Today's outline - February 11, 2020

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Homework Assignment #02:
Problems on Blackboard
due Tuesday, February 18, 2020

Today's outline - February 11, 2020

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- Fresnel lenses and zone plates
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Homework Assignment #02:
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due Tuesday, February 18, 2020

APS Visit:
10-BM: Friday, April 24, 2020

Beamtime at MRCAT

One day has been set aside for our class to be at Sector 10 MRCAT at the Advanced Photon Source

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Friday, April 24, 2020 – bending magnet line

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We will do flux measurements, reflectivity, x-ray absorption spectroscopy measurements, use ion chambers and the multielement detector, and more

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I will try to record the session for those of you not in Chicago

Writing a General User Proposal

1. Log into the APS site
2. Start a general user proposal
3. Add an Abstract
4. Choose a beam line
5. Answer the 6 important questions

A tutorial can be found on the course home page

http://csrri.iit.edu/∼segre/phys570/20S/gu_proposal.html

Register & log into the APS Portal

Argonne NATIONAL LABORATORY

User Registration for Advanced Photon Source (APS) and Center for Nanoscale Materials (CNM)

Welcome Users and Visitors

New Users

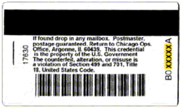
- Never been assigned an Argonne ID badge number
- Never been to Argonne before
- Plan to conduct hands-on work
- Need remote computer access to an Argonne User Facility

New User

Returning Users

- Update existing biographical/contact information
- Renew my approval for site access

Note: You must have a user badge # to access this site. Badge number appears on the back of your badge, see below.



My APS Portal

CNM Returning User

Visiting Argonne

- Not conducting hands-on work/research
- Short-term visit to Argonne (e.g. a meeting speaker, family member, traveling companion, conference/workshop attendee, tour group member)
- Only utilizing the ANL/APS guest computer network
- Not a current facility user

Visitor Pass

Need assistance? E-Mail: apsuser@aps.anl.gov.

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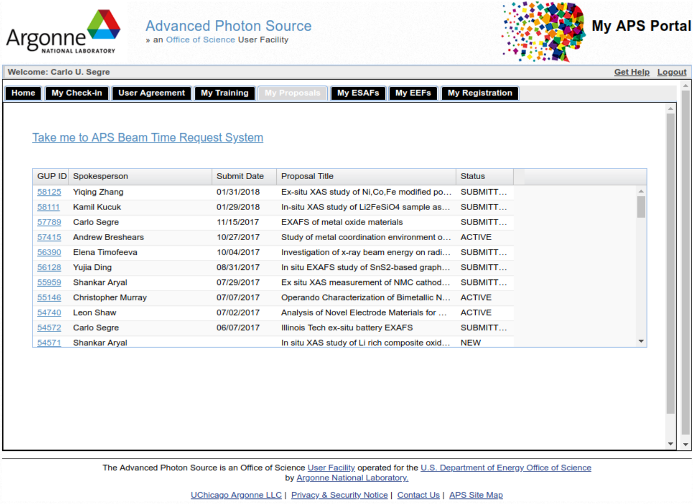
U.S. DEPARTMENT OF ENERGY

APS Portal details


Argonne NATIONAL LABORATORY

Advanced Photon Source
» an Office of Science User Facility

My APS Portal

Welcome: Carlo U. Segre — Get Help Logout

Home | My Check-in | User Agreement | My Training | My Proposals | My ESAFs | My EEFs | My Registration

Take me to APS Beam Time Request System

GUP ID	Spokesperson	Submit Date	Proposal Title	Status
58125	Yiqing Zhang	01/31/2018	Ex-situ XAS study of Ni,Co,Fe modified po…	SUBMITT…
58111	Kamil Kucuk	01/29/2018	In-situ XAS study of Li2FeSiO4 sample as…	SUBMITT…
57789	Carlo Segre	11/15/2017	EXAFS of metal oxide materials	SUBMITT…
57415	Andrew Breshears	10/27/2017	Study of metal coordination environment o…	ACTIVE
56390	Elena Timofeeva	10/04/2017	Investigation of x-ray beam energy on radi…	SUBMITT…
56128	Yujia Ding	08/31/2017	In situ EXAFS study of SnS2-based graph…	SUBMITT…
55959	Shankar Aryal	07/29/2017	Ex situ XAS measurement of NMC cathod…	SUBMITT…
55146	Christopher Murray	07/07/2017	Operando Characterization of Bimetallic N…	ACTIVE
54740	Leon Shaw	07/02/2017	Analysis of Novel Electrode Materials for …	ACTIVE
54572	Carlo Segre	06/07/2017	Illinois Tech ex-situ battery EXAFS	SUBMITT…
54571	Shankar Aryal		In situ XAS study of Li rich composite oxid…	NEW

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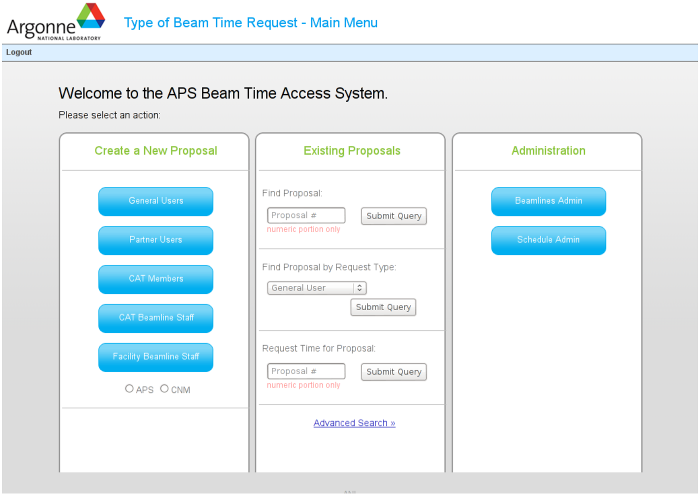
Start a General User Proposal



Add title & answer details

Argonne NATIONAL LABORATORY

APS - General User Proposal

Main Menu Search Criteria Instructions Logout

General

GUP--1
General User Program: gu_program@aps.anl.gov, 630-252-9090
Technical assistance: mis_mgrs@aps.anl.gov

*Proposal Title:

Shifts Recommended by PRP:	not available	Shifts Allocated by BAC or Scheduled by Beamline in current cycle	(0)	Shifts Used to date:	(0)	Shifts Remaining:	not available

