Dye Lasers

- Tunability in a broad spectral (visible) range.
- A dye dissolved in a solvent (water, alcohol) at $\sim 10^{-4} M$ which is pumped by a flashlamp or by another laser.
- Dyes ~50 atoms, comprised of hydrocarbons

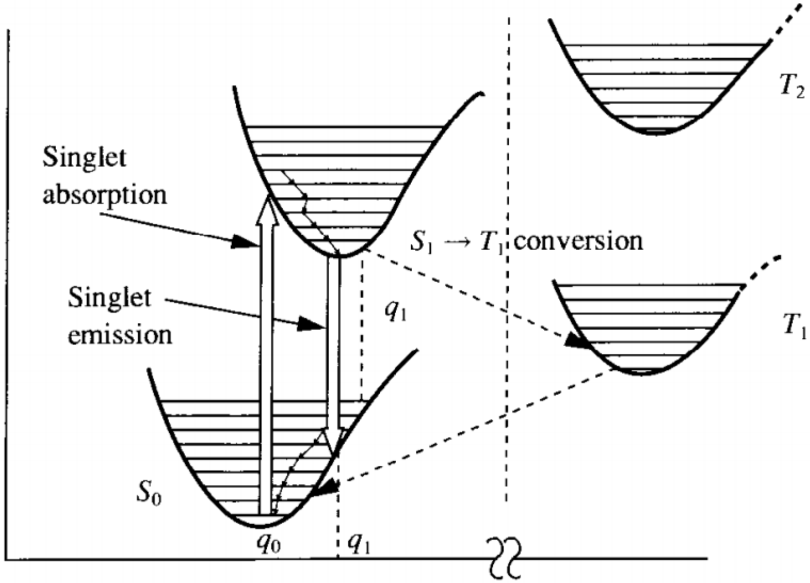


FIGURE 10.19. Energy-level diagram typical of a dye. (Data from Bass et al. [9]).

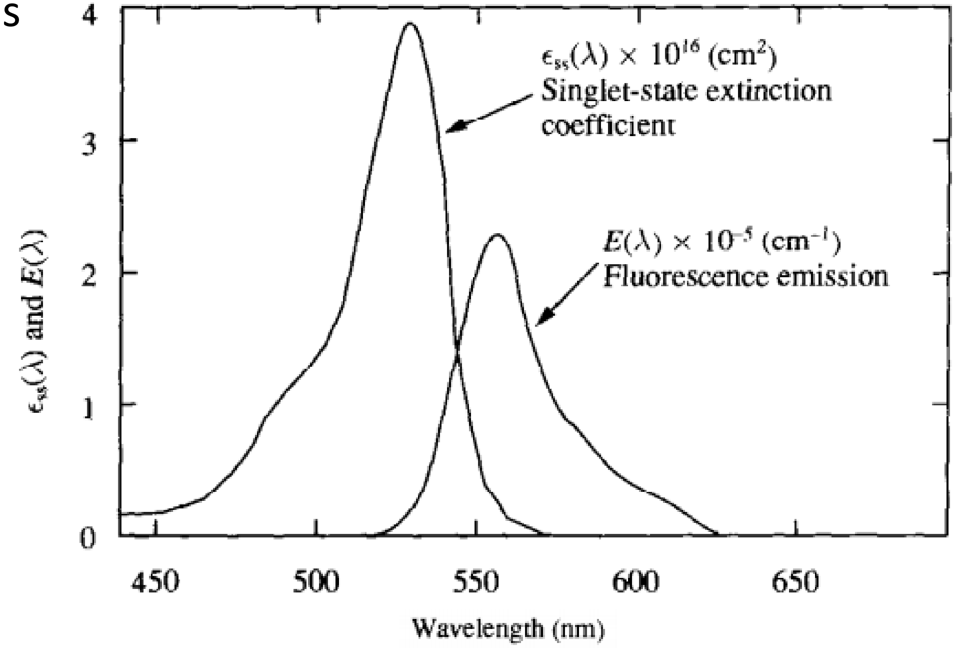


FIGURE 10.20. Singlet-state absorption and fluorescence spectra of rhodamine 6G obtained from measurements with a 10^{-4}M ethanol solution of the dye. (Data from Snavely [8].)

