Light-induced Shift Current Vortex Crystals in Moiré Heterobilayers

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Employing light to drive different phenomena or to induce and tune exotic phases of matter is one of the central themes of modern condensed matter science and optoelectronic technologies. Two-dimensional transition metal dichalcogenide (TMD) moiré superlattices provide an emerging platform to explore various light-induced phenomena. Recently, the discoveries of novel moiré excitons have attracted great interest. The nonlinear optical responses of these semiconducting systems are however still underexplored. Here, we report investigation of light-induced shift currents (a second-order response generating DC current from optical illumination) in the WSe_2/WS_2 bilayer moiré superlattice [1], based on a newly-developed *ab intio* time-dependent interacting Green's function approach [2]. We discover a striking phenomenon of the formation of shift current vortex crystals—i.e., two-dimensional periodic arrays of moiré-scale current vortices and associated magnetic fields with remarkable intensity under laboratory laser setup. Furthermore, we demonstrate high optical tunability of these current vortices—their location, shape, chirality, and magnitude can be tuned by the frequency, polarization, and intensity of the incident light. Electron-hole interactions (excitonic effects) are found to play a crucial role in the generation and nature of the shift current intensity and distribution. Our findings provide a promising all-optical control route to manipulate nanoscale shift current density distributions and magnetic field patterns, as well as shed light on nonlinear optical responses in moiré quantum matter and their possible applications in optoelectronics and photovoltaics.

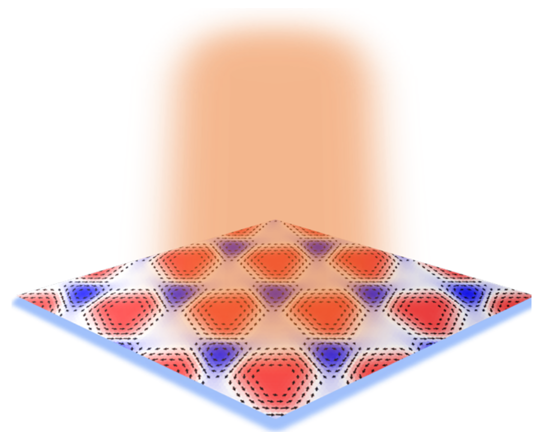

Fig.1 Photoexcited shift current vortex crystal. Arrows indicate the photoinduced DC current density, and colors denote the magnetic field intensity (red for positive and blue for negative) along the direction normal to the atomic planes of the WSe_2/WS_2 bilayer moiré superlattice.

References

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[2] Y.-H. Chan, D. Y. Qiu, F. H. da Jornada, and S. G. Louie, Proc. Natl. Acad. Sci. **118**, e1906938118 (2021).