

Selected organic gain media for tunable DFB laser action

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The aims of present doctoral dissertation were to highlight the advantages of organic materials for purposes of light amplification, especially for tunable distributed feedback (DFB) laser action. The studies were performed on organic layers consisted of passive polymeric matrices doped with luminescent dyes, or luminescent macromolecules capable to form films. Tunability of laser line emitted by fabricated materials was demonstrated owing to the utilization of holographic pumping technique, allowing simultaneous excitation of the medium, and generation of the temporal DFB resonator with proper spatial period – disappearing with cessation of the pumping. The dissertation was divided into four parts concerning photo-physics of chosen materials, emphasizing material properties important for the thesis aims.

In the first part it was shown that DFB laser action can be generated in poly(methyl methacrylate) (PMMA) medium doped with luminescent crystals of pyrazoline derivative DCNP, which inherently exhibits random lasing phenomenon. Thus, the random feedback, resulting from the presence of light scattering provided by the dye crystals dispersed within the matrix, could be coupled to the well-defined DFB resonator, leading to the desired laser line selection. The relatively broad wavelength tuning within 65 nm was possible due to the presence of the two neighboring stimulated emission bands of DCNP/PMMA material. The studies indicate that the crystallization of a luminescent dye inside the gain material, often treated as detrimental, in some cases may lead to unique and advantageous properties of laser active media – in presented example, to the broad tunability.

The second part of thesis is devoted to tailoring of gain region spectral position in organic media. On the example of xanthene derivatives Rhodamine 6G and Rodamine B, and phenoxazine derivative Nile Blue, each doped to poly(vinyl alcohol) (PVA), it was shown that both, gain profile spectral position and width, can be controlled by changes of a dye concentration in the matrix. These parameters reflect the available spectral range of laser action tuning in the presence of a resonator. The abovementioned effect was feasible due to the ability of dyes to form luminescent molecular aggregates, exhibiting red-shifted emission. Additional spectral shift between the position of an excitation line and stimulated emission bands was achieved via the sequence of Förster resonance energy transfers, involving molecules and aggregates of donor and acceptor dyes. As a consequence, DFB laser action was obtained in the longer wavelengths spectral region.

The third part concerned the issue of laser action tunability range enlargement in organic gain media. As previously, the studies were performed for compounds in intentionally aggregated forms. For this purpose the pyrazoline derivative DCNP crystals and molecular aggregates of xanthene derivative Rhodamine 700 have been chosen. The presented approach relied on the optimization of the two luminescent dyes mixture ratio in the PMMA matrix. Both dyes were exhibiting spectrally shifted luminescence with respect to each other, and were able to be pumped directly with the same excitation line. As a result of the optimization, the DFB lasing wavelength tuning range of 125 nm was achieved. This value is almost twice broader than for DCNP/PMMA described earlier. In this part of dissertation it has been stressed, that utilization of luminescent components of laser active media in the crystallized form, may bring another beneficial feature resulting from their lower susceptibility to undergo nonradiative emission quenching by potential energy acceptor.

The fourth part of thesis demonstrates an example of organic gain media molecular engineering opportunities, showing how to obtain desired properties of laser active material by the utilization of planned synthesis approach. On the example of synthesized macromolecules with luminescent centers of anthracene derivative Ant-PMMA and Lemke's chromophore derivative Lem-PMMA, it was shown that the chemical structure of the fluorophores covalently immobilized within the medium, can determine the DFB lasing feedback mechanism and influence its efficiency. In the case of abovementioned compounds, the ability of Lem-PMMA fluorophore to undergo *cis-trans* photoisomerization was found to be advantageous as it allowed generation of temporary DFB resonator based on refractive index modulation.