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Effect of plasmonic nanoparticles on the optical and lasing properties of merocyanine dyes with different polymethine chain lengths

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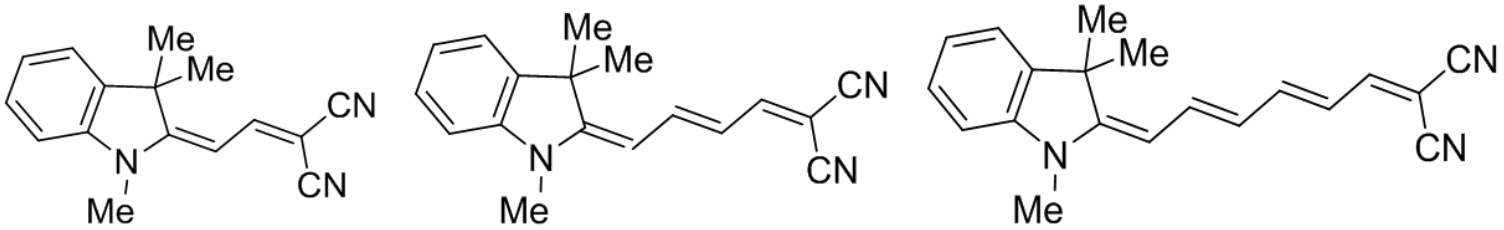
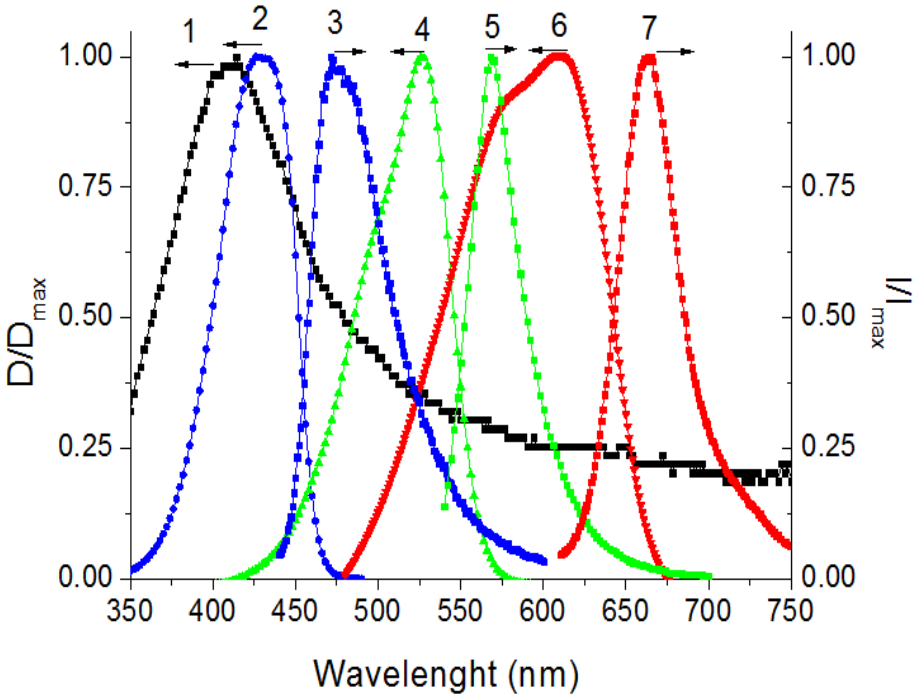
The aim of the work: studding the effect of silver nanoparticles (NPs) on the spectral-luminescent and lasing properties of polymethine dyes depending on their structure. For this purpose a vinylogous series of neutral merocyanine dyes **1-3** was selected.

