# Ultra-fast all optical switching in spintronic devices

J. Gorchon[1], T. Hauet[1], M. Hehn[1], J. Hohlfeld[1], G. Malinowski[1] and **S. Mangin**[1]
[1] Université de Lorraine, CNRS, Institut Jean Lamour, F-54000 Nancy, France
Stephane.mangin@univ-lorraine.fr

In 1996, Bigot et al. made a significant discovery that established the new field of ultra-fast magnetism. They demonstrated that excitation with a femtosecond laser pulse could induce sub-picosecond demagnetization of a thin Ni film [1]. However, it was not until ten years later that Theo Rasing's group in Nijmegen demonstrated complete deterministic all-optical switching (AOS) using circularly polarized laser pulses on a GdFeCo ferrimagnetic alloy [2]. This phenomenon was subsequently termed all-optical helicity-dependent switching (AO-HDS) [3], observable in a wide range of samples [4,5]. A major drawback of AO-HDS in most magnetic films is its requirement for a large number of pulses, rendering the process relatively slow [6]. Conversely, single-pulse all-optical helicity-independent switching (AO-HIS) emerges as a more promising approach for practical applications, owing to its need for just one laser pulse and significantly quicker response [7]. However, in the case of metallic samples, AO-HIS appears to be restricted to Gd-based materials (alloys and multilayers) [8-11] and MnRuGa [12]. Recently, another type of single-pulse all-optical switching has been observed, attributed to magnetization precession during anisotropy reorientation [13,14]. Despite its novelty, this all-optical precessional switching process is comparatively slow, occurring over several hundred picoseconds.
During the seminar we will examine magnetization reversal resulting from the direct interaction between the ultra-short laser pulse and the magnetization. Additionally, we will discuss how light can produce heat pulses or spin-polarized femtosecond current pulses which can then be exploited to reverse the magnetization of thin ferromagnetic films and magnetic heterostructures [15,16,17].
Part of the ultra-fast magnetism community is now focusing on deterministic magnetization switching induced by single femtosecond or picosecond laser pulses in spintronic devices, such as spin valves [18-24] and tunnel junctions [25,26]. During the talk we will show recent results on ultra-fast magnetization reversal (starting within less than one picosecond) in various ferrimagnetic and ferromagnetic spin-valve structures as shown in figure 1, both perpendicularly magnetized [18-23] and in-plane magnetized [24]. Concerning perpendicularly magnetized systems, we have recently demonstrated optically induced ultrafast magnetization reversal occurring in less than a picosecond in rare-earth-free archetypal spin valves ([Pt/Co]/Cu/[Co/Pt]) commonly utilized for current-induced spin-transfer torque (STT) switching [23]. We discovered that the magnetization of the free layer can be switched from parallel to antiparallel alignment, akin to STT switching, revealing the presence of an unexpected, intense, and ultrafast source of opposite angular momentum in our structures.
Additionnaly, we will also show results on ultrafast optical control of exchanged biased structures. Indeed, we have shown that for an exchanged biased IrMn/GdCo bilayer, not only can a single laser pulse switch the ferrimagnetic GdCo layer, but it can also change the sign of the exchange bias, demonstrating that the magnetic configuration in the antiferromagnetic IrMn layer is affected by the laser pulse [27]. These findings pave the way for ultrafast magnetization control by combining concepts from spintronics and ultrafast magnetism.

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## Figures

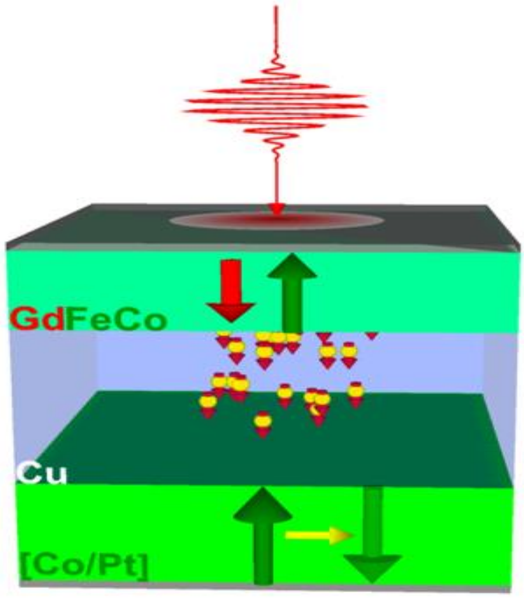


**Figure 1.** Sketch of a spin-valve structure used to demonstrate femto-second single pulse switching of each magnetic layer independently. The generation of femto-second spin current is shown to play a major role [17-23]