Josephson Diode Effect in High-Mobility InSb Nanoflags

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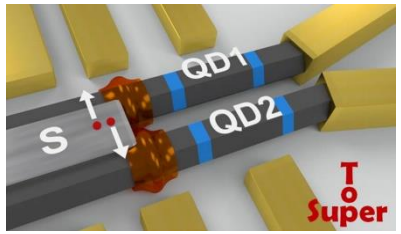

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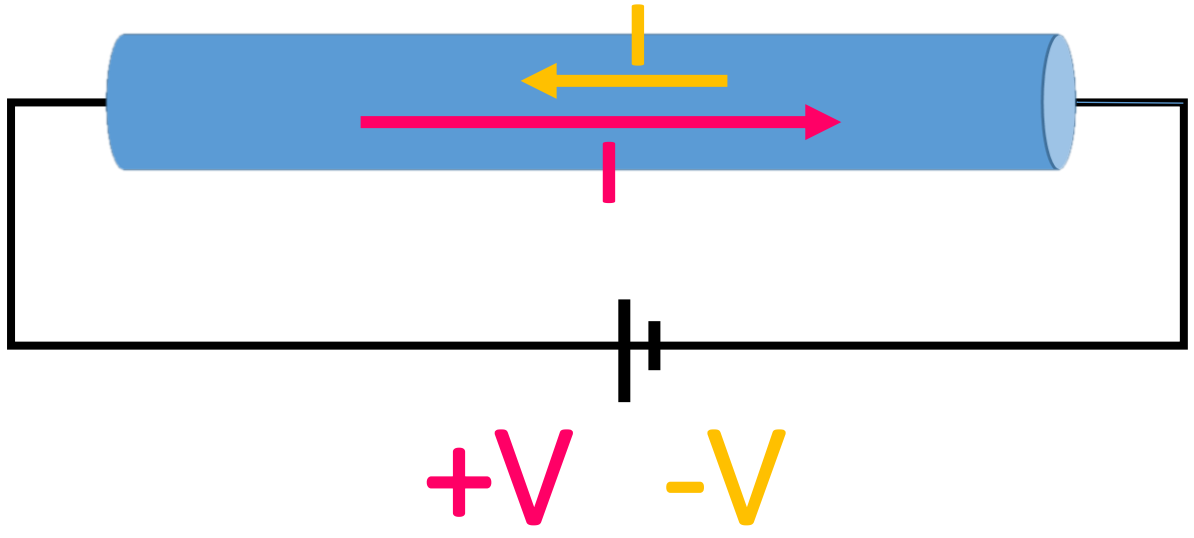
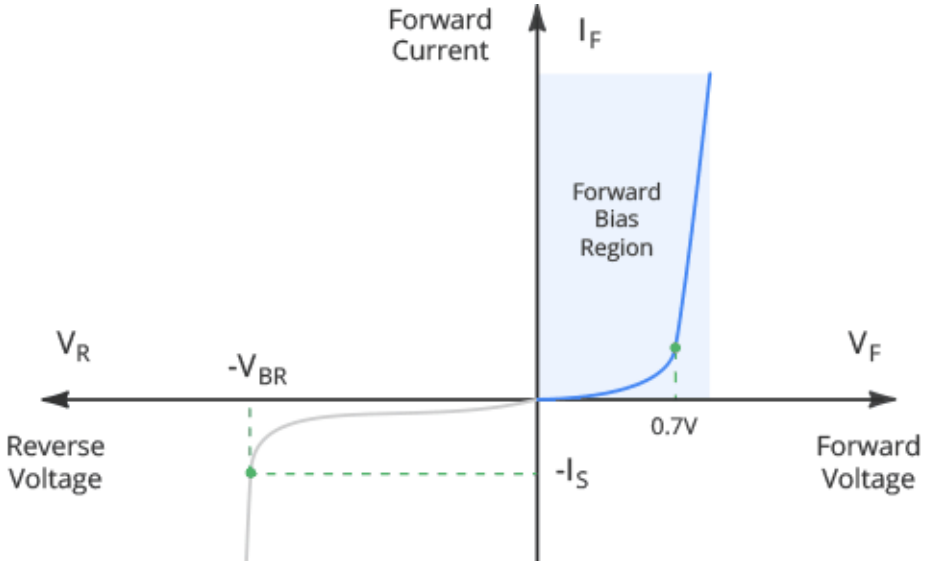
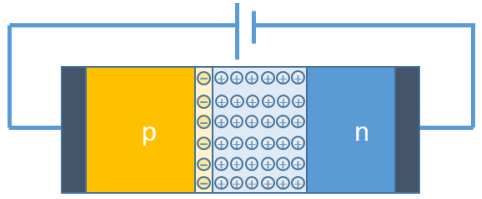
Introduction





Non-reciprocity implies $I_+ \neq |I_-|$.
A common example: the p-n junction.



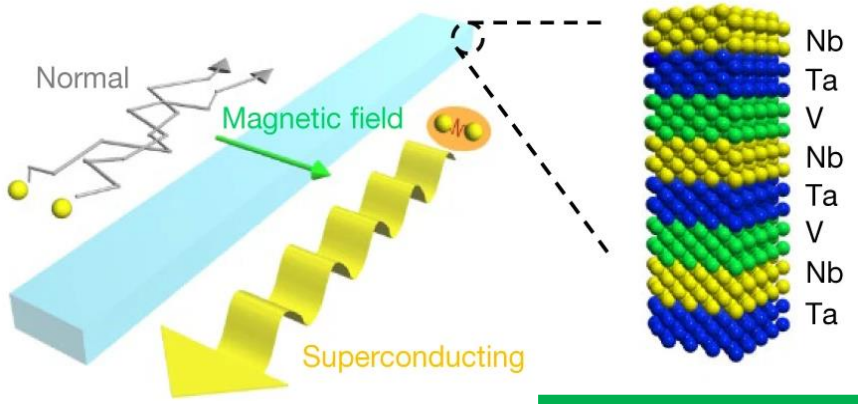
Superconducting diodes?

