Lesson 46
A Laser Diode Beam Converter

This lesson will show how to design the optics to convert a beam from a laser diode into a circular collimated beam. We start with the specs for a typical laser diode, which has a different divergence in X and Y. The task is more complicated than a typical beam shaper due to that difference. Here are the data we will work with:

Beam divergence in Y: 8.5 degrees

Divergence in X: 19 degrees

Wavelength: 0.403 um.

We will use the OBG object format, which requires the Gaussian waist radius as a parameter. So we first have to convert the divergence into a radius.

From Section 3.1.2 in the User's Manual, we learn that the program converts the beam radius to a divergence with the formula

DIV = WAV(p) **M2** / π **WAIST** No

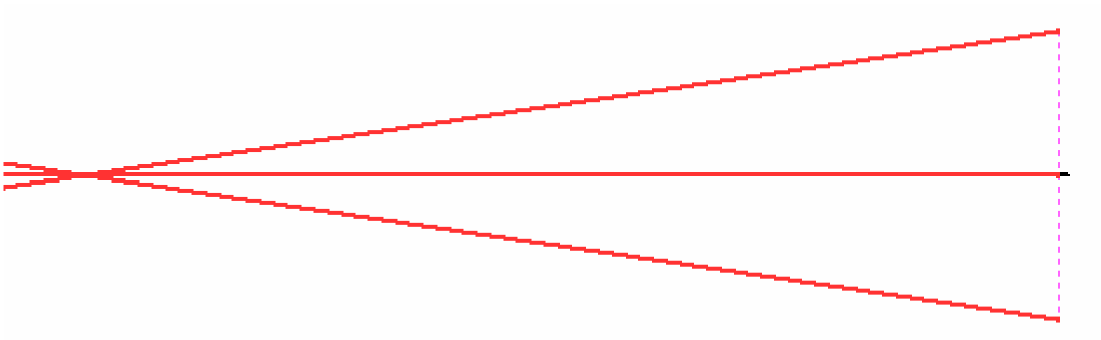
Simple algebra then says that

WAIST = WAV(p) **M2** / π **DIV** No

From this we get GWR = 0.0008644 in Y and 0.0003868 in X. Now we can create a starting RLE file. In the EE editor, type

```
RLE
ID LASER DIODE BEAM CONVERTER
UNI MM
WA1 .403
OBG 0.0008644 1 .0003868
1 TH 20
2
END
```

Then run this input, and you get a very simple system, our starting point.

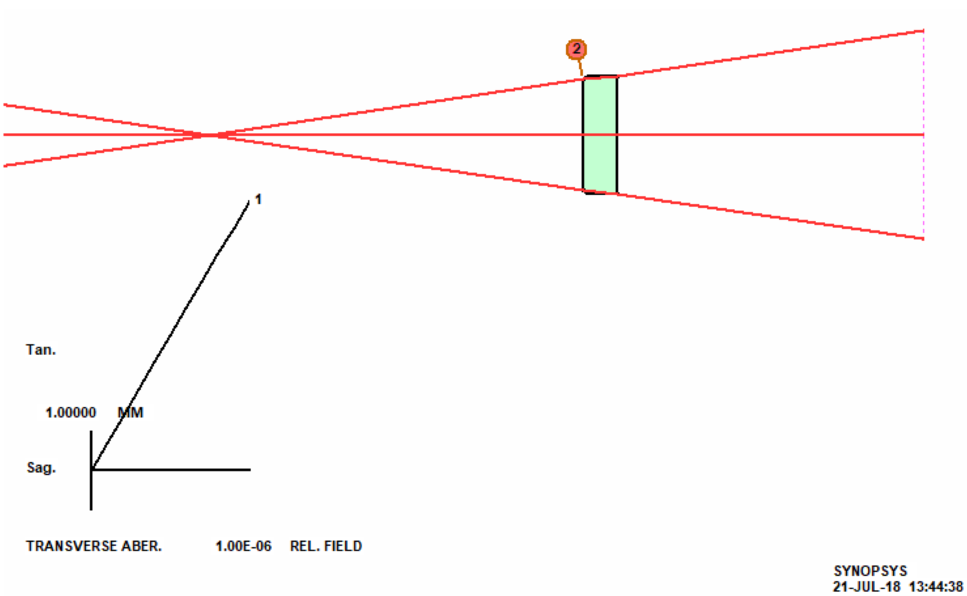


It is easy to see how the beam properties in the X direction differ from those in Y:

