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Phase-Slip Events in a Wide Superconducting Film Induced by Proximity to a Half-Metallic Strip

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Abstract

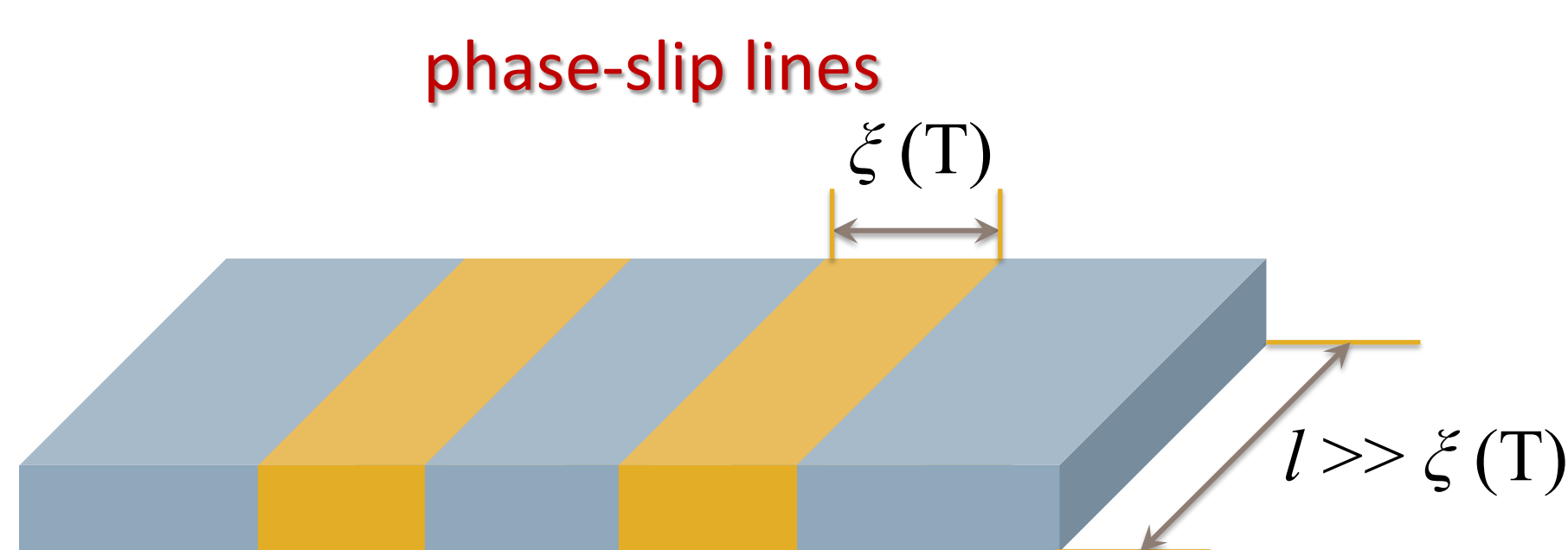