Superconducting diodes

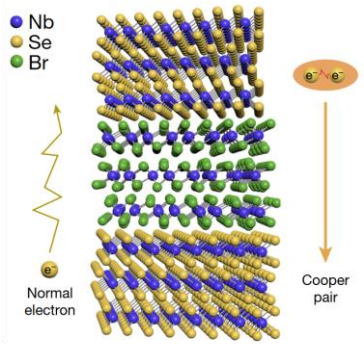
Rashba superconductors

Requirements:

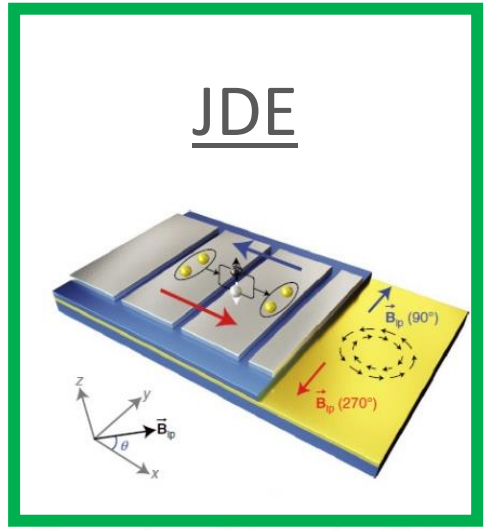
- ❑ Breaking of TR symmetry
- ❑ Breaking of I symmetry
- ❑ Robust superconducting order



Field-free SDE



JDE



Ando *et al.*, *Nature* **584**, 373–376 (2020)
Wu *et al.*, *Nature* **604**, 653–656 (2022)
Baumgartner *et al.*, *Nat. Nanotechnol.* **17**, 39–44 (2022)

Experimental results

1. The InSb *nanoflag*
2. Gate-controlled Josephson regime
3. Josephson diode effect

Turini, B. *et al.*, arXiv:2207.08772 (2022)

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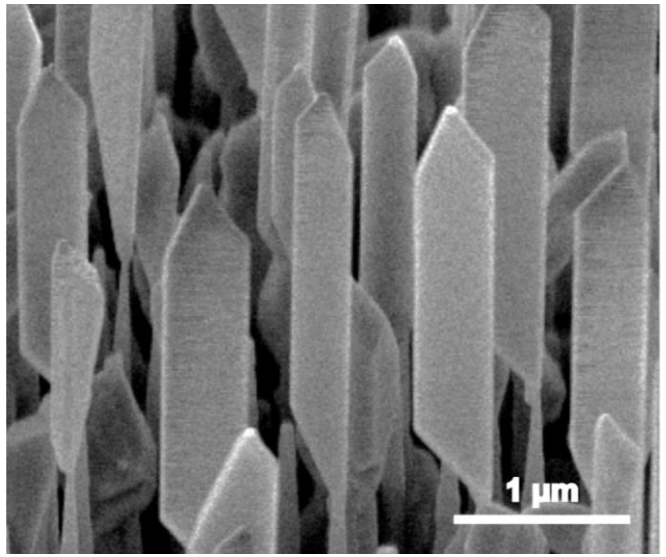
InSb-based hybrid devices

- Small effective mass $m^* = 0.02 m_e$
- Large g-factor $g^* \sim 50$
- Strong SOC $\mathrm{E}_{SOC} \sim 200\ \mu\mathrm{eV}$

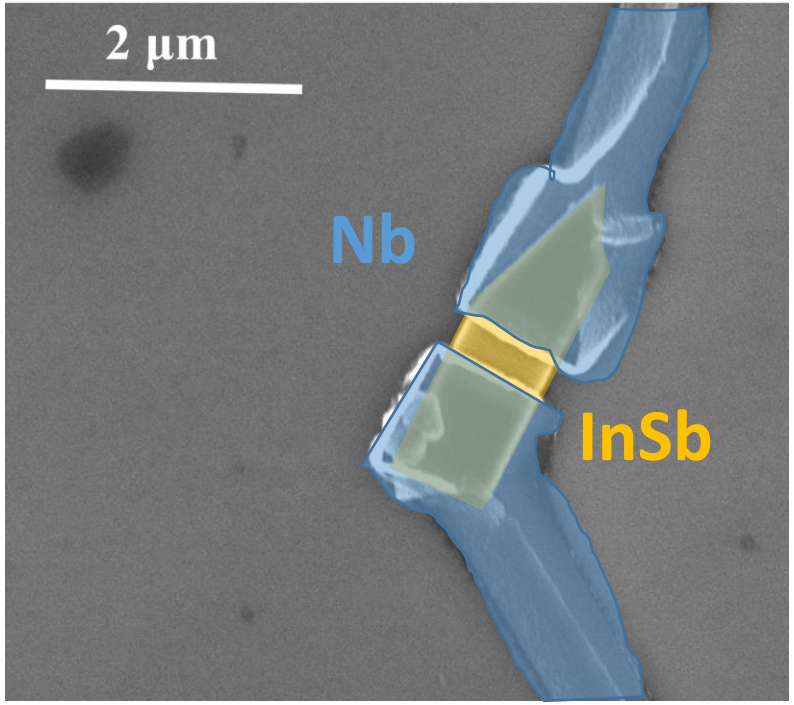


Nanoflags:

- $t \sim 100$ nm
- $\mathrm{W} \sim 500$ nm
- $L \sim 2\ \mu\mathrm{m}$

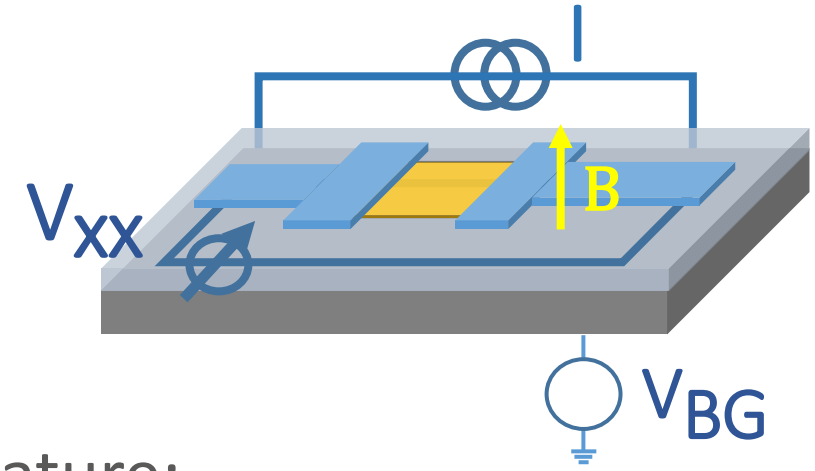
- $\mu = 3 \times 10^4\ \mathrm{cm}^2/\mathrm{Vs}$

