Epsilon-near-zero-driven enhancement of terahertz Faraday rotation using iron slot antennas

Hoyeol Lee†, Hyoung-Taek Lee†, Jeonghoon Kim, Miju Park, Changhee Sohn and Hyeong-Ryeol Park*

Department of physics, Ulsan National Institute of Science and Technology (UNIST), Ulsan 44919, Republic of Korea

† These authors contributed equally to this work.

**Corresponding author: Hyeong-Ryeol Park, nano@unist.ac.kr*

We report a substantial enhancement of terahertz magneto-optical (MO) effects in ferromagn etic metasurfaces using subwavelength iron slot antennas [1,2]. By systematically varying the slot width from 20 μm to 300 nm, we observed that the Faraday rotation angle increases s ignificantly as the slot narrows, reaching a maximum at a width of 1 μm [3,4]. This behavi or is attributed to the epsilon-near-zero (ENZ) condition in the effective dielectric function, which enhances light–matter interaction within the slot [5]. Interestingly, further reduction bel ow 1 μm leads to a suppression of the MO response, likely due to increased effective per mittivity and plasmonic damping. The results provide practical design principles for THz m agneto-plasmonic devices, especially for nonreciprocal photonic applications. In addition, we aim to investigate how the thickness of the deposited iron film affects the Faraday rotation, as thinner films may lead to enhanced absorption and influence the MO response in ultrathin regimes.

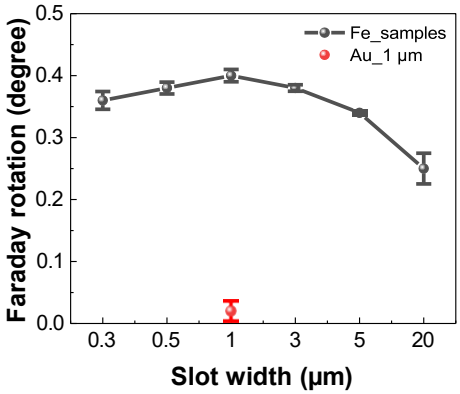

Figure 1. Measured Faraday rotation angles for Fe slot antennas as a function of slot width. The rotation is maximized at 1 μm due to ENZ-induced field enhancement.

References

1. G. A. Wurtz, *et al.*, "Controlling optical transmission through magneto-plasmonic crystals with an external magnetic field," *New J. Phys.*, vol. 10, no. 10, 2008.
2. B. Sepúlveda, *et al.*, "Plasmon-induced magneto-optical activity in nanosized gold disks," *Phys. Rev. Lett.*, vol. 104, no. 14, 2010.
3. J. Y. Chin, *et al.*, "Nonreciprocal plasmonics enables giant enhancement of thin-film Faraday rotation," *Nat. Commun.*, vol. 4, no. 1, 2013.
4. D. Floess, *et al.*, "Plasmonic analog of electromagnetically induced absorption leads to giant thin film Faraday rotation of 14°," *Phys. Rev. X*, vol. 7, no. 2, 2017.
5. K. Ikeda, *et al.*, "Enhanced magneto-optical effects in epsilon-near-zero indium tin oxide at telecommunication wavelengths," *Adv. Opt. Mater.*, vol. 12, no. 2, 2024.