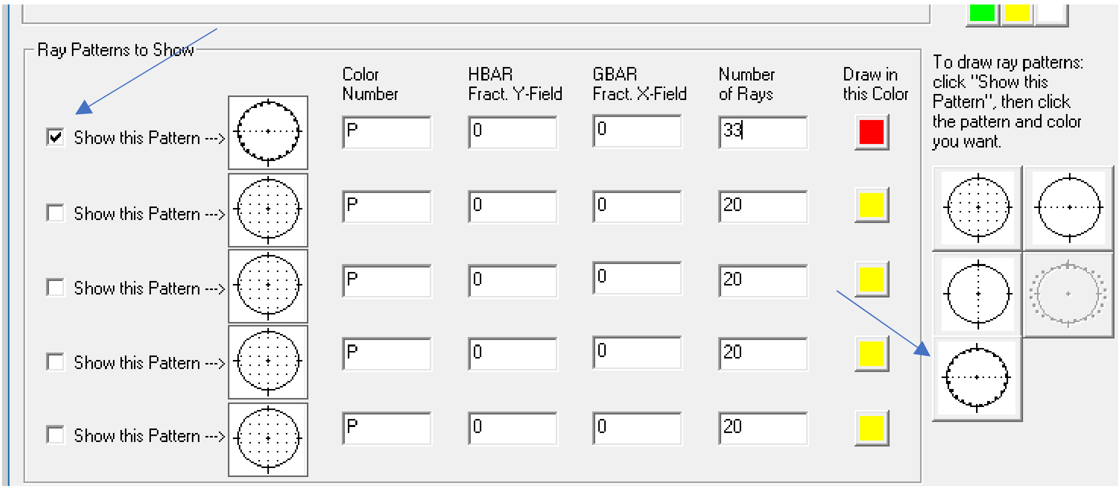
```
 SYNOPSYS AI>BEAM

 ID LASER DIODE BEAM CONVERTER             2434            21-JUL-18
13:43:50

 GAUSSIAN BEAM ANALYSIS

 SURF    BEAM RADIUS  WAIST LOCATION    WAIST RADIUS      DIVERGENCE
 ____________________________________________________________________
   1  8.6440000E-04 -3.8714234E-16  8.6440000E-04       0.148402
   2        2.968045      -20.000000  8.6440000E-04       0.148402
 SYNOPSYS AI>XBEAM

 ID LASER DIODE BEAM CONVERTER             2434            21-JUL-18
13:43:52

 GAUSSIAN BEAM ANALYSIS

 SURF    BEAM RADIUS  WAIST LOCATION    WAIST RADIUS      DIVERGENCE
 ____________________________________________________________________
 BEAM ANALYSIS IS IN THE X-Z PLANE
   1  3.8680000E-04 -6.0536896E-16  3.8680000E-04       0.331641
   2        6.632828      -20.000000  3.8680000E-04       0.331641
 SYNOPSYS AI>
```

Indeed. The GBR at surface 2 is much smaller in Y than in X. Our first job is to even those out.

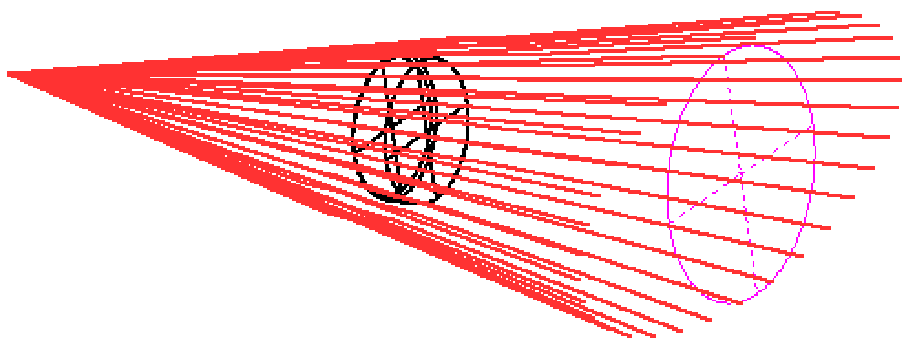
We have to insert a lens at about the center of the beam shown above. In the WorkSheet, make a checkpoint, and then click the Insert Element button  in the WS toolbar. Then click in the PAD display, near the center. The program adds an element.