S-N-S junction



Verma *et al.*, *ACS Applied Nano Materials* 4 (2021) 5825

Magneto-transport measurements

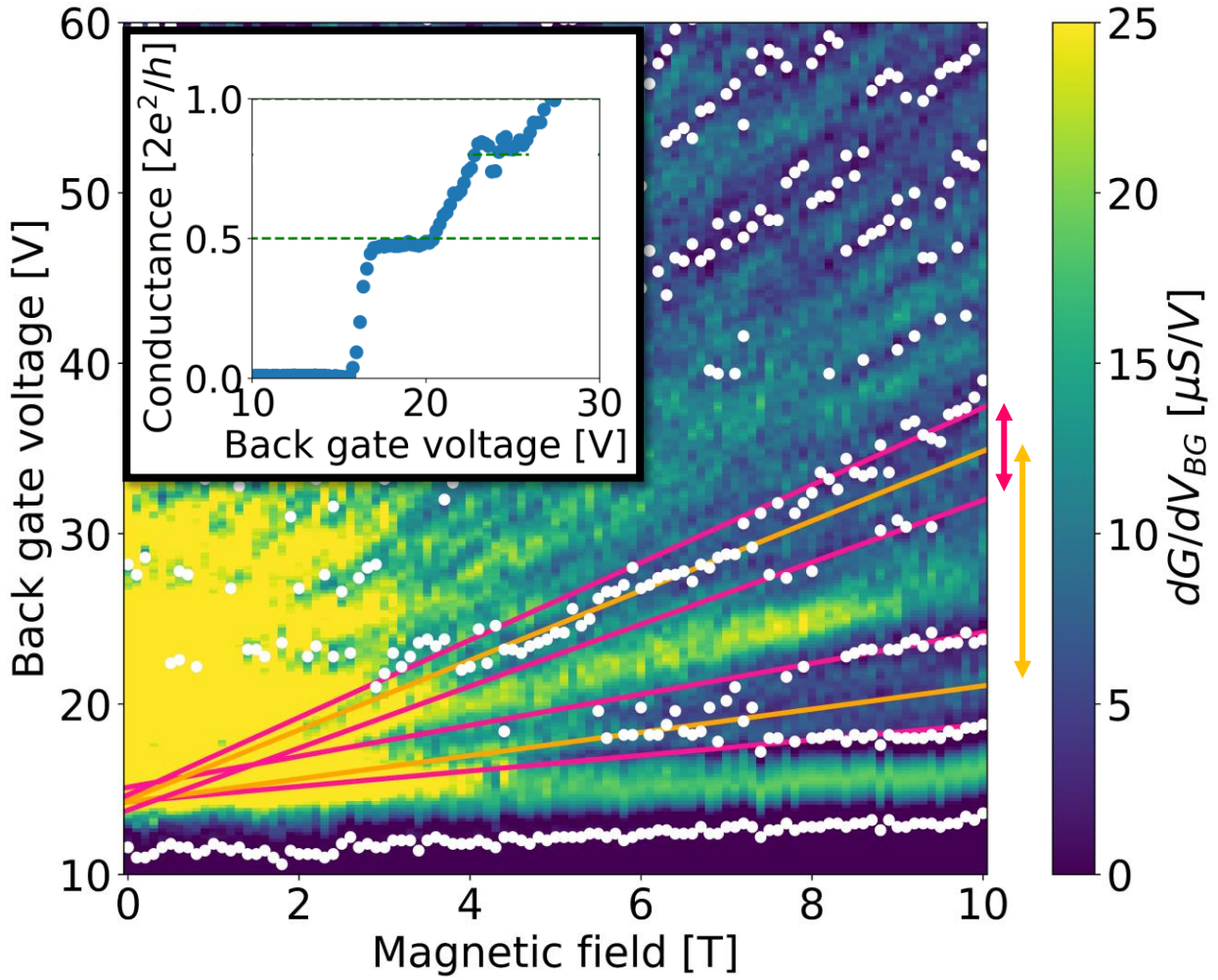


- 2D nature:

  Quantum Hall regime

- Estimation of the g-factor:

$$g^* = 44$$



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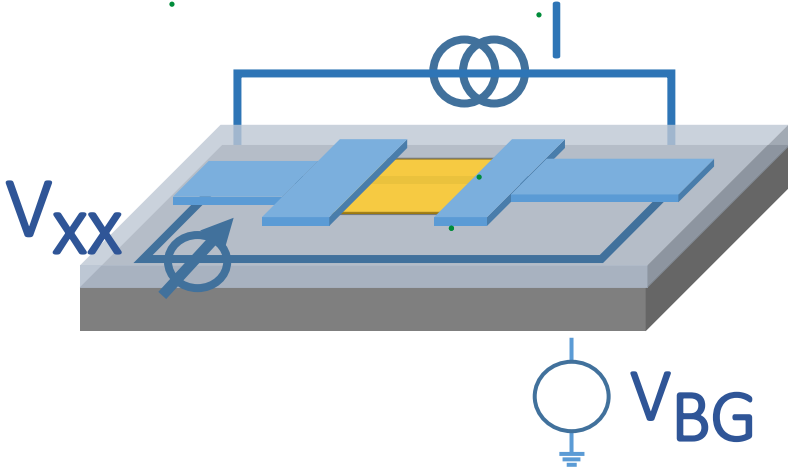
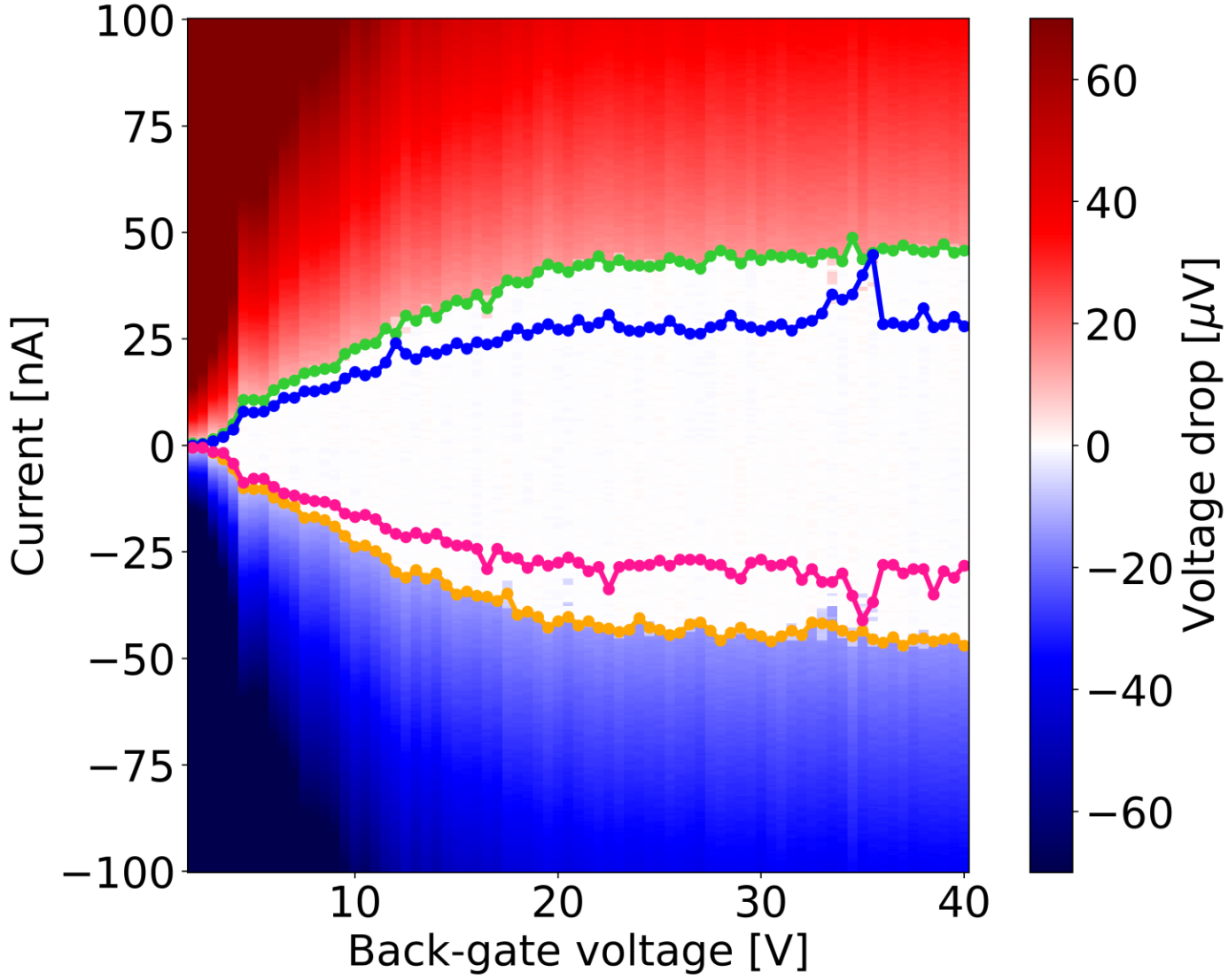
The Josephson regime





