Beryllium compound refractive lenses with Continuously Variable Focal Length

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Outline:

- motivations
- Beryllium compound refractive lenses
- Experiment at sector 7
- Future improvement

Motivations:

Time resolved experiments:

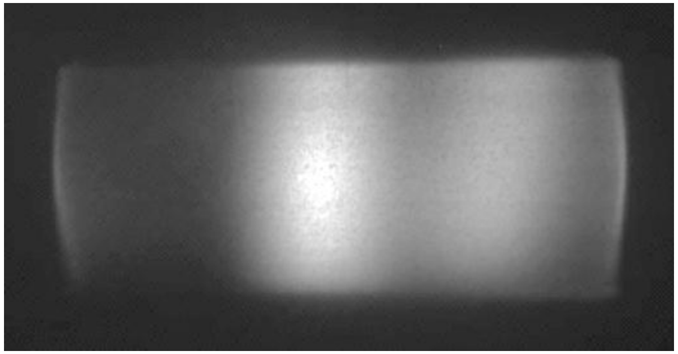
synchronized to a 1 or 5 kHz femtosecond laser:

Only the x-rays coincident with the laser matters

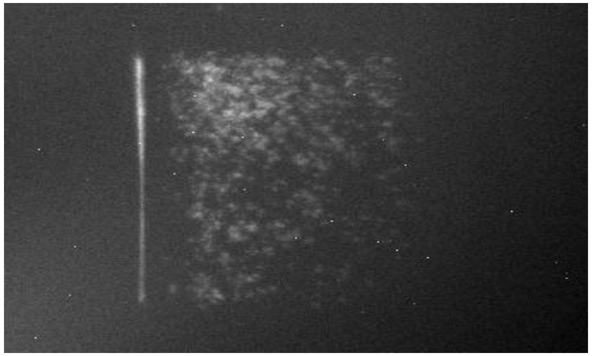
the count rates are reduced by a factor 1000-5000 since the APS repetition rate is 6.5 MHz..

Streak camera detector:

CsI photocathode. Low quantum efficiency.
10 microns slit.



100ms exposure. Direct X-ray beam in 324 bunch mode

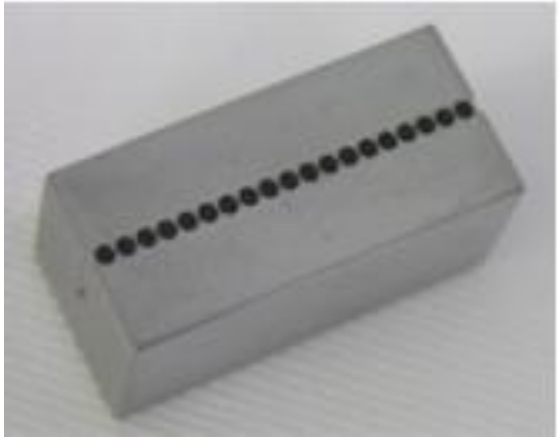


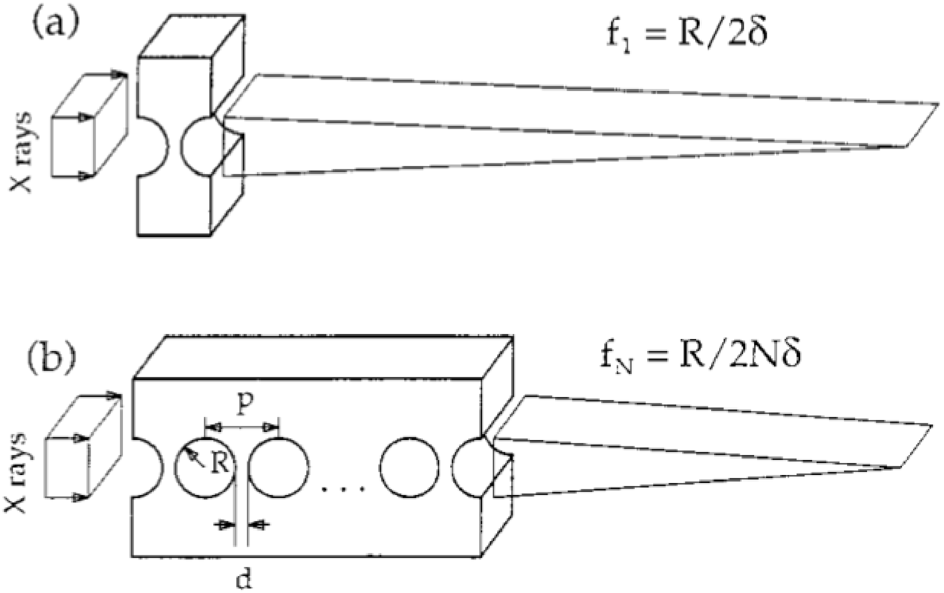
30 minutes exposure. Double diffraction setup.

Beryllium compound refractive lenses:

Refractive index for X-rays is close to 1 for all materials. The focusing achieved by using a conventional lens is extremely small. Together with strong absorption in the lens material, this has made conventional lenses for X-ray focusing inappropriate.

