PHGN 480: Laser Physics due 14 Nov 2012
Homework 5

1) Pump laser optics: a Ti:sapphire laser is pumped with a collimated green laser beam (532nm, diameter *d*=2mm) and lases at 800nm. To get good pump overlap with the laser mode, the pump beam is focused through the curved dielectric mirror that is near the laser crystal. This curved mirror acts like a negative lens for the pump beam.
   a. If the curved mirror radius is 100mm, and the pump lens focal length is 75mm, determine the distance the lens must be from the curved mirror to place the geometric pump beam focus at the focal point of the curved mirror. Treat both optics as "thin". You can solve this either with ABCD or the imaging equation.

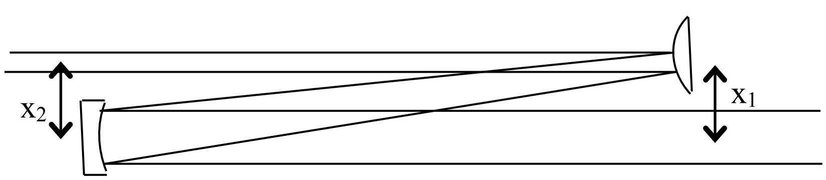
   b. What is the f-number of the final beam focus? (f-number = dist to focus/beam diameter). If we now treat the beam as a Gaussian laser beam ($d = 1/e^2$ diameter), what would the diffraction-limited focal spot diameter be?

2) A CW laser beam has a Gaussian intensity profile $I(r) = I_{pk}\exp\left(-r^2/w_0^2\right)$.
   a. Calculate an expression for the power in the beam, in terms of I_{pk} and w_0 .

   b. Suppose we set up a 1W laser beam ($\lambda = 514nm$) here in Golden to signal to a team at DIA airport 35 miles away. To get the minimum spread in the beam, we would have a slight focus to put the beam waist at half of the distance. What is the smallest initial beam size that we can use under this condition?

   c. What is the intensity of the beam at the target?

3) *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. If the first (convex) mirror is tilted by the angle θ_1 , calculate an expression for the focal length difference in the horizontal and vertical planes. This defines the location of the source points for the second curved mirror.

b. 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 so that the second, concave mirror collimates both beam planes. The input beam is collimated and you may treat this problem with geometric (ray) optics. You may assume that the incident angles are small (so as to expand the cos( ) functions to the first non-zero order) and that the mirror separation d is close to the separation required to collimate the beam if the mirrors were at zero incident angle, i.e. $d = f_2 - f_1$.

4) Using the idea that the curved mirrors are chosen to match the radius curvature of the Gaussian beam wavefront, determine the mirror spacing between a mirror with 50mm radius of curvature and a flat mirror so that the beam waist radius is 75microns. This is close to the scenario we have for the diode-pumped Nd lasers we are building in the lab.