	Yes	No
Do you want this proposal to be considered for project status? description	○	◉
Does this proposal require mail-in service?	○	◉
*Does this research involve macromolecular crystallography (single crystals) ?	○	○
*Will the data collected be considered proprietary ?	○	○
*Will the data collected be considered classified ?	○	○
Does this research involve human subjects or materials ?	○	○
Does this research involve live animals?	○	○
*Are there known safety hazards associated with the proposed experimental procedures or your samples ?	○	○
*Does this research involve the use of radioactive samples/materials ?	○	○
*Does this research involve samples/materials that require a BSL-2 or BSL-3 facility?	○	○
Is this research required for a student's thesis ?	○	○
Have you spoken to a beamline staff member?	○	○
Does this proposal involve the use of a sample from the ATR library?	○	○
*Is this proposal related to another general user proposal ? If so, which one(s) and how ?	○	○

More details

(500 characters or less)

*Subject of Research:

- ☐ Materials science
- ☐ Physics
- ☐ Chemistry
- ☐ Polymers
- ☐ Medical applications
- ☐ Biological and life sciences
- ☐ Earth sciences
- ☐ Environmental sciences
- ☐ Optics (excluding x-ray optics)
- ☐ Engineering
- ☐ Instrumentation related to user facilities
- ☐ Purchase of specialty service or materials
- ☐ Other (specify)

Specify Other :

Next

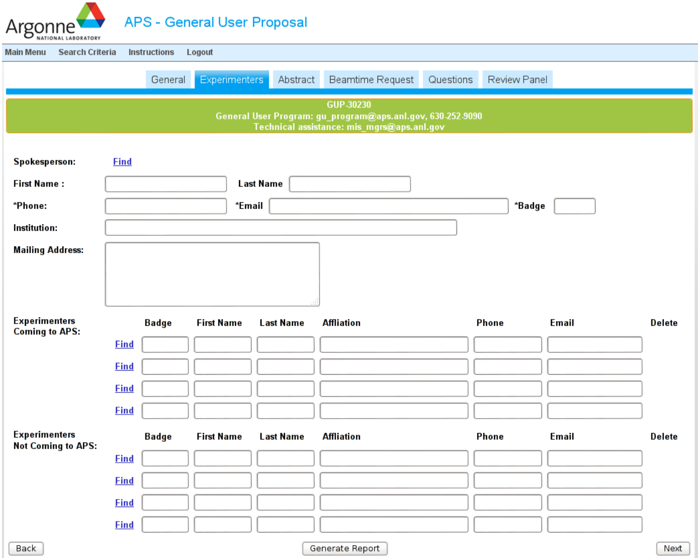
Pressing SAVE will allow you to save this proposal and continue to make changes. Notifications will not be sent. Save

Pressing SUBMIT will save this proposal AND notifications will be sent to the APS. No changes can be made thereafter. Submit

GUP--1

ANL

Select experimenters



Argonne NATIONAL LABORATORY — APS - General User Proposal

Main Menu | Search Criteria | Instructions | Logout

General | Experimenters | Abstract | Beamtime Request | Questions | Review Panel

GUP-30230
General User Program: gu_program@aps.anl.gov, 630-252-9090
Technical assistance: mis_mgrs@aps.anl.gov

Spokesperson: Find
First Name : Last Name
*Phone: *Email *Badge
Institution:
Mailing Address:

Experimenters Coming to APS:

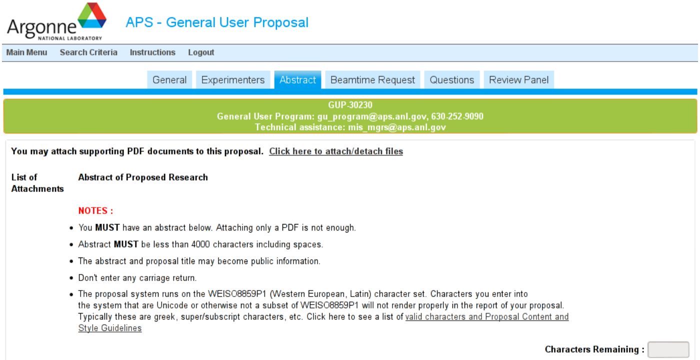
	Badge	First Name	Last Name	Affliation	Phone	Email	Delete
Find							
Find							
Find							
Find							

Experimenters Not Coming to APS:

	Badge	First Name	Last Name	Affliation	Phone	Email	Delete
Find							
Find							
Find							
Find							

Back | Generate Report | Next

Insert abstract



Argonne NATIONAL LABORATORY

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You may attach supporting PDF documents to this proposal. **Click here to attach/detach files**

List of Attachments

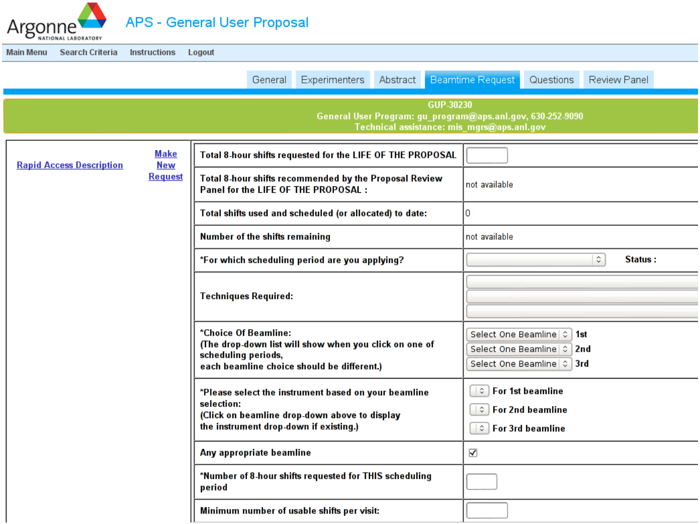
Abstract of Proposed Research

NOTES :

- You **MUST** have an abstract below. Attaching only a PDF is not enough.
- Abstract **MUST** be less than 4000 characters including spaces.
- The abstract and proposal title may become public information.
- Don't enter any carriage return.
- The proposal system runs on the WEISO8859P1 (Western European, Latin) character set. Characters you enter into the system that are Unicode or otherwise not a subset of WEISO8859P1 will not render properly in the report of your proposal. Typically these are greek, super/subscript characters, etc. Click here to see a list of valid characters and Proposal Content and Style Guidelines

