Towards THz spintronics: generation and transport of subpicosecond spin current pulses

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Abstract— The origin of the ultrafast demagnetisation has been a mystery for a long time. Recently we have proposed an approach based on spin dependent electron superdiffusion.[1-3] A number of experimental works have confirmed the importance and the amplitude of the superdiffusive spin transport for ultrafast magnetisation dynamics.[4-7] In particular the spin superdiffusion model predicted the transfer of magnetisation in the non-magnetic substrate and the possibility of increasing the magnetisation: both phenomena were experimentally confirmed.[4-5]

The discovery of the possibility of not only manipulating the magnetisation in the sub-picosecond regime, but of transporting it is a critical step forwards, since it proves the possibility of constructing all the components of ultrafast spintronics: a huge improvement compared to merely ultrafast storage, the only electronics application that an ultrafast, but purely local, manipulation of magnetisation could have achieved.

However, in order to achieve this goal, all the basic electronics elements, like diodes and transistors, have to be redeveloped. The very same wiring needs to be redesigned. The ultrashort spin currents propagate poorly in metals, due to the high number of scatterings. Semiconductors are much better candidates. However the ultrashort spin pulses have to be injected in them from the ferromagnetic metal where they are generated.

We predict the possibility of injecting ultrashort (sub-picosecond) spin current pulses from a ferromagnetic metallic layer undergoing ultrafast demagnetisation into a semiconducting substrate. [8-9] After laser excitation, energetic carriers can overcome the semiconductor bandgap. We address the complex interplay of spin diffusion, the formation of high electric fields at the metal/semiconductor interface, and the concomitant thermalisation of the laser excited carriers by state-of-the-art numerical techniques. We show that spin currents pulses hundreds of femtoseconds long are injected in the semiconductor and present a record spin polarisation.

Such current pulses have the possibility to become the carriers of information in future spintronics running at unprecedented frequencies above the THz regime.

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