Boltzmann distribution in each manifold q_1 is shifted with respect to q_0

Absorption: (1) $h\nu_{pump} + (\text{dye at } q_0 \text{ in } S_0) \rightarrow (\text{dye at } q_0 \text{ in } S_1)$

Relaxation in S_1: (2) $(\text{dye at } q_0 \text{ in } S_1) + (\text{solvent}) \rightarrow\rightarrow (\text{dye at } q_1 \text{ in } S_1)$ [very fast]

Emission: (3) $(\text{dye at } q_1 \text{ in } S_1) + h\nu_{laser} \rightarrow\rightarrow (\text{dye at } q_1 \text{ in } S_0)$ [Stim. Emission.]

Relaxation in S_0: (4) $(\text{dye at } q_1 \text{ in } S_0) + (\text{solvent}) \rightarrow\rightarrow (\text{dye at } q_0 \text{ in } S_0)$ [very fast]

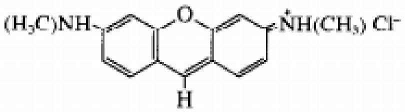
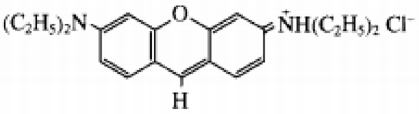
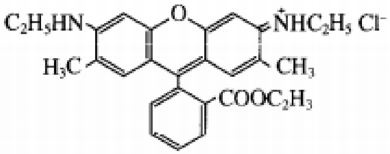
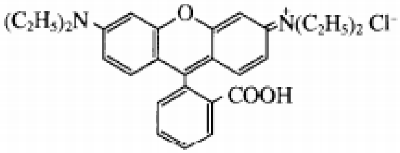
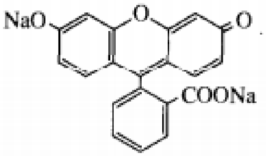
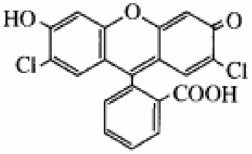
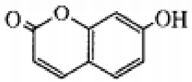
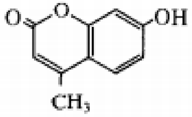
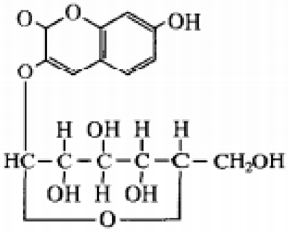
Dye	Structure	Solvent	Wavelength
Acridine red		EtOH	Red 600–630 nm
Puronin B		MeOH H_2O	Yellow
Rhodamine 6G		EtOH MeOH H_2O DMSO Polymethyl-methacrylate	Yellow 570–610 nm
Rhodamine B		EtOH MeOH Polymethyl-methacrylate	Red 605–635 nm
Na-fluorescein		EtOH H_2O	Green 530–560 nm
2,7-Dichloro-fluorescein		EtOH	Green 530–560 nm
7-Hydroxy-coumarin		H_2O (pH ~ 9)	Blue 450–470 nm
4-Methylem-belliferone		H_2O (pH ~ 9)	Blue 450–470 nm
Esculin		H_2O (pH ~ 9)	Blue 450–470 nm

FIGURE 10.17. Molecular structure, laser wavelength, and solvents for some laser dyes. (Data from Snavely [8].)

