The Advent of Non-linear Optical Components Made From Plasmas

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When the worldwide program in Inertial Confinement Fusion (ICF) pushed forward to build MJ scale lasers it was recognized that the stimulated scattering processes that occur when individual laser beams interact with a small scale plasma, would also allow beams to interact with each other and exchange significant energy and power with the increased scale length expected in the target plasmas produced by these lasers [1]. As a result NIF and other lasers now provide the capability to adjust the wavelengths of the individual beams to control the seeding of Stimulated Brillouin Scattering of one beam by another via the process of Cross Beam Energy Transfer (CBET) [1]. From the outset of indirect drive experiments on NIF, CBET controlled by wavelength tuning was shown to be effective in redistributing large fractions of the incident power between the cones of beams, which improved implosion symmetry and performance in important cases [1,2]. As a result many lasers now exist with wavelength tuning to control CBET as does a wide range of data to validate CBET models. These capabilities are presently being rapidly employed to produce optical devices made of plasma using CBET interactions for many applications [3,4]. The most recent demonstration is a plasma-based optic that combines the energy and fluence of many laser beams into a single bright beam, thus creating a new technique for designing future high energy density physics experiments. The technique has shown for the first time that a plasma can combine beams to produce a single beam that emerges from the target with energy and fluence beyond that of any of the input beams for delivery to another experimental target. In an initial demonstration, multiple beams of the National Ignition Facility (NIF) laser have been combined in a plasma to produce a directed pulse of light with 4 ± 1 kJ of energy in its 1 ns duration which is 3.6 times the energy and 3.2 times the fluence of any of the incident beams during that period and is NIFs brightest 1ns duration beam of UV light [4]. Work performed at Lawrence Livermore National Lab., Contract DE-AC52-07NA27344.

[1] R. K. Kirkwood et al Plasma Phys. Control. Fusion 55, 103001 (2013).

[2] O. Hurricane et al Nature 506, 343–348 (2014). [3] D. Turnbull, et al, Phys. Rev. Lett. 116, 205001 (2016).

[4] R. K. Kirkwood et al Nature Physics online: 2 Oct. 2017, and Nature Physics, 14, 80, January (2018).