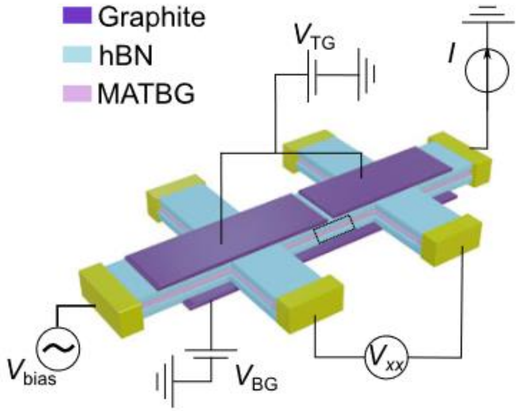
Different superconducting diodes exist



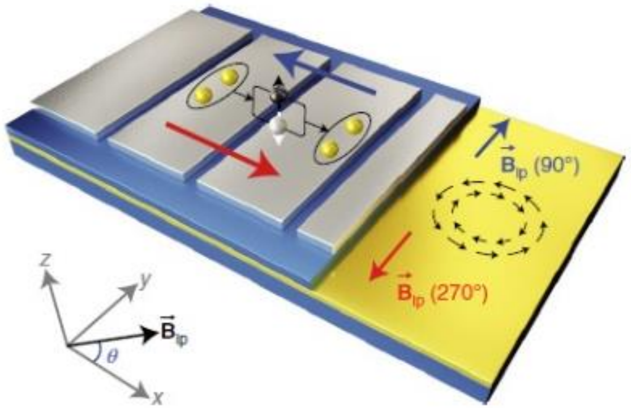




Ono's lab (2020)

