

ENEE408E Problem 2.1

$$n := 1.5$$

$$R_1 := 100 \quad R_2 := -120 \quad d := 25$$

variables in mm

$$D_1 := \frac{n-1}{R_1} \quad D_2 := \frac{1-n}{R_2} \quad \text{powers of surfaces}$$

$$A := 1 - \frac{d \cdot D_1}{n} \quad B := \frac{d}{n}$$

$$C := \frac{d \cdot D_1 \cdot D_2}{n} - D_1 - D_2 \quad D := 1 - \frac{d \cdot D_2}{n}$$

$$A \cdot D - B \cdot C = 1$$

$$h_1 := \frac{A-1}{C} \quad h_2 := \frac{D-1}{C} \quad f := \frac{-1}{C}$$

$$f = 113.386 \quad h_1 = 9.449 \quad h_2 = 7.874$$

Code V gives $f=113.3968$ difference arises because BK3 is not exactly $n=1.5$

$$113.3968 - 103.9477 = 9.449 \quad h_1 \text{ from Code V}$$

$$113.3968 - 105.5226 = 7.874 \quad h_2 \text{ from Code V}$$

408E22

| | RDY | THI | RMD | GLA | CCY | THC | GLC |
|--------|------------|------------|-----|------------|-----|-----|-----|
| > OBJ: | INFINITY | INFINITY | | | 100 | 100 | |
| STO: | 100.00000 | 25.000000 | | BK3_SCHOTT | 100 | 100 | |
| 2: | -120.00000 | 103.947715 | | | 100 | PIM | |
| IMG: | INFINITY | 0.000000 | | | 100 | 100 | |

SPECIFICATION DATA

| | |
|-----|----------|
| EPD | 50.00000 |
| DIM | MM |
| WL | 550.00 |
| REF | 1 |
| WTW | 1 |
| XAN | 0.00000 |
| YAN | 0.00000 |
| WTF | 1.00000 |
| VUY | 0.00000 |
| VLY | 0.00000 |

REFRACTIVE INDICES

| | |
|------------|----------|
| GLASS CODE | 550.00 |
| BK3_SCHOTT | 1.499950 |

SOLVES

PIM

No pickups defined in system

INFINITE CONJUGATES

| | |
|----------------|-----------|
| EFL | 113.3968 |
| BFL | 103.9477 |
| FFL | -105.5226 |
| FNO | 2.2679 |
| IMG DIS | 103.9477 |
| OAL | 25.0000 |
| PARAXIAL IMAGE | |
| HT | 0.0000 |
| ANG | 0.0000 |
| ENTRANCE PUPIL | |
| DIA | 50.0000 |
| THI | 0.0000 |
| EXIT PUPIL | |
| DIA | 53.7311 |
| THI | -17.9110 |

(3)

(v) A concave mirror with $R = 5$; $u = 8$

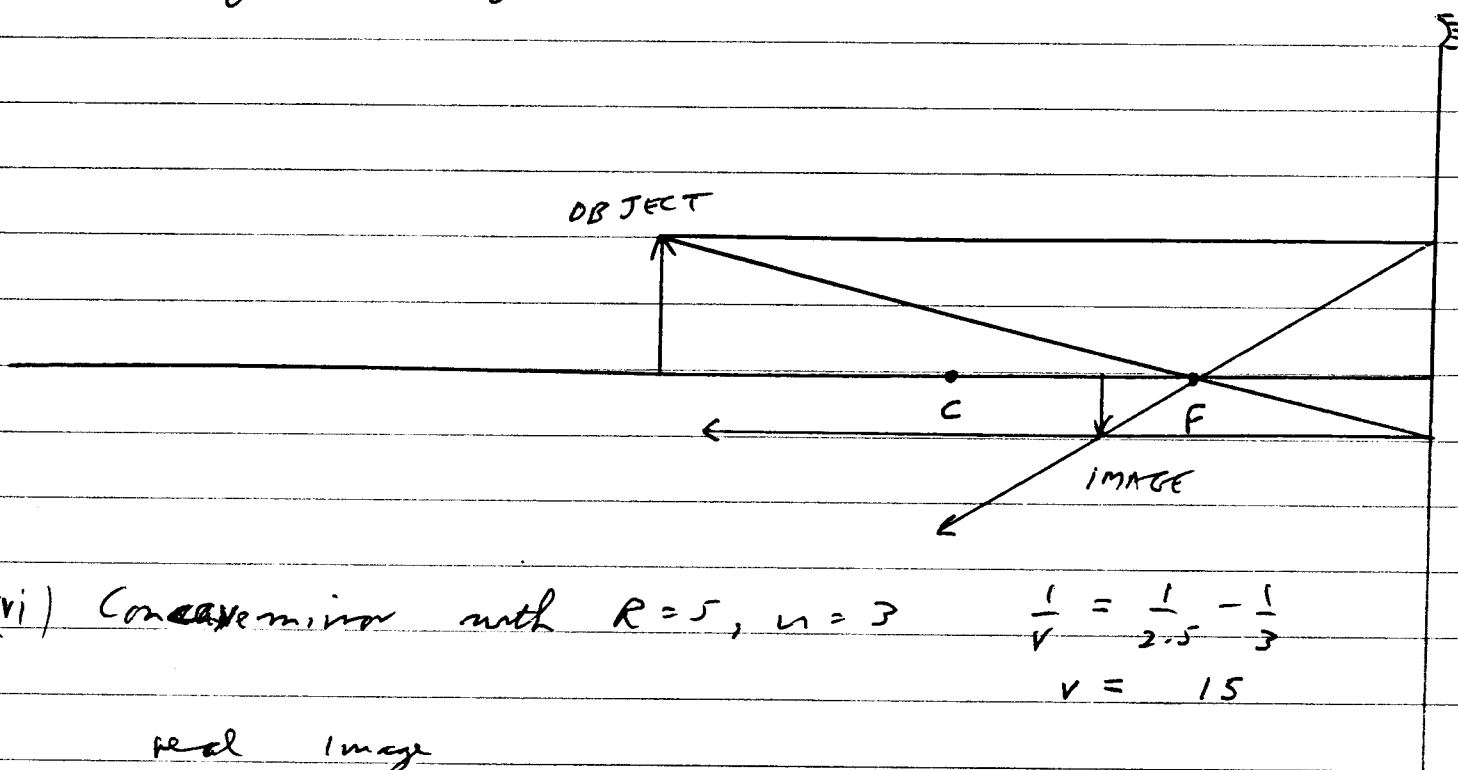
$$f = R/2 = 2.5$$

$$\frac{1}{v} = \frac{1}{2.5} - \frac{1}{8} \quad v = \frac{40}{11} \quad (3.63636)$$

real image

$$\text{linear mag} = v/u = 5/11$$

$$\text{ang. mag} = 11/5$$



(vi) Concave mirror with $R = 5$, $u = 3$

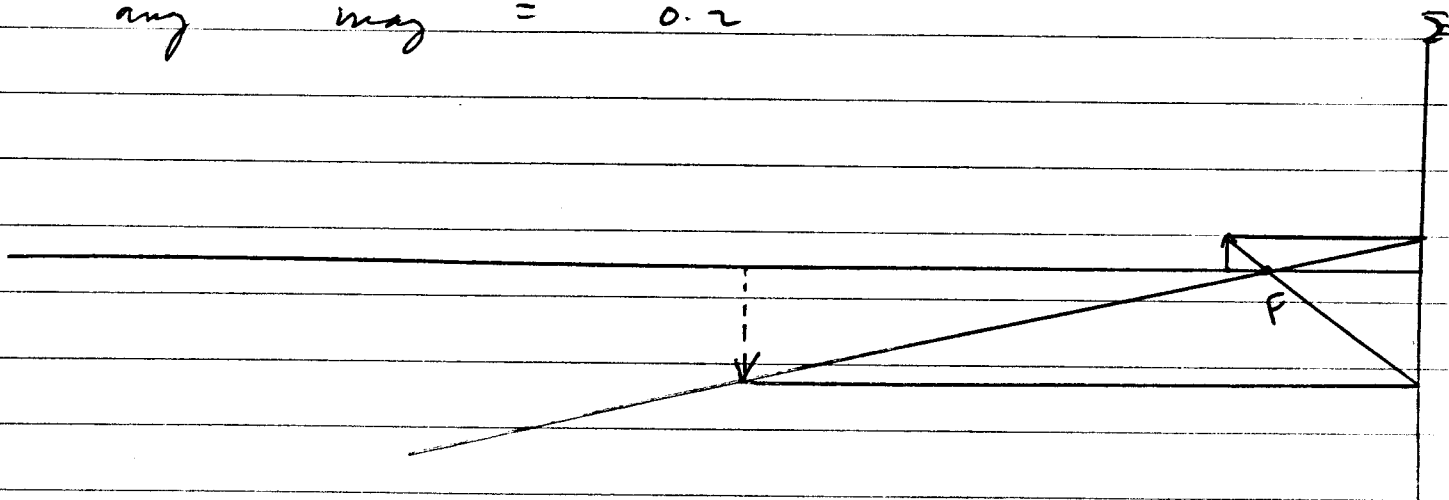
$$\frac{1}{v} = \frac{1}{2.5} - \frac{1}{3}$$

