Ultra-short-pulse oscillator, pre-amplifier and high-power Ho:YAG slab amplifier

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Power scaling high repetition-rate ultra-short-pulse lasers, operating beyond 2.0 µm, offers new welding and modification capabilities for IR transparent materials such as silicon, provides efficient non-linear conversion to 3-5 µm, and will enables interesting ultra-fast laser-matter interaction studies. However, current off-the-shelf mode-locked fibre laser oscillator technology is limited to few-hundred mW average output power when the wavelength is pushed to 2.1 µm while producing ps-pulse durations at MHz repetition rates. To scale the power and energy to relevant levels for the applications, requires the development of solid-state laser amplifier systems operating in this wavelength band.

In this work we present a high-power Ho:YAG slab amplifier, pumped by an in-house developed 300 W-class Tm:YLF slab laser, and seeded by a commercial mode-locked laser oscillator (200 mW, 5 ps, 23 MHz) operating at a central wavelength of 2.090 µm, coupled into a Tm:fibre-laser-pumped Ho:YAG rod double-pass pre-amplifier.

Without implementing any pulse broadening techniques nor reducing the repetition rate, the pre-amplifier provided a 9x single-pass gain to produce 1.8 W average output power, at the start of gain saturation. In the double-pass configuration, it produced 4 W average output power at the same pump power, with further linear power scaling possible. The expected small-signal gain for the main amplifier has been confirmed. With the full pre-amplified seed beam, spatially shaped to match the wide pump beam in the 10mm x 1.5mm x 55mm Ho:YAG slab amplifier gain crystal, we have been able to reach up to 16W of usable output power, which bring us in the vicinity of the 1µJ per pulse needed for silicon welding. We will be presenting our experimental power scaling results, alongside initial ultra-fast laser-matter interaction studies on relevant infrared materials.

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