New Laser Dyes for Q-Switching and Mode Synchronization in Neodymium Lasers

Dye lasers presently operate in the range from 308.5 nm to 1.85 μm, and nonlinear optical methods extend this range down to about 80 nm.[1] Recent advances in the understanding of structure-property relationships have led to the engineering of new laser dyes.[2] In addition to a wide selection of classical laser dyes, we now list a variety of new polymethine dyes that demonstrate unique features.

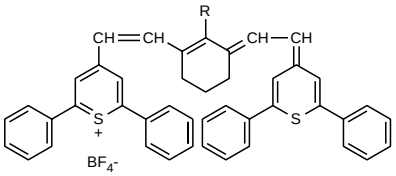
Dyes **1** and **2** can be used as active laser media generating picosecond-range radiation pulses in the wavelength range of 1100-1200 nm. As a result of their long relaxation times (τ) and large absorption cross section (σ), the bleaching requires only low-intensity pumping. Their τ parameters are highly sensitive to changes in the polarity of the medium.[3,4]

Dye No.	F.W.	mp °C (dec)	λ_{max} nm ($\varepsilon 10^5$)	τ ps	σ 1060 nm 10^{16} cm^2	Working Medium
1	749.15	222	1061 (2.8)*	50	10.6	Chlorinated solvents dichloroethane, chlorobenzene, etc.
2	790.80	240	1040 (2.9)*	35	9.2	
3	838.80	192	1100 (0.9)*	6	3.5	
4	824.78	220	1135 (1.3)*	5	2.6	Alcohols
5	711.44	230	1051 (2.1)**	7	7.9	
6	739.93	230	1048 (2.0)**	7	8.0	

t lifetime of the bleached state * in dichloromethane ** in ethanol
t and s values depend on solvent

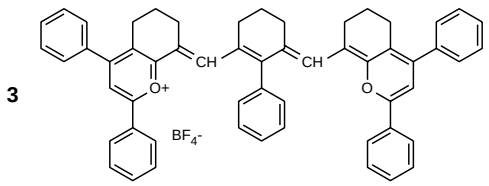
Dyes **3** and **4** are remarkable for their extremely short excited state lifetimes. They enable passive mode synchronization regimes to be realized in lasers generating ultra-short pulses of minimum duration at the wavelengths λ_{pad} = 1055-1080 nm.[3-6]

Dyes **5**, **6,** and **7** are characterized by high photostability in various solvents, small τ values, and maximum σ values as compared to other organic dyes at radiation wavelengths typical of neodymium lasers. Their ethanol or isobutanol solutions are effective laser Q-switches. Relaxation times for these three dyes are slightly sensitive to the polarity of the medium.[4,7] The maximum Q-switching efficiency of the ethanol solutions amounts to 36% for **5** and 60% for **6** and **7**. The photostability of the latter two dyes is 2.5 times that of **5**. The solvents (particularly alcohols) to be used for laser applications of dyes **5-7** should be free of alkaline impurities.

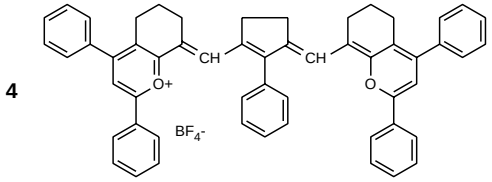


40,512-4 **4-(2-{2-Chloro-3-[(2,6-diphenyl-4*H*-thiopyran-4-ylidene)ethylidene]-1-cyclohexen-1-yl}ethenyl)-2,6-diphenylthiopyrylium tetrafluoroborate**, dye content ~80% **(1)**

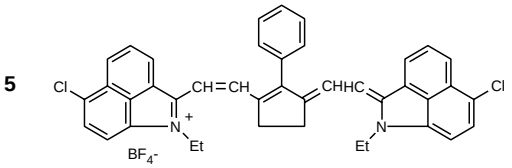
40,513-2 **4-(2-{3-[(2,6-Diphenyl-4*H*-thiopyran-4-ylidene)-ethylidene]-2-phenyl-1-cyclohexen-1-yl}ethenyl)-2,6-diphenylthiopyrylium tetrafluoroborate**, dye content ~95% **(2)**



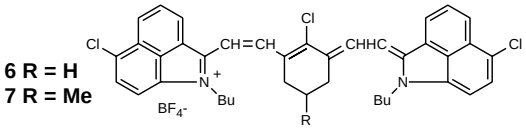
40,514-0 **8-({3-[(6,7-Dihydro-2,4-diphenyl-5*H*-1-benzopyran-8-yl)methylene]-2-phenyl-1-cyclohexen-1-yl}-methylene)-5,6,7,8-tetrahydro-2,4-diphenyl-1-benzopyrylium tetrafluoroborate**, Dye content ~95% **(3)**



40,515-9 **8-({3-[(6,7-Dihydro-2,4-diphenyl-5*H*-1-benzopyran-8-yl)methylene]-2-phenyl-1-cyclopenten-1-yl}-methylene)-5,6,7,8-tetrahydro-2,4-diphenyl-1-benzopyrylium tetrafluoroborate**, dye content ~97% **(4)**



40,516-7 **6-Chloro-2-(2-{3-[(6-chloro-1-ethylbenz[*cd*]indol-2(1*H*)-ylidene)ethylidene]-2-phenyl-1-cyclopenten-1-yl}-1-ethenyl)benz[*cd*]indolium tetrafluoroborate**, dye content ~95% **(5)**



40,517-5 **1-Butyl-2-(2-{3-[(1-butyl-6-chlorobenz[*cd*]indol-2(1*H*)-ylidene)ethylidene]-2-chloro-1-cyclohexen-yl}-ethenyl)-6-chlorobenz[*cd*]indolium tetrafluoroborate**, dye content ~97% **(6)**

40,518-3 **1-Butyl-2-(2-{3-[(1-butyl-6-chlorobenz[*cd*]indol-2(1*H*)-ylidene)ethylidene]-2-chloro-5-methyl-1-cyclohexen-1-yl}ethenyl)-6-chlorobenz[*cd*]-indolium tetrafluoroborate**, dye content ~97% **(7)**

References: (1) Schäfer, F.P. *Appl. Phys.* **1988**, *B46,* 199. (2) Tolmachev, A.I. *Teubner Texte für Physik* **1987**, *13*, 115. Fabian, J. et al. *Chem. Rev.* **1992**, *92*, 1197. (3) Babenko, V.A. et al. *Kvantovaya Elektronika* **1980**, *7*, 1796. Bareika, B.F. et al. *ibid.* **1982**, *9*, 2289. (4) Penzkofer, A. *Appl. Phys. B* **1988**, *46*, 43. (5) Demchuk, M.I. et al. *Zh. Prikl. Spektrosk.* **1985,** *42,* 718. (6) Grigonis, R. et al. *Lasers and Ultrafast Processes;* Vilnius University Press: Vilnius, Lithuania, 1991; Vol. 4, pp 197-199. (7) Ishchenko, A.A. et al. *Opt. Spektrosk.* **1988**, *64*, 653. *Ukr. Khim. Zh.* **1989**, *55,* 979.