$$v = 15$$

real image

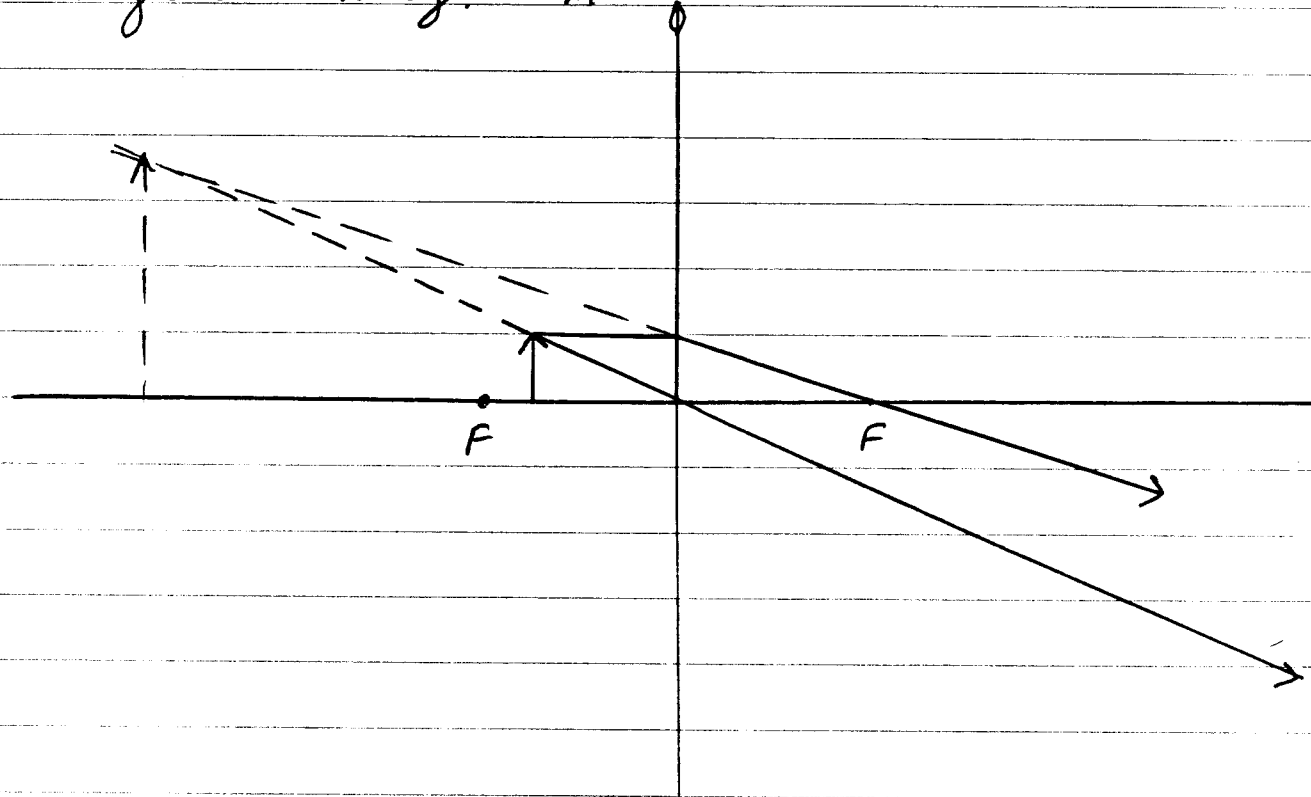
$$\text{linear mag} = v/u = 5$$

$$\text{ang. mag} = 0.2$$



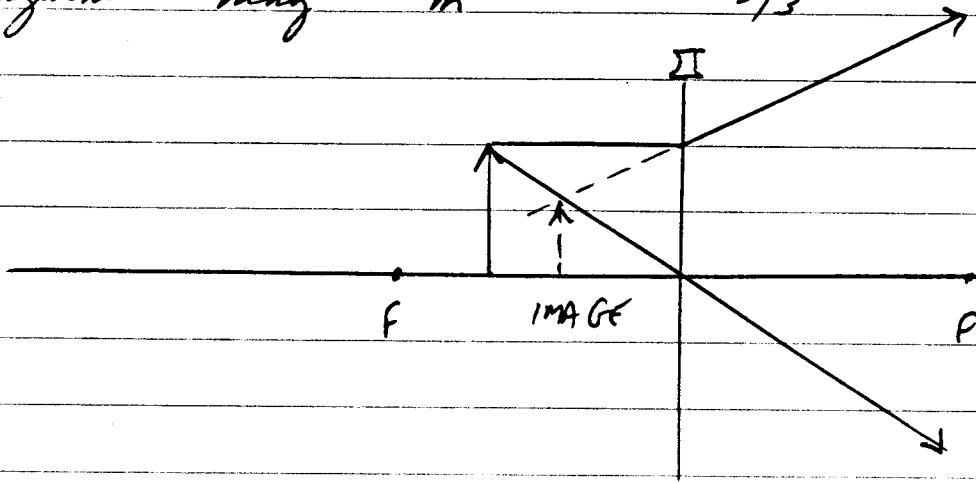
(iii) $f = 2$ $u = 1.5$ $\frac{1}{v} = \frac{1}{2} - \frac{1}{1.5} \Rightarrow v = -6$

virtual image
 linear mag. $m = v/u = -4$
 angular mag. $m' = -0.25$



(iv) $f = -3$ $u = 2$ $\frac{1}{v} = -\frac{1}{3} - \frac{1}{2} \Rightarrow v = -\frac{6}{5}$

virtual image
 linear mag. $m = v/u = -3/5$
 angular mag. $m' = -5/3$



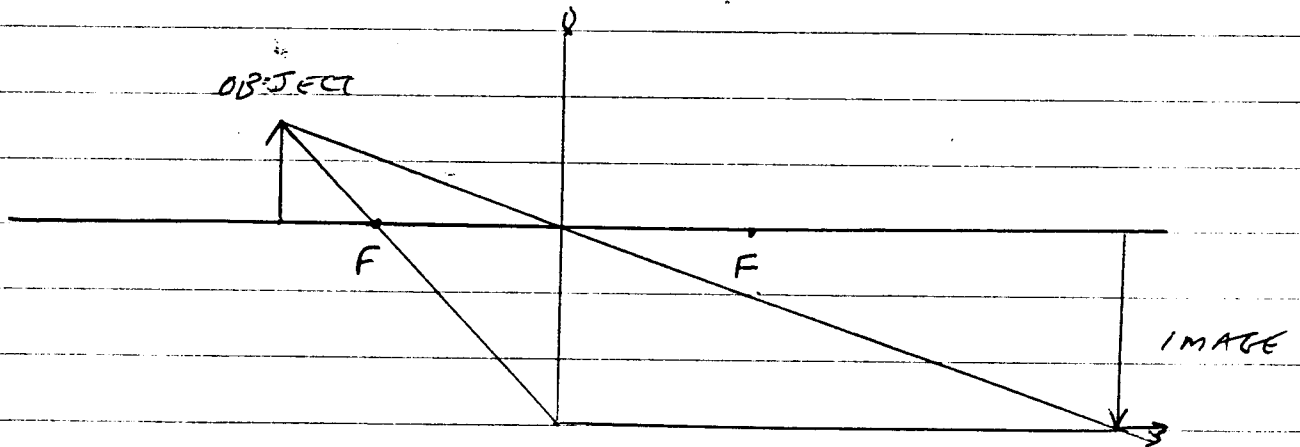
(8) (i) $f = 2$ $u = 3$ $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

$$\frac{1}{v} = \frac{1}{2} - \frac{1}{3} \Rightarrow v = 6$$

Real image

linear magnification $m = \frac{v}{u} = 2$

angular magnification $m' = 1/m = 0.5$

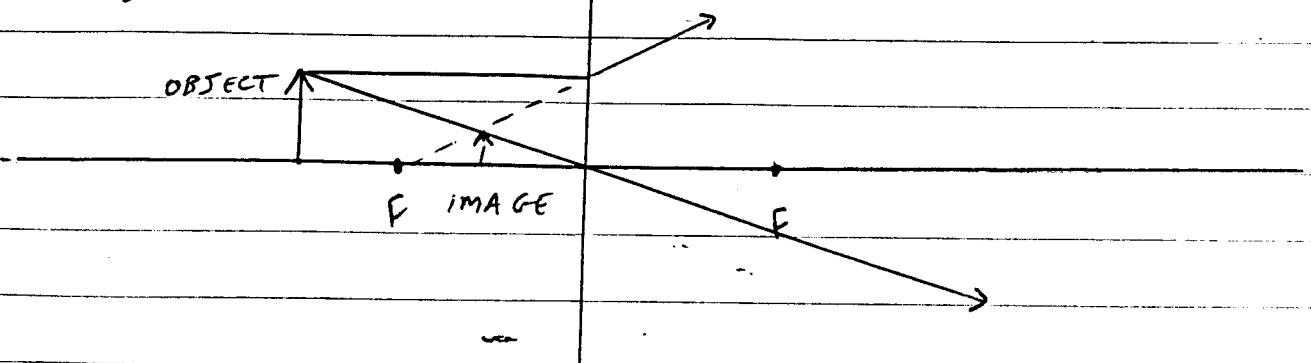


(ii) $f = -2$ $u = 3$ $\frac{1}{v} = -\frac{1}{2} - \frac{1}{3}$ $v = -\frac{6}{5}$

Virtual image

linear mag $m = v/u = -\frac{2}{3}$

angular mag $m' = -\frac{5}{2}$



Achromat with optimized glasses

| | RDY | THI | RMD | GLA | CCY | THC | GLC |
|------|------------|-----------|-----|---------------|-----|-----|-----|
| OBJ: | INFINITY | INFINITY | | | 100 | 100 | |
| STO: | 64.22452 | 13.000000 | | SK5_SCHOTT | 0 | 0 | |
| > 2: | -49.74144 | 2.200000 | | LAF11A_SCHOTT | 0 | 0 | |
| 3: | -175.62811 | 91.753666 | | | 0 | PIM | |
| IMG: | INFINITY | -0.087214 | | | 100 | 0 | |

SPECIFICATION DATA

| | | |
|-----|---------|--------|
| FNO | 4.00000 | |
| DIM | MM | |
| WL | 650.00 | 450.00 |
| REF | 1 | |
| WTW | 1 | 1 |
| INI | ORA | |
| XAN | 0.00000 | |
| YAN | 0.00000 | |
| WTF | 1.00000 | |
| VUY | 0.00000 | |
| VLY | 0.00000 | |

REFRACTIVE INDICES

| GLASS CODE | 650.00 | 450.00 |
|---------------|----------|----------|
| LAF11A_SCHOTT | 1.750500 | 1.783369 |
| SK5_SCHOTT | 1.586426 | 1.599354 |

