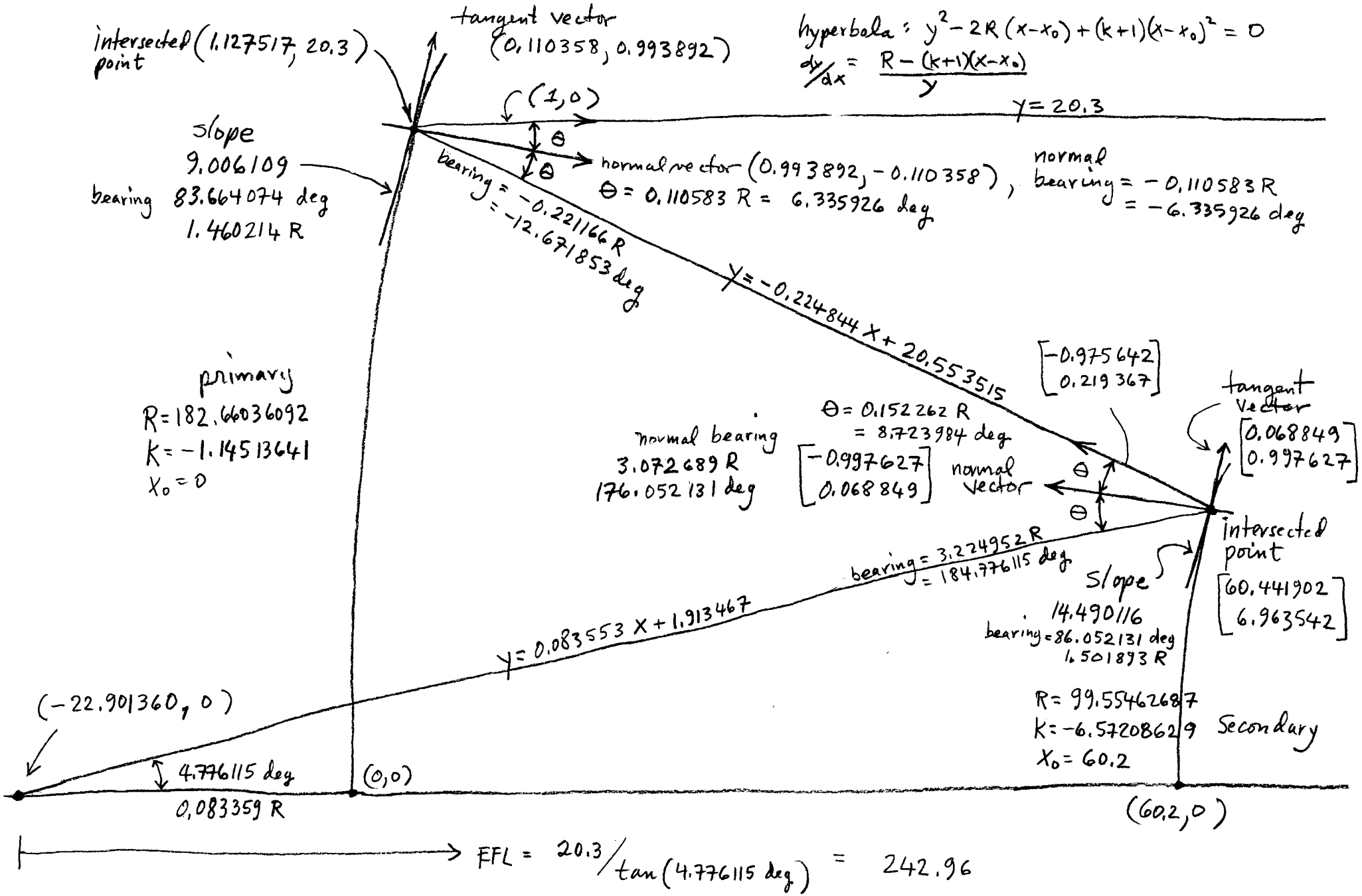

intersected point (1.127517, 20.3)
tangent vector (0.110358, 0.993892)
hyperbola: $y^2 - 2R(x-x_0) + (k+1)(x-x_0)^2 = 0$
$\frac{dy}{dx} = \frac{R-(k+1)(x-x_0)}{y}$
(1,0)
y = 20.3
slope
9.006109
bearing 83.664074 deg
1.460214 R
θ
θ
normal vector (0.993892, -0.110358)
θ = 0.110583 R = 6.335926 deg
normal bearing = -0.110583 R
= -6.335926 deg
bearing = -0.221166 R
= -12.671853 deg
y = -0.224844 x + 20.553515
primary
R = 182.66036092
K = -1.14513641
X0 = 0
[-0.975642
0.219367]
tangent vector
[0.068849
0.997627]
θ = 0.152262 R
= 8.723984 deg
normal bearing
3.072689 R
176.052131 deg
[-0.997627
0.068849]
normal vector
θ
θ
intersected point
[60.441902
6.963542]
bearing = 3.224952 R
= 184.776115 deg
slope
14.490116
bearing = 86.052131 deg
1.501893 R
y = 0.083553 x + 1.913467
R = 99.55462687
K = -6.57208629
X0 = 60.2
Secondary
(-22.901360, 0)
4.776115 deg
0.083359 R
(0,0)
(60.2, 0)
FFL = 20.3 / tan(4.776115 deg) = 242.96

```
% gen4.m  30-aug-10
% generate data for photo1-hw1 ray trace
% ritchey-chretien telescope like landsat TM
% do with analytical derivatives for best accuracy

