X-Ray Optics Calculator – A Web-based application for X-Ray Scientists

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X-Ray Optics Calculator – A Web-based application for X-Ray Scientists

Similar web-based applications:

- X-Ray Interactions With Matter at Lawrence Berkeley National Laboratory
- X-Ray Form Factor, Attenuation and Scattering Tabulation at NIST
- XCOM: Photon Cross Sections Database at NIST
- Elastic Photon-Atom Scattering at Lawrence Livermore National Laboratory
- Compound Refractive Lenses Calculator at II. Physikalisches Institut B - RWTH Aachen

X-Ray Optics Calculator – A Web-based application for X-Ray Scientists

- The X-Ray Optics Calculator is an interactive system based on web technologies and a database of interaction of x-ray radiation with the condensed matter. The database of interaction of x-ray radiation with the condensed matter is based on open data.
- The system is accessible through the Internet and gives the possibility to carry out calculations of parameters necessary for
- the development of high resolution x-ray optics elements,
- the preparation and carrying out of experiments in optical schemes on the basis of these elements.

X-Ray Optics Calculator – A Web-based application for X-Ray Scientists

By means of the system it is possible:

- to calculate main parameters of interaction of x-ray radiation with condensed matter for a wide range of materials (single element materials, predefined set of compounds, any custom compounds with given chemical formula and density),
- to develop the refractive and Fresnel optics elements and to estimate their optical characteristics,
- to evaluate the parameters of single-lens and double-lens optical schemes.
- to provide the information on the basic physical parameters of the Periodic table elements, the energy of the hard x-ray emission lines, the values of atomic scattering factors.

X-Ray Optics Calculator – A Web-based application for X-Ray Scientists

Platform:

PHP, HTML, SQL, Javascript, MySQL, Apache Web-server

Tested in following browsers:

Internet Explorer, Mozilla Firefox, Safari

X-Ray Optics Calculator – A Web-based application for X-Ray Scientists

Online version http://www.iptm.ru/xcalc

Offline version

X-Ray Optics Calculator

Introduction

Available functions

Lens Formula

- Single Lens
- Two separated Lenses

Unit Conversion

- Energy <=> Wavelength
- radian <=> arc sec

Refractive Optics

- Refraction Index Decrement
- Compound Refractive Lens (cylindrical)
- Compound Refractive Lens (parabolical)
- Planar Parabolic Refractive Lens
- Planar Kinoform Refractive Lens

Fresnel Optics

- First Fresnel Zone Size
- Fresnel Zone Plate
- Composite Fresnel Zone Plate

Transmission through matter

- X-ray attenuation in air

Table Data

- Elements data table
- Compounds data table
- Characteristic lines

X-Ray Optics Calculator

Lens Formula

Single Lens Formula

- F - Focal distance of the lens
- D_s - Source distance
- D_i - Image distance

$$1/F = 1/D_s + 1/D_i$$

or

$$D_i = D_s * F /(D_s - F)$$

Two separated Lenses

- F_1, F_2 - Focal distances of first and second lenses
- D_{12} - Distance between lenses
- F - Focal distance of the two-lens system (from the position of the first lens)

$$F = (F_1F_2 + F_1D_{12} - D_{12}^2)/(F_1 + F_2 - D_{12})$$

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X-Ray Optics Calculator

Lens Formula
Single Lens
Two separated lenses

Single Lens Formula

Thin lens formula		Fixed parameter
Source-to-Lens distance, m	40	◉
Lens-to-Image distance, m	0.5063	○
Focal distance, m	0.5	○

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X-Ray Optics Calculator

Lens Formula
Single Lens
Two separated lenses

Image distance of two separated lenses

Two lenses formula		Parameter of interest
Source distance, m	40	○
First Lens Focal distance, m	1	○
Second Lens Focal distance, m	2	○
Distance between lenses, m	0.5	○
Image distance from the first lens, m	0.920716112	◉

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X-Ray Optics Calculator

Unit Conversion
Energy <=> Wavelength
radian <=> arc sec

Unit Conversion

Energy <=> Wavelength

Wavelength and photon energy relationship:

Wavelength (Å) * Energy (keV) = 