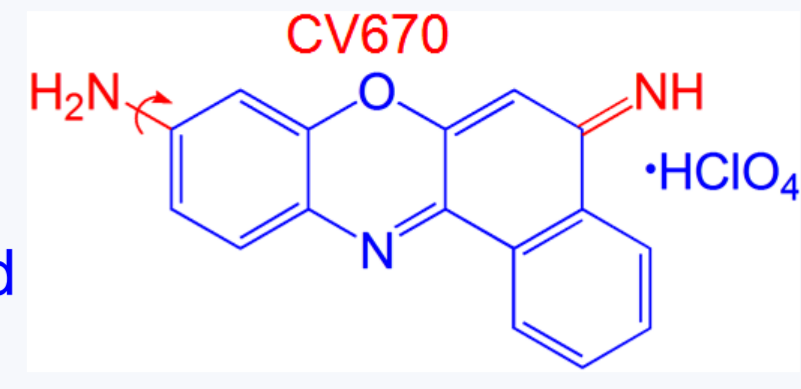
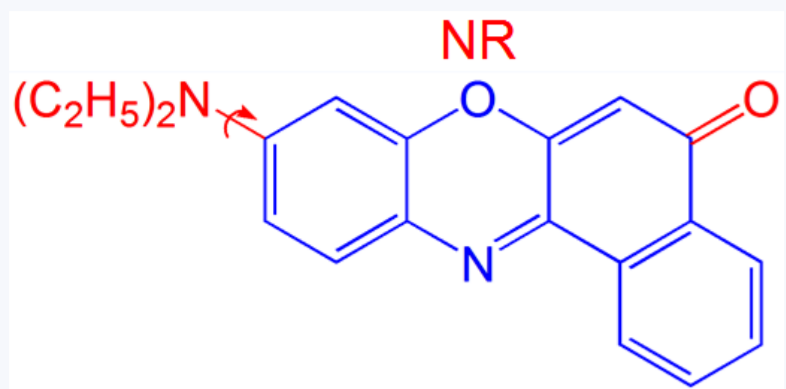


# Characteristics of laser dye Nile red in a series of solvents

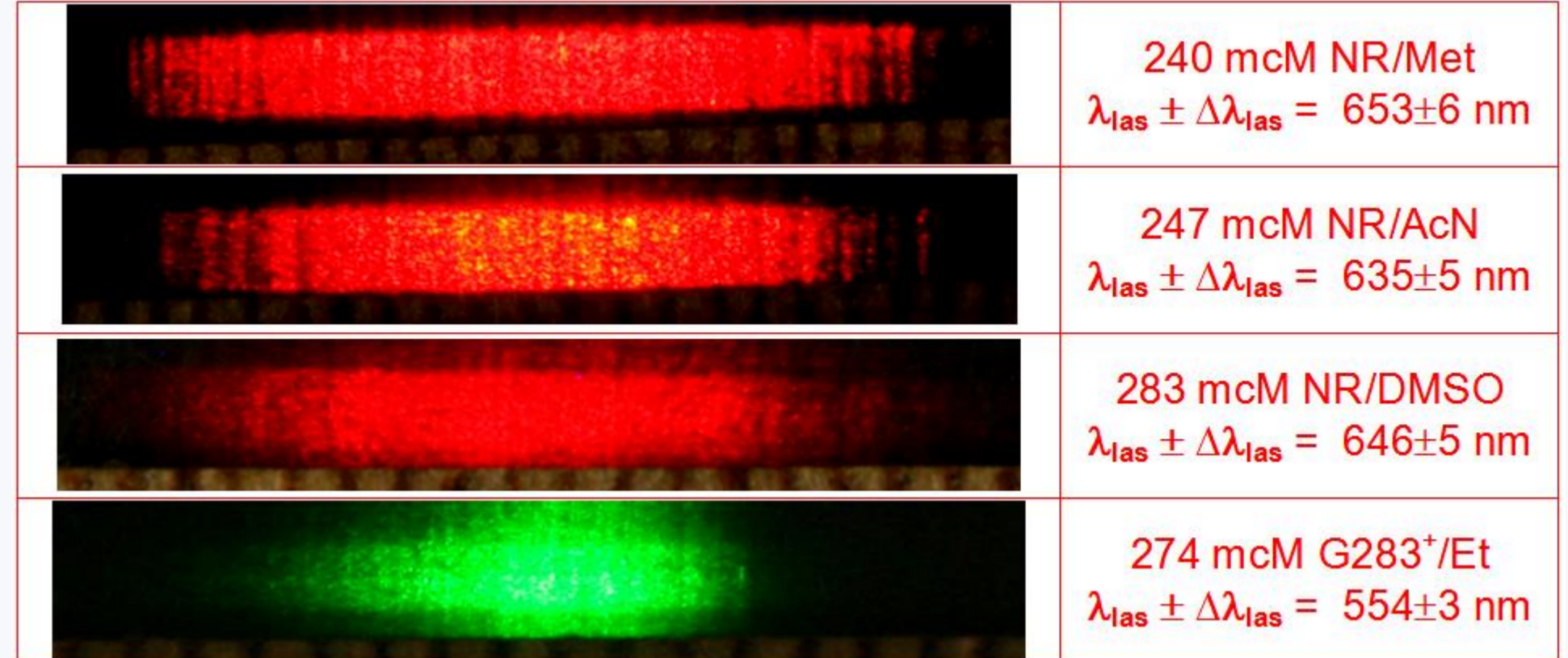
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Continuing our studies of the influence of the molecular environment on the spectral and emission characteristics of solutions of laser oxazine dyes in order to expand the possibilities of creating active photonic elements for the red region of the spectrum based on them [1], we conducted a series of similar measurements of the characteristics of their close structural analogue - the effective laser dye **Nile Red (NR)**. This dye, from the very beginning of its use in lasers [2], differed from other laser dyes in its energy photostability. In addition, its ability to bind to a number of biological tissues makes it a common probe for their visualization [3].