format long g

% take approximate design parameters to generate curves
F=243.8 % cm, effective focal length
B=83.1 % cm, back focal length
D=60.2 % cm, distance between mirrors

% compute the dependent parameters
% primary R1,K1,x0=0
% secondary R2,K2,x0=60.2

R1=(2*D*F)/(F-B) % cm primary radius at center
R2=(2*D*B)/(F-B-D)
M=(F-B)/D
K1=-1 - 2/(M^3) * (B/D)
K2=-1 - 2/((M-1)^3) * (M*(2*M-1) + B/D)

% the primary mirror
c=0;
b=-2*R1;
a=K1+1;

% intersect the incoming ray (horizontal line) with the primary
y=20.3;
c=y^2;
% choose the correct one from quadratic
x=(-b - sqrt(b^2 - 4*a*c))/(2*a);
disp('intersection with primary');
x
y

% ok let's get slope analytically and check

disp('analytical slope of surface')
slope=(R1-(K1+1)*x)/y
analyt_tanvec=[1;slope]
analyt_tanvec=analyt_tanvec/sqrt(analyt_tanvec'*analyt_tanvec)

disp('perpvec');
nrm=[analyt_tanvec(2); -analyt_tanvec(1)]
nrm=nrm/sqrt(nrm'*nrm)
brg_nrm=atan2(nrm(2),nrm(1))
```

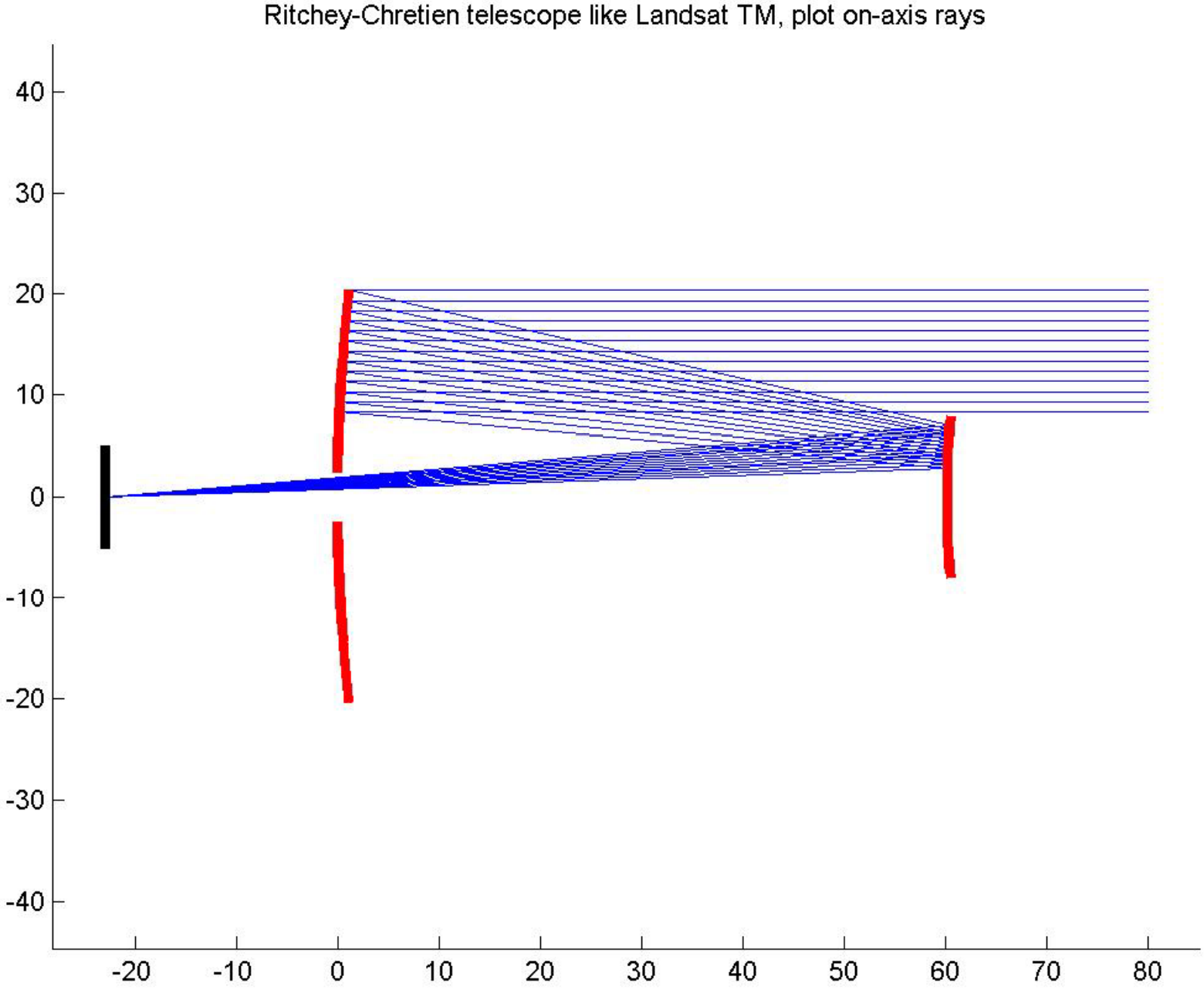
```
% incoming ray (negated)
inc=[1; 0]
% get angle of incidence (=angle of reflection)
costh=dot(nrm,inc)
