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A Xenon Ion Pumped Blue Dye Laser

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A Xenon Ion Pumped Blue Dye Laser

D. W. FAHEY AND L. D. SCHEARER

Abstract—**A pulsed xenon ion laser with an output power of 5 kW at 364.5 nm has been used as a pump source for several blue dyes. Broadband conversion efficiencies exceed 20 percent. The use of a birefringent filter provides tunable output in the blue region of the spectrum with a bandwidth of 0.08 nm and a pulsewidth of 120 ns.**

In this note we report the use of a pulsed xenon ion laser, with an output power of 5 kW at 364.5 nm, to pump diphenylstilbene (DPS) and a coumarin dye. Broad-band conversion efficiencies exceed 20 percent. The use of a birefringent filter provides tunable output in the blue region of the spectrum with a bandwidth of 0.08 nm and a pulsewidth of 120 ns. The observations reported here, along with earlier reports utilizing the visible output of the xenon ion laser to pump the rhodamine dyes [1]-[3], demonstrate the possibility of obtaining narrow-band tunable output from 400 nm to over 700 nm in a relatively simple, inexpensive system. Further, the use of the high output power from the xenon ion laser at 231.5 nm may ultimately permit shorter wavelength dyes to be pumped, thus extending the tuning range into the near UV.

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Marling [4] demonstrated the rather unique features of the xenon ion pulsed laser which in a simple system is capable of providing kilowatts of peak pulse power at 231.5, 364.5 nm, and in the blue-green region of the spectrum. Earlier, we reported the use of the visible output from the xenon ion laser as a pump source for the rhodamine dyes [2]. The work reported here utilizes the same xenon ion laser for the pump source with the single exception of the xenon ion laser cavity mirrors. The active medium is xenon gas at several microns in a discharge volume of 190 cm of 8 mm inside diameter Pyrex glass tubing and is excited by a spark-gap controlled 0.3 μF capacitor charged to 12 kV. The repetition rate of 10 Hz was limited only by the power supply. The cavity was tuned for maximum gain at 364.5 nm (Xe IV) by dielectric coated mirrors which provided 40 percent output coupling at one surface. The output power at 364.5 nm was measured to be approximately 5 kW with a pulsewidth of 200 ns [full width at half maximum (FWHM)]. Power and pulsewidth measurements were made with a calibrated photoconductive silicon detector.

The dye laser cavity configuration is shown in Fig. 1. The three-mirror folded cavity with the dye cell at Brewster's angle is the astigmatically compensated cavity used largely in CW

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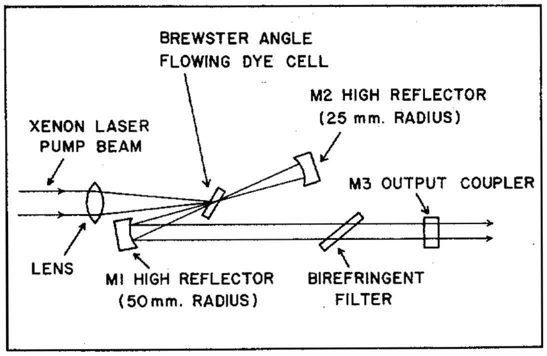

Fig. 1. A three-mirror astigmatically compensated dye laser cavity for a xenon laser pump beam.

dye lasers [5]. The dye cell is a spectrophotometer flow cell made of optical glass with a 1 mm path length. The pump beam is brought to a point focus inside the dye cell by a 5 cm focal length lens. The high reflectors, *M*1 and *M*2, are dielectric coated spherical mirrors with focal lengths of 12.5 and 25 mm, respectively, with a reflectivity in excess of 99 percent from 400 to 500 nm. The optional intracavity tuning element is a birefringent filter consisting of three crystalline quartz plates oriented at Brewster's angle [6]. The optical path length in the three-mirror cavity was 15 cm without the filter and 22 cm with the filter.

The initial success of the xenon ion pumped dye laser has been achieved using two blue dyes: DPS (4, 4′-diphenylstilbene) and Coumarin 460 (7D4MC: 7-diethylamino-4-methylcoumarin). When a saturated solution of DPS (less than 1.2×10^{-3} M) in *p*-dioxane in a closed cell is pumped, lasing is readily observed yielding a broad-band output with a 407 nm peak and a 3.2 nm half-width. The peak broad-band power is measured to be 500 W with a pulsewidth of 120 ns corresponding to a conversion efficiency of approximately 10 percent. Insertion of the birefringent filter yielded a narrow-band output of approximately 0.06 nm with 40 percent peak broad-band power. The useful tunable output exceeded the range of 404 to 401 nm.

For the lasing of Coumarin 460, a flowcell and reservoir were used to help retard dye deterioration and to allow simple adjustment of the dye concentration. Lasing was observed for dye concentrations between 1.5×10^{-4} and 3.0×10^{-3} M in ETOH, where the latter value is thought to be near the optimum molarity. The broad-band lasing output peaked at 460 nm with a 9.8 nm half-width. The peak power was measured to be 1 kW with a pulsewidth of 120 ns corresponding to a conversion efficiency of approximately 20 percent. Insertion of the birefringent filter yielded a narrow-band output of approximately 0.08 nm with 60 percent peak broad-band power. The useful tunable output exceeded the range of 456 to 463 nm.

The tranmission sidebands of the birefringent filter and the high cavity gain limit the maximum attainable bandwidth. An intracavity etalon could easily be used to provide a bandwidth less than 0.05 nm with a higher power per unit bandwidth. The output coupler which provides 20 percent transmission from 400 to 500 nm is thought to be close to the optimum value for the gain realized in this cavity. Lasing was observed in both dyes with output couplers of 40 and 5 percent transmission but with a substantially lower power. With the 5 kW pump source, lasing was not achieved using the dye BBQ (4, 4″-bis-butylactyloxy-quaterphenyl) which has a broad-band peak at 386 nm when pumped with a nitrogen laser. The pump source power is the limiting factor since absorption was occurring as evidenced by the observed fluorescence.

Having achieved tunable output as low as 400 nm, the performance of this system is extrapolated to a tunable output for the continuum of longer visible wavelengths. The blue dyes are sufficient in number that for a given wavelength interval in the blue, an efficient dye can be chosen that has adequate absorption at 364.5 nm. For longer wavelengths, the xenon laser can be tuned to higher power green lines that are highly absorbed in the rhodamine dyes. A tunable output up to 700 nm has been achieved in our laboratory using the rhodamines with perchlorate additives.

Future work in this system will include the addition of an intracavity etalon and the design of an oscillator-amplifier configuration.

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