Passive Mode Locking of a Diode Pumped $Nd:Sc_{0.2}Y_{0.8}SiO_5$ Laser

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Abstract: We demonstrate passive mode-locking of a $Nd:Sc_{0.2}Y_{0.8}SiO_5$ laser using a semiconductor saturable absorber mirror. The pulse train shows output power of 0.5 W and pulse duration of 3.5 ps at repetition rate of 118 MHz.
OCIS codes: (140.3530) Lasers, neodymium; (140.4050) Mode-locked lasers

Recently, diode-pumped solid-state lasers based on Nd-doped disordered crystals have attracted significant attention. In mode-locking operation, they have a potential to generate tunable laser radiation as well as to emit multi-wavelength ultra-short pulses, which makes them attractive for terahertz generation [1]. The main drawback that limits the output power is the lower thermal conductivity and the lower stimulated emission cross-section of Nd-doped disordered crystals in comparison with that of Nd:YAG and Nd^{3+} doped vanadates.

Nowadays, mixed $LuYSiO_5$ and $ScYSiO_5$ crystals are introduced as innovative laser hosts with favorable thermal properties. They provide strong inhomogeneous field for Nd^{3+} ions, which induces large ground-state split and inhomogeneously broadened optical spectra. The emission spectrum of lasers based on mixed silicate crystals have multiple closely spaced and well defined spectral bands. Recently, a dual-wavelength mode-locked $Nd:LuYSiO_5$ laser with output power of 1.7 W and pulse duration of 8.9 ps has been demonstrated [2]. Multi-wavelength operation in continuous-wave and Q-switched $Nd:ScYSiO_5$ laser with output power higher than 1 W has also been reported [3]. However, mode-locking operation of $Nd:ScYSiO_5$ laser has not been reported yet.

In this paper we report the first realisation of a diode pumped $Nd:Sc_{0.2}Y_{0.8}SiO_5$ laser, mode-locked by semiconductor saturable absorber mirror (SESAM). We achieve a stable pulse train having pulse duration of 3.5 ps, average output power of 0.5 W and repetition rate of 118 MHz at central wavelength of 1074.6 nm.

The design of the mode-locked laser is based on a 1.3 m long linear cavity (fig. 1). The active element is a 5 mm long $Nd:Sc_{0.2}Y_{0.8}SiO_5$ crystal with 0.8 at. % Nd-dopant. Both 3 x 3 mm^2 end faces are antireflection coated for the laser and pump wavelengths. The crystal is mounted in a copper holder and the temperature is stabilized at 20°C by circulating water. The $Nd:Sc_{0.2}Y_{0.8}SiO_5$ laser is longitudinally pumped by the unpolarized radiation of a 810 nm laser diode bar coupled into an optical fiber with core diameter of 200 μm (NA=0.22). The output beam from the fiber is focused by a reimaging unit and delivered onto the $Nd:Sc_{0.2}Y_{0.8}SiO_5$ crystal with spot diameter of ~270 μm through the highly reflecting mirror M3 which transmits the pump radiation. In order to compensate for the thermal lens in the active element (F_L≈100 mm at absorbed pump power of 5.2 W) and to keep TEM_{00} mode in the cavity at high pump power (5.2 W), M3 is chosen to be a convex mirror with radius of curvature of -413 mm.

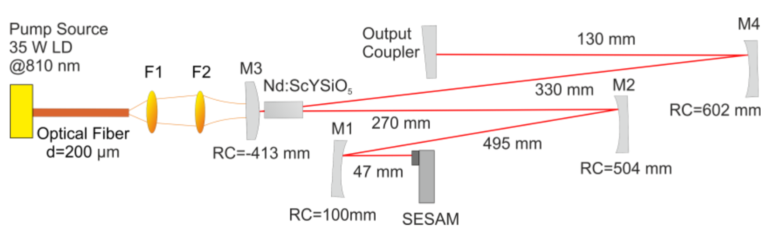

Fig. 1 Laser cavity layout. F1 and F2: aspheric lenses (1.3x imaging unit); active element: $Nd:Sc_{0.2}Y_{0.8}SiO_5$ crystal; M1, M2, M3, M4: highly reflective at 1075 nm; M3: highly transmitting at 810 nm; output coupler: transmitting 5% at 1075 nm.