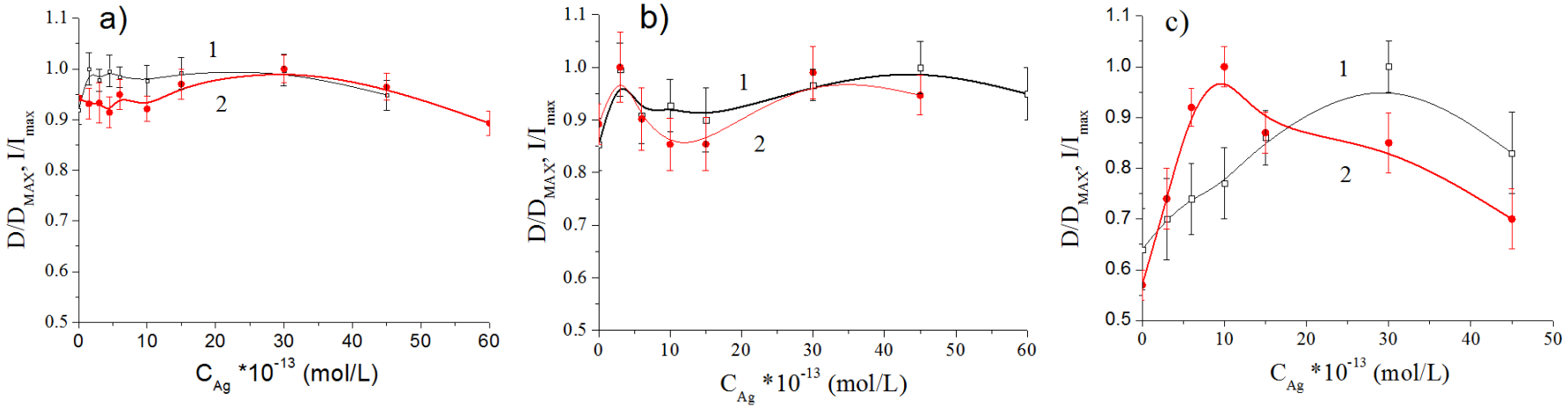


1 **2** **3**



Normalized absorption spectra of silver NPs (1), absorption spectra (2, 4, 6) and fluorescence (3, 5, 7) of dyes **1** (2, 3), **2** (4, 5), **3** (6, 7) in ethanol

Effect of silver NPs on optical properties of merocyanine dyes in solutions



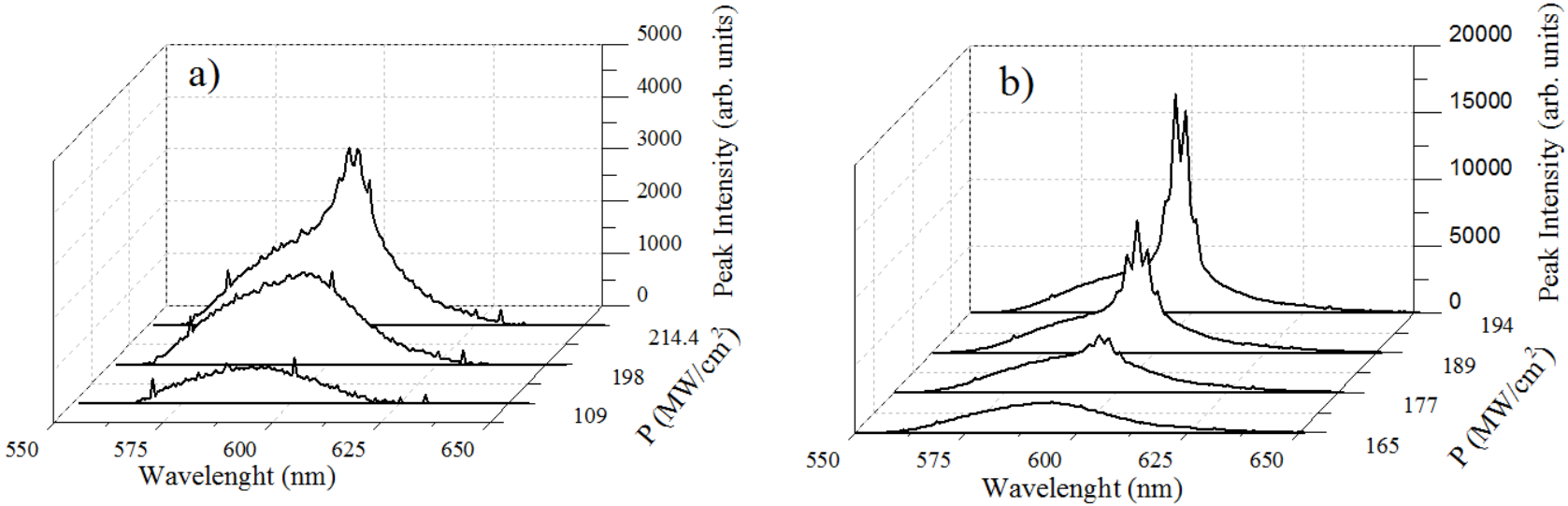
Optical density *D* (1) and fluorescence intensity I_{FL} (2) of dyes **1** (a), **2** (b), **3** (c) in solutions with different concentrations of NPs