SOLVES

PIM

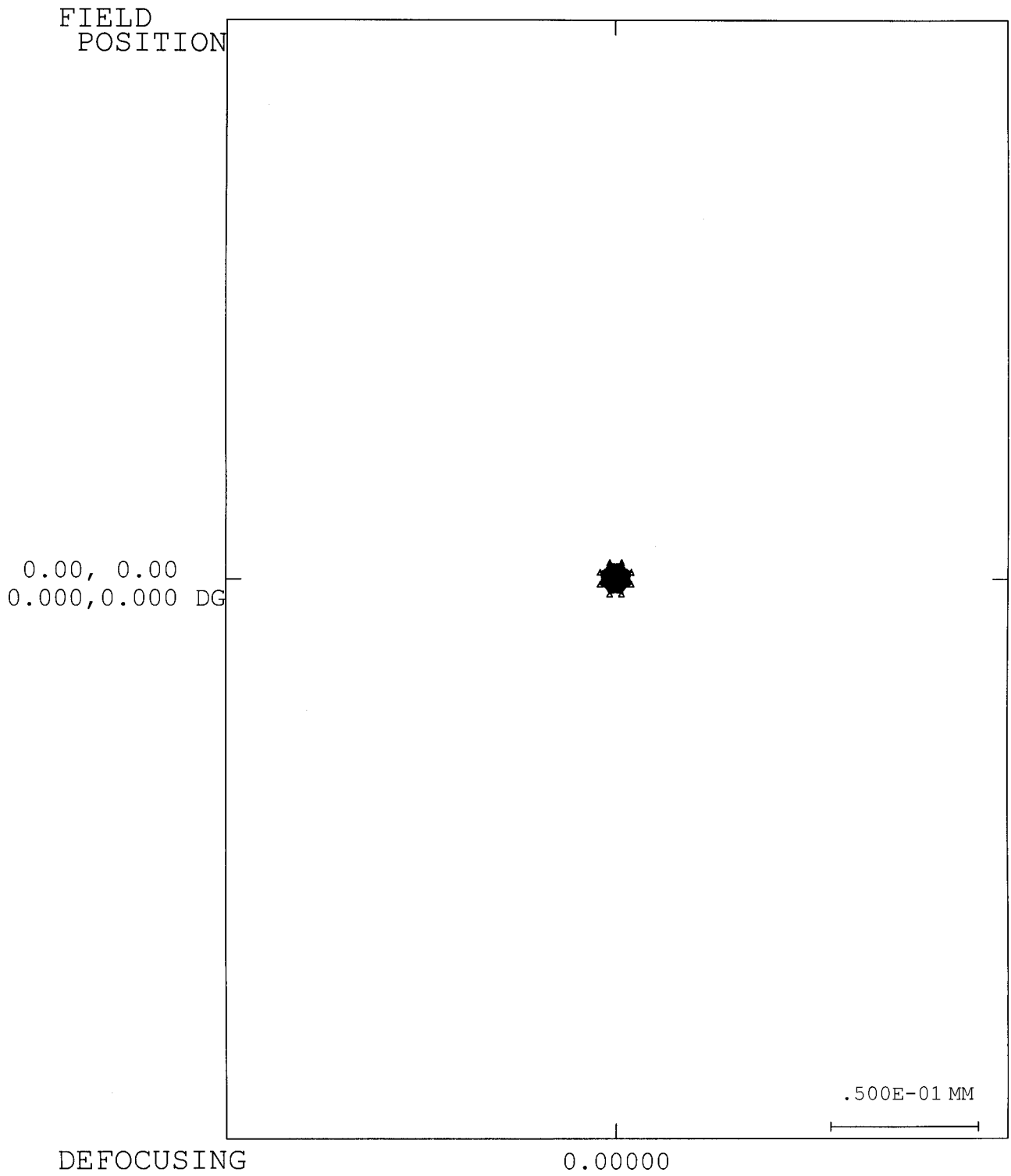
No pickups defined in system

INFINITE CONJUGATES

| | |
|----------------|----------|
| EFL | 100.0000 |
| BFL | 91.7537 |
| FFL | -98.6497 |
| FNO | 4.0000 |
| IMG DIS | 91.6665 |
| OAL | 15.2000 |
| PARAXIAL IMAGE | |
| HT | 0.0000 |
| ANG | 0.0000 |
| ENTRANCE PUPIL | |
| DIA | 25.0000 |
| THI | 0.0000 |
| EXIT PUPIL | |
| DIA | 25.3422 |
| THI | -9.6151 |

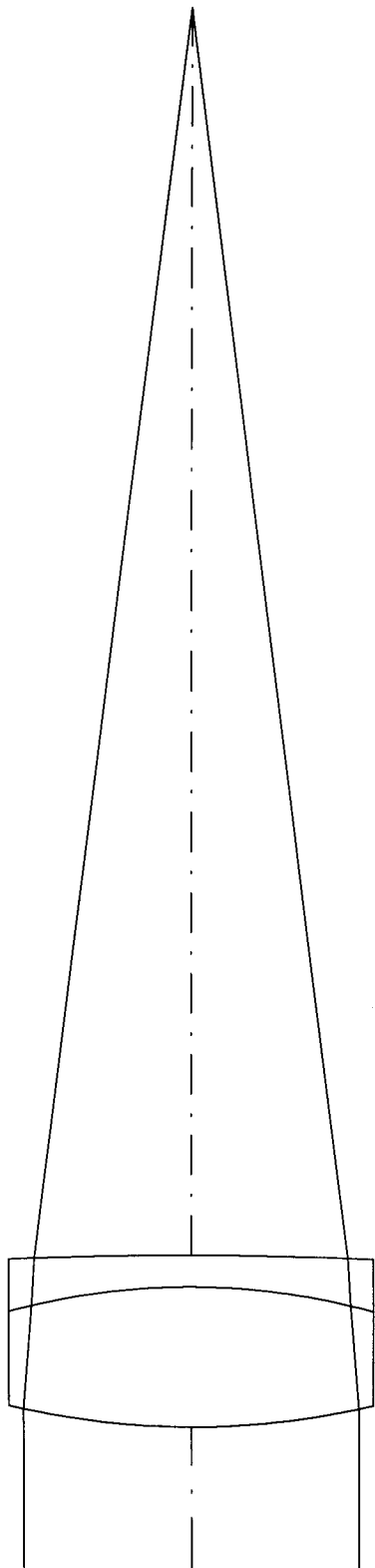
| <p>Doublet</p> <p>DIFFRACTION MTF</p> | <p>26-Oct-01</p> | <p>----- DIFFRACTION LIMIT</p> <p>_____ AXIS</p> | <p>WAVELENGTH</p> <p>650.0 NM</p> <p>450.0 NM</p> | <p>WEIGHT</p> <p>1</p> <p>1</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------|---------------------------------------------------|---------------------------------|-------------------------------|-------------------------|--------------------------|---|------|------|----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|
| <p>ORA</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>DEFOCUSING 0.00000</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <table border="1"> <caption>Approximate data points from the MTF plot</caption> <thead> <tr> <th>Spatial Frequency (cycles/mm)</th> <th>Modulation (Solid Line)</th> <th>Modulation (Dashed Line)</th> </tr> </thead> <tbody> <tr><td>9</td><td>1.00</td><td>1.00</td></tr> <tr><td>63</td><td>0.85</td><td>0.85</td></tr> <tr><td>117</td><td>0.75</td><td>0.75</td></tr> <tr><td>171</td><td>0.65</td><td>0.65</td></tr> <tr><td>225</td><td>0.55</td><td>0.55</td></tr> <tr><td>279</td><td>0.45</td><td>0.50</td></tr> <tr><td>333</td><td>0.35</td><td>0.55</td></tr> <tr><td>387</td><td>0.25</td><td>0.60</td></tr> <tr><td>441</td><td>0.15</td><td>0.65</td></tr> <tr><td>495</td><td>0.08</td><td>0.70</td></tr> <tr><td>549</td><td>0.04</td><td>0.75</td></tr> </tbody> </table> | | | | | Spatial Frequency (cycles/mm) | Modulation (Solid Line) | Modulation (Dashed Line) | 9 | 1.00 | 1.00 | 63 | 0.85 | 0.85 | 117 | 0.75 | 0.75 | 171 | 0.65 | 0.65 | 225 | 0.55 | 0.55 | 279 | 0.45 | 0.50 | 333 | 0.35 | 0.55 | 387 | 0.25 | 0.60 | 441 | 0.15 | 0.65 | 495 | 0.08 | 0.70 | 549 | 0.04 | 0.75 |
| Spatial Frequency (cycles/mm) | Modulation (Solid Line) | Modulation (Dashed Line) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | 1.00 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 63 | 0.85 | 0.85 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 117 | 0.75 | 0.75 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 171 | 0.65 | 0.65 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 225 | 0.55 | 0.55 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 279 | 0.45 | 0.50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 333 | 0.35 | 0.55 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 387 | 0.25 | 0.60 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 441 | 0.15 | 0.65 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 495 | 0.08 | 0.70 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 549 | 0.04 | 0.75 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

408E27 Achromatic Doublet



Doublet

408E27 Achromatic Doublet



13.89 MM

Doublet

Scale: 1.80 ORA 26-Oct-01

408E Design Problem Set #2 Question 6

The aberrations I calculated were:

- (1) biconvex lens: 1.44525mm
- (2) plano-convex lens 0.77325mm
- (3) convex meniscus lens 1.17818