L	250 nm
ξ_S	750 nm
λ_{MFP}	500 nm

- short-ballistic junction
- gate-controlled SC

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Experimental results

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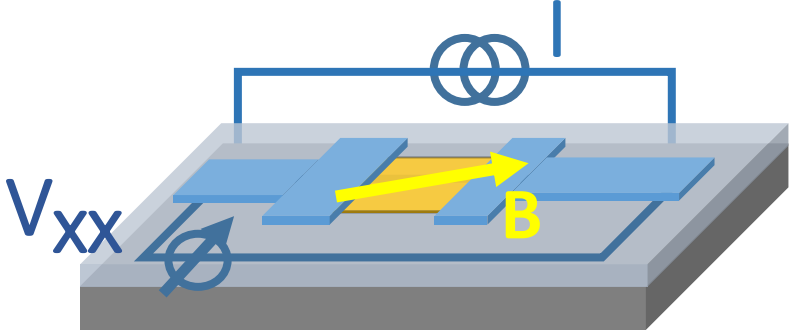
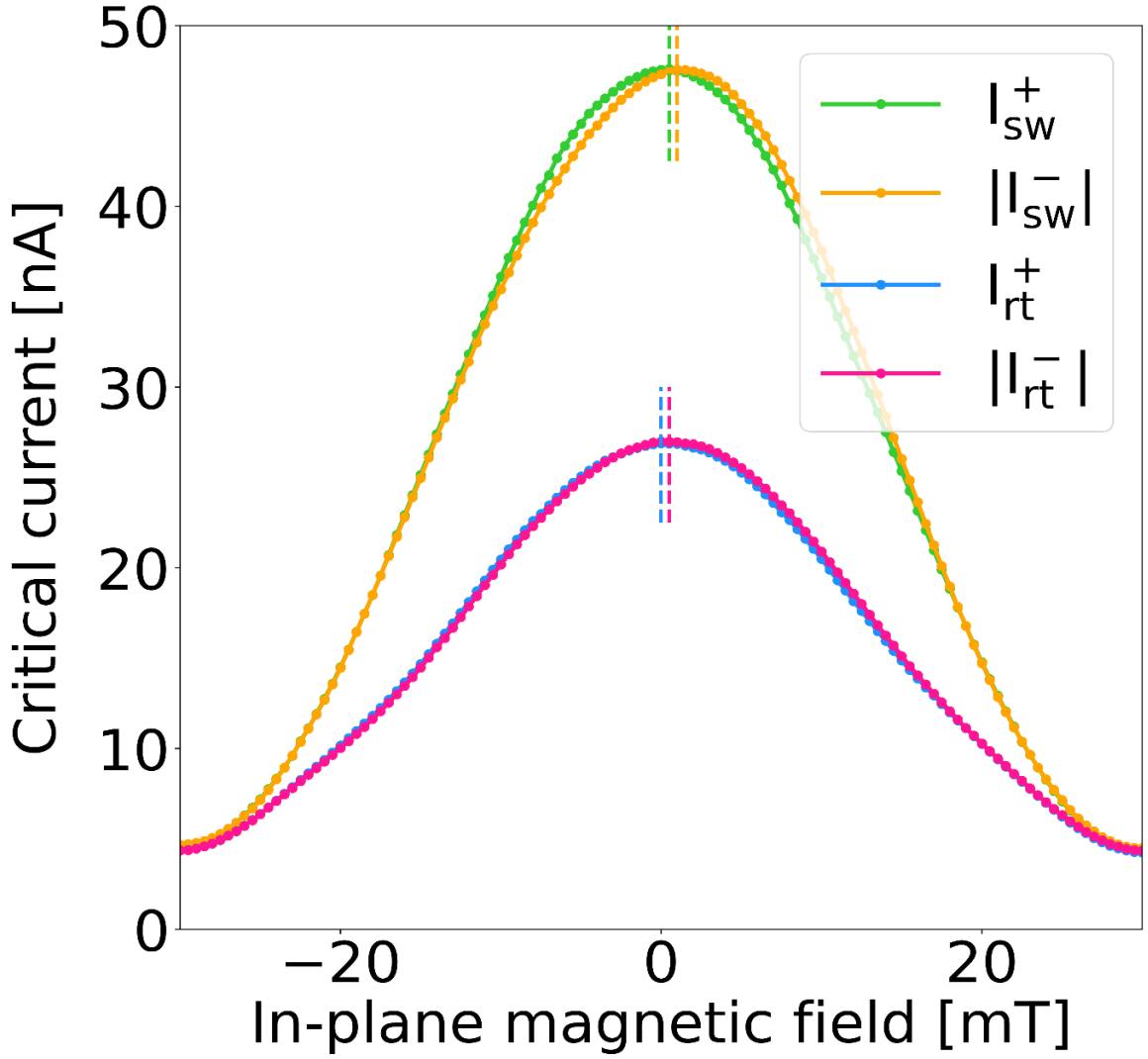
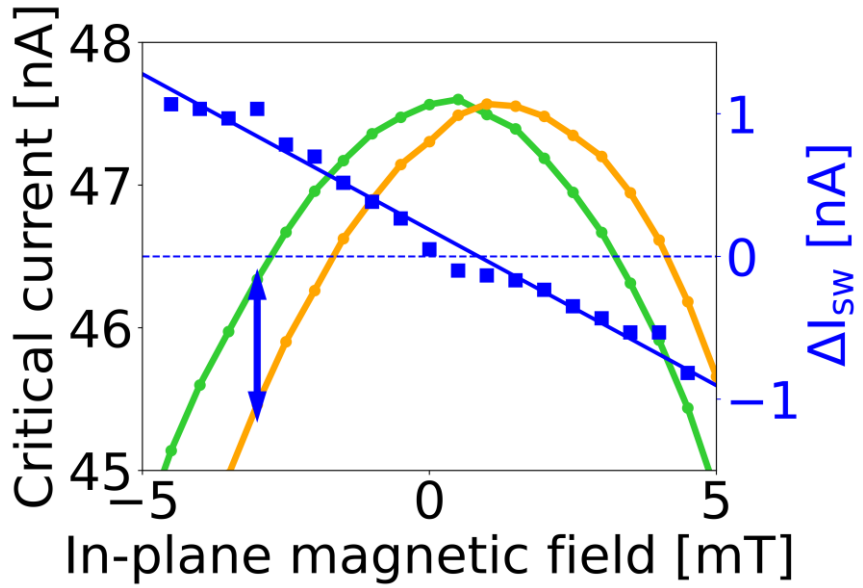
Turini, B. *et al.*, arXiv:2207.08772 (2022)