Spectral-fluorescence characteristics of ethanol solutions of merocyanine dyes

Dye	${}^{a}\lambda_{max}$, nm	$\Delta^{a}\lambda_{1/2}$, nm	${}^{f}\lambda_{max}$, nm	$\Delta^{f}\lambda_{1/2}$, nm	Φ_f	τ_f, ns	f	$\omega \cdot 10^{15}$, *rad*/s	p, D
1	426	52	469	68	0.004	0.26	0.93	4.16	9.4
2	524	87	582	50	0.008	0.15	0.97	3.42	10.7
3	606	139	670	45	0.05	0.39	1.30	2.92	13.3

Maxima (${}^{a}\lambda_{max}$, ${}^{f}\lambda_{max}$) of optical density (*a*) and fluorescence intensities (*f*) of dyes and their half-widths ($\Delta^{a}\lambda_{1/2}, \Delta^{f}\lambda_{1/2}$); Φ_f – quantum yield of fluorescence; τ – luminescence lifetime; f – oscillator strength; ω – frequency of the transition from the ground state (S_0) to the first excited singlet state (S_1); p – electron dipole moment of the transition.

Effect of silver NPs on stimulated emission properties of merocyanine dyes **2** and **3**



Emission spectra of the dye **2** in ethanol without silver NPs (a) and at C_{NP} = 3×10^{-12} mol/l (b) at different pump power densities

Characteristics of stimulated emissions of dyes **2**, **3** in ethanol with silver NPs

Samples	Threshold of generation (P_{tr}), MW/cm^2	$\Delta\lambda_{1/2}$, nm
Dye **2** without NPs	186	11
Dye **2** + Ag NPs (3×10^{-12} mol/l)	172.5	5.8
Dye **3** without NPs	33.5	2
Dye **3** + Ag NPs (10^{-12} mol/l)	26	2

Conclusions:

- 1. Addition of silver NPs to the dye solutions increases the optical density *D* and the fluorescence intensity I_{FL} of dyes **1-3**. The effect of silver NPs on *D* and I_{FL} values increases with increasing the length of the polymethine chain.
- 2. The spectral overlap between silver NPs and merocyanines molecules decreases with increasing the length of the polymethine chain. An increase in the effect of silver NPs on the optical properties of the dye solutions may be related to an increase in the electron dipole moment (*p*) of the transition from the ground state to the first excited state with an increase in the length of the polymethine chain.
- 3. Changes in value of quantum yield Φ_f in the series of dyes **1-3** correspond to changes observed in *D* and I_{FL} values of dyes in the presence of silver NPs.
- 4. The presence of NPs in the solution with dyes **2** and **3** leads to a decrease in the generation threshold P_{tr} of stimulated radiation of dyes. The decrease in the value P_{tr} corresponds to the changes observed for *D,* I_{FL} and Φ_f values of the luminescence of dyes **2**, **3**.

Thank you for attention!

This research is funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP08856161).