

High-performance frequency conversion for future ICF laser chains

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We report on an original surface cooling technique suitable for high-energy frequency conversion to the ultraviolet at high repetition rates. This technique was experimentally demonstrated in a three-step picosecond fourth-harmonic generation setup in LBO. The first stages of a Yb:YAG laser chain operating at 1 kHz repetition rate generate few-picosecond chirped pulses at 1030 nm fundamental wavelength and energy up to 800 mJ. They are frequency-converted in a cascade of three LBO crystals to generate the second-, third-, and fourth-harmonics at 515 nm, 343 nm and 257 nm respectively. Crystals thicknesses and angular phase-matching detuning were calculated as a function of pulse duration through broadband nonlinear optical numerical simulations. Last crystal is both conduction-cooled on edge and surface-cooled at center through forced-air flow to mitigate heating due to nonlinear absorption in the deep-UV and reduce temperature gradients. Chirped-pulse duration was experimentally adjusted to achieve stable 20% overall conversion efficiency at input energy limited to 220 mJ for this first campaign. To the best of our knowledge, these performances represent a world record in peak-power in the deep-ultraviolet, only excluding laser fusion chains operating at much lower repetition rates of a few shots per day.

Near-field beam profiles were continuously recorded at 10 Hz, for all four wavelengths involved, together with corresponding energies, showing no significant beam degradation over 50 hours. Temperatures of the two last crystals were monitored, and helped optimize surface cooling for future energy and power ramping-up that is promising according to optical and thermal simulations.

LBO is also a material of choice for the final frequency conversion to 351 nm in laser chains for inertial confinement fusion. We will show that substituting LBO for KDP crystals currently used on the National Ignition Facility or the Megajoule laser is straightforward, without sacrificing the spectral band. Tiled LBO crystals of adapted thickness would make it possible to obtain performances identical to the UV records of 14 kJ per beam (2.6 MJ for 192 beams) obtained on NIF but at repetition rates of several tens of Hz thanks to surface cooling.