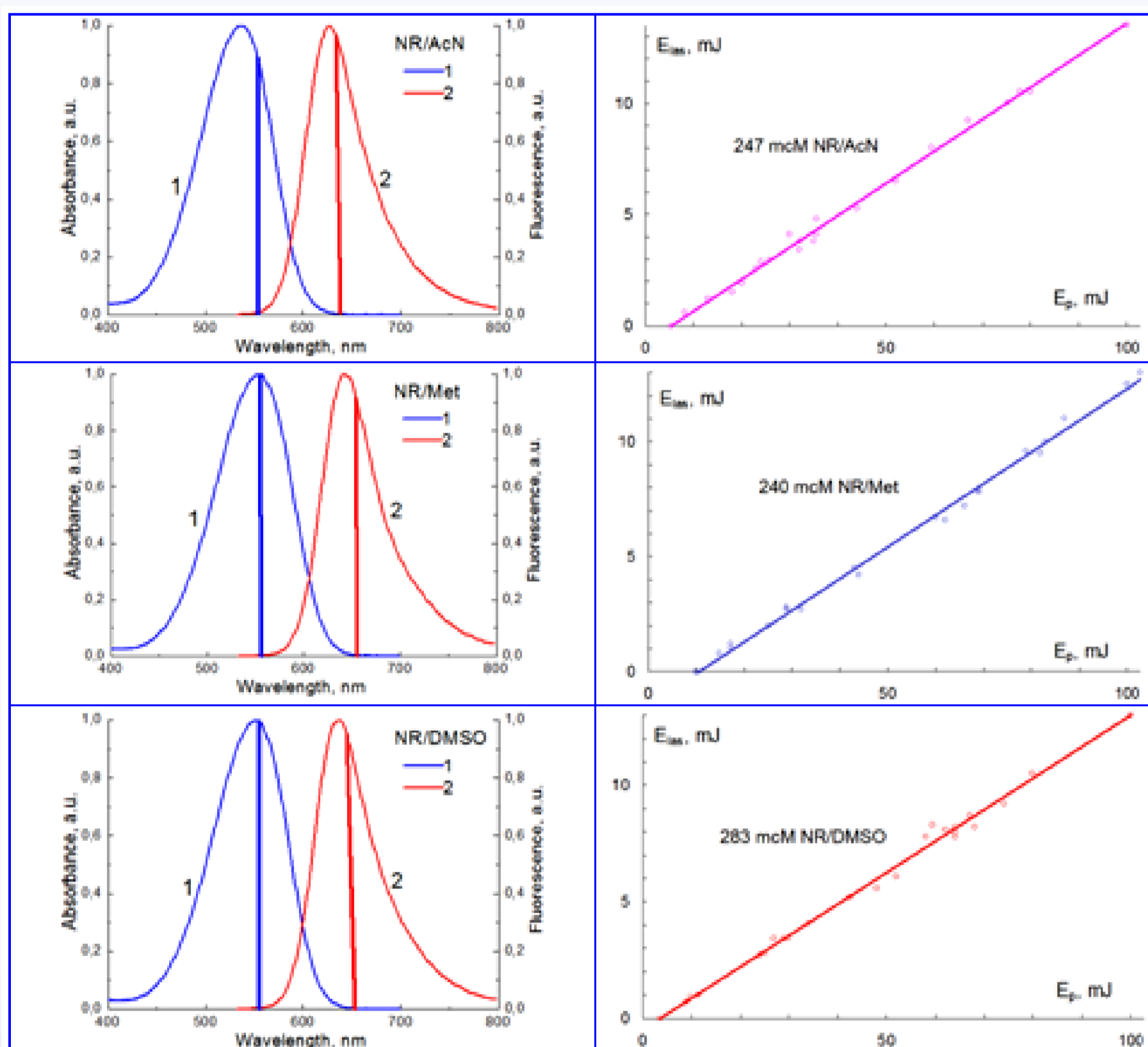


The measurements of spectral, fluorescent, and laser characteristics of Nile red in methanol (Met), acetonitrile (AcN), and dimethyl sulfoxide (DMSO) showed its significant differences from the previously studied [1] oxazine derivatives CV670 and Ox720. The presence in its structure of a carbonyl group, which has proton-acceptor properties, changed the nature of the interaction of this dye with its solvate environment. As a result, the solvents acetonitrile and DMSO showed themselves in this case as aprotic, and in the **absorption spectra of this dye** in all solutions only one long-wave band is observed, which is shifted to the green region by 40–50 nm relative to CV670 and by 70–80 nm relative