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Chiral Molecule Detection via Optical Rectification in Spin-Momentum Locking

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Abstract : Chirality is omnipresent, in nature, in life, and in the field of physics. One intriguing example is the homochirality that has remained a great secret of life. Another is the pairs of mirror-image molecules – enantiomers. They are identical in atomic composition and therefore indistinguishable in the scalar physical properties. Yet, they can be either therapeutic or toxic, depending on their chirality. Recent studies suggest a potential link between abnormal levels of certain D-amino acids and some serious health impairments, including schizophrenia, amyotrophic lateral sclerosis, and potentially cancer. Although indistinguishable in their scalar properties, the chirality of a molecule reveals itself in interaction with the surrounding of a certain chirality, or more generally, a broken mirror-symmetry. In this work, we report on a system for chiral molecule detection, in which the mirror-symmetry is doubly broken, first by asymmetric structuring a nanopatterned plasmonic surface than by the incidence of circularly polarized light (CPL). In this system, the incident circularly-polarized light induces a surface plasmon polariton (SPP) wave, propagating along the asymmetric plasmonic surface. This SPP field itself is chiral, evanescently bound to a near-field zone on the surface (~10nm thick), but with an amplitude greatly intensified (by up to 104) over that of the incident light. It hence probes just the molecules on the surface instead of those in the volume. In coupling to molecules along its path on the surface, the chiral SPP wave favors one chirality over the other, allowing for chirality detection via the change in an optical rectification current measured at the edges of the sample. The asymmetrically structured surface converts the high-frequency electron plasmonic-oscillations in the SPP wave into a net DC drift current that can be measured at the edge of the sample via the mechanism of optical rectification. The measured results validate these design concepts and principles. The observed optical rectification current exhibits a clear differentiation between a pair of enantiomers. Experiments were performed by focusing a 1064nm CW laser light at the sample - a gold grating microchip submerged in an approximately 1.82M solution of either L-arabinose or D-arabinose and water. A measurement of the current output was then recorded under both rights and left circularly polarized lights. Measurements were recorded at various angles of incidence to optimize the coupling between the spin-momentums of the incident light and that of the SPP, that is, spin-momentum locking. In order to suppress the background, the values of the photocurrent for the right CPL are subtracted from those for the left CPL. Comparison between the two arabinose enantiomers reveals a preferential signal response of one enantiomer to left CPL and the other enantiomer to right CPL. In sum, this work reports on the first experimental evidence of the feasibility of chiral molecule detection via optical rectification in a metal meta-grating. This nanoscale interfaced electrical detection technology is advantageous over other detection methods due to its size, cost, ease of use, and integration ability with read-out electronic circuits for data processing and interpretation.

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