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Injection-Locked Dye Laser Pumped by a Xenon-Ion Laser

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***Abstract*—Injection locking of a dye laser is reported for a 4-mirror ring-cavity dye laser pumped by a xenon-ion laser. Both a He–Ne laser and tunable CW dye laser were used as the injection sources.**

DESPITE its seeming advantages, the use of injection-locking techniques to obtain high-power narrow-bandwidth pulsed laser radiation has been relatively little used. Injection narrowing utilizes a low-power spectrally-narrow laser to provide a radiation field within the high-power laser cavity, which substantially exceeds the normal spontaneous emission in the cavity in which the laser oscillations preferentially build up. Thus, the spectral characteristics of the output of the high-power laser are determined by the injection laser.

Injection narrowing was first demonstrated in 1971 by Erickson and Szabo [1] for a N_2-pumped dye laser and pulsed Ar laser. Recently, additional work has been reported in which very narrow-band high-power laser output has been obtained from injection-locked flash-lamp pumped dye lasers [2], [3]. In both of these cases a ring laser cavity was employed in order to avoid feedback (and the resulting pulling effects) into the injection source.

In this paper we report the injection-locking of a dye laser with a 4-mirror ring-cavity which is pumped by a pulsed xenon-ion laser [4]. The cavity, as shown in Fig. 1, includes two spherical mirrors of 5-cm focal length at $M1$ and $M2$ and a flat total reflector at $M3$. A 50 percent flat output coupler is located at $M4$. The total cavity length was approximately 40 cm. A dye cell with a 1-mm path length contained the 10^{-3} m RhB-ethanol dye solution and was placed at the Brewster angle at the common focus of $M1$ and $M2$. The angles between the dye laser beam and the spherical mirror axes can be chosen to offset any astigmatism introduced by the dye cell and the off-axis use of the spherical mirrors [5].

The xenon-ion pump source had a peak pulse power of approximately 2 kW in several lines in the blue–green region of the spectrum. The optical pulsewidth was 250 ns with a repetition rate of 5–10 Hz. Under the conditions described and in the absence of an injection beam, the ring laser output consisted of two identical beams whose broad-band peak power was 400 W per beam. The laser ouptut was highly linearly polarized as determined by the Brewster angle of the dye cell. The power output of each beam as a function of wavelength is shown in Fig. 2 as the top curve and was obtained by sampling a portion of the beam with a grating monochromator with an instrumental width of 0.1 nm.

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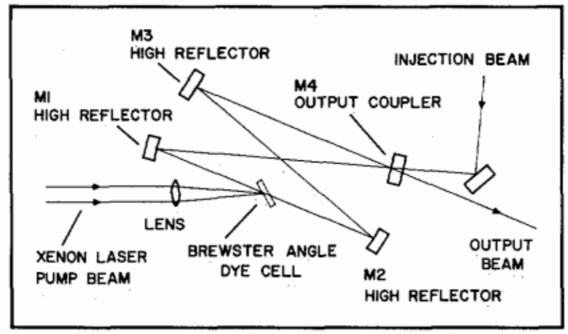

Fig. 1. Schematic of ring-cavity dye laser. High reflectors $M1$ and $M2$ are spherical mirrors of 5 cm focal length. High reflector $M3$ and output coupler $M4$ are flat mirrors.

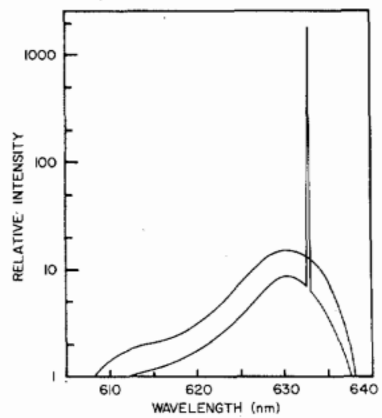

Fig. 2. Plot of the relative intensity versus wavelength of the output of the noninjected and injected ring-cavity dye laser. The upper curve is the noninjected output. The lower curve is the injected output when the injection wavelength is 632.8 nm.

A CW He–Ne laser, Spectra-Physics Model 125, was utilized as the injection source. Approximately 17 mW of CW laser emission at 632.8 nm entered the dye laser cavity through the 50 percent output coupler of which about one-third or 6 mW was contained within the pumped volume. The spectral width of the He–Ne laser is 1.5 GHz. On injecting the 632.8 nm radiation into the dye laser cavity collinear with one of the dye laser output beams as shown in Fig. 1, the broad-band power in both dye beams decreases noticeably by about a factor of 2. This decrease of 200 W of broad-band power in each of the two dye laser beams emerges as an increase of 400 W at 632.8 nm in the single dye laser beam propagating along the direction of the CW injection source. Thus, the power within the 1.5 GHz bandwidth defined by the He–Ne laser increases from several milliwatts to over 400 W.

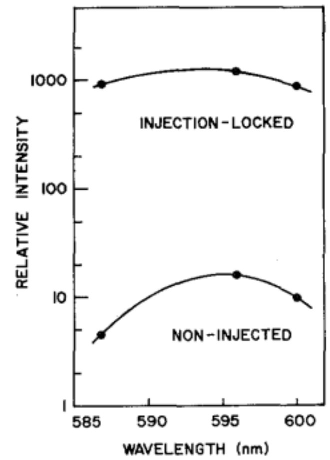

Fig. 3. Plot of the relative intensity versus wavelength of the output of the noninjected and injected ring-cavity dye laser when the injection source is a CW jet-stream dye laser.

The injection-locked output at 632.8 nm was examined with a 1 m Jarrell-Ash monochromator which provided a resolution of 0.005 nm at that wavelength. A comparison of the pulsed injection-locked dye laser output with the CW He-Ne laser beam indicated that their bandwidths were identical within the instrumental width of the monochromator. The lower curve in Fig. 2 shows the dye laser output versus wavelength when the dye laser is injection locked at 632.8 nm. The curve was also obtained with a grating monochromator of 0.1 nm instrumental width and thus the power per unit bandwidth at 632.8 nm is not accurately represented by the curve.

A Coherent Radiation Model 590 jet-stream dye laser using a 5 W Ar^+ pump laser and providing an output bandwidth of 0.025 nm was also used as an injection source. In this case, injection locking with characteristics similar to those described in the earlier paragraphs was obtained over a wide tuning range. In Fig. 3, the relative intensity of the injected versus noninjected output of the ring-cavity dye laser is shown for the jet stream injection source. The lower curve is the intensity versus wavelength of the noninjected ring-cavity laser with Rh 6G dye solution. The upper trace is the relative intensity of the output of the ring-cavity laser at the injected wavelength as measured by a monochromator with 0.1-nm instrumental width.

The results reported here are similar to those obtained by Vrehen and Breimer [6] and demonstrate both the ease and the utility of the injection-locking method for obtaining narrowband high-power laser emission. The work reported here differs principally in the use of a ring-cavity configuration to prevent feedback effects as demonstrated by Blit *et al.* [2] and in the use of a xenon-ion laser as the pump source for the dye laser. The xenon-ion laser has modest power outputs both in the blue-green and UV (364.5 and 231.5 nm) region of the spectrum. Thus, the dye laser region from 400 to 700 nm can be utilized provided that suitable injection-locking sources are available. [7]

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