Graphene Mode-Locked Diode-Pumped Cr:LiSAF Laser at 857 nm

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The Cr:LiSAF gain medium, belonging to the class of Cr:colquiirite lasers, possesses a broad gain bandwidth suitable for the generation of femtosecond pulses near 850 nm [1]. Because the nonlinear refractive index of these media is typically low, Kerr lens mode locking alone does not provide sufficient modulation for stable mode locking. To increase the effective modulation depth for mode-locked operation, gain matched output couplers [2], semiconductor saturable absorber mirrors (SESAM) [3], and single-walled carbon nanotubes (SWCNT) [4] have been used in previous studies. One drawback of SESAMs and SWCNTs is the narrow operation bandwidth which limits the pulse widths as well as the mode-locked tuning range. An attractive alternative involves use of the graphene saturable absorber (GSA) which provides constant absorption over a very broad wavelength range due to the zero band-gap energy [5]. However, one challenge remains in the case of Cr.colquiirite lasers since the relatively low optical gain may not be sufficient to overcome the small signal loss of the GSA (around 5% per round trip), especially in low-power systems. In previous studies, GSA has been used to generate mode-locked pulses from bulk solid-state lasers between 800 and 2500 nm [6, 7].

In this study, we report, for the first time to our knowledge, GSA-based mode-locked operation of a Cr:LiSAF laser. We further demonstrate that, a low-threshold resonator design, with only two 135-mW single-mode pump diodes, provides sufficient optical gain to overcome the insertion loss of the GSA . Pulses of 100 fs duration and 10 mW of average power were obtained at the wavelength of 857 nm.

In the experiments, an astigmatically compensated x-cavity containing a 7-mm-long Cr:LiSAF crystal (1.5% Cr doping) was end pumped with two single spatial-mode diodes, providing a total pump power of 270mW. A monolayer graphene transferred onto an infrasil substrate was located at a second beam waist inside the cavity formed by using two more curved high reflectors, each with a radius of 75 mm. By using lasing threshold data taken with different output couplers, the round trip loss of the gain crystal and the GSA was estimated to be 0.55% and 6.3 %, respectively. The mode locking experiments were performed with the 0.5 % output coupler. For pump powers above 200 mW, stable continuous-wave (cw) mode locking could be obtained by translating the output coupler. Figure 1 shows the optical spectrum and the autocorrelation of the pulses generated with 267 mW of pump power. By assuming a sech^2 pulse profile, the pulse width (FWHM) was determined to be 100 fs and the corresponding measured spectral bandwidth of 9 nm gave a time-bandwidth product of 0.363. This indicates that the pulses were nearly transform limited. As high as 10 mW of average mode-locked output power was obtained at the pulse repetition rate of 133 MHz. We acknowledge the financial support from The Scientific and Technological Research Council of Turkey under project 112T967.

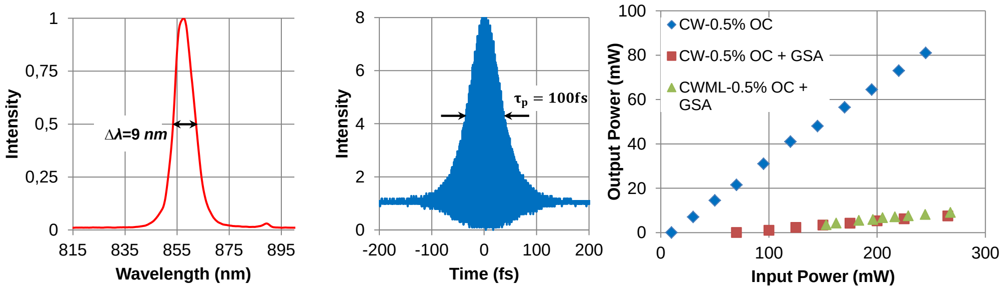

Fig. 1 Measured optical spectrum (left), interferometric autocorrelation (middle), and power efficiency curves (right) of the GSA mode-locked Cr:LiSAF laser.

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