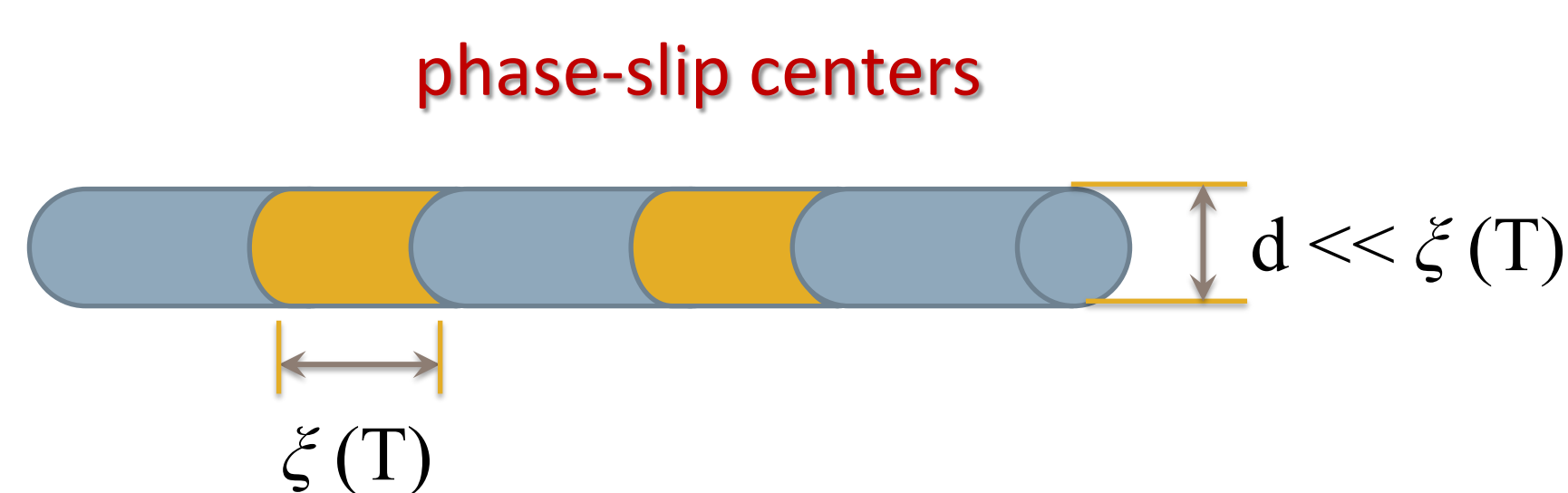
Emergence of phase-slip lines is one of the main mechanisms for dissipation in current-carrying superconducting (S) thin films with lateral dimensions larger than the superconducting coherence length.

