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# Line Narrowing in the Sulforhodamine B Dye Solution with $TiO_2$ Scattering Center

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**Abstract:** A random laser is a non-conventional laser whose feedback mechanism is based on dissorder-induced light. However, random lasers occur in gain media with numerous scatterers and produce coherent laser emission without any predesigned cavity. The generation of coherent emission from multiple scattering is quite general and its basic principles are shown here using sulforhodamine B-TiO suspensions system. These suspensions were pumped with 337.1 nm pulses from $N_2$ laser and the spectral and temporal behavior of light emitted from the pumped surface was recorded. When we pump power above a certain threshold a dramatic narrowing of the emission line width and a shortening of the emitted pulses were observed. We have experimentally found that in a random laser based scattering, the threshold pumping density decreases with pump energy increased.

## Introduction

When an amplifying medium is placed between two parallel mirrors, reflection makes that almost no light lost in the direction perpendicular to the mirrors. Light that has once been emitted is reflected by mirrors and can pass several times through the amplification medium

This mechanism is referred to as feedback [1]. A standing wave can arise for wavelengths being an integer fraction of the distance between the mirrors. The specificity of the wavelength selection depends on the quality factor of the mirrors cavity which determined by the reflectivity of the mirrors. When one of the mirrors is slightly transmitting part of the amplified light comes out at that side as a spatially and temporally coherent beam [2].

In articles of Langendijk and Wiersma [3,4] showed that the scattering amplifying media were given new familiar name, random laser. A random laser combines amplification with scattering of light. On one hand these systems have properties similar to ordinary laser like narrowing of the spectrum and presence of threshold in out put energy, on the other hand random laser can be viewed as multiple scattering system in which the propagation of the light is highly affected by the presence of gain [5]. When we excite the amplifying medium of a random laser by pumping it in its absorption band, we observe a broad fluorescence spectrum which will get narrower if the pumping intensity is increased. Besides on pumping intensity ,the so-called gain narrowing effect is dependent on a number of parameter like the absorption and transport mean free path [6], the dimensions of the gain volume [7] and the gain length, then one of the most noticeable properties of a random laser is the narrowing of the frequency spectrum of the emitted light.

The random laser threshold was first observed [8] in the intensity and spectral width of the emission. Spontaneous emission acts as the noise of the laser amplifier that can start the laser oscillation spontaneously emitted radiation that happens in a cavity mode which can be amplified by stimulated emission if available gain at that frequency is sufficient to compensate mode losses. This condition is called threshold [9].

In case of a transparent gain medium it is easy for light to leave the pumped volume, so there must be an appreciable inversion to observe spectral narrowing effects. If we can reuse the emitted light to stimulated other atoms or molecules to decay “feedback” the effects under consideration will occur at lower pumping intensities and usually in much more pronounced fashion [10]. At low pumping power, the inversion of the amplification medium of the random laser is low and we can assume all atoms or molecules to decay by spontaneous emission. When measurements are done on random laser not only a narrowing of the spectrum is observed, but usually also a red shift of maximum of the emission profile [11].

A gain medium that is used in many practical systems is a dye solution. It consists of organic fluorescent molecules in any solution. A dye can exhibit very high gain and can be pumped efficiently due to the large gain and absorption, cross section and large fluorescent efficiency [12]. For these reasons we chose to use dye as the gain medium in our studies.

## Experiment

A block diagram of the laser system developed in this study is shown in Fig. (1). A nitrogen laser as a pump source which is 10 ns pulse duration, 10 mJ output energy, and lasing wavelength is 337.1 nm.

Sulforhodamin B(Sr.B) laser dye molecule was chosen. It's usually disolved in methanol. The high gain amplifying random media used in this study were performed with samples consisting of $TiO_2$ as colloidal particles suspended in $1x10^{-3}$M Sr.B laser in methanol. The system of Sr.B/$TiO_2$ suspension is optically pumped with $N_2$ laser. The suspension is contained in a round quartz container with a 3mm thick quartz window. The samples are rotating slowly to prevent sedimentation of dye degradation. The pulse energy was measured using a joule meter (Molectron J3-05DW).

The absorption spectrum of the samples was measured with Shimadsu dual wavelength spectrophotometer UV-300 and the photo-luminescence emission spectrum was measured by using an optical multichanel analyzer III (EG&G Princton Applied Research, model 1461). A quartz lens was used to shape the excitation beam an aperture before the quartz lens was used to fix the size of the optical beam.