th=acos(costh)
% bearing of reflected ray
brg_ray=brg_nrm - th
% slope of reflected ray
disp('parameters for the first reflected ray');
mm=tan(brg_ray)
% equation of line of reflected ray. point x,y slope m
% slope = m = tan(brg_ray)

bb=-mm*x + y

% now intersect line y=mm*x + bb with secondary mirror

% the secondary mirror
x0=60.2;
% solve for y at intersection
a=(K2+1)/mm^2 + 1;
b=-(2*(K2+1)*bb/mm^2 + (2*x0*(K2+1) + 2*R2)/mm);
c=(K2+1)*bb^2/mm^2 + (2*x0*(K2+1) + 2*R2)*bb/mm + (K2+1)*x0^2 +
2*R2*x0;
% select the correct one
y1=(-b + sqrt(b^2 - 4*a*c))/(2*a)
y2=(-b - sqrt(b^2 - 4*a*c))/(2*a)
y=y1; % this is correct one
% now solve another quadratic for the x-coordinate
a=K2+1;
b=-(2*x0*(K2+1) + 2*R2);
c=(K2+1)*x0^2 + y^2 + 2*R2*x0;
% select the correct one
x1=(-b + sqrt(b^2 - 4*a*c))/(2*a)
x2=(-b - sqrt(b^2 - 4*a*c))/(2*a)
x=x2; % this is correct one
% now we have intersection point with secondary mirror
disp('intersection with secondary');
x
y
% now do reflection again
% ok let's get slope analytically

disp('analytical slope #2')
slope=(R2-(K2+1)*(x-x0))/y
analyt_tanvec=[1;slope]
