Microwave–induced spin-population inversion in hybrid magnetic point contacts

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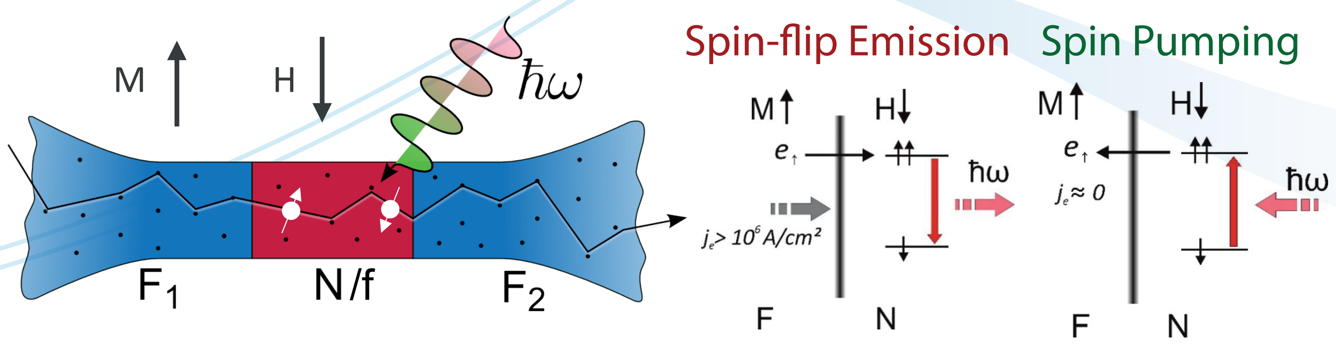
INTRODUCTION

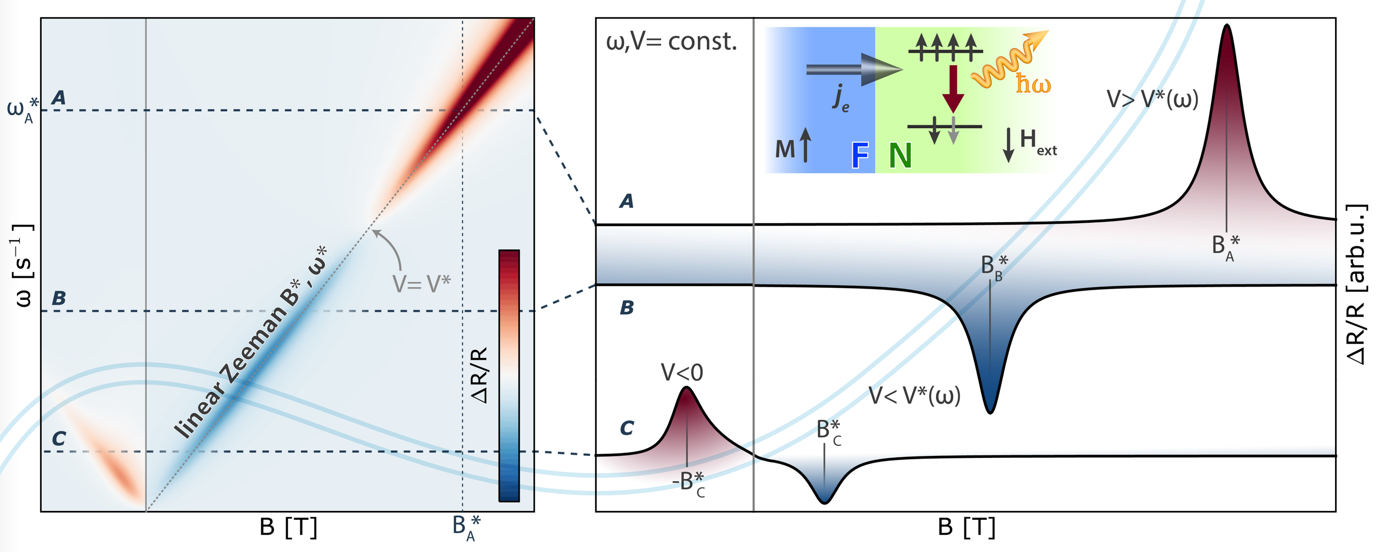
Recently, all-metallic spin-flip lasing devices have been proposed as a fundamentally new type of highly tunable, miniaturized radiation source in the GHz and THz range with giant intensity compared to state of the art semiconductor quantum cascade lasers. The basic idea behind these spin-flip lasers is that radiant relaxation of hot, spin-polarized electrons takes places in a two-level system, i.e. energy split spin-subbands, upon creation of a spin-population inversion.
Herein we experimentally demonstrate spin-inversion in hybrid magnetic point contacts in the ballistic regime.

