Next-generation Industrial Laser Technologies

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Within the EPSRC Centre for Innovative Manufacturing in Laser-based Production Processes, and in close partnership with our industrial collaborators, we demonstrated next-generation industrial laser technologies enabling new laser material processing regimes. We covered three areas: high-power laser diode module at 0.9 µm wavelength, ultra-short-pulse amplifiers for 1 µm wavelength, and new technologies for 2 µm wavelength lasers.

The objective of the laser diode module development was to demonstrate the highest achievable beam brightness from six combined laser diode mini-bars, each with 5 broad-area single emitters with a total installed optical power of 280 W. The 30 beams were spatially, spectrally and polarisation-combined. A key aspect is our custom-designed laser-machined micro-optics, produced by our partner PowerPhotonic Ltd. The target application for the demonstrator module is for direct use in powder bed additive manufacturing.

Our ultra-short-pulse 1 µm amplifiers demonstrated energy-scalable architectures for MHz rates and ~1 picosecond pulses. We utilised a commercial seed (344 fs pulses, 10 MHz, 140 nJ) for a dual-end-pumped Yb:YAG single crystal fibre pre-amplifier, followed by our high-energy Yb:YAG planar waveguide amplifier. A seven-pass configuration produced 8.7 µJ for sub-ps pulses at a pump power of 860 W. A key aspect was to suppress unwanted parasitic oscillations in this high-gain technology.

To extend the 2 µm laser technology we have developed a 300 W Tm:YLF slab laser to pump a Ho:YAG slab amplifier with significant gain at 2.1 µm. The first seed source was a Q-switched Ho:YAG laser at multi-kHz rates and mJ pulse energies, which can be amplified to 150 W average power under optimal conditions. Our collaborators provided an ultra-short-pulse 200 fs Tm:$LuScO_3$ laser as an alternative, for which we measured a single-pass gain of 10. We are implementing a pre-amplifier to scale the seed for efficient energy extraction from the main Ho:YAG amplifier.