to Ox720. In this case, the Stokes shift of the fluorescence spectra  $\Delta\nu^{St}$  increases by 3–4 times. This shift is the result of a significant increase in the dipole moment of the NR molecule upon its excitation to the upper  $S_1$  state.

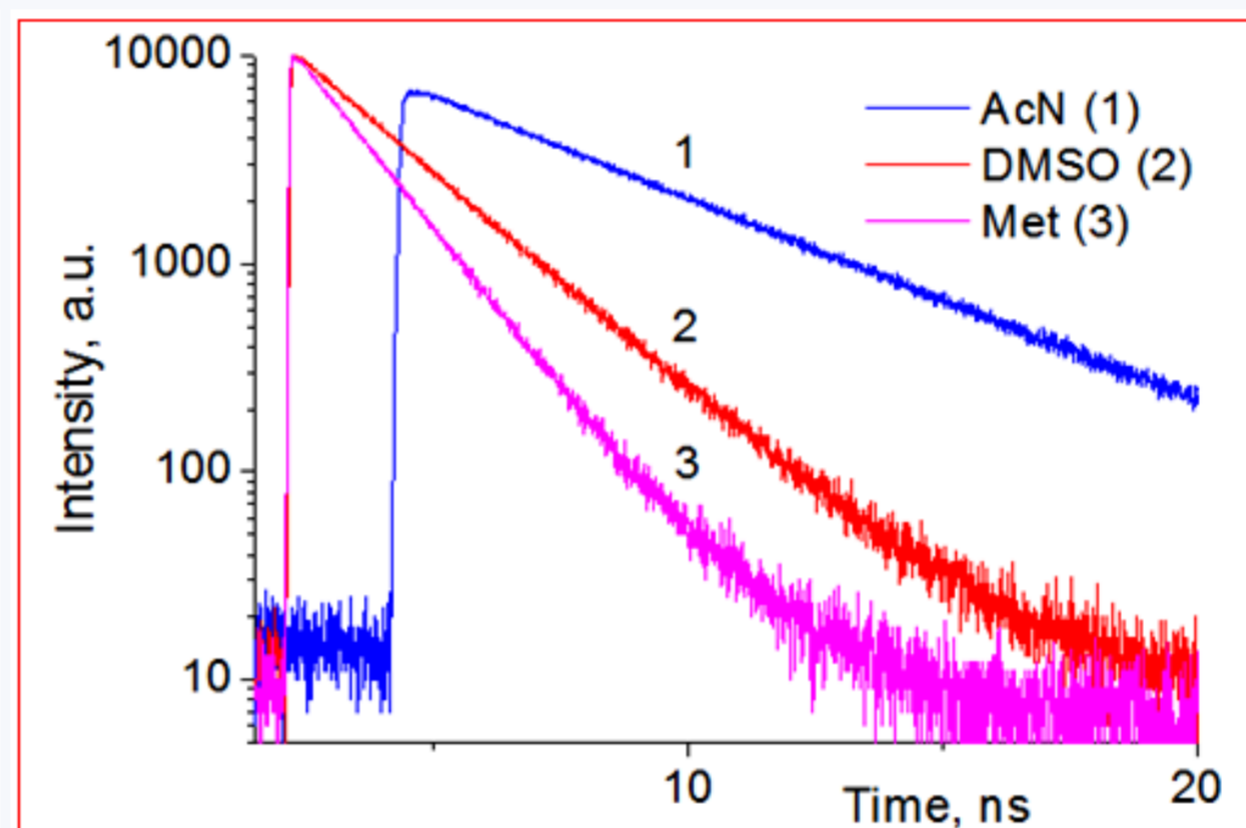


Lasing of NR in methanol ( $\lambda_{las} = 653$  nm) under excitation with a flashlamp-pumped dye laser ( $\lambda_p = 554$  nm)

Laser spectra of NR in Met, AcN and DMSO (top 3 lines), below is one of G283<sup>+</sup> in EtOH



Absorption (1) and fluorescence (2) spectra and the positions of pumping (I) and lasing (II) spectra in them - left column. Dependence of output laser energy of NR solutions on the pumping energy - right column.



