MTW Crystal Large-Aperture Ring Amplifier

The crystal large-aperture ring amplifier (CLARA) is used to amplify the regen output to an energy level suitable either for pumping a pair of optical parametric chirped-pulse–amplification (OPCPA) stages in the broadband mode or for injection into the Nd:glass amplifiers in the narrowband mode. A limited number of gain media are suitable for this. Because MTW was built as a prototype front end for the kilojoule OMEGA EP Laser System, a 5-Hz repetition rate was required to align its main amplifiers and numerous diagnostics. This repetition rate poses challenges for joule-scale, flashlamp-pumped Nd:glass amplifiers because of the thermal load and degradation of the amplified beam. Instead Nd:YLF was selected because it matches the gain peak of Nd-doped phosphate laser glasses and has relatively high thermal conductivity with low thermal astigmatism. Water cooling of 25.4-mm-diam, 110-mm-long rods is sufficient to support joule-scale pulses at a 5-Hz rate.

The transmitted wavefront quality of commercially available, large-aperture Nd:YLF laser rods was dramatically improved by magnetorheological finishing (MRF). Two 25.4-mm Nd:YLF rods were polished on one face of using MRF to compensate for bulk inhomogeneities that cause the transmitted wavefront errors, while the other surface was polished flat. Correcting these errors increases the usable aperture of the rods, resulting in a higher energy extraction. The MRF-corrected rods have transmitted wavefront errors, when correctly aligned, that are <0.1λ at 1053 nm, reduced from typical values exceeding 0.5λ for uncorrected rods.

The CLARA architecture is based on a *Q*-switched, cavity-dumped, self-imaging laser cavity. The Gaussian beam from the regen is expanded to 30 mm (FWHM) and shaped by a beam apodizer, shown in the insets in Fig. 1. The image of the apodizer is translated between two Nd: YLF rods by a four-lens vacuum spatial filter with positive and negative lenses to image relay the beam through successive round trips in the cavity at the same plane.

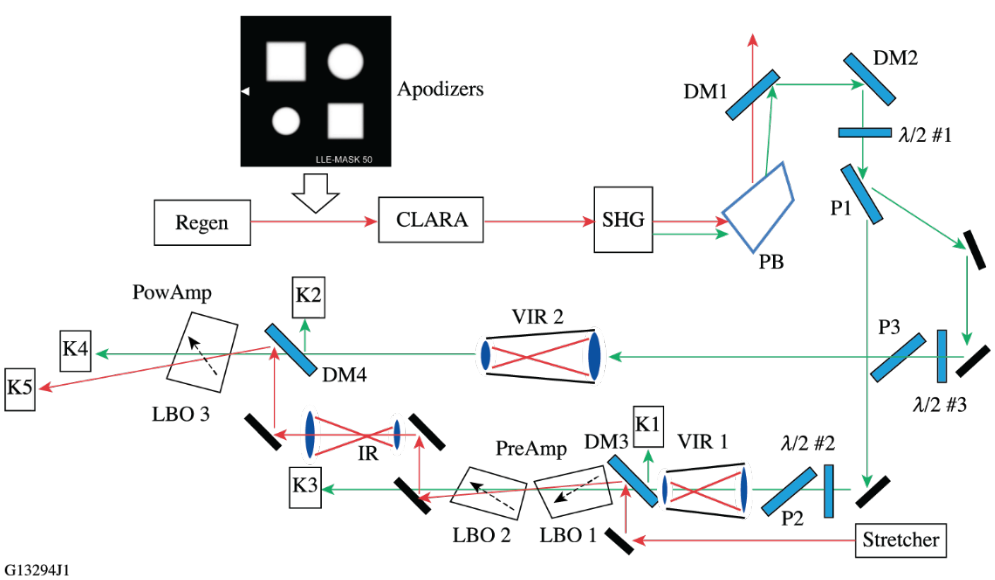

Fig. 1. OPCPA layout. VIR: vacuum image relay; PB: Pellin–Broca prism; DM: dichroic mirror; P: polarizers, λ/2: half-wave plates; LBO: lithium triborate crystals; PreAmp: preliminary amplifier; PowAmp: power amplifier; K: calorimeters; SHG: second-harmonic generator. Inset: a plate with four apodizers.

A 25.4-mm-aperture PC sets the number of round trips in the 7-m (21-ns) round-trip cavity. All of the MTW operation modes are met with either three or four round trips. The output energy for a 14 × 14-mm^2 beam is up to 3.2 J. The energy stability of the laser is excellent, achieving better than 0.5% rms and 3.8% peak-to-mean over a 10,000-shot count at 5 Hz.

Second-Harmonic Generation

The CLARA image is relayed to the second-harmonic–generation (SHG) stage, consisting of a lithium triborate crystal (LBO), which chosen due to its relatively high nonlinearity and angular acceptance.

A diagnostics package consisting of beam cameras, energy meters, and a Hamamatsu photomultiplier for pulse measurements is used to characterize and optimize the SHG process. The second-harmonic conversion efficiency typically exceeds 70%. The maximum SHG energy used for pumping the MTW OPCPA stages is kept below 1.1 J. A nominal SHG beam profile is demonstrated in Fig. 2(a). A typical second-harmonic pulse is shown in Fig. 2(b). The pulse is approximately super-Gaussian with an order N = 34 and a duration of 2.8 ns (FWHM). For most of the MTW applications, the pulse duration is in the 1- to 2.8-ns range. However, the flexibility of the narrowband front end allows the output pulse shape to be optimized, for example, to pre-compensate pulse distortion in subsequent glass amplifiers or to meet a particular pulse shape requested for experiments.

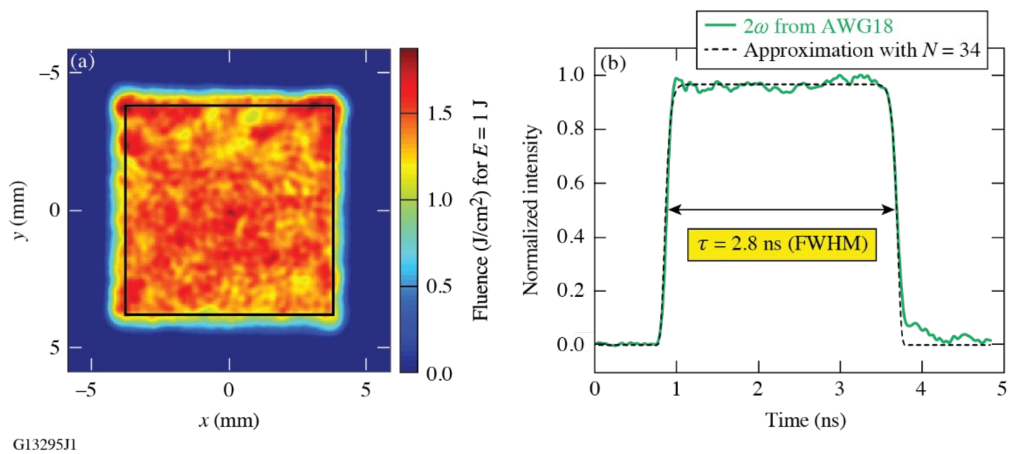

Fig. 2. (a) Typical second-harmonic beam profile and (b) its pulse shape with the approximation by the super-Gaussian shape (N = 34).