External stimuli like external magnetic field or proximity of a nearby ferromagnet (F) (magnetic dots on the top of a superconducting film or magnetic impurities inside it) can control the resistive state of the superconducting layer.

In this contribution, we demonstrate that the same effect is achieved by evaporating a half-metallic Co₂CrAl strip directly onto a type-II superconducting Mo₅₆Re₄₄-alloy film and by tuning the spin-polarized injection current I_{in} .

It is shown that the spin-polarized injection can serve as an effective tool to control critical parameters in the wide resistive region between pure superconducting (dissipation-free) and normal (completely ohmic) transport regimes.

We have found that low magnetic fields, even lower than the lower critical field of the MoRe alloy, can have a significant impact on the S-to-N transition region due to the magnetic ordering in the F film that produces a strong coupling between transport characteristics of the proximized S film and the magnetic response of the F layer.



Features of phase slips

The characteristic features of the phase-slippage events are :

- a voltage jump from zero voltage at some critical current ;
- all resistive branches have approximately the same excess current given by the intersection of their slopes with the current axis ;
- the differential resistance of a resistive branch is proportional to its number.

Acknowledgments

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Objective of the study

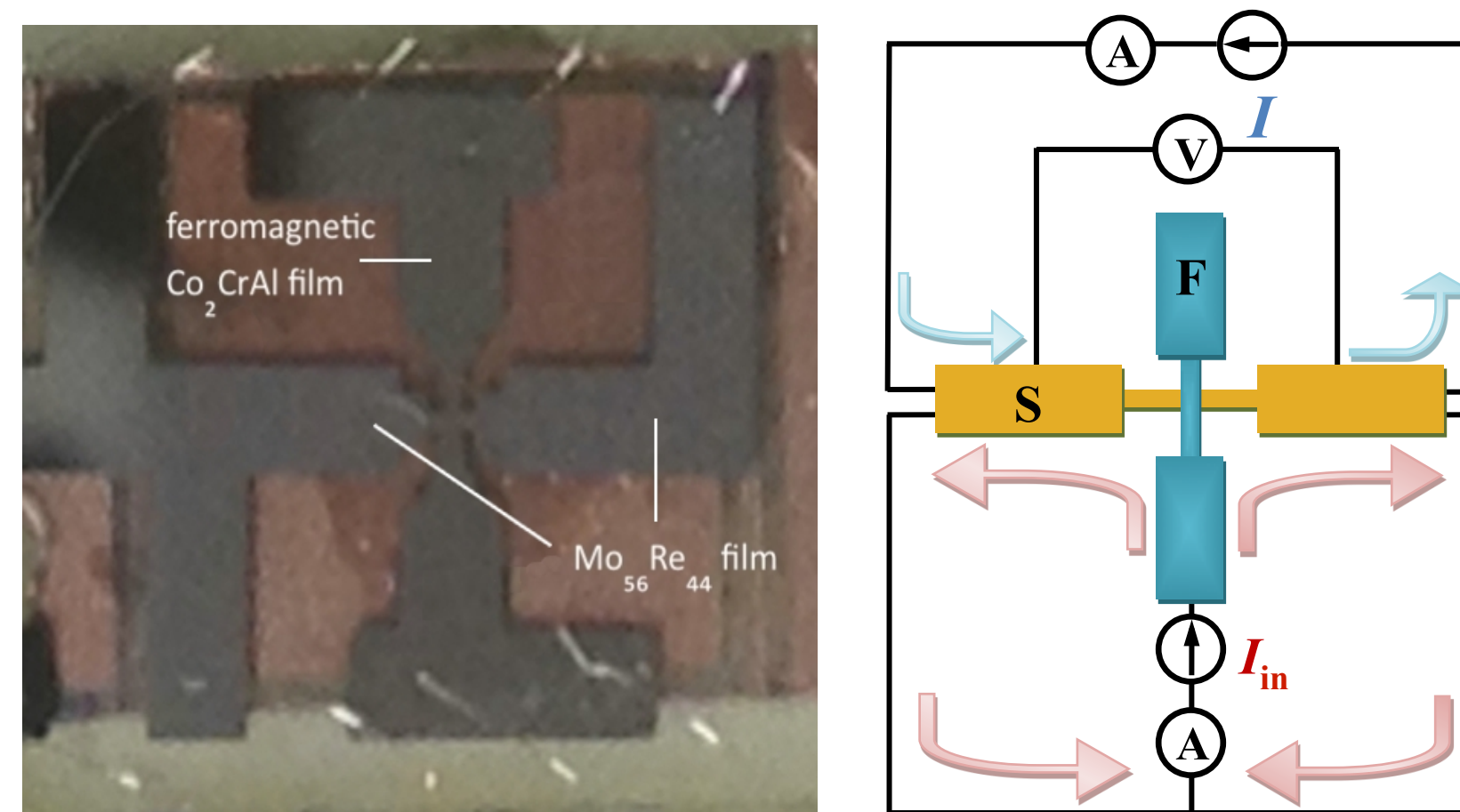
It has been found [1] that the phase-slippage effects in wide superconducting films can be efficiently triggered by a small amount of Gd magnetic impurities introduced into wide superconducting Nb films.

In this work we show that the same effect can be achieved by evaporating a half-metallic Co₂CrAl strip directly onto a superconducting Mo-Re film and by tuning the spin-polarized injection current.

We argue that this technique is simpler and does not require any specific engineering from the viewpoint of future phase-slip-based devices.

