Compact Femtosecond Nd:glass Lasers Pumped by a Low-Power Single-Mode Laser Diode

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Low-power femtosecond lasers pumped by single-spatial-mode laser diodes [1,2] have attracted recently much attention as a cost-effective solution for many applications, such as seeding of ultrafast amplifiers and biomedical diagnostic, requiring only modest average power of few milliwatts. Recently we demonstrated a 173-fs Nd:phosphate laser pumped by a low-power 150-mW single-mode laser diode [3]. Now we report on a Nd:silicate glass laser pumped by a 200-mW single-mode laser diode. The resonator was based on an X-folded cavity as in Fig. 1. The mirror M3 is meant only for cw operation. In this regime, after minimizing the mismatch between the pump beam and the transversal mode resonating in the cavity we obtained a maximum output power of 37.5 mW with an optimum coupling of 3% that allowed 36% slope efficiency, the highest reported for this laser material to the best of our knowledge.

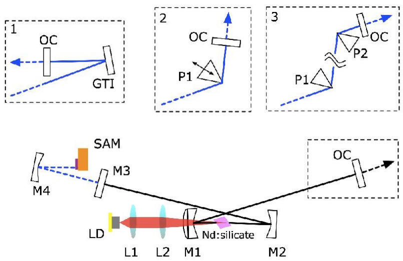

Fig. 1 Cavity setup.

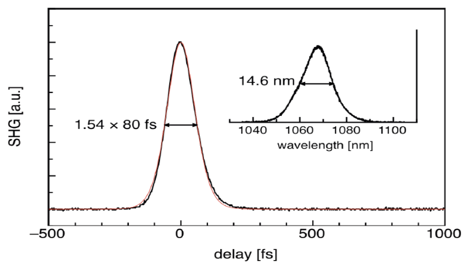

Fig. 2 Pulse autocorrelation and spectrum.

For the investigation of the mode-locking regime the mirror M3 was replaced by a concave mirror M4 (75-mm radius of curvature) in order to focus the cavity mode on the semiconductor saturable absorber mirror (SAM, 1.2% modulation depth).

In order to compensate for the group-velocity dispersion (GVD), we employed initially a Gires-Tournois mirror (nominal dispersion of -375 fs^2) that yielded self-starting mode-locking with spectral bandwidth of 8.6 nm and pulse duration of 147 fs at 190-MHz repetition rate with average power of 7 mW. Moreover we employed a standard GVD-compensation scheme using an SF10 prism pair that allowed to achieve pulses as short as 80 fs, with 14.6-nm spectral bandwidth (Fig. 2) at a repetition rate of 170 MHz with 6.5 mW of average power. Eventually, we exploited a single prism setup after a careful modeling of the resonator dispersive properties through ABCD ray-tracing, suggesting fused silica as the most promising prism material. In particular, we found that the transversal dispersion $dx/d\lambda$ occurring in the gain medium, given the resonator geometry and the pulse spectrum width, is proportional to the prism glass dispersion $dn/d\lambda$. Therefore, the effective bandwidth $\Delta\lambda_{eff}$: $2\sqrt{g}\ w/|dx - d\lambda|$ of the single-prism dispersive resonator can be estimated by assuming that the transverse shift of the mode axis in the laser medium at $\lambda+\Delta\lambda$ produces a round-trip maximum gain reduction comparable to the saturated gain g, considering a gaussian pump distribution of radius w. For this reason we chose fused-silica prism instead of SF10 that has $dn/d\lambda$ twice as larger, to minimize the transversal wavelength dispersion in the gain medium. This optimizes the resonator effective bandwidth $\Delta\lambda_{eff}$ and minimizes the pulse width. Pulse as short as 158 fs ($\Delta\lambda$=9.8nm) were generated at 1062 nm, while the tuning range extended from 1058 nm to 1076 nm, with output power from 7 to 14 mW and 250-MHz repetition rate. The pulse width increased to 240 fs at the longest and shortest wavelengths. For this single-prism cavity we used a 0.8% transmissivity output coupler that allowed an efficient power extraction given the total (unsaturable) intracavity losses of about 1% and considering the inability of the laser to sustain a bandwidth larger than 10 nm owing to wavelength spatial dispersion in the glass medium. For comparison, the shortest 80-fs pulse duration with the two-prism setup was obtained by a 0.4% transmissivity output coupler that increased the intracavity energy and self-phase-modulation effect.

References

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