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Characterization and optimization of a homemade ring dye laser

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ABSTRACT

Objectives: The characteristics of dye laser such as purity, concentration and dye solvent velocity have significant effects on the output power of laser. The main objective was to investigate the effects of the dye solvent velocity on the laser output power.
Methods/Statistical analysis: A homemade ring dye laser (Rhodamine 6G) was used and the liquid dye was injected by a liquid jet and pumped by beam of a 6 W argon ion laser ($\lambda = 488$ nm). By using mechanical pumping, the liquid pressure was controlled and different velocities were selected.
Findings: It was observed that by increasing the pressure, the output power of dye laser, was increased initially and then in a certain pressure variation region (0.65–0.69 MPa), some slight changes were detected. By increasing more dye liquid pressure, the laser output was decreased considerably. The maximum output laser power obtained in a wavelength ranges within 5702–6072 Å, was approximately 140 mW. It was seen that by increasing the pumping power, the dye laser output power was increased. Moreover, for each specific wavelength, there was a threshold power (in pumping laser) for dye laser emission in order to be initiated. For example for the laser emission at 5763 Å and 5990 Å, the minimum pumping laser powers are ~4.1 and 5.2 W, respectively. Dye solvent velocity in output power of dye laser is not appropriately discussed in previous studies, so it can be stated that in the current study, it was carried out with different conditions.
Application/Improvements: Applying suitable dye solvent velocity is one of the important issues in designing ring dye laser that has been correctly discussed and utilized in the current study.

1. Introduction

The CW dye laser is a well known tool of optical science which plays a major role as a source of tunable radiation in the visible and near-visible regions of the electromagnetic spectrum. The dye laser has many unique features from which broad tunability, single mode operation and the potential for extremely high resolution can be mentioned as the typical advantages of using this family of lasers [1,2]. Such specific characteristics have made it as a coherent light of source applicable for different applications in industry, medicine and scientific researches [3–6]. It has been almost more than four decades that the dye lasers have been studied and a large number of dye-laser have been developed [7–11]. Particularly, there have been some reports on studying CW dye lasers [5,12–14]. Dye lasers typically have an active medium of liquid dye, which are optically pumped by flash lamps or by using other lasers [1–3]. In dye laser the active medium material is circulated by a mechanical pump in a closed path which circulates the dye fluid by two methods: (i) in a closed circulated cell with connected pipelines, (ii) by means of a dye jet. The employment of dye jet [15] and following its developments during last three decades (e.g. see reference [16]) have had significant contributions to the success and applicability of the dye lasers. As dye jets provide rapid flow rates, therefore much higher output powers can be achieved with dye jets, rather than simple cells. However, in some cases, solid dye lasers have been used instead of liquid ones [17,18]. In this type of dye lasers, the jet or cell is not involved to the laser structure. In solid dye lasers, some other features such as the effect of impurity in active medium have been investigated [17,18].

In liquid dye laser, by choosing the type of dye solvent and suitable design of dye active medium in the cavity, it is possible to create coherent radiation in a specific spectral range of the visible region [2]. There are considerable number of dye solvents which almost covering the visible spectrum [1,3,12,19]. It must be noted that by using suitable optical elements the output radiation can be tuned consistently in a specific wavelength with a narrow line shape spectrum [1–4].

There have been many reports to improve the performance of the laser output [14,20]. Runge et al. made important developments which enhanced the performance of the dye laser [15]. They

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modified the jet-stream dye circulation system, which provided more reliable and high power operation. In parallel with this achievement, the spectral resolving powers of these lasers were also enhanced by developing appropriate frequency stabilization techniques (e.g. see [14,20]).

Using ring resonators, traveling wave dye lasers were developed and extensively used. In these type of lasers both the spectral characteristics and the power output from the CW dye lasers were improved [21,22]. The incorporation of computer control has provided automatic long-range tuning and enhanced data-collection capabilities in development of dye lasers [23,24].

Laser characterization and optimization of dye lasers cavities have always been very important for having the best performance of the laser operation. In laser characterization, determination of laser parameters such as radiation spectrum, output power, its efficiency and stability are of great importance. In dye lasers, the specification of dye solvent (concentration and purity), its fluid characteristics (such as fluid velocity), are also very important as they can significantly affect the laser efficiency. The pumping laser characteristics are also important in dye laser operation efficiency [25].

There are many reports on characterizing the varieties of dye lasers (e.g. see [4,16,17]). Albeit, looking in showing there is no report to show extensive investigation on characterizing the ring dye laser.

