Fundamentally mode-locked Yb^{3+}-doped glass waveguide lasers with repetition rate of up to 15.2 GHz

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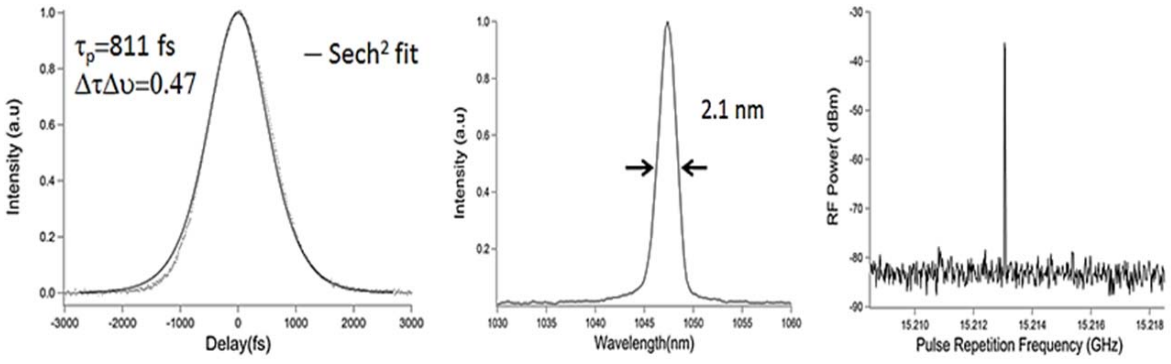
Ultrafast lasers with multi-GHz repetition rates can have applications in areas such as biophotonics, optical frequency metrology, optical sampling, optical communications and as astro-combs. Ultrafast waveguide lasers with monolithically integrated saturable absorber elements are very promising candidates for multi-GHz operation, benefiting from a low-threshold mode-locked operation and high efficiency due to the small guided-mode size and consequent strong saturation of both gain medium and saturable absorber. One of the most attractive features of such devices is their compactness and compatibility with integrated optics technology.

Recently, we have demonstrated the first passively mode-locked Yb:glass channel waveguide laser operating with a repetition rate of 4.9 GHz [1]. In this work we report the pulse repetition frequency as high as 15.2 GHz from a diode-pumped Yb:glass waveguide laser which produces a pulse duration of 811 fs with an output power of 27 mW at around 1047 nm.

Channel waveguides in a 12 wt% Yb-doped phosphate glass (Schott IOG-1) were fabricated by defining Aluminium masks on the glass substrates, through a combination of e-beam metal evaporation and photolithography, followed by ion exchange [2] in a melt with the composition of 45 mol% KNO_3 – 50 mol% $NaNO_3$ – 5 mol% $AgNO_3$ at 325 ^oC for 10 min. The channel openings were from 1 μm to 10 μm in steps of 0.2 μm. After the mask removal, the glass samples were polished to lengths of 6.5 mm, 8 mm and 9.4 mm.

A single-mode fiber-coupled laser diode with a maximum power of 850 mW at 973.4nm (3S Photonics) was used to pump the waveguides. The beam was collimated and then launched into the channels by a 20× (f=8mm) and a 16× (f=11mm) aspheric lenses, respectively, resulting in a beam radius of 4.4 μm. Continuous wave laser operation was characterised by end-butting a thin HR mirror to one end and a 2% output coupler to the other end of waveguide sample. All fabricated channels in each sample were characterised in order to determine the best candidates for mode-locking experiments.

To perform the mode-locking experiments the HR mirror was replaced by a SESAM (Batop Gmbh, 0.4% modulation depth, 0.3% non-saturable losses, 0.5 ps relaxation time). The gap between the end facet of the waveguide and the SESAM was varied in order to manipulate the net cavity dispersion [1] and was monitored with a CCD camera. Stable mode-locking was achieved for a gap of around 26 μm. A pulse repetition rate of 10.4 GHz was observed for the 9.4-mm-long sample, with pulse duration of 757 fs and an output power of 60 mW. The repetition rate was found to be 12 GHz for the 8-mm-long sample with pulse duration of 824 fs and an output power of 45 mW. Figure 1 (a) shows the autocorrelation trace for the 6.5-mm-long sample at an output power of 27 mw. The pulse duration was measured to be 811 fs and the corresponding optical spectrum (Fig. 1(b)) has a FWHM of 2.1 nm, giving a time-bandwidth product of 0.47. The fundamental pulse repetition frequency was measured to be 15.2 GHz (Fig. 1(c)).



a. b. c.

Fig. 1 Intensity autocorrelation (a), optical (b) and radio frequency (10 MHz Span, 10 KHz RBW) (c) spectra of the mode-locked Yb:glass waveguide laser.

References

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