Chiral light-matter interaction in the multiphoton regime

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Chiral molecules are ubiquitous in nature — from the building blocks of life such as sugars and amino acids to unidirectional molecular motors. Since left- and right-handed versions of a chiral molecule share the same energy spectrum, their interaction with light differs in subtle ways. Traditional wisdom attributes these differences to magnetic-dipole interactions, typically manifesting as weak optical activity with left/right differences below 0.1%. However, thanks to femtosecond laser technology, the last decade has seen the emergence of a variety of multiphoton chiral effects exclusively governed by electric-dipole interactions, yielding strong left-right differences exceeding 10% [1,2]. These phenomena not only challenge conventional paradigms but also open up powerful routes for imaging, controlling, and exploiting chirality in molecular systems. In this colloquium, I will give an overview of how multiphoton processes can be harnessed to encode molecular chirality in observables such as photoelectron vortices [3], photoelectron angular distributions [4,5], photoinduced orientation [6,7], high-harmonic spectra [8,9], and photochemical reaction pathways [10]. These advances reveal a rich and rapidly evolving landscape at the intersection of ultrafast dynamics, strong-field physics, and stereochemistry, with direct applications in chemistry and nanotechnology.

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