Acceptable answers will vary

408E25

WAVELENGTH 550.0 NM
WEIGHT 1

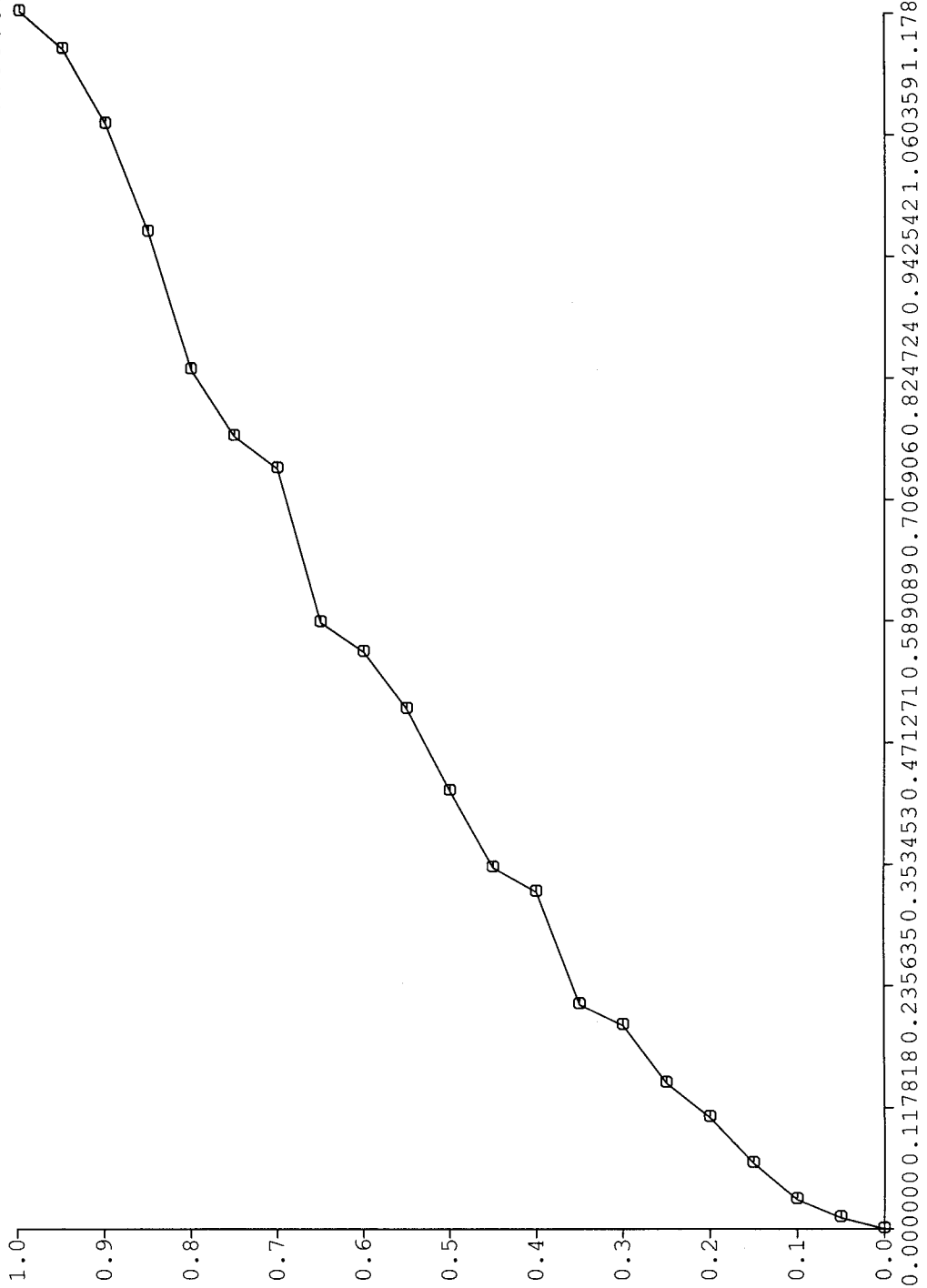
FOCUS --- 0.00000
FIELD (X, Y) PCT
(0.00, 0.00)MAX
(0.0, 0.0)DEG
10 0.02879
20 0.10835
30 0.19742
40 0.32631
50 0.42403
60 0.55830
70 0.73600
80 0.83129
90 1.06950
100 1.17818

408E25

(0.000, 0.000) DEGREES

19-Oct-01

DEFOCUSING 0.00000



ENCRICLED ENERGY

DIAMETER OF CIRCLE (MM)

