THz Twistoptics – Engineering Canalized Phonon Polaritons

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The terahertz (THz) frequency range is key to studying collective excitations in many crystals and organic molecules. Nonetheless, due to the large wavelength of THz radiation, the local probing of these excitations in tiny (crystalline) structures or arrangements of a few molecule only, requires sophisticated methods in order to confine THz light down to the nanometer length scale, as well as to manipulate such a confined radiation [1]. For this purpose, taking advantage of hyperbolic phonon polaritons (HPhPs) in highly anisotropic (stacked) van der Waals (vdW) materials [2,3] and topological insulators [3] has emerged as such a promising approach, offering a multitude of opportunities, such as the control on the wavefront shape and propagation direction.

Here, we demonstrate the THz application of twist-angle-induced HPhP manipulation [4], designing the propagation of confined THz radiation between 8.39 and 8.98 THz in the vdW material α-molybdenum trioxide (α-MoO_3) [5], hence extending twistoptics into the THz gap. Our images, recorded by near-field optical microscopy using the free-electron-laser FELBE, show the frequency- and twist-angle-dependent changes between hyperbolic and elliptic polariton propagation, revealing a polaritonic, topological transition at THz frequencies. As a result, we are able to allocate canalization (highly collimated propagation) of confined THz radiation by carefully adjusting these two parameters, i.e. the THz frequency and the twist angle. Specifically, we report polariton canalization in α-MoO_3 at 8.67 THz for a twist angle of 50°. Our results demonstrate the precise control and manipulation of confined collective excitations at THz frequencies, particularly offering possibilities for nanophotonic applications as are nanoimaging, (bio)-sensing, or polaritonic thermal management. Moreover, we also show that generating twisted asymmetric stacks of biaxial vdW materials, as shown for α-MoO_3 on β-Ga_2O_3 induces ray polaritons that propagate unidirectionally [7].

References:

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