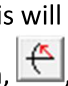


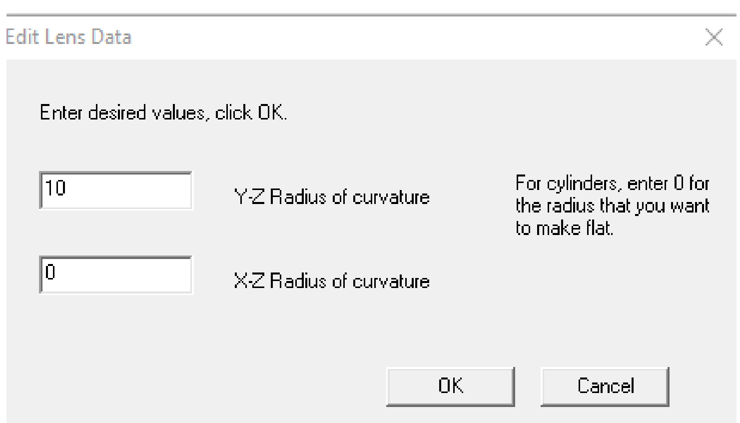
A good first step. Let's look at the beam as it goes through. Type MPE, select the Rotating Perspective option, and show a pattern of a circle around the edge of the beam, in red. Then click Execute.



Spinning the display around, you see the beam in X much larger than in Y, as expected.



Correcting this will require a cylinder lens on surface 3. In WS, select that surface, click the Curvature Dialog button, , then select the Toric or cylinder button and give the Y-Z radius 10 mm and the X-Z radius 0, making it flat in that direction. Click OK and Close.

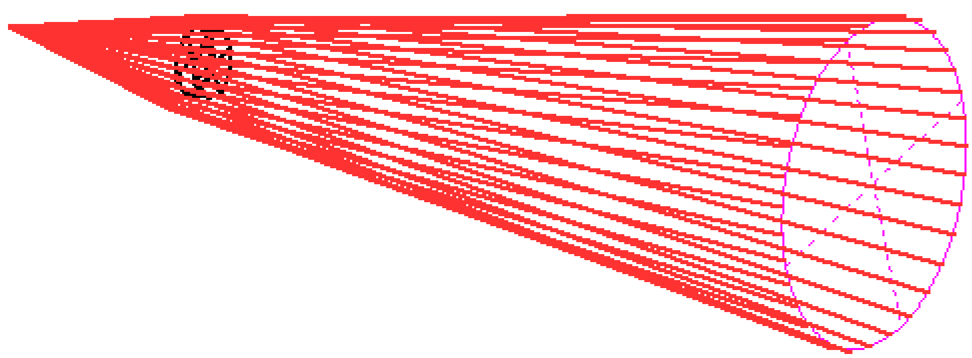


Now we have a cylinder on 3, but we have to adjust it so the beam radius on surface 4 is the same in X and Y. Make a new checkpoint.