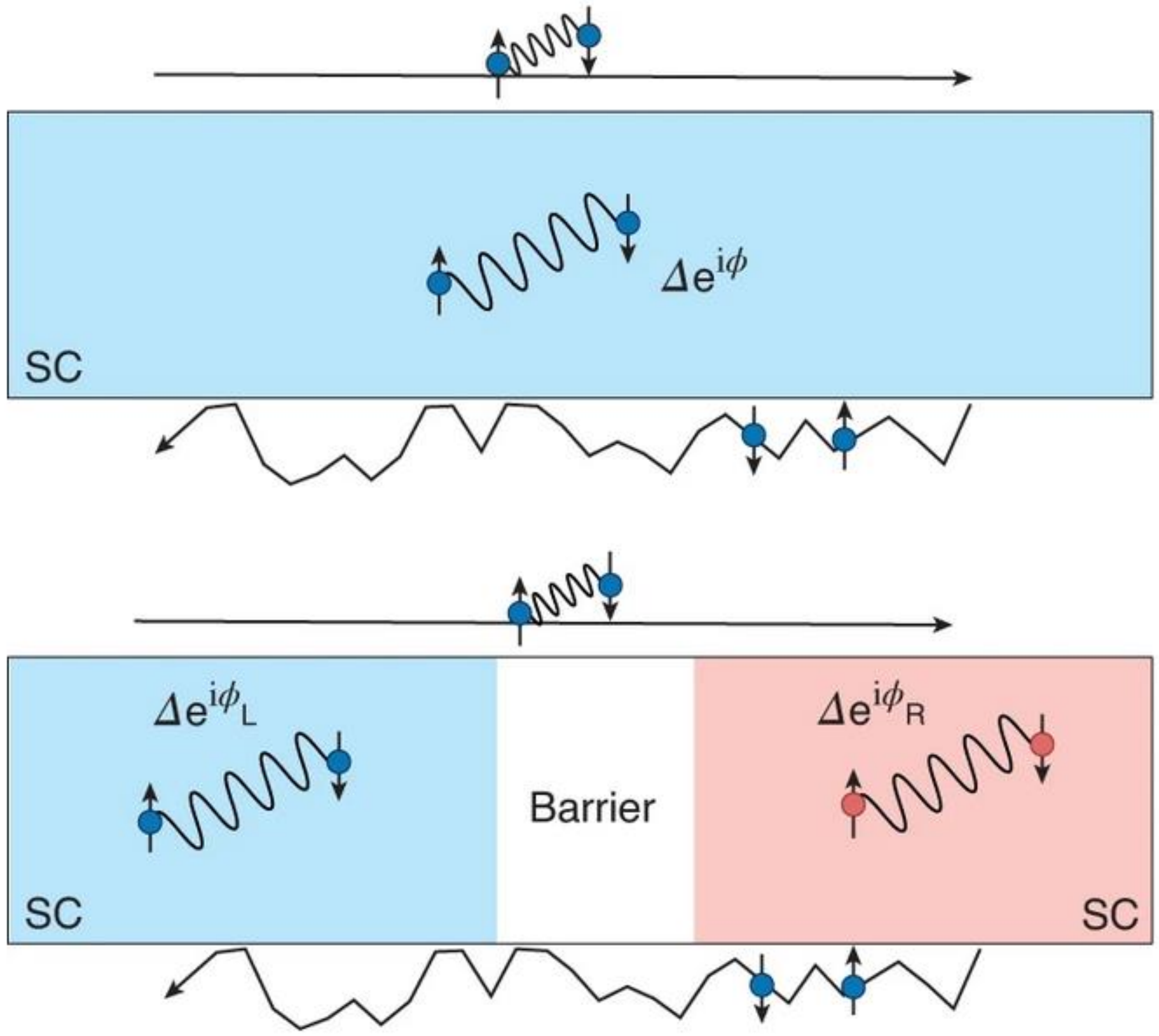


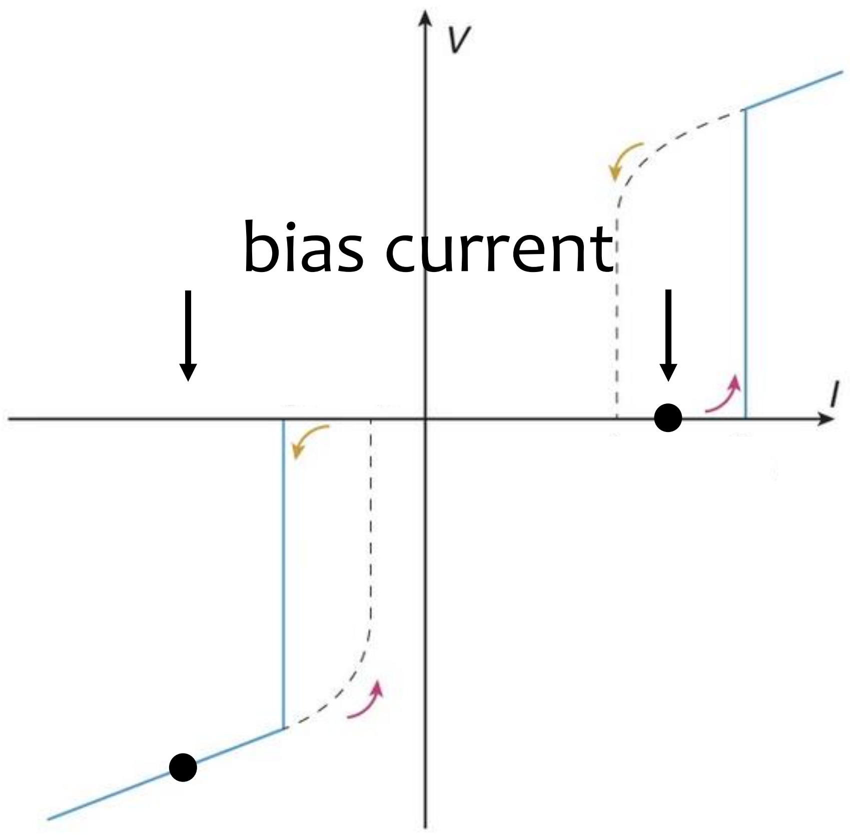
Efetov's lab (2023)



