FYS-5400/5406 Laser Phyiscs **Examination 27.11.2007**

Allowed in the exam: A3-size (2-sided A4) handwritten notes to be returned with the answers.

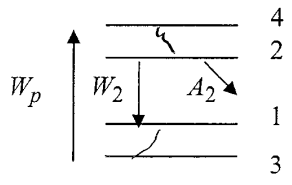
1. Explain the following concepts:
   a) Inhomogenous broadening
   b) Spatial hole burning
   c) Resonator lifetime
   d) Q-switching
   e) Power broadening (10)

2. We want to design a stable laser cavity with two identical concave mirrors of radius of curvature R so that the size of the waist is minimum.
   a) How to place the mirrors (we note L the distance between the mirrors)?
   b) The beam from this resonator is characterized by the parameters w_0 (waist size), Z_R (Rayleigh range) and λ (operating wavelength). We assume $Z_R > L$.
   At which distance from the waist the beam size is twice that of the waist? (12)

3. We want to design a laser resonator using one spherical mirror and one plane mirror. The laser resonator should have the following characteristics:
   - operating wavelength: 600 nm
   - total divergence angle: 0.4 mrad
   - single transverse mode (TEM_{00})
   - longitudinal mode spacing: 150 MHz

   Calculate the radius of curvature of the mirrors, the diameters of the mirrors and the distance between the mirrors. (8)

4. A dye laser works according to the 4-level scheme shown below.



A_2 and W_2 are the spontaneous and stimulated emission rates. The transitions from 4 to 2 and 1 to 3 are so fast that the populations in levels 1 and 4 can be neglected. The pump process is described with a pump rate per molecule W_p. The density of molecules is N_t. The number of molecules per volume unit participating to the process is supposed to be much less than N_t.

a) Write the rate equations for the population density in level 2.
   We assume that a stationary state is reached.
b) Give an expression for the population density N_2 for a given intensity I in the medium. (Use the stimulated emission cross-section σ, the laser frequency ν, W_p, N_t, and the lifetime τ of level 2).
c) We want to calculate the amplification through a thin medium with thickness d. Express $I(d)$ as a function of $I(0)$. (12)

5. A NdYAG laser emitting Q-switched pulses at a wavelength of 1064 nm is pumped at 3 times the threshold power. The peak power and duration of the output pulses are 1 kW and $\Delta\tau_p$=10 ns, respectively. The mirrors are spaced by 10 cm and have reflectivities of R_1=100% and R_2=95%. The diameter of the beam in the YAG rod is 1 mm. The refractive index of the rod is 1.82. We assume that the internal losses are negligible. Calculate the length and emission cross-section of the YAG rod. (8)

6. We consider a HeNe laser (operating wavelength 633 nm) with a 1 m long resonator. The linewidth is broadened to 1.5 GHz due to the Doppler effect. The laser is pumped at a power equal to four times the threshold power.
   a) Explain what is Doppler broadening.
   b) How many modes can oscillate simultaneously?
   c) We assume that all the modes are locked together. What is the repetition rate of the laser (inverse of time between consecutive pulses)? What would be the pulse width and compare it to that of typical mode-locked lasers. (10)

Good Luck!

(...and don't panic)