Characters Remaining :

Make Beam Time Request


Argonne NATIONAL LABORATORY
APS - General User Proposal

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General | Experimenters | Abstract | Beamtime Request | Questions | Review Panel

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Rapid Access Description | Make New Request

Total 8-hour shifts requested for the LIFE OF THE PROPOSAL	
Total 8-hour shifts recommended by the Proposal Review Panel for the LIFE OF THE PROPOSAL :	not available
Total shifts used and scheduled (or allocated) to date:	0
Number of the shifts remaining	not available
*For which scheduling period are you applying?	Status :
Techniques Required:	
*Choice Of Beamline: (The drop-down list will show when you click on one of scheduling periods, each beamline choice should be different.)	Select One Beamline 1st Select One Beamline 2nd Select One Beamline 3rd
*Please select the instrument based on your beamline selection: (Click on beamline drop-down above to display the instrument drop-down if existing.)	For 1st beamline For 2nd beamline For 3rd beamline
Any appropriate beamline	☑
*Number of 8-hour shifts requested for THIS scheduling period	
Minimum number of usable shifts per visit:	

Beam Time Request continued

Do you have specific scheduling requirements ?	
What equipment is required ? What equipment will you bring ?	
Please list any new publications resulting from your work at the APS.	
Describe the progress made during your most recent beamtime. (2000 characters including spaces)	
Prefered Dates (MM/DD/YYYY)	From / To to to to to
Unacceptable Dates (MM/DD/YYYY)	From / To to to to to

Back

Generate Report

Answer the 6 important questions

Argonne NATIONAL LABORATORY

APS - General User Proposal

Main Menu | Search Criteria | Instructions | Logout

General | Experimenters | Abstract | Beamtime Request | Questions | Review Panel

GUP-30230
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Please specify the funding source(s) for your proposed research:

☐ DOD (specify)	☐ DOE, Office of Basic Energy Sciences	☐ DOE, Office of Biological and Environmental Research
☐ DOE, Other (specify)	☐ Foreign (specify)	☐ HHIH
☐ Howard Hughes Medical Institute (HHMI)	☐ Industry	☐ NASA
☐ NIH	☐ NSF	☐ Other U.S. Government
☐ USDA	☐ Other (specify)	**Specify Other:**

What is the scientific or technical purpose and importance of the proposed research? (limit : 500 words)

Answer the 6 important questions

What is the scientific or technical purpose and importance of the proposed research? (limit: 500 words)

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What is the scientific or technical purpose and importance of the proposed research? (limit: 500 words)

Why do you need the APS for this research? (limit: 100 words)

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Why do you need the beamline you have chosen? (limit: 100 words)

Answer the 6 important questions

What is the scientific or technical purpose and importance of the proposed research? (limit: 500 words)

Why do you need the APS for this research? (limit: 100 words)

Why do you need the beamline you have chosen? (limit: 100 words)

Describe the participants' previous experience with synchrotron radiation and the experimental results obtained. (If you refer to previous publications, be sure to include complete citations.) (limit: 100 words)

Answer the 6 important questions

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Why do you need the beamline you have chosen? (limit: 100 words)

Describe the participants' previous experience with synchrotron radiation and the experimental results obtained. (If you refer to previous publications, be sure to include complete citations.) (limit: 100 words)

Describe samples and explain the proposed experiment, including procedures. Explain the basis for your estimated beam time needs. (limit: 500 words)

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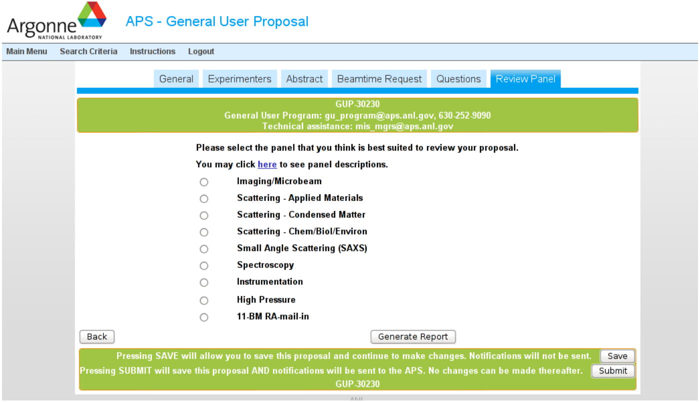
Describe the participants' previous experience with synchrotron radiation and the experimental results obtained. (If you refer to previous publications, be sure to include complete citations.) (limit: 100 words)

Describe samples and explain the proposed experiment, including procedures. Explain the basis for your estimated beam time needs. (limit: 500 words)

Provide an overall estimate of the amount of beam time you will need to accomplish the goals of your proposed experimental program. How many visits during the two-year proposal period do you expect to need? How many shifts will you need during each visit (approximately)? (limit: 500 words)

Select the review panel



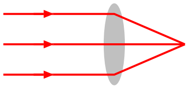
Refractive optics

Just as with visible, light, it is possible to make refractive optics for x-rays

Refractive optics

Just as with visible, light, it is possible to make refractive optics for x-rays

visible light:



$$n \sim 1.2 - 1.5$$
$$f \sim 0.1\text{m}$$

Refractive optics

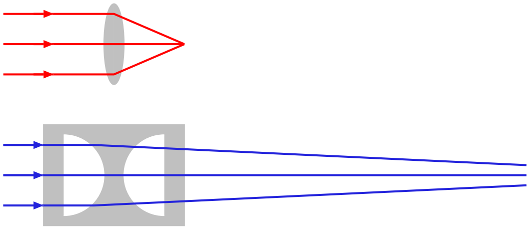
Just as with visible, light, it is possible to make refractive optics for x-rays

visible light:

$$n \sim 1.2 - 1.5$$
$$f \sim 0.1\text{m}$$

x-rays:

$$n \approx 1 - \delta,\ \delta \sim 10^{-5}$$
$$f \sim 100\text{m!}$$



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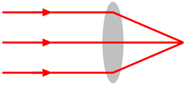

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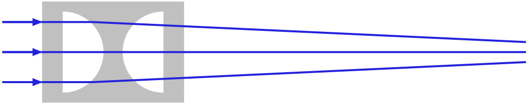

x-ray lenses are complementary to those for visible light

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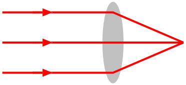