Samples

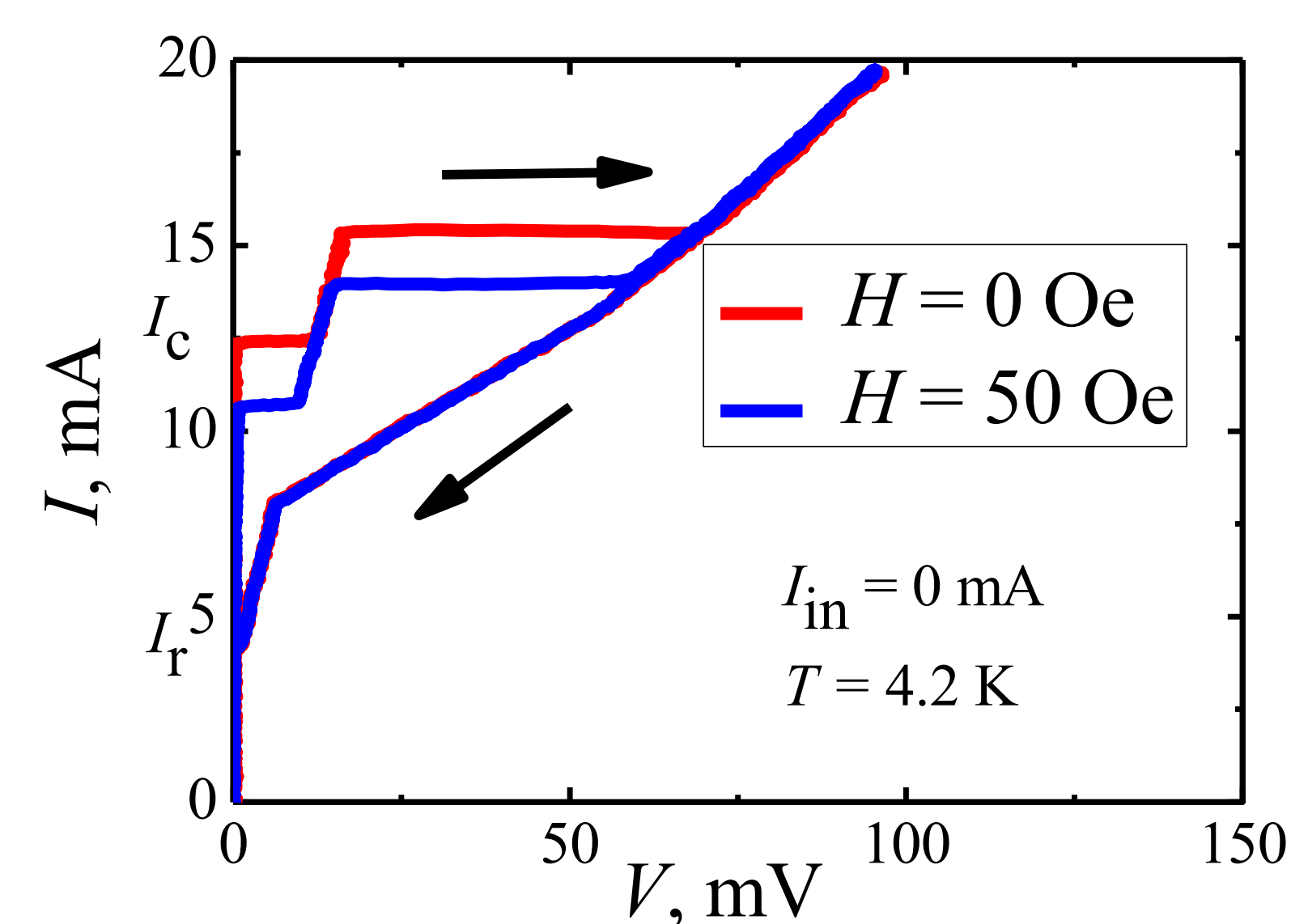
The superconductor-ferromagnet bilayers were fabricated employing a 100 nm-thick Mo-Re alloy film as a type-II superconducting electrode and a half-metallic Co₂CrAl layer known to have a metallic density of states in one of the spin sub-bands and a gap in the density of states in the other spin sub-band. The two films were in direct contact without any barrier between them.



