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Solvent effects on lasing characteristics for Rh B laser dye

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ABSTRACT

We demonstrate pulsed, photopumped multimode laser emission in the visible spectral range from rhodamine B dye dissolved in various solvents. The laser emission is characterized by a well-defined, low threshold pump power at which the emission spectral intensity dramatically increases and collapsed into several dominant laser modes with reduced mode spacing and spectral width. The modes were found to originate from the subcavities formed by the plane-parallel walls of the cuvette containing the gain medium. The cavity lasing spectral structure and the numbers of longitudinal modes were easily controlled by changing the solvents. A shift in the emission spectra has been also observed by changing the solvents will allow a limited range of tuning of laser emission wavelength. We also determined the gain coefficient and stimulated emission cross-section for the Rh B dye dissolved liquid laser system. A detailed discussion of the solvent effect in the lasing characteristics of Rh B in different solution is explained along with the computational data.

1. Introduction

The first laser was built in 1960 by Maiman [1], 44 years after Einstein's discovery of stimulated emission. Six years after, the first dye laser was realized by Sorokin and Lankard [2].The ultra-wide wavelength tuning range and the ability to generate both narrow linewidth continuous wave output and ultra-short pulses make dye lasers an ideal coherent source for spectroscopy [3]. Generally, laser dyes are complex organic molecules containing long chains of conjugated double bonds. The complex molecular structure will leads to many vibrational and rotational energy levels within a single electronic state. Therefore, laser dyes often have strong and wide absorption bands in the UV and visible region [4,5]. Liquid dye lasers are the first material systems used to study the laser action and other optical processes in microcavities. In liquid dye lasers, tuning of the laser wavelength is performed either by changing the concentration of the dye, *concentration tuning* or by changing the optical path length in the cavity. To change the optical path of the cavity, the solvent of the dye can be changed, thereby changing the refractive index in the cavity. This method is so called *solvent tuning*. One should keep in mind that by changing the solvent, other properties of the fluid which can affect the laser wavelength may be changed due to the interaction between dye molecules and solvent molecules.

The solvent plays an important role in photophysical properties of laser dye. In this paper, we analyze the solvent effects on the laser emission characteristics for Rhodamine B (Rh B) laser dye. In our study, Rh B dye is dissolved in different solvents such as ethanol, methanol, butanol, ethylene glycol and glycerol, which are pumped longitudinally with short light pulses of several energies [6,7]. Apart from its particularly large cross section, it has high photochemical stability, which is important in practice to withstand multiple excitation cycles with a pulsed pump laser. Organic laser dyes typically show a large fluorescence yield ranging from about 0.6 to near the optimum 1.0. Fig. 1 shows the absorption spectra of Rh B with a concentration of 5×10^{-4} mol/dm^3, which is dissolved in ethanol, butanol and glycerol respectively. These spectra were measured in a cuvette of diameter 0.1 cm using a UV–vis spectrophotometer (Jasco V-570). The absorption spectra exhibit a solvatochromic shifts after exchange between one solvent to another. Due to the electron redistribution within the solvent molecules, the energy difference between ground state and excited states will vary.

Fig. 2 shows the tuning of emission wavelength peak with variation in the dye concentration in methanol. The peak emission wavelength of Rh B dye with 1×10^{-4} mol/dm^3 concentration is

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found to be at 589 nm. By increasing the concentration of Rh B, the peak wavelength shows a clear redshift and at 5×10^{-3} mol/dm^3 concentration the emission peak is at 624 nm. Due to Stokes shift, the shorter wavelength of emission spectrum is absorbed by Rh B molecule and re-emit to the higher wavelength. The increase in concentration will increase the interaction between the dye molecules and the fluorescence light will result the shifting of the emitted fluorescence peak towards the longer wavelength region. This type of concentration dependent red-shift was also reported by Schafer [3]. These types of tuning of the emission wavelength by changing the concentration of the dye are generally known as *concentration tuning*. The inset of Fig. 2 shows the redshift of emission spectra as a function of dye concentration. From this, it is clear that the lasing wavelength is tunable over a wide range (589–624 nm) due to the overlap of absorption and emission spectra of Rh B dye. However, after a particular dye concentration, the shift tends to exhibit saturation behavior.