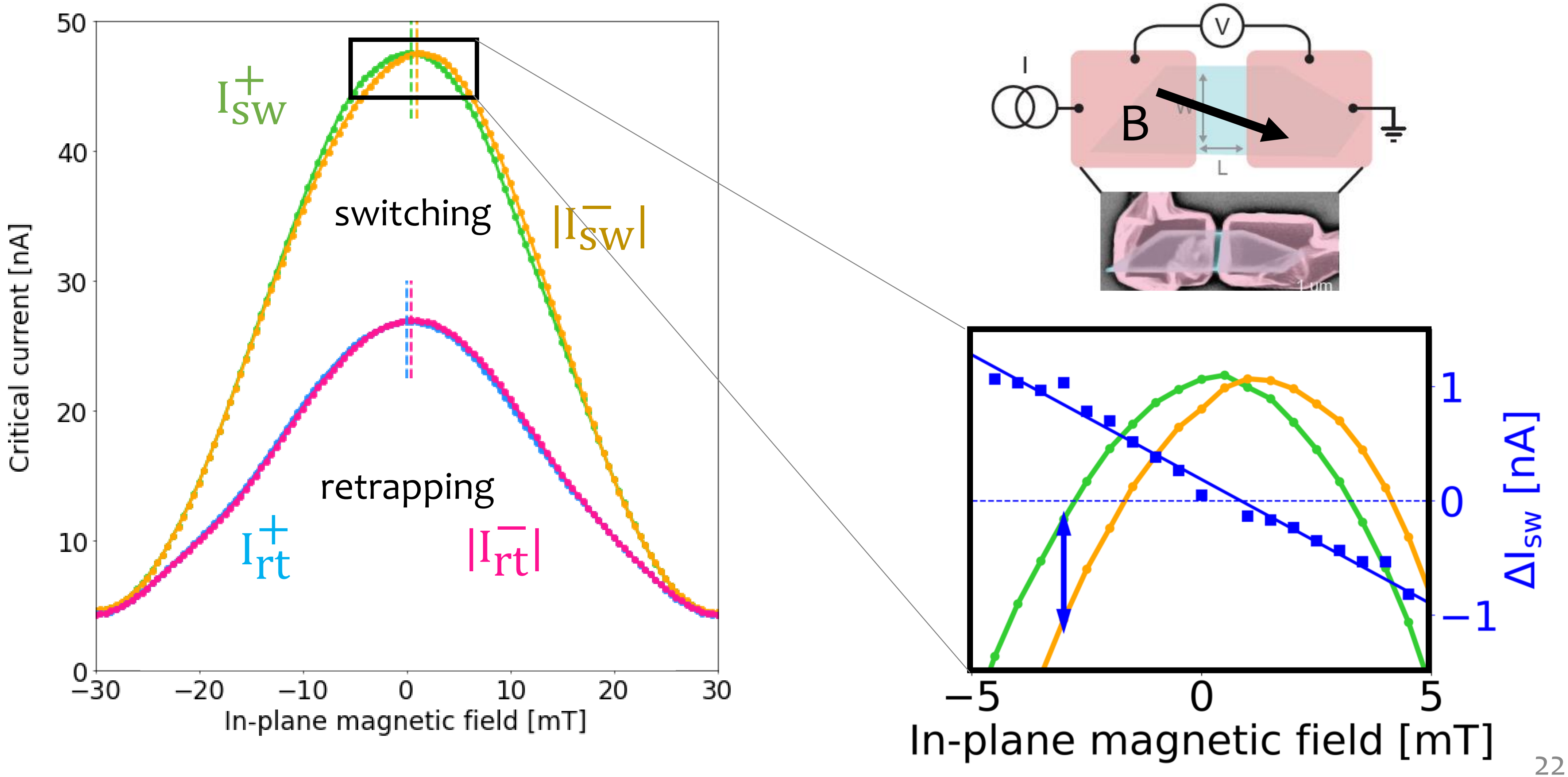
Strunk's lab (2022)

