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Spectroscopic measurements of amplified spontaneous emission in organic thin films

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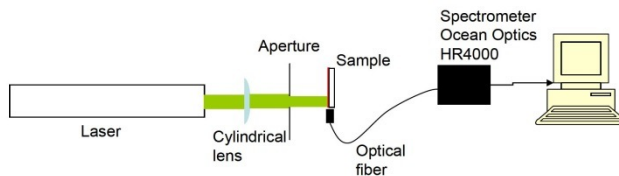
Organic materials are promising candidates for building wide variety of components for optics and photonics. One of such opportunities would be to build cheap and effective dye laser sources that would be based on organic materials. By finding the appropriate materials, such lasers could operate over the entire range of visible spectrum. Since the first demonstration of a dye laser by Soffer and McFarland in 1967 an ever increasing effort has been devoted towards synthesis and investigation of new organic materials that could be used as gain medium in the dye waveguide lasers. For the material characterization and observation of lasing conditions usually a spectrometric setup is used.

Background

In this application note spectrometric techniques are used for the characterization of physical effects in the newly synthesized material DWK-1 in PMMA matrix [1]. The DWK-1 is a derivative of widely used and commonly known DCM (Sigma Aldrich Nr. 410497). Previous studies have shown that DCM in an Alq₃ matrix is a lasing medium with amplified spontaneous emission threshold energy of 3 $\mu\text{J}/\text{cm}^2$. In contrast to DCM, the DWK-1 and DWK-2 do not form aggregates at low doping concentration of PMMA matrix which is due to trityloxyethyl groups of derivatives. For the investigation, the DWK-1 and DWK-2 in PMMA are prepared as thin films with various weight percentages – 0.1, 1, 3, 5 and 10 wt%. The thickness of the thin film is approximately 300 nm. For these films photoluminescence spectrum and amplified spontaneous emission measurements were performed.

Experimental Setup

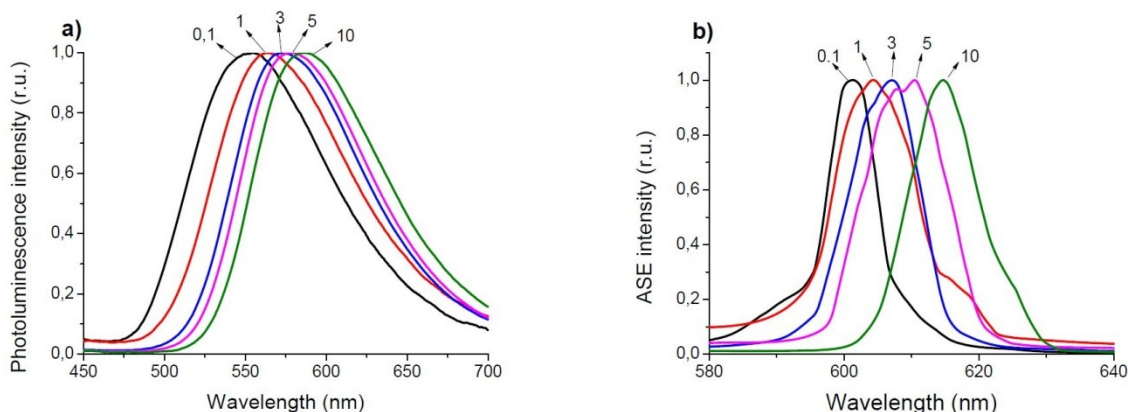
The photoluminescence was excited by continuum wave diode laser with wavelength of 405 nm and calibrated OceanOptics HR4000 spectrometer was used for capturing the photoluminescence spectrum. For measurement of amplified spontaneous emission a custom build experimental setup was used. The scheme of the experimental setup is shown in figure below. The sample is illuminated by a pulsed 532 nm laser and the amplified spontaneous emission is collected by OceanOptics HR4000 spectrometer.