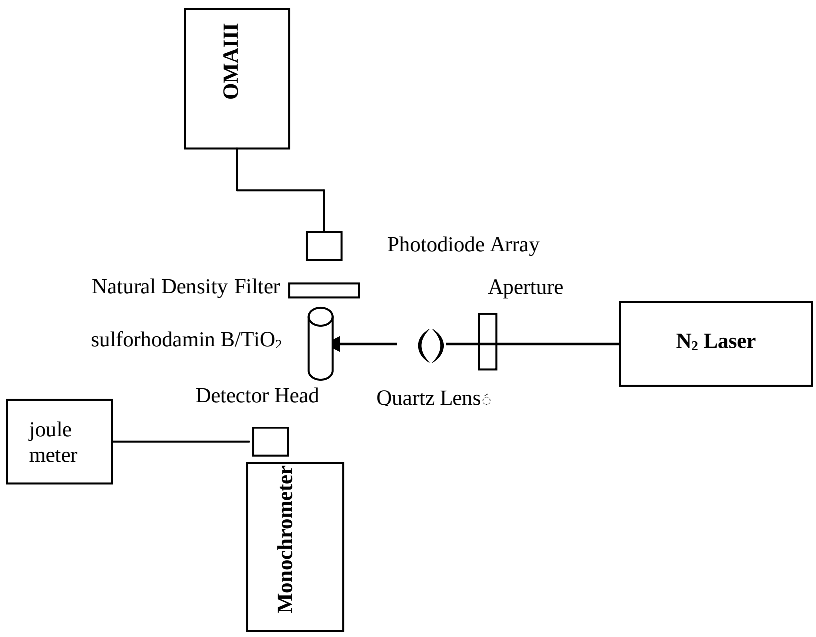


**Fig. (1):** Experimental setup for laser emission

## Results and discussion

When the sample is pumped by laser beam of variable intensity, it shows clear spectral narrowing [13]. The width of the pulsed spectra decreased as the pump power increased from 45 nm at 1 μJ/mm$^2$ to 15 nm at 1 mJ/mm$^2$ as shown in Fig. (2).

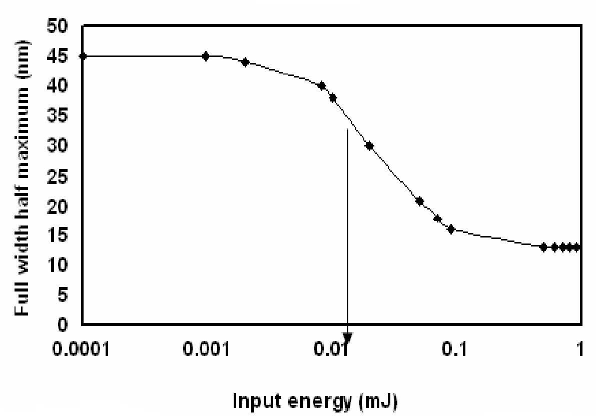


**Fig. (2):** Linewidth as a function of pump energy. The solid line is a fitted curve. The threshold is indicated by the arrow.

In order to measure the threshold of our system, we monitor the fluorescence through a monochromator as a function of pump energy. The monochromating spectrograph is set at the peak wavelength of the narrowed spectrum. For low pump energy intensities the emission from the samples is low but increasing slowly as shown in Fig. (3). We determined the laser threshold by extrapolation from the high pump energy region for Sr.B in methanol samples to be around 0.02 mJ, while above threshold the intensity of the emission from the samples increases linearly with pump energy.

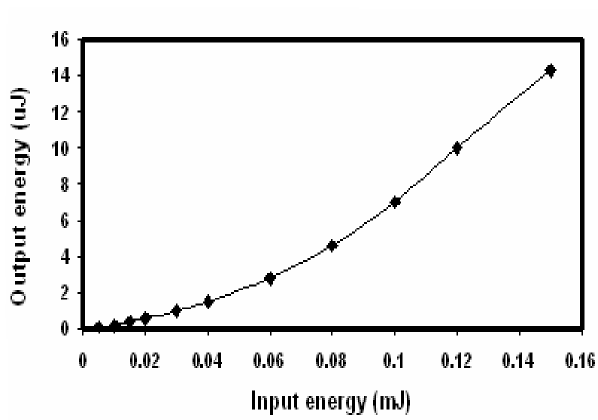


**Fig. (3):** Output energy of the peak of the emission spectrum as a function of pump pulse input energy.

Below threshold the fluorescence consists of spontaneous emission only, stimulated emission on other hand is generated instaneously so that emission above threshold resulting mainly from stimulated processes.