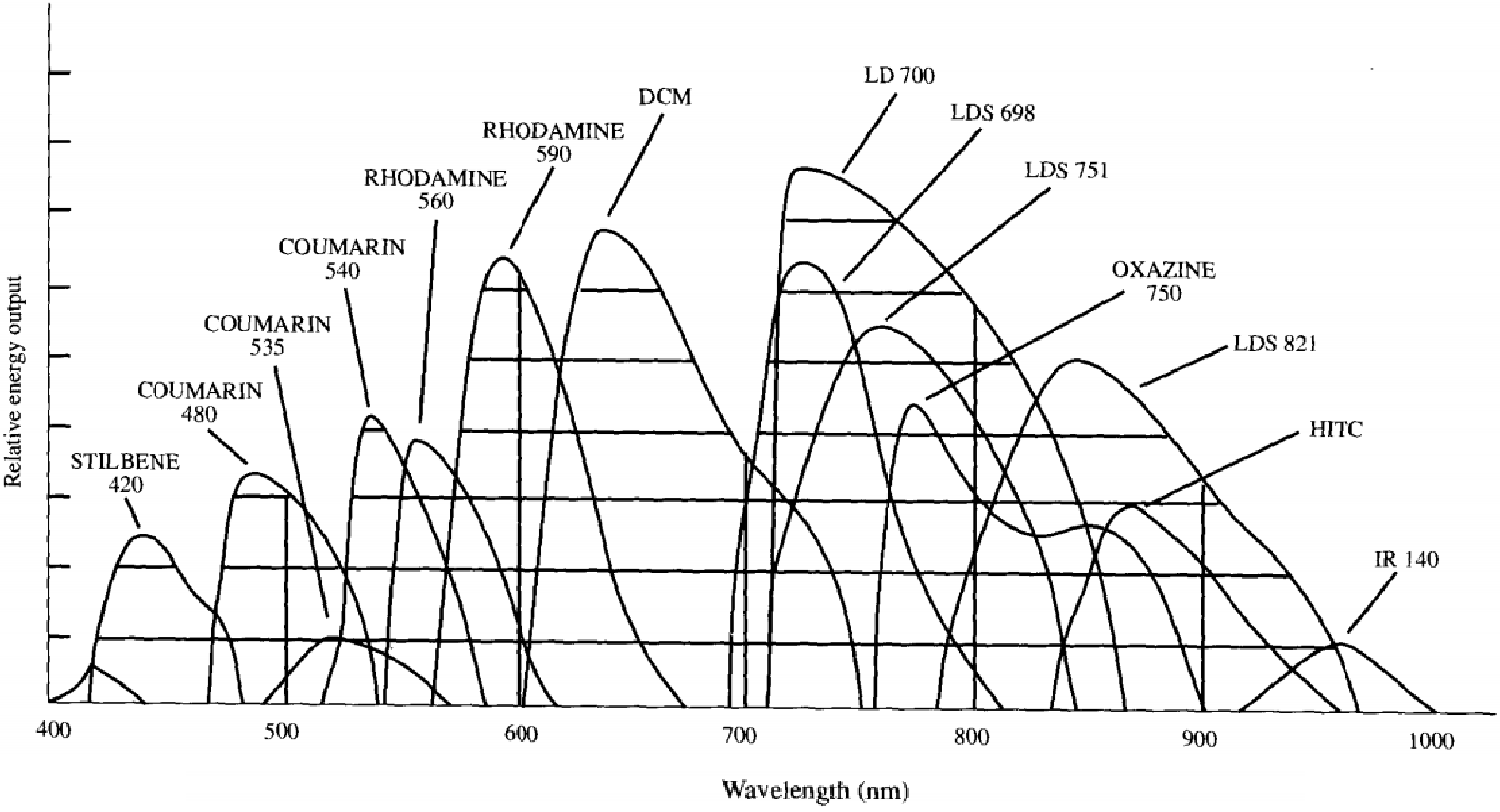


FIGURE 10.18. Performance of various dyes when pumped with an argon-ion or Krypton-ion laser (Data from Spectra-Physics and advertised in Exuton, Inc. catalog, p.4 [61].)

A dye laser tends to be self-terminating, owing to the buildup of the triplet T_1 population. Thus most flash lamp pumped dye lasers are pulsed with pulse duration on the order of 100 to 1000 ns.

To avoid the triplet buildup, there is flow of the dye through the cavity.

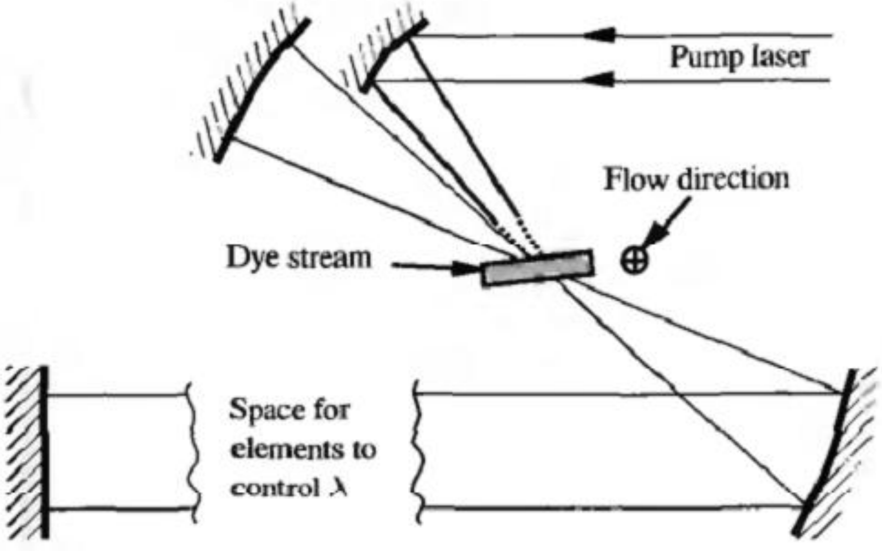


FIGURE 10.21. Typical configuration for a CW dye laser.