analyt_tanvec=analyt_tanvec/sqrt(analyt_tanvec'*analyt_tanvec)
```

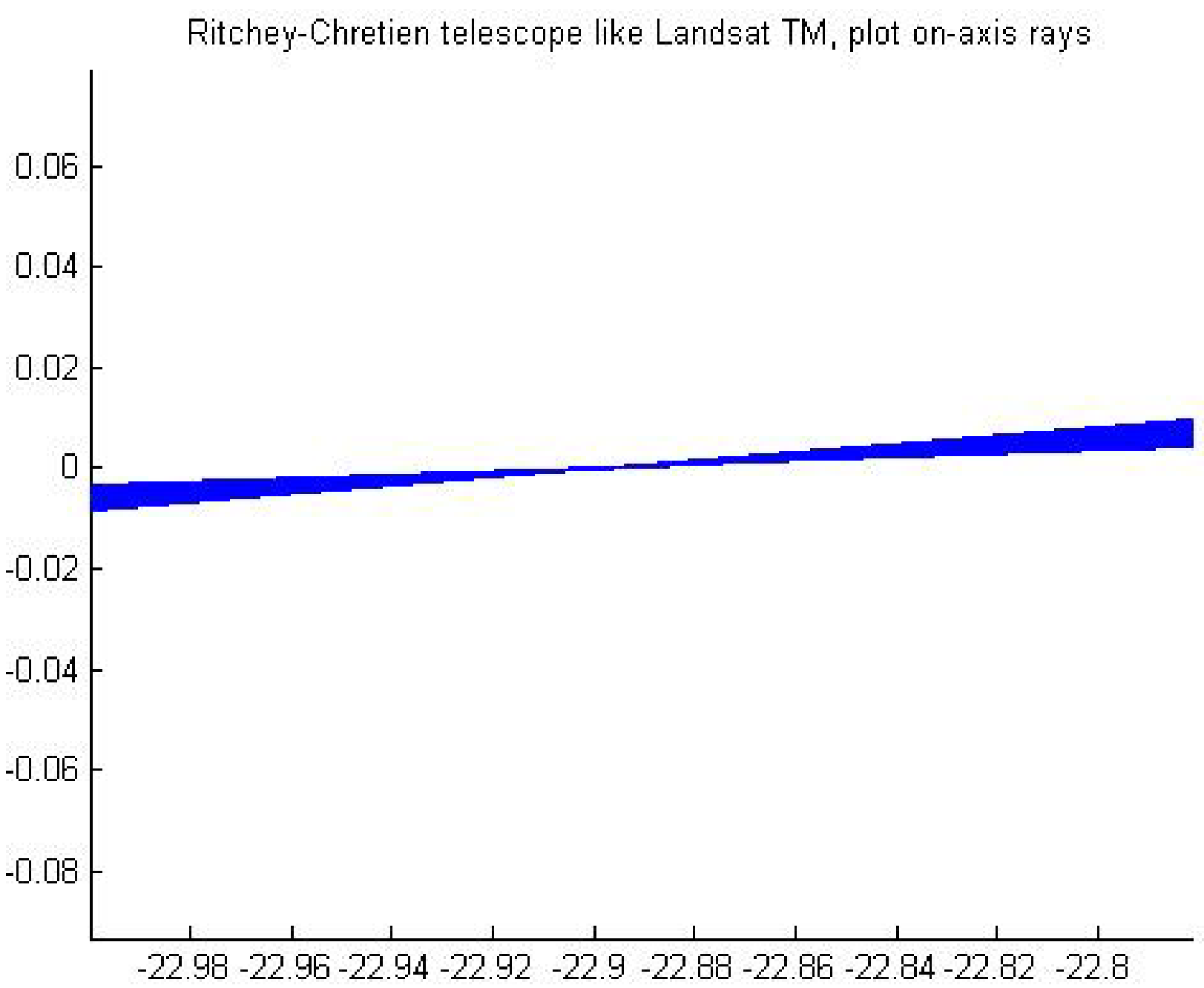
```
disp('perpvec');
nrm=[-analyt_tanvec(2); analyt_tanvec(1)]
nrm=nrm/sqrt(nrm'*nrm)
brg_nrm=atan2(nrm(2),nrm(1))

% incoming ray
inc=[1; mm]
inc=-inc
inc=inc/sqrt(inc'*inc)
% get angle of incidence with secondary
costh=dot(nrm,inc)
th=acos(costh)
% get bearing of reflected ray
brg_ray=brg_nrm + th
disp('parameters for the second reflected ray');
mm=tan(brg_ray)
% equation of line of reflected ray
% (x,y)=(x1,y1);
% slope = m = brg_ray

bb=-mm*x + y
% find zero crossing
disp('zero crossing');

xzc=-bb/mm

% angle of final ray
intsc_angle=brg_ray - pi;
efl=20.3/tan(intsc_angle)
```

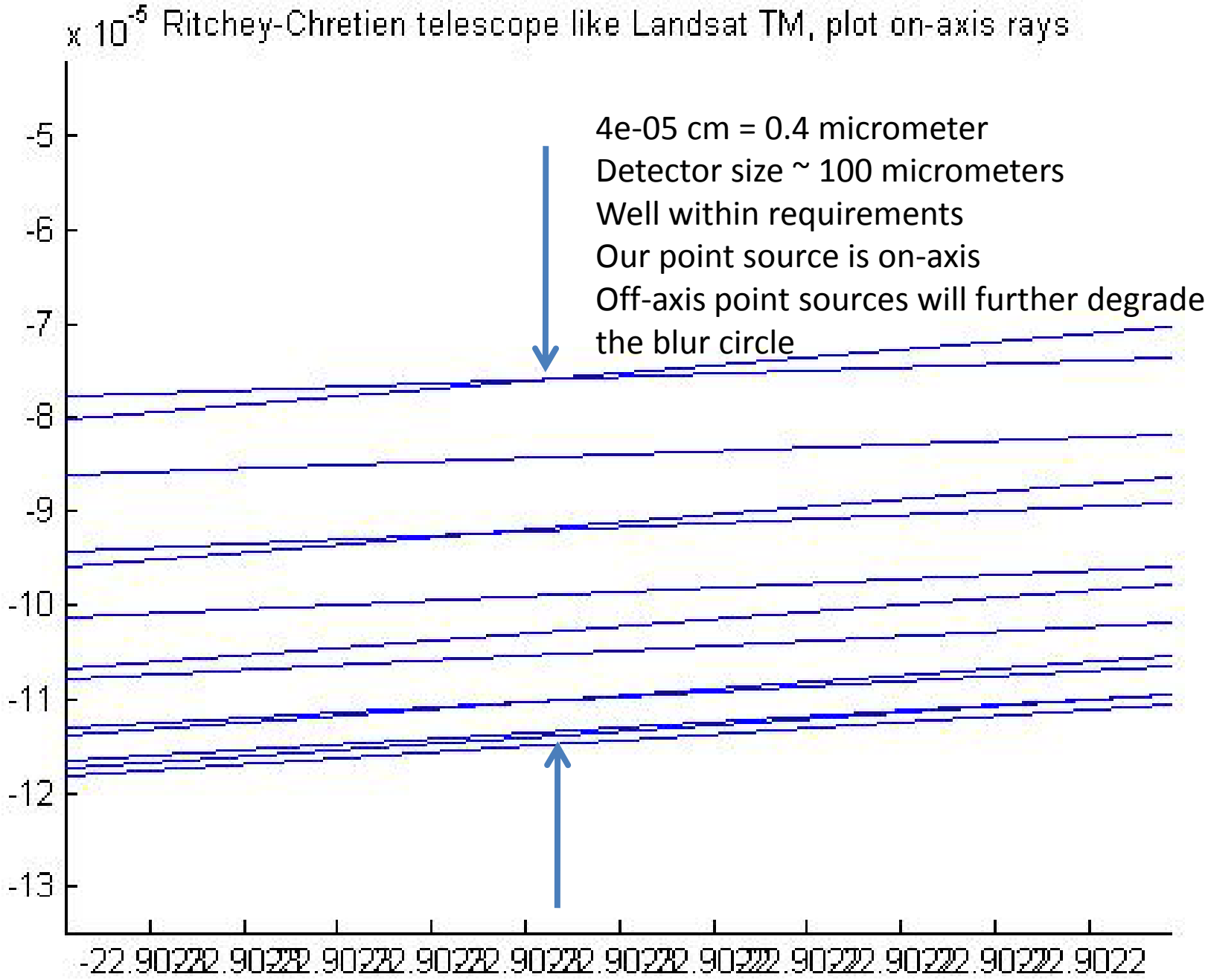
```
gen4
F =
                    243.8
B =
                     83.1
D =
                     60.2
R1 =
         182.660360920971
R2 =
         99.5546268656716
M =
         2.66943521594684
K1 =
        -1.14513640840313
K2 =
        -6.57208628671696
intersection with primary
x =
         1.12751744999788
y =
                     20.3
analytical slope of surface