A compound refractive lens (CRL) consist of a linear array of many individual lenses manufactured in low-Z materials





A. Khounsary-SPIE-2006

V.A. Chernov et al. / Nuclear Instruments and Methods in Physics Research A 543 (2005) 326–332

Focusing properties of a Compound refractive lens

Determine by the complex refractive index *n* of the lens material

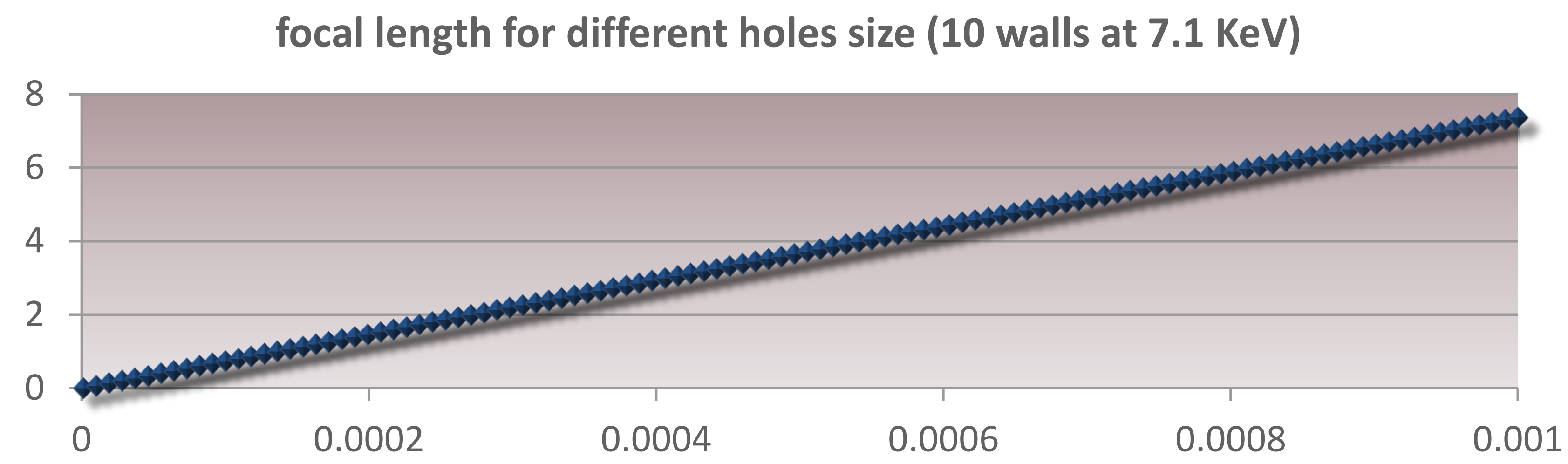
$$n = 1 - \delta + i\beta$$

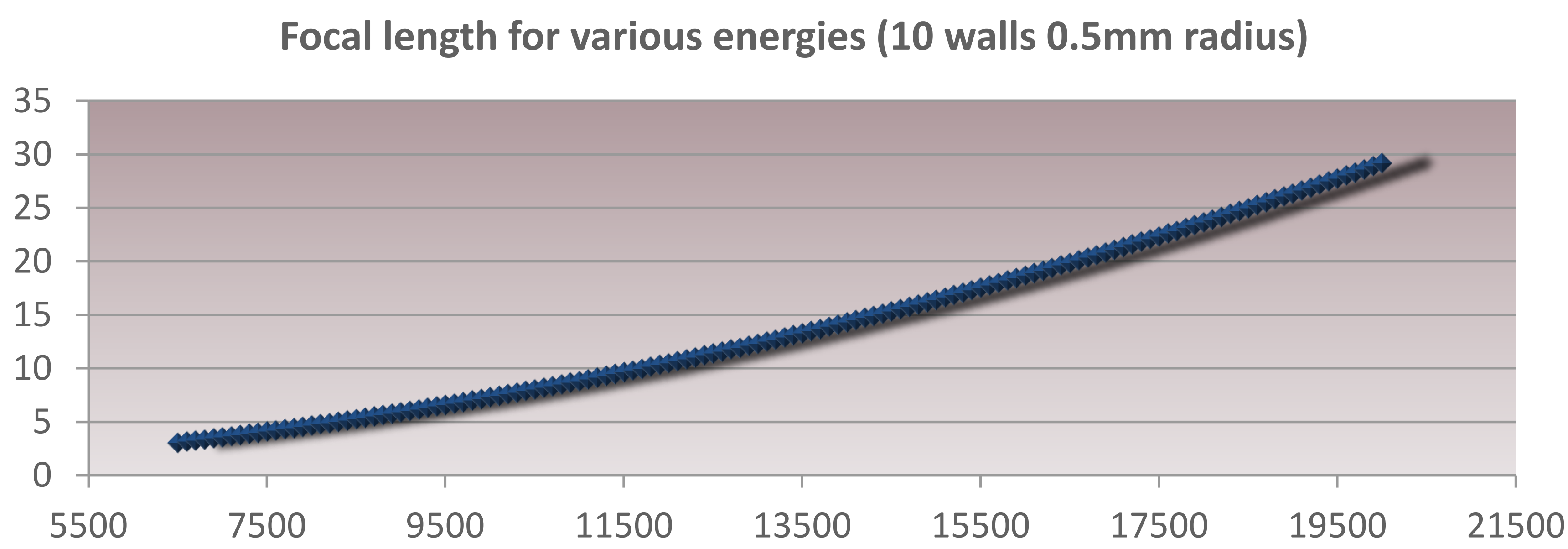
Refractive index decrement

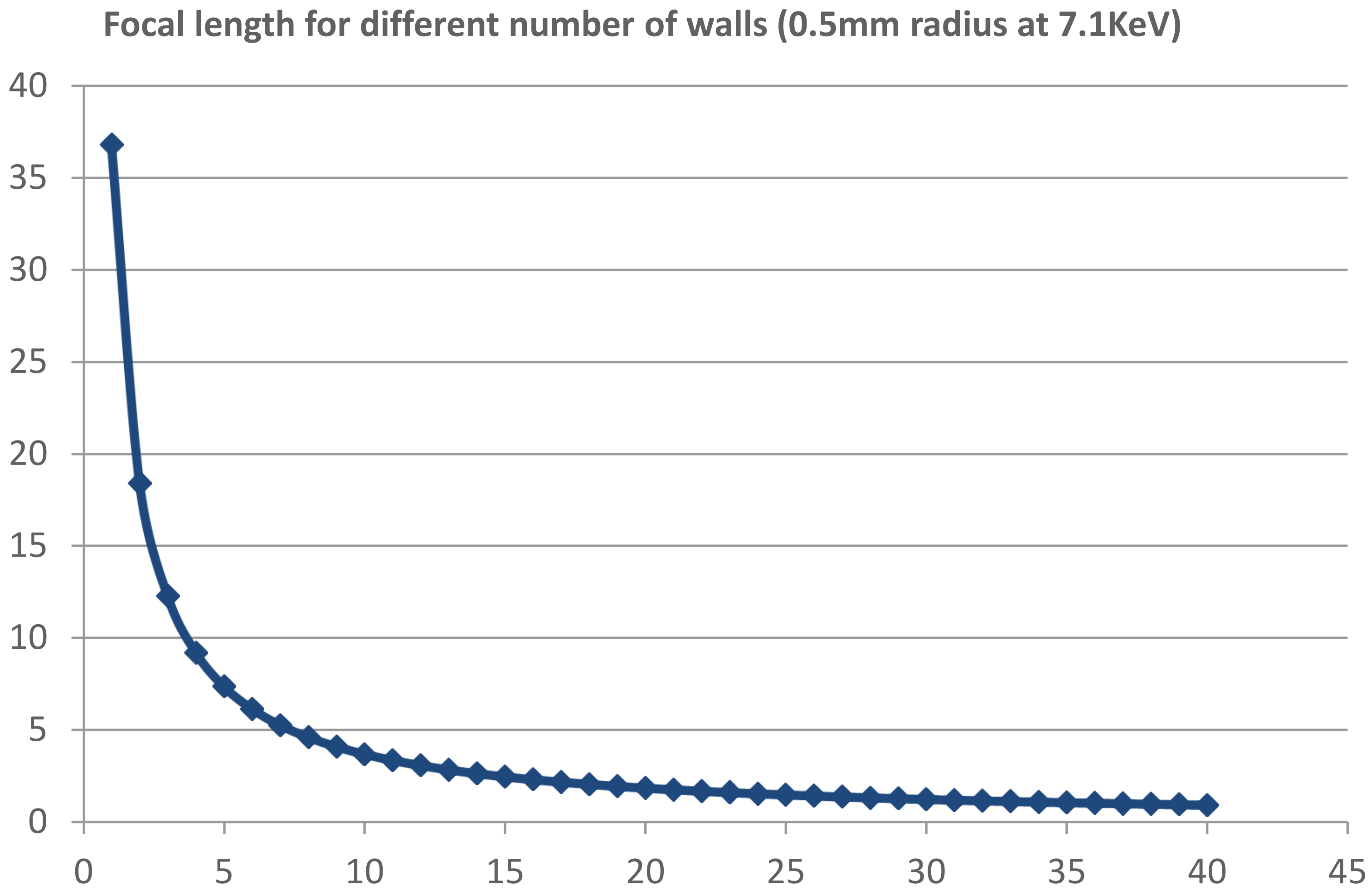
$$\delta \cong Z(r_0 \lambda^2 N_a / 2\pi A)\rho$$