Different superconducting diodes exist



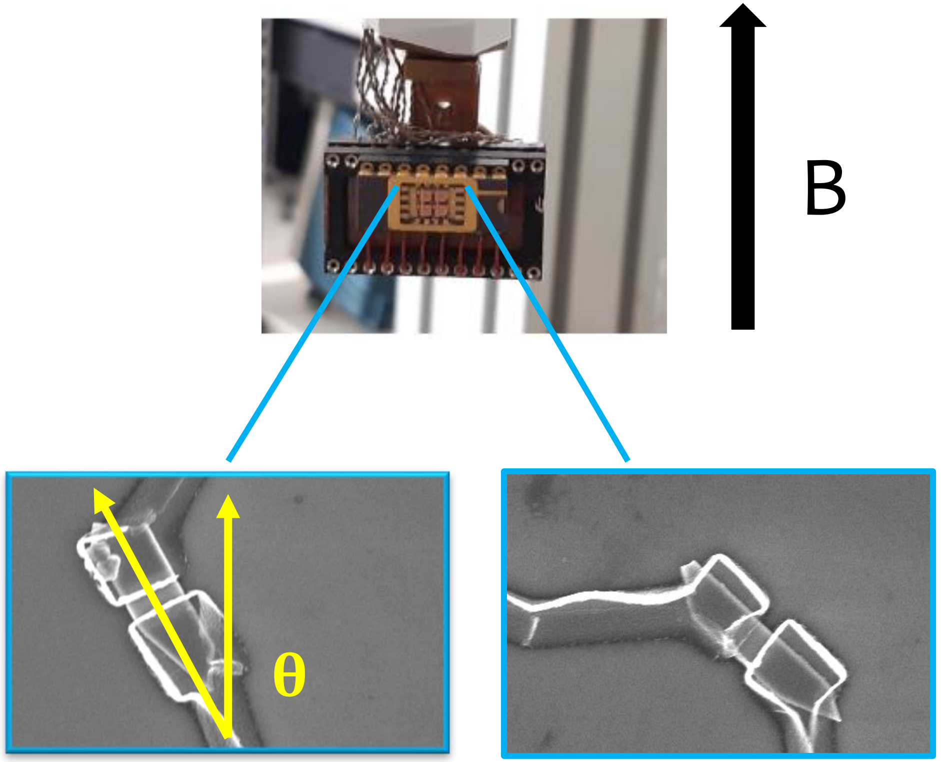


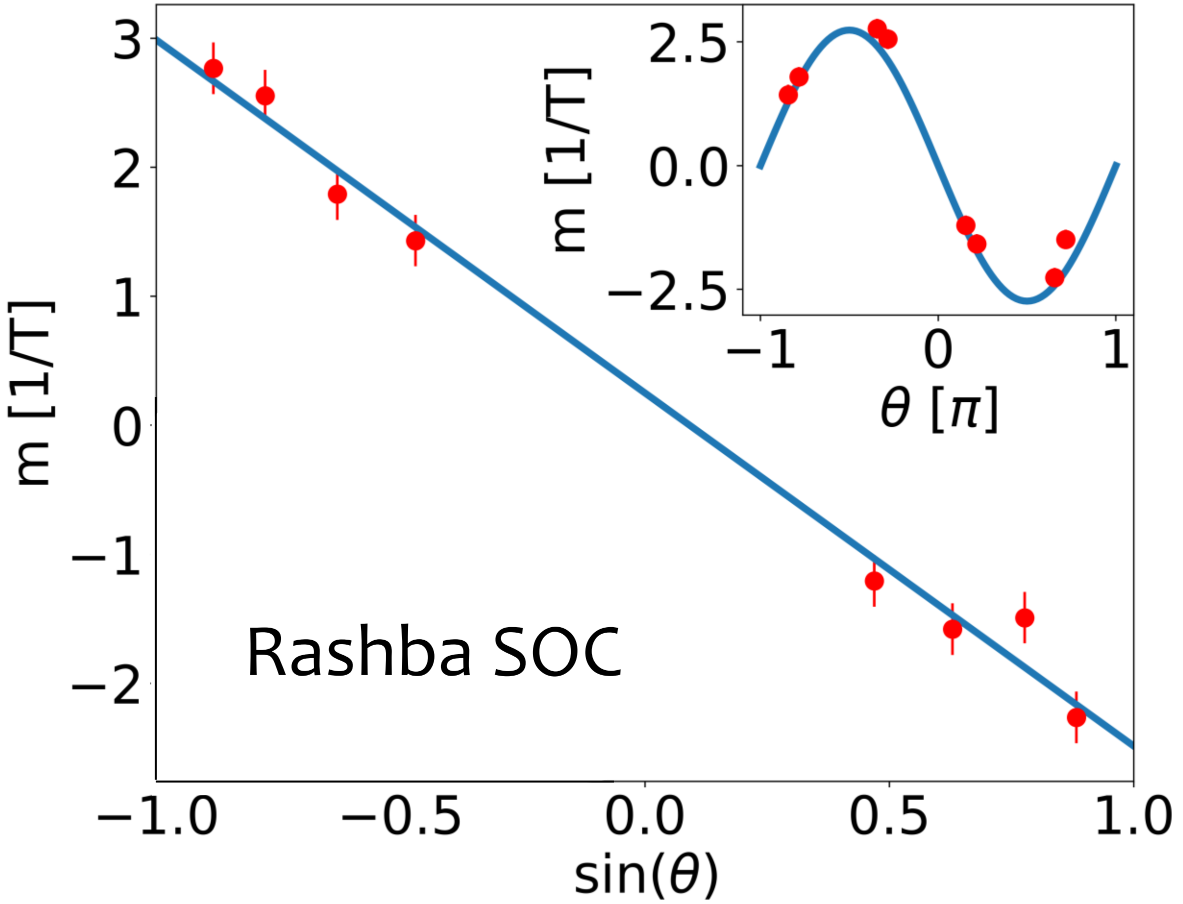