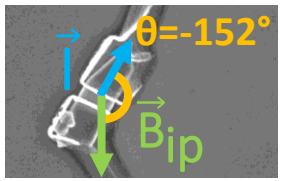
Magnetic field-driven JDE

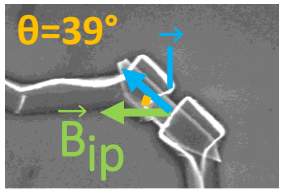


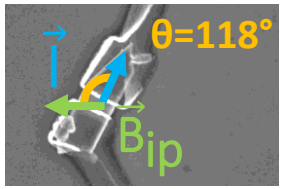


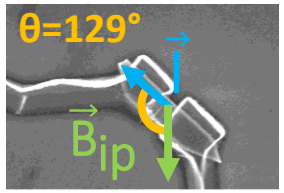


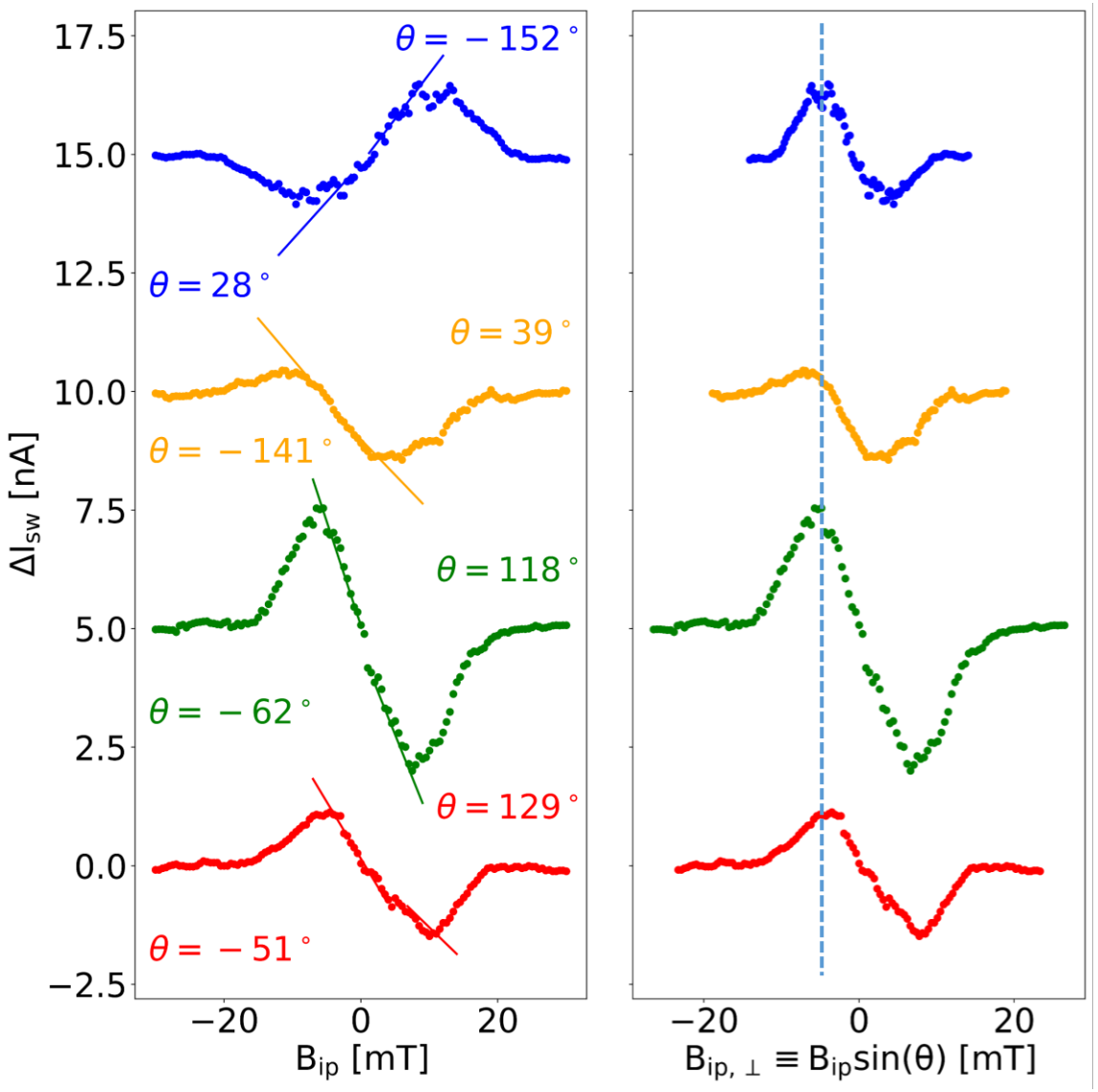
Dependence on the angle







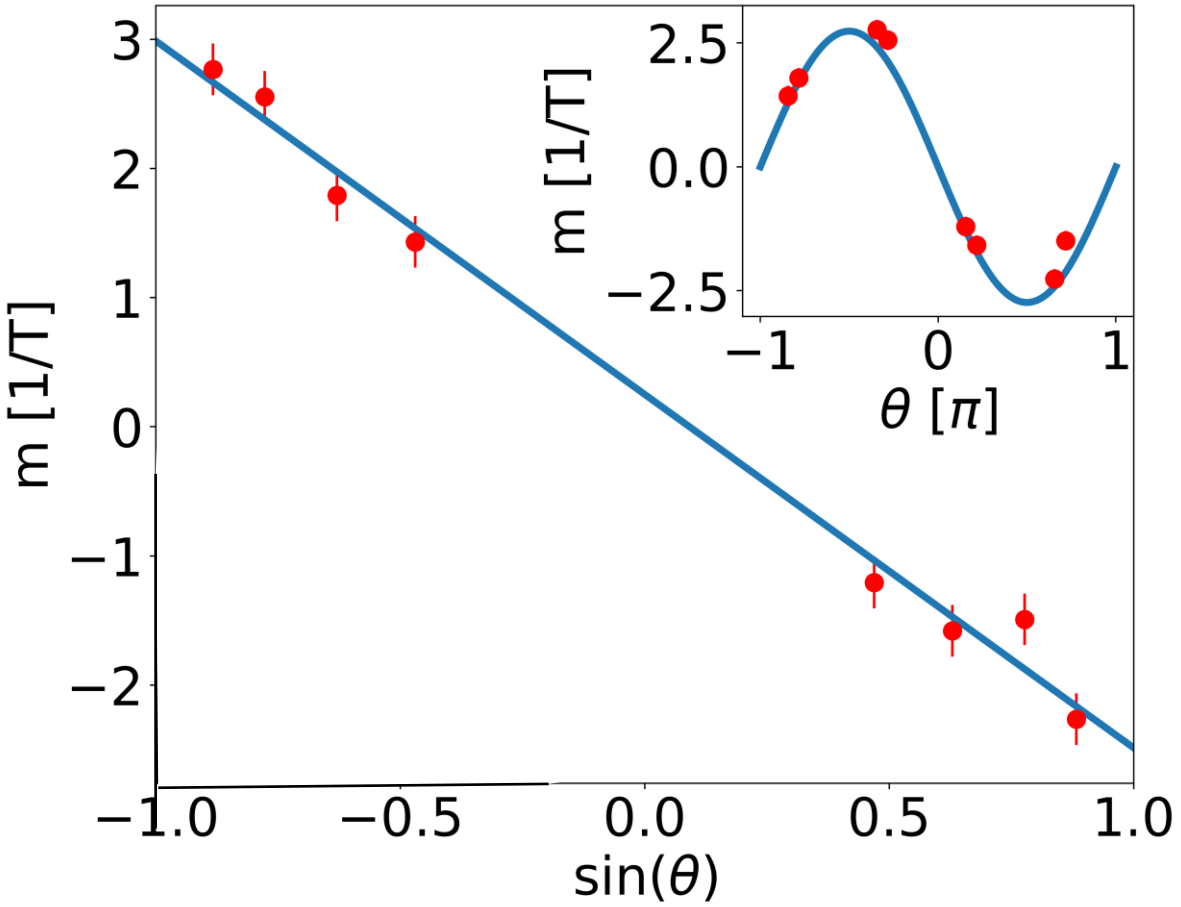