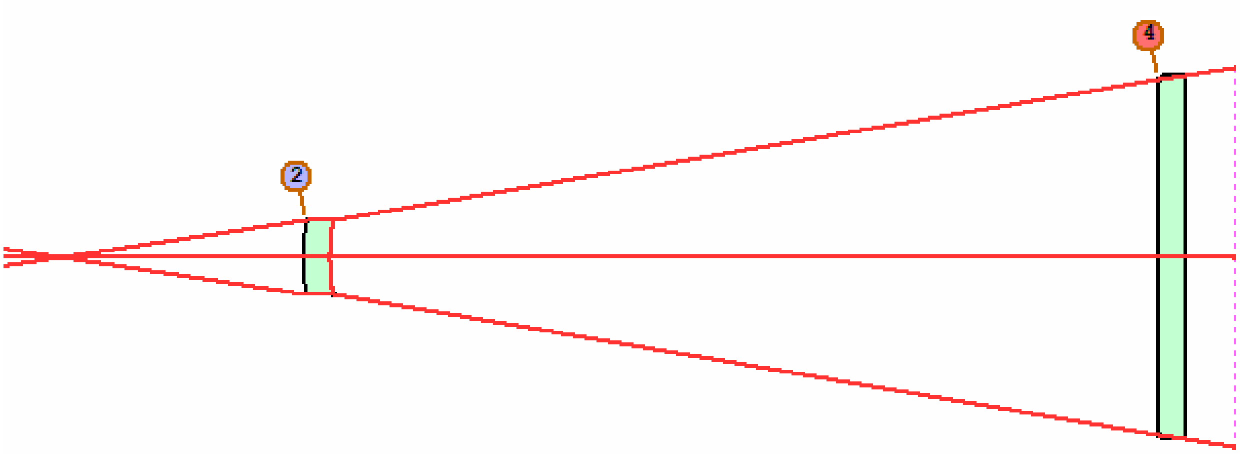
Make a new MACro. We don't want the beam too steep (which will be hard to correct), so we ask for thickness 3 to grow to 33 mm.

```
PANT
VY 2 RAD
VY 3 RAD
VY 3 TH
END

AANT
M 33 1 A TH 3
M 7 1 A P YA 0 0 1 0 4
M 7 1 A P XA 0 1 0 0 4
END

SNAP
SYNO 10
```

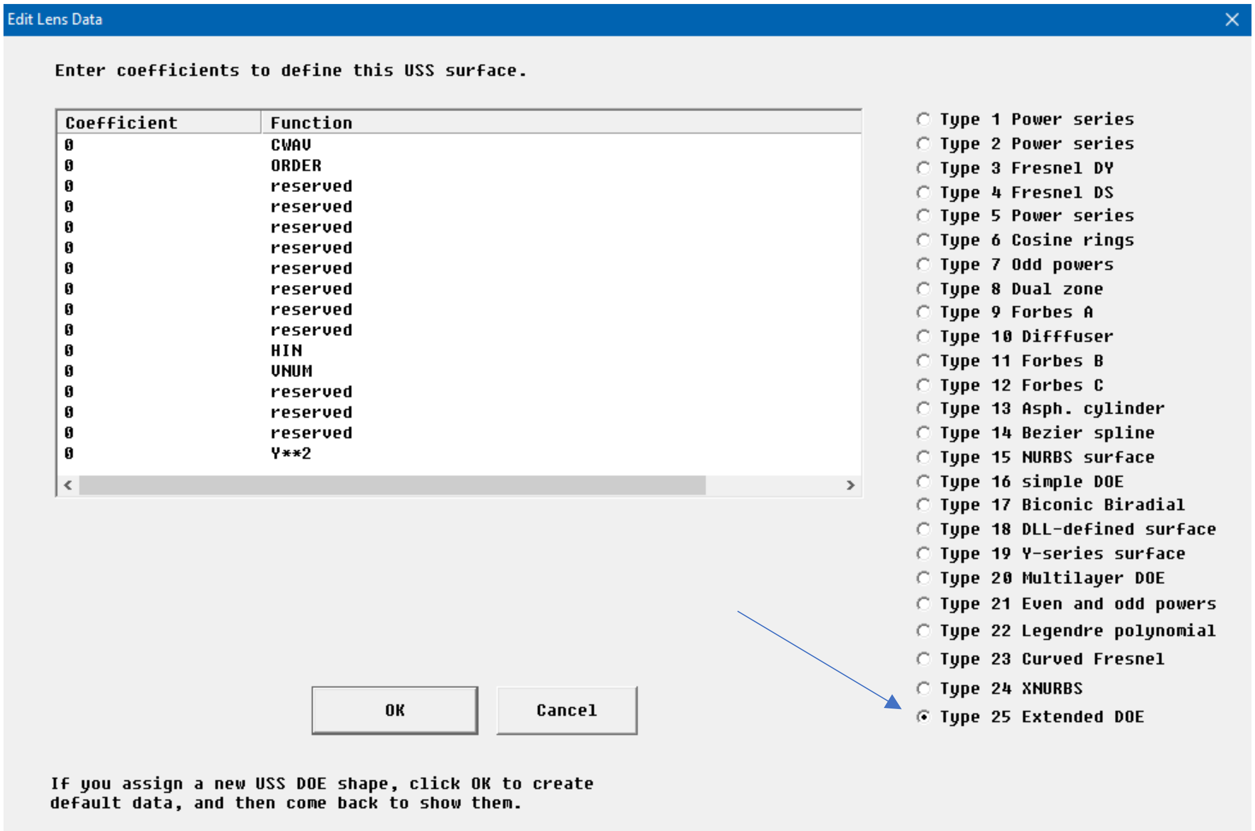
After running this, make a new RPER drawing. The beam is indeed circular at 4, as we wanted.