Self-injection scenario

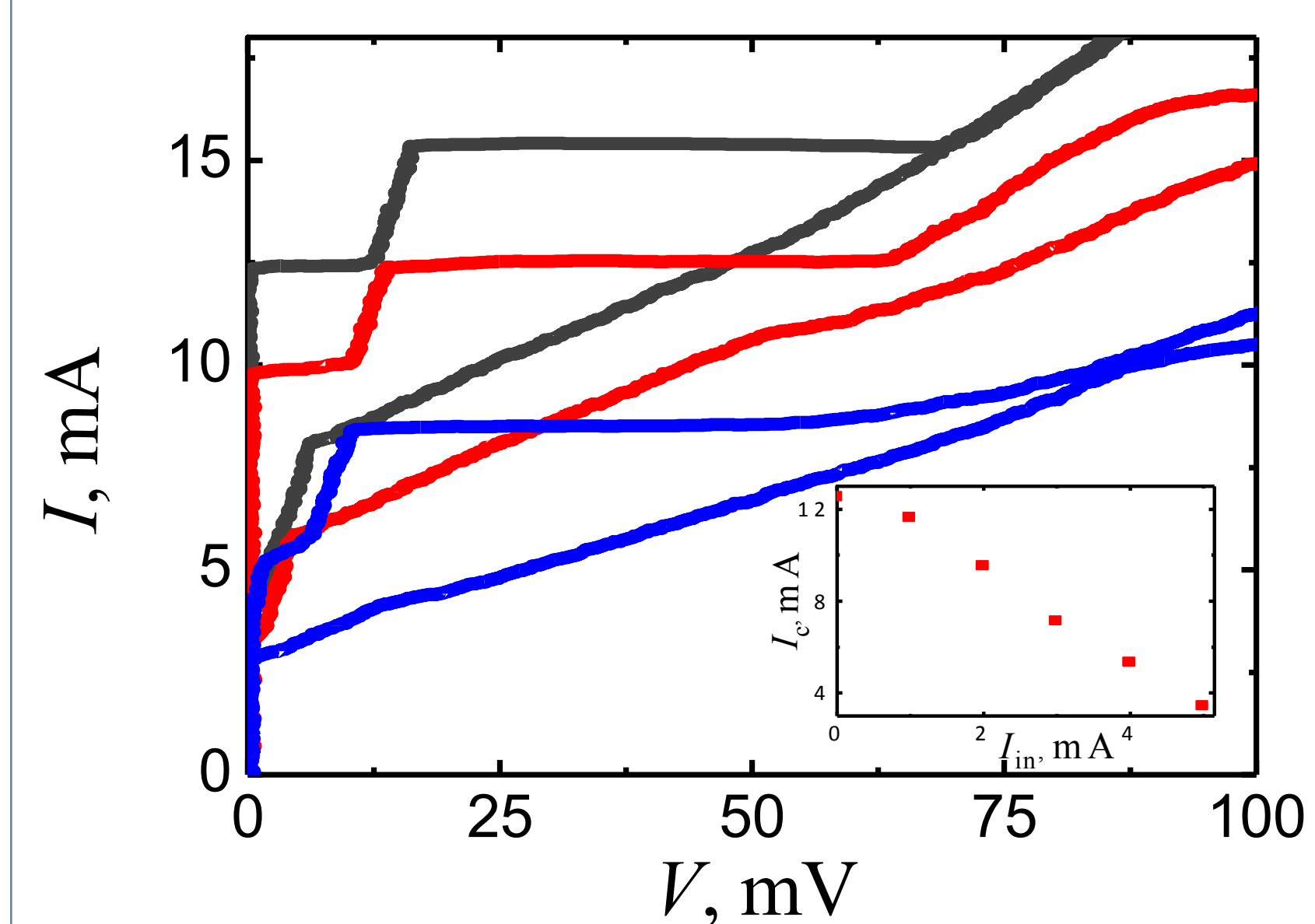
Isolated superconducting Mo-Re films exhibited trivial transitions from S to N state.

But in proximity to half-metallic strips, without any spin-polarized injection of quasiparticles, we have revealed steps-like features in current-voltage characteristics of Mo-Re films.



