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High-energy Laser Pulses at 1064 nm with Complex Temporal Shapes

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Laser pulses are a powerful tool for inducing a large diversity of dynamical phenomena in matter. Control over the temporal shape of light pulses therefore also provides a means to control such dynamics on a wide range of timescales. Our aim is to improve control over laser-produced plasmas (LPP) and its short-wavelength emission characteristics, where plasma dynamics at nanosecond (ns) timescales play an important role. To investigate and control such dynamics, we need to combine GHz bandwidth pulse shaping capabilities with high pulse energies. The development of fast, compact, integrated electro-optic modulators (EOM) has made arbitrary temporal shaping at GHz speed accessible [1,2]. However, the penalty for their fast modulation speed is a low power threshold, usually in the mW regime. Therefore, to enable fast temporal shaping of high-energy laser pulses, amplification after shaping is necessary. Here we present a laser system capable of delivering arbitrary shaped pulses with 0.5 ns temporal resolution and up to 440 mJ of pulse energy at 1064 nm wavelength and 100 Hz repetition rate. A grazing incidence amplifier utilizing Nd:YVO_4 crystals pumped at 880 nm [3] is seeded by a modulated 2W CW laser. Further amplification is obtained by utilizing a quasi-CW diode-pumped Nd:YAG power amplifier. A schematic of the full setup is shown in Figure 1a.

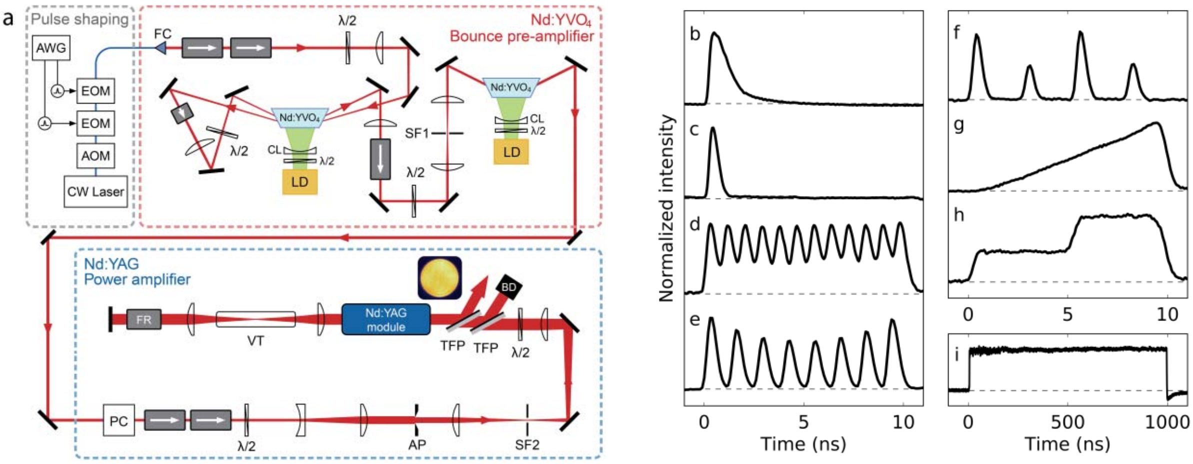

Fig. 1 a) Schematic of the laser system. The inset shows the top-hat beam profile of the output. (AOM: acousto-optic modulator, EOM: electro-optic modulator, AWG: arbitrary waveform generator, FC: Fibre collimator, CL: Cylindrical lens, LD: Laser diode, SF: Spatial filter, PC: Pockels cell, AP: Aperture, TFP: Thin film polarizer, VT: Vacuum tube, FR: Faraday rotator, BD: Beam dump). **b-i)** Measured temporal pulse shapes demonstrating the shaping capabilities of our system. Pulses are measured at a focus using a >15 GHz photodiode and a 4 GHz oscilloscope.

Precise modulation of the CW seed light is achieved by combining two consecutive 2 GHz bandwidth EOMs that are driven by a 2.4 Gs/s arbitrary waveform generator. An AOM precedes the EOMs and gates the CW signal, rendering high suppression and limiting the average seed power to below the damage threshold of the EOM. Using two EOMs gives us the necessary suppression to negate the strong distortion of the pulse shape due to saturation of the amplifier. Figure 1b shows the measured pulse shape produced by the amplifiers for a square 500 ns input pulse, showing gain depletion from the amplifiers within only a few ns. With active shaping, we achieve a minimum pulse duration of 0.43 ns, as shown in Figure 1c. Figure 1d-h display several complex pulse shapes over a time span of 10 ns, demonstrating the fast pulse shaping capabilities. Furthermore, as shown in Figure 1i, the system can generate pulses up to 1 µs, spanning four orders of magnitude in pulse length. All pulse shapes are produced with >300 mJ pulse energy. This all-diode-pumped system has a long-term energy stability of 0.5% rms over 24h. At present we have implemented a feedback algorithm that optimizes towards basic pulse shapes, and we envision a genetic algorithm approach to enable automatic optimization to any complex shape, optimizing for specific experimental parameters.

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