Using pump lasers to create plasma lenses that focus at very high intensity levels

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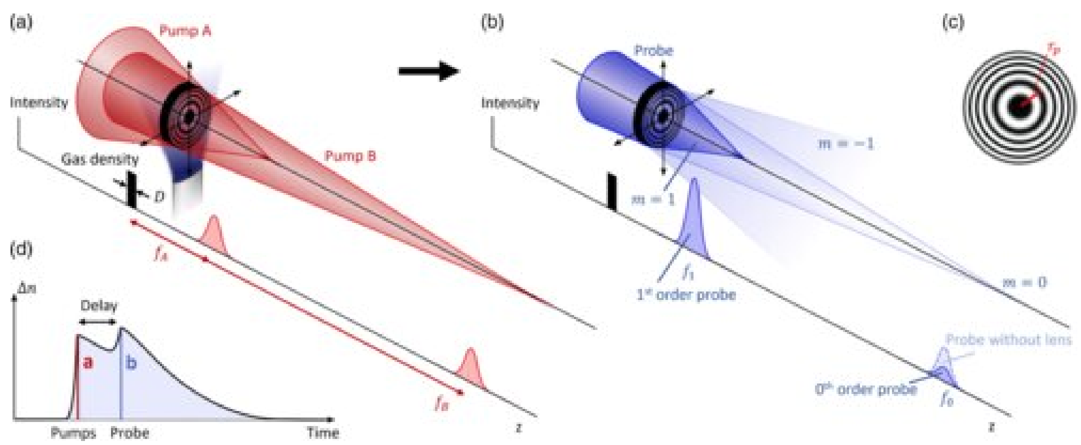

Schematic of a holographic plasma lens. (a) Two pump lasers overlap in a gas (extent along z is D), arranged so that their interference pattern is a sinusoidal zone plate. (b) At a delayed time, a probe laser passes through the resulting structure and is diffracted into one or more orders. (c) The intensity profile of the overlapped pumps and the resultant index modulation. (d) The peak index of refraction modulation as a function of time, showing the formation of the structure with the arrival of the pumps, followed by a decay and possible modification by the probe. The amplitude and timescale both depend on the chosen nonlinear mechanism. Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.065003

A team of researchers from Lawrence Livermore National Laboratory, the University of California at Berkeley and Princeton University has developed plasma-based techniques to build a lens for laser beams with petawatt-scale power. In their paper published in the journal *Physical*

Review Letters, the group describes the two techniques they developed.

Physicists conducting work with particle accelerators and fusion research efforts are hopeful that other researchers will build lasers that are more powerful than those currently available. Such work has been held up by the solid-state optics technology used to create lasers—giving them more power would damage the parts used to generate the laser, making them useless. In this new effort, the researchers noted that other researchers have found that plasma can be used to create optic components such as amplifiers and mirrors. They wondered if the same might be true for the kind of lens needed to produce extremely powerful laser beams. They came up with a concept that involved inducing patterns of high and low density in a given plasma. Light moving through it, they note, would experience a phase shift based on the density of the plasma.

The researchers did not actually build such a laser, but instead, proposed two ways that it might be built. The first method involved firing two pump lasers at a gas sample. The first laser ionized the gas into a plasma, while the second did not. The result was a plasma with a bulls-eye configuration of high and low-density plasma rings, which could be used as a laser lens.

The second approach involved firing two pump lasers at an already existing plasma in a way that pushed some parts of it toward high intensity areas while others were pushed to low areas. The end result, as with the first approach, was the development of a bulls-eye configuration that could be used as a high-powered laser lens.

The researchers created simulations to test their ideas and found that the first approach could be used to create laser beams with intensities up to 10^{15} W/cm^2, while the second could be used to create beams with intensities as high as 10^{18} W/cm^2.

More information: M. R. Edwards et al, Holographic Plasma Lenses, *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.065003