408E25

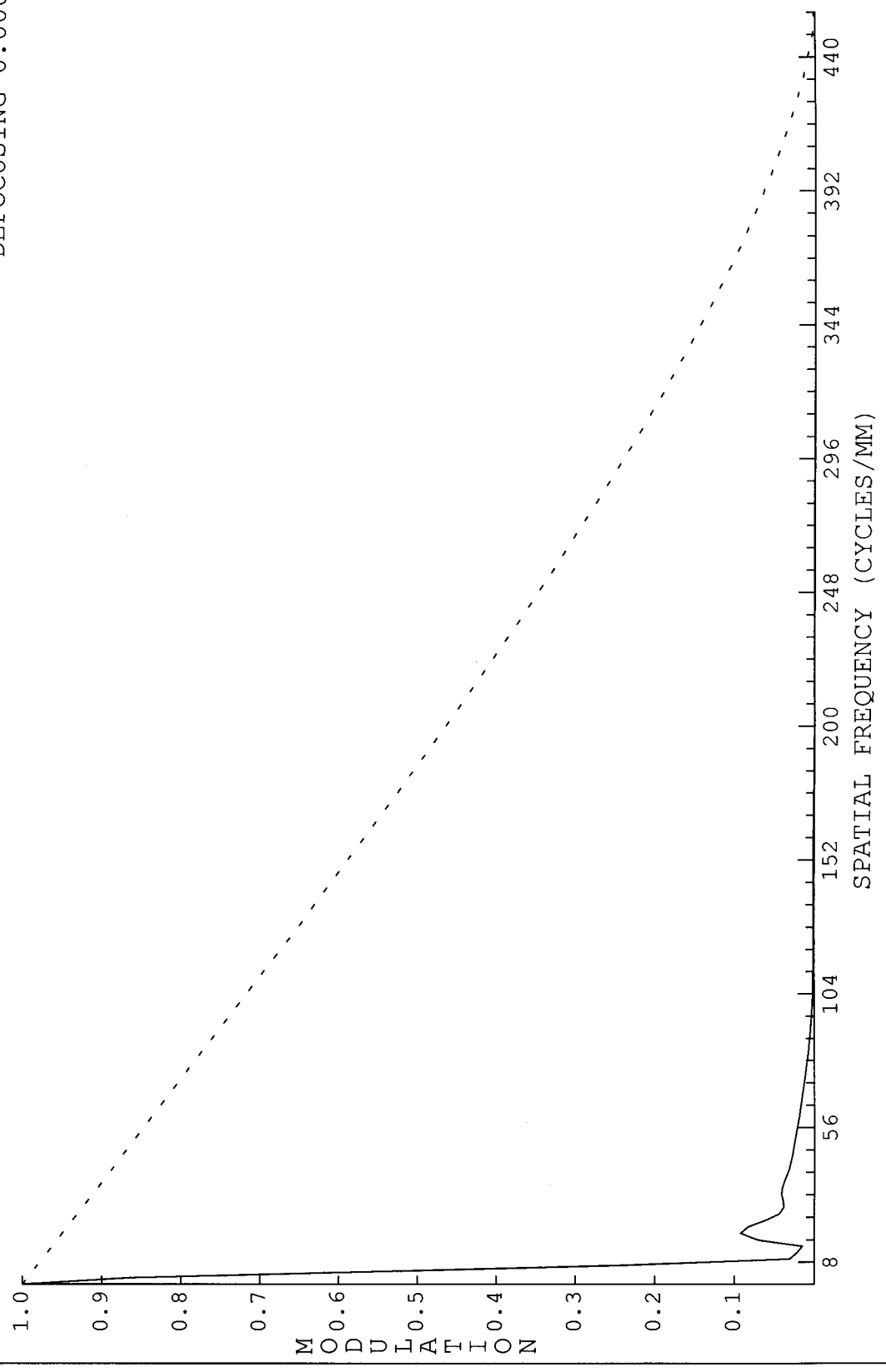
DIFFRACTION MTF

19-Oct-01

----- DIFFRACTION LIMIT
_____ AXIS

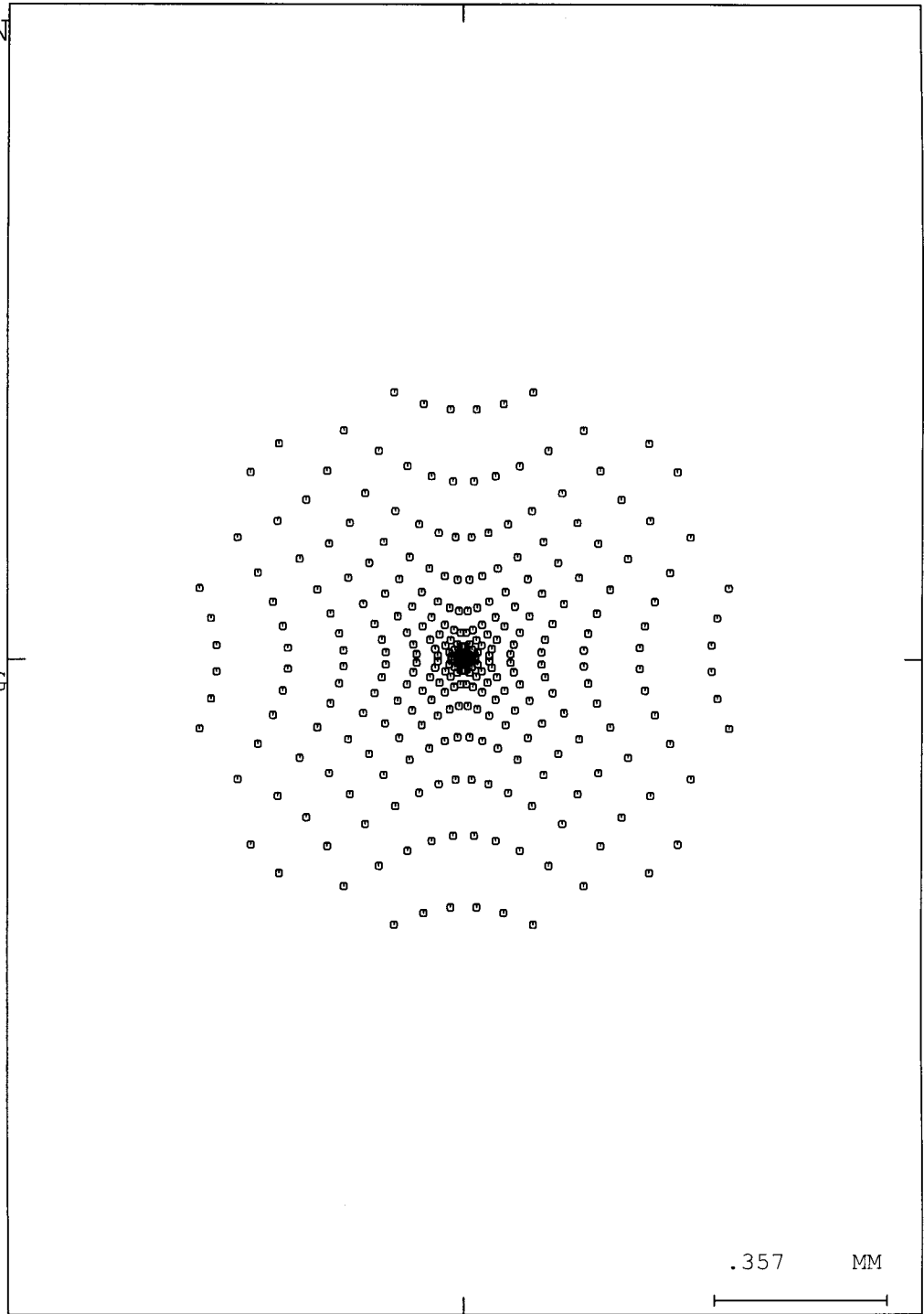
WAVELENGTH 550.0 NM
WEIGHT 1

DEFOCUSING 0.00000



FIELD
POSITION

0.00, 0.00
0.000, 0.000 DG

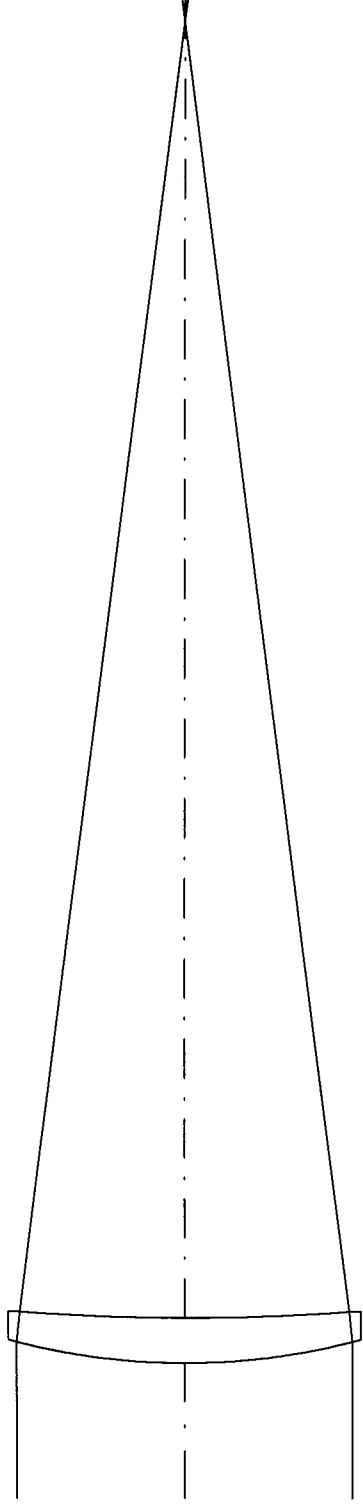


DEFOCUSING

0.00000

.357 MM

408E25



41.67 MM

408E24

DIFFRACTION MTF

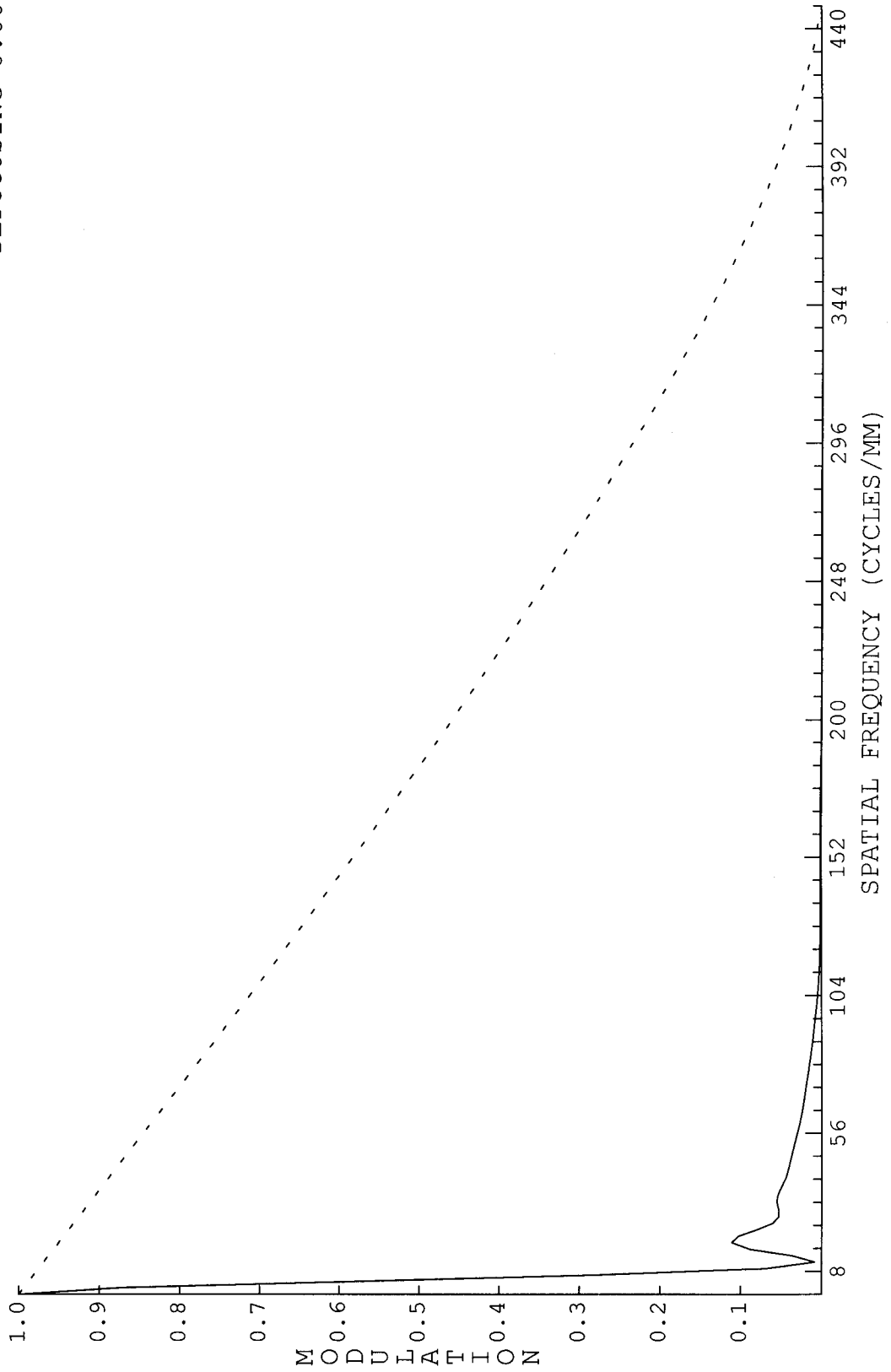
19-Oct-01

----- DIFFRACTION LIMIT

_____ AXIS

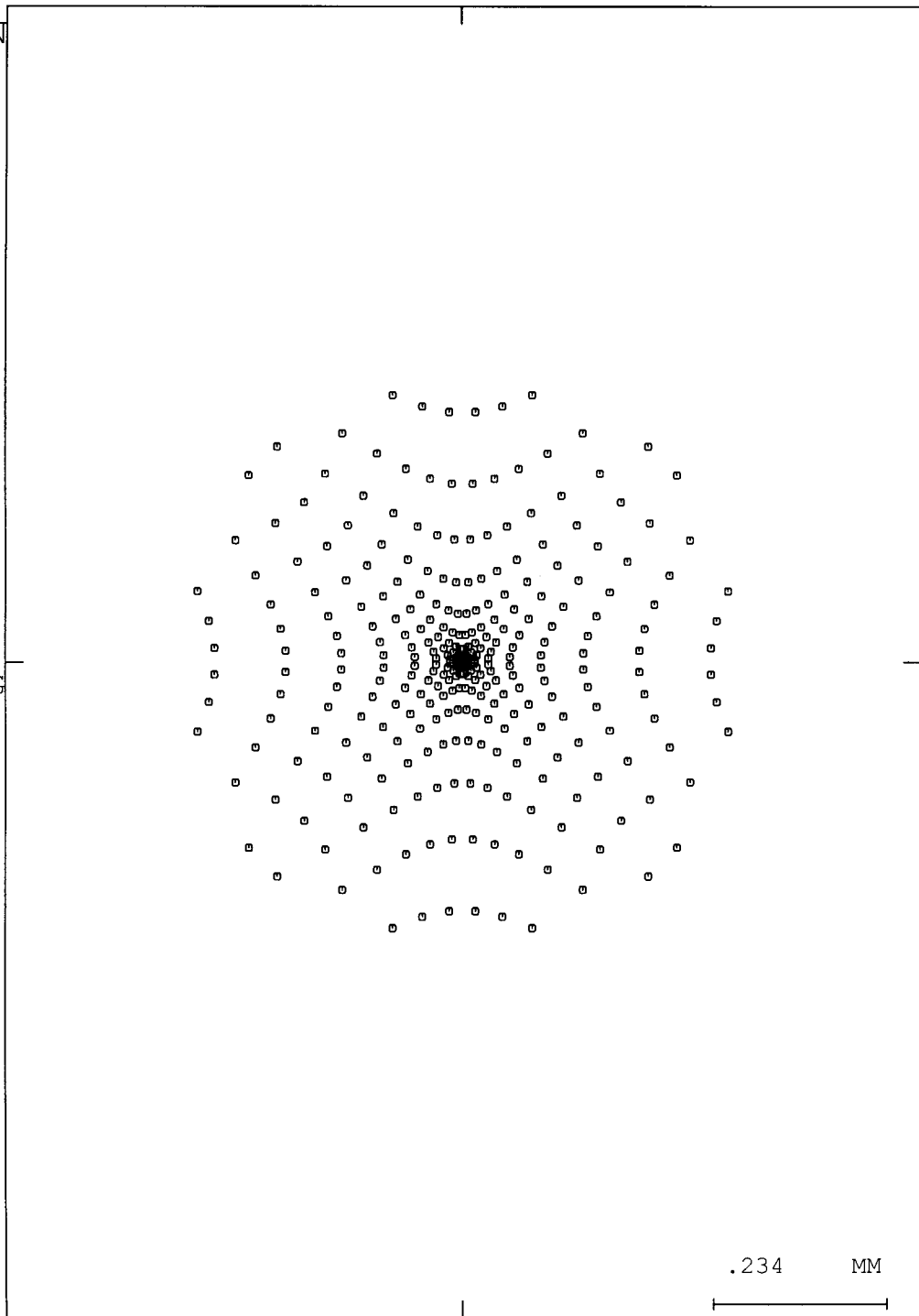
WAVELENGTH 550.0 NM
WEIGHT 1

DEFOCUSING 0.00000



FIELD
POSITION

0.00, 0.00
0.000, 0.000 DG



DEFOCUSING

0.0000

.234 MM

408E24

17:16:27

408E24

WAVELENGTH 550.0 NM
WEIGHT 1

FOCUS --- 0.00000
FIELD (X, Y) PCT
(0.00, 0.00)MAX
(0.0, 0.0)DEG

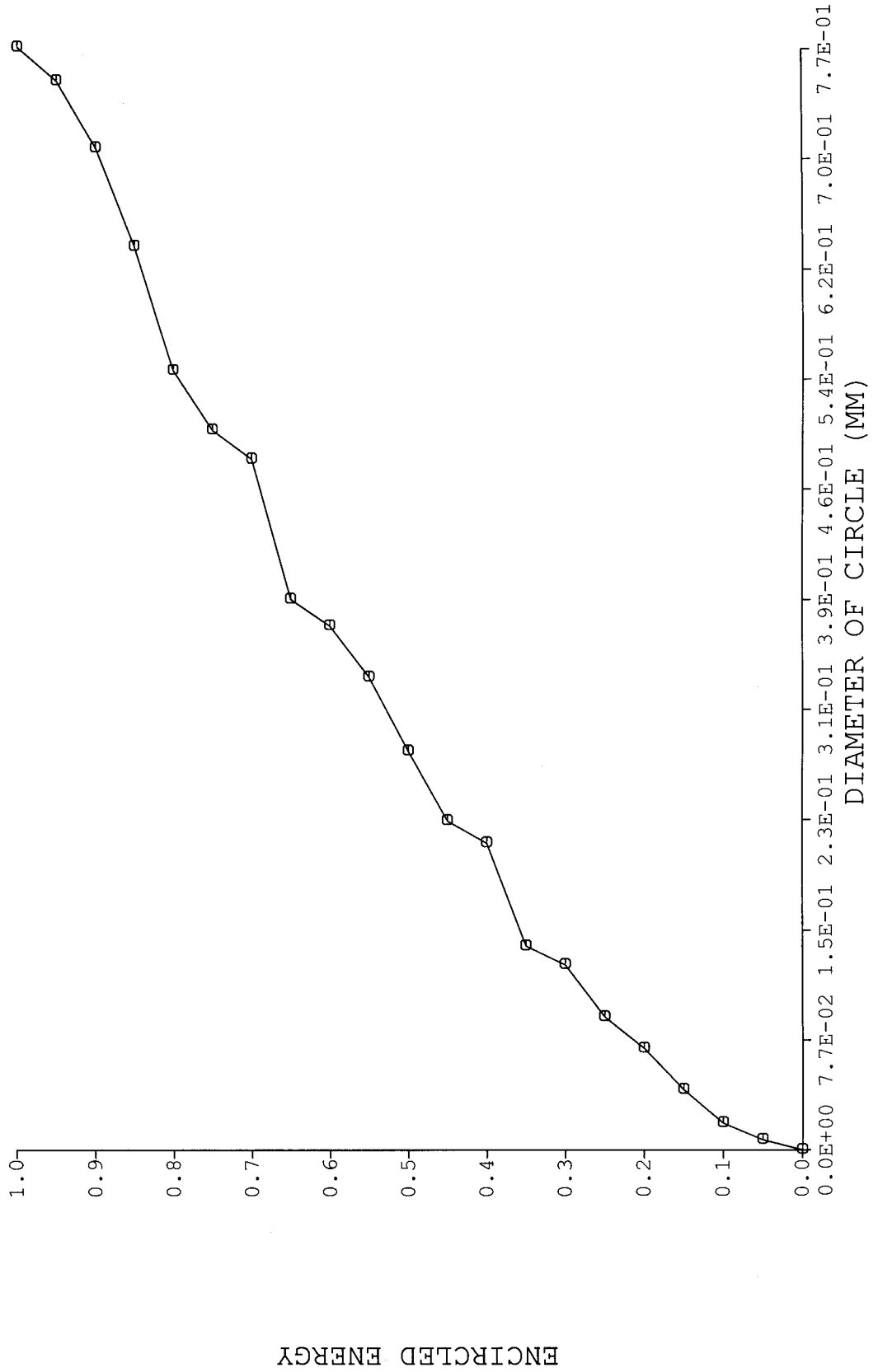
