Problem Set 9

Problem 9.1: Fast Saturable Absorber Mode-Locked Ti:sapphire Laser - Part II
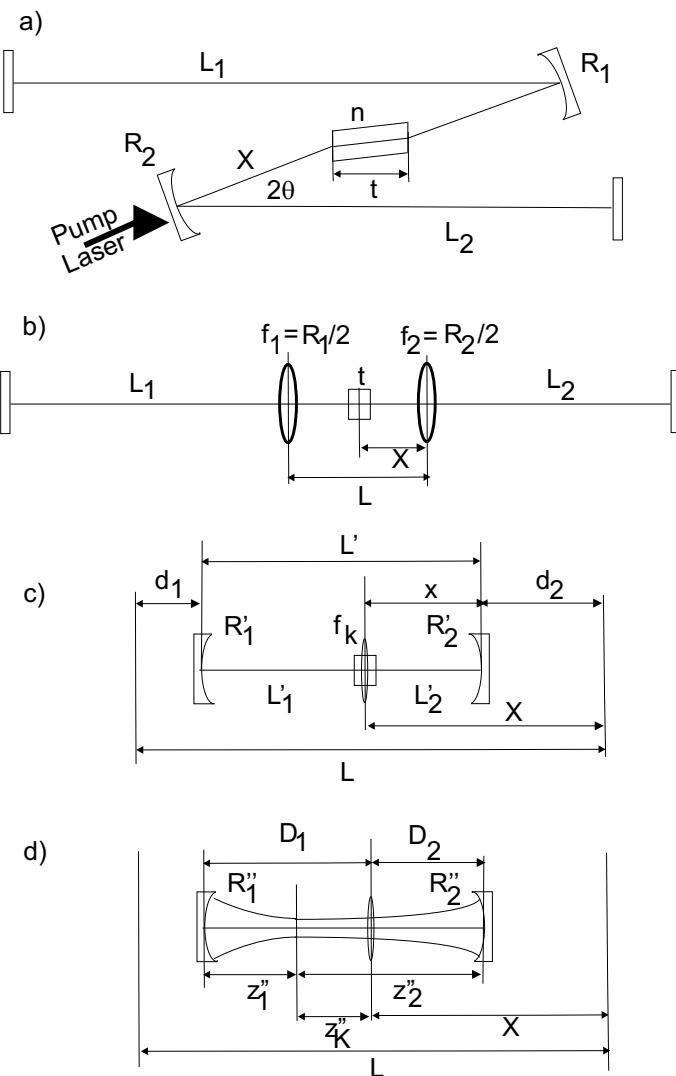
Figure 1: a) Four-mirror resonator with gain medium of thickness t. b) Equivalent resonator with lenses. c) Equivalent two-mirror resonator by imaging of the end mirrors. d) The gain medium is replaced by a Kerr-Lens in its center. The Kerr-Lens can be included in the mirrors of a new two-mirror resonator with new radii and positions from the center of the gain medium.

In the last Problem Set, we designed the linear 4-mirror resonator. In this Problem, we will evaluate how an additional Kerr-Lens in the gain medium affects the resonator mode. Figure 1 a)-d) shows the procedure.

In the class, we already derived the equivalent two-mirror resonator shown in c). The Kerr lens with assumed focal length f_K that is building up in the center of the gain medium at high intensities will change the mode size in the resonator and also changes the stability range of the resonator as a function of the distance L between the two focusing mirrors and the distance X between the center of the Kerr-Medium to the pump mirror with radius R_2. One can also use the distance L' between the folding mirror images in c) and the corresponding distance of the crystal x to the image of the pump mirror. The following parameters are same as those in Problem 8.1: $R_1 = R_2 = 10$ cm and $L_1 = 80$ cm and $L_2 = 60$ cm. The gain medium is modelled only as a fixed Kerr lens with focal length f_K. The thickness of the gain medium shall be neglected for the following.

(a) Compute the parameters of the equivalent two-mirror cavity shown in Figure 1 c).

(b) The part of the resonator to the left of the center of the Kerr Lens can be replaced by an equivalent mirror R_1'' at a distance D_1, see Figure 1 d). The same can be done for the right part of the resonator. Determine R_1'', D_1 and R_2'', D_2, as well as the waist of the resonator mode, its location z_1'' and its distance to the Kerr Lens z_K'' as a function of f_K, L' and x.

(c) Determine the cavity parameters g_1'' and g_2'' of the equivalent resonator shown in Figure 1 d). Discuss the cavity stability for an assumed Kerr lens with focal strength $f_{K1} = 10000$ mm and $f_{K2} = 100$ mm, over the full range of L' and -20 mm $< x <$ 10 mm.

(d) Plot the change in mode waist as a function of L' and for -20 mm $< x <$ 10 mm, when the focal strength of the Kerr-Lens switches between the values f_{K1} and f_{K2}. Discuss this beam size variations in the context of Kerr-lens mode locking.

(e) How would you align the focus of the pump beam, and with it the location of the gain region inside the laser crystal, to achieve maximum equivalent saturable absorber action by the Kerr lensing effect? The saturable absorber action is quantified by the change in gain between having the Kerr lens and without a Kerr lens. Assume that the shape of the gain profile stays Gaussian and its peak value is saturated to a given fixed value g_s.