Appl. Phys. 5, 181—182 (1974)

Applied Physics

Single Mode Operation of a Tunable cw Dye Laser

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Received 28 March 1974/Accepted 28 May 1974

Abstract. Details of single longitudinal mode operation of an argon laser pumped cw dye laser using a low-loss interferometric mode selector are described. Typical output powers of 5 mw with a bandwidth of 30 MHz for an input power of 700 mw have been obtained.

For many recent spectroscopic applications that make use of dye lasers, very narrow bandwidth or single mode operation is important. The bandwidth and long term frequency stability of the laser should be much smaller than the Doppler widths of the atomic and molecular spectral lines to be investigated. A number of techniques for reducing the bandwidth and limiting the number of simultaneously oscillating longitudinal modes have been developed [1]. We wish to describe the use of an achromatic Michelson-type interferometric mode selector in an astigmatically compensated cw dye laser [2]. The merits of this particular mode selection technique lie in the fact that linear continuous or nearly continuous tuning of a cw dye laser with a long resonator design over a wide frequency range is feasible. Michelson-type interferometers have been used as wavelength selectors in single-mode gas lasers [1], flashlamp pumped [3], and cw dye lasers [4]. The optical scheme reported here provides a simple compact and low-loss alternative to an intracavity pressure-tuned Fabry-Perot type interferometer [5] in eliminating the need for compensating the nonlinear tuning characteristics, associated with the usual tilted intracavity etalon.

The schematic of the single frequency cw dye laser is shown in Fig. 1. The "third" mirror in the usual folded 3 mirror cw dye laser configurations [2] is replaced by a Michelson-type 3 mirror interferometric mode selector, designed as a single stable assembly [3]. The success of this technique relies on the homogeneous broadening of the dye laser gain medium which permits lasing of a single axial mode when there is a coincidence of a laser resonator mode with an interferometer resonance. The dye laser uses a $3 \cdot 10^{-4}$ molar solution of rhodamine 6G in water with 6% by volume ammonyx LO added. The dye flows at about 15 m sec^{-1} through a closed cell with a dye channel of 1 mm thickness. The dye laser cavity comprises mirrors M_1 to M_5. Considerable care is taken to minimize mechanical and thermal instabilities of the laser system[1] and to reduce the dye flow and pump

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[1] Dye laser cell configuration is based on a design by H. Walther and R. Schieder of „I. Physikalisches Institut der Universität Köln".

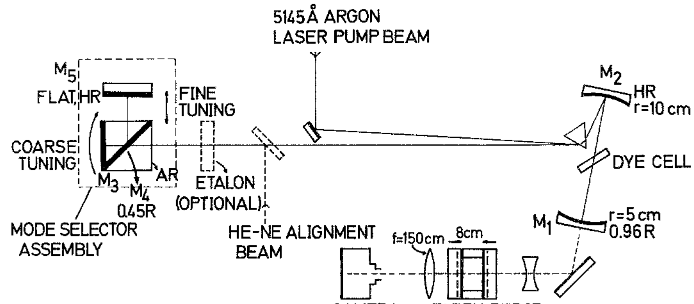

Fig. 1. Optical schematic of single mode cw dye laser

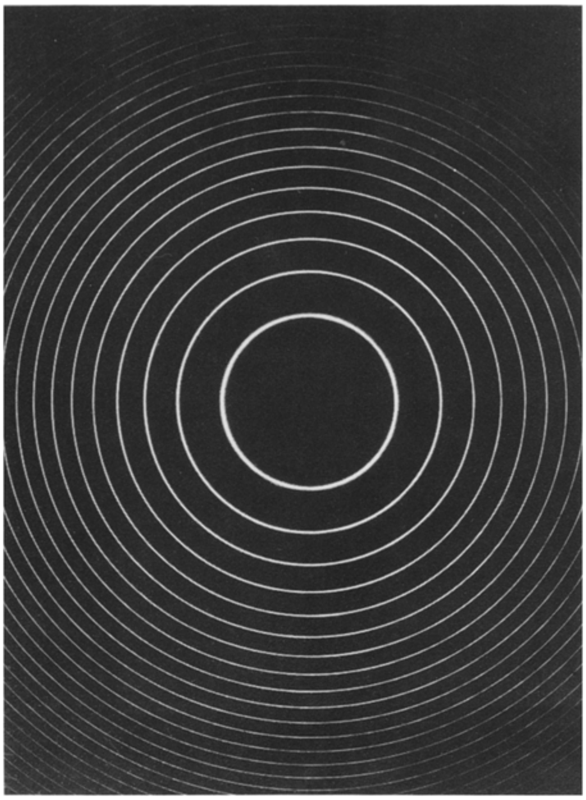

Fig. 2. Interferogram of single mode dye laser output

beam fluctuations. The tuning arm of the cavity terminated by the mode selector assembly could be varied in length. Typically, the cavity lengths ranged from 60 to 100 cm.

Single mode operation of this dye laser configuration is possible at low excitation powers with a quasi-continuous tuning range of about 100 GHz. Fine tuning is accomplished by varying the position of mirror M_5. The output of the dye laser is modulated by laser cavity mode "jumps", which can be eliminated by synchronized tracking of the resonator length with a piezoelectric mounted mirror M_1 [4] or minimized by choosing a longitudinal mode spacing small compared to Doppler linewidths. Coarse tuning from 569 to 632 nm is obtained by rotating the interferometer assembly. Easy alignment of the nondispersive interferometer is possible with a He–Ne reference beam which can be conveniently coupled into the resonator with a Brewster plate. When the alignment of the interferometer is optimized, it exhibits a peak reflectivity so that no significant change in the laser threshold power occured when substituting a single end reflector with the interferometer assembly.

The bandwidth characteristics of the cw dye laser were studied with an external analysing Fabry-Perot interferometer with a free spectral range of 1.6 GHz. The bandwidth of the free running dye laser was typically 20 GHz using a single dispersive intracavity prism and flat end reflector. Upon insertion of the aligned mode selector the laser operated in a single mode, as shown by the interferogram in Fig. 2.

Densitometric evaluation of the interferograms indicate average bandwidths of 30 MHz for outputs of the order of 5 mw and a pump power level of 700 mw. The long term stability of the output bandwidth is 100 MHz without any provision for stabilization of the laser cavity or components. This bandwidth is smaller than typical Doppler bandwidths. With higher pump powers several axial mode oscillate. However, insertion of an intracavity etalon of 2 mm thickness and 33% reflectivity restores single mode operation and permits higher output powers than 5 mw.

Acknowledgements. The authors would like to acknowledge helpful discussions with H. Walther, H. Welling and F. P. Schäfer. The research was supported by Fonds of the "Chemischen Industrie" and the "Deutsche Forschungsgemeinschaft".

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