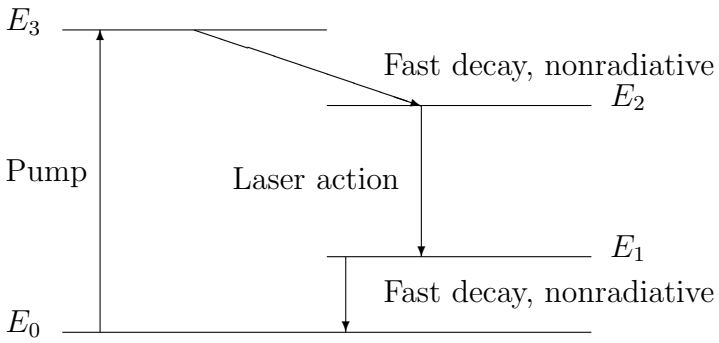
Problem 1.

Draw the energy level diagram for a 4-level laser and explain in words how it works.

Solution



An energy source excites the lasing material from the ground state, E_0 to the excited state, E_3. The material then quickly relaxes to the E_2 state. Material in the E_1 state quickly decays to the E_0 state, where it can be excited $E_0 \xrightarrow{\text{Excitation}} E_3 \xrightarrow{\text{Fast decay}} E_2$. This forms the population inversion such that $N_{E_2} > N_{E_1}$. At this point, when a photon of energy $h\nu_{32}$ passes near the lasing material in state E_2, it stimulates an emission of a second photon of the same energy ("stimulated emission"). This leaves the atom in state E_1, where it non-radiatively relaxes to E_0 and can be excited again.

Problem 2.

Calculate the (a) peak output and (b) average power for a laser that produces 12 ps pulses at a repetition rate of 1000 kHz with an energy of 100 µJ/pulse.

Solution

Part (a)

$$\begin{aligned} 100\,\mu\text{J} &= \frac{100 \times 10^{-6}\,\text{J/pulse}}{12 \times 10^{-12}\,\text{s/pulse}} \\ &= 8\,\text{MW} \end{aligned}$$

Part (b)

$$100 \times 10^{-6}\,\text{J/pulse} \times 1000 \times 10^{3}\,\text{s}^{-1} = 100\,\text{W}$$

Problem 3.

Briefly explain how a Q-switch works and the effect it has on the laser output.

Solution

Problem 4.

Explain how CW, pulsed, and Q-switched laser pulses differ from each other.

Solution

Problem 5.

Define the three χ terms which arise from the polarization in nonlinear optics and identify what frequency they oscillate at.

Solution

Nonlinear optical effects arise from especially intense electric fields. At low field intensities, the material is essentially unaffected by the beam electric field. At higher intensities/applied electric fields the material can be polarized and induce nonlinear effects:

$$P = \epsilon_0 \left(\chi^{(1)} E^{(1)} + \chi^{(2)} E^{(2)} + \chi^{(3)} E^{(3)} + ... \right)$$

Part (a)

$\chi^{(1)}$

- applies at low electric fields
- oscillates at incident frequency ω
- light is refracted normally

Part (b)

$\chi^{(2)}$

- only significant at high irradiances
- doubles frequency ($\omega \to 2\omega$)
- same direction as incident laser, still monochromatic

Part (c)

$\chi^{(3)}$

- triples frequency ($\omega \to 3\omega$)

Problem 6.

A Nd:YVO4 laser has two output wavelengths in the IR wavelength region, 1064 nm and 1342 nm. We would like to use non-linear optics to create the harmonics of the 1342 nm line. Identify the following wavelengths:

(a) Fundamental,

(b) Second harmonic, and

(c) Third harmonic.

Solution

Problem 7.

Describe how a CCD works.

Solution

Problem 8.

What is the difference between random and non-random noise and is each one fundamental or non-fundamental?

Solution

Problem 9.

Identify the following types of noise as either fundamental (F) or non-fundamental (NF):

(a) Shot noise,

(b) Pink noise,

(c) Interference,

(d) Dark current noise,

(e) Readout noise, and

(f) Impulse noise.

Solution

Problem 10.

Identify and define the 3 types of atomic spectroscopy.

Solution

Part (a)

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Part (b)

Lorem ipsum dolor simet.

Part (c)

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