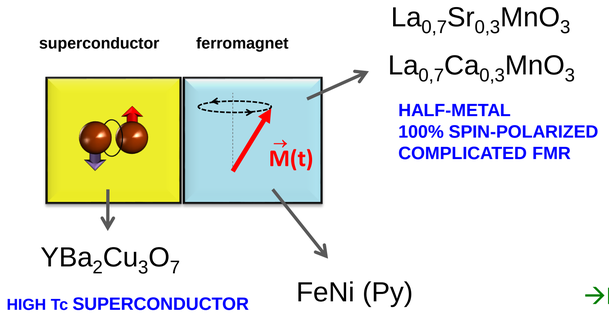
Probing superconductor/ferromagnet proximity effect by Ferromagnetic resonance

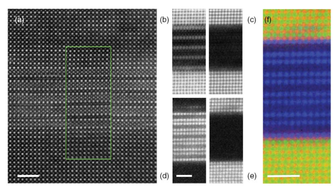
David Sánchez-Manzano[1], Myoung-Woo Yoo[2], Victor Rouco[2], Pierre Mergy[2], Hiroshi Naganuma[2,3], Jacobo Santamaría[1], Abdelmadjid Anane[2] and Javier E. Villegas[2]

[1] GFMC, Universidad Complutense de Madrid, Madrid, Spain
[2]Unite Mixte de Physique, CNRS, Thales, Univ. Paris-Sud, Universite Paris Saclay, France
[3]Department of Applied Physics, Tokyo University of Science, 1-3, Kagurazaka, Shinjuku-ku, Tokyo Japan

Ferromagnetism F and superconductivity S are antagonistic phenomena. At F/S interfaces proximity effect is suppressed due to the different density of states for majority and minority bands at the Fermi level. In the case of a half meta, proximity effect is completely suppressed. In spin active interfaces F/S proximity occurs through the formation of odd triplet Cooper pairs opening the door to spin polarized phase coherent quasiparticles. We study the superconductor/ferromagnet proximity effect by using ferromagnetic resonance (FMR) [1][2]. We have prepared S/F bilayers that combine the high-temperature superconductor YBa2Cu3O7 with Permalloy (NiFe) with and without a strong spin orbit spacer layer (Au) which has been predicted to promote the creation of triplet Cooper pairs. We analyze the temperature dependence (293K-3K) of magnetic damping of 2 samples, with and without gold in between when the sample is cooled down across the superconducting transition. In absence of the gold spacer, the suppressed proximity effect causes that the spin current generated by the ferromagnetic resonance cannot relax by diffusing into the superconductor. As a result, a reduced magnetic damping is observed as compared to the case of samples with the gold spacer, where proximity induced triplet Cooper pairs provide a mechanism for the spin current to relax by penetrating the superconductor. Results will be discussed in the frame of the spin-pumping theory considering the superconductor a spin sink where part of the FMR generated angular momentum relaxes. [3] As it turns out, magnetic damping and its temperature dependence below the superconducting transition is a delicate probe of the non conventional proximity effect at our F/S interfaces.

Motivation





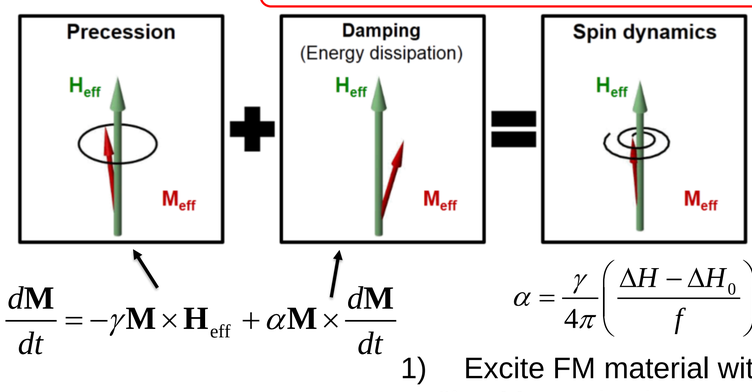
UNUSUAL S/F PROXIMITY EFFECT

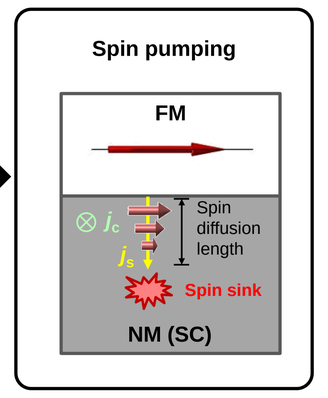
→MAGNETIZATION DYNAMICS COUPLED TO PROXIMITY EFECTS? [3] [4]
→SPIN RELAXATION IN NORMAL AND SC STATE

Previous experiments [1] have shown that proximity effect can affect the FMR signal of a ferromagnetic material in contact with low Tc supercoductors.

