Generation of coherent cw radiation tunable from 211 nm to 216 nm

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Many spectroscopic studies require a source of coherent cw radiation tunable in the uv. Continuous wave radiation in the 257–360-nm range has been generated by sum frequency mixing, in potassium dihydrogen phosphate (KDP) and its isomorphs, selected output lines from an argon or krypton ion laser with the output of a cw dye laser.[1] Recent studies of mixing in potassium pentaborate (KB5) using pulsed laser systems[2] however suggested that cw radiation at wavelengths considerably shorter than 257 nm could be generated by mixing, in an angle-tuned KB5 crystal, with the uv output lines of an ion laser. The input wavelengths required to produce phase matched sum frequency mixing with the uv lines of an argon ion laser, calculated by use of the data obtained using pulsed laser systems,[2] are shown in Fig. 1, as a function of the angle ϕ between the direction of propagation of the interacting beams and the b axis of the crystal, for angle tuning in both the **ab** and bc planes. It is evident from Fig. 1 that, with input wavelengths readily available from cw dye laser systems, tunable uv radiation can be generated over a considerable wavelength range which extends below that obtainable by direct second harmonic generation. The present Letter reports the generation of tunable cw radiation in the 211–216-nm range by mixing in KB5.

A Spectra-Physics model 375 dye laser was used in the present study and provided an output linewidth of ~0.5 Å. The dyes employed were rhodamine 110 and rhodamine 6G. The output of the dye laser was combined with the uv output of a Spectra-Physics model 171 argon ion laser by means of a dichroic mirror. The superposed beams, which were both vertically polarized, were optimally focused[3] into the mixing crystal by a 100-mm focal length fused quartz lens. In order to compensate for the chromatic aberration introduced by this lens, the dye laser beam was prefocused prior to superposition of the beams so that the interacting beams had common waists and focal positions within the crystal. The powers in the input beams were determined by use of a thermopile. The output beam emerging from the crystal was recollimated by a fused quartz lens and was separated from the remaining input radiation by a fused quartz prism. The output radiation was detected either by the fluorescence it generated on a phosphor screen or by a calibrated EMR type 541-G-08-18 solar blind photomultiplier, which was also used to determine the output power.

The KB5 crystal employed was a cube of 10-mm sides with entrance and exit faces perpendicular to the b axis. The crystal was located in a sealed cell equipped with fused quartz windows and oriented such that the input beams were polarized along the a axis. The cell was fixed in a mount which provided rotation about a vertical axis. At other than normal incidence the two input beams are refracted through slightly different angles as they enter the mixing crystal, and, in consequence, minor adjustments in input beam alignment are

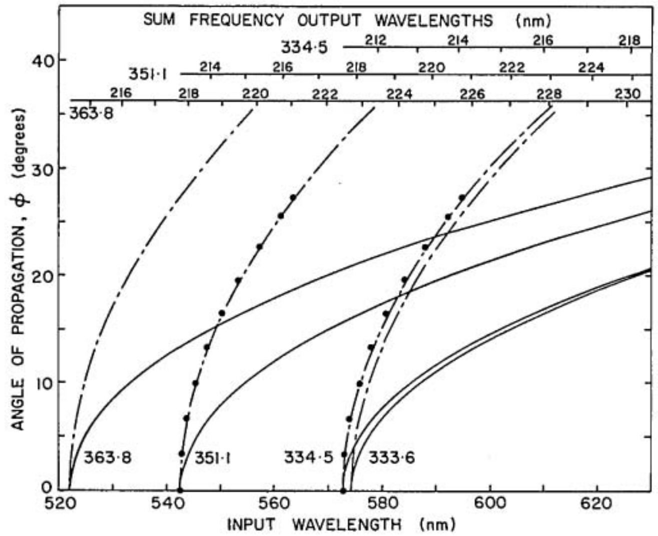

Fig. 1. Angle-tuning curves for sum frequency mixing with the uv output lines of an argon ion laser in KB5. Output wavelength scales for mixing with individual uv lines are included. ● experimental data; calculated values, — angle tuning in ab plane, – – – – – – angle tuning in bc plane.

required to optimize the output power at different angles of propagation.

The measured angle tuning data for sum frequency mixing with the 334.5-nm and 351.1-nm argon lines are shown in Fig. 1 and are in excellent agreement with the calibrated angle-tuning curves. Mixing with the 363.8-nm argon line was not investigated as the dye laser optics required for operation with the coumarin dyes were not available. In the present work cw radiation continuously tunable from 211 nm to 216 nm was generated, although, as is evident from Fig. 1, tunable cw radiation at wavelengths extending beyond 230 nm can be generated in a KB5 crystal angle tuned in the ab plane.

The sum frequency conversion efficiency, defined as the ratio of the output power to the product of the input powers, was also determined. Efficiencies of $\sim 5 \times 10^{-6}$ W^{-1} were realized at $\phi = 0$, decreasing to $\sim 1.5 \times 10^{-6}$ W^{-1} at ϕ 25°. These conversion efficiencies are much less than those realized in KDP and its isomorphs as a result of the small nonlinear coefficient of KB5.[4] Nonetheless given the input powers typically available from cw dye lasers and argon and krypton ion lasers, these efficiencies are sufficient to enable the generation of cw output powers of ~50–100 nW, more than sufficient for a wide variety of spectroscopic applications.

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