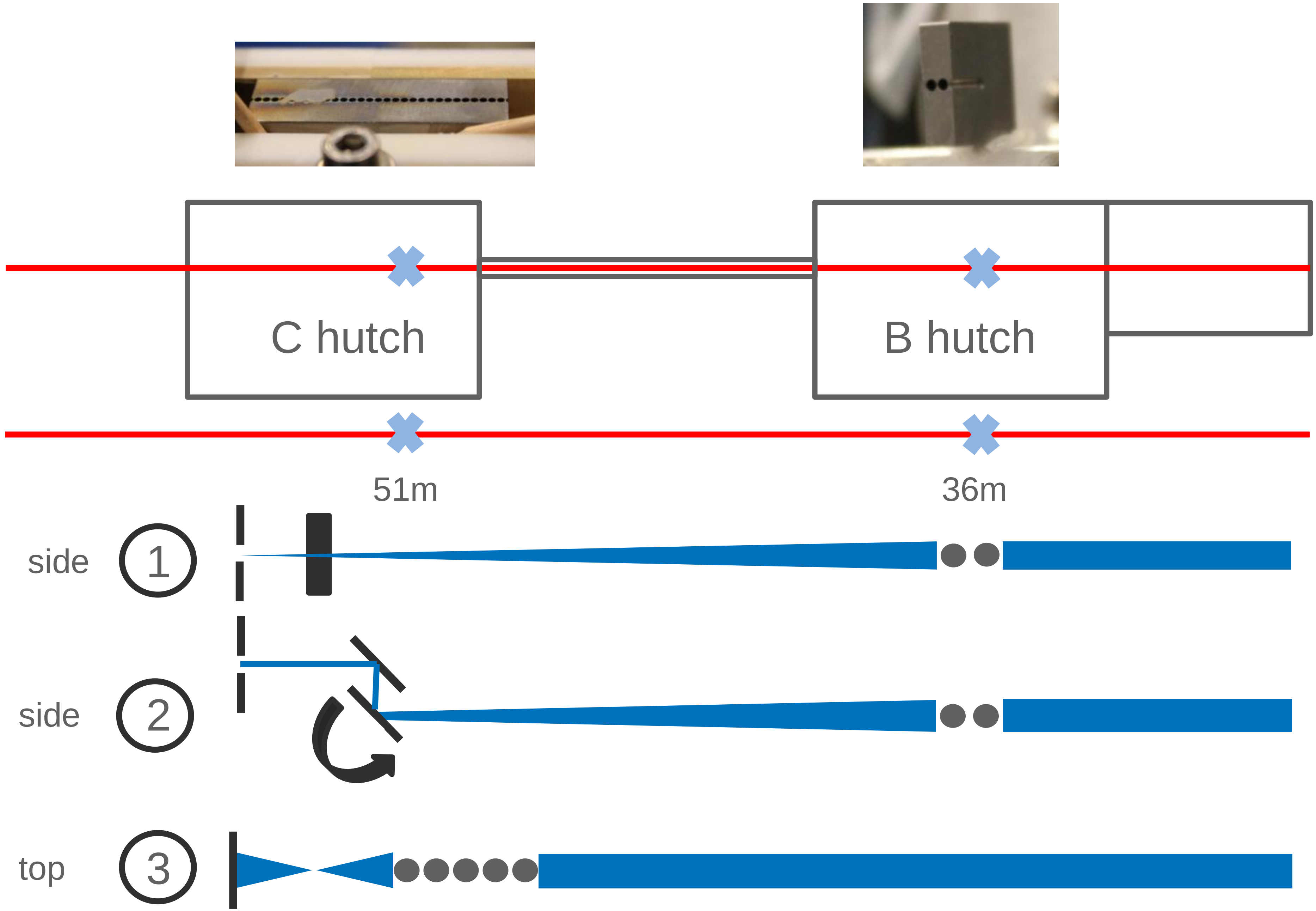
Focal Length

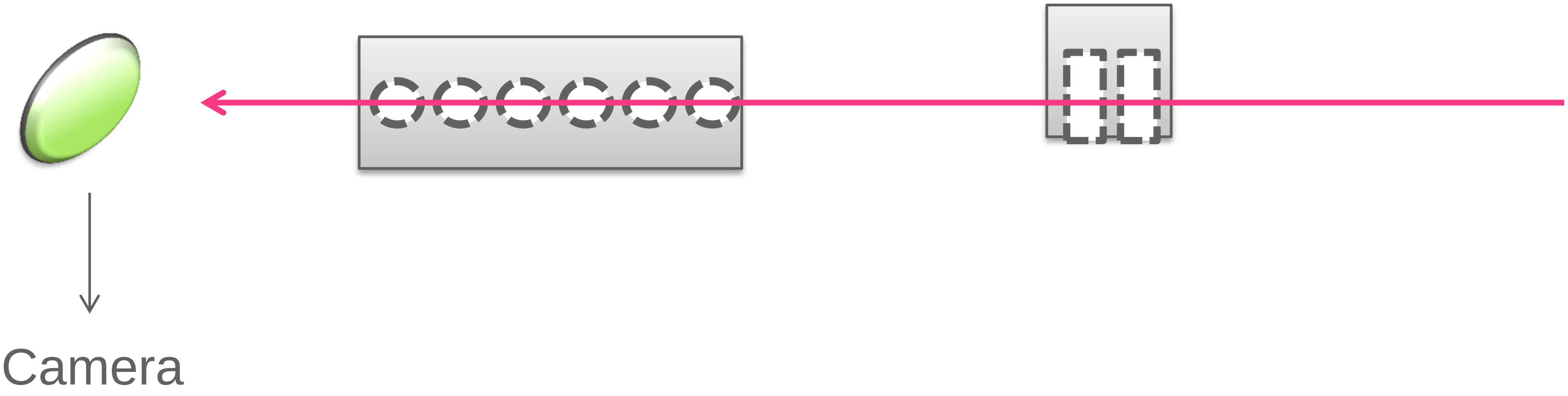
$$F = \frac{R}{2N\delta}$$

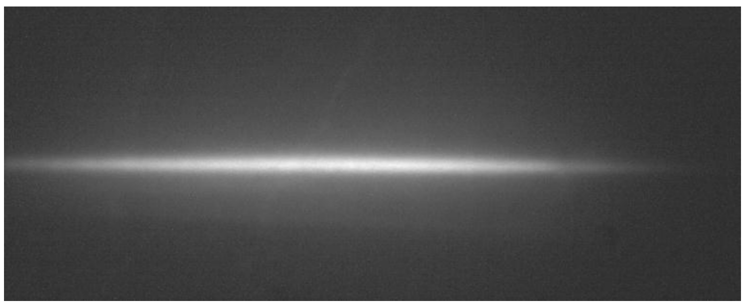

focal length for different holes size (10 walls at 7.1 KeV)
8
6
4
2
0
0
0.0002
0.0004
0.0006
0.0008
0.001

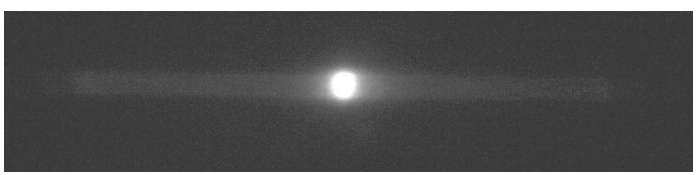

Focal length for various energies (10 walls 0.5mm radius)
35
30
25
20
15
10
5
0
5500
7500
9500
11500
13500
15500
17500
19500
21500

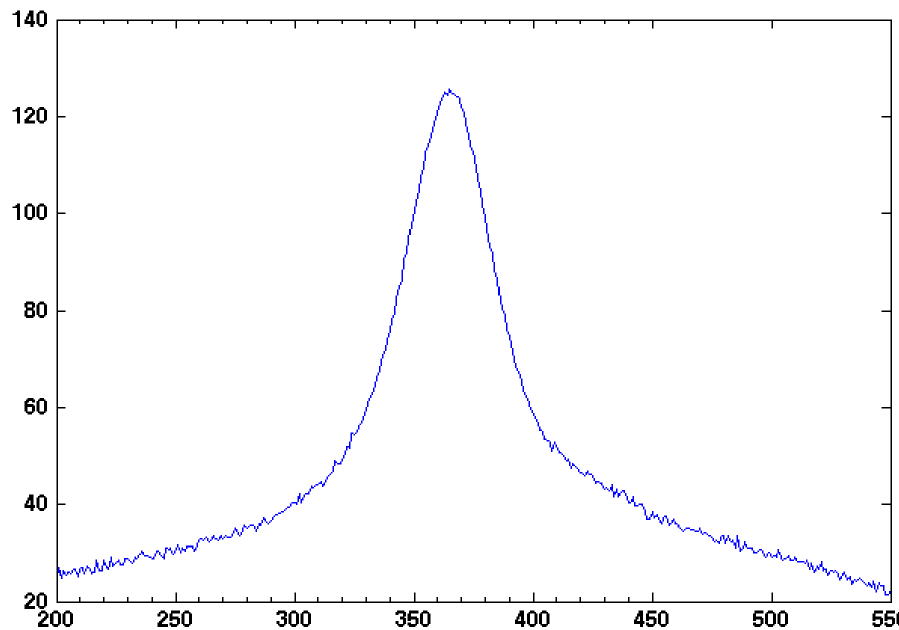

Focal length for different number of walls (0.5mm radius at 7.1KeV)
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
45

