# Coherent control of THz-scale spin resonances using optical spin—orbit torques

**Julian Hintermayr**[1], Paul M. P. van Kuppevelt[1], Bert Koopmans[1]
[1]Eindhoven University of Technology, Department of Applied Physics, P.O. Box 513, 5600 MB Eindhoven, Netherlands

j.hintermayr@tue.nl

The ultrafast manipulation of spins on the nanoscale poses one of the core challenges in spintronics [1]. Recent breakthroughs have revealed the potential of optically generating spin currents in non-magnetic heavy metals, which can be injected into neighbouring ferromagnetic layers, exerting a spin–transfer torque [2, 3]. This novel phenomenon was termed optical spin-orbit torque (OSOT), as it exploits spin-orbit interactions. Notably, the spin current's polarization can be reversed by changing the circular polarization of the laser pulse. This offers a more versatile approach for exciting spin dynamics compared to alternatives like ultrafast demagnetization of a neighboring layer, where the spin current's polarization is predetermined by the magnetization direction of said layer [4, 5].

This study explores coherent control of spin resonance modes using multiple pump beams with adjustable delays and polarization states (see Fig. 1 **a**). Employing time-resolved magneto-optical studies, we demonstrate that ferromagnetic resonance modes in Pt/Co/Pt can be triggered by the first pump pulse, with the second pulse amplifying or suppressing the mode based on its delay and polarization, as shown in Fig. 1 **b**. Extending this concept, we find that ferrimagnetic exchange resonances in Co/Gd-based systems—offering much higher frequencies (~THz) and obviating the need for external fields—can likewise be manipulated through this method. Furthermore, investigating phase and amplitude of the exchange-driven modes, we identify features that challenge the current understanding of optically generated spin–orbit torques, and we discuss possible explanations. These insights hold great promise for the advancement of ultrafast spintronic computation devices.

## References

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## Figures

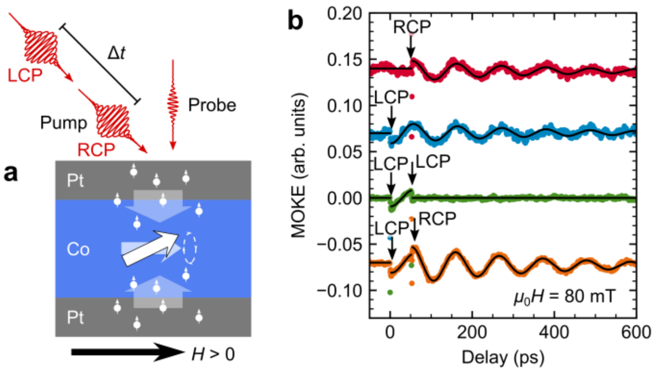


**Figure 1. a** Schematic representation of the double pump excitation scheme and spin excitation in Pt to drive FMR dynamics in the FM layer. **b** TR-MOKE measurements of OSOT-driven FMR dynamics and demonstration of coherent control.