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Plasma-based generation and manipulation of intense structured laser pulses

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Light can possess orbital angular momentum (OAM) depending on its phase structure and spin angular momentum (SAM) depending on its polarization state. In recent years, much attention has been focused on structured light where one can arbitrarily tailor light in all its degrees of freedom, especially phase and polarization. The most familiar examples of structured light are the vortex and vector beams. The vortex beams have helical phase fronts and phase singularities, while the vector beams have spatially variable polarization states and polarization singularities. Despite many potential applications enabled by such pulses, the generation and manipulation of high-power/-intensity structured laser beams remains challenging due to the low damage thresholds of conventional solid-state-based optics.

Since a fully ionized plasma can sustain extremely high electromagnetic fields, the use of plasma as advanced optical components is a promising solution. In this talk, I will introduce several new schemes for generating and manipulating intense structured laser pulses such as relativistic vortex and vector pulses using plasma-based optics, focusing on energy amplification, frequency conversion, phase shaping, and polarization control. For example, I will show that intense near-infrared vortex and vector pulses can be efficiently generated through strongly coupled stimulated Brillouin amplification in plasmas, combined with all-optical phase and polarization manipulation of the amplified seed pulse[1], as shown in Figure 1. Additionally, I will show the capability to efficiently produce intense vortex and vector beams in the ultraviolet and soft X-ray wavelength ranges via the frequency up-conversion process based on surface harmonics generation in plasmas[2-3]. Finally, I will show that by utilizing plasma-based difference frequency generation and spin-orbit conversion, sub- or single-cycle, relativistic, CEP-stable mid-infrared vortex and vector pulses can be generated from circularly-polarized Gaussian beams with high efficiency[4-5].

References
[1]Yipeng Wu, et al. Commun Phys 7, 18 (2024).
[2]Yipeng Wu, et al. arXiv:2311.13907
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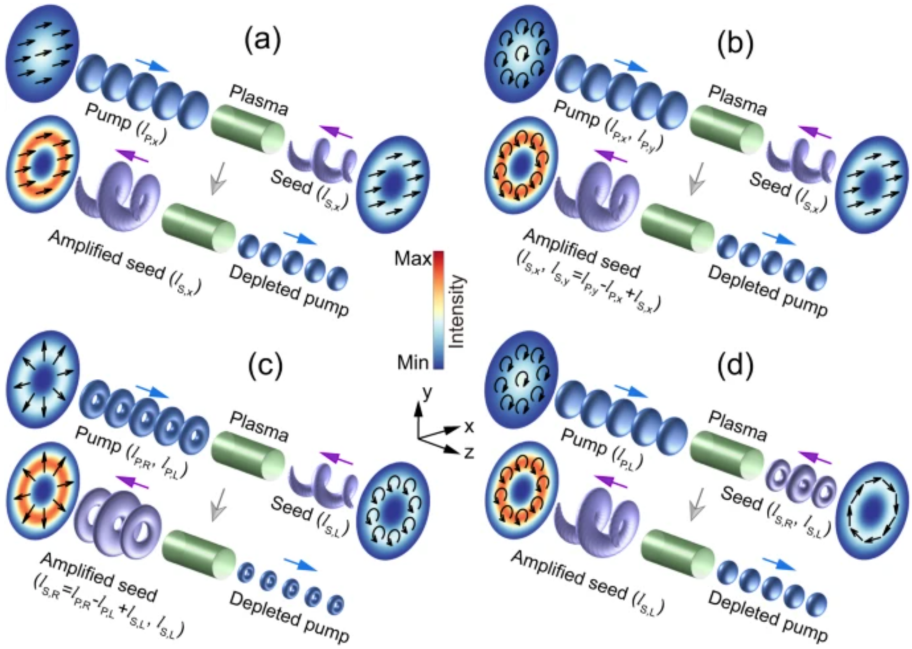

Figure 1. Schematic diagram for the generation and amplification of vortex and vector beams via strongly coupled stimulated Brillouin scattering. The pump/seed lasers propagate in the direction of the blue/purple arrow, respectively. The plasma is shown by the green cylinder. The back/front projections show the intensity profile and polarization pattern of the closest laser. (a) Amplification of vortex beams by Gaussian or Laguerre-Gaussian pump beams. (b) Generation and amplification of vortex beams with new OAM modes and controllable polarization. (c) Generation and amplification of vector beams from vortex seed beams. (d) Generation and amplification of vortex beams from vector seed beams.