$$\Delta I_{sw} \propto |\boldsymbol{B} \times \boldsymbol{I}|$$

Dominant Rashba spin-orbit coupling

Field-driven JDE



In the SO-dominated regime:

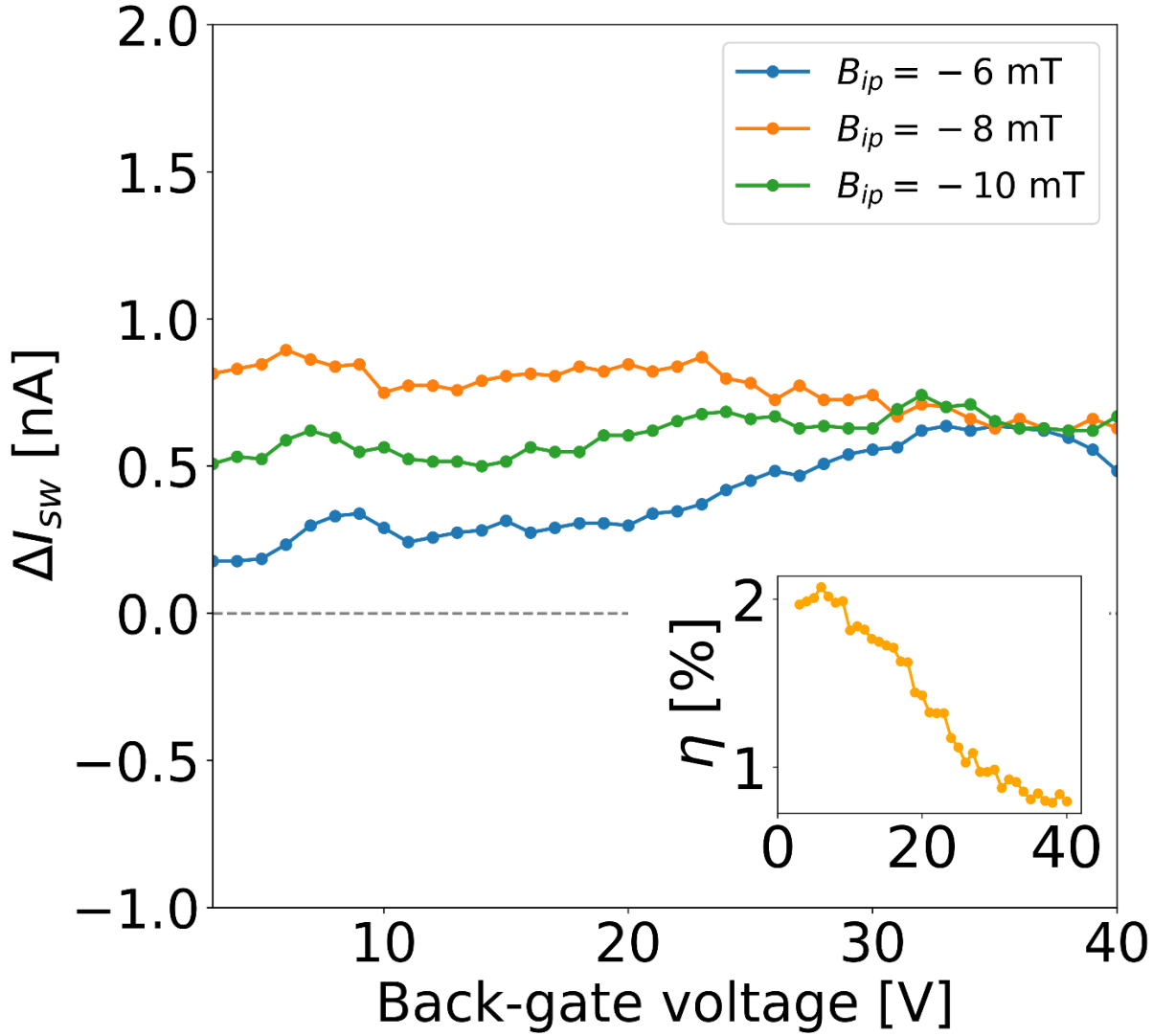
$$\eta = \frac{\Delta I_c}{I_c^+ + |I_c^-|} = \frac{2g^*\mu_B}{\pi\Delta^*}B \equiv \alpha B.$$