But it is not yet collimated, as we would like. Add another element, with WS, near the end.



We are going to make surface 5 a non-rotationally-symmetric kinoform surface, using shape USS 25. Make a checkpoint, select that surface in WS, and again open the Curvature Dialog. The USS option is greyed out at the moment, since you have to start with a flat surface to change to any of the USS shapes. So click the FLAT button, and then the USS button. When a new dialog opens, select Type 25 Extended DOE, and click OK and Close.



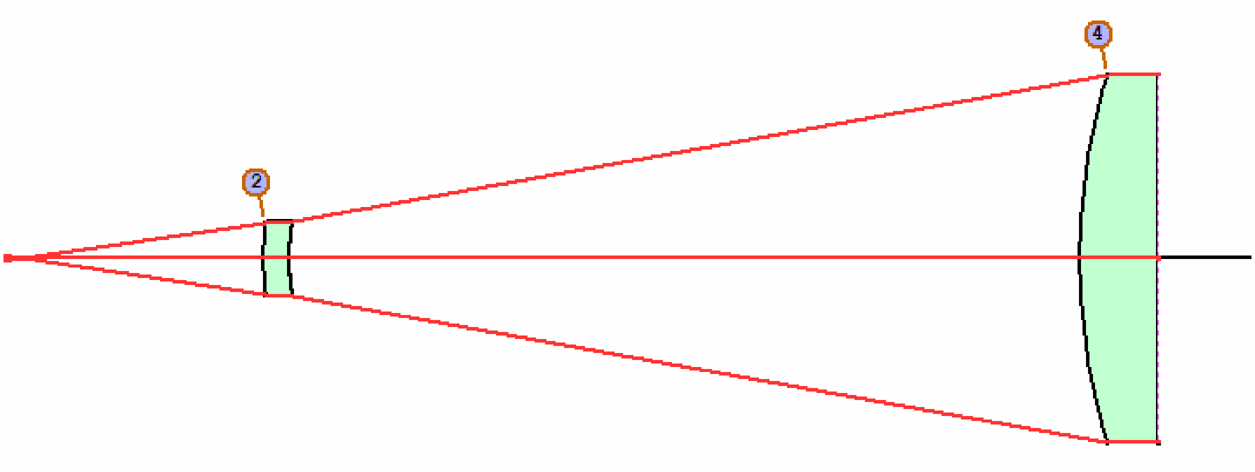
This looks like a useful starting system, so let's try to achieve our goals. We want the output to be collimated (which it is not at the moment), so add a surface 7 and make the system AFOCL.

Then make a new MACro:

```
PANT
VY 2 RD
VY 3 RD
VY 4 RD
VY 3 TH

VY 5 G 16
VY 5 G 17
VY 5 G 18
VY 5 G 19
VY 5 G 20
VY 5 G 21

VY 5 G 24
VY 5 G 25
VY 5 G 26
VY 5 G 27
VY 5 G 28
```

```
VY 5 G 29

VY 5 G 32
VY 5 G 33
VY 5 G 34
VY 5 G 35
VY 5 G 36
VY 5 G 37

END
AANT
M 0 10 A P HH 0 0 1 0 5
M 7.0 1 A P YA 0 0 1 0 5
M 7.0 1 A P XA 0 1 0 0 5

GNR 0 .1 9 P
GNO 0 .1 9 P

END

SNAP
SYNO 22
```

