32% efficient, 9.6 W, continuous-wave, Yb-fiber-laser-pumped single-pass second-harmonic-generation in MgO:sPPLT

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Advances in laser technology continually rely on the development of novel coherent light sources in new temporal and spectral regions. Combined with nonlinear frequency conversion techniques including second-harmonic-generation (SHG), sum-frequency-mixing, optical parametric generation, amplification, and oscillation, such new sources can provide unprecedented capabilities in previously inaccessible temporal and spectral regions across the UV, visible and IR [1]. A particularly important cornerstone of laser technology over the past decade has been the generation of green radiation, for example, as workhorse for pumping of Ti:sapphire and other tunable laser systems. In the continuous-wave (cw) regime, the current status of this technology relies almost exclusively on internal frequency doubling of cw Nd-based solid-state lasers [2]. However, the high cost and design complexity of such systems point to the need for the development of alternative techniques offering simpler design, improved practicality, and lower cost. By taking advantage of the major advances in fiber laser technology and improved nonlinear materials, it is now possible to develop a new generation of efficient, high-power and practical cw green sources in compact, portable and cost-effective design using simplified nonlinear frequency conversion techniques. Here, we present such a source based on simple single-pass SHG of a cw ytterbium (Yb) fiber laser in MgO:sPPLT, providing a single-frequency cw power of as much as 9.64 W at 532 nm with a conversion efficiency of 32.7%.

The experimental set-up consists of cw single-frequency Yb fiber laser (IPG Photonics, YLR-30-1064-LP-SF) at 1064 nm, which delivers an output power of 30 W in a linearly polarized beam of diameter of 3.0 mm, M^2 factor <1.01 and instantaneous linewidth of 12.5 MHz. The nonlinear crystal is a 30-mm-long MgO:sPPLT [3], containing single grating (Λ_{QPM}=7.97 µm), and housed in an oven with a temperature stability of ±0.1°C. The fiber laser beam is focused to a waist radius of w_0~31 µm at the centre of the crystal. A dichroic mirror (R>99%@1064 nm; T>94%@532 nm) separates the pump from the generated SH beam. Figure 1 shows the variation of the generated SH power and conversion efficiency with input pump power, where a quadratic increase in SH power and linear increase in conversion efficiency is observed up to 22 W of pump power, after which saturation occurs, essentially due to appreciable thermal phase-mismatch in the MgO:sPPLT crystal. At the phase-matching temperature of 50.5 °C and maximum input pump power of 29.5 W, we obtain SH power of 9.64 W, corresponding to a conversion efficiency of 32.7%. The long-term power stability near the maximum green power of 9.64 W is shown in Fig. 2. Under free-running conditions and in the absence of thermal isolation, the green power exhibits a peak-to-peak fluctuation of 7.6% over the first 8 h and 9% over 13 h. The inset of Fig. 2 shows the measured green beam profile and corresponding to TEM_{00} power distribution. In order to confirm the transverse power distribution, we have measured M^2 values of the green beam to be M_x^2~1.29 and M_y^2~1.23 with an ellipticity ~0.96. We have also measured the frequency stability of the generated green at 9.64 W using a wavemeter (High finesse, WS/U-30). Under free-running conditions and in the absence of thermal isolation, the green output exhibits a pk-to-pk frequency stability <115 MHz over the 90 min, with a short term stability <32 MHz over 30 min, showing higher frequency stability than a commercially cw green source (Coherent, Verdi-10) in our laboratory, which we measure to have a frequency stability of 2.2 GHz over 40 min. We expect to achieve power scaling beyond 9.64 W by improved management of thermal effects and this will also be discussed.

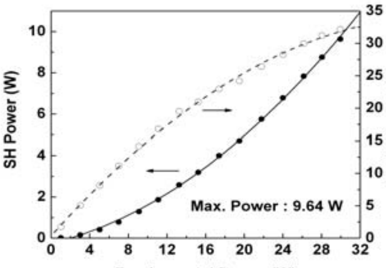

Fig. 1 SH power and SH efficiency as a function of input pump power. Maximum output power is 9.64 W corresponding to 32.7% conversion efficiency

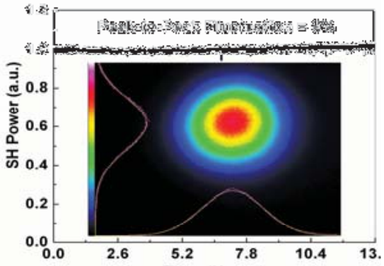

Fig. 2 Green output power stability at 9.64 W over 13 hours (Inset- far-field TEM_{00} power distribution and beam profiles of the generated green beam)

References

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[2] See, for example, commercial systems such as Coherent, Verdi; Spectra-Physics, Millennia; and others.
[3] G. K. Samanta, G. R. Fayaz, and M. Ebrahim-Zadeh, "High-power, continuous-wave, singly resonant optical parametric oscillator based on MgO:sPPLT," Opt. Lett., 32, 2623 (2007). MgO:sPPLT crystal was supplied by HC Photonics Corporation, Taiwan.

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