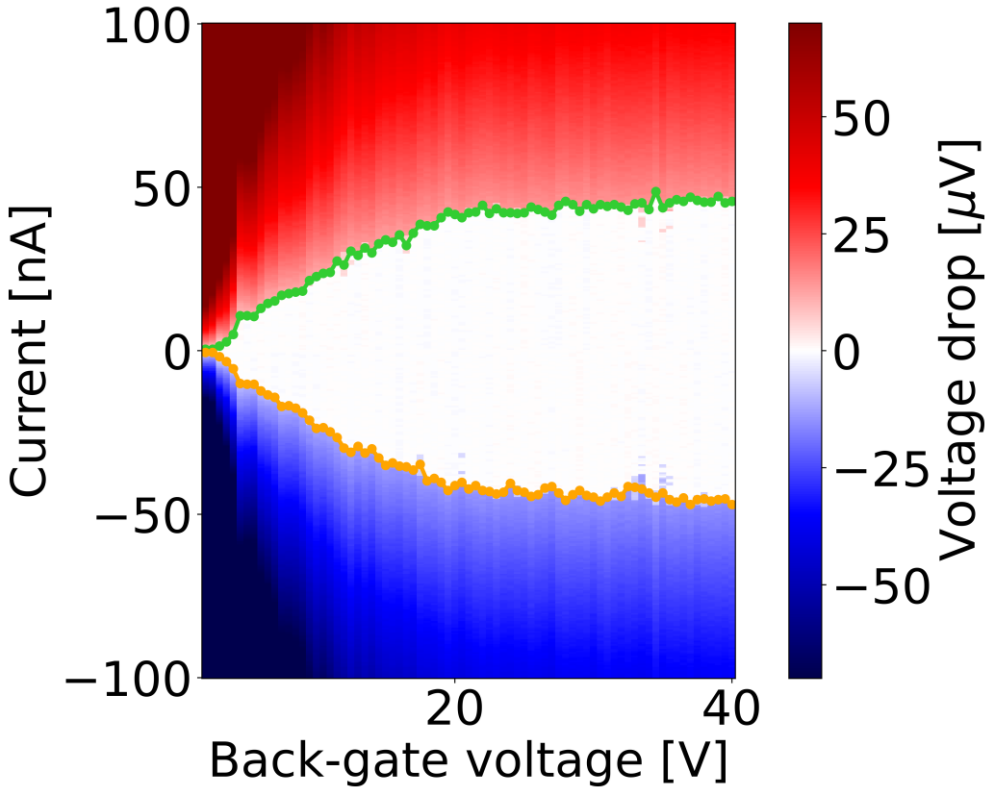
$$\alpha_{exp} = 3.0 \pm 0.2\ T^{-1}$$

$$\alpha_{th} = 8.5\ T^{-1}$$

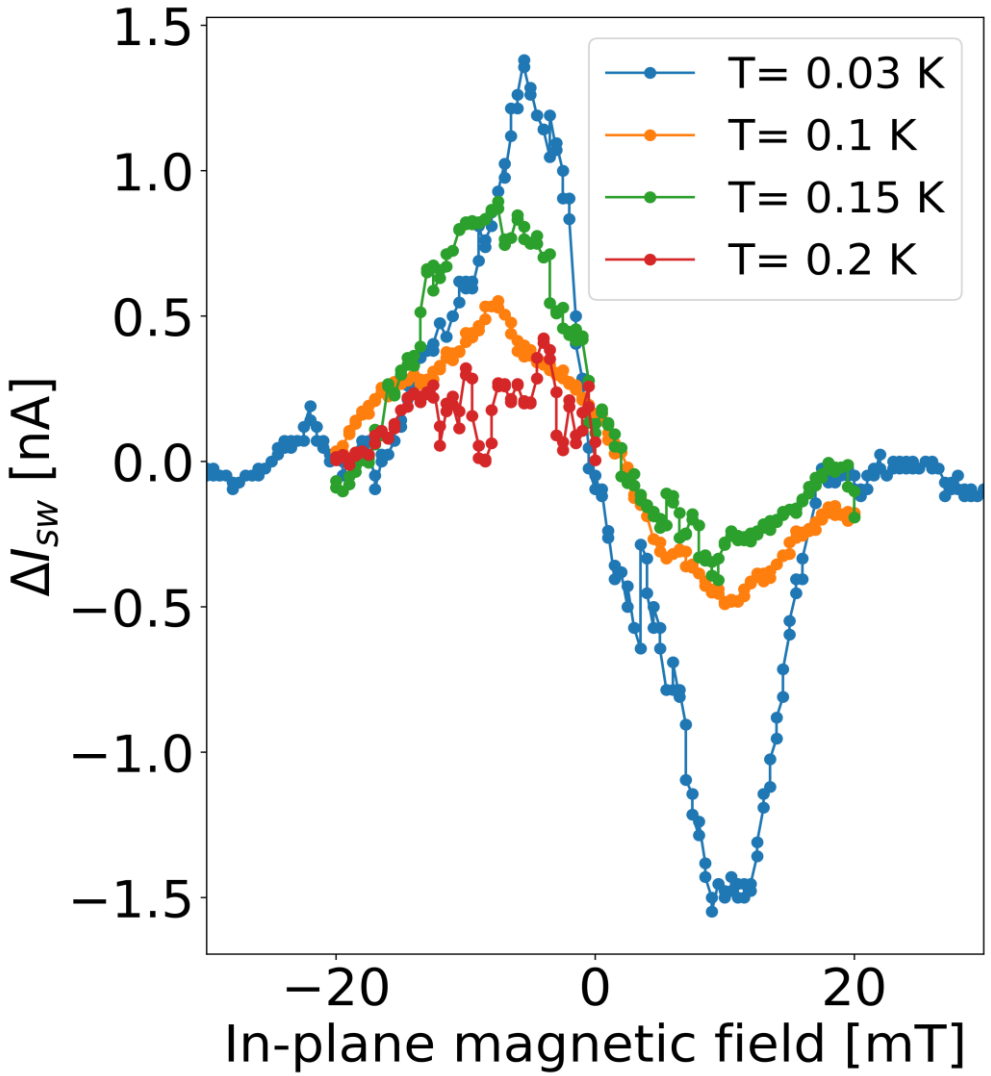
Dolcini *et al.*, Phys. Rev. B 92, 03542 (2015)
Davydova *et al.*, Science Advances 8, eabo0309 (2022)