slope =
         9.00610860857514
analyt_tanvec =
                        1
         9.00610860857514
analyt_tanvec =
        0.110357535782192
        0.993891953029142
perpvec
nrm =
        0.993891953029142
       -0.110357535782192
nrm =
        0.993891953029142
       -0.110357535782192
brg_nrm =
       -0.110582775859892
inc =
     1
     0
costh =
        0.993891953029142
th =
        0.110582775859891
brg_ray =
```

```
        -0.221165551719783
parameters for the first reflected ray
mm =
        -0.224843577023024
bb =
          20.5535150566134
y1 =
          6.96354169046061
y2 =
          15.3088071357969
x1 =
          24.2247583739217
x2 =
          60.4419016370708
intersection with secondary
x =
          60.4419016370708
y =
          6.96354169046061
analytical slope #2
slope =
          14.4901155397052
analyt_tanvec =
                         1
          14.4901155397052
analyt_tanvec =
        0.0688488026984029
         0.997627105870223
perpvec
nrm =
        -0.997627105870223
        0.0688488026984029
nrm =
        -0.997627105870223
        0.0688488026984029
brg_nrm =
          3.07268934217726
inc =
                         1
        -0.224843577023024
inc =
                        -1
         0.224843577023024
inc =
        -0.975642428592164
         0.219366933540093
costh =
         0.988430483126452
```

```
th =
         0.152262240307252
brg_ray =
          3.22495158248451
parameters for the second reflected ray
mm =
        0.0835525461046723
bb =
          1.91346691727519
zero crossing
xzc =
          -22.901359760815
efl =
          242.960878470043
diary off
```


Ritchey-Chretien telescope like Landsat TM, plot on-axis rays
40
30
20
10
0
-10
-20
-30
-40
-20
-10
0
10
20
30
40
50
60
70
80


Ritchey-Chretien telescope like Landsat TM, plot on-axis rays
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-22.98 -22.96 -22.94 -22.92 -22.9 -22.88 -22.86 -22.84 -22.82 -22.8


x 10^-5 Ritchey-Chretien telescope like Landsat TM, plot on-axis rays
-5
-6
-7
-8
-9
-10
-11
-12
-13
4e-05 cm = 0.4 micrometer
Detector size ~ 100 micrometers
Well within requirements
Our point source is on-axis
Off-axis point sources will further degrade
the blur circle