Laser Physics: PHYS 5734/4734

Spring 2009, Homework Set - 2

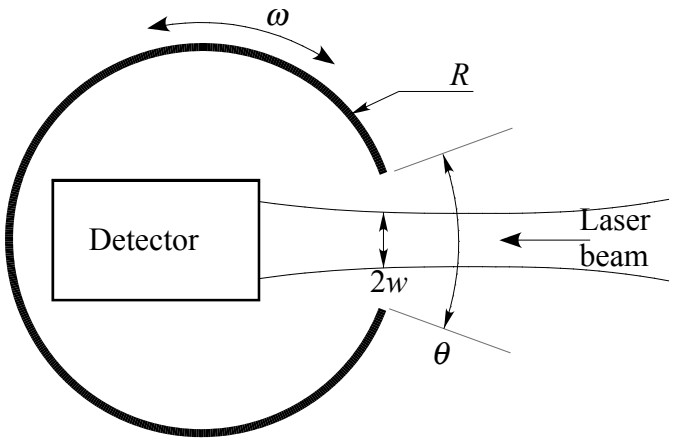
Due: Tuesday, Feb. 17, 2009.

6(a) **Mirage Mirror:** Given the ABCD matrix of an optical system, show that the condition for an image formation is $B = 0$. What then is the magnification of the image relative to the object? [See the write up for Lab 1].

(b) A toy optical system consists of two spherical mirrors of the same focal length facing each other. One of the mirrors (top) has a hole in the center and the spacing between the mirrors is equal to their common focal length. If an object is placed at the center of the bottom mirror, a real inverted image is formed at the hole of the top mirror. When you see it you want to touch it. Treating the distance between the mirrors as a variable d, use matrix method to discuss how it works.

7 **Measuring the spot size of a gaussian beam:** One way of measuring the spot size of a gaussian beam is to advance a knife edge into the beam with a micrometer and measure the power of the beam with a digital power meter downstream from the knife edge. Between what two percentages of power will the knife edge advance a distance equal to $2w$? (Make your advance symmetrical about the peak. That is, take one measurement with $-\infty < x < w$ blocked and the other with $w < x < \infty$ blocked corresponding to σ% and (100-σ)% of total power.).

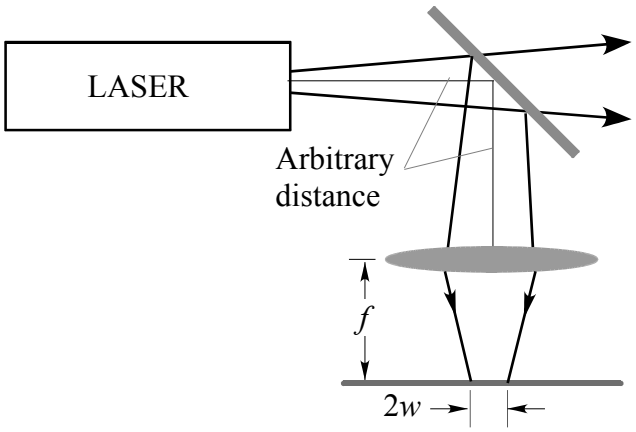
A commercial instrument uses the scheme below to automate the spot measuring process. A cylindrical knife-edge rotates at angular speed ω. If the open aperture subtends an angle θ at the center and the radius of the tube is R, write down an expression for the *rise-time* of the signal at the detector as a function of the spot radius, where the rise-time is defined as being between the same two percentages as calculated above.



8 **Determination of beam divergence:** An arrangement for measuring the divergence of a gaussian beam uses a beam splitter in the beam path as in the sketch. The reflected beam is focused by a lens of focal length f. Show that, independent of the lens position relative to its waist, the divergence of the incident beam is given by

$$\theta = \frac{w}{f},$$

where $2w$ is the beam spot diameter in the focal plane of the lens. Note that the focal plane is not necessarily a waist.



9 **Optical Data Storage:** A common use of lasers is to read and write data on CDs and DVDs, where the data are stored as changes in the surface reflectivity of the disk. These changes can be written and read by a laser beam focused on the disk. A key advantage of such systems over *near-field* storage systems like the conventional magnetic disk is that bits much smaller than the distance between the laser head and the surface of the disk can be read and written.

Assume that the bits on a CD are marks about 1 μm in diameter, that the laser beam ($\lambda = 780$ nm) used to read them is gaussian and is focused so that its $1/e^2$ intensity diameter is equal to the mark size.

(a) Ideally, the focus of the laser beam lies on the surface of the disk. If the focusing lens moves away from its ideal position (due, for example, to the automobile in which the CD player sits hitting a bump), the size on the laser beam on the surface will be larger than nominal, and the ability to resolve the bits will be degraded. If the acceptable tolerance is a $\sqrt{2}$ increase in the size of the spot, how far can the focus of the beam be from the nominal distance? Maintaining such tight control over the height of the head is one of the challenges in engineering a robust CD player (and data is buffered to allow occasional loss of tracking without interrupting the music).

(b) If the lens flies at a height of 1 mm above the disk, and its diameter is chosen to pass 99% of the light, what must the diameter be?

10 **He-Ne laser Beam:** A He-Ne laser operating in pure Gaussian fundamental mode at $\lambda = 632.8$ nm with an output power of $P = 5.0$ mW has a far field divergence angle of 1 mrad. Calculate the spot size, peak intensity and peak electric field at the waist position.