

Coupled magnetic dynamics in ferromagnet–superconductor multilayers

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Hybrid ferromagnet–superconductor (FM–SC) systems attract considerable attention because they enable control of the magnetization dynamics of the ferromagnet through electromagnetic interaction with the superconductor [1]. The simplest realizations of such systems are SC/FM multilayer structures.

The dynamic properties of SC/FM/SC trilayers have been extensively studied, both experimentally [2] and theoretically [3], due to the discovered dramatic increase in the resonance frequency in such structures, which was recently reinterpreted and experimentally verified [4]. A further question was whether other interesting effects would appear when considering multilayers with an arbitrary number of layers. E.g. experimental investigation of a five-layer SC/FM/SC/FM/SC system has shown the appearance of two FMR modes, corresponding to in-phase and out-of-phase magnetization oscillations in two FM layers [5].

In this work, we present an analytical model describing ferromagnetic resonance in SC/FM/SC/FM/SC systems. The main idea behind the proposed model is similar to this proposed for SC/FM/SC trilayers [4]: an external magnetic field creates a torque that induces magnetization precession in each FM layer, leading to a periodic change of the magnetic flux in the system. According to Faraday’s law, this flux variation generates alternating electric currents in the superconductors, which in turn produce an alternating magnetic field in the FM films, thereby modifying the FMR frequencies. However, the dynamics of the SC/FM/SC/FM/SC system - particularly the coupling between the FM layers - can be counterintuitive. This coupling is governed by the net superconducting current carried by the central superconducting layer. In turn, that current depends not only on the ferromagnetic layers’ thicknesses and their separation, but also on structural asymmetry within the stack, such as unequal layer thicknesses.

References:

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