STABILITY CONDITIONS OF THE DYE–LASER CIRCULATION SYSTEM

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The passive stability of the dye laser through the construction of an improved dye circulation system are studied. All expected troubles in a free dye jet stream which affects directly the frequency stability of the laser are discussed and experimental results are achieved.

I. INTRODUCTION

The single mode continuous-wave dye laser is an extremely useful device. It is widely used in many scientific and industryial application, especially in the field of spectroscopy. This is due to its tunability and narrow linewidth. Using several dyes the spectral range of these lasers can be extended to both UV and IR regions through the use of nonlinear optical mixing techniques [1, 2]. The frequency changes of a free running dye ring laser occur by various means, such as: The geometrical circumference of the resonator can change mechanical vibrations, changing the refractive index of air in the resonator by temperature changes, air pressure changes, turbulence and acoustic waves. These changes in general lead to high and slow frequency changes in the range of a few kHz.

On the other hand there are fast frequency changes caused by the bad optical quality of the dye stream. The optical quality is effected by nonuniformities and turbulences taking place at the outlet of the jet-nozzel window. Changes of the stream velocity in the laser focus with time lead to unstable thickness of the dye stream. Many publications dealt with the problem of the active frequency stabilization of the laser beam using complicated electronic systems [3–6]. In dye lasers the quality of the dye circulation system, the avoidance of its troubles and its passive effects in this system are decisive in the laser stabilization. Some results in the research in this field have already been gained [7–9].

Because of the importance of this point, this paper treats the passive stability conditions of dye lasers and their complications by the creation of an improved dye circulation system.

An organic dye solution is used in the dye laser as the active medium. It consists of organic dye molecules built-up from a great number of atoms solved in a suitable solvent. The laser characteristics of the dye solution can be understood by using the term scheme of an organic dye [10]. By putting the dye solution in an optical

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resonator and using a suitable optical pumping source with enough power, for example the argon-ion laser. The laser oscillates as long as the threshold conditions are experimentally realized. The energy levels responsible for the laser oscillation belong to the ground state and the first singlet state.

II. CONSTRUCTIONS AND EXPERIMENTAL SET UP

For stable work of a single mode dye laser, the quality of the active medium depends on the jet. It must be put in a resonator as a Brewster plate with plane parallel surfaces. The essential parts of the circulation system are connected as shown in Fig. 1.

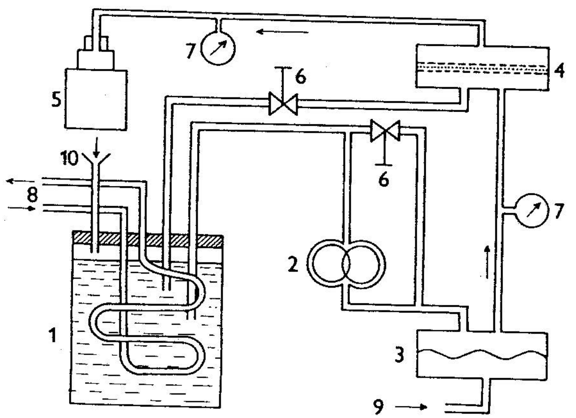

Fig. 1. Dye circulation system, 1 – Dye reservoir, 2 – Micropump, 3 – Buffer, 4 – Filter, 5 – Jet-nozzel, 6 – By-pass, 7 – Two pressure gauges, 8 – cooling system, 9 – air pressure, 10 – collection tube. All connection by plastic tubes.

A closed glass reservoir contains the dye solution (Rhodamin 6G solved in ethylene glycole in our case) and is connected with a micropump (model V-096.07-F1-Firma Verder GmbH-West Germany) by soft plastic tubing. The solution will be sucked and pumped to a buffer and filter. In the filter a part of the solution will return through an adjustable by-pass valve again to the reservoir which often contains air bubbles and some particles such as dust. The other part will flow through a filter system to a jet-nozzel of the type discussed in [11], and returns to the dye reservoir. This means that a free stream jet of the dye solution is pumped under a certain pressure with the cross-section controlled by a nozzel. On the other hand the dye stream is practically in air without limiting surfaces.

An experimental test for the optical quality of the jet, the existence of air bubbles and unrelated particles, which effects directly the frequency stability of the laser, is performed. A focused laser beam from He-Ne laser (model 155 Spectra Physics) is incident on the free running dye jet stream. The reflected beam from the front and back surfaces interfers on a screen as in Fig. 2 and the transmitted beam

is detected by a sensitive detector. The signal can be observed on an socilloscope and used as a test for the existence of air bubbles and other particles. Fig. 3 shows a photograp of the oscilliscope screen in passing an air bubble.

