Sum Frequency Generation of Narrowband cw 194 nm Radiation in Potassium Pentaborate

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Radiation pressure cooling and optical pumping of electromagnetically confined mercury ions, which have enormous potential in optical and microwave frequency standards [1], require a narrowband cw source near the $6s^2S_{\frac{1}{2}} - 6p^2P_{\frac{1}{2}}$ first resonance line at 194 nm. We describe a method for producing 194 nm radiation by sum-frequency-mixing, in a potassium pentaborate (KB5) crystal, the 257 nm second harmonic of the output of a single mode cw 515 nm argon-ion laser with the output of a tunable cw laser in the 792 nm region [2,3].

A schematic of the experimental set up is shown in Fig. 1. The primary radiation sources are a ring dye laser operating with the dye LD700 near 792 nm and a 257 nm source which is the frequency-doubled output of the 515 nm line of an argon-ion laser. The 257 nm second harmonic is generated in an ammonium dihydrogen phosphate (ADP) crystal, which is placed in an external ring cavity that is resonant at the fundamental frequency. A 30mm x 5mm x 5mm Brewster-cut KB5 crystal is used for sum frequency mixing. In order to enhance the 792 nm radiation power inside the crystal, this crystal is also placed inside an external ring cavity. With input powers of 25 mW at 257 nm and 220 mW at 792 nm, and a power enhancement of 12 in the external cavity, about 2 μW of single frequency 194 nm radiation is obtained. This corresponds to an efficiency parameter of about $3 \times 10^{-5} W^{-1}$ for the sum frequency mixing process. The linewidth of the 194 nm output is less than 2 MHz since the linewidth of each primary beam is about 1 MHz.

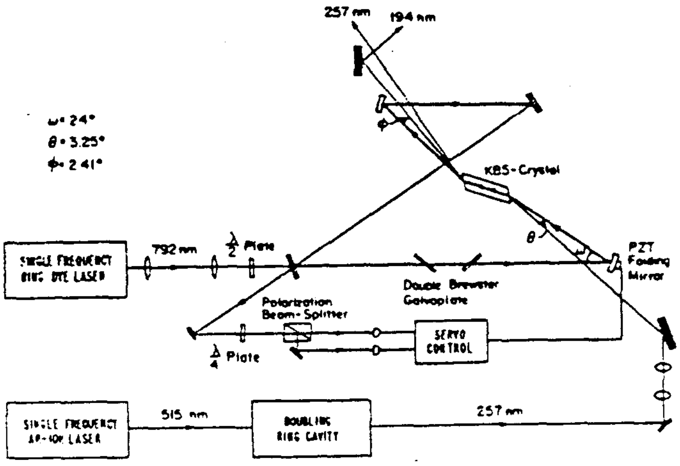
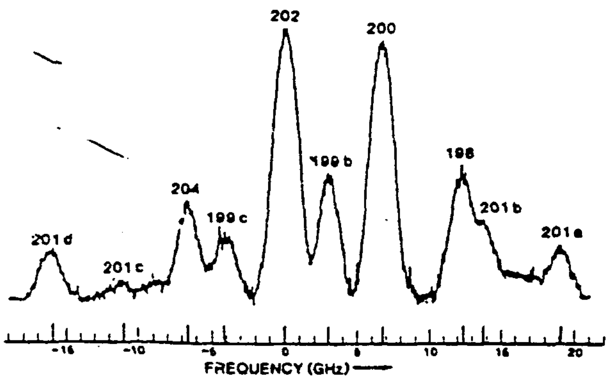


Figure 1. Experimental setup for generation of 194 nm radiation in an external ring cavity

A study was made of the isotope and hyperfine structure of the $6s^2S_{\frac{1}{2}}$ - $^2P_{\frac{1}{2}}$ 194.2 nm transition of singly ionized mercury ions by absorption)ectroscopy. The Ar-ion laser was stabilized to a hyperfine)mponent in $^{127}I_2$ while the dye laser was tuned in frequency. The :ternal enhancement ring cavity was locked and synchronously scanned ,th the dye laser. The absorption spectrum was obtained by probing the ound state of the mercury ions which are created in a cell excited by i electrodeless rf discharge. A single scan of the isotope and 'perfine structure of the 194 nm transition is shown in Fig. 2. An ;solute wavelength measurement was made of the $^{202}Hg^+$ line by means of a :velength meter which uses a stabilized He-Ne laser reference and has an :curacy of a few parts in 10^7. The vacuum wave number for the $6s^2S_{\frac{1}{2}}$ - $^2P_{\frac{1}{2}}$ transition of $^{202}Hg^+$ was measured to be 51485.904(20)cm^{-1}.



gure 2. Isotope and hyperfine-structure components of the 194.2 nm resonance line in natural HgII

As a final comment we note that ~0.5mW of cw narrowband, tunable 243 ı radiation was generated by sum-frequency-mixing 351 nm radiation with 9 nm radiation in a Brewster-cut ADP crystal held near 8°C. This quired only minor modification to the 194 nm source: the exchange of e KB5 crystal for the ADP crystal and the single frequency operation of e argon-ion laser on the 351 nm line. With another cavity locked to sonance with the 243 nm laser we achieved ~6mW of circulating power. is narrowband laser source not only promises to improve considerably e measured value of the ground state Lamb shift of atomic hydrogen; in dition, through direct frequency measurements of the 1S-2S two-photon ansition in hydrogen and deuterium, a more precise value of the Rydberg nstant and of the electron-to-proton-mass ratio may also be obtained.

knowledgments
is work was supported in part by the Air Force Office of Scientific search and the Office of Naval Research.

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