In order to increase the net gain, we use a cavity configuration with double pass through the laser crystal. The radii of curvature of the mirrors M1, M2, M3 and M4 and the separations given in Fig. 1 are chosen in such a way in order to ensure a beam diameter of ~50 μm ($1/e^2$) on the SESAM and ~250 μm in the active element. The used SESAM has saturation fluence $F_{sat,A}$=50 μJ/cm^2 and modulation depth ΔR=0.5%. A plane mirror with transmission of 5% is employed as an output coupler.

Figure 2(a) shows the measured average output power (black squares) and the slope efficiency (red line) as a function of the absorbed pump power and the slope efficiency (red line) of the laser. The laser threshold corresponds to 0.8 W of absorbed pump power and the slope efficiency is fitted to be 14%. Increasing the absorbed pump power to the range of 4.6-5.0 W, Q-switched mode-locking (Q-ML) regime is observed. Stable continuous-wave mode-locking (CW-ML) operation is obtained at absorbed pump power of 5.3 W with average output power of 0.5 W (fig. 2 (a)). The pulse duration in CW-ML operation is 3.5 ps (FWHM) assuming $sech^2$ pulse shape calculated from the measured autocorrelation curve (fig. 2 (b)). The measured spectrum has a FWHM of 0.6 nm with central wavelength of 1074.6 nm (fig. 2 (b) inset). The time-bandwidth product is 0.58 corresponding to 1.8 times the Fourier limit for $sech^2$ pulse shape.

When the absorbed pump power is increased up to 6 W, a second region of mode-locking operation is observed. In this region a second spectral band centered at 1078.2 nm appears in the spectrum, having about three times lower intensity than the intensity of the one centred at 1074.6 nm. The output power in this regime is around 0.6 W. However, the pulse train stability is very poor.

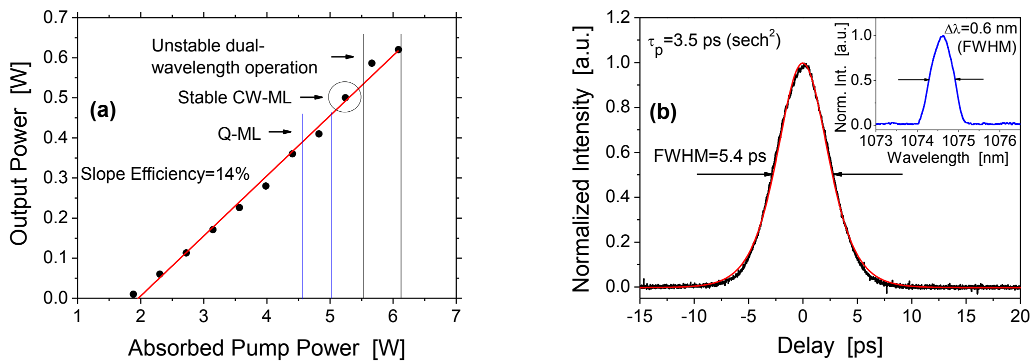

Fig. 2 (a) Input–output characteristics of the $Nd:Sc_{0.2}Y_{0.8}SiO_5$ laser. The region of mode-locked operation marked by a circle; (b) Autocorrelation curve (black), fit assuming $sech^2$ pulse shape (red) and optical spectrum (inset).

In conclusion, we demonstrate passive mode-locking in a diode-pumped $Nd:Sc_{0.2}Y_{0.8}SiO_5$laser with a SESAM. The stable pulse train has average output power of 0.5 W at absorbed pump power of 5.2 W. The pulse duration is 3.5 ps at repetition rate of 118 MHz and central wavelength of 1074.6 nm. To the best of our knowledge, this is the first demonstration of a mode-locking operation of a $Nd:ScYSiO_5$ laser.

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