Estimation Problem: Laser Through the Umbilic Torus

Given an aperture the size of the umbilic torus and a red HeNe laser,

1. *What focal length lenses would be needed to fill the aperture?*

2. *At least how far would you have to be to see the far field diffraction pattern?*

Using a Keplerian or Galilean beam expander design, two lens elements are needed. The magnification factor, m, is given by

$$m = \frac{f_2}{f_1}$$

where f_1 is the focal length of the first lens, and f_2 is the focal length of the second element. Let's estimate that the output diameter of a HeNe laser is 1 mm (0.001 m), and the umbilic torus is about 2 m in diameter.

$$m = \frac{2}{0.001} = 2000$$

The focal lengths can be any value, as long as f_2 is 2000 times greater than f_1.

The far field diffraction pattern can be seen when distance L is much larger than $\frac{W^2}{\lambda}$.

$$L \gg \frac{2^2}{6.33 * 10^{-7}} \approx 6 * 10^6 \text{ m} = 6 * 10^3 \text{ km}$$