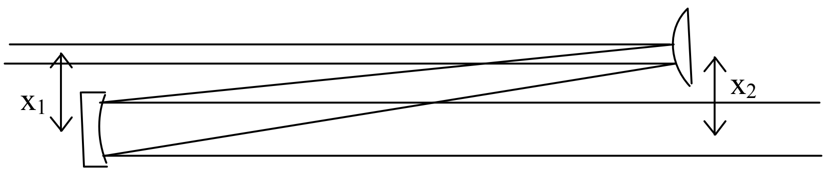
PHGN 480: Laser Physics due 2 Nov 2011
Homework 7

1) *Astigmatism correction in a beam expander.* To expand a laser beam, it is often desirable to use curved mirrors instead of lenses, both to avoid extra dispersion and because the damage threshold for mirrors is higher than for lenses. The trouble is that tilting a curved mirror introduces astigmatism. A sketch of a system that avoids any intermediate focus is shown below.



The mirrors must be tilted to get the beam through, and a tilted mirror is astigmatic (the focal lengths in the horizontal and vertical planes are different). If θ is the incident angle (measured from the local surface normal to the center of the beam), the horizontal focal length (in the plane of the diagram) of a tilted mirror will be shortened: $f_H = f_0 \cos\theta$, where the normal focal length is f_0. The vertical focal length is lengthened to $f_V = f_0 / \cos\theta$.

a. Determine a simple relationship between the ratios of the focal lengths f_1 and f_2 and the incident angles θ_1 and θ_2. You may assume that the incident angles are small (but not necessarily the same as they appear in the figure) and that the mirror separation *d* is close to the separation required for zero incident angle.
b. Using your resultDesign a 5x beam expander that will take a collimated input (5mm diameter) and deliver a collimated output. The overall length should be no more than 300mm and there must be at least 25mm clearance between the center of the convex mirror and the outgoing beam (distance x_2).
c. An initially round beam will become slightly elliptical since the magnifications are different for the H and V planes. Calculate the ratio of magnification that you get for your design.

As part of the design, you may use Mathematica if you need/want to. The easiest way, however is to use the lens imaging equation and repeated application of the small angle approximation.
Hint: if *d* is the distance between the two mirrors, the condition for a collimated output beam is $d = f_2 - f_1$. This must be true for both horizontal and vertical planes.
Extra credit: use the ray tracing code I have posted to show a ray trace of the system, making separate traces for the horizontal and vertical planes. Come talk to me if you need guidance.

2) *Focusing into a dielectric medium.* A Gaussian laser beam is focused with a lens (focal length *f*) into a dielectric sample at normal incidence to the flat interface. The position of the interface is at a distance from the lens that is less than the lens focal

length. Examples of this situation: focusing a pump beam into a laser crystal and laser microscopy where the beam is focused through a glass slide into a sample.

a. What is the spot size at the resulting waist compared to the spot size without the dielectric medium?
b. Where is the focal spot location with respect to the lens and the dielectric interface? This part will take some algebraic work. You will need to think carefully about what happens to a Gaussian beam as it passes through a planar interface. I recommend using the ABCD matrices to figure this out. Example 4.6 should be helpful.

Resonator problems: in designing a laser, the resonator design is as critical as the rate equations, bandwidth, or other aspects. As you work through these notice that it is not just a question of whether the cavity is stable, within the stability range, the spot size within the cavity varies, and in a real laser, this must be optimized.

3) Svelto 5.3. You can work through 5.2 as a guide (5.2 solutions in book).

4) Svelto 5.8. Modify the Mathematica file to work this problem numerically. Use L_1 = 50cm, L_2 = 100cm, and plot the stability parameter vs the lens focal length, f. Also plot the beam sizes at the lens and two end mirrors vs. f for the ranges of f that are stable.