Exploiting light angular momentum wave-mixing from visible down to EUV regime

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Project description:

As they travel through space, some light beams rotate, a property which is related to angular momentum. There are two particularly important ways in which a light beam can rotate: if every polarization vector rotates, the light has spin (spin angular momentum, SAM); if the phase structure rotates, the light has orbital angular momentum (OAM), which can be many times greater than the SAM. Such quantized topological structure, also called “vortex beam”, has been intensively studied in literature, leading to many applications including optical tweezers, micromanipulation, classical and quantum communications, phase-contrast imaging in microscopy, and applications in quantum information and metrology [1,2]. The similarities and differences between SAM and OAM have led to new ways of thinking about their interaction with condensed matter systems. In particular, in the context of nonlinear light-matter interactions, OAM light may enable a more general paradigm for performing wave-mixing processes, related not only to the conservation of wavevector and energy of the input beams, but also to the conservation of total angular momentum. Recently, some theoretical predictions of spin-to-orbital angular momentum transfer have been experimentally verified at optical wavelengths [3-5].

In this project, we propose to study this new class of interactions between matter and light angular momentum, exploiting it firstly in conventional optical laser systems, with the idea to transfer the gained knowledge to short wavelengths produced in more sophisticated sources, like EUV/soft X-ray free-electron lasers (FELs). We envision a set of experiments for which the spin-to-orbital angular momentum transfer can become a privileged measuring tool: the study of ultrafast magnetization dynamics of non-uniform magnetic patterns after optical excitations [6,7] and the study of chiral properties of non-centrosymmetric biological molecules [8]. The candidate will work in collaboration with DiProI, EIS-Timer and the FERMI machine physics teams, that have strong experience in wave-mixing experiments both in the optical and EUV regime [9,10], as well as in the manipulation of OAM modes generated both with spiral diffractive optics and directly from the FEL source [11,12]. Inside the project, we foresee that the candidate will conduct part of the experimental activities in the Laboratory for Micro- and Nanotechnology at PSI Villigen (Switzerland), directed by Dr. Christian David, to fabricate spiral zone plates for the generation of OAM modes, and in the Laboratory of Quantum Optics at Ajdovščina (Slovenia), directed by Prof. Giovanni De Ninno, to conduct OAM-based experiments with table-top high-harmonic generation sources. Additionally, the candidate will be encouraged to submit proposals at different large-scale user facilities, to consolidate his/her training path and to build a future network of international collaborations.

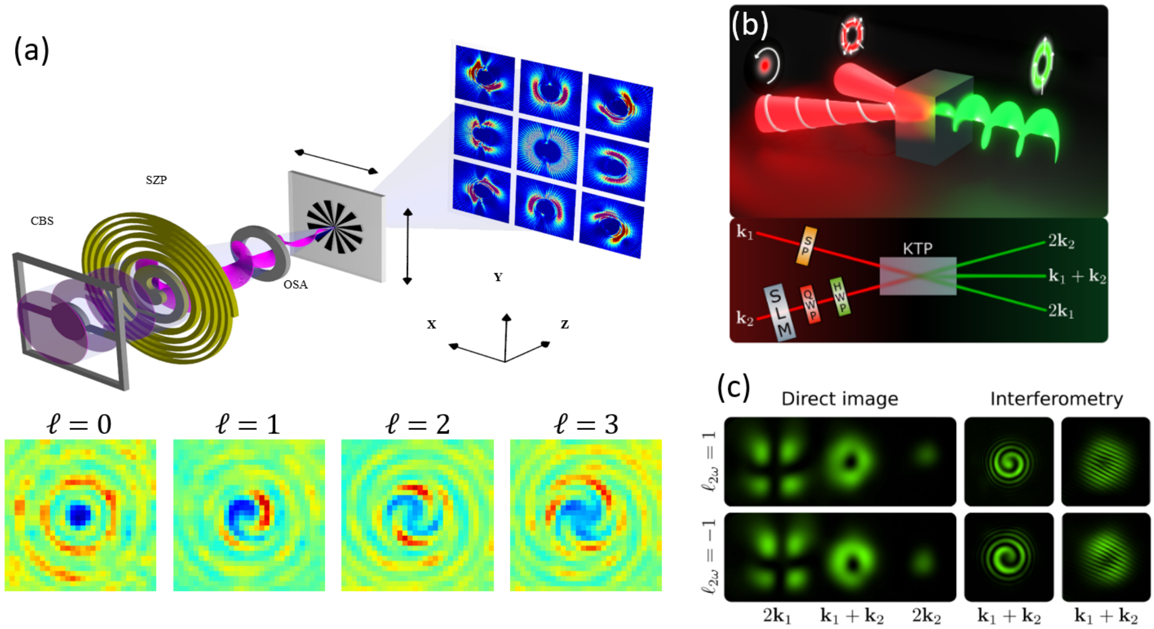

Figure 1. (a) Sketch of an experimental setup for the generation of OAM beams from spiral zone plates (SZP). The four images below the schematic are the far-field interference patterns between Laguerre-Gaussian OAM beams and a planar wave for different ℓ topological charges (ℓ = 0, 1, 2, 3). (b) Scheme for spin-to-orbital angular momentum transfer in second harmonic generation. Two input beams (sketched in red) with same frequency but different OAM interact inside a non-linear medium, due to a wave-mixing process. A second harmonic beam with double frequency is generated, while conserving the input momentum and transferring spin to orbital angular momentum. Reproduced from [5]. (c) Far-field intensity distribution of the three outputs of the second harmonic field. Laguerre-Gaussian modes with topological charges ℓ = +/- 1 are evident in the k1 + k2 beam. Reproduced from [5].

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