All-solid-state continuous-wave laser source at 313 nm for laser cooling of Be^+ ions

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An all-solid-state laser system operated at a wavelength of 313 nm is developed for laser cooling of Be^+ ions aimed at hyperfine anomaly measurements of Be isotope ions, including the neutron halo nucleus ^{11}Be[1], and sympathetic cooling of highly charged ions with Be^+ ions.

Laser beams at 313 nm were traditionally produced by second-harmonic generation (SHG) of a 626 nm radiation obtained from a dye laser[2]. However, compared with such a liquid laser, a solid-state laser is more suitable for long-term operation because of its reliability and stability. In recent years, solid-state laser systems to provide light in a single-mode at 313 nm have been demonstrated: sum-frequency generation (SFG) of a 532 nm frequency doubled Nd:YAG laser and a 760 nm Ti:sapphire laser[3], frequency quintupling of a 1565 nm amplified fiber laser system[4], SHG of a 626 nm laser light by SFG of amplified fiber laser systems at 1550 nm and 1051 nm[5], and frequency doubling of a 626 nm light from a cooled down diode laser[6]. Although some of these can produce 313 nm light with a high power of more than 100 mW, they are expensive. The procedure in Ref.[6] is the cheapest but it requires a very high finesse SHG cavity, which might cause a noisy output because the fluctuation of the cavity length needs to be suppressed to the level much smaller than the ratio of the laser wavelength to the finesse and the fluctuation of the laser frequency is required to be much smaller than the ratio of the free spectral range to the finesse.

We develop a cost-efficient laser system with a reasonably high output power as shown in Fig. 1. Laser light at 939 nm from a Littrow configuration external-cavity diode laser (ECDL) is amplified up to ~2 W through a tapered amplifier (TA) chip (m2k-TA-095-2000). The high power 939 nm light is delivered through an optical fiber and divided into two beams. One is injected into a SHG cavity with a type-I phase-matching BiB_3O_6 crystal to produce 470 nm laser light. The other 939 nm beam and the 470 nm SHG output beam are injected into a SFG cavity with a type-I phase-matching BBO crystal to produce 313 nm laser light with an expected power of ~5 mW, which is high enough for laser cooling of Be^+ ions. The cavity lengths are controlled by using Pound-Drever-Hall locking[7] with the reflected pump beams from the input couplers, which are monitored by photodetectors (PDs). The sidebands required for the locking scheme are generated by an electro optical modulator (EOM).

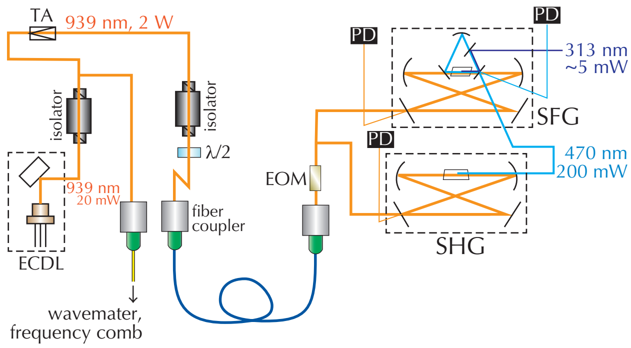

Fig. 1. Schematic diagram of the laser setup.

Figure 2 (a) shows the measurement results of the injection current dependence of the output power from the TA chip at 22.01 °C with a seed light of 10 mW. The output power of the single-mode laser light from the fiber output coupler was 900 mW with a fiber input of 1.72 W, including the amplified spontaneous emission background. The highest 620 mW power of the 470 nm laser was obtained from SHG at a pump power of 900 mW, as shown in Fig. 2 (b), which means we achieved a high second harmonic conversion efficiency of ~70 %. Although tuning of SFG cavity is now under way, we have a high degree of expectation for this novel scheme to produce laser light at 313 nm intense enough for laser cooling experiments.

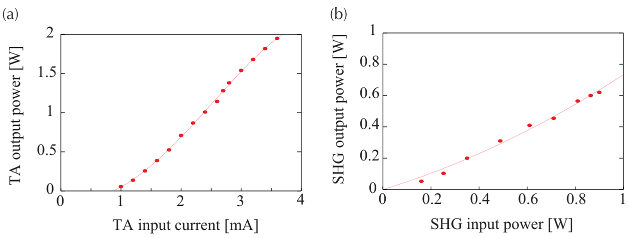

Fig. 2. (a) TA output power as a function of injection currents with a seed light of 10 mW at 939 nm. (b) Output power of SHG as a function of the input power of 939 nm laser light.

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