Q-switched Nd-doped depressed clad hollow optical fiber laser operating at 927 nm and its frequency doubling to blue light

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Cladding-pumping has enabled unsurpassed scaling of the average output power of fiber lasers. However, the relatively low pump absorption compared to core-pumped fibers creates problems for three-level fiber laser at several wavelengths. One example is Nd-doped fiber lasers at ~ 930 nm. Nonlinear degradation is another problem which can even limit the pulse energies and peak powers of pulsed fibers to lower values with cladding-pumping than with core-pumping. This can be a concern for frequency-doubling in crystals such as BiB_3O_6. A large core facilitates three-level operation of cladding-pumped fibers and also mitigates nonlinear degradation such as spectral broadening. In addition, it improves the energy storage as well as the damage threshold.

In this work, we used a Nd-doped depressed clad hollow optical fiber (DCHOF) geometry[1], which is comprised of a ring-shaped core, an air hole in the centre and depressed inner clad. This allows for core area scaling of cladding pumped 930 nm fiber lasers. A DCHOF has a LP_{01} mode cut-off at a finite wavelength, which makes the fiber act as a distributed wavelength filter that suppresses competing emission at 1060 nm. We achieved 1.3 kW of peak power in 140 ns long pulses at 927 nm from a Q-switched Nd:Al-doped DCHOF laser. The pulses were then frequency doubled in a BiB_3O_6 crystal which resulted in 50 mW of average power at 463.5 nm. The experimental setup is shown in Fig. 1. An end-pumped 8 m long Nd-DCHOF was perpendicularly cleaved in the pump launch end to provide 4% Fresnel feedback for the laser cavity. At the other end a high reflector (100% @ 930 nm) was used to close the laser cavity. The fiber end was angle-cleaved. The pump absorption was 0.48 dB/m at 808 nm. The laser cavity was Q-switched by an acousto-optic modulator (AOM) between the fiber and the cavity reflector. The transmission of the AOM was ~70% in its deflecting "on" state. At 5 kHz repetition rate, the maximum pulse energy and peak power were achieved. The laser output was taken from the pump launch end. The maximum average output power was 902 mW at a wavelength of 927 nm (Fig. 2a). The pulse energy and pulse width were 176 μJ and 140 ns respectively. The corresponding peak power was 1.3 kW. The output beam, after passing through a half wave-plate, was focused into the BiB_3O_6 nonlinear crystal. The frequency-doubled power and spectrum are shown in Fig. 2b. The maximum blue average power was 50 mW at 463.5 nm. In spite of the mixed-polarized output at 927 nm, blue light generation via simple frequency doubling in the crystal was possible due to the high peak power of the laser output at 927 nm with M^2 ~ 1.08.

Higher powers and frequency-doubling efficiencies have previously been demonstrated with an amplified Q-switched Nd:YVO4 laser [2]. Compared to that result, our set-up is simpler and uses a fiber with larger core and inner cladding. This will allow for significant scaling of average power once higher-power pump diodes become available.

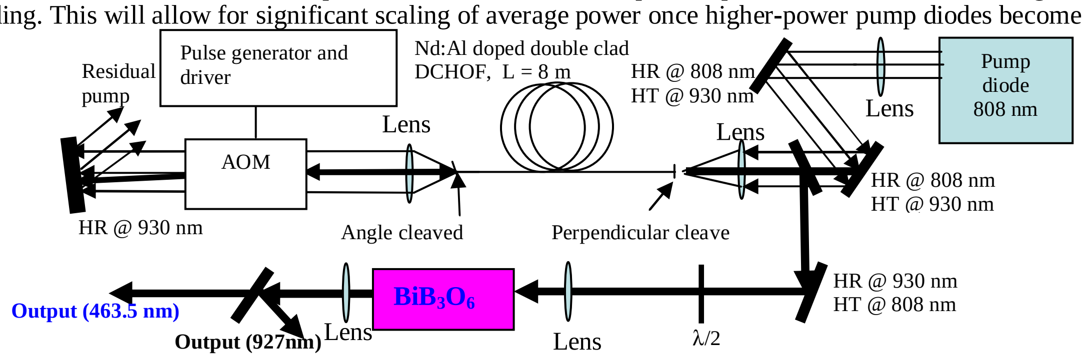

Fig. 1 Experimental set-up of the Q-switched Nd:Al -doped DCHOF laser at 927 nm and its frequency doubling.

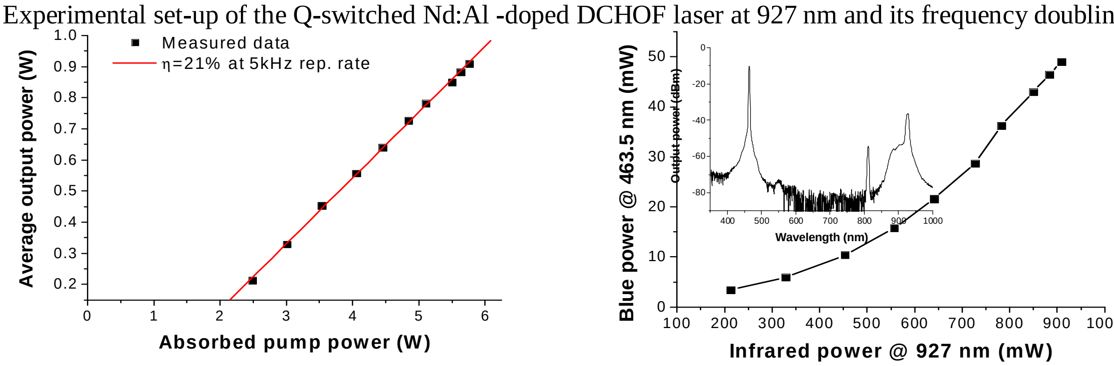

Fig. 2a. Q-switched laser output characteristics at 927 nm. **Fig. 2b** 463.5 nm blue light output characteristic and spectrum (OSA resolution: 2 nm). The maximum blue power was 50 mW.

References

1. J. Kim, P. Dupriez, D. B. S. Soh, J. Nilsson, and J. K. Sahu, Optics Letters, 31(19), 2833-2835 (2006).
2. T. J. Kane, et al., in Proc. Advanced Solid-State Photonics, Santa Fe, USA, Feb. 2–5, 2004, Paper MD8.