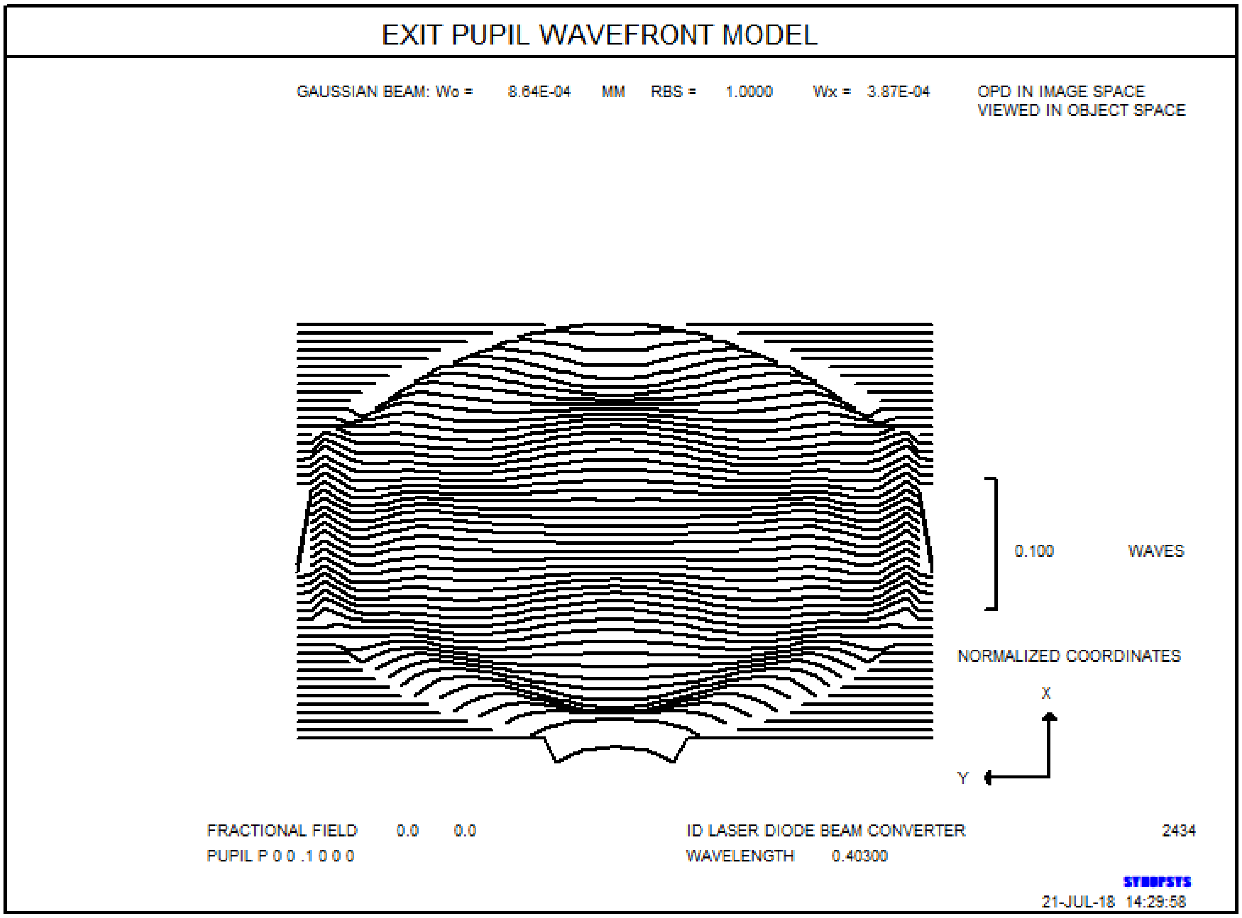
This will vary most of the coefficients of the new DOE, keep the beam radius equal to 7 mm in X and Y, ask for the marginal ray to exit with an angle of zero, and correct both transverse and OPD aberrations. The process converges nicely – but element 2 is too thin, so increase the thickness to 3 mm and run the optimization once more. Here is our design:



How well corrected is it? Go to MDI and ask for a pupil plot, scale 0.1 waves/inch. Not bad; less than 1/10 wave of error.

