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Diffractive Plasma Optics for Compact Ultra-High-Power Femtosecond Lasers

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Plasmas are an attractive medium for ultra-high-power laser optics because they can withstand several orders of magnitude higher light intensity than glass, metal, or crystal; plasma optics can be much smaller than their solid-state counterparts. As a result, high-power lasers built using plasma optics could be much smaller than solid-state systems with equivalent performance. This provides an opportunity to build compact multi-petawatt lasers, and a possible path to building lasers with substantially higher peak powers than what is currently viable.

Here we describe the design and performance of diffraction gratings [1] and lenses [2] based on laser-structured plasmas. Our experiments have demonstrated high-efficiency manipulation of beams at intensities above 10^{14} W/cm^2, and we have characterized the optical properties of plasma diffraction gratings, showing that spatial and temporal quality can be maintained as a beam propagates through a plasma optic of this type [3,4]. Additionally, we discuss how the sub-picosecond turn-on of plasma gratings allows them to be used for temporal contrast improvement [4], with more than five orders of magnitude improvement. Similarly constructed gas-phase optics offer exceptional control of high-energy lasers suitable for inertial fusion, and we discuss how these optics allow damage-free control of beams with high efficiency and stability [5,6].

Our experimental and computational results on the properties of plasma optics suggest possible designs for future high-power laser systems based on plasma components. Taking full advantage of the properties of these optics requires adjustments to standard chirped-pulse-amplification designs but should enable extremely powerful laser pulses from systems with compact footprints.

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References

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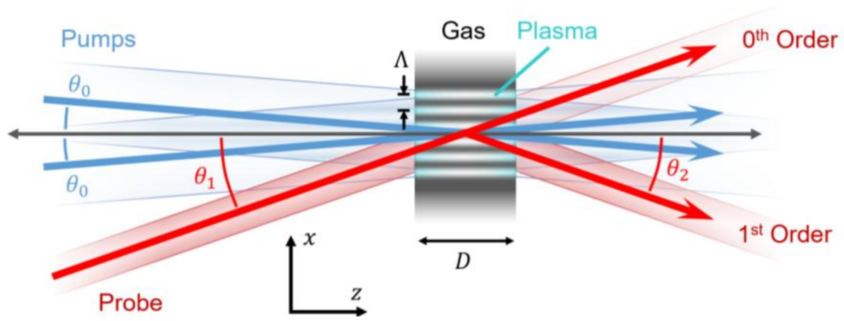

Figure 1: Schematic showing the formation of an ionization grating in a gas by two pump beams. The grating redirects an incident probe beam into its first order.