must be satisfied for radiation to be reflected back along the cavity axis. In this equation λ is the oscillating wavelength of the laser and d is the grating spacing. Light of other wavelengths is not reflected back along the cavity axis and consequently this radiation sees a very lossy resonator and oscillation is prevented. Thus narrow bandwidth laser output is obtained and wavelength tuning may be accomplished simply by rotating the grating. Prisms, Fabry-Perot étalons, and combinations of these elements with diffraction gratings have all been used as tuning elements in flashlamp-pumped dye lasers and the bandwidths obtained range typically from 0·3-3·0 Å. Flashlamp-pumped dye lasers can be very cheap and simple to make and output energies of up to several Joules per pulse have been obtained. Generally, however, the pulse repetition rate is too low and the output spectral bandwidth is too large to permit their use in high-resolution atomic spectroscopy.

14.2.3. Laser-pumped dye lasers - pulsed systems.

(a) Solid state laser-pumped dye lasers. The first reported dye lasers were pumped by giant pulse (Q-switched) solid state lasers such as the ruby laser at 694·3 nm and the frequency-doubled neodymium laser at 530·0 nm. These pump sources continue to play an important part in applications requiring very high peak powers. The inherently short pulse length of the Q-switched solid state lasers, 5-100 ns, effectively eliminates the problems of triplet state absorption and dye laser efficiencies of up to 50 per cent have been reported in certain cases.

These laser-pumped dyes exhibit very large gain coefficients, $\approx 10^3\ \mathrm{mm}^{-1}$, and low-Q optical cavities containing several rather lossy tuning elements may be used. Thus by combining a Littrow mounted échelle grating and one or more Fabry-Perot étalons, single mode operation with bandwidths of less than 0·01 Å can be achieved. Ruby laser pumping is essential for most of the infrared dye lasers since the absorption bands of these molecules lie towards the red end of the spectrum and moreover these dyes are easily destroyed by photodissociation when sources of shorter wavelength are used. However, solid state laser-pumped dyes are not restricted to the long wavelength end of the spectrum, for efficient second and fourth harmonic generation makes the ruby (347·2 nm) and neodymium (265·0 nm) lasers very effective pump sources for dye lasers in the near ultraviolet.

Laser pumping certainly provides the easiest route to tunable dye laser radiation once the pump laser exists. Unfortunately the very low repetition rate of many of the Q-switched solid state lasers is a great disadvantage in experiments in atomic and molecular spectroscopy.

(b) Molecular nitrogen laser-pumped dye lasers. A particularly reliable and convenient pump source is the pulsed nitrogen laser operating at 337·1 nm. The short wavelength of this laser radiation excites many dyes to high-lying singlet levels, but in all cases the molecules relax very quickly to the bottom edge of the lowest excited singlet level, dissipating the excess energy in the solvent, and dye laser oscillation occurs on the $S_1 \rightarrow S_0$ transition. Since most dyes have a strong absorption band in the ultraviolet region the nitrogen laser provides an almost universal pump source. The short pulse length and high repetition frequency of this laser provide a convenience similar to that of C.W. operation and it is one of the most widely used systems in atomic spectroscopy.

A schematic diagram of the nitrogen laser-pumped dye laser system developed by Hänsch (1972) is shown in Fig. 14.5. The nitrogen laser consists of a rectangular channel ≈ 1 m long through which a rapid discharge is passed from a triggered high-voltage capacitor system. Nitrogen molecules are excited to the $C\ {}^3\Pi_u$ state by collisions with fast electrons and a transient inversion is created on the $B\ {}^3\Pi_g \leftrightarrow C\ {}^3\Pi_u$ ultraviolet emission band. The radiation emitted by the laser is self-terminating because the lower level has a longer lifetime than that of the upper level and in most of these devices the output consists of a pulse of amplified spontaneous emission