Passively mode-locked diode-pumped monolithic channel waveguide laser with a repetition rate of 4.9 GHz

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Ultrashort-pulse laser systems operating at gigahertz repetition rates are of considerable interest for applications ranging from biophotonics to optical frequency metrology. Waveguide solid-state lasers in combination with passive mode-locking techniques can offer attractive features for multi-GHz operation. They combine the favourable properties of low-threshold and high-efficiency operation, stable mode-locking at reduced intracavity pulse energy due to strong saturation of both gain medium and a saturable absorber and compatibility with monolithic short cavity designs. Previously, passively mode-locked Er-doped waveguide lasers operating around 1.5 µm have been demonstrated, however, these devices had pulse repetition frequencies in the megahertz range and at low average output powers of about or less than 1 mW level [1,2].

Here we report, for the first time to our knowledge, a passively mode locked Yb:glass channel waveguide laser assembled into a diode pumped monolithic configuration. The laser produced pulses with a duration of 740 fs at around 1.05 µm centre wavelength with a fundamental pulse repetition frequency of 4.93 GHz and an average output power of 81 mW.

An ion-exchange method was used to fabricate channel waveguides in a 12 wt% Yb-doped IOG-1 phosphate glass sample [3]. A 200 nm thick Aluminium mask was used to define channel openings with widths varying from 1 µm to 10 µm after which ion exchange was carried out at 325 ^{o}C for 10 min with a melt composition of 45 mol% KNO_3 – 50 mol% $NaNO_3$ – 5 mol% $AgNO_3$. Following the ion-exchange step, the Al mask was chemically removed and the end facets of the glass were polished to give a device length of 20 mm.

A single-mode fiber-coupled laser diode operating at 980.6 nm and delivering up to 750 mW of average power was used as the pump source. Its beam was coupled into the waveguide through an output coupler by using a 16× aspheric lens that provided 8.8 µm diameter pump spot size. A dichroic beam splitter was used to separate pump and laser radiation. During continuous wave operation of the Yb:glass waveguide laser (the laser cavity was formed by a high-reflector (HR) dielectric mirror and an output coupler (OC) both end butted to the waveguide) average powers of up to 108 mW and 156 mW with 2% and 4% OCs, respectively, were produced. When the HR mirror was replaced by a SESAM (0.4% modulation depth, 0.3% non-saturable losses, 0.5 ps relaxation time), stable mode locking was achieved after careful adjustment of both SESAM and OC positions relatively to the waveguide end facets. With the 2% OC in place, pulses as short as 740fs (Fig. 1(a)) were generated with an average output power of 31 mW at pulse repetition frequency of about 4.93 GHz (Fig. 1(c)). The corresponding optical spectrum (Fig. 1(b)) was centred at 1058 nm with a bandwidth of 2.3 nm implying a time-bandwidth product of 0.46. An average output power up to 81 mW was reached during mode locking at slightly longer pulse durations of 0.8 ps when 4% OC was employed. The waveguide laser output was nearly diffraction limited with M^2 of about 1.1 for both *x* and *y* directions.

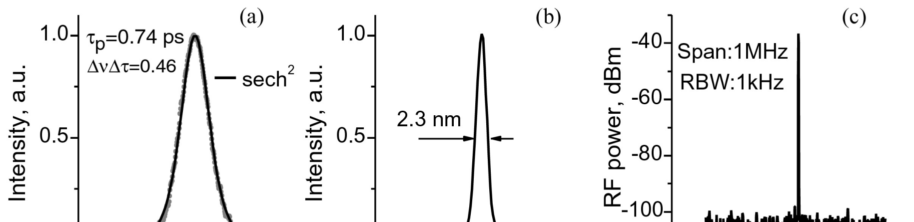

Fig. 1 Intensity autocorrelation (a), optical (b) and radio frequency (c) spectra of the mode-locked Yb:glass waveguide laser.

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