| | |
|-----|---------|
| 10 | 0.01908 |
| 20 | 0.07170 |
| 30 | 0.13051 |
| 40 | 0.21545 |
| 50 | 0.27974 |
| 60 | 0.36793 |
| 70 | 0.48442 |
| 80 | 0.54678 |
| 90 | 0.70239 |
| 100 | 0.77325 |

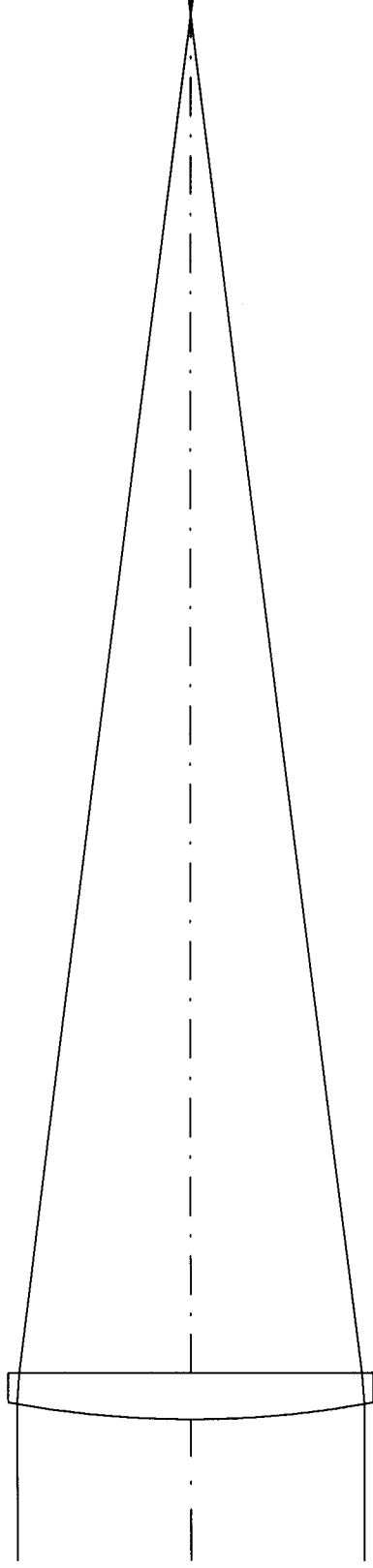
408E24

(0.000, 0.000) DEGREES

19-Oct-01

DEFOCUSING 0.00000





39.06 MM

40823

WAVELENGTH 550.0 NM
WEIGHT 1

FOCUS --- 0.00000
FIELD (X, Y) PCT
(0.00, 0.00)MAX
(0.0, 0.0)DEG

| | |
|-----|---------|
| 10 | 0.03558 |
| 20 | 0.13378 |
| 30 | 0.24355 |
| 40 | 0.40217 |
| 50 | 0.52227 |
| 60 | 0.68707 |
| 70 | 0.90486 |
| 80 | 1.02148 |
| 90 | 1.31262 |
| 100 | 1.44525 |

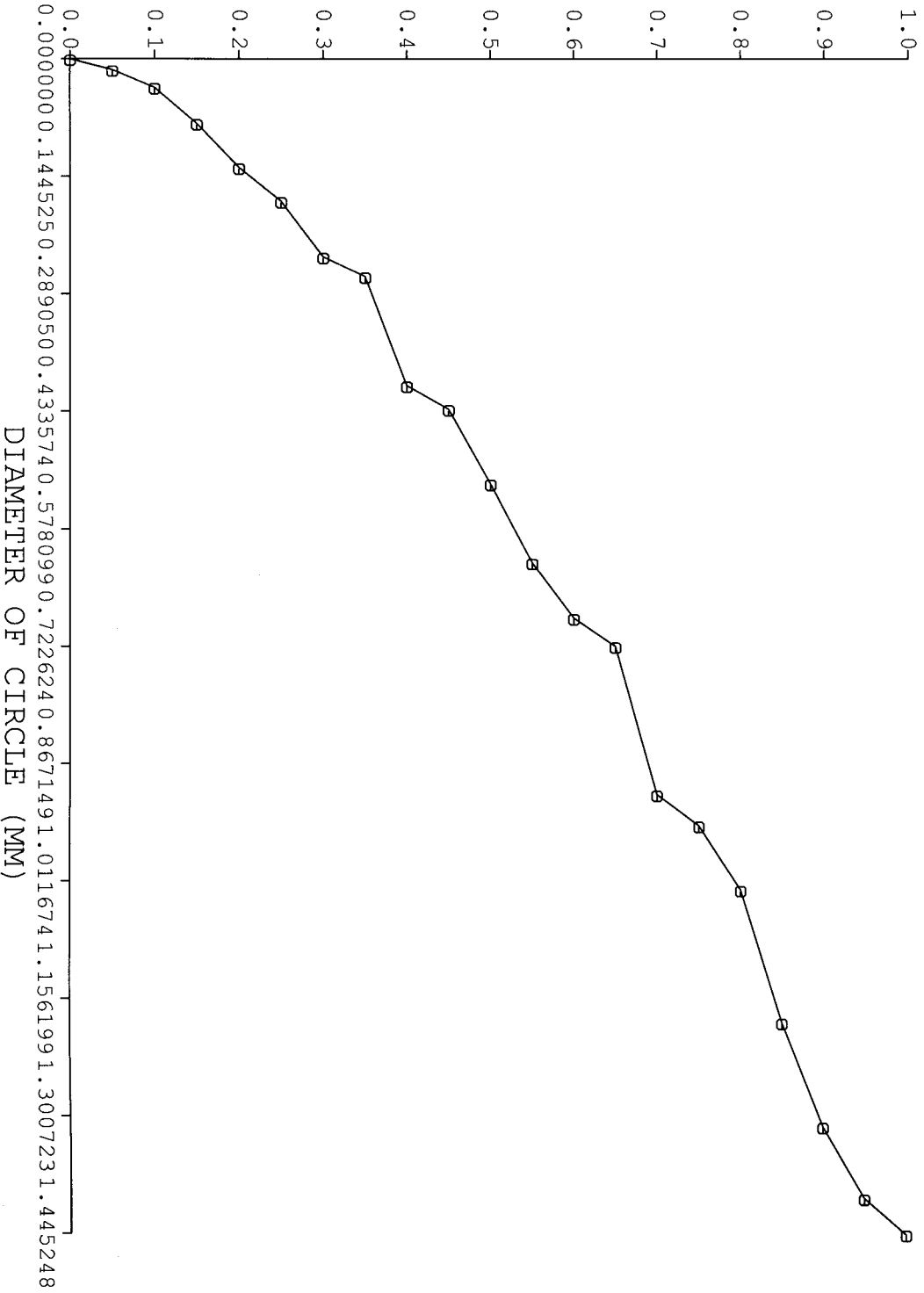
40823

(0.000, 0.000) DEGREES

19-Oct-01

DEFOCUSING 0.00000

ENCIRCLED ENERGY



DIAMETER OF CIRCLE (MM)