SPIN-FLIP LASING IN METALS



Diffusive point contact under hf irradiation. A high forward voltage bias injects a spin-polarized current from F1 into the active region N/f.
A spin-up electron is shown to move along a diffusive trajectory from metal F1 to N/f where it resonantly interacts with the electromagnetic field, which results in a spin-flip, implying a change of the magneto-resistance of the contact:

$$\frac{\Delta R}{R} = \frac{4\pi\beta_{tr}^2}{3}\frac{c}{v_F}\frac{(\mu_B H_{rf})^2}{\epsilon_F \hbar \nu_{sf}}(n_0 V_{PC})\left(\frac{2e^2}{h}R\right)\arctan\left(\frac{2\xi}{1-\xi^2+\left(\frac{\hbar\omega - g\mu_B B}{\hbar\nu_{sf}}\right)^2}\right)$$

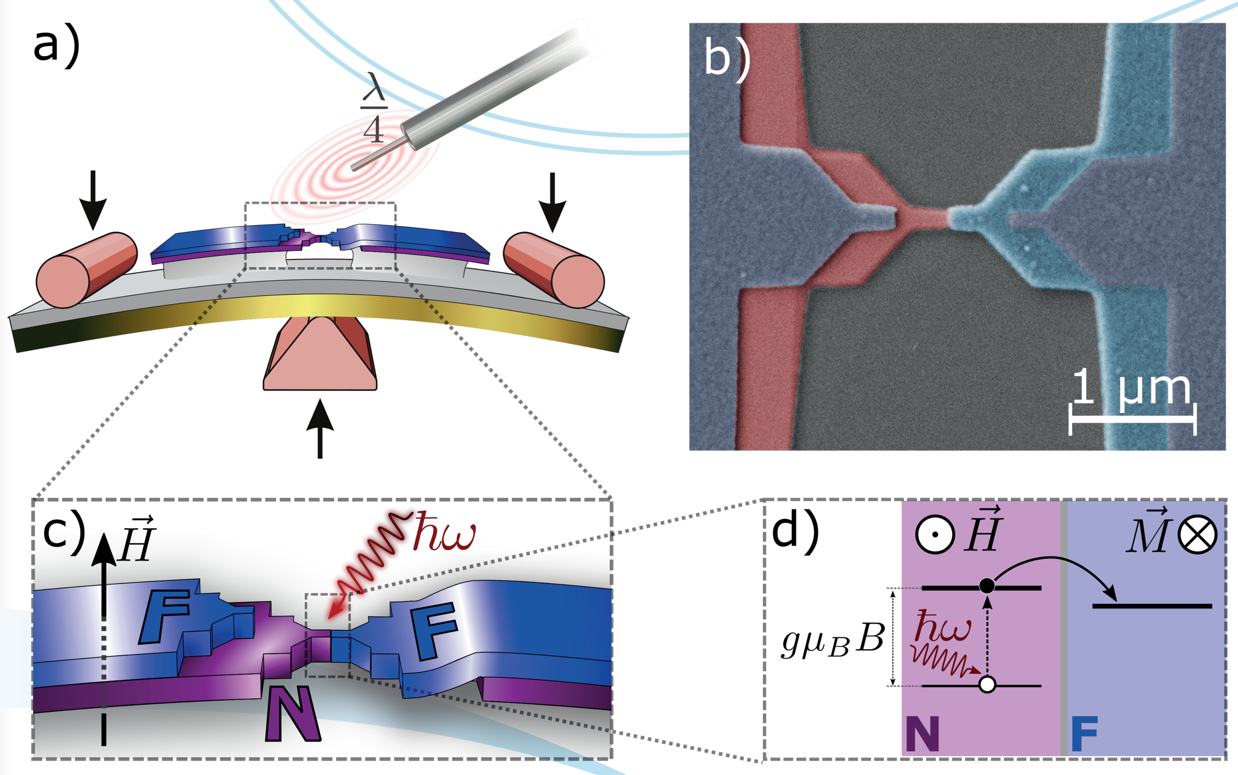


Expected transport behaviour of a diffusive F/N hetero-point contact due to spin-flip photoemission and absorption according to the semi-classical transport theory reported in:

