Coursework 2 - Atom-Photon Physics
Deadline: 09 of December 2011

1. Address the following issues related to the laser modes in a cavity:
   (a) (10/100) Explain how transverse and longitudinal modes build up in a cavity. What constitutes a "good" cavity and a "bad" cavity?Why?
   (b) (15/100) What should be the curvature of two spherical mirrors at two points z_1, z_2 in a cavity in order to optimize the propagation of a Gaussian wavefront at each point in the cavity?Why?Provide a semi-quantitative explanation.
2. (15/100) Give examples of particular properties of laser light as compared to an incandescent light bulb. Explain where the physical differences come from and why they are useful for applications such as nonlinear optics.
3. Address the questions related to the types of line broadening below:
   (a) (5/100) Where does the natural linewidth come from? Is there any way to avoid it? Justify your answer.
   (b) (15/100) What shape does a naturally broadened line exhibit? Provide a semi-quantitative explanation considering a decaying level coupled to an external field.
4. (15/100) Explain why hole burning is useful to study transitions masked by the Doppler broadening. Start by giving an idea of how a Doppler broadened looks like and why (base your answer on the Maxwell velocity distribution). Discuss this in the context of saturation absorption spectroscopy.
5. Consider a four level system as shown below.
   (a) (5/100) Write the rate equations for this system and indicate the lasing transition.
   (b) (10/100) Derive the condition for population inversion from the stationary-state populations. Provide a physical interpretation for this condition in terms of the relaxation rates from level 3 to level 2 and from level 2 to level 1. Thereby, assume that the upper level will relax primarily into level 3.
   (c) (10/100) What system is more efficient for building a laser?The system discussed above or a three-level system?Explain why. Use population-inversion arguments.

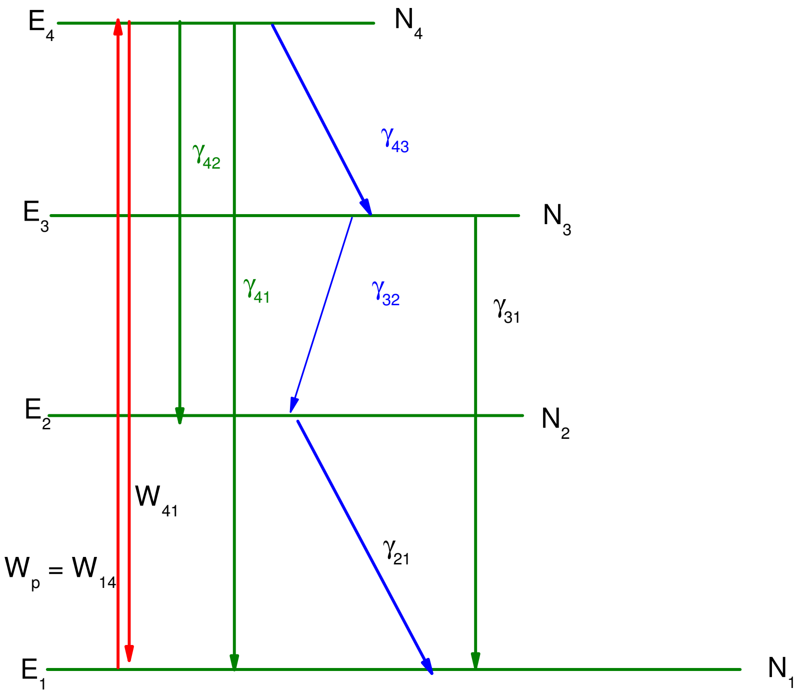

Figure 1: Schematic representation of a four-level system, with bound-state populations N_1, N_2 N_3 and N_4, and pumping rate $W_p = W_{14}$. The decay rates from the level n to the level m are indicated as γ_{nm} The excitation rates γ_{mn} can be neglected and are not shown in the figure. We assumed that the pumping process in this system produces a stimulated emission probability $W_{41} = W_{14} = W_p$.