JDE is driven by the magnetic field



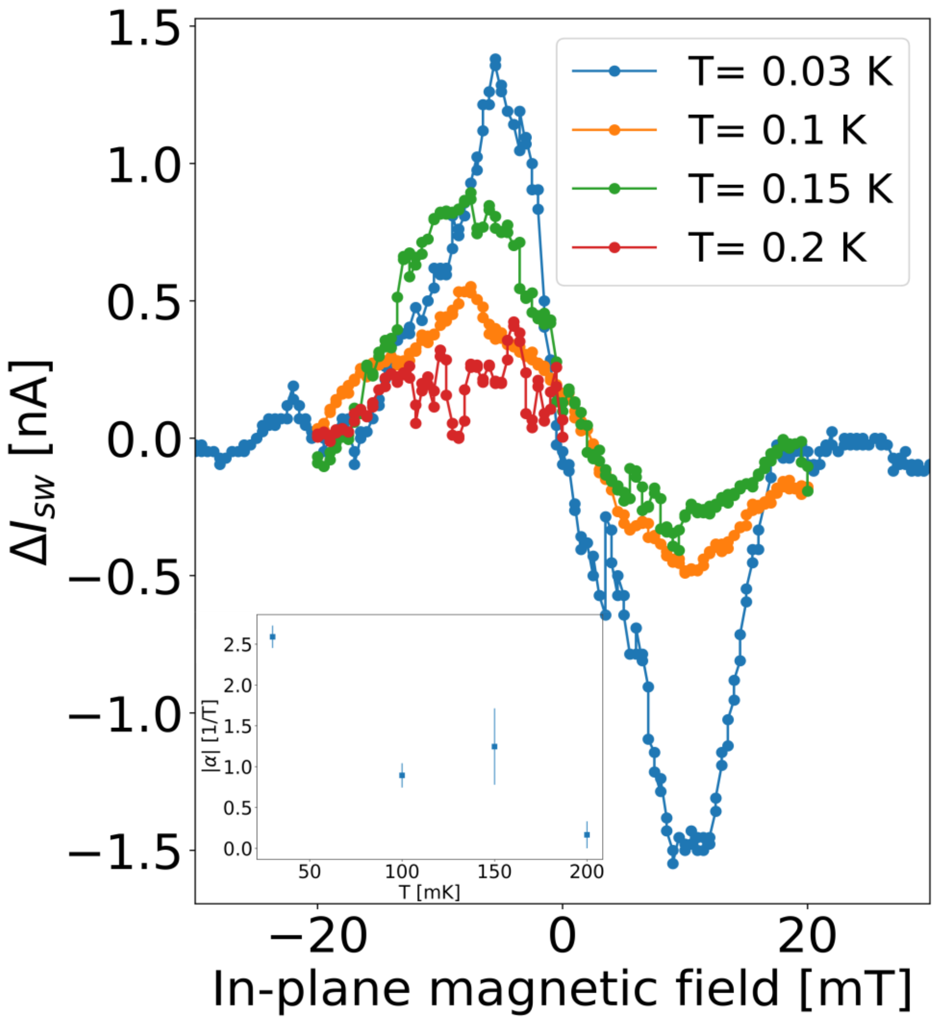