ΔH changes below Tc, but how does damping (α) change?

Magnetization dynamics





Spin pumping into SC

1) Excite FM material with MW
2) Magnetization precess
3) Injection of Spin current perpendicular to SC interface
4) Relaxation of the spin current

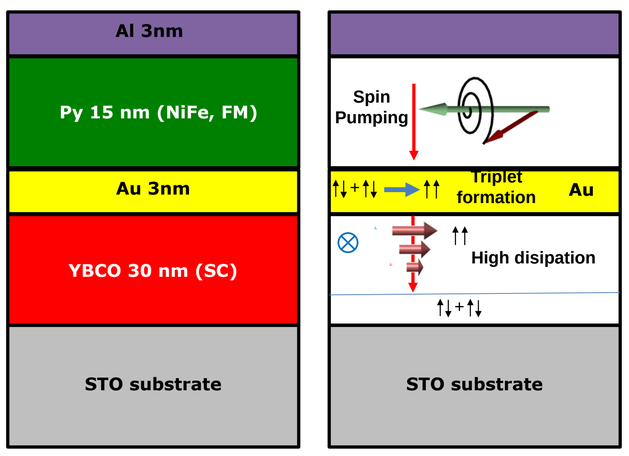
→FMR AS A PROBE FOR SPIN RELAXATION IN SC

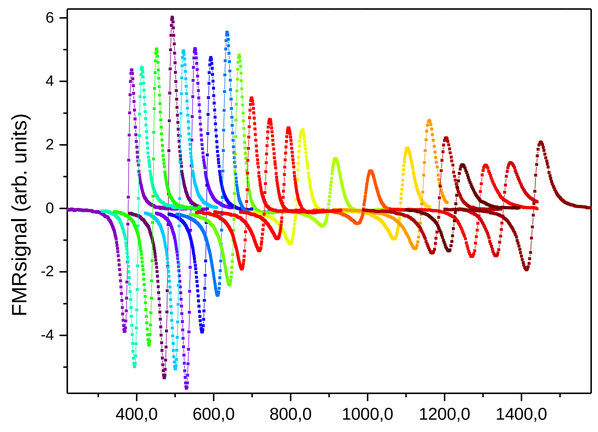
Device with gold spacer

Large signal-noise ratio

Al capping to prevent oxidation of Py

Au space layer to promote the formation of triplet states



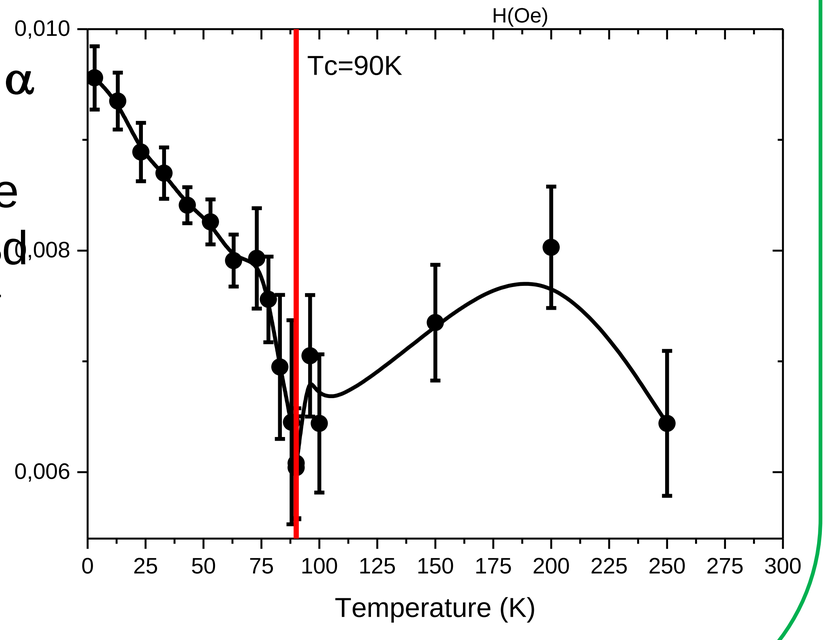


Above Tc α is bigger than in Py alone due to gold, were the spin current can relax

Just **below Tc α increases**→ Increase in the absorption (and dissipation) of the spin current