The scheme of the experimental setup for the measurement of amplified spontaneous emission

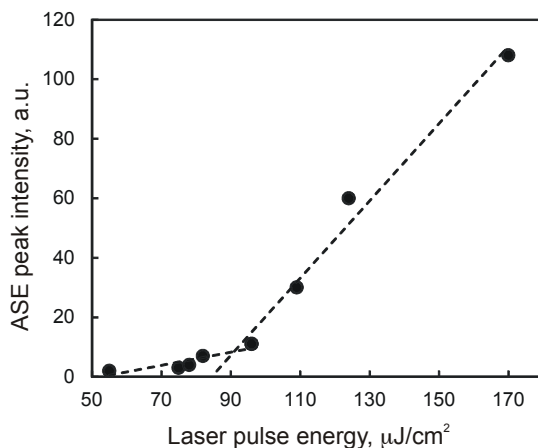
Results and Conclusions

The spectrometric luminescence spectra measurement show that DCM compound is red shifted with respect to **DWK-1** compound. Photoluminescence spectrum dependence on compound concentration in the matrix could be the reason of red shifted photoluminescence spectrum of **DCM** in **PMMA**. Spectrum has red shift by increasing active molecule concentration in polymer as shown in figure below. It means that direct comparison between photoluminescence spectra within one concentration is incorrect. The same red shift was observed also in amplified spontaneous emission spectra as illustrated in figure below. It is explained by solvatochromic effect. Usually this effect takes place in solutions. At the same time it also could be applied to guest-host system where molecules are dissolved in solid solution.



Dependence of a) photoluminescence and b) amplified spontaneous emission spectra on DWK-1 molecule concentration in PMMA matrix

Variations of the peak intensity of the amplified spontaneous emission spectra by changing the pump beam intensity are shown in Figure below. It can be clearly seen that two linear relations with different slopes can be obtained. First linear increase of emission intensity with smaller slope is related to photoluminescence. Second linear increase at the high pump energies corresponds to amplified spontaneous emission. Excitation threshold value of amplified spontaneous emission was obtained at the point of intersection of these two lines. Amplified spontaneous emission was not possible to observe in polymer system with 0.1 wt %



Amplified spontaneous emission (ASE) peak intensity of DWK-1 as a function of pump laser pulse energy

Further investigations show that at higher concentration than 10 wt% could be possible to obtain smaller threshold value. Within the investigated concentration the best result of threshold value ($10 \mu\text{J}/\text{cm}^2$) was reached for 10 wt% DWK-1 in PMMA matrix. It is at least one order of magnitude lower compared to the best system of DCM in PMMA ($286 \text{ J}/\text{cm}^2$). It means that DWK-1 molecule is perspective for laser media. Obtained results could be explained by previously measured photoluminescence quantum yield dependence on dye concentration in matrix. DWK-1 molecule showed negligible photoluminescence quantum yield dependence on concentration wherewith decreasing of excitation threshold value of amplified spontaneous emission.

Conclusions

Spectroscopic measurements have shown that photoluminescence and amplified spontaneous emission spectra exhibit red shift with increasing active molecule concentration in polymer. It is explained by positive solvatochromic effect when dielectric constant in system is increasing with the active molecule

concentration. Amplified spontaneous emission excitation threshold energy is decreasing by the increase of DWK-1 molecule concentration in PMMA matrix. It is due to small intermolecular interaction which leads to negligible photoluminescence quantum yield changes on dye concentration. Moreover, we are able to reduce more than one order of magnitude threshold value in the system DWK-1 in PMMA compared to the system DCM in PMMA. It means that DWK-1 compound is perspective for practical use in light amplification systems.

References

1. Aivars Vembris, Elmars Zarinsh, Valdis Kokars, Amplified spontaneous emission of glass forming DCM derivatives in PMMA films, SPIE Proceedings, 9137, 91371E, (2014), DOI: 10.1117/12.2052508