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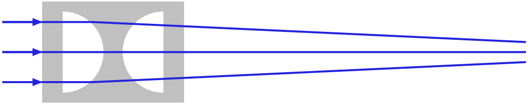
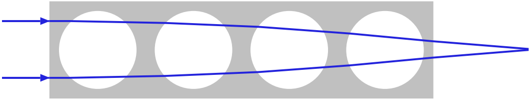
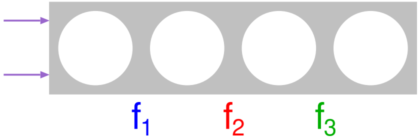


x-ray lenses are complementary to those for visible light

getting manageable focal distances requires making compound lenses

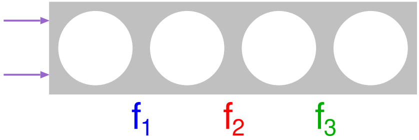


Focal length of a compound lens



Start with a 3-element compound lens, calculate effective focal length

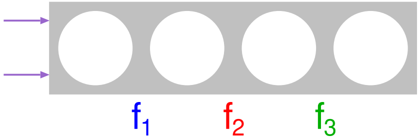
Focal length of a compound lens



$$\frac{1}{i} + \frac{1}{o} = \frac{1}{f}$$

Start with a 3-element compound lens, calculate effective focal length assuming each lens has the same focal length, f

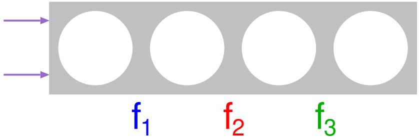
Focal length of a compound lens



$$\frac{1}{i} + \frac{1}{o} = \frac{1}{f} \rightarrow \frac{1}{i} = \frac{1}{f} - \frac{1}{o}$$

Start with a 3-element compound lens, calculate effective focal length assuming each lens has the same focal length, f

Focal length of a compound lens

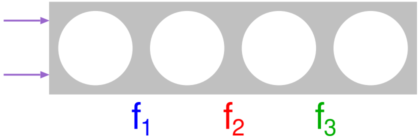


Start with a 3-element compound lens, calculate effective focal length assuming each lens has the same focal length, f

$$\frac{1}{i} + \frac{1}{o} = \frac{1}{f} \rightarrow \frac{1}{i} = \frac{1}{f} - \frac{1}{o}$$

$$\frac{1}{i_1} = \frac{1}{f_1} - \frac{1}{o_1}$$

Focal length of a compound lens



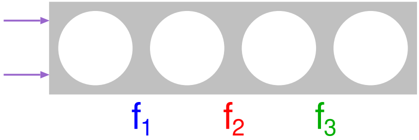
Start with a 3-element compound lens, calculate effective focal length assuming each lens has the same focal length, f

$$\frac{1}{i}+\frac{1}{o}=\frac{1}{f} \rightarrow \frac{1}{i}=\frac{1}{f}-\frac{1}{o}$$

$$\frac{1}{i_1}=\frac{1}{f_1}-\frac{1}{o_1} \rightarrow \frac{1}{i_1}=\frac{1}{f}$$

$f_1 = f$, $o_1 = \infty$

Focal length of a compound lens



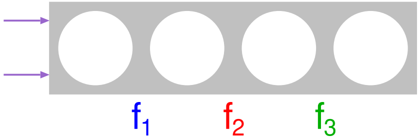
Start with a 3-element compound lens, calculate effective focal length assuming each lens has the same focal length, f

$$\frac{1}{i} + \frac{1}{o} = \frac{1}{f} \rightarrow \frac{1}{i} = \frac{1}{f} - \frac{1}{o}$$

$f_1 = f$, $o_1 = \infty$

$$\frac{1}{i_1} = \frac{1}{f_1} - \frac{1}{o_1} \rightarrow \frac{1}{i_1} = \frac{1}{f} \rightarrow i_1 = f$$

Focal length of a compound lens



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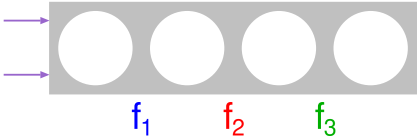
$$\frac{1}{i_2} = \frac{1}{f_2} - \frac{1}{o_2}$$

Start with a 3-element compound lens, calculate effective focal length assuming each lens has the same focal length, f

$f_1 = f$, $o_1 = \infty$

for the second lens, the image i_1 is a virtual object, $o_2 = -i_1$

Focal length of a compound lens



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$$\frac{1}{i_1} = \frac{1}{f_1} - \frac{1}{o_1} \rightarrow \frac{1}{i_1} = \frac{1}{f} \rightarrow i_1 = f$$

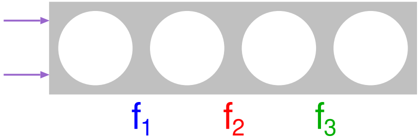
$$\frac{1}{i_2} = \frac{1}{f_2} - \frac{1}{o_2} \rightarrow \frac{1}{i_2} = \frac{1}{f} + \frac{1}{f}$$

Start with a 3-element compound lens, calculate effective focal length assuming each lens has the same focal length, f

$f_1 = f$, $o_1 = \infty$

for the second lens, the image i_1 is a virtual object, $o_2 = -i_1$

Focal length of a compound lens



$$\frac{1}{i}+\frac{1}{o}=\frac{1}{f}\rightarrow\frac{1}{i}=\frac{1}{f}-\frac{1}{o}$$

$$\frac{1}{i_1}=\frac{1}{f_1}-\frac{1}{o_1}\rightarrow\frac{1}{i_1}=\frac{1}{f}\rightarrow i_1=f$$

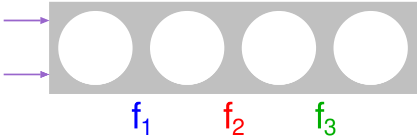
$$\frac{1}{i_2}=\frac{1}{f_2}-\frac{1}{o_2}\rightarrow\frac{1}{i_2}=\frac{1}{f}+\frac{1}{f}\rightarrow i_2=\frac{f}{2}$$

Start with a 3-element compound lens, calculate effective focal length assuming each lens has the same focal length, f