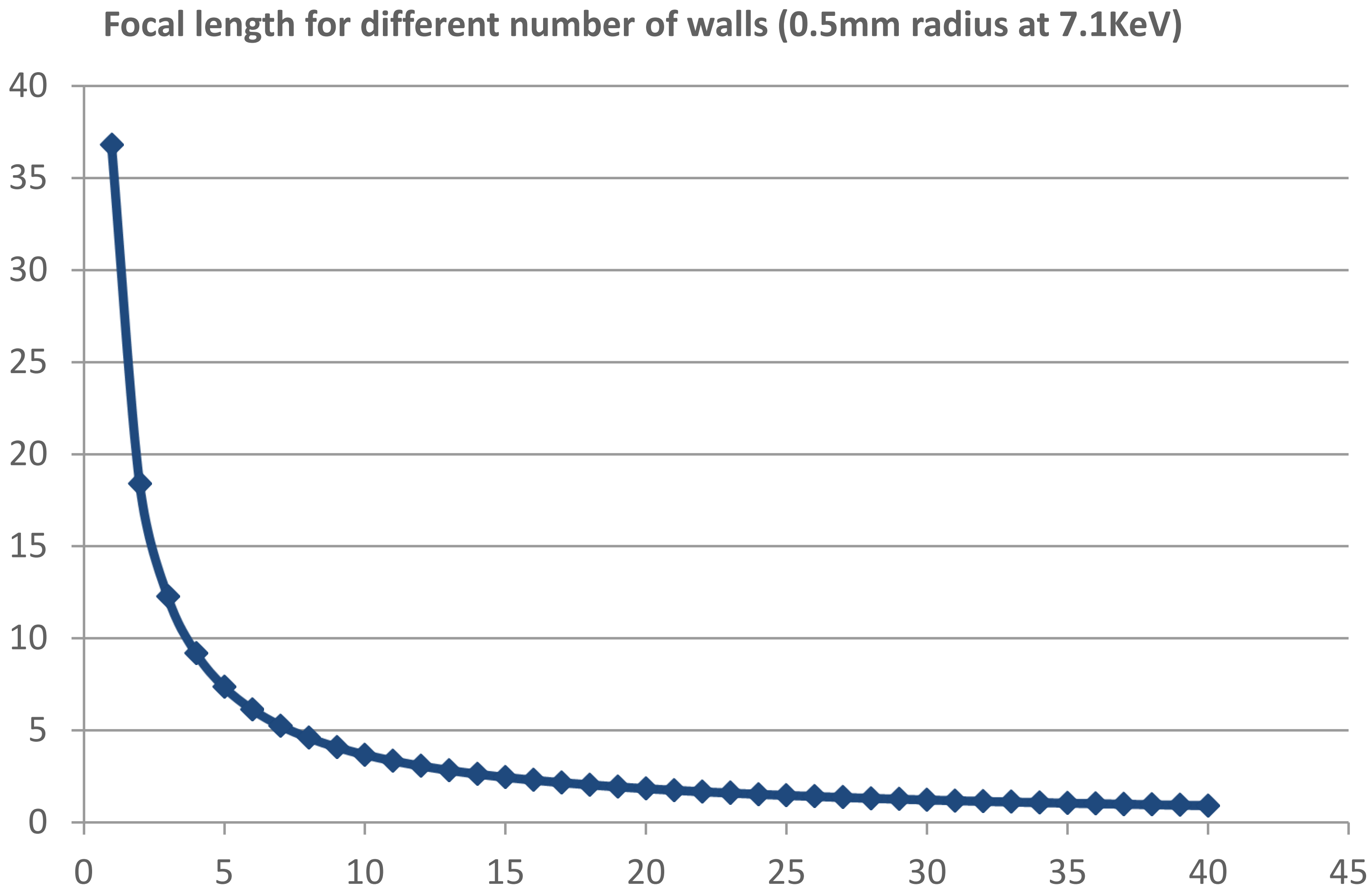

C hutch
B hutch
51m
36m
side
1
side
2
top
3


Camera

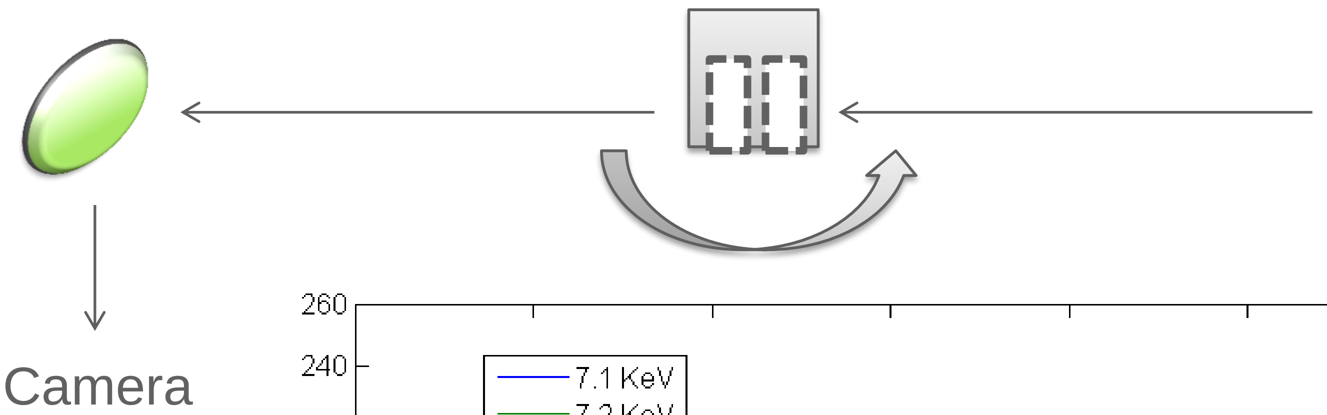


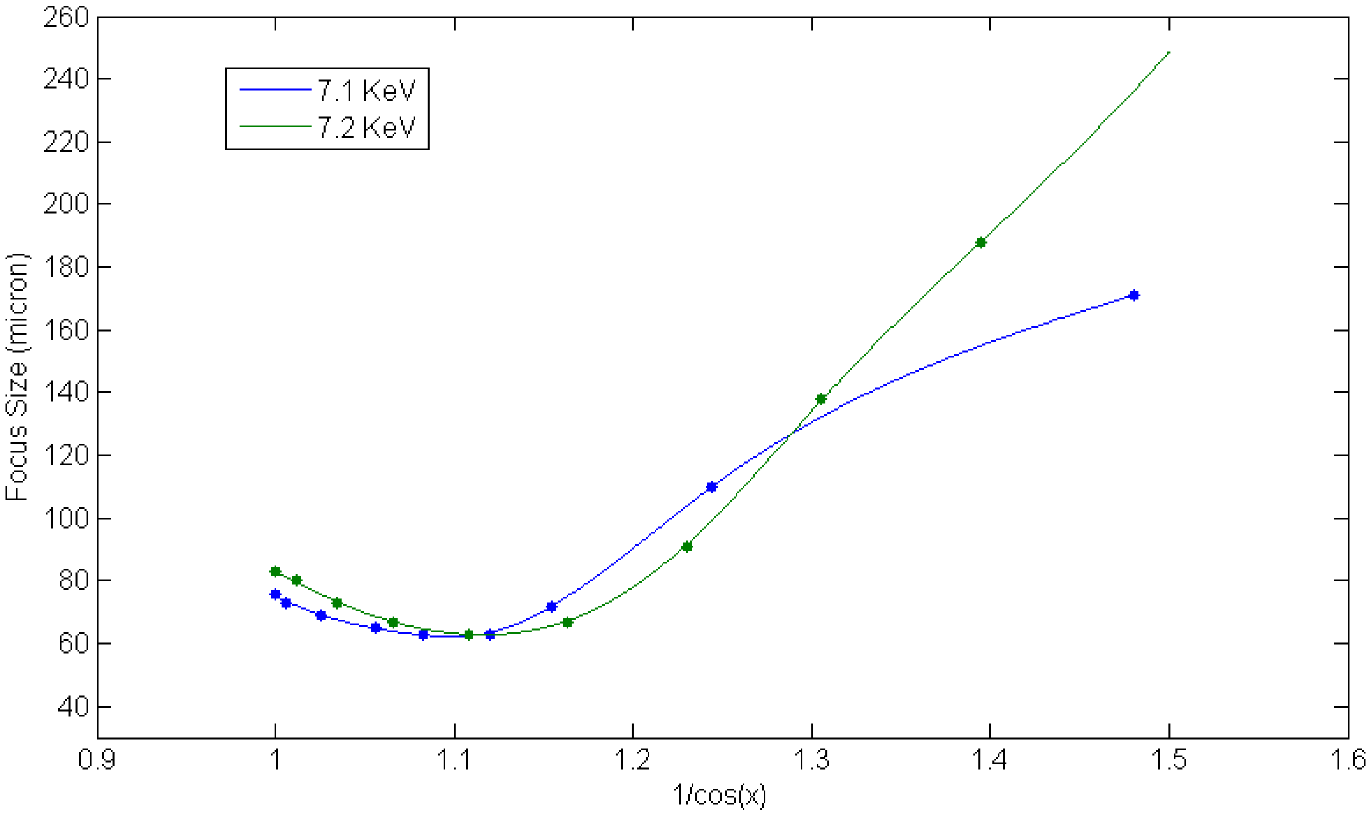


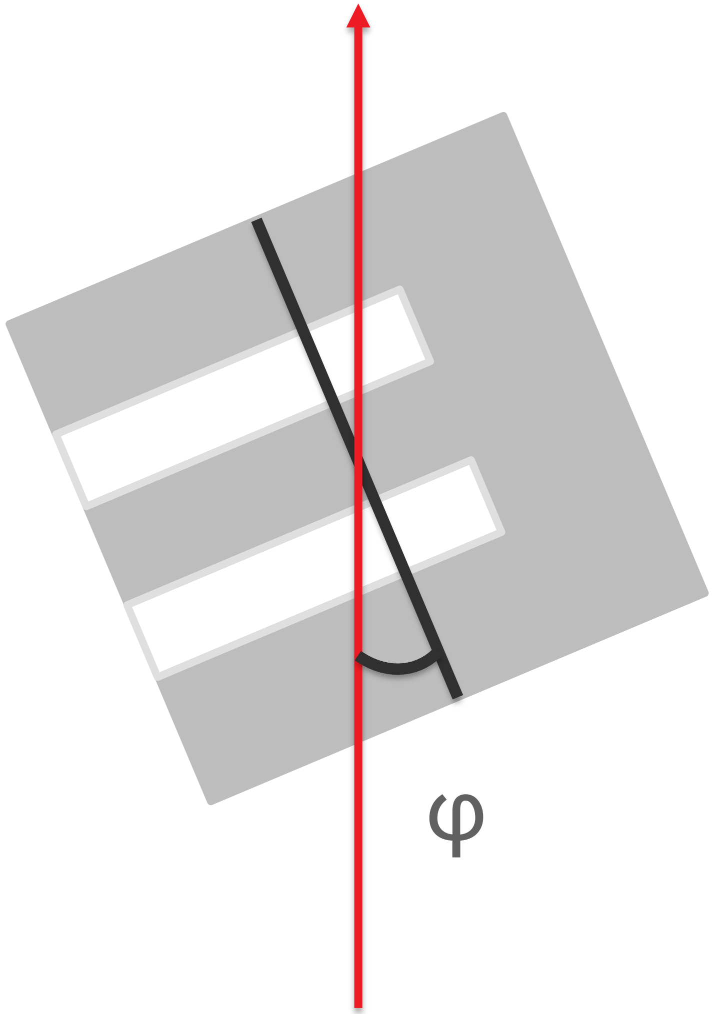

140
120
100
80
60
40
20
200
250
300
350
400
450
500
550


Focal length for different number of walls (0.5mm radius at 7.1KeV)
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
45