In this paper, a homemade ring dye laser was characterized by extensive investigations. The ring dye laser, operated by Rhodamine 6G as the laser active medium, is optically pumped by an argon ion laser. The dye laser is characterized by measuring the output power, in various optical spectrum regions, versus the dye liquid pressure, and then by pumping the laser power. The results are pointed out briefly in terms of a fundamental physical theory.

2. LASER description and its diagnostics

The homemade laser was a ring dye laser (Rhodamine 6G), optically pumped by an argon ion laser (Melles Griot wavelength = 488 nm). Fig. 1 shows the schematic view of the laser and its components.

Table 1
Laser mirrors characteristics.

	Curvature (mm)	Outer diameter (mm)	Thickness of mirror in the center (mm)
M_1	60.0	6.0	6.0
M_2	60.0	8.0	2.0
M_3	212.0	15.0	6.0
M_4	200	15.0	6.0
M_p	50.0	8.0	6.0

The laser resonator consists of 4 mirrors, M_1, M_2, M_3, and M_4. The M_P mirror was used for reflecting and focusing the pumping laser (argon ion laser) on the liquid jet. Some characteristics of these mirrors are listed in Table 1.

The active environment was the dye solvent Rhodamine 6G which was flowed inside the resonator by a mechanical pump and a small nuzzle. The mechanical pump was used to control the velocity or the pressure of the liquid dye in the optical pumping area. The nuzzle had a rectangular cross section (3 mm × 0.4 mm) and made a fluid sheet at an appropriate location inside the resonator (Fig. 1). An appropriate pipe at the opposite side of the jet exit could collect the high speed liquid flow in order to return it to the reservoir for circulation.

The speed of the dye fluid could be controlled by the mechanical pump. It is worth mentioning that the speed of the dye fluid was linearly related to the pressure provided by the mechanical pump. A typical fluid speed of 18 m/s (when the mechanical pump operated at a pressure of 0.65 MPa) could be provided by a nuzzle at the jet position. The fluid speed could be precisely tuned by the mechanical pump pressure.

The argon ion laser was operated by a maximum power of 6 W. The pumping beam was reflected and focused by mirror M_P on the surface of the liquid jet at Brewster angle. The pumping beam spot size on the jet surface was ~1 mm in diameter.

The dye fluid was made of Rhodamine 6G powder (Merck) and pure methyl alcohol solvent (99.9%). The density of the dye fluid was controlled by the amount of the solvent. In this experiment, the optimum condition for the dye solvent density, was determined by try and error and the dye fluid was produced by solving 1 g of Rhodamine 6G powder in 50 mL methyl alcohol and then the rest of the solvent was combined with ethylene glycols (99.9%) to

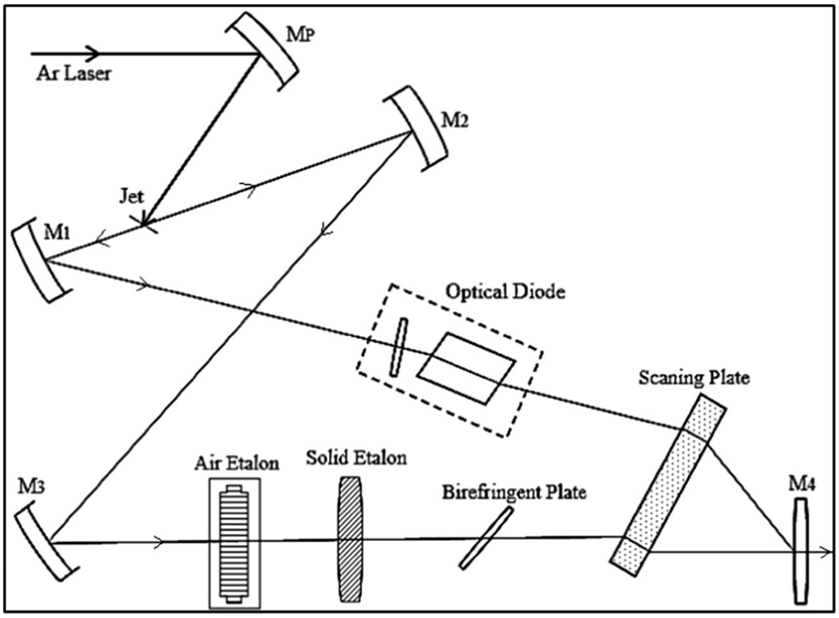

Fig. 1. A schematic view of the ring dye laser and its optical components.

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