JDE depends on the relative angle

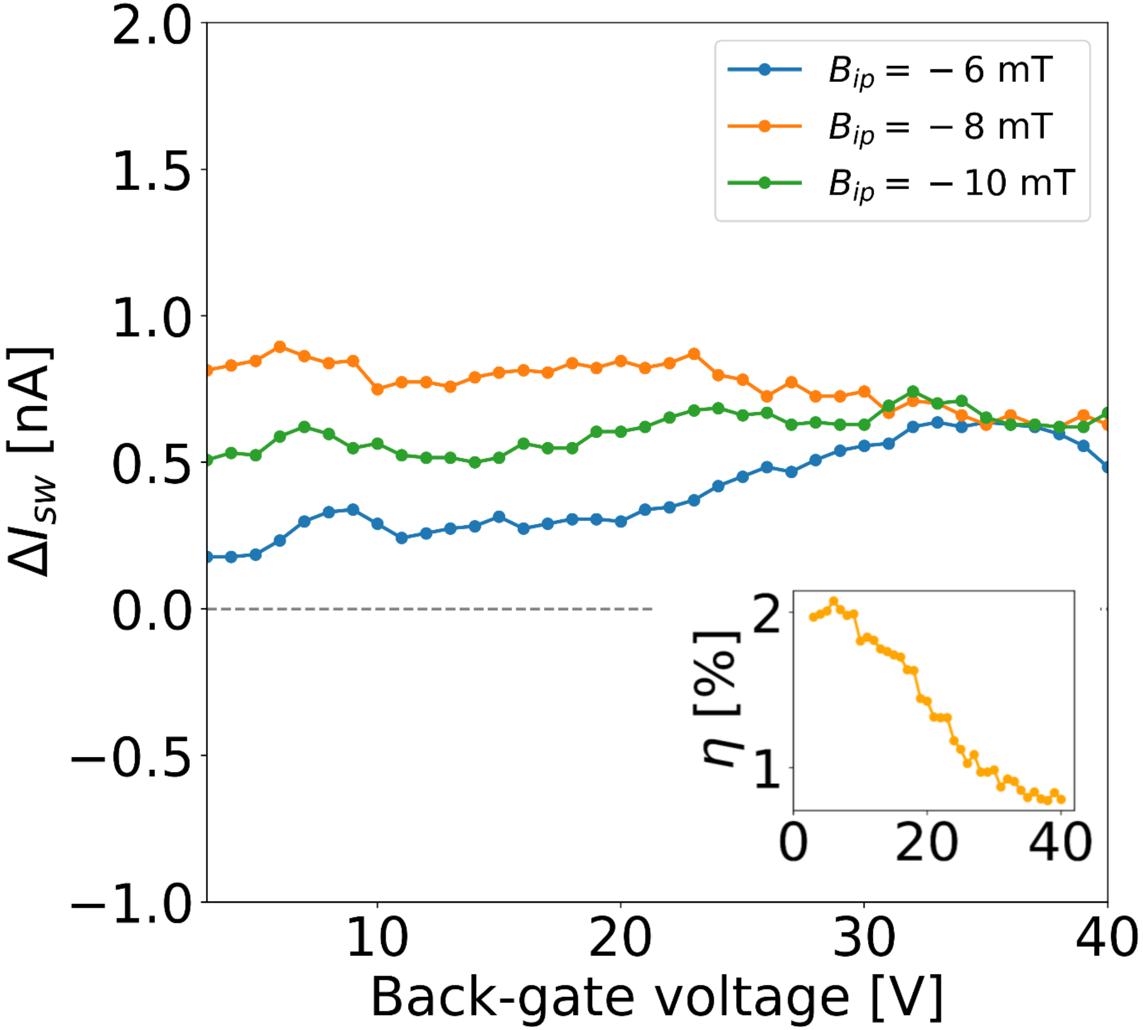
Rasmussen *et al.*, PRB (2016)