Changing the focal length:







Thicker Beryllium layer between the holes

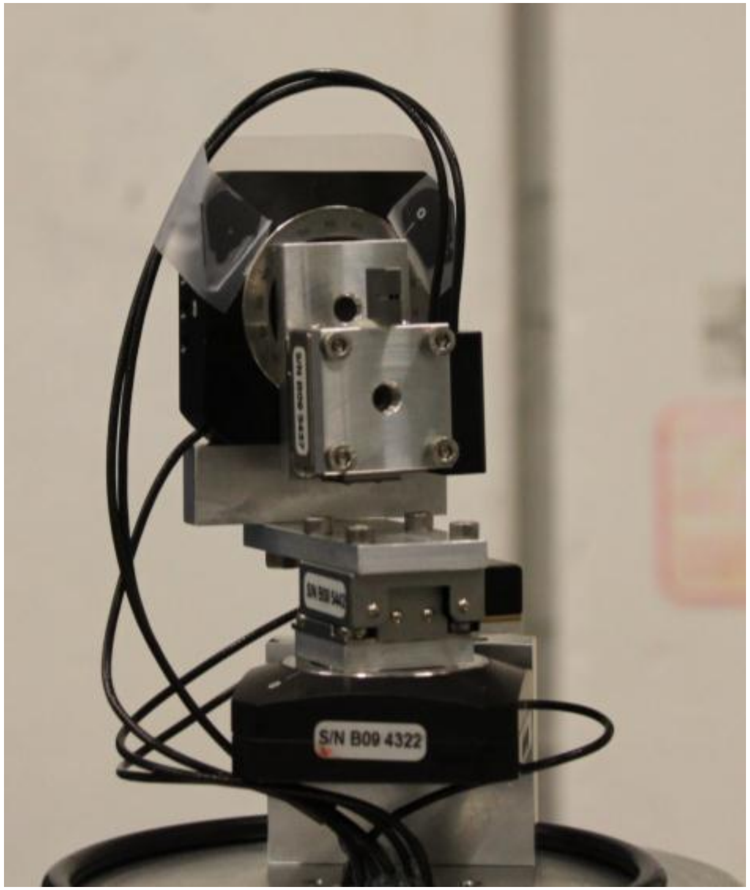
Scaling factor of 1/cos(φ)

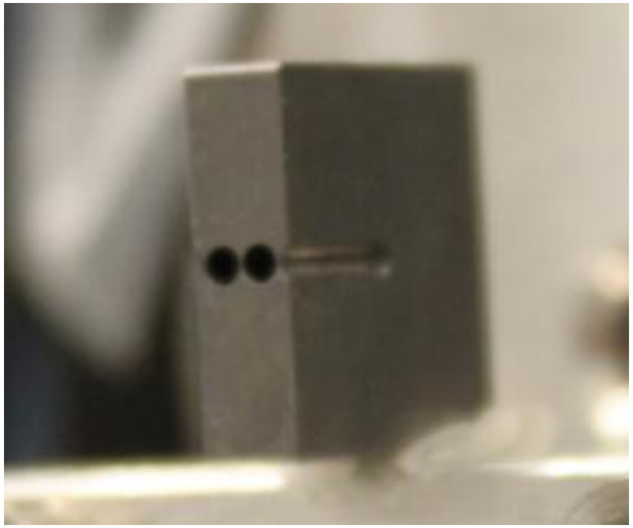
Angle proportional to Nδ

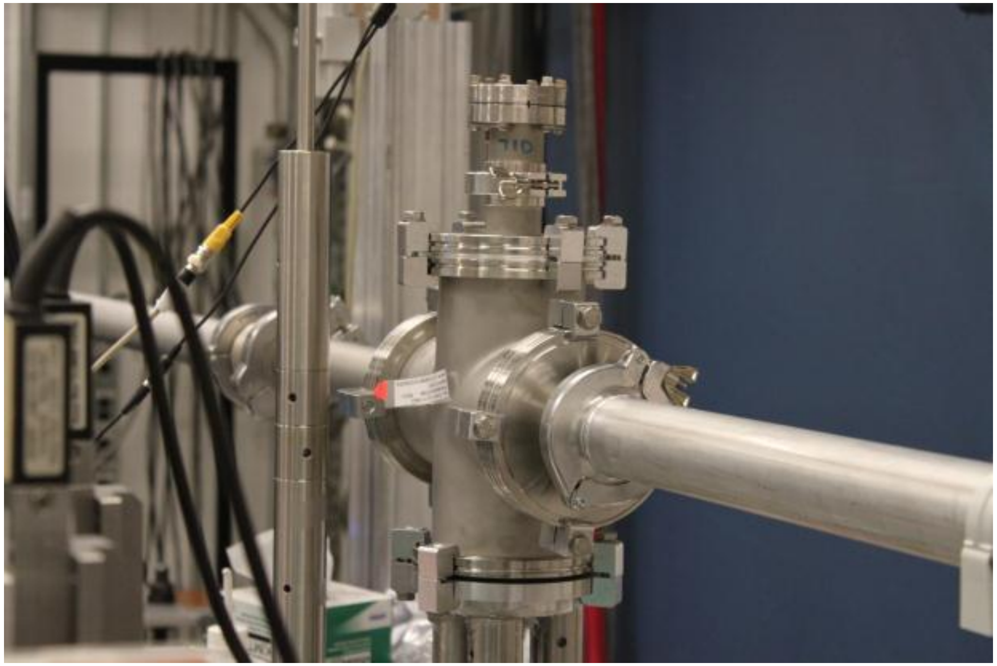
Tune the focus position precisely.