$f_1=f$, $o_1=\infty$

for the second lens, the image i_1 is a virtual object, $o_2=-i_1$

Focal length of a compound lens



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$$\frac{1}{i} + \frac{1}{o} = \frac{1}{f} \rightarrow \frac{1}{i} = \frac{1}{f} - \frac{1}{o}$$

$f_1 = f$, $o_1 = \infty$

$$\frac{1}{i_1} = \frac{1}{f_1} - \frac{1}{o_1} \rightarrow \frac{1}{i_1} = \frac{1}{f} \rightarrow i_1 = f$$

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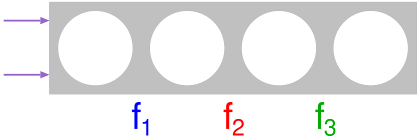

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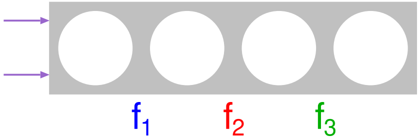

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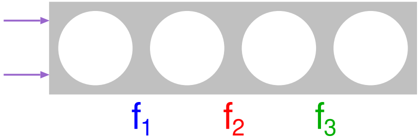

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so for N lenses $f_{eff} = f/N$

Rephasing distance

A spherical surface is not the ideal lens as it introduces aberrations. Derive the ideal shape for perfect focusing of x-rays.

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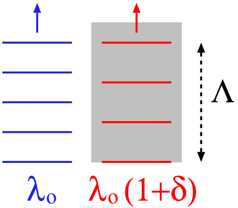

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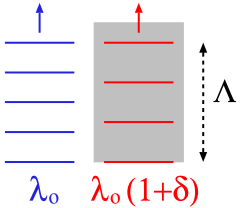

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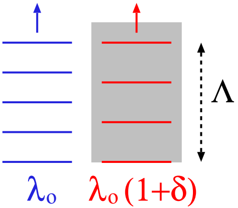

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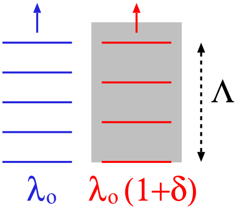

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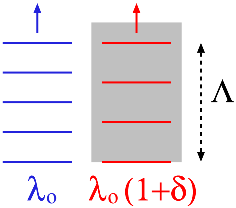

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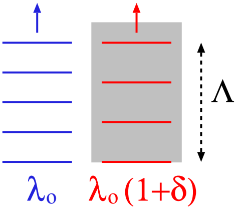

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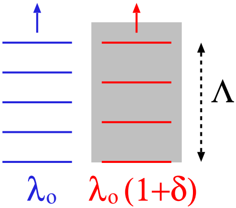

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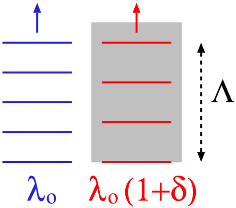

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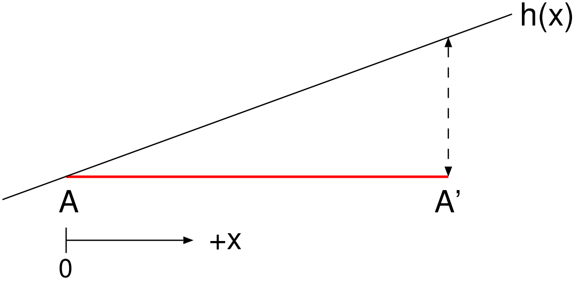
Ideal interface profile - “thin” lens



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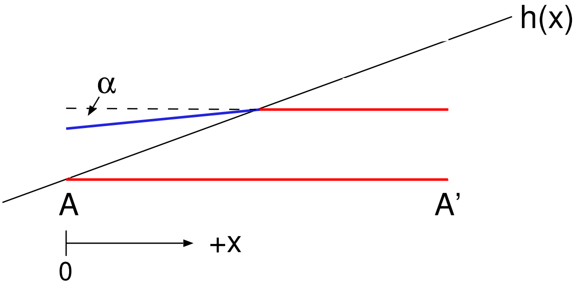

The wave exits the material into vacuum through a surface of profile $h(x)$, and is twisted by an angle α.

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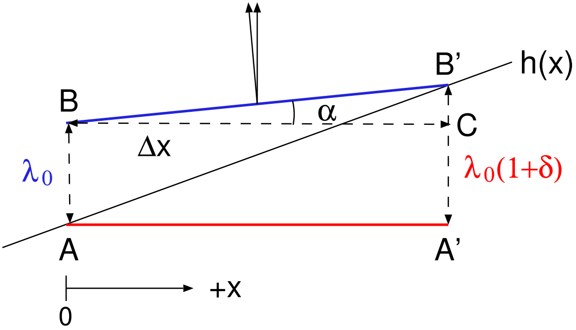

The wave exits the material into vacuum through a surface of profile $h(x)$, and is twisted by an angle α.

Follow the path of two points on the wave-front, A and A' as they propagate to B and B'.

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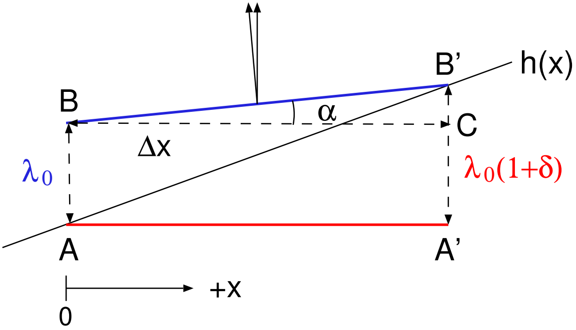

from the $AA'B'$ triangle

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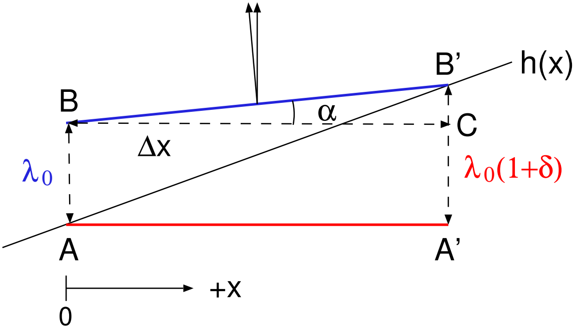