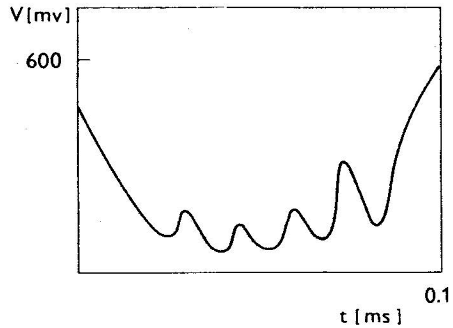

Fig. 2. The jet-nozzel interference pattern

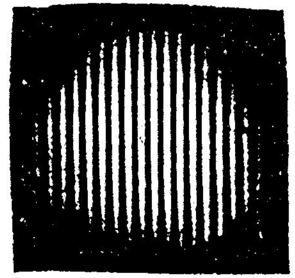

Fig. 3. A photographic picture of bubble on oscilloscope

III. RESULTS AND CONCLUSION

1) The output power of the laser depends on the optical characteristics (the thickness) of the jet which in turn depend on the dye solution pressure by the nozzel [11]. The pressure fluctuation caused by the vibration of the motor pump or by the pump mechanics can be seen as the frequency jitter in the laser beam. This effect can be eliminated to a great extent by using a buffer made of aluminium or stainless steel and connected directly next to the pump in the circulation scheme. The solution in the buffer flows over a pressure air polyester foil which neutralizes the pressure changes of the pump. On one side of the buffer one finds a volume of air under pressure equal to the pressure of the dye solution from the other side. The polyester foil separates the two sides, and neutralizes the pressure fluctuations due to pump pressure changes. Under another condition the dye solution pressure must be adjusted using a by-pass valve in the pump itself.

2) another complicated problem in the circulation system is the existence of air bubbles and dust particles in the dye solvent. When one of these two has passed with a certain velocity through the jet, the laser beam will be for some time disturbed. This will affect the laser frequency directly, especially when the laser is stabilized to single frequency. This problem is avoided by using three filters, two of them made of stainless steel and the other from a filter membrane with pores the size of about 0.8μm and a diameter of 142 mm (filter typre: Sartorius SM 11104). The filter separates the air bubbles which return through the by-pass directly to the dye reservoir. The values of pressures in the circulation system are 600 and 570 kPa before and after the filter. This means that the pressure drop at a clean and new filter membrane is of about 30 kPa. The membrane requires replacement

after several days of operation, probably because it is satured with dust particles. The bubbles repetition time was more than 25 minutes (pressure drop due to filter = 30 kPa).

3) The air bubbles originated not only from leaks in the circulation system, especially at the inlet and the outlet of the pump but also at the impact point between the dye stream and the wall of the plastic connection tube between the nozzel and the dye solution reservoir. This can be eliminated by adjusting the angle between the dye stream and the wall of the tube smaller than (< 10 degrees). This means that the position of the collection tube must be adjustable in different directions. This may be done by using a special holder, where all displacements and rotations are carried out together for the jet and the collection tube. The impact point between the dye solution and the wall of the collection tube must be observed to avoid dye stream turbulence. The plastic tube itself must be soft, long and like a spring.

4) The circulation system is tested using Rhodamin 6G and Rhodamin 110 solved in water, methanol and ethylene glycole. The experiment showed that a high optical quality and good flat plane parallel surfaces for the jet stream can be obtained in the case of a higher viscosity solvent.

5) The temperature changes of the dye solution due to the strong fraction at the pumping and from the pumping light source, which cause a time changeable refractive index in the laser focus, are avoided using a heat exchanger made from a copper spring suspended in the dye reservoir, where cool water flows through it.

6) The travelling of small dust particles and air bubbles through the laser focus changes the thickness and the refractive index of the dye stream for a short time. This in turn affects the laser frequency. An estimated value for the celocity of frequency changes of the laser caused by any disturbance of the dye stream can be calculated using the velocity of the dye stream. When the velocity of the dye stream equals 15 m/sec and the beam radius $w = 16\mu m$ in the focus of the ring laser, then the crossing time $t = 2.1\,\mu$sec. Such an event was described by the normal distribution of the time constant t and the spectral distribution with the half halfwidth of $\nu_{1/2} = \sqrt{ln\,2}/2\pi t = 63\,\text{kHz}$. This means that the frequency changes of the laser caused by the dye stream are realized by very high velocity.

From the above results one concludes that all the sources of disturbance in the dye laser circulation system which have an effect on the stability of the laser frequency are avoided. Accordingly a stable and high optical quality of the dye stream is achieved.

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УСЛОВИЯ СТАБИЛЬНОСТИ СИСТЕМЫ ПРОТОКА В ЛАЗЕРАХ НА КРАСИТЕЛЯХ

Изучается система позволяющая улучшить перекачку красителей и ее влияние на стабилность лазера. На основании экспериментальных результатов обсуждается возможные проблемы с свободной струей красителя которая прямо влияет на стабильность частоты лазера.