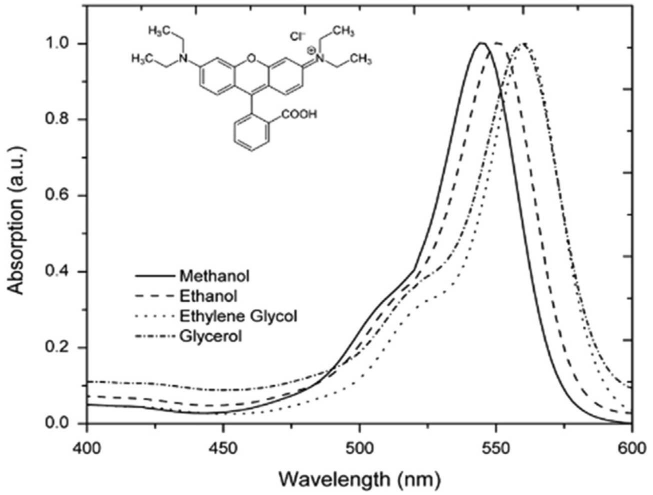

Fig. 1. Absorption spectra of Rh B dye (5×10^{-4} mol/dm^3) dissolved in various solvent. Inset shows the molecular formula of Rh B.

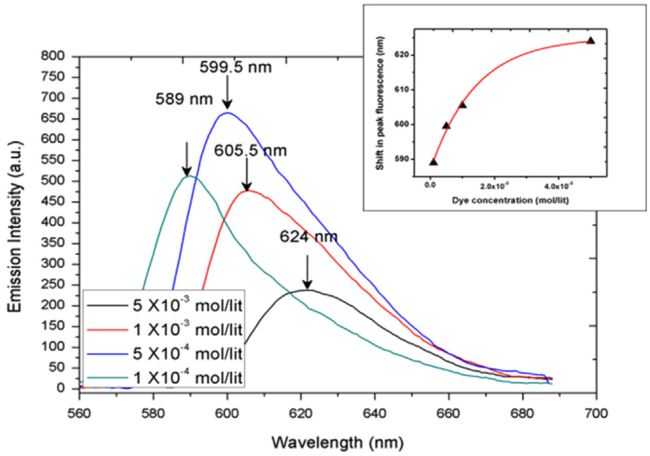

Fig. 2. Florescence spectra of Rh B dye dissolved in methanol with different concentration. Inset shows red-shift of peak fluorescence with the concentration of Rh B.

2. Experimental setup

To observe lasing from the different dye solution, we used the second harmonic output of a Q-switched Nd:YAG laser that emits pulses of 8 ns duration at a repetition rate of 10 Hz as the excitation source. The pump power was adjusted with neutral density filters, and focused by a cylindrical lens into a 0.2 mm × 4 mm stripe transverse to a quartz cuvette of 1 cm inner length that contained dye solution. The schematic of the experimental setup is shown in the left inset of Fig. 3. This optical setup induces amplified spontaneous emission (ASE) along with the gain guiding and laser emission. The parallel windows of the quartz cuvette will provide the optical feedback, which is necessary for laser action. The emissions guided along the excitation stripe were collected from the side of the cuvette using a collecting fiber, and were then spectrally analyzed using a spectrometer and a charge coupled device. All the investigations were done in Rh B dye solutions with a constant dye concentration of 5×10^{-4} mol/dm^3 in different solvents, while all the experimental conditions such as pump power, ambient temperature, excitation length of the gain medium and mode of collection remained the same.

3. Photophysical properties of dye

The unique features of dye lasers are directly linked to the molecular structure and the photophysical properties of organic dye molecules. The complex molecular structure also leads to many vibrational and rotational levels within the single electronic state. The effective homogeneous line-broadening mechanism due to the

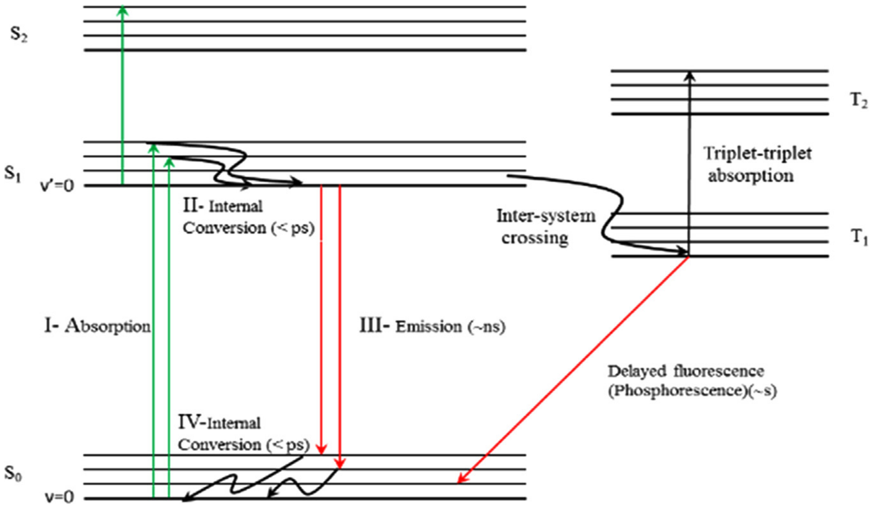

Fig. 3. Typical energy level diagram of dye molecule.