Fig. 8.1. Schematic diagram of a general optically pumped laser system. In a good laser system, the transfer coefficient should be close to unity and transfer should occur rapidly.
Fig. 8.2. Examples of output spectra from various flashlamps at different flashlamps current densities; $f_x$ is the fraction of explosion energy at which each lamp was operated: (a) 1.5 cm-bore lamp; (b) 4.2 cm-bore lamp[8,2].
Fig. 8.3. Ellipsoidal cavity for solid-state laser pumping that provides axisymmetric illumination of a cylindrical laser rod by a cylindrical lamp. [8.34,8.6].
Fig. 8.4. Absorption and emission properties of titanium doped sapphire.

Absorption

Emission

Wavelength (nm)

Strength (arbitrary units)
Fig. 8.5: Energy level diagram for Nd³⁺: YAG. The emissions $I_1$ and $I_2$ correspond to the two transitions that make up the laser line[80].
Fig. 8.6. Spontaneous emission spectrum of the 1.06 \mu m transition in Nd\textsuperscript{3+}:YAG at room temperature. The two Lorentzian lineshapes that contribute to the laser transition are shown by dashed lines\textsuperscript{[8,6]}. The factor \( a \) is a lineshape factor that gives the contribution to the intensity at the center of \( \ell_2 \) from the line \( \ell_1 \).
Fig. 8.7. Performance of CW Nd:YAG lasers at 1.06 μm pumped by krypton arc lamps: (a) 6.3×100 mm rod in a single-elliptical pump cavity, (b) 6.3×100 mm rod in a double-elliptical cavity, (c) eight 6 mm×75 mm rods in series, each pumped with an individual lamp[8,7].
Fig. 8.8. Schematic arrangement of apparatus for pulling a crystal boule from the melt by the Czochralski method.
Fig. 8.9. Spontaneous emission lineshape of the 1.06 \( \mu \text{m} \) neodymium laser transition in various glasses at 295 K\(^{[8,8]}\).
Fig. 8.10. Lifetime of the upper laser level as a function of Nd$^{3+}$ concentration for different silicate glass laser materials.

The $\sigma$ values quoted are the peak values of the stimulated emission cross sections of the $^4F_{3/2} \rightarrow ^4I_{11/2}$ transition$^{[8,9]}$. 

Graphical representation:

- LG–650, $\sigma = 1 \times 10^{-20}$ cm$^2$
- LG–660, $\sigma = 1.8 \times 10^{-20}$ cm$^2$
- LG–670, $\sigma = 2.7 \times 10^{-20}$ cm$^2$
Fig. 8.11. Absorption spectrum and energy levels of Nd$^{3+}$ in glass$^{[8,10]}$. 

Energy
(1000 cm$^{-1}$)

$^4D_{1/2}, ^3J_2$

$^2P_{3/2}$

$^2P_{1/2}$

$^2D_{5/2}$

$^2G_{1/2}, ^3J_2 + ^2D_{3/2} + ^2K_{15/2}$

$^2G_{9/2}, ^3J_2 + ^2K_{13/2}$

$^4G_{5/2}, ^7J_2$

$^2H_{11/2}$

$^4F_{9/2}$

$^4F_{7/2} + ^4S_{3/2}$

$^4F_{5/2} + ^2H_{9/2}$

$^4F_{3/2}$

0.92 1.34 μm

1.06

$^4I_{15/2}$

$^4I_{13/2}$

$^4I_{11/2}$

$^4I_{9/2}$
Fig. 8.12. Schematic arrangement of oscillator/amplifier chain for production of very high energy laser pulses from a Nd$^{3+}$ laser. The isolators allow radiation to pass only in one direction. Spatial filters clean up the radial intensity profile of the beam. As the beam increases in intensity down this chain the size of the beam increases as does the size of the successive rod amplifiers (RA) and disk amplifiers (DA).
Fig 8.13. Lamp/reflector configurations used in close optical coupling arrangements for solid state laser pumping.
Reflector configurations used in face pumping of slab amplifiers. The classification numbers indicate the number of lamps and reflector type used by the Lawrence Livermore National Laboratory. C - cylindrical reflector, F - flat, R - Rab\textsuperscript{[8,11]}. 

Fig. 8.14.
Fig 8.15. Circularly symmetric illumination of a laser rod showing the refraction of rays through the cylindrical surface.
Fig. 8.17. Normalized energy density as a function of radius in a transparent cylindrical rod illuminated uniformly in a cylinder cross-section. In the two-dimensional model all illuminating rays travel in planes orthogonal to the cylinder axis. In the three-dimensional model the illuminating rays take all possible directions\(^{[8,12]}\).
Fig. 8.18. Normalized energy density inside a cylindrical laser rod uniformly illuminated with linearly polarized light polarized along the cylinder axis. The energy density distributions are shown for different amounts of rod absorption where $d = \text{cylinder diameter} \times \text{absorption coefficient}^{[8,12]}$. 

\[ \frac{\rho(R)}{\rho_0} \]

$d = 0.04425$

$d = 0.4425$

$d = 1.77$

$d = 3.54$

$R/R_0$
Fig. 8.19. Composite cylindrical laser rod with doped center.
Fig. 8.20. Schematic arrangement of a 'zig-zag' face-pumped laser amplifier module that incorporates prisms and index matching coolant for reducing Fresnel reflection losses at the neodymium glass (ED2) slabs\(^{[8,14]}\).
Fig. 8.21. Monolithic integrated diode-pumped ND:YAG laser – the Miser laser\[8,15\]. Faraday rotation within the laser crystal, produced by integral permanent magnet, leads to unidirectional oscillation and single longitudinal mode oscillation as described in Chapter 7. The curved face is partially transmitting and selects a specific polarization state for oscillation. Total internal reflection occurs at points B, C, and D. Faraday radiation takes place along the paths AB and DA.
Fig. 8.22. Schematic illustration of the 'spiking' phenomenon in the output of a pulsed solid state laser.
Fig. 8.23. Illustration of how oscillation can jump from one longitudinal mode to another in successive 'spikes' because of population depletion.
Fig. 8.24. Illustration of how two different longitudinal modes partially avoid competition with each other by using different spatial regions of inverted population in a gain medium.

Antinodes of mode with $m = 5$

Antinodes of mode with $m = 4$

Mirror

Longitudinal mode with $m = 5$

Longitudinal mode with $m = 4$
Fig. 8.25. Almost idealized relaxation oscillations obtained from a $\text{Nd}^{3+}:\text{CaWO}_4$ laser.
Fig. 8.26. Relaxation oscillations in the output of a semiconductor diode laser, pumped Nd:YAG laser. (Courtesy of Dr. Simon P. Bush.)
Fig. 8.27. Rotating intracavity wheel with a hole for Q-switching.
Fig. 8.28. (a) Q-switching with one fixed cavity mirror and a rotating roof prism. (b) Laser rod with roof prism fashioned on one end where Q-switching is accomplished by spinning the other cavity reflector.
Fig. 8.29. Arrangement for Q-switching with an electrooptic crystal.

EO modulator

Linear polarizer

Amplifying medium
Fig. 8.30. Numerical simulation of $Q$-switch behavior from Eqs. (8.105) and (8.106) for a system that is pumped initially to 10 times above threshold.
Fig. 8.31. Numerical simulation of $Q$-switched behavior from Eqs. (8.105) and (8.106) for a system that is pumped initially to 50 times above threshold.