

Chemically tuned light source with an optical pump

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Abstract—This article presents the latest results of rhodamine B and fluorescein solution emissions at different weight concentrations. The shift of an emitted central peak wavelength is observed to change in weight concentrations of active material in samples. By using only two active materials photoluminescence at a desired wavelength from the range 524–660nm can be achieved. All samples were excited sequentially by a laser source and two blue light-emitting diodes without significant changes in the emitted spectra.

Photoluminescence is a type of radiation which is of non-thermal origin. It is energy emission of preceding higher energy absorption. Absorbed electromagnetic radiation may come from the visible spectrum, ultra violet, or even infrared region. The emitted light has energy lower than that of a light exciter, and thus a greater wavelength. As a result of photon absorption, molecules or atoms are excited to higher electronic states. To return to the basic state they must return this energy in the form of radiation.

Photoluminescence can be divided into one of two types: fluorescence and phosphorescence. The main difference between them is the time that must pass between energy absorption and emission. This division depends on the nature of the excitation state (see Fig. 1).

Fluorescence occurs for singlet states. The electron in the excited state is paired with an electron in the ground state with the opposite spin. The consequence of this is a very quick return of the electron to the ground state and photon emission, which takes nearly 10 nanoseconds.

Phosphorescence, on the other hand, is the emission of light from the excited triplet state. In that case, the electrons in the excited and fundamental states have the same spins. Direct transition to the ground state is prohibited, and emission is slower than for fluorescence – typically, an order of milliseconds. Phosphorescence lifetimes of several minutes are even possible [1].

Substances showing singlet-triplet mixed states are possible to obtain. The processes of absorption and emission of radiation are presented in the Jabłoński diagram and shown in Fig. 1.

The emitted spectrum of a fluorescent sample depends on a variety of factors such as concentration, pH, absorbed wavelength and others [2]. The fluorescence spectrum profile can be described by the Gauss function which main parameter is the concentration of an active material (AM) [3]. Amplitude, peak wavelength, half width of the emitted spectrum and decay time can be influenced not

only by the concentration of AM but also by temperature, solvent, or impurities [3–9]. These properties allow the construction of photonic devices and the most promising is ability to control the peak wavelength by using a designed optofluidic system [10]. Fluorescent materials have the potential for being integrated into optical fiber technology [11–12].

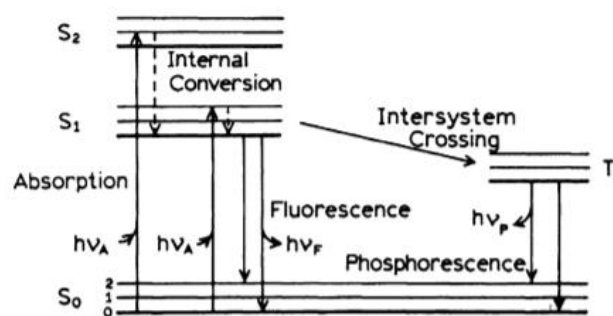


Fig. 1. One form of Jabłoński diagram: S – singlet state, T – triplet state. [1].

In our research two substances showing fluorescent properties, rhodamine B and fluorescein, were used as an AM. As the liquids hosts, in which AM were dissolved, water and 1-Propanol were used. Sample mixtures were prepared to have a wide range of weight concentrations from 6‰ down to 0.01‰ (Fig. 2).

The measurement setup consisted of a light source, mixture container, optical and analysing system. The setup was upgraded with additional custom made elements by 3D printing methods. The prepared samples were illuminated by a laser with a wavelength of 405nm and a half-width of 5.23nm or one of two light-emitting diodes with wavelengths of 405nm and 455nm, and half-widths of 12.59nm and 17.71nm, respectively. Containers with mixtures were placed in the designed element and the AM emission was inducted. The optical response of the sample was measured by a USB4000 spectrometer.



Fig. 2. Selected samples illuminated by a 405nm laser.

A significant influence of solutions weight concentration on the emitted central wavelength was observed. The emitted central wavelength increases with an increase in samples weight concentration. The figures below (Figures 3÷6) show the obtained results of the emission of four mixtures: rhodamine B with water, rhodamine B with propanol, fluorescein with water and fluorescein with propanol excited by a laser light source.

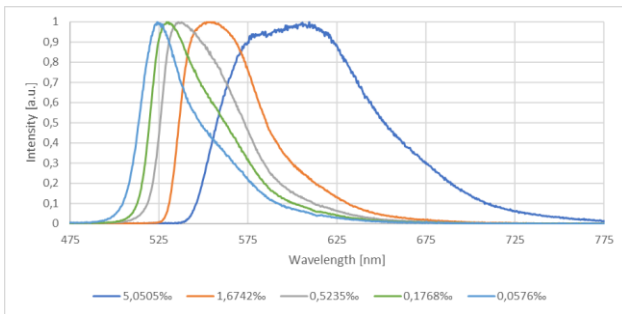


Fig. 3. Emission spectrum change as a concentration function of fluorescein with water sample.

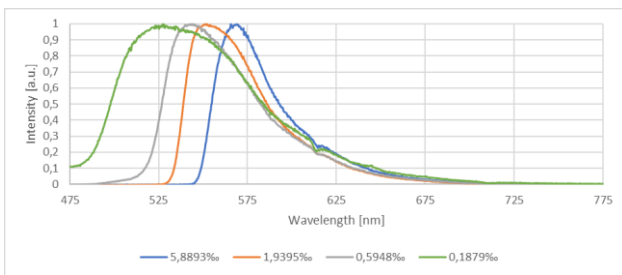


Fig. 4. Emission spectrum change as a concentration function of fluorescein with a propanol sample.