40823

DIFFRACTION MTF

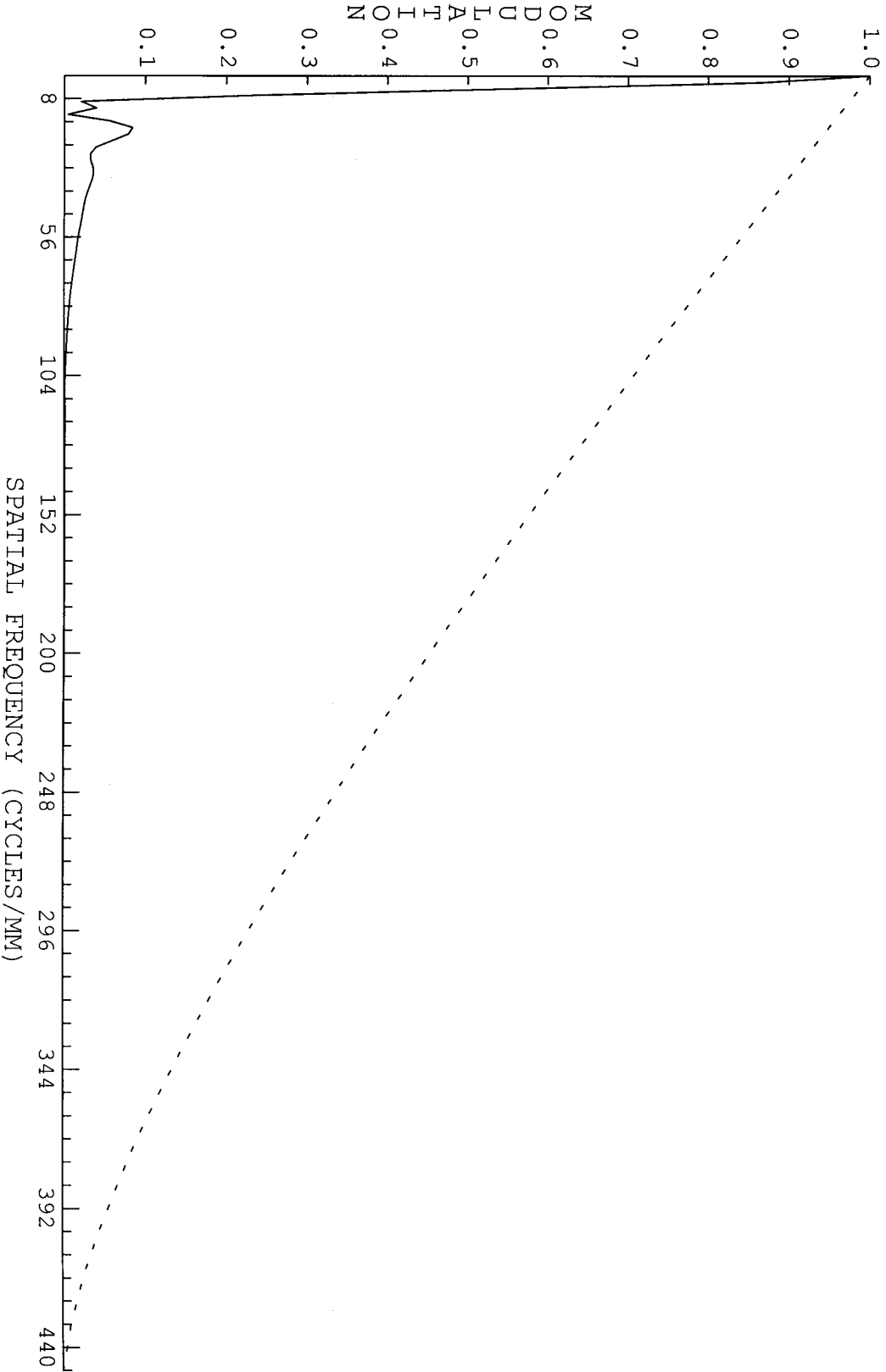
19-Oct-01

----- DIFFRACTION LIMIT

_____ AXIS

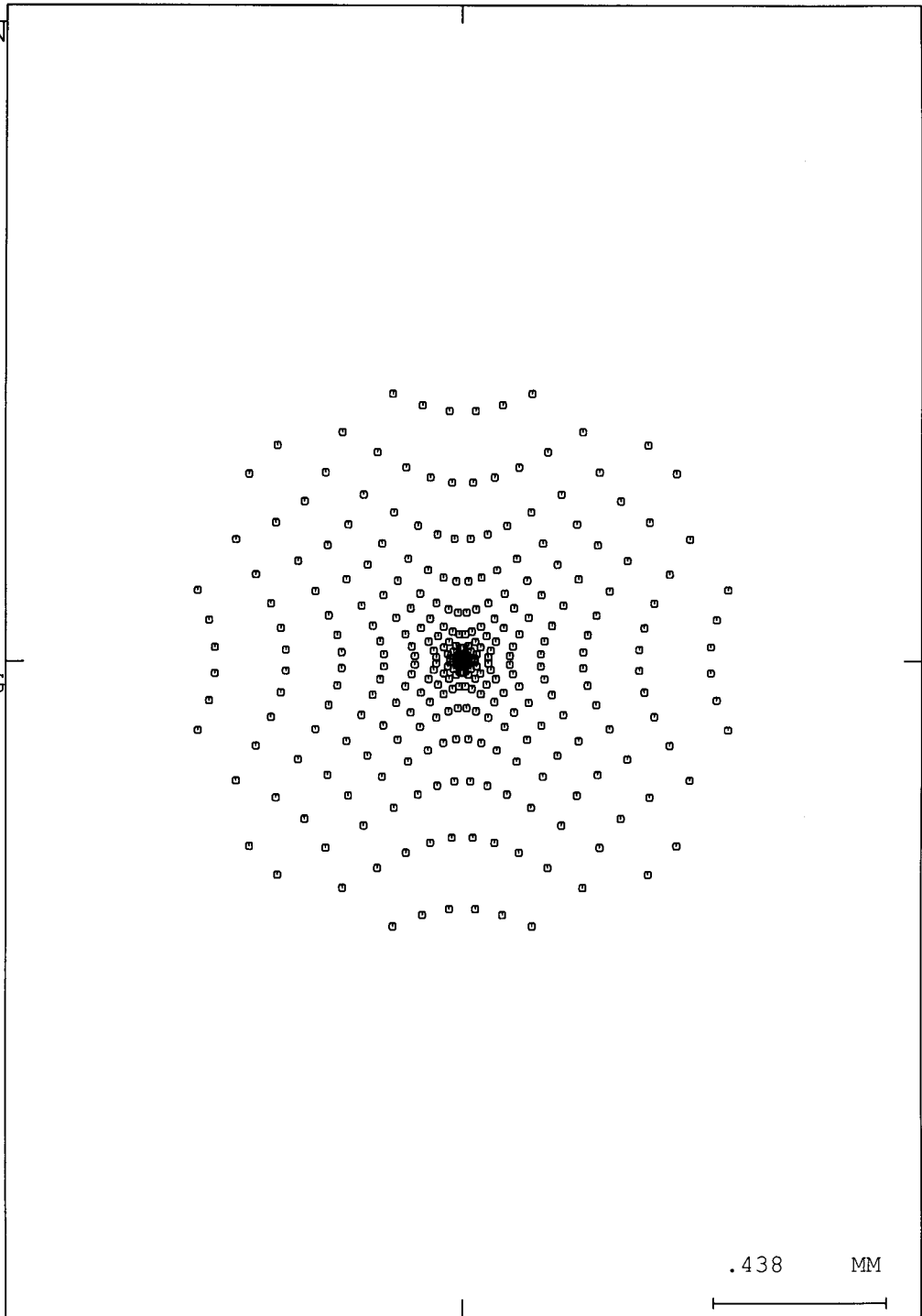
WAVELENGTH WEIGHT
550.0 NM 1

DEFOCUSING 0.00000



FIELD
POSITION

0.00, 0.00
0.000, 0.000 DG



DEFOCUSING

0.00000

.438 MM

40823

16:52:50

40823

| | RDY | THI | RMD | GLA | CCY | THC | GLC |
|--------|------------|------------|-----|-------------|-----|-----|-----|
| OBJ: | INFINITY | INFINITY | | | 100 | 100 | |
| > STO: | 427.40252 | 10.000000 | | LAK8_SCHOTT | 0 | 100 | |
| 2: | -427.40252 | 297.071669 | | | PIK | PIM | |
| IMG: | INFINITY | 0.000000 | | | 100 | 100 | |

SPECIFICATION DATA

| | |
|-----|---------|
| FNO | 4.00000 |
| DIM | MM |
| WL | 550.00 |
| REF | 1 |
| WTW | 1 |
| XAN | 0.00000 |
| YAN | 0.00000 |
| WTF | 1.00000 |
| VUY | 0.00000 |
| VLY | 0.00000 |

