Superconducting Quantum Interference Devices based on InSb Nanoflag Josephson Junctions

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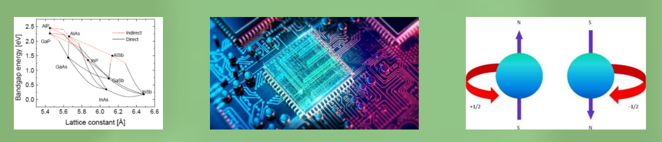
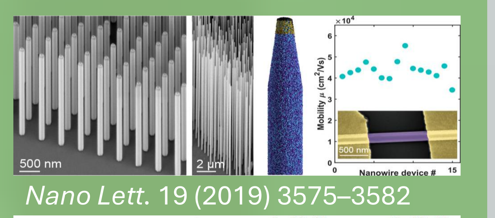
Why InSb?

- Narrow bandgap (0.23 eV)
- High bulk electron mobility (7.7 x 10^4 $cm^2/(Vs)$)
- Small effective mass (0.018 m_e)
- Strong spin-orbit interaction ($E_{SOI} \sim 200\ \mu eV$)
- Large Landé g-factor ($g^* \sim 50$)



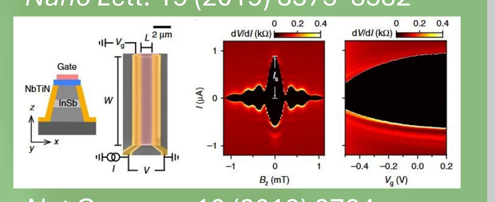
InSb nanostructures

InSb nanowires:



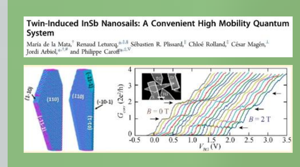
Nano Lett. 19 (2019) 3575–3582

InSb quantum wells:

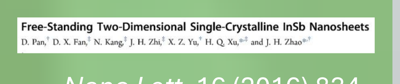


Nat Commun 10 (2019) 3764

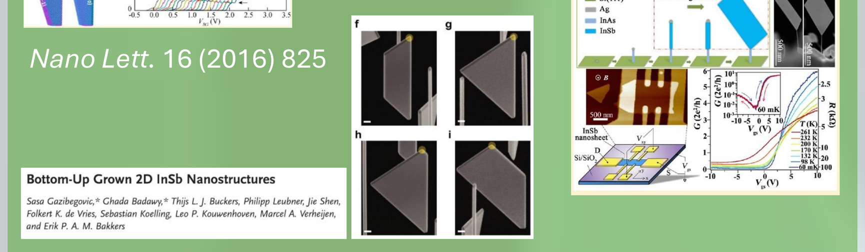
2D Nanoflags (NFs)



Nano Lett. 16 (2016) 825



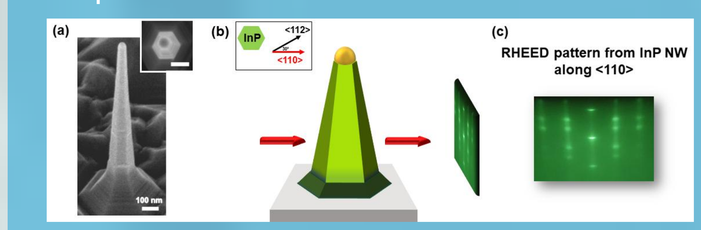
Nano Lett. 16 (2016) 834



Adv. Mater. 31 (2019) 1808181

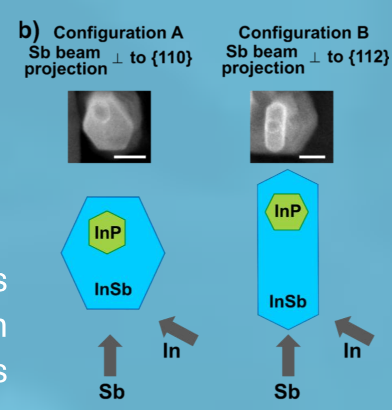
From Nanowires (1D) to Nanoflags (2D)