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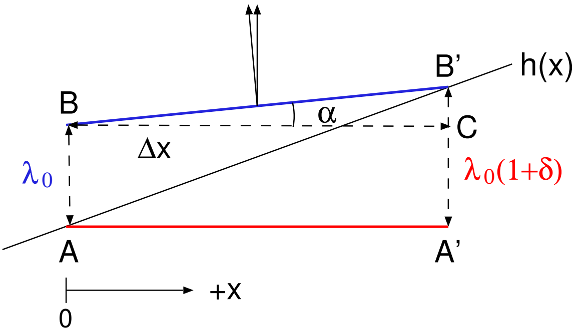

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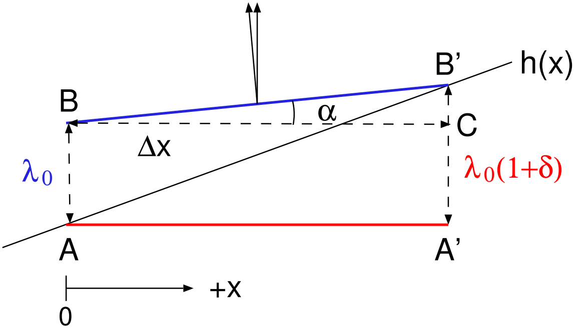

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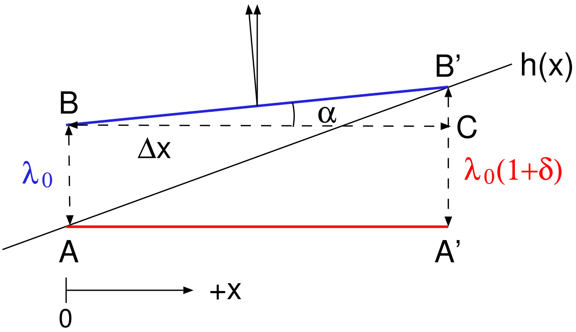

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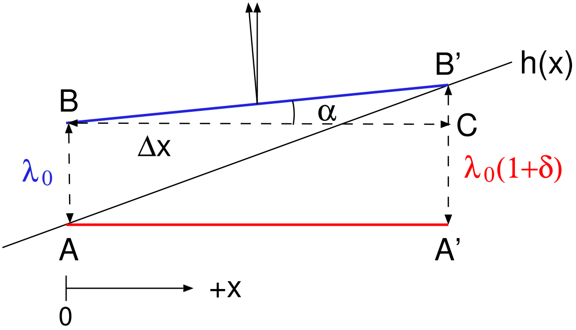

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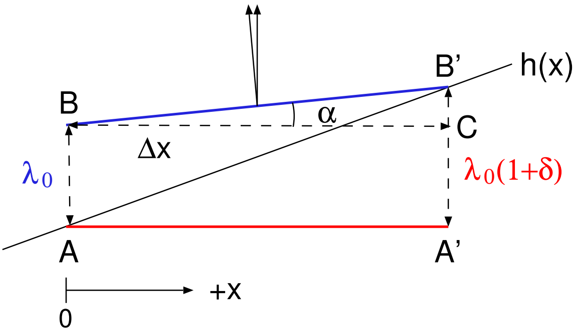

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using $\Lambda = \lambda_0/\delta$

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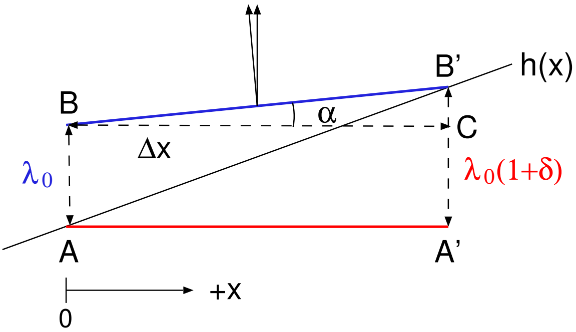

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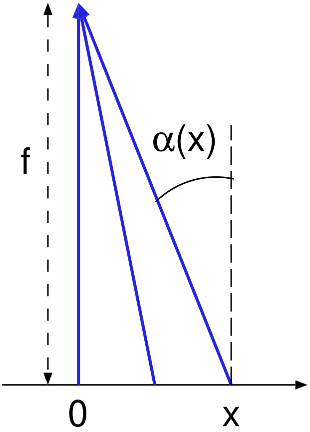
$$\alpha(x) \approx \frac{\lambda_0 \delta}{\Delta x} = h'(x)\delta = h'(x)\frac{\lambda_0}{\Lambda}$$

using $\Lambda = \lambda_0/\delta$

Ideal interface profile - “thin” lens

If the desired focal length of this lens is f, the wave must be redirected at an angle which depends on the distance from the optical axis



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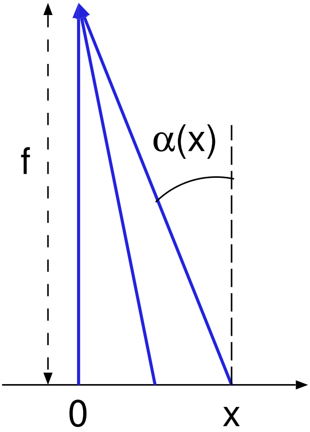
$$\alpha(x) = \frac{x}{f}$$



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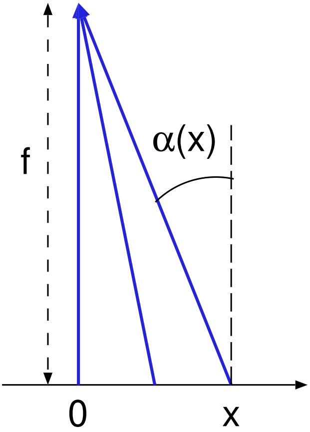
combining, we have

$$\frac{\lambda_0 h'(x)}{\Lambda} = \frac{x}{f}$$



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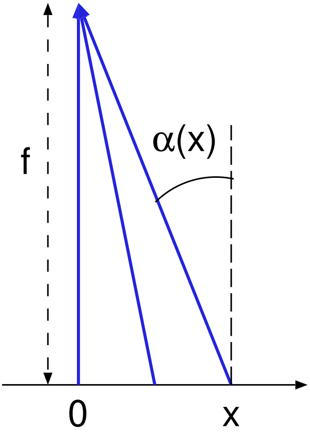