REFERENCES

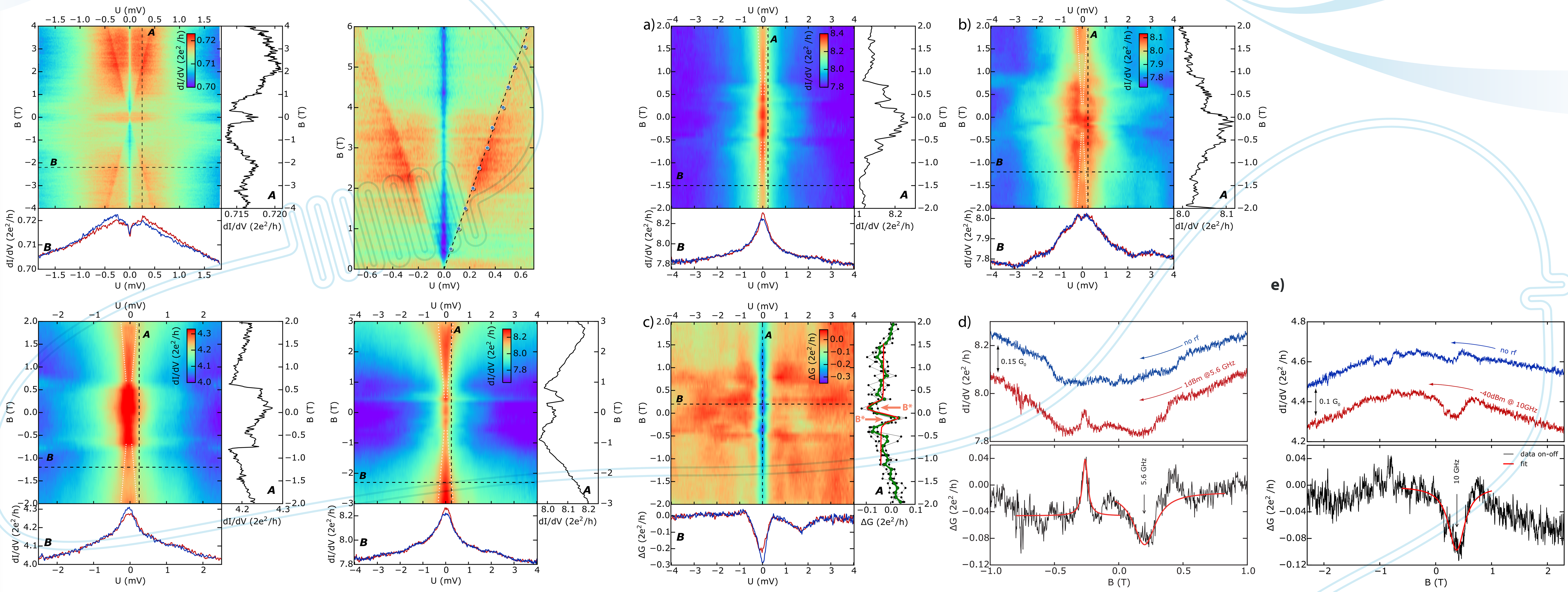
A. Kadigrobov et al., Europhys. Lett. 67, 948 (2004).
A. Kadigrobov, et al., Low Temp. Phys. 38, 1133 (2012).
Y. Naidyuk et al., New J. Phys. 14, 093021 1 (2012).
R. Shekhter et al., Opt. Lett. 36, 2381 (2011).

ATOMIC-SIZE HYBRID POINT CONTATCS



Tunable hetero point contacts are fabricated using the mechanically controllable break-junction technique, where a suspended, micro-fabricated metal bridge is carefully stretched to adjust the contact size.
Spin-population inversion upon micro-wave absorption or -emission is detected via point contact spectroscopy.

ELECTRONIC TRANSPORT & MICROWAVE SPECTROSCOPY



Differential conductance maps of Pd and Co/Pd hybrid point contacts as a function of bias voltage and magnetic flux show a Zeeman splitting in the LDOS. Line traces at the positions A and B indicated in the pseudocolor plots resemble the magneto-conductance and point contact spectra.

Conductance maps of a Pd/Co point contacts at 8.2 G0; high-frequency irradiation suppresses the ZBA and leads to distinct conductance changes (c) at the resonance field B*. The rf induced conductance change is well described within the theory of spin-flip lasing; both spin pumping (d) and spin-flip emission in voltage biased contacts (e) are observed.

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