Fluorescence quenching of NR in AcN, DMSO, and Met

Another important difference between **NR** and CV670 and Ox720 is that its **fluorescence decay in all three solvents has a highly reliable exponential character** (extrapolation error is  $\leq 0.5\%$ ). Moreover, in aprotic AcN and DMSO, time of this decay is 20–30% longer than for the oxazines, constant of non-radiative transitions is 2.2–5.9 times smaller, and that of radiative ones is 1.4–2.1 times larger. **The fluorescence quantum yield also increases by**

**1.4–2.8 times.**

As for the methanol solution of **NR**, the possibility of creating **hydrogen bonds** of its molecule at the proton-acceptor oxygen of the carbonyl group **with methanol** molecules leads to a **violation of the planarity** of the **NR molecule in the excited  $S_1$  state**. As a result, the probability of **non-radiative transitions** from it **increases**. Thus, compared with CV670,  $k^{nr}$  increased by 1.5 times, the fluorescence quantum yield decreased by 30%. At the same time, the fluorescence decay remains exponential, although its time decreased by 15%.

Comparing the absorption spectra of NR in the solvents used, we note that bipolar DMSO has the same effect on the dye molecule in the ground state as methanol compared to the less polar aprotic AcN.

But in the excited state, **methanol**, which can form hydrogen bonds with the NR molecule, gives a **larger bathofloric shift than DMSO**. And if the value of molar extinction  $\epsilon$  in these solvents does not differ much, then the **fluorescence quantum yield  $Q$**  of NR according to our measurements **is maximal in bipolar DMSO**.

## Spectral, fluorescent and laser characteristics of Nile red

Solvent	$\lambda_a$ , nm	$\epsilon \cdot 10^{-3}$ , $\text{cm}^{-1}\text{M}^{-1}$	$\lambda_f$ , nm	$Q$	$\tau_f$ , ns	$k^r \cdot 10$ , $\text{ns}^{-1}$	$k^{nr} \cdot 10$ , $\text{ns}^{-1}$	$\Delta\nu^{St}$ , $\text{cm}^{-1}$	$\lambda_{las}$ , nm	$\Delta\lambda_{las}$ , nm	$\Delta\nu^{las}$ , $\text{cm}^{-1}$	$E_{thr}$ , mJ	$E_{100}$ , mJ
Met	553	45,0	642	0,45	2,82	1,60	1,95	2500	653	6	260	10	12,5
AcN	537	46,0	627	0,76	4,40	1,73	0,54	2670	635	5	200	5,5	13,5
DMSO	553	43,0	635	0,84	4,14	2,03	0,39	2340	646	5	270	3,7	13,0

The **laser characteristics** of the **NR** dye were investigated when its solutions were excited by the radiation of a flashlamp-pumping dye laser on the iminocoumarin G283<sup>+</sup> [4] with wavelength of 554 nm and output energy of up to 120 mJ under the same conditions and on the same setup as the oxazine derivatives [1]. The measurements of these characteristics showed that all the investigated **NR** solutions effectively **generate radiation** in a non-selective resonator in the region of **630–660 nm** with a **bandwidth of 10 nm**, and at a pumping energy of 100 mJ their **output energy significantly by 1.5–6.5 times exceeds** the similar values obtained at the same pumping for **CV670** and **Ox720**. We also note that the **threshold pumping energy  $E_{thr}$**  of different solutions **correlates well with the quantum yield of NR fluorescence  $Q$**  in these solutions: namely,  $E_{thr}$  is **minimal in DMSO and maximal in methanol**. But at a pumping of 100 mJ, which is many times greater than  $E_{thr}$ , the output laser energy  **$E_{100}$  of all solutions is practically the same** with an accuracy of up to the error of its measurement ( $\pm 0.5$  mJ).

[1] V. V. Maslov and I. M. Pritula, Low Temp. Phys. 52, 28 (2026). <https://doi.org/10.1063/10.0042159>

[2] D. Basting, D. Ouw, F. P. Schafer, Optics Commun. 18, 260 (1976). [https://doi.org/10.1016/0030-4018\(76\)90126-7](https://doi.org/10.1016/0030-4018(76)90126-7)

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