Engineering Optics

Lecture 23

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by

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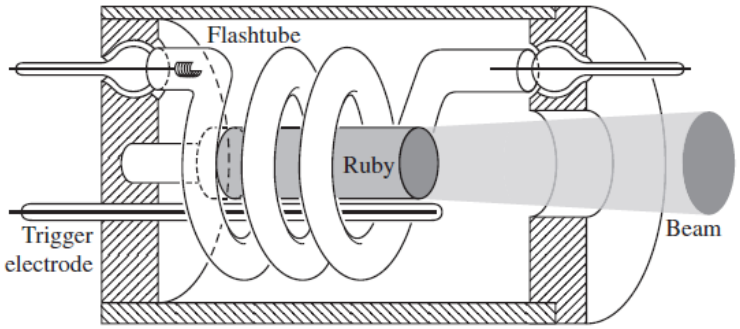
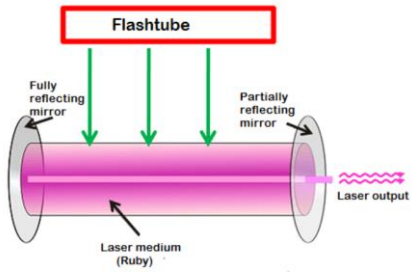
Working principle





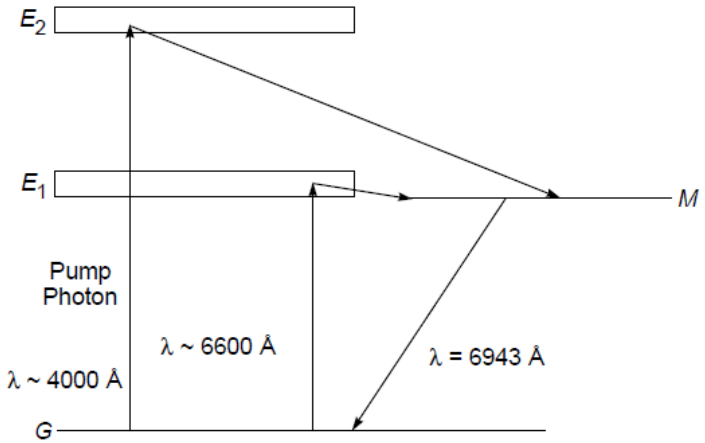
The energy levels of the chromium ion; G and M represent the ground and metastable states, respectively.

Optics, Ghatak; Hecht

1. photons are produced by the flash lamp
2. The chromium ion in its ground state can absorb a photon (~ 4000 Å) and make a transition to E_2 → by optical pumping OR to E_1 (6600 Å)
3. Once in E_2 or E_1 → it immediately makes a **nonradiative transition** (in a time ~ 10^{-8} s) **to the metastable state *M*** *(3 ms lifetime)*
4. the excess energy (transition from E_2/E_1 to M) is absorbed by the lattice and does not appear as EM radiation.
5. *M* has a very long life, the number of atoms in this state keeps increasing and one may achieve population inversion between states *M* and *G*.
6. Once population inversion is achieved, light amplification can take place, with two reflecting ends of the ruby rod forming a cavity.

- The ruby laser is an example of a three-level laser.
- Applications: medical and cosmetic procedures, holography

Working principle



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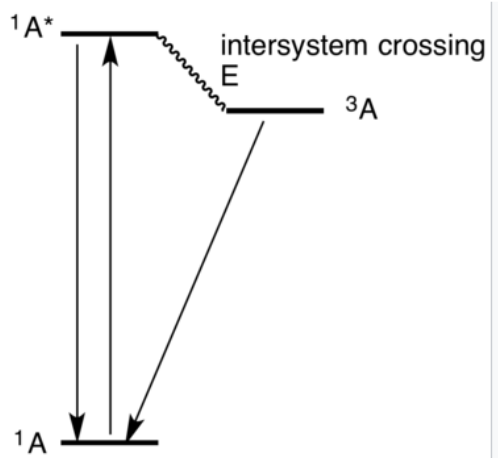


A Jablonski diagram showing the excitation of molecule A to its singlet excited state ($^1A^*$) followed by intersystem crossing to the triplet state (^3A) that relaxes to the ground state by phosphorescence.

Wikipedia

The chromium ion in its ground state can absorb a photon (whose wavelength is around 6600 Å) and make a transition to one of the states in the band E_1. It could also absorb a photon of $\lambda \sim 4000$ Å and make a transition to one of the states in the band E_2—this is known as optical pumping, and the photons which are absorbed by the chromium ions are produced by the flash lamp (see Fig. 26.16). In either case, it immediately makes a nonradiative transition (in a time $\sim 10^{-8}$ s) to the metastable state M—in a nonradiative transition, the excess energy is absorbed by the lattice and does not appear in the form of electromagnetic radiation.

Also since state M has a very long life, the number of atoms in this state keeps increasing and one may achieve population inversion between states M and G. Once population inversion is achieved, light amplification can take place, with two reflecting ends of the ruby rod forming a cavity. The ruby laser is an example of a three-level laser.