JDE depends on temperature and back-gate voltage





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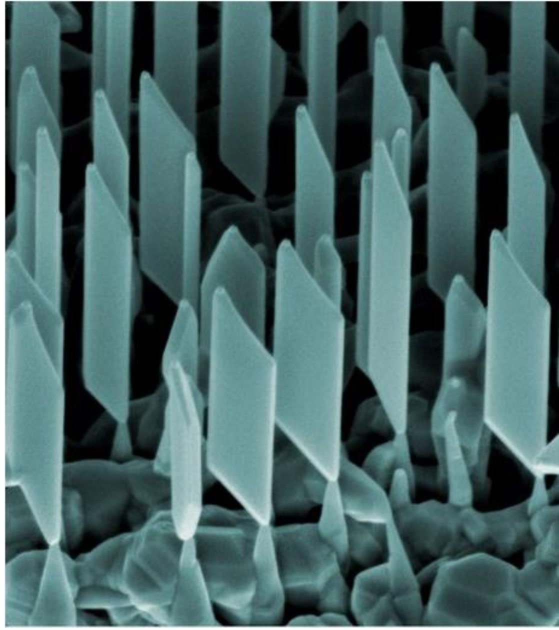

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high-mobility
giant g*-factor

NF-based Josephson junctions

S. Salimian *et al.*, APL (2021)

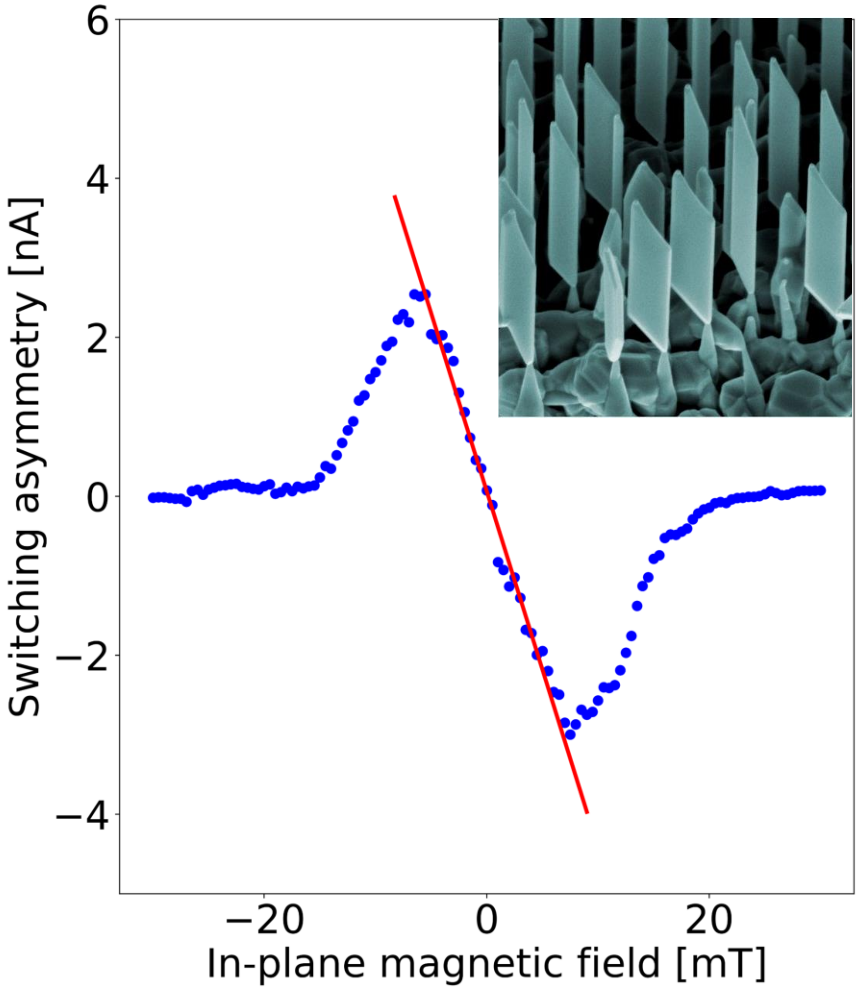
short-ballistic
$\Delta_S \sim E_{SOC}$

Observation of the JDE

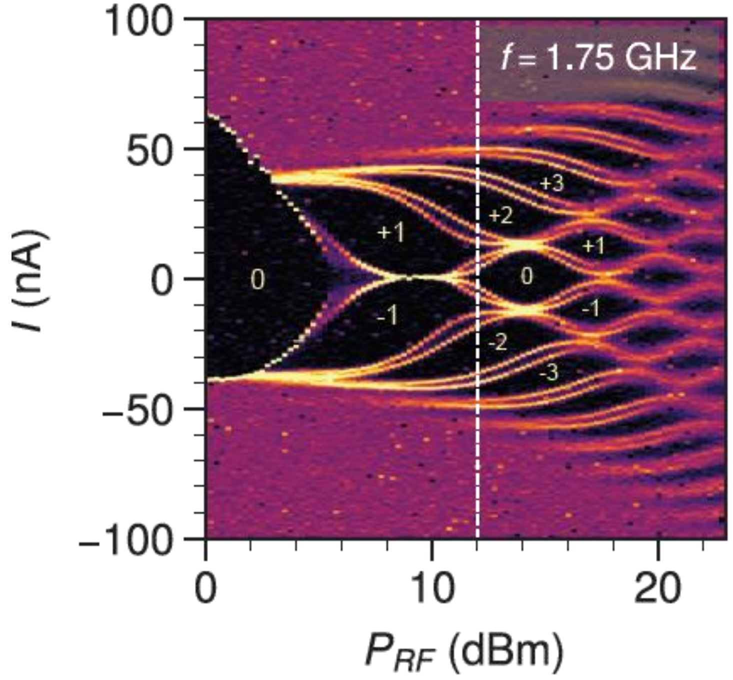
B. Turini *et al.*, Nano Lett. (2022)

field-induced JDE
Rashba-type system
gate-dependent η

NF-based JJs are a unique platform for exotic superconductivity



-> Half-integer Shapiro steps



Josephson Diode Effect in High-Mobility InSb Nanoflags

AndQC

SUPERTED

SUPER GATE

Growth

V. Zannier

I. Verma

L. Sorba

Fab

S. Salimian

Theory

M. Carrega

Transport

F. Paolucci

A. Iorio

E. Strambini

F. Giazotto

S. Heun

NF growth
ACS ANM
(2021)

NF-based JJs
APL
(2021)

JDE in InSb nanoflags
Nano Lett.
(2022)

Half-integer Shapiro steps
PRR
(2023)