But we're not quite finished. The first element needs a rectangular aperture, and at the moment it has the default circular aperture. We assign the RAO:

```
CHG
2 RAO 8 3
3 RAO 8 3
END
```



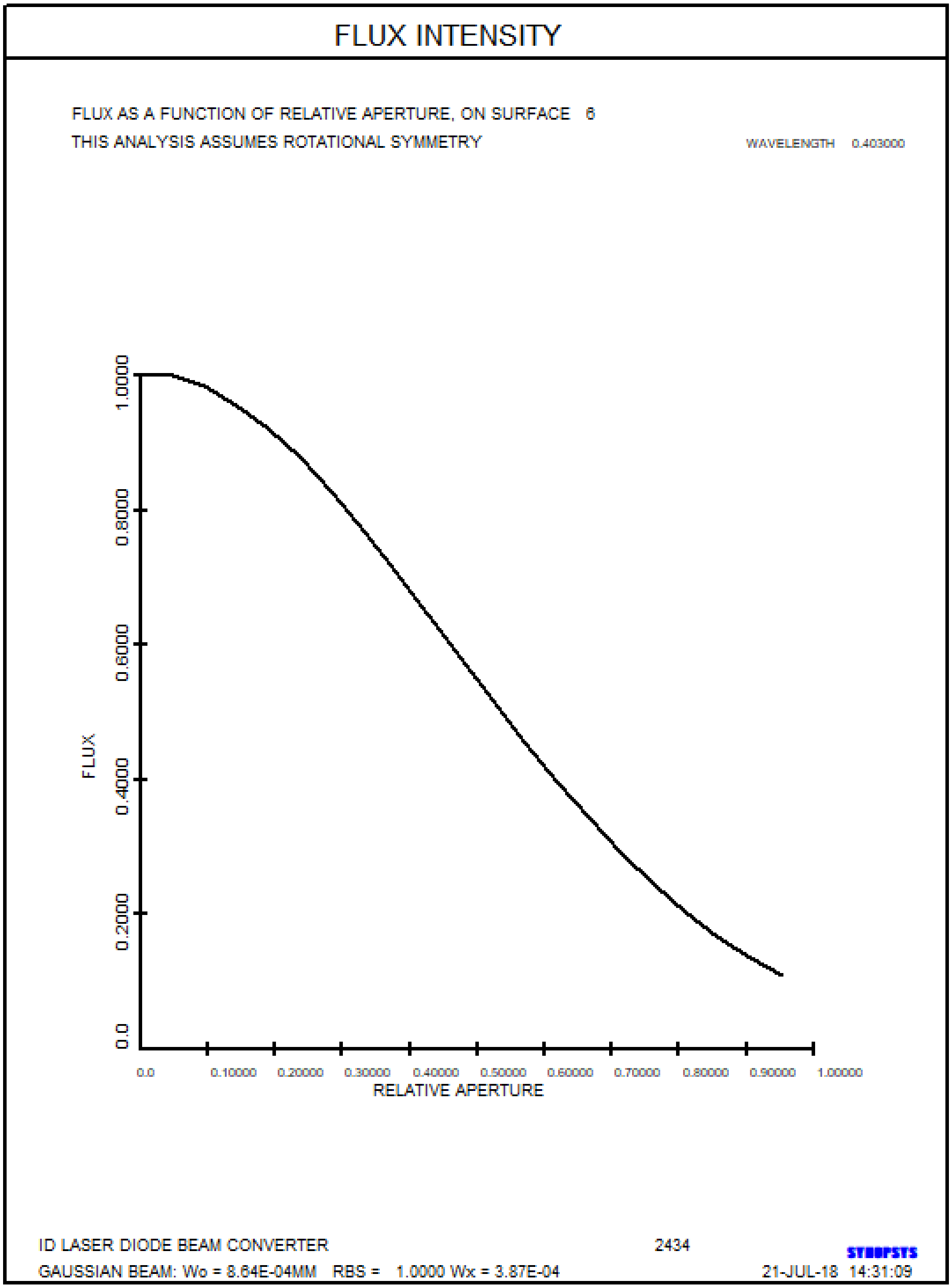
We haven't said anything about the intensity falloff yet. This is a laser diode, remember, and we assume the intensity profile is Gaussian. Let's check that.