REFRACTIVE INDICES

| | |
|-------------|----------|
| GLASS CODE | 550.00 |
| LAK8_SCHOTT | 1.715831 |

SOLVES

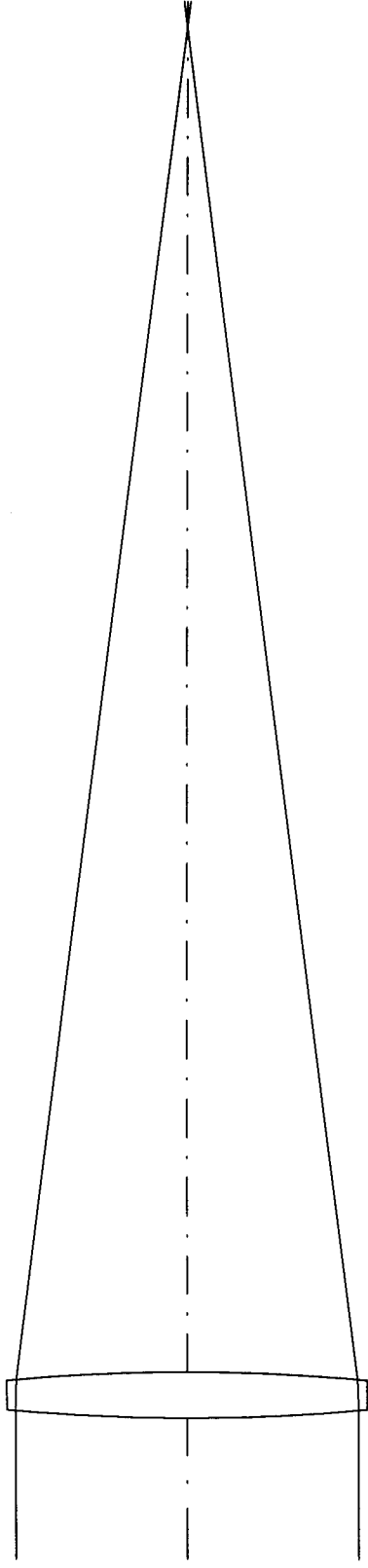
PIM

PICKUPS

PIK RDY S2 Z1 RDY S1 Z1 -1.000000

INFINITE CONJUGATES

| | |
|----------------|-----------|
| EFL | 300.0000 |
| BFL | 297.0717 |
| FFL | -297.0717 |
| FNO | 4.0000 |
| IMG DIS | 297.0717 |
| OAL | 10.0000 |
| PARAXIAL IMAGE | |
| HT | 0.0000 |
| ANG | 0.0000 |
| ENTRANCE PUPIL | |
| DIA | 75.0000 |
| THI | 0.0000 |
| EXIT PUPIL | |
| DIA | 75.7393 |
| THI | -5.8855 |



39.68 MM

19-Oct-01

R A D I A L E N E R G Y D I S T R I B U T I O N
SPOT DIAMETERS

POSI

408E22

WAVELENGTH 550.0 NM
WEIGHT 1

FOCUS --- 0.00000
FIELD (X,Y) PCT
(0.00, 0.00)MAX
(0.0, 0.0)DEG
10 0.08259
20 0.31432
30 0.57823
40 0.96703
50 1.26672
60 1.68492
70 2.24924
80 2.55673
90 3.33996
100 3.70403

Radial Energy Distribution

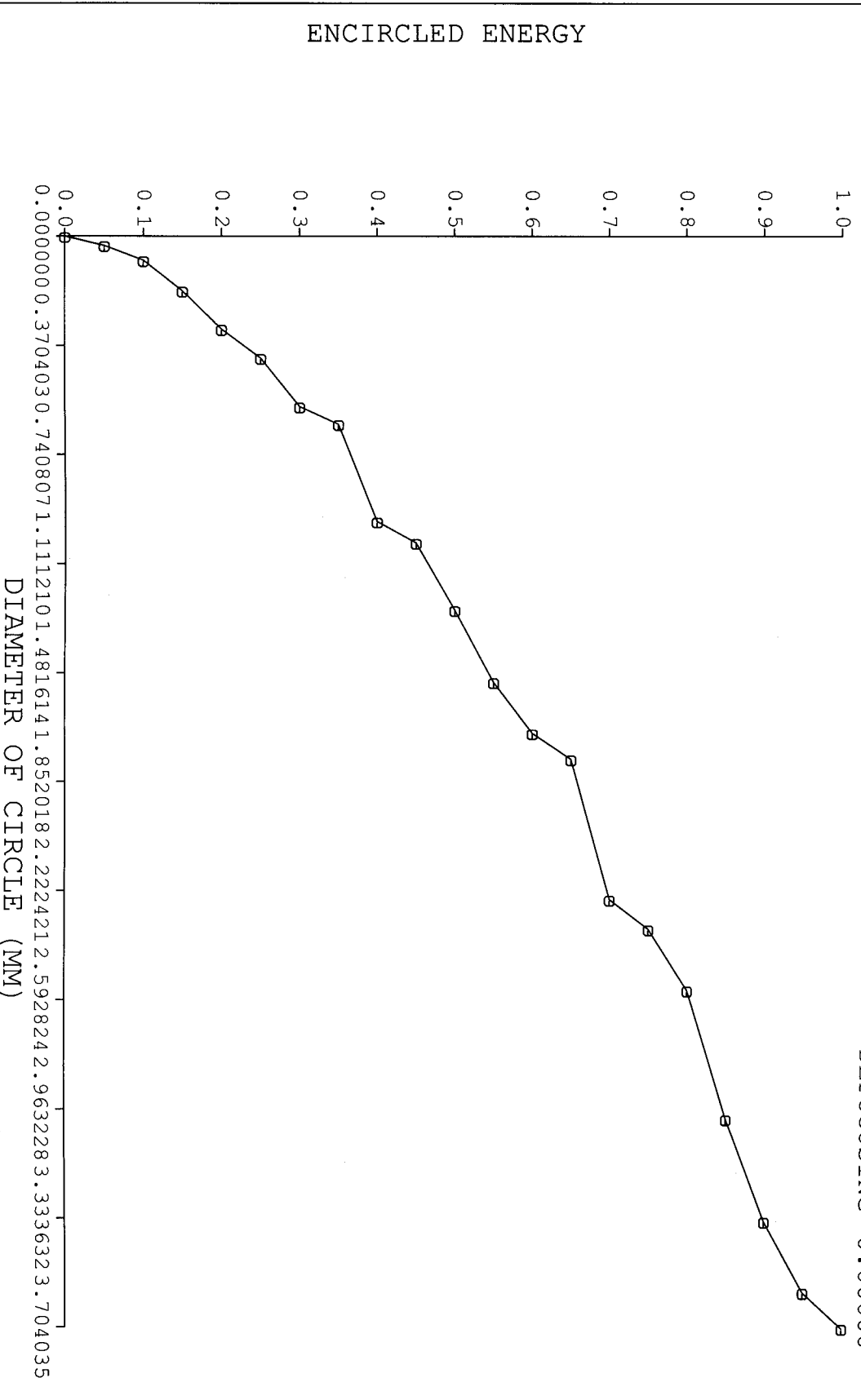
408E22

Radial Energy

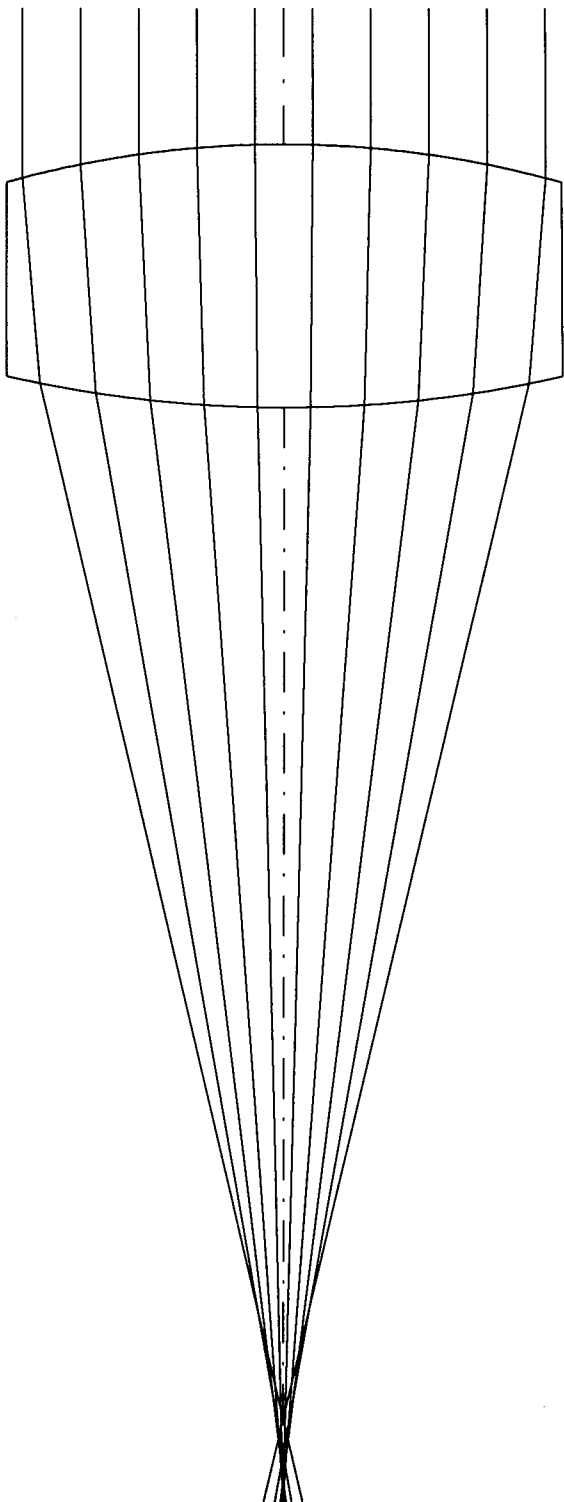
Distance (mm)

19-Oct-01

DEFOCUSING 0.00000



408E 2.1



408E 2.1

17.86 MM

Scale: 1.40

19-Oct-01

408E 2.1

(vii) A convex mirror with $|R| = 5$; $u = 3$

$$f = -2.5 \quad \frac{1}{v} = -\frac{1}{2.5} - \frac{1}{3} \quad v = \frac{-15}{11}$$

virtual image

$$\text{linear mag} = \frac{v}{u} = -\frac{5}{11}$$

$$\text{angular mag} = \frac{-11}{5}$$