Tapered InP nanowires are used as *stems*

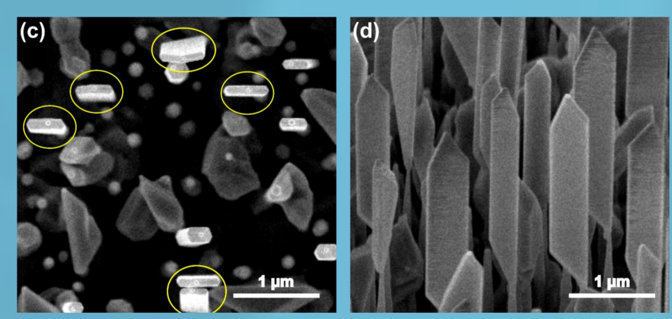


I. Verma et al., ACS Applied Nano Materials 4 (2021) 5825.

The 2D shape is obtained with directional fluxes

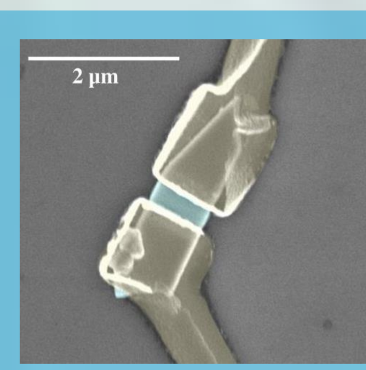


Growth of InSb nanoflags by CBE



Defect-free InSb zinc blende lattice

InSb nanoflags:
Length 2-3 μm
Width 500 nm
Thickness 100 nm

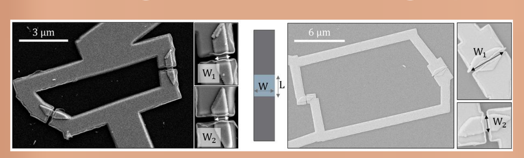


Appl. Phys. Lett. 119 (2021) 214004.

SQUIDs based on InSb nanoflags

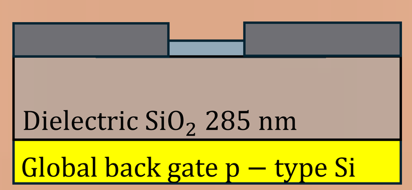
Symmetric SQUID · Asymmetric SQUID

Scanning electron micrographs



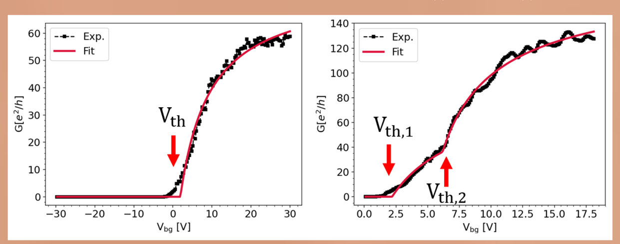
- $L \approx 200$ nm
- $W_1 = W_2 \approx 0.4\ \mu m$