Keep the focal length constant during Energy scan

B-hutch CRL setup







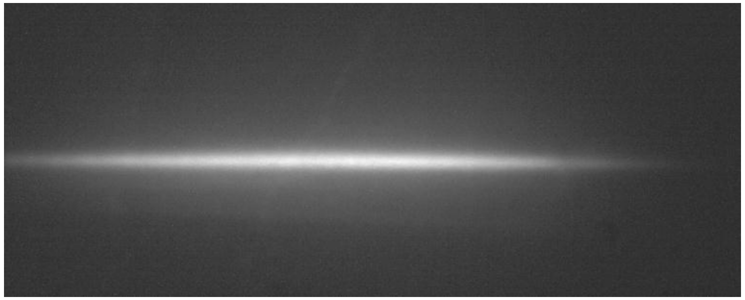
Lens performance:

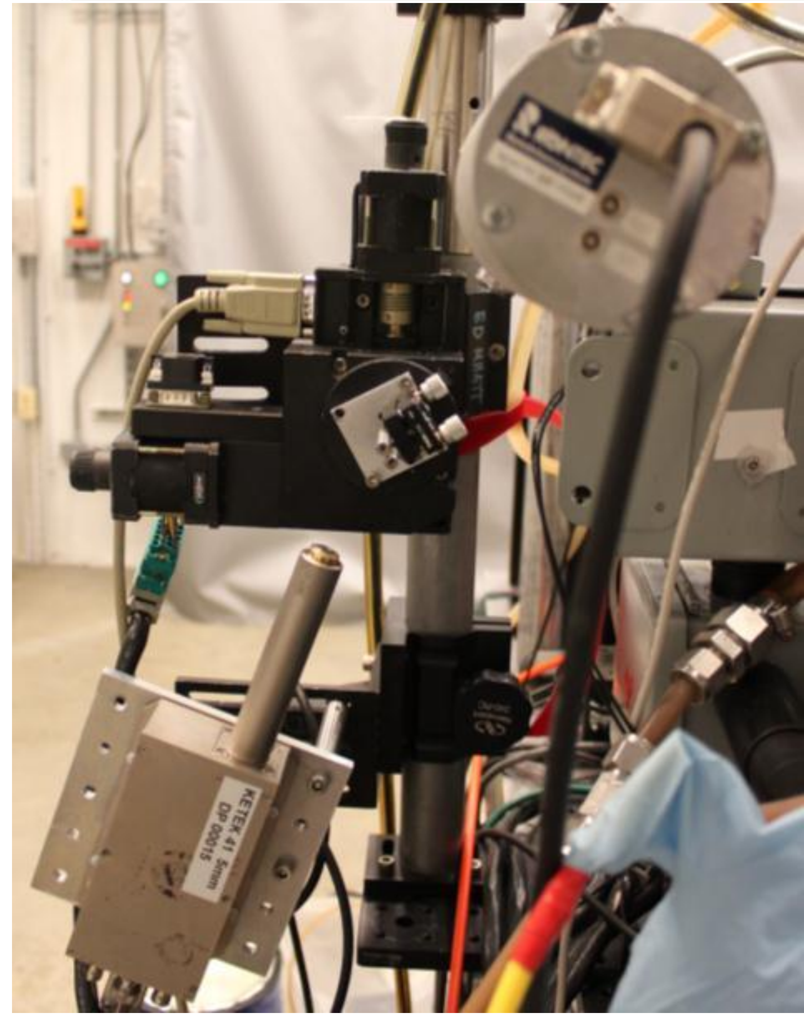
- Fabrication precision (surface profile and smoothness)
- Subsurface damage
- Material impurity
- Grain structure of the base material

Single crystal Beryllium lens:

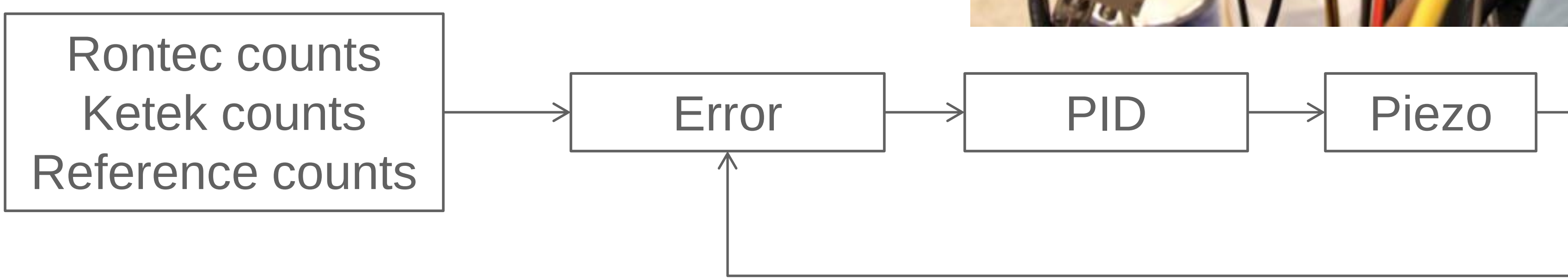
- Reduce small angle scattering
- Higher transmission
- Etching and polishing to reduce aberrations

Custom Beam Position Monitor





Rontec and Ketek detectors to look at the fluorescence signal from 2 rods slit.



Conclusion:

- Compound Refractive Lenses (CRL) provide a simple and inexpensive way for focusing / collimating X-rays.
- Enable Energy scans with a lens with a fixed number of holes
- development and verification of precision single crystal beryllium lenses to get closer to “ideal” lenses.