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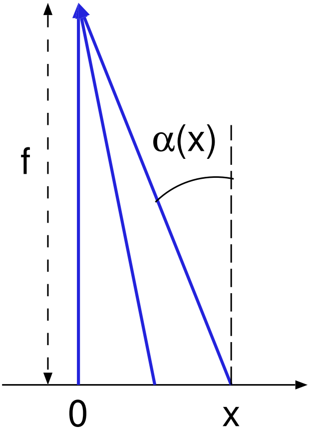
this can be directly integrated



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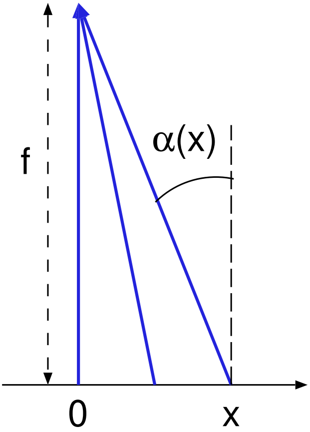
this can be directly integrated

$$\frac{h(x)}{\Lambda} = \frac{x^2}{2f\lambda_0}$$



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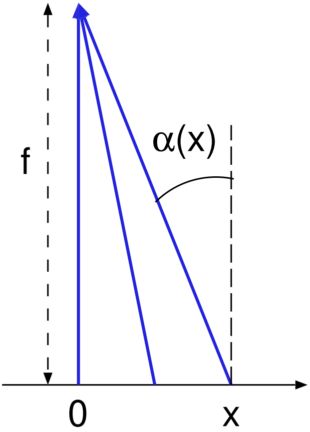
$$\frac{h(x)}{\Lambda} = \frac{x^2}{2f\lambda_0} = \left[\frac{x}{\sqrt{2f\lambda_0}}\right]^2$$



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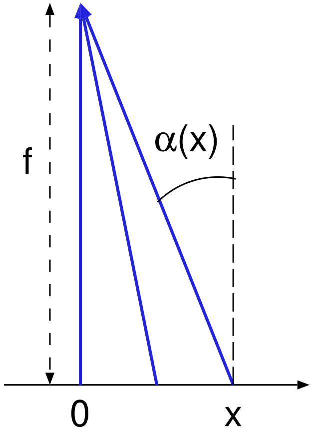

a parabola is the ideal surface shape for focusing by refraction for a "thin" lens with limited aperture

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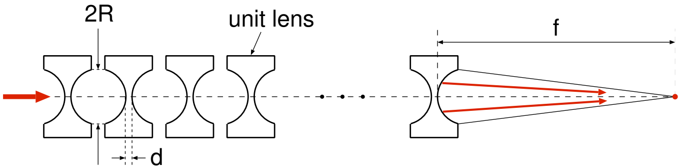
for $2N$ circular lenses we have

$$f_{2N} \approx \frac{R}{2N\delta}$$

Focussing by a beryllium lens



H.R. Beguiristain et al., "X-ray focusing with compound lenses made from beryllium," *Optics Lett.*, **27**, 778 (2007).

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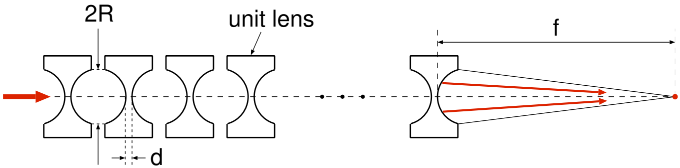

For 50 holes of radius $R = 1$mm in beryllium (Be) at $E = 10$keV, we can calculate the focal length, knowing $\delta = 3.41 \times 10^{-6}$

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

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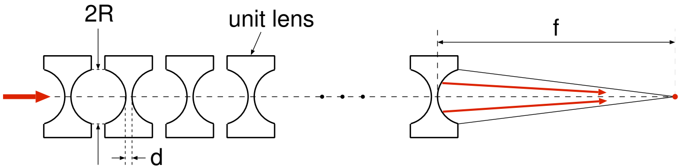

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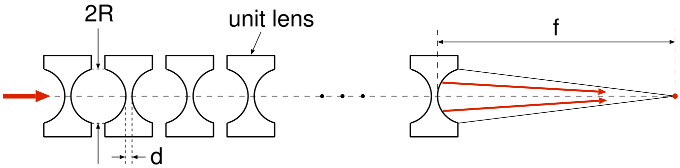

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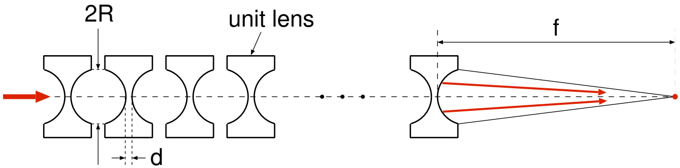

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depending on the wall thickness of the lenslets, the transmission can be up to 74%

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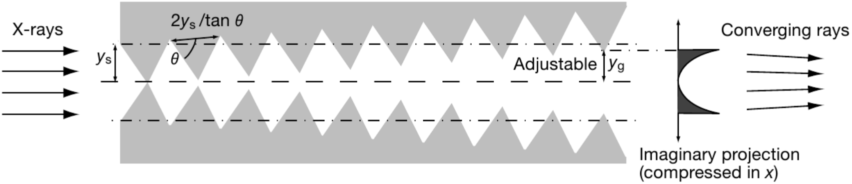
Alligator-type lenses

Perhaps one of the most original x-ray lenses has been made by using old vinyl records in an “alligator” configuration.



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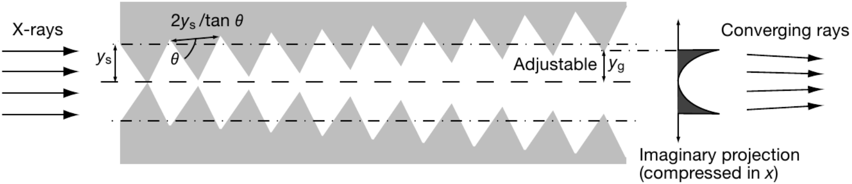

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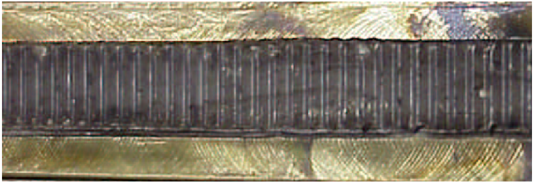

This design has also been used to make lenses out of lithium metal.

