Graphene Q-switched Yb:Phosphate Glass Channel Waveguide Laser

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Q-switched lasers can generate high-energy pulses that can have applications in medicine, material processing and defence. Waveguide lasers have several attractive features such as a low laser threshold and a high slope efficiency, provided that the propagation losses are kept low, compactness and mass-producibility. Ion-exchange is a simple and cheap technique to fabricate loss-loss waveguides in glass, with mode-locked operation being demonstrated in ion-exchanged Yb:phosphate glass lasers [1] using a semiconductor saturable absorber mirror (SESAM). Using graphene as a saturable absorber has several key advantages over SESAMs such as a broad wavelength operating range, cost-effectiveness and ease of fabrication. Graphene has previously been used as a saturable absorber to demonstrate Q-switched mode-locking in a femtosecond-written glass waveguide laser [2] and Q-switched operation in a carbon-irradiated Nd:YAG ceramic channel waveguide laser [3]. In this paper we present an ion-exchanged Yb:phosphate glass waveguide laser, Q-switched using a graphene saturable absorber.

A 200-nm-thick layer of aluminium (Al) was deposited on a surface-polished Yb:phosphate glass (IOG-1, Schott glass) sample using e-beam evaporation. Using photolithography, channel openings of widths 1 μm to 10 μm were defined in the metal mask, after which the glass sample was immersed into a salt mixture consisting of 45 mol% KNO_3–50 mol% $NaNO_3$–5 mol% $AgNO_3$ kept at 325 ^{o}C for 10 minutes. Following the (Ag^+, K^+)-Na^+ ion-exchange, the Al layer was removed and the glass was polished to a length of 17.8 mm. Graphene was grown on ultra-flat copper using atmospheric-pressure chemical vapour deposition (APCVD) [4]. Using PMMA, the graphene was transferred onto an output coupler (OC) with a transmission of 2% at the laser wavelength.

A fibre-coupled single-mode laser diode (3S Photonics) operating at 975 nm was used as a pump. The fibre output was collimated by an f = 8 mm aspheric lens, following which a half –wave plate and an isolator were installed to block any back-reflections from the waveguide. An aspheric lens with f = 11 mm was used to launch into a waveguide, fabricated with a channel opening width of ~6 μm. The waveguide cavity was formed by end-butting a 200-μm-thick mirror with reflectivity of >99.9% (at 1055 nm) at the input facet and the graphene-coated OC at the output facet. On increasing the incident power to 220 mW, 17 nJ pulses were generated at a repetition rate of 392 kHz and with a full-width-at-half-maximum (FWHM) duration of 292 ns. The variation in pulse width and pulse energy with the incident power is shown in Fig. 1 (a). For the highest pump power of 652 mW, 27 nJ pulses were generated with a FWHM duration of 140 ns and at a repetition rate of 781 kHz. A typical pulse train (measured at 652 mW) is shown in Fig. 1 (b) and the average power and repetition rate versus incident power is shown in Fig. 1 (c). The slope efficiency obtained during Q-switched operation was 3.2% and the wavelength of operation was 1055 nm. In conclusion we have demonstrated the first, to the best of our knowledge graphene Q-switched ion-exchanged waveguide laser. Mode-locking and power-scaling experiments are under progress.

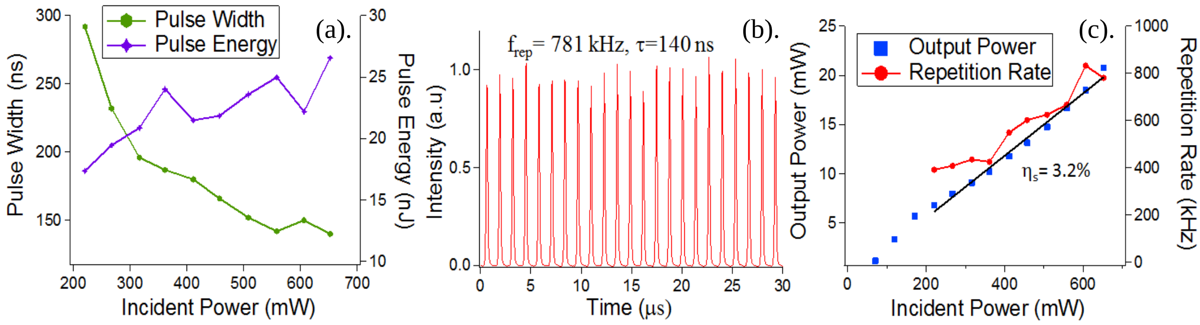

Fig. 1 (a) Pulse width and pulse energy vs. incident power, (b) pulse train measured at an incident power of 652 mW, and (c) output power and repetition rate vs. incident power.

References

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