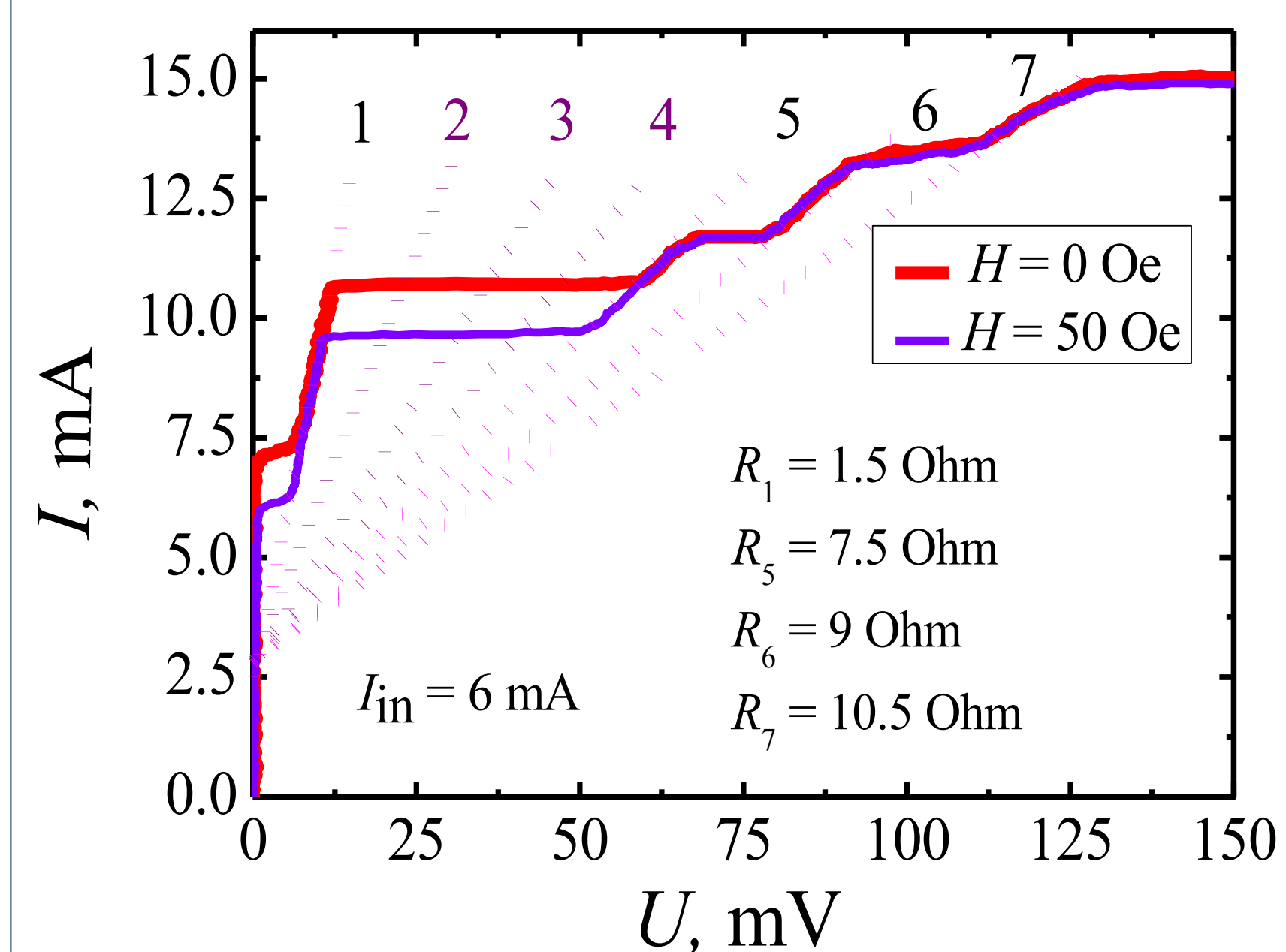
We attribute this effect to the local destruction of superconductivity, even when the injection current $I_{in} = 0$. In our opinion it can be explained with a "self-injection" scenario in contacts formed by F and S layers, as proposed in [2].

Spin-polarized injection



The injection current is $I_{in} = 0$ (black line); 4 mA (red line) and 8 mA (blue line). The inset shows dependence of the critical current I_c on I_{in} .

At all values of the injection current except $I_{in} = 6$ mA we have observed only one resistive state. But for $I_{in} = 6$ mA we have unexpectedly revealed four resistive metastable states.



We have observed a strong response to an external magnetic field $H = 50$ Oe smaller than the lower critical field for the MoRe alloy of about 300 Oe.

Conclusions

The spin-polarized quasiparticle injection current can serve as an effective tool to control critical parameters in the wide resistive region between pure superconducting (dissipation-free) and normal (completely ohmic) transport regimes.

Low magnetic fields, even lower than the lower critical field of the MoRe alloy, can have a significant impact on the S-to-N transition region. This is not due to its effect on the superconducting subsystem but rather to the magnetic ordering in the F film that induces a strong coupling between the transport characteristics of the proximized S film and the magnetic response of the F layer.

We believe that the bilayers formed by superconducting and half-metallic films are perspective candidates for the fabrication of phase-slip-based devices for future metrological applications [3].

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