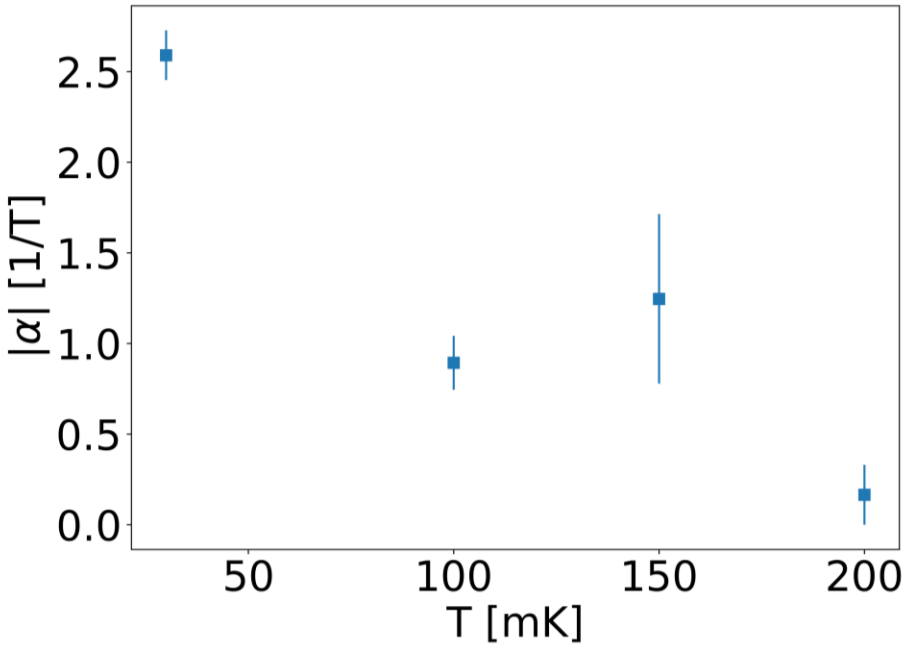
Back-gate dependence





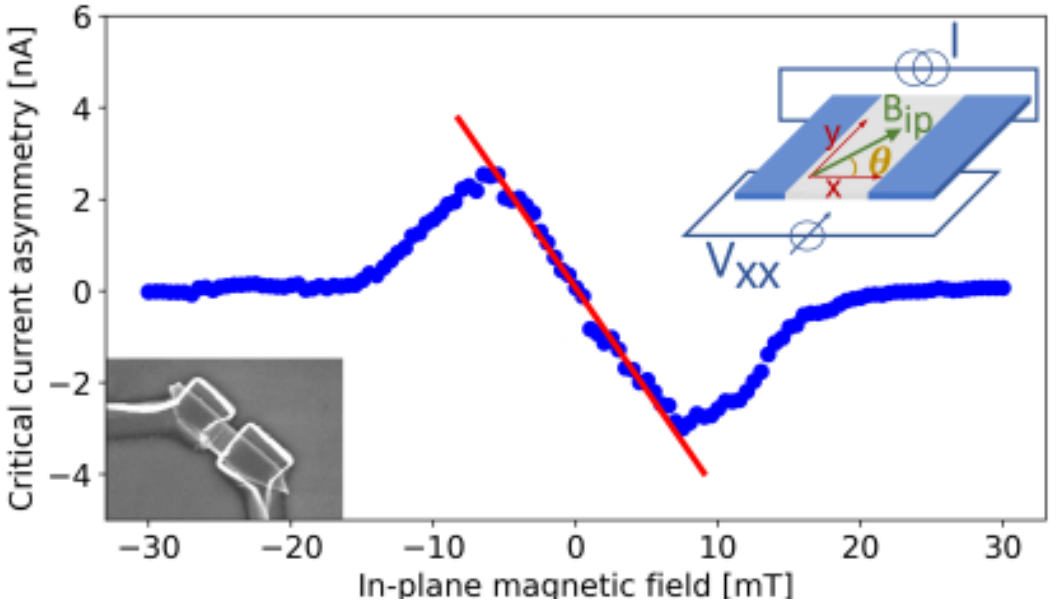
Temperature dependence





Conclusions

- Nanoflag characterization
- Analysis of the Josephson regime
- First observation of the JDE in InSb
  - Magnetic-field driven non-reciprocity
  - Back-gate and temperature dependence



Turini, B. *et al.*,
Josephson Diode Effect
in High Mobility InSb
Nanoflags. (2022)
arXiv:2207.08772

People Involved

Growth activity

Valentina Zannier

Lucia Sorba

Devices

Sedighe Salimian

Theory

Matteo Carrega

Transport measurements

Federico Paolucci

Andrea Iorio

Elia Strambini

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SUPERTED

SUPER GATE

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