T<Tc

α ↑↑

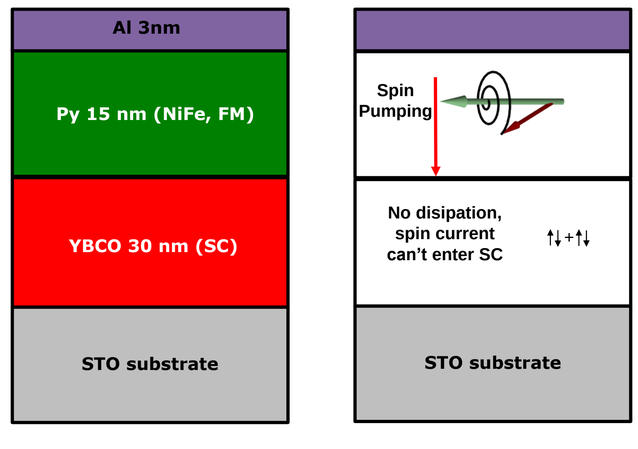


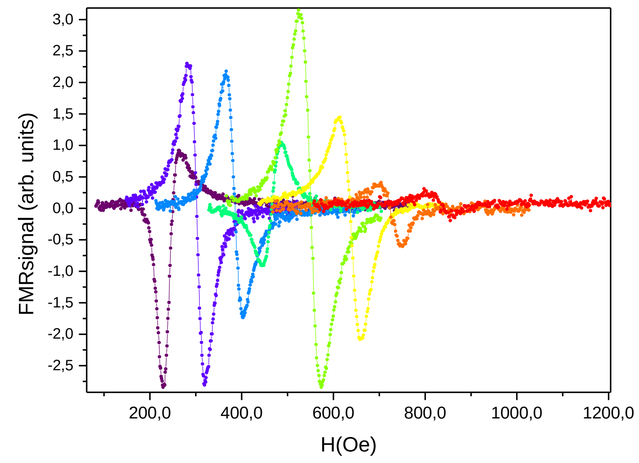
Device without gold spacer

Lower signal-noise ratio

Al capping to prevent oxidation of Py

Without Au space layer → No triplet states



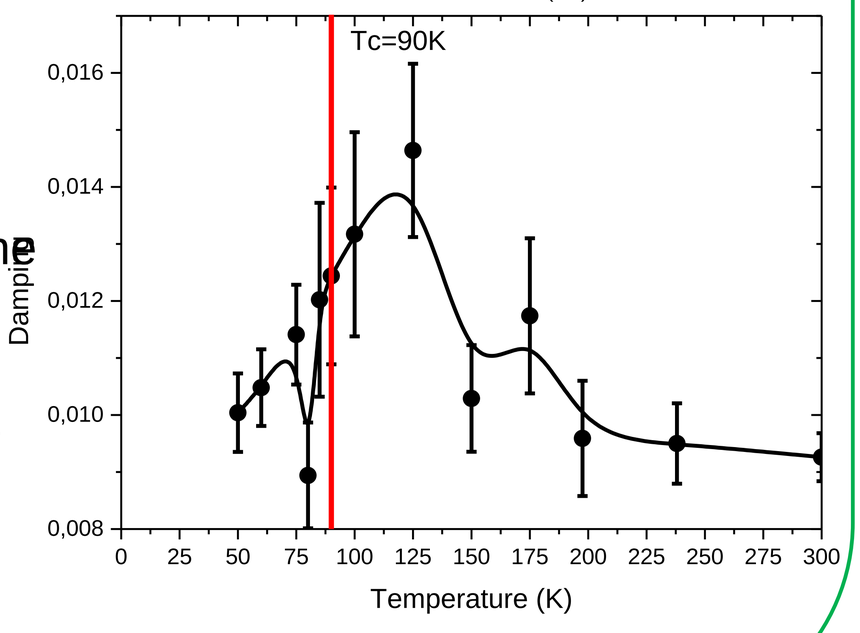


At room temperature α close to the value tabulated for Py

Below Tc α decreases, indicating a decrease in the absorption of the spin current

T<Tc

α ↓



CONCLUSIONS

In this work we have used FMR to probe F/S proximity interaction caused by the leakage of triplet Cooper pairs in the SC. We have demonstrated that the presence of a layer with strong spin orbit interaction between a SC and a FM promotes the formation of triplet Cooper pairs. This allows the injection of a spin current into the SC where it eventually relaxes, causing an increase of the damping. On the other hand, in absence of the spin orbit interlayer, the spin current cannot penetrate the SC, and, as a result, a decrease in the damping is observed.

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