7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Plasma-based generation and application of intense vector beams

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With the rapid development of revolutionary laser techniques, a new type of laser fields—vector beams [1] with spatially varied polarization distributions have gained increasing attention because of their unique properties that are different from traditional scalar light fields[2]. Due to the thermal damage threshold, generation and manipulation of high-intensity vector beams are challenging, while the plasma-based optical components composed of free electrons and ions become potential alternatives for high-power laser manipulation and have been extensively studied in recent years [3-5].

Previously, we proposed a magnetized- plasma-based q-plate scheme to convert incident circularly-polarized beam into twisted beam by employing the birefringence effect [6]. In this study, we propose a new scheme to convert incident linear/circularly-polarized Gaussian beams into cylindrical vector/vortex beams by employing the Faraday rotation effect in an azimuthally distributed axially magnetized plasma [7], as shown in Fig.1. 3D particle-in-cell(PIC) simulations demonstrate large conversion efficiency and wide applicable frequency range.

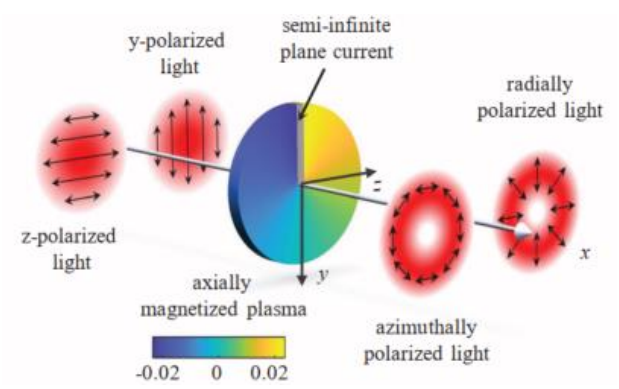

Figure 1: Illustration of a linearly $\hat{y}/\hat{z}$-polarized beam transformed into a radially polarized / azimuthally polarized beam after passing through an axially ($\hat{x}$) magnetized plasma.

In addition, considering that the intensity pattern of an Laguerre-Gaussian (LG) beam with nonzero azimuthal mode index l and radial mode index p consists of $p+1$ halos separated from each other by dark rings and a dark center, we construct a plasma zone plate (PZP) driven by the ponderomotive force of an LG beam with a nonzero p irradiating an underdense plasma slice [8]. As shown in Fig. 2, the LG pump beam modulates the plasma to form an annular distribution of alternating high and low density rings, which allows multi-focal focusing of high power probe beams. The multi-focal intensity distributions are consistent with the characteristics of the traditional Fresnel zone plate, and the probe intensity can be magnified up to more than two orders of magnitude as demonstrated in Fig. 2(d).

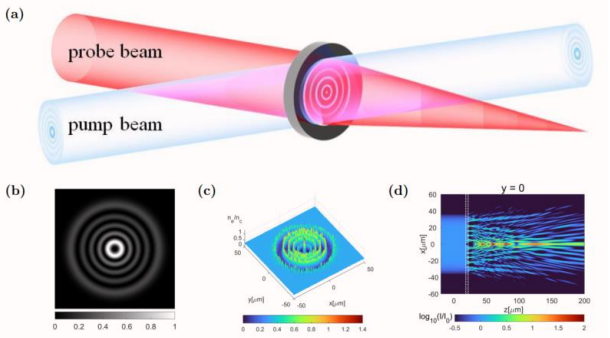

Figure2. (a) Schematic of a PZP. An LG beam (l=2, p=4) is launched into the plasma and generates a PZP, which can be used to focus a probe beam. (b) Intensity pattern of the pump beam. (c) Transverse density distribution of the PZP. (d) The intensity distribution of the probe beam after traversing the PZP.

The above proposed schemes offer new plasma-based methods to manipulate high-power lasers and pave the way for further studies on ultra-strong vector beams.

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