Two new blue laser emission lines from an intracavity Raman laser

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Abstract: Here we report quasi-CW operation of intracavity Raman laser generating three blue laser emission lines at 454 nm, 473 nm and 495 nm with a maximum output power of 230 mW.
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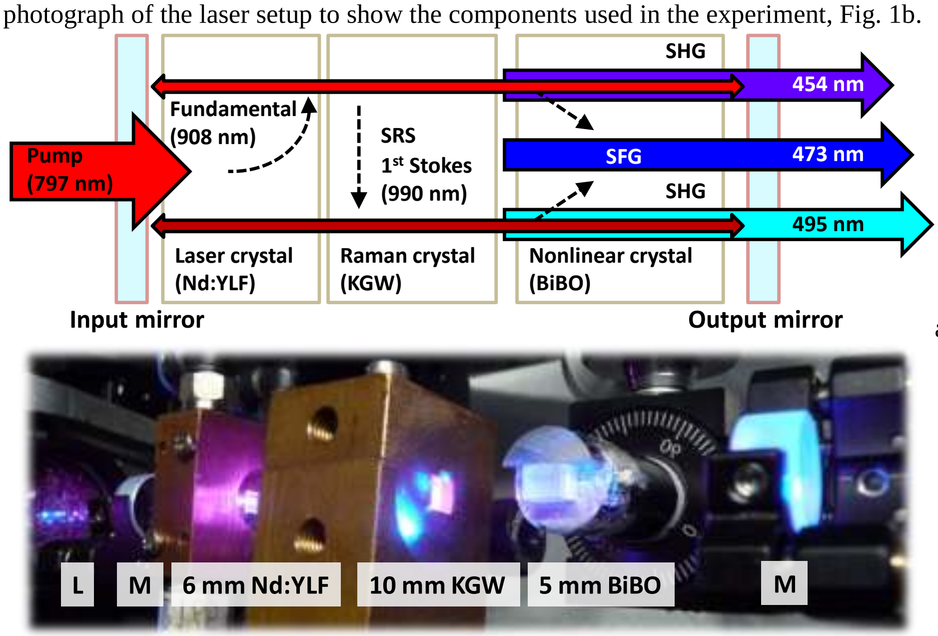
1. Introduction

Crystalline intracavity Raman lasers offer an efficient approach to generating CW or Q-switched laser output at many wavelengths in the near-infrared and visible spectral regions, that are "hard to reach" by other means [1,2]. In CW Raman lasers, stimulated Raman scattering (SRS) takes place inside a high-Q cavity where it profits from the highly enhanced intracavity fundamental field [3]. By further incorporating intracavity sum frequency generation, laser output in the yellow-orange-red spectral region can be obtained [4–6]. Aided by continuous improvements in crystal quality and coating technologies, optical to optical (diode pump to visible) efficiencies in excess of 20% have been achieved [4]. Here we present, to the best of our knowledge, the first intracavity Raman laser emitting three blue emission lines at 454 nm, 473 nm and 495 nm.

2. Experimental setup

The Raman laser is based on a fundamental field at 908 nm originating from a Nd(0.6%):YLF operating at its quasi three level transition. A fiber-coupled quasi-CW diode source at 797 nm with a pulse duration of 691 μs at 50 Hz is used to pump the Nd:YLF crystal. Inside the same cavity a KGW crystal is placed with its orientation $E//N_m$ to access the 901 cm^{-1} Stokes shift, resulting in a buildup of Stokes emission at 990 nm. Using a BiBO frequency doubling crystal inside the cavity SHG of the fundamental or Stokes field is generated resulting in emissions at 454 nm and 495 nm, respectively. The coexistence of both fundamental and Stokes fields inside the cavity further allows SFG, generating an emission at 473 nm. A schematic of the involved optical processes is presented in Fig. 1a, supported by a photograph of the laser setup to show the components used in the experiment, Fig. 1b.



a)
b)

Fig. 1, a) Schematic representation of the setup used to generate the blue laser emission, and b) a photograph of the setup generating laser emission at 473 nm. Here "M" indicates the position of two concave (ROC = 50 mm) cavity mirrors and "L" indicates the pump focusing lens. Note that both figures are aligned with respect to each other, for ease of identification of the used components.

3. Laser performance at 454 nm, 473 nm and 495 nm

By simply changing the angle of the BiBO frequency doubling crystal, by a few degrees, three blue emission lines could be generated. The three recorded spectra are shown in Fig. 2.

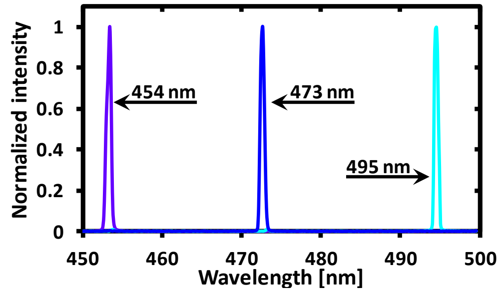


Fig. 2. Recorded spectra of the three blue laser emission lines at 454 nm, 473 nm and 495 nm.

A maximum output power of 570 mW was measured at 454 nm, the second harmonic of the 908 nm fundamental. The second harmonic of the Stokes emission occurred at 495 nm, and the maximum power achieved was 30 mW. However laser instabilities hampered a thorough characterization of this emission line, and we speculate that this may have been due to competition effects between the optical process occurring in the resonator. Stable emission was observed at 473 nm, the sum frequency of the fundamental and Stokes fields, and therefore laser performance at this wavelength was investigated in greater detail. Two BiBO crystal lengths of 5 mm and 10 mm were investigated, resulting in output powers of 0.23 W and 90 mW respectively, as shown in fig. 3. Note that these reported quasi-CW powers are measured during the on-time, and that a similar amount of blue light was generated in the counter propagation direction, and not included in this characterization.

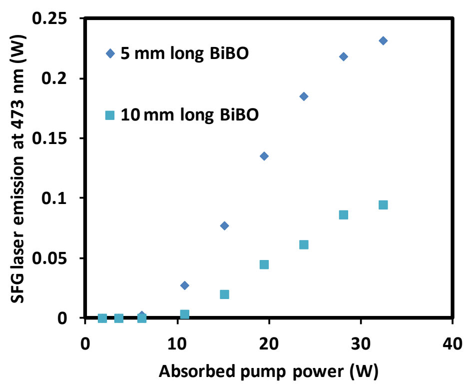


Fig. 4. Input-output curves of the single sided blue laser emission at 473 nm using 5 and 10 mm long BiBO crystals.

4. Conclusions and discussion

Here we report, to the best of our knowledge, the first blue laser based on an intracavity Raman laser. We have observed output at three blue wavelengths: 454 nm, 473 nm and 495 nm with output powers of 570 mW, 230 mW and 90 mW respectively. The interaction of the intracavity fields leads to complex laser dynamics which hamper efficient extraction of the 495 nm spectral emission line, and we anticipate further investigation of these will lead to improved laser performance.

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5. References

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