Spin-locking in chiral plasmonic modes.

Y. Gorodetski*

Mechanical Engineering and Mechatronics and Electrical Engineering and Electronics Department,

Ariel University, 40700, Ariel, Israel

**corresponding author: yurig@ariel.ac.il*

Abstract - We experimentally demonstrate an effect of the plasmonic spin-locking leading to anomalous polarization dependent behavior. This phenomenon is attributed to the coupling of the intrinsic transverse plasmonic spin with the light's chirality due to the specific nanostructure geometry.

It has been shown[1], that a plasmonic wave propagating in *x* direction on a metal-air interface carries a transverse spin angular momentum (TSAM) given by $\boldsymbol{s}_\perp = \frac{Re\mathbf{k}\times Im\mathbf{k}}{(Re\mathbf{k})^2}$, where $\mathbf{k} = k_{SP}\hat{\mathbf{x}} + i\kappa\hat{\mathbf{z}}$ is the complex valued evanescent wave vector, $\kappa = \sqrt{k_{SP}^2 - k_0^2}$ and k_{SP} and k_0 are the plasmonic and the free space wavenumbers respectively. The transverse spin results from the circulation of the resultant of the vectorial plasmonic field, $\mathbf{E}_{SP} = E_p(\hat{\mathbf{z}} + i\chi\hat{\mathbf{x}})$ in a transverse plane with respect to the propagation direction. Remarkably, the TSAM is independent of the polarization and solely arises from the amplitude ratio between the longitudinal and the transverse field components which is directly obtained from Maxwell's equations, $s_\perp = \chi = \frac{\kappa}{k_{SP}}$. Accordingly, $s_\perp$ is locked to the SPs propagation direction and can appear with a single handedness. This additional degree of freedom has been already utilized for the spin-dependent unidirectional plasmonic excitation, for nanoparticle tweezing, etc[2-4]. In contrast with the previously demonstrated plasmonic (longitudinal) spin-orbit interaction[5-8], where the SP behavior depends on the incident circular polarization of light, we are interested in utilizing the transverse spin. Specifically, we use nanofabricated 3D structures in order to transfer the intrinsic transverse spin of plasmon to a measurable property of the propagating light – its polarization.

First we use an adiabatically sharpening plasmonic nanotip to generate a far-field emission with a perfect circular polarization. This is done by first generating a singular plasmonic field on a flat metallic surface using a spiral structure. The incident circularly polarized beam excites a spin-dependent helical SP wavefront which is guided on a curved surface of the tapered metallic nanotip placed at the structure center. The mode propagating toward the apex accelerates and the azimuthal field component grows which leads to the increase of the $s_\perp$. Finally, the light beams out from the tip at almost pure circular state of a desired handedness. In an additional experiment we demonstrate the anomalous polarization emerging from a subwavelength holes. Also in this case the spiral SP wavefront leads to a non-zero projection of the incident light's chirality to the plasmonic TSAM. Finally we demonstrate a metasurface based on the transverse spin-locking effect. We design a periodic structure in which the incident spin efficiently couples to a plasmonic TSAM and creates a unidirectional SP launching.

This spin-locking effect may play a key role in plasmonic interactions and eventually can provide an important physical basis for novel type of spin-based nanophotonics.

REFERENCES

1. K. Y. Bliokh, F. Nori, Phys. Rep. **592**, 1 (2015).
2. A. Aiello, P. Banzer, M. Neugebauer, and G. Leuchs, Nature Photon. **9**, 789 (2015).
3. A. Canaguier-Durand and C. Genet, Phys. Rev. A **89**, 033841
4. D. O'Connor, P. Ginzburg, F.J. Rodríguez-Fortuño, G. A. Wurtz, and A. V. Zayats, Nature Comm. **5**, 5327 (2014).
5. N. M. Litchinitser, Science, **337**, 1054 (2012).
6. N. Shitrit, I. Yulevich, E. Maguid, D. Ozeri, D. Veksler, V.Kleiner, and E. Hasman, Science **340**, 724 (2013).
7. Y. Gorodetski, A. Niv, V. Kleiner, and E. Hasman, Phys. Rev. Lett. **101**, 043903 (2008).
8. N. Shitrit, I. Yulevich, V. Kleiner, and E. Hasman, Appl. Phys. Lett. **103**, 211114 (2013).
9. D. Garoli, P. Zilio, Y. Gorodetski, F. Tantussi, and F. De Angelis, Nano Lett. **16**, 6636 (2016).
10. D. Garoli, P. Zilio, F. De Angelis, Y. Gorodetski, Nanoscale, **9**, 6965 (2017).
11. M. Revah, S. Nechayev, Y. Gorodetski, Opt. Lett. **43**, 4374 (2018).