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Quantitative detection of ultrashort spin current pulses in spin valve heterostructures

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The emergence of spin currents after ultrafast laser excitation of a magnetic thin film was predicted in the theory of superdiffusive spin currents, which was originally developed to describe the process of ultrafast demagnetization [1]. Experimentally, spin current pulses have been detected by magneto-optical measurements using fs-pulsed VUV radiation [2,3], or through the emission of THz bursts [4]. These techniques, however, do not yield quantitative results on the amount of transported spins, or probe the spins in a rather indirect way, whereas x-ray magnetic circular dichroism (XMCD) directly measures the concentration of injected spins.

Here we show our recent fs time-resolved XMCD measurements that were performed at the LCLS SXR instrument using circularly polarized soft x-rays [5]. For a direct comparison with [2], we investigated the same kind of Ni/Ru/Fe multilayers. In these samples, the upper film (Ni) is excited by a fs laser pulse and loses its magnetization, and the spins are assumed to move deeper into the multilayer by superdiffusion [1]. As a result, the lower film (Fe) may gain magnetic moment by absorbing the spin current, thereby enhancing its own magnetization as was found in [2,3]. In our time- and element-resolved XMCD measurements we find however that the amount of spins transported into the lower Fe layer is almost negligible, which suggests that here the effectiveness of spin transport is strongly limited, contrary to previous results that were obtained using other techniques [2,3].

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