2012.10.15. La3NET school CAEN, GANIL

Problem 1: Image relay of a Gaussian beam to the cathode

The 4th harmonic of and Nd:YLF laser operating at 1047nm needs to be image relayed from the conversions crystal plane to the cathode, which is 11m away. 2 lenses are used on the optical table in the laser room, which is the first 3m of the transport. The first lens f= 120mm is placed 167mm from the crystal. At the crystal for simplicity we take a waist with 0.25mm size and a perfect Gaussian profile.

a) Using simple lens makers equation, calculate the required position for the second, f=1500mm lens to get 12mm 4σ beamsize (magnification of 12) on the cathode.

b) How much can the beamsize be varied by moving the position of the second lens +/-10cm from the perfect imaging position?

Optional questions to think about:

At what energy/ pulse level will the focal spot sizes in this case can cause air-breakdown?

In the question b) how far does the object plane moves, if the cathode is considered to be the image plane.

What diameter would you choose for the second lens to avoid diffration due to beam clipping?

Where could you place a hard aperture in the lab to image onto the cathode?

$\lambda := 0.262 \cdot 10^{-3}$ Wavelength

Beam parameters assuming waist at the crystal (M2 and beamsize has to be experimentaly defined)

$wcx := 0.25$ waist size

$Mx2 := 1$ M square

$Zrx := \frac{\pi \cdot wcx^2}{\lambda}$ Rayleigh-range

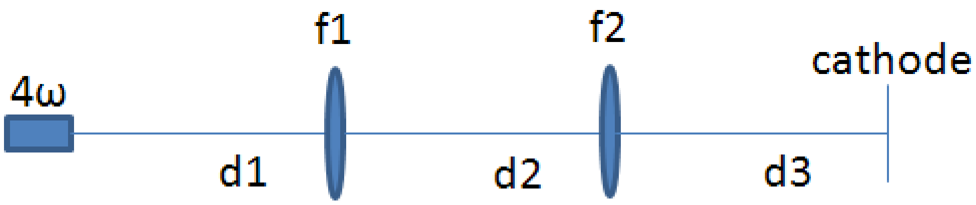
$qcx := \left(\frac{-i}{Zrx}\right)^{-1}$ complex beam parameter

Propagation matrices

propagation in space $s(d) := \begin{pmatrix} 1 & d \\ 0 & 1 \end{pmatrix}$

propagation thorugh a lens $l(f) := \begin{pmatrix} 1 & 0 \\ \frac{-1}{f} & 1 \end{pmatrix}$

Optimisation of the beam transport



$dtot := 11000$ overall distance to the cathode

$dlab := 3000$ distance accessible in the lab

required beam size at the cathode

$wcath := 12$ beamsize required (4sigma)

$Magn := \frac{wcath}{wcx \cdot 4}$ $Magn = 12$ magnification required

Setting the conditions for image relay with two lenses in the lab and the required magnification

Guess $d1g := 407$ $d2g := 2018$ $d3g := dtot - d1g - d2g$ $f1g := 120$ $f2g := 1500$

Given

$(d1g + d2g) < dlab$

$d1g + d2g + d3g = dtot$

$$\frac{1}{d2g - \left(d1g \cdot \frac{f1g}{d1g - f1g}\right)} + \frac{1}{d3g} = \frac{1}{f2g}$$

$$d3g \cdot \frac{f1g}{\left(d2g - d1g \cdot \frac{f1g}{d1g - f1g}\right) \cdot (d1g - f1g)} = Magn$$

$F := Find(d1g, d2g, d3g)$

$$F = \begin{pmatrix} 167.272 \\ 2.242 \times 10^3 \\ 8.591 \times 10^3 \end{pmatrix}$$

$d1 := F_0$ $f2 := f2g$

$d2 := F_1$ $f1 := f1g$

$d3 := F_2$

$cathode(d2) := s(d3) \cdot l(f2) \cdot s(d2) \cdot l(f1) \cdot s(d1)$

$$qoutx(d2) := \frac{\left(cathode(d2)_{0,0} \cdot qcx + cathode(d2)_{0,1}\right)}{cathode(d2)_{1,0} \cdot qcx + cathode(d2)_{1,1}}$$

$$woutx(d2) := \sqrt{\left(\mathrm{Im}\left(\frac{1}{qoutx(d2)}\right) \cdot -1 \cdot \frac{\pi}{\lambda \cdot Mx2}\right)^{-1}}$$

beam size at the cathode

$$woutx\left(F_1\right) = 3$$

$$ls(z, f) := s(z) \cdot l(f)$$

full propagation matrix

$$prop(z, d1, d2, f1, f2) := \begin{cases} s(z) & \text{if } z \le d1 \\ (ls(z - d1, f1) \cdot s(d1)) & \text{if } d1 < z \le d1 + d2 \\ [ls[z - (d1 + d2), f2] \cdot ls(d2, f1) \cdot s(d1)] & \text{if } d1 + d2 < z \end{cases}$$

