Tutorial 4 - Gaussian Beam transformations by optical systems

Table of Contents

Sidney Self's formula

Introduction

Sidney Self's formula relates the location of the beam waists in the object and image space (z and z' respectively) as obtained with a lens of focal length f using a formula that is similar to the Gaussian len's formula -

$$\frac{z'}{f} - 1 = \frac{\frac{z}{f} - 1}{\left(\frac{z}{f-1}\right)^2 + \left(\frac{z_0}{f}\right)}.$$

Here all distances are normalized with respect to the focal length of the lens, and z_0 is the Rayleigh distance.

Task 1

Plot the above graph for $\frac{z_0}{f} = 0, 0.5, 1, 10$ and see if you can reproduce the graphs obtained in his paper.

Task 2

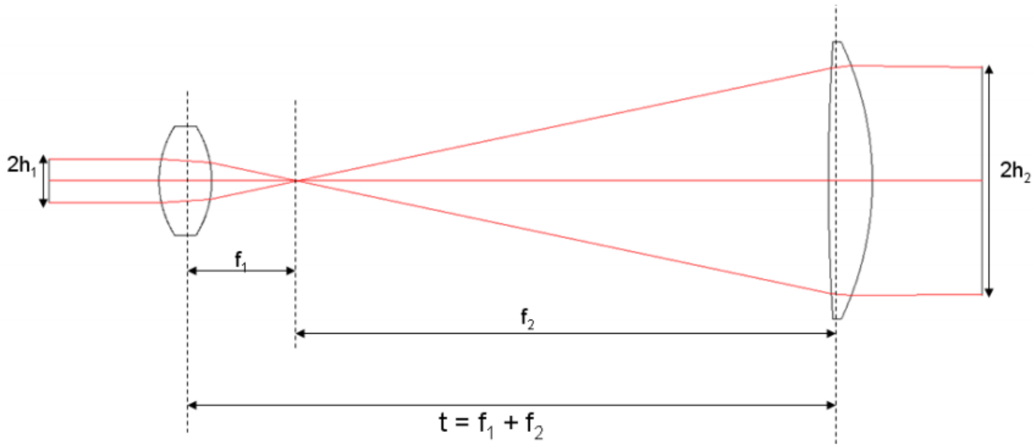
Plot m vs. z/f using the expression for magnification provided in Self's paper. See if it matches the results presented there.

Laser Beam Expander

Introduction

You have a 1 mW 632 nm He-Ne laser (Stabilized Red HeNe Laser (thorlabs.com)). Using this laser, you would like to obtain a collimated laser beam of diameter 5 cm. To achieve this, you will have to build a laser beam expander.

The simplest configuration is based on a Keplerian configuration as shown below.



In the lab, you have it in the following configuration -

Lens 1 - Diameter: 12.7 mm, Focal length: 25.4 mm.

Lens 2 - Diameter: 76.2 mm, Focal length: 100 mm.

Separation between Lens 1 and Lens 2 - 125.4 mm.

Task 0

What are the beam parameters of your laser?

```
%Enter the values
w0 = 0
z0 = 0
q1 = 0 + 0*i
```

Task 1

Calculate the magnification you would expect from this configuration using the paraxial ray optics and thin lens approximation.

```
%Refer to codes from the tutorial on paraxial ray matrices if necessary
```

Task 2

Using analytical expressions, calculate the radius of curvature of the laser beam just before Lens 2.

```
%You will need to use multiple expressions. Draw a rough figure of the
%laser beam as it propagates through the optical system, it will help you
%to visualize the problem.
```

Task 3

Using analytical expressions and the result from Task 2 above, calculate the beam parameters (radius of curvature of the laser beam, beam waist location, Rayleigh distance and beam divergence) after Lens 2.

Task 4

Using the generalized q-parameter transformation approach, calculate the q-parameter of the laser beam as it exits the Keplerian beam expander. Compare this result with the results you obtained above using analytical expressions.

```
%Hint - you should be able to define ONE system matrix.
```

Task 5

Did you meet your target of achieving the desired 5 cm diameter beam?