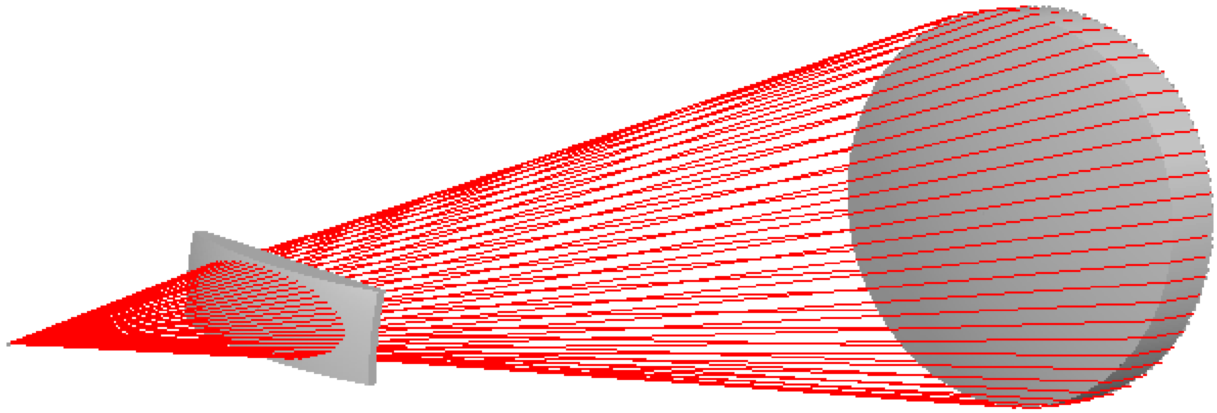
FLUX 20 P 6

Indeed. The flux falls off exactly as we expected. Now we can address the problem of making the profile uniform.

But that is exactly what we did in Lesson 13, so we leave that step as an exercise for the student. Read that lesson and apply the same logic to this case, taking into account the difference in lens construction. If you succeed, you are ready for your diploma. Congratulations.

For reference, the design we did for this lesson is listed below.


FLUX INTENSITY
FLUX AS A FUNCTION OF RELATIVE APERTURE, ON SURFACE 6
THIS ANALYSIS ASSUMES ROTATIONAL SYMMETRY
WAVELENGTH 0.403000
FLUX
1.0000
0.8000
0.6000
0.4000
0.2000
0.0
0.0
0.10000
0.20000
0.30000
0.40000
0.50000
0.60000
0.70000
0.80000
0.90000
1.00000
RELATIVE APERTURE
ID LASER DIODE BEAM CONVERTER
2434
SYNOPSYS
GAUSSIAN BEAM: Wo = 8.64E-04MM RBS = 1.0000 Wx = 3.87E-04
21-JUL-18 14:31:09



```
RLE
ID LASER DIODE BEAM CONVERTER              2601
 MERIT   0.202029E-04
 LOG     2601
 WA1 .4030000
 WT1 1.00000
 APS                 1
 AFOCAL
 XPXT
 EPUPIL
 UNITS MM
 OBG 0.0008644  1. 0.0003868

   0 AIR
   1 CV      0.0000000000000   TH      9.14848864 AIR
   2 RAO      8.00000000       3.00000000       0.00000000       0.00000000
   2 CV      0.0868899628935   TH      1.00000000
   2 GLM      1.60000000             50.00000000
   3 RAO      8.00000000       3.00000000       0.00000000       0.00000000
   3 CV      0.1150730958709   TH     30.13218529 AIR
   3 TORIC      0.00000000
   4 CV      0.0405917229030   TH      3.00000000
   4 N1 1.62117979
   4 GID 'GLM-NdVd         '
   4 PIN    2
   5 CV      0.0000000000000   TH      0.00000000 AIR
   5 USS  25
 CWAV        0.632800
 HIN        1.500000       55.000000
   RNORM    1.00000
   5 XDD  1   1.2488956E+00 -3.3430350E-02 -4.8801165E-05  2.3986731E-06 -6.1541865E-08
   5 XDD  2   5.6129758E-10  0.0000000E+00  0.0000000E+00 -5.9233478E+00 -4.6744410E-02
   5 XDD  3  -3.7078023E-05 -2.2003760E-06  3.6721484E-08 -4.9776438E-10  0.0000000E+00
   5 XDD  4   0.0000000E+00 -7.0629761E-02 -4.0279060E-05  5.1724603E-07 -6.0078137E-05
   5 XDD  5   1.4720853E-06 -1.2222347E-08  0.0000000E+00  0.0000000E+00  0.0000000E+00
   6 CV      0.0000000000000   TH      0.00000000 AIR
   7 CV      0.0000000000000   TH      0.00000000 AIR
 END
```