

Biopolymer Random Laser Consisting of Rhodamine 6G and Silica Nanoparticles Incorporated to Bacterial Cellulose

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Abstract: We demonstrate random lasing action in a biopolymer that has large potential for medical applications. The novel random laser consists of nanofibers of bacterial cellulose impregnated with silica nanoparticles and Rhodamine 6G.

OCIS codes: (140.2050) Dye lasers; (160.1435) Biomaterials; (160.5470) Polymers; (260.2510) Fluorescence; (290.4210) Multiple scattering.

1. Introduction

Random lasers (RLs) are a special class of lasers in which the optical feedback is due to scattering processes in an amplifying media instead of conventional Fabry-Perot cavities. After the demonstration made by Lawandy et al. [1] of RLs based on dye solutions containing TiO₂ nanoparticles, the interest in this subject increased and RL action has been observed in a large variety of systems such as dye doped polymer films [2,3] and semiconductor powders [4,5]. In this paper we demonstrate a novel RL system based on a biocomposite consisting of bacterial cellulose with silica nanoparticles. The bacterial cellulose is a biomaterial produced by bacteria *Acetobacter xylinum* that offers large potential for applications in biomedicine [6,7]. The cellulose has a three-dimensional nanostructure and presents relatively high porosity allowing the incorporation of TiO₂ and silica nanoparticles.

The present RL was fabricated using bacterial cellulose doped with Rhodamine 6G (Rh6G). Silica nanoparticles were incorporated to the cellulose membranes to obtain the required feedback for laser action. The results show typical RL characteristics such as nonlinear intensity dependence with the excitation intensity and large spectral linewidth narrowing.

2. Experiment

The samples of bacterial cellulose and silica nanoparticles were prepared from the hydrolysis/condensation of tetraethoxysilane (TEOS) on the cellulose microfibrils at different concentrations of silica/bacterial cellulose (wt%). The silica nanoparticles incorporated to the cellulose were spherical having ≈ 25 nm in diameter and the cellulose sheets have dimensions of $30 \times 30 \times 0.5$ mm³. To add the gain medium the samples were immersed inside an ethanol solution having 10^{-4} M of Rhodamine 6G and kept under strong stirring by 24 h at room temperature. Finally, the membranes were extracted from the dye solution and placed in an oven at 50 °C by 2 h to evaporate the ethanol.

Laser emission was achieved focusing the second harmonic of a Nd:YAG laser beam (532 nm, 6 ns) on the face of the membranes. The spot of laser beam on the sample had 3 mm diameter. The emission spectra were analyzed by a monochromator with 0.3 nm resolution coupled with a CCD camera. Single shot detection was used to avoid uncertainties in the results due to damage of the samples.

3. Results and discussions

Fig. 1 illustrates the spectral narrowing of the luminescence emitted by the sample having a concentration of 1500% silica/bacterial cellulose under two different excitation conditions. Notice that the linewidth was reduced from ≈ 50 nm to ≈ 5 nm when the excitation pulse energy was above the RL threshold. Fig. 2 summarizes the dependence of the peak intensity and the full-width-half-maximum (FWHM) behavior as a function of the excitation pulse energy. Threshold energy of ≈ 1 mJ/pulse was determined considering the pumping energy corresponding to half of the maximum linewidth. This value is comparable with results obtained in ref. [1] where the dye concentration was one-order of magnitude larger than in the present work.

4. Conclusions

We demonstrated efficient laser action in bacterial cellulose doped with silica NPs and Rh6G dye. This work opens the possibility of new applications of the random laser phenomenon in biomedicine such as in regenerative medicine where light with a narrow linewidth is necessary to activate the processes.

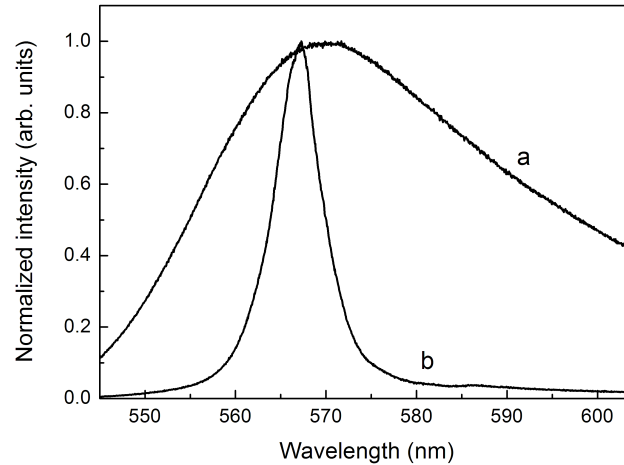


Fig. 1. Normalized emission spectra for the sample containing 10^{-4} M of Rh6G and silica NPs. (a) below the RL threshold (0.04 mJ/pulse). (b) above threshold (3.1 mJ/pulse).

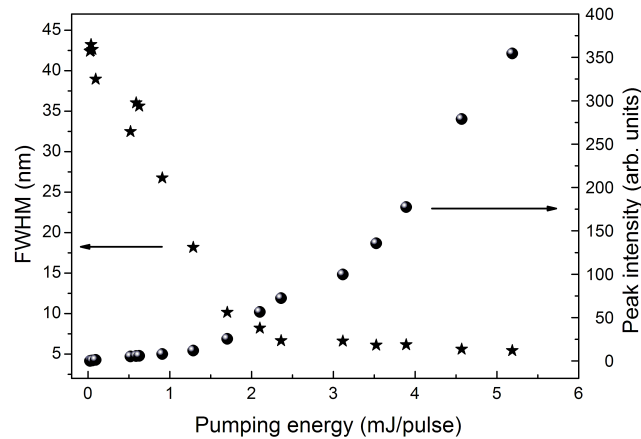


Fig. 2. Peak intensity and full-width-at-half-maximum (FWHM) vs the pumping energy per pulse.

5. References

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