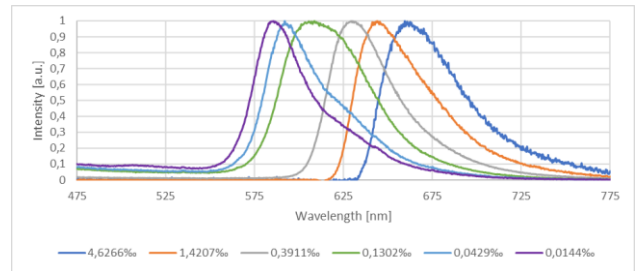


Fig. 5. Emission spectrum change as a concentration function of rhodamine B with a water sample.

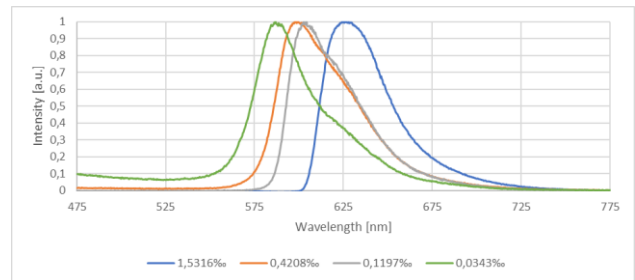


Fig. 6. Emission spectrum change as a concentration function of rhodamine B with a propanol sample.

The characteristics of the central wavelength of emitted light were analysed. The following relationship was determined:

$$\lambda_c = A * \exp(B * \rho),$$

where: λ_c – the central wavelength; ρ – the weight concentration; A, B – the material and base liquid dependent parameters.

Table 1. Parameters depending on the mixtures after laser illumination.

Mixture	Par. A [nm]	Par. B [1/‰]
Fluorescein with water	526.3484(25)	1.0259(12)
Fluorescein with alcohol	535.0001(96)	1.0114(31)
Rhodamine B with water	605.635(16)	1.0225(79)
Rhodamine B with alcohol	599.1968(15)	1.0310(18)

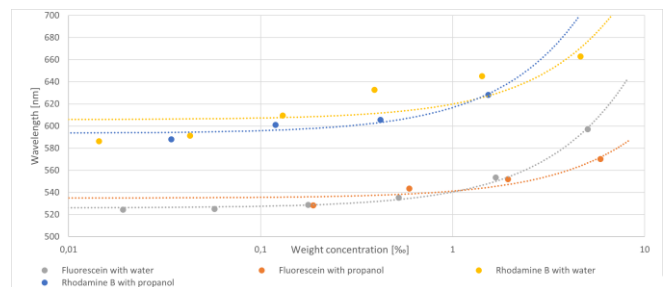


Fig. 7. Central wavelength change as a concentration function.

Emissions induced by light-emitting diodes (405nm and 455nm) did not make any significant changes in the emissions spectra of stimulated samples compared to a laser light source (Figures 8÷9).

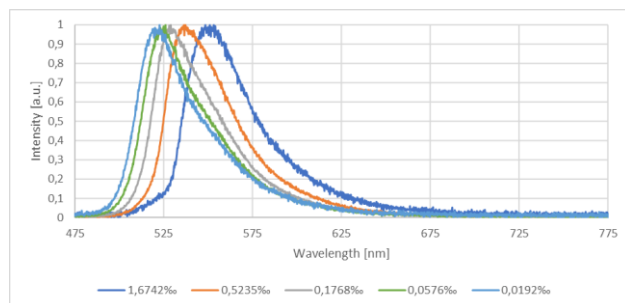


Fig. 8. Emission spectrum change as a concentration function of fluoresceine with a water sample (LED 405nm).

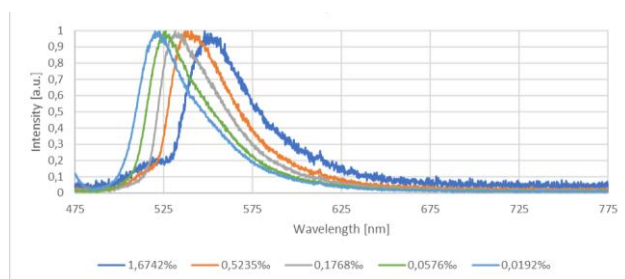


Fig. 9. Emission spectrum change as a concentration function of fluoresceine with water sample (LED 455nm).

Summarizing, samples based on fluorescein and rhodamine B were prepared and emissions spectra were measured for different concentrations. The results show an increase in the wavelength of emitted radiation with an increase in the weight concentration of the solution. This change can be described using an exponential function. No significant change was observed in the emission spectra between the samples with the same active material and different liquid hosts.

For a sample of fluorescein with water, in the concentration range from ~0,02‰ to 5‰, a shift of emitted central wavelength was obtained of nearly 85 nm and for rhodamine B with water the shift is 75 nm. Parameters were determined for this solution dependence of the emitted wavelength on concentration. Thanks to this, it is possible to obtain the source with a selected wavelength.

The main advantage of these substances is a fine-tuned secondary light source which is also easy and quick to prepare. This indicates that there could be practical implementation of the experiment.

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