Tunable Solid State Lasers

Ti:Sapphire Lasers

- TiO_3 is doped (1% by atomic weight) into a crystal of Al_2O_3 (sapphire) with Ti substituting for some of the Al atoms in the lattice structure.
- Amplification within wavelength range 700 – 1020 nm
- Pumped by Ar^+ laser at 5145 Å or 2ω of YAG at 5320 Å

Vibronic states of $^2T_{2g}$ are occupied according to Boltzmann distribution, thus high lying levels are mostly empty. The pump promotes the system to ^2E_g where it quickly (~ps) goes to the minimum energy by emission of one or more phonons. Lifetime for ^2E_g ~3.2 μs.

The stimulated emission by another photon along with a simultaneous emission of one or more phonons returns the system back to the $^2T_{2g}$ vibronic states.

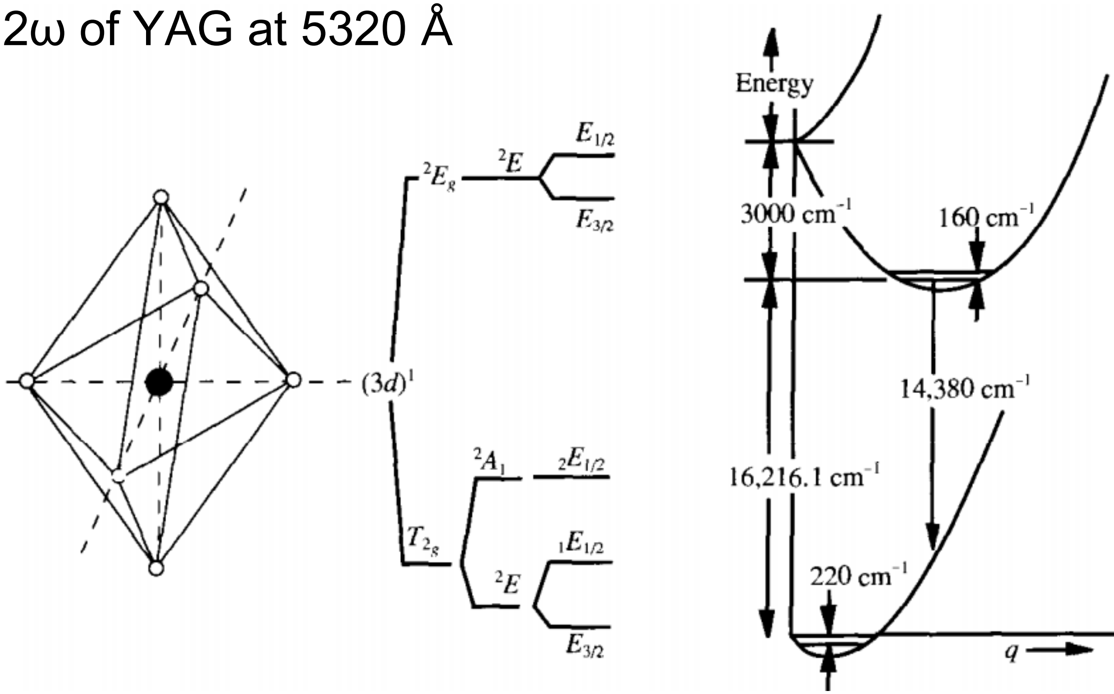


FIGURE 10.22. (a) The octahedral site for the *titanium* ion (solid) surrounded by the six oxygen atoms in sapphire. (b) Term splitting by the crystalline fields. (c) Simplified schematic of the potential energy curves for the $^2T_{2g}$ and the ^2E_g states of Ti^{3+} in sapphire. (Same as Fig. 1 of Byvik and Buoncristiani [79]. Numerical values for (c) from Fig. 3 of Gächter and Koningstein [85].)

Large role of <u>phonons:</u>
"phonon-terminated"

Cavities for Tunable Lasers

Selection of a single λ for lasers with wide bandwidth gain.

Uses the chromatic dispersion of the glass in the prisms, and cascades many such prisms for additional selectivity.