E.M. Dufresne et al., “Lithium metal for x-ray refractive optics”, *Appl. Phys. Lett.* **79**, 4085 (2001).

Extruded Al lens

The compound refractive lenses (CRL) are useful for fixed focus but are difficult to use if a variable focal distance and a long focal length is required.

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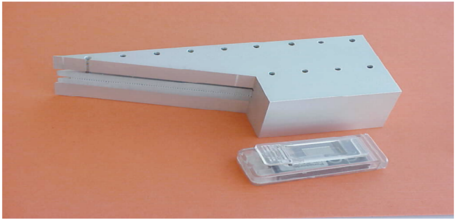

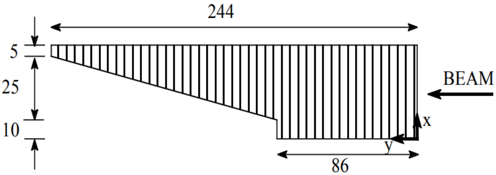

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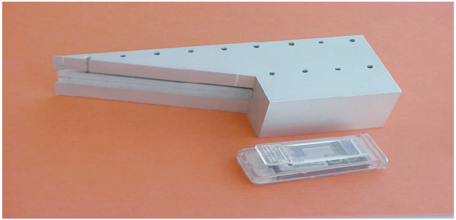
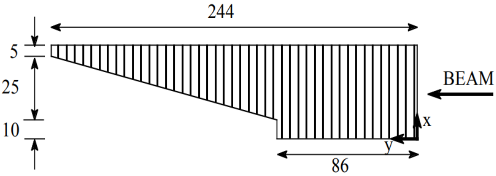


Extruded aluminum lens with parabolic figure



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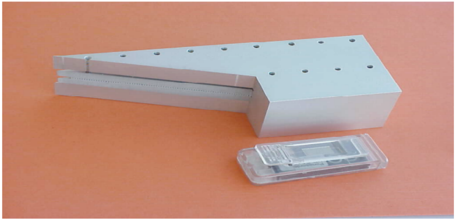

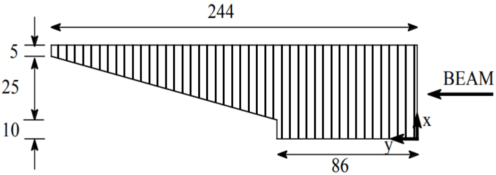

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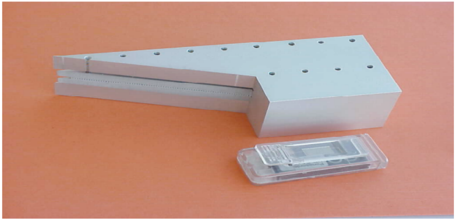

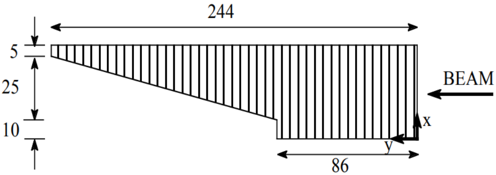

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Horizontal translation allows change in focal length but it is quantized, not continuous

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Variable focal length CRL

A continuously variable focal length is very important for two specific reasons: tracking sample position, and keeping the focal length constant as energy is changed.

B. Adams and C. Rose-Petruck, "X-ray focusing scheme with continuously variable lens," *J. Synchrotron Radiation* **22**, 16-22 (2015).

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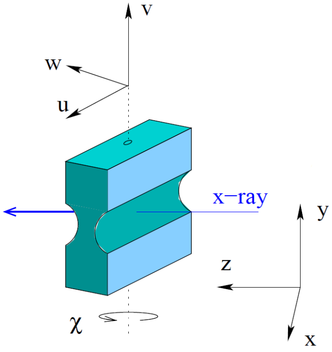
Start with a 2 hole CRL.



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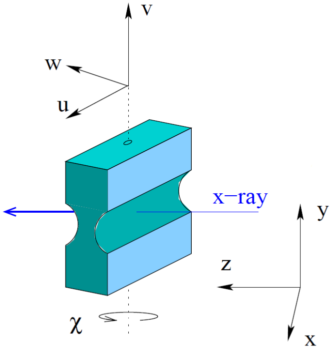
Start with a 2 hole CRL. Rotate by an angle χ about vertical axis



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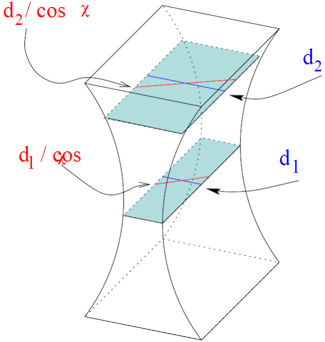

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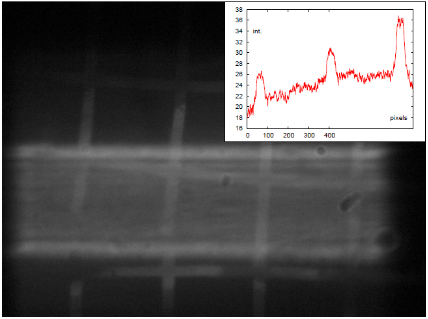

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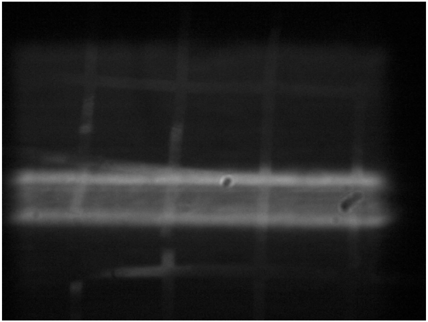
At $\chi = 30^\circ$, it is under 50μm



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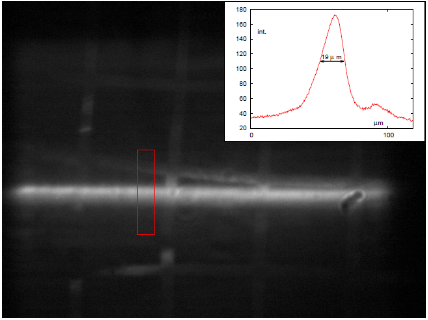
Optimal focus is 20μm at $\chi = 40^\circ$



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