Tfy-125.4433/422 LASER PYSICS Exam 7.5.2009

1. The resonator of a He-Ne laser is 30 cm long. The Doppler broadened gain bandwidth is 1.5 GHz and the effective index of refraction of the gain medium is n=1. The output mirror of the laser is flat and the end mirror is concave with a radius of curvature of 16 m.

   a) What is the frequency separation of the longitudinal modes of the laser?
   b) Show that the resonator is stable.
   c) What would the gain bandwidth be, if the gas temperature would go up by a factor of two?

2. Explain what is meant by Q-switching of a laser and how it can be realized in practice.

3. a) What is meant by homogeneous and inhomogeneous line broadenings? What are the various physical conditions and mechanisms that produce these line broadenings? (4 p)

   b) Describe the effects and approximate magnitudes of these two line broadening mechanisms in the case of 1) gases, 2) liquids, and 3) solids. (2 p)

4. The spot sizes on the mirrors of a general two-mirror resonator of length L are given by

$$w_{1,2} = \left(\frac{L\lambda}{\pi}\right)^{1/2} \left[\frac{g_{2,1}}{g_{1,2}(1-g_1 g_2)}\right]^{1/4}.$$

   Consider the special case of symmetric resonators with mirror radii $R_1 = R_2 = R$.

   a) Find an expression for the spot size at the beam waist in the resonator. (2 p)

   b) Keeping L constant, sketch the behavior of the spot size at the mirrors and at the waist as a function of the g-parameter for the stable symmetric resonators when the mirror radii change from $R = \infty$ (plane resonator) through $R = L$ (confocal resonator) to $R = 2L$ (concentric resonator). (3 p)

   c) In particular, what is the ratio of the spot size at the mirror and at the waist for the confocal resonator? (1 p)

5. Derive an expression for the lifetime of a photon in a passive optical resonator with mirror reflectivities R_1 and R_2, and with a fractional internal loss per pass of T_1. What is the resonator Q-value?