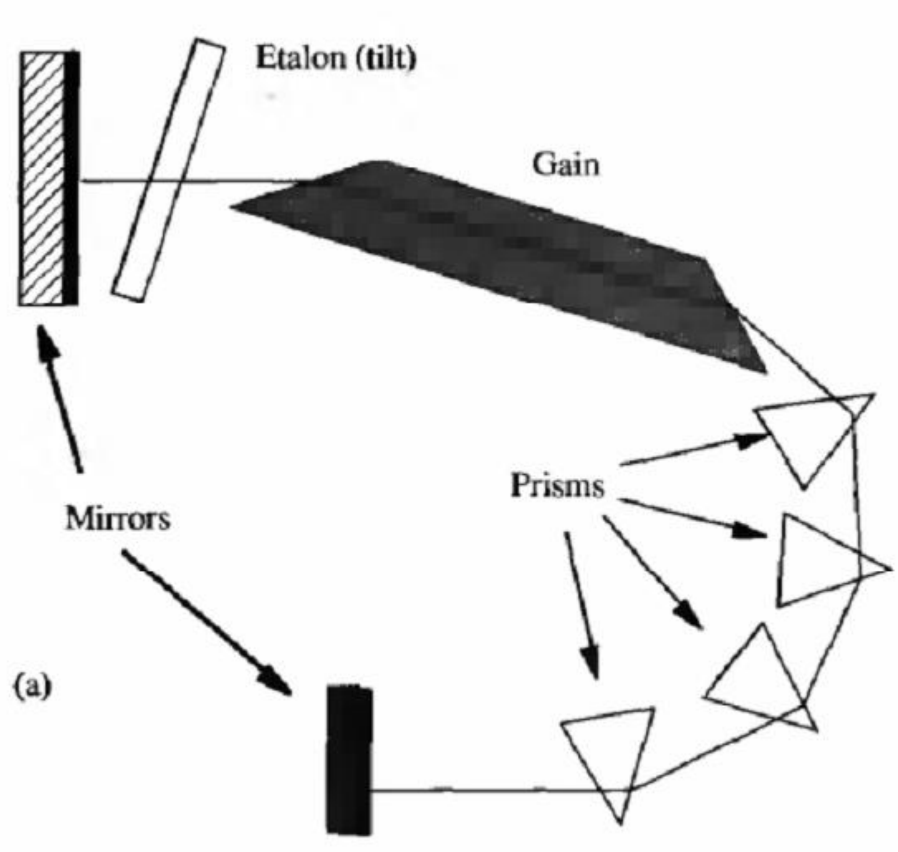


FIGURE 10.27. Various methods of tuning a laser.

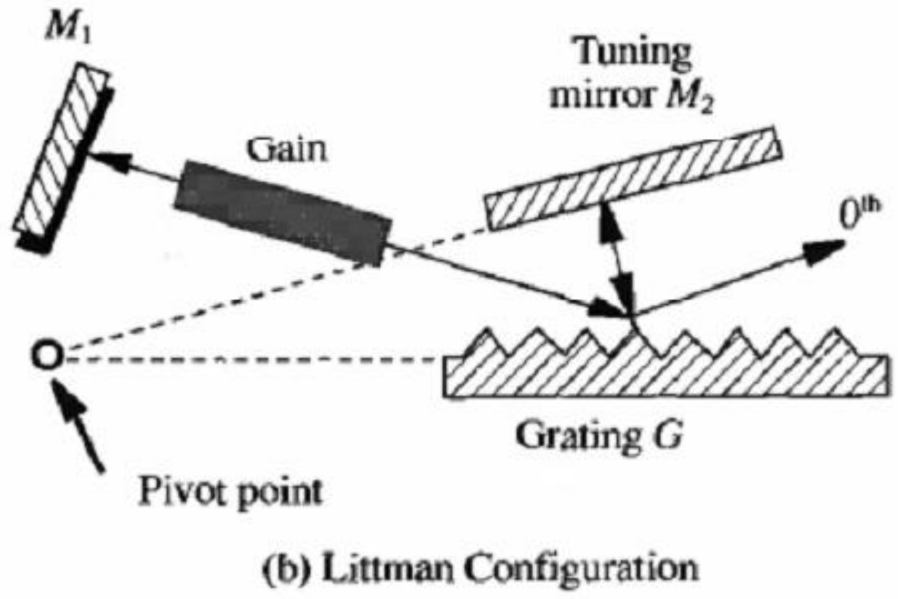
Cavities for Tunable Lasers

Selection of a single λ for lasers with wide bandwidth gain.

Uses a diffraction grating at grazing incidence. Feedback is provided by the tuning mirror M_2, which is adjusted to be perpendicular to the 1st order diffraction. M_2 sends the diffracted beam back to the grating and back to M.

The "output" is through the 0th order of the grating (i.e. the grating appears as a simple turning mirror).

A single cavity mode can be tuned if both M_2 and G are rotated about a common pivot point found by extrapolating both surfaces back to the intersection.



(b) Littman Configuration

FIGURE 10.27. Various methods of tuning a laser.