Ultrafast transport of laser-induced spin polarized carriers in Au/Fe/MgO(001)

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The ultrafast magnetization dynamics induced by a transport of spin polarized carriers is a hot topic due to the fundamental interest in spin excitations, their coupling to electron and lattice sub-systems and applications in spintronics and data storage. To understand the underlying elementary processes, we have developed a time domain approach to probe the hot electron-induced spin dynamics. Here we report on experiments in epitaxial Au/Fe/MgO(001) structures, where the Au layer thickness is much larger than the optical penetration depth and comparable to the electron mean free path. Hot carriers are excited in the magnetized Fe layer by 800 nm 35 fs 30 nJ pump pulses of Ti:sapphire oscillator focused from the side of MgO substrate. Owing to the exchange-split Fe band structure, minority and majority carriers are excited at different energies and concentrations. These *hot*, or *non-equilibrium*, spin-polarized carriers propagate across the Fe/Au *interface* towards the Au *surface* forming a spin-polarized current with the charge component screened by a displacement of *equilibrium* carriers in Au. The transient spin polarization (SP) of the Au *surface* is detected by *(surface sensitive!)* magneto-induced second harmonic generation from the probe pulse focused from the side of Au layer of thickness d_{Au}. After a 40 fs pump-probe delay similar to d_{Au}=50 nm divided by the Fermi velocity, a detectable magneto-optical signal builds up, changes its sign at a 300 fs time scale and then vanishes at a 1 ps time scale. Increasing d_{Au} increases the delay of this build-up and stretches the time profile. According to *ab initio* band structure calculations, the observed non-monotonicity can be attributed to different life times of hot carriers with different SP. If the negative SP is transported predominantly in the ballistic regime, the transport of positive SP is essentially diffusive and thus has a considerably smaller velocity. Under certain experimental conditions it can be suppressed almost completely, which results in a single-polarity 50-100 fs pulse of spin current corresponding to spin polarized carrier transport on the order of 10^{10} A/cm^2. The polarity is defined by the magnetization of Fe layer and thus can be easily varied in experiments on the spin transfer torque-induced magnetization dynamics.