Optics, Ghatak

Spike in Ruby LASER

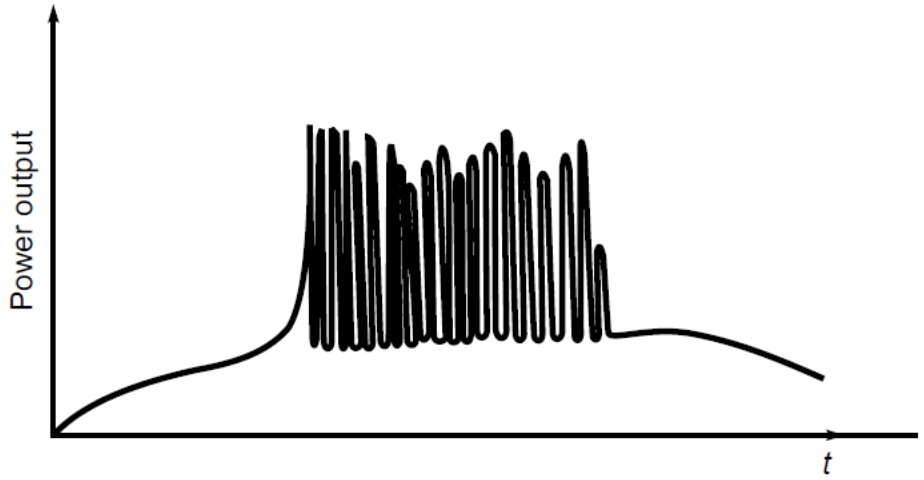
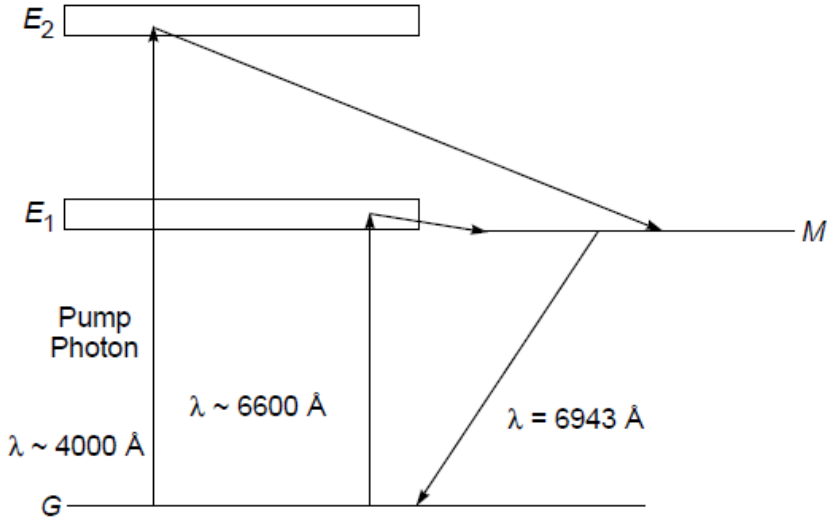


Fig. 26.19 The characteristic spiking of a ruby laser.



The energy levels of the chromium ion; *G* and *M* represent the ground and metastable states, respectively.

Optics, Ghatak

- Sometimes one finds that the emission is made up of spikes of high-intensity emissions → spiking
- Steady state of Lasing → steady pumping rate
- If the pump is suddenly switched on to a value > threshold, the population inversion > threshold value
- photon number builds up rapidly to a value much higher than the steady-state value.
- Output > the steady-state value,
- the rate of stimulated transitions > much higher than the pump rate.
- Consequence? → the population inversion decreases → output decreases
- the emission stops for a few microseconds, within which time the flash lamp again pumps the ground-state atoms to the upper level, and laser oscillations begin again. This process repeats itself till the flash lamp power falls below the threshold value and the lasing action stops

Ruby laser

- https://physicswave.com/ruby-laser-construction-and-working/

Solid-State Lasers

- Along with **ruby**, great many other solid-state lasers whose outputs range from 170 nm to 3900 nm.
- lasers use a glass or crystal rod doped with ions capable of supplying the needed energy states.
- Recall that ruby is corundum doped with chromium.
- The trivalent rare earths Nd^{3+}, Ho^{3+},Gd^{3+} Tm^{3+}, Er^{3+}, Pr^{3+}, and Eu^{3+} undergo laser action in hosts, such as $CaWO_4$, Y_2O_3, $SrMoO_4$, LaF_3, yttrium aluminum garnet (YAG for short), and glass.
- Nd:YAG (Nd:$Y_3Al_5O_{12}$) lasers are among the most widely used solid-state laser.
- Applications in surgery, target designation, range finding, frequency doubling, and material processing, among others.

Optics, Hecht

Solid-State Lasers

Type	Wavelengths (nm)
Cr:Al_2O_3 (Ruby)	694.3
Cr:$BeAl_2O_3$ (Alexandrite)	700–830
Cr:LiCaF	700–830
Cr:LiSrAlF	800–1050
Cr:ZnSe	2200–2800
Er:YAG	2940
Ho:YAG	2100
Nd:Glass	1080, 1062, 1054
Nd:YAG	1064.1, 266, 355, 532, 1320
Nd:YCOB	≈1060
Nd:YLF	1047, 1053
Nd:YVO_4	1064
Pr:Glass	933, 1098
Sm:CaF_2	708.5
Ti:sapphire	650–1180
Tm:YAG	2000
U:CaF_2	2500
Yb:Glass	1030
Yb:YAG	1030

Thank You