Structuring ultrafast laser light through highly nonlinear physics

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The degree of control we have achieved over the manipulation of light is truly amazing. Initiated by our Greek ancestors using mirrors to guide light, we live in a world where the most advanced laser technology allows us to create and sculpt light beams with great precision. In particular, nowadays we can create ultrashort attosecond pulses (with durations of trillionths of a second), of very high frequencies (up to the soft X-rays), and with increasingly complex spatial structures thanks to our ability to harness their angular momentum.

In this talk we will review our recent work in the generation of structured ultrashort laser pulses. Thanks to the highly nonlinear process of high harmonic generation, we can tailor the spin and orbital angular momentum properties of extreme ultraviolet/soft x-ray laser pulses directly at their generation. By properly controlling the process of high harmonic generation, from the driving laser beam to the target (gas or solid), different families of structured ultrashort laser beams can be created: self-torqued beams, vector-vortex beams, tunable high-frequency combs, or hexagonal harmonic beams.

These new optical tools allow us to fantasize of new laser-matter interaction processes at the nanoscale, whose physical laws are yet to be discovered. For example, structured laser pulses offer an appealing alternative to study sub-femtosecond magnetization dynamics, where a complete understanding of the electronic and spin interactions remains unexplored.