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Plasma optics for high-power laser sciences and inertial confinement fusion

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Higher laser power and intensity have been continuously pursued since the laser was invented. In particular, the invention of chirped pulse amplification technique by Strickland and Mourou in 1985 dramatically boosted the peak power of laser pulses to an unprecedented level [1]. High-power laser pulses not only bring about many prospective applications but also become a unique tool to create extreme conditions for fundamental research. With increasing laser peak power, however, conventional solid-state optical components must be proportionally enlarged to avoid laser-induced damage. In general, multi-petawatt laser systems require metre-scale optical components, which are economically costly and technically challenging. In contrast, plasma-based optical components offer an attractive solution to this issue, since all materials are at least partially ionized by an intense laser pulse and the resultant plasma can be used to manipulate the laser pulse. The design and application of high-power lasers has the potential to be revolutionized by plasma-based optics, which may pave the way for the study of laser-matter interactions at unprecedented intensities.

In this talk, we will firstly give a short introduction and review the progress on plasma optics. Based on plasma optics, novel concepts have been proposed and/or demonstrated for the manipulation or amplification of intense laser pulses. So far, plasma mirrors are widely used for enhancing the temporal contrast of intense laser pulses [2]. The Raman and Brillouin scatterings are studied for the amplification of laser pulses [3]. The cross-beam energy transfer is studied for tuning the implosion symmetry in laser fusion [4]. Plasma density gratings induced by intersecting laser pulses are broadly studied as the plasma compressor, the plasma waveplate, and the transient plasma photonic devices for high-power lasers [5].

In the talk, we would also like to review our recent progress on plasma optics. Firstly, we will report an extreme case of the Faraday effect that a linearly polarized ultrashort laser pulse can split in time into two circularly polarized (CP) laser pulses of opposite handedness during its propagation in a highly magnetized plasma [6]. This extreme Faraday effect offers a new degree of freedom to manipulate ultra-short ultra-intense laser pulses, hence it may pave the way for novel optical devices such as magnetized plasma polarizers. The latter could allow the generation of CP laser pulses as high power as 10 PW in up-to-date laser facilities. The resultant high-power CP pulses are particularly attractive for laser-driven ion acceleration. Moreover, this extreme Faraday effect may offer a powerful means to measure strong magnetic fields broadly existing in objects in the universe and in laser–matter interactions in laboratories. Secondly, we will review our recent progress on the frequency modulation of intense laser pulses by plasma-based optical modulators, which could be applied for the generation of relativistic near-single-cycle mid-infrared laser pulses or broadband high power laser pulses [7-9]. The intense mid-infrared pulses generated are particularly useful for ultrafast science, super-resolution spectroscopy, particle acceleration, high-field physics, and the production of brighter hard X-rays and shorter attosecond pulses [9]. While the modulated intense laser pulses with broad bands may bring some new physics and applications associated with intense laser-matter interactions. For example, laser pulses with an ultrabroad bandwidth can play an important role in the suppression of parameter instabilities in laser-plasma interactions [10], which is one of the key issues in laser-driven inertial confinement fusion.

In summary, plasma optics plays an increasingly important role in the amplification and manipulation of intense laser pulses. It will make the laser more powerful and more colorful.

References

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