- $L \approx 200$ nm
- $W_1 \approx 1.7 \mu m$
- $W_2 \approx 0.5\ \mu m$



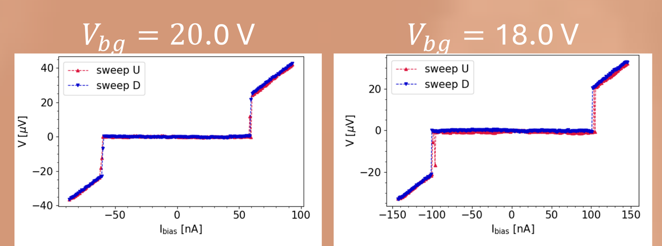
Symmetric SQUID · Asymmetric SQUID

SQUID conductance $G = G_{JJ1} + G_{JJ2}$

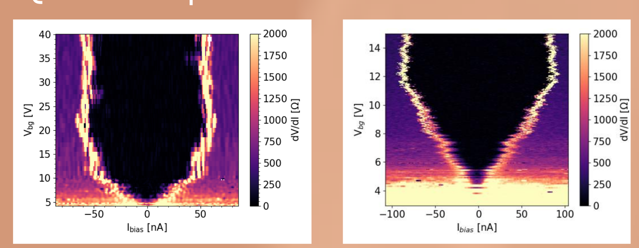


$T = 2$ K

VI traces @ $T = 350$ mK



SQUID Josephson Field Effect Transistor

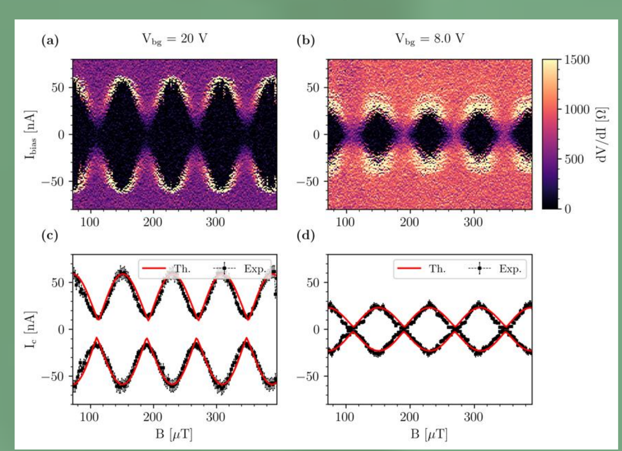


$T = 350$ mK

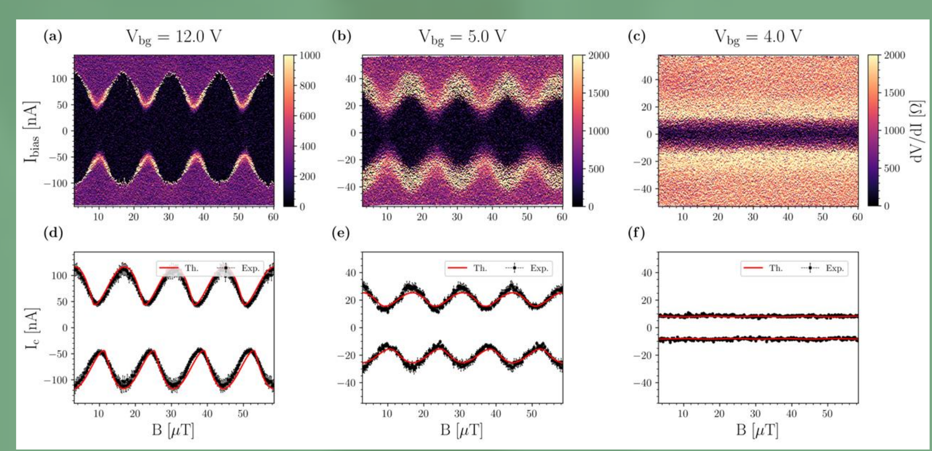
Back gate control of supercurrent

Interference in the SQUID

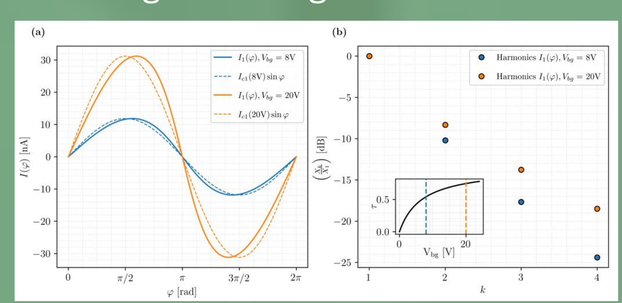
Interference in the symmetric SQUID



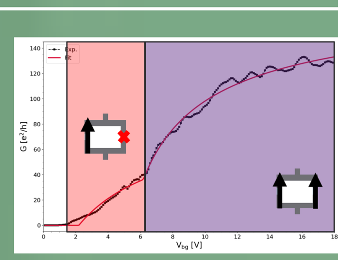
Results for the asymmetric SQUID



Tight-binding simulations

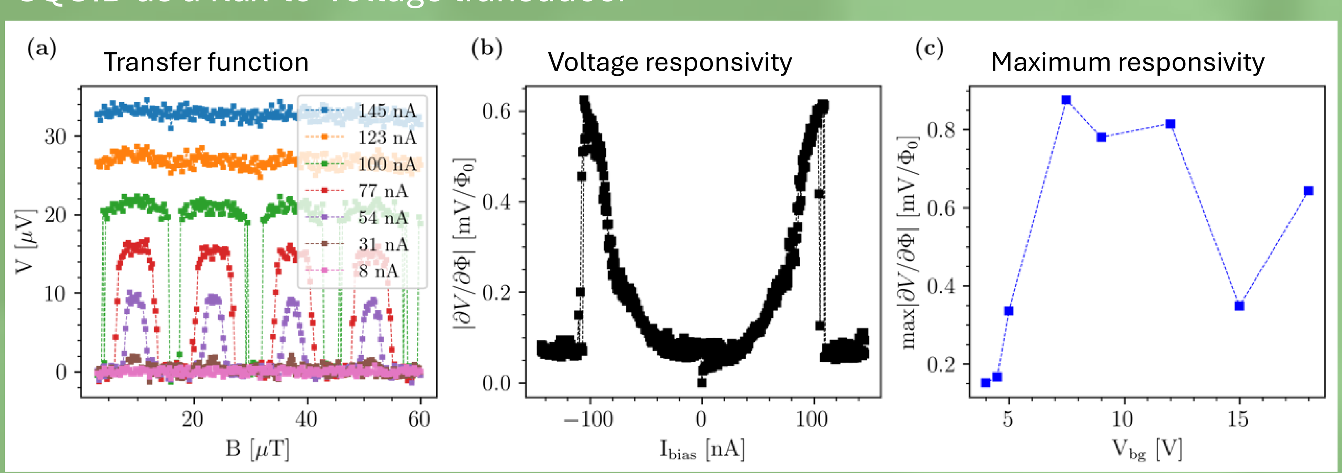


Loss of interference



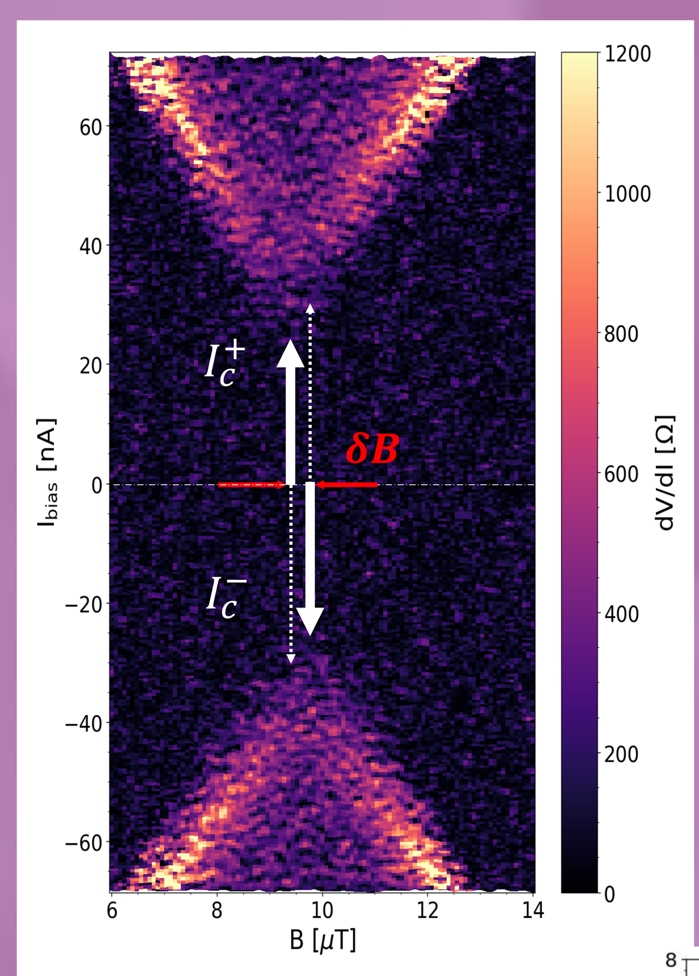
