Tunable single-frequency Nd:YVO_4/BiB_3O_6 red laser for lithium spectroscopy

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All solid-state continuous-wave (cw) narrow-linewidth tunable red lasers are convenient alternative sources to bulky and expensive dye-lasers for high-precision laser spectroscopy. In order to efficiently laser cool Lithium atoms (Li) on the $^2S_{1/2}$– $^2P_{1/2}$ dipolar transition (as a preliminary step toward Bose-Einstein Condensation), watt-level single-frequency (i.e. single-longitudinal mode or SLM) laser source at 671nm is required. This wavelength can be synthesized from a frequency-doubled diode-pumped Nd^{3+}:YVO_4 laser operating on the π-polarized $^4F_{3/2}$ - $^4I_{13/2}$ transition (λ=1342nm). Most of the works related to cw intracavity second-harmonic generation (ICSHG) of 1.34 μm Nd-lasers employed linear standing-wave resonators and were focused on power scaling rather than spectral purity [1,2]. Stable single-frequency operation was only achieved at 671nm with 370 mW using a standing-wave cavity and a type II non-critically phase matched LBO crystal that served also as a birefringent etalon for hole-burning and axial mode suppression [3]. In this work [4], in order to avoid hole-burning modes we employ a single-end longitudinally pumped, unidirectional Nd:YVO_4 ring resonator containing a type-I cut (θ=8.6°,φ=0°) BiB_3O_6 (BiBO) nonlinear. A low-doped (0,15at%) 10 mm long Nd:YVO_4 crystal is used in order to decrease the thermal lens generated inside the crystal, resulting in ~90% absorbed fiber-coupled diode pump power at 808nm. A fused silica thin etalon with facets reflectivity of 40% is placed near the larger beam focus inside the cavity to minimize insertion loss. The unidirectional operation is obtained using a Brewster-cut TGG Faraday rotator and a zero-order half wave plate. The 10 mm long BiBO crystal is placed between two curved mirrors at the smaller cavity waist (w_0~ 50μm).

Before investigating the ICSHG performance, we have preliminary optimised the fundamental wave (FH) output power performance of the laser by replacing one mirror with partially transmitting output couplers (T = 1%, 2%, and 5% at 1342 nm). The optimum output coupler was found to be T=2% giving a maximum in a multimode operation of 1.7 W output power at an absorbed pump power of P_{abs} = 10.5 W without any etalon, Fig. 1a. When the BiBO was inserted the laser oscillates in single frequency with a record of 680mW owing to the self-suppression of longitudinal modes in a homogeneously broadened laser (higher loss experienced by sum frequency processes between longitudinal modes). Using the theory of single-frequency ICSHG developed by Polloni *et al* [5], the efficiency of conversion was measured as 5%. Due to the effect of excited-state absorption (ESA) on the π-polarized stimulated emission (SE) cross-section at 1339.5nm the tuning profile is asymmetric (Fig.1c), decreasing the SLM red power available at the Li ($^2S_{1/2}$– $^2P_{1/2,3/2}$) transition (670.97nm) to ~200mW. A higher red efficiency and power could be achieved using a longer BiBO crystal or a periodically-poled crystal with higher nonlinearity such as ppKTP (d_{eff} = 9pm/V). Direct diode pumping at ~880nm into the $^4F_{3/2}$ emitting level can also be envisioned to reduce the thermal load of the Nd:YVO_4 crystal.

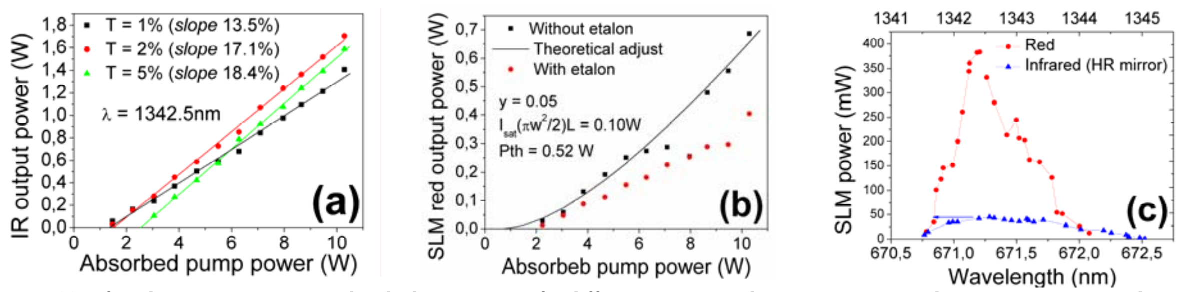

Fig. 1. (a) Infrared output power versus absorbed pump power for different output couplers transmittance without any intracavity etalon. (b) Red output power versus absorbed pump power with (circles) and without (square) the R=40% coated thin etalon with the theoretical adjust and (c) Tuning curve of the red emission (circles) and infrared emission when HR mirrors were used (triangles).

References

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