$$qx(z, d1, d2, f1, f2) := \frac{\left(prop(z, d1, d2, f1, f2)_{0,0} \cdot qcx + prop(z, d1, d2, f1, f2)_{0,1}\right)}{prop(z, d1, d2, f1, f2)_{1,0} \cdot qcx + prop(z, d1, d2, f1, f2)_{1,1}}$$

$$wxprop(z, d1, d2, f1, f2) := \sqrt{\left(\mathrm{Im}\left(\frac{1}{qx(z, d1, d2, f1, f2)}\right) \cdot -1 \cdot \frac{\pi}{\lambda \cdot Mx2}\right)^{-1}}$$

$$N := 10000$$
$$i := 0 .. N - 1$$

$$dz := \frac{(dtot + 200)}{N}$$

$$wx_i := wxprop(i \cdot dz, d1, d2, f1, f2)$$

beamsize along the propagation

lens positions

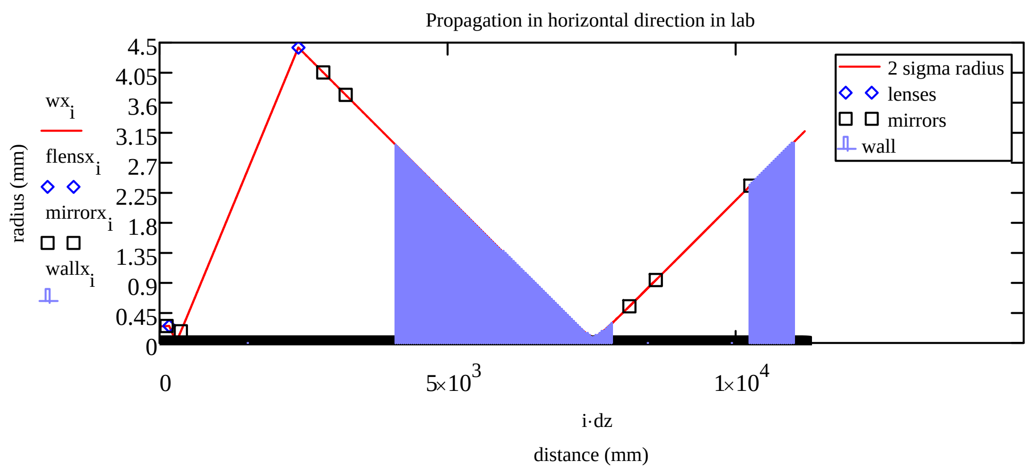
$$flensx_i := \begin{cases} wx_i & \text{if } i = ceil\left(\frac{d1}{dz}\right) \\ wx_i & \text{if } i = ceil\left[\frac{(d1 + d2)}{dz}\right] \\ 0 & \text{otherwise} \end{cases}$$

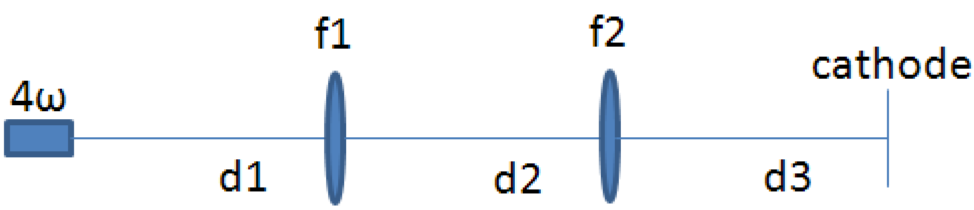
mirror positions for this specific system

$$
\text{mirrorx}_i := \begin{cases} wx_i & \text{if } i = \text{ceil}\left(\frac{120}{dz}\right) \\ wx_i & \text{if } i = \text{ceil}\left[\frac{(120+250)}{dz}\right] \\ wx_i & \text{if } i = \text{ceil}\left[\frac{(120+250+2470)}{dz}\right] \\ wx_i & \text{if } i = \text{ceil}\left[\frac{(120+250+2470+390)}{dz}\right] \\ wx_i & \text{if } i = \text{ceil}\left(\frac{120+250+2470+390+4070+855}{dz}\right) \\ wx_i & \text{if } i = \text{ceil}\left[\frac{(120+250+2470+390+4070+855+460)}{dz}\right] \\ wx_i & \text{if } i = \text{ceil}\left[\frac{(120+250+2470+390+4070+855+460+1470+170)}{dz}\right] \\ 0 & \text{otherwise} \end{cases}
$$

inside walls, where there is no access to optics

$$
\text{wallx}_i := \begin{cases} wx_i & \text{if } \text{ceil}\left(\frac{120+250+2470+390+3770+855}{dz}\right) > i \geq \text{ceil}\left(\frac{120+250+2470+390+855}{dz}\right) \\ wx_i & \text{if } \text{ceil}\left(\frac{dtot}{dz}\right) > i \geq \text{ceil}\left(\frac{120+250+2470+390+4070+855+460+1470+170}{dz}\right) \\ 0 & \text{otherwise} \end{cases}
$$





$d1 = 167.272$ $d2 = 2.242 \times 10^3$ $d3 = 8.591 \times 10^3$ $f1 = 120$ $f2 = 1.5 \times 10^3$

$woutx(d2) = 3$

beam sizes at the cathode

this is 2sigma radius