Wavelength selectable Raman laser in the ultraviolet (266 to 321nm)

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A small number of ultraviolet (UV) lasers sources are available at wavelengths between the 3rd and 4th harmonics of Nd lasers (265-350 nm), a spectral region where there is emerging demand in biohazard detection, environmental sensing and defence. Cerium doped fluoride lasers and AlGaN semiconductor diodes are presently receiving substantial interest owing to their significant practical advantages over frequency-doubled dye lasers and optical parametric oscillators. There is a need, however, for robust narrow-band UV sources with a broad range of output wavelengths.

Raman lasers based on crystalline Raman materials are versatile sources of laser output in the mid-infrared and yellow orange regions of the spectrum. The fundamental laser source is usually a Nd laser, such as Nd:YAG or Nd:vanadate, due to its wide availability and suitably high spectral power density and conversion efficiencies for the Raman process often exceed 50%. While direct nonlinear frequency conversion of visible (eg., yellow) Raman lasers provide a straightforward method of generating UV output near 290nm[1], important advantages are to be gained by placing the sum frequency / second harmonic medium intracavity. The higher intracavity fields in the nonlinear medium assist in enhancing conversion efficiency. Also, for resonators designed to co-oscillate fundamental and multiple Stokes fields, output at a range of sum-frequencies or second-harmonics may be selected according to the phasematching conditions in the nonlinear crystal. For example, switchable output amongst 4 laser wavelengths in the range 532-606 nm has been demonstrated for an intracavity Raman laser by angle tuning or temperature tuning an intracavity sum frequency mixing crystal[2].

We now report a solid-state UV Raman laser pumped at by a Q-switched 532 nm laser that utilizes intracavity sum-frequency mixing to generate more than 20 wavelengths in range 266-321nm. The Raman laser consisted of a $KGd(WO_4)_2$ Raman crystal and beta-barium borate (BBO) crystal positioned in a resonator as shown in the Figure. The input coupler is highly transmissive at 532 nm and highly reflective for the first three Stokes orders (HR 559-660 nm). The second harmonic or sum frequencies of the intracavity Stokes and fundamental fields were coupled from the resonator using a UV reflecting dichroic mirror placed between the BBO crystal and the Raman crystal. This method of output coupling ensures that generated UV does not impinge on the $KGd(WO_4)_2$ crystal, which has poor transmission for $\lambda<350$ nm.

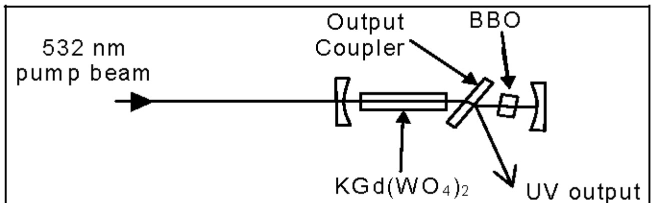

Figure: Layout of the Raman laser with intracavity nonlinear mixing.

When the $KGd(WO_4)_2$ is oriented for excitation of the 901cm^{-1} Raman mode (ie.,the pump polarization is aligned to the N_m crystallographic axis), we observe wavelength selectable output between 8 wavelengths spaced in frequency by the Raman shift. Output at longer wavelengths, corresponding to frequency mixing of high Stokes orders, was limited due to the limited bandwidth of the resonator mirrors. Output pulse energies of up to 0.22 mJ at 10 Hz pulse repetition rate and average output powers up to 48 mW at 5 kHz were achieved. Output efficiencies were typically 1-5% depending on the selected output wavelength.

Many applications often require specific targeting of wavelengths and access to more wavelengths are desirable. We also show that output on up to 15 additional wavelengths can be achieved by simply rotating the Raman crystal 90° about the beam axis. For this orientation, the Raman gain cross-section is comparable for the 768cm^{-1} and 901cm^{-1} modes and as a result the generated Stokes fields include mixtures of the two Raman shifts. The first 4 Stokes orders of the 768cm^{-1} Raman mode are generated along with the first Stokes of the 901cm^{-1} mode and this line shifted by up to 3 orders by the Raman 768cm^{-1} mode. The UV output consists of a large range of possible harmonics including the second harmonic and sum frequency of the fundamental and Stokes orders of the 768cm^{-1} Raman mode (eg., 271.6, 277.4, 284.5, 289.7, 296.3, 303.2 and 310.4nm) and lines involving the Stokes component of the 901cm^{-1} mode (eg., 272.6, 284.5, 290.8, 304.4, 305.7, 311.7 and 320.7nm).

We conclude that the intracavity Raman laser provides a wavelength versatile source of UV at wavelengths spanning and neighouring the UV-B (285-315nm). Note that wavelength choice can be considerably extended by suitable choice of pump laser and Raman material.

References

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