Magnetometer performance

SQUID as a flux-to-voltage transducer



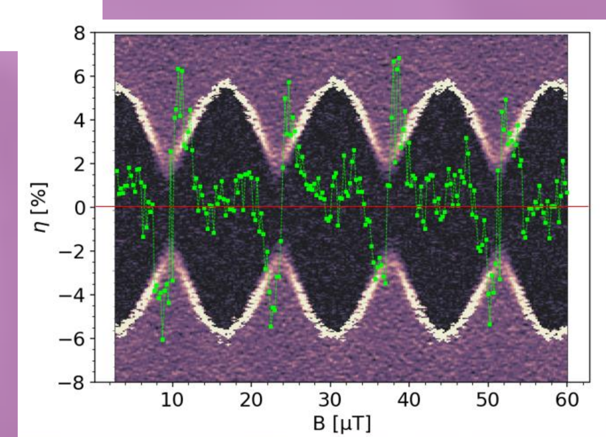
Magnetic flux noise amplitude $S_\Phi^{1/2} = 4.4 \times 10^{-6}\ \Phi_0/\sqrt{Hz}$

Non-reciprocal transport



Minima in I_{c+}, I_{c-} for different magnetic fields

$$\eta[\%] = \frac{I_{c+} - |I_{c-}|}{I_{c+} + |I_{c-}|} \cdot 100$$



Conclusions

- SQUIDs realized using InSb nanoflag Josephson junctions.
- Symmetric and asymmetric geometries were implemented.
- Theoretical framework accounts for all observations.
- Transparency of the junctions can be modulated by a back gate.
- Non-reciprocal transport demonstrated (Josephson Diode Effect).
- SQUID performance as magnetometer has been evaluated.

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