Fig. (4) shows a red shift in the emission spectrum of samples compared to the neat dye. This is due to the self-absorption.

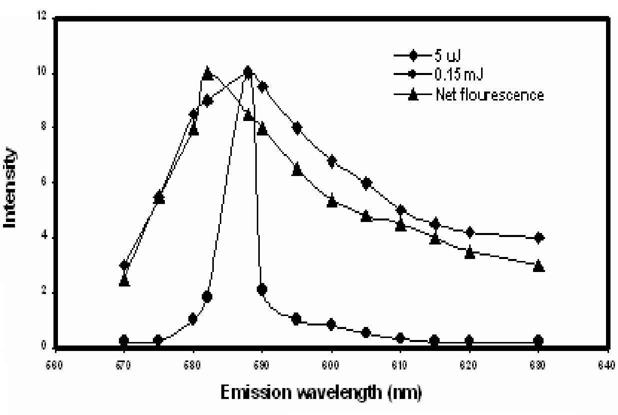


**Fig. (4):** Fluorescence of $TiO_2$ -dye suspension at 5 J and (B) 0-15 mJ pump pulse energy compared to the fluorescence at the neat dye solution.

The diameter of the pump beam strongly influences the threshold intensity (Fig. 5). At small spots, the threshold pump influence is increased by a factor of 30 with respect to the threshold large pump diameter. This means that for small excitation beam diameter, the light path will very probably leave the amplifying region after a short time, with a small chance to return [8]. That means that larger gain is required to compensate losses, i.e., the threshold energy is higher.

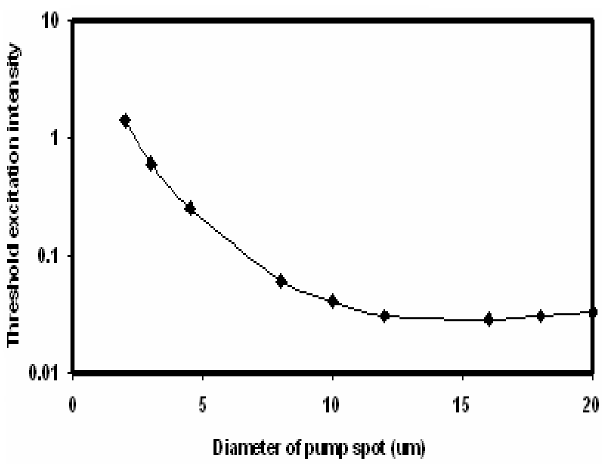


**Fig. (5):** The threshold excitation intensity as a function of pump beam diameter.

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# تضييق عرض الخط الطيفي في محلول صبغة السلفورودامين ب مع اوكسيد التيتانيوم كمركز استطارة


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**الخلاصة**

الليزر العشوائي من الليزرات غير التقليدية التي يحدث فيها الفعل الليزري دون الحاجة لوجود حجرة ليزرية مسبقة التصميم والصنع بل يعتمد على وجود مراكز استطارة قوية في اوساط ليزرية مثل الصبغات الليزرية المذابة في مذيبات مختلفة . الدراسة الحالية تناولت الموضوع باختيار صبغة السلفورودامين ب المذابة بالميثانول كمذيب حيث اضيف اوكسيد التيتانيوم الى المحلول ليعمل كمراكز استطارة قوية . ضخ هذا النظام بواسطة ليزر النتروجين بطول موجي 337.1 nm وبقدرات مختلفة . اهتمت الدراسة بموصفات الخط الطيفي المنبعث وعلاقته بطاقة الضخ وتبين ان زيادة طاقة الضخ تؤدي الى انخفاض ملحوظ في عرض الخط الطيفي المنبعث وتقليل واضح في زمن النبضة . كثافة الضخ وعلاقتها مع الطاقة الحرجة للبعث الليزري كانت من اهتمام هذه الدراسة حيث تبين ان زيادة كثافة الضخ تؤدي الى انخفاض قيمة الطاقة الحرجة للأبعاث .