Lightwave Control of Topological Properties in 2D Materials

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Modern light generation technology offers extraordinary capabilities for sculpting light pulses, with full control over individual electric field oscillations within each laser cycle [1]. These capabilities are at the core of lightwave electronics – the dream of ultrafast lightwave control over electron dynamics in solids, on a few-cycle to sub-cycle timescale, aiming at information processing at tera-Hertz to peta-Hertz rates. At the same time, quantum materials encompass fascinating properties such as the possibility to harness extra electronic degrees of freedom, e.g., the valley pseudospin [2]. Previous works have established optical initialization of the valley pseudospin via resonant circular pulses [3-5], taking advantage of the optical valley selection rules. Still, manipulating and reading the valley degree of freedom on timescales shorter than valley depolarization and in a non-material-specific (non-resonant) way remains a crucial challenge.

Bringing the frequency-domain concept of topological Floquet systems to the few-femtosecond time domain, we will present an all-optical, non-resonant approach to control the injection of carriers into the valleys on a few-femtosecond timescale by controlling the sub-cycle structure of non-resonant driving fields, and read the valley pseudospin in graphene-like monolayers by using the imprint of the Berry curvature on the high harmonic generation spectrum [6]. Such valley control does not rely on the optical valley selection rule. Instead, the tailored field modifies the laser-driven band structure on a sub-cycle timescale, allowing ultrafast optical control of the topological properties of 2D graphene-like quantum materials [7].

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