Hot-electrons transport as a driving force for sub-picosecond manipulation of magnetization

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Determining the ultimate speed for deterministic control of magnetization dynamics is a hot-topic in modern magnetism, mainly due to technological application in data manipulation [1]. In this context, ultrafast quenching of magnetization upon femtosecond laser excitation has driven intensive experimental and theoretical works [2] since its discovery in 1996 [3]. The mechanisms which govern the dissipation of angular momentum at the sub-picosecond time scale are still heavily debated. Among those mechanisms, the transport of laser-excited hot-electrons in magnetic multilayers has been highlighted as a possible channel for angular momentum transfer [4,5,6]. Recently, a new interest for the role of hot-electrons transport has emerged since sub-picosecond magnetization dynamics induced by hot-electrons was observed [7], demonstrating that direct interaction of photons and electrons of the magnetic material is not the only source of ultrafast dynamics. Nevertheless, these pioneer results are strongly contested [8] and further experimental works is needed in order to solve this controversy.

In this work, we studied ultrafast demagnetization dynamics in Glass/Ta/Pt/FM/Cu(x)/Pt(2) samples for x varying from 0 to 300 nm and with FM being either a Co/Pt or a Co/Ni multilayers. Both systems have a perpendicular magnetic anisotropy. The experiments were carried out by pumping our samples with a 800 nm laser femtosecond pulse from the front side and probing the induced change in magnetization from the back side (glass) with a 400 nm laser pulse (figure 1) by monitoring the transient MOKE signal. In order to control the excitation in our systems, we carefully determined the Cu layer absorption as a function of x and we extracted an attenuation length of 11 nm.

First, we observed for both Co/Pt and Co/Ni multilayers a clear modification of the magnetization dynamics (characteristic time and demagnetization amplitude) between direct optical excitation (x = 0 nm) and excitation by hot electrons (x > 20 nm), in contradiction with pioneers works by Eschenlohr and al [7] (figure 1). Second, we extracted the demagnetization time and rate as a function of Cu thickness, as well as the propagation time of hot-electrons in Cu (figure 1). Our results give valuable information on laser-induce hot electrons transport properties and give a new insight on their role to understand ultrafast magnetization dynamics [9,10].

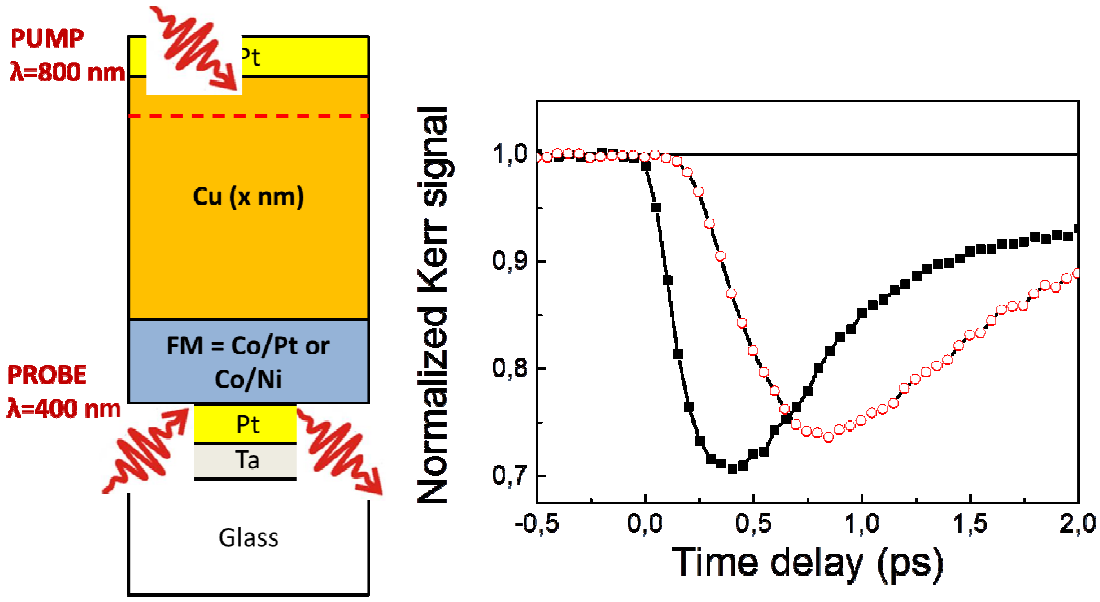

Figure 1: (left) Scheme of the samples investigated and experimental geometry for time resolved MOKE in the perpendicular geometry. The data acquisition is based on a pump-probe experiment. The pump pulse is absorbed by the thick Cu layer, generating out of equilibrium electrons distribution (so called hot-electrons) that propagate toward the buried ferromagnetic (FM) layer. The magnetization dynamics is probed by analyzing the polarization of the probe pulse reflected by the FM layer through the glass substrate as a function of time delay between the pump and the probe pulses. A permanent magnetic field saturates the magnetization in the out of plane direction. (right) Transient MOKE signal as a function of time for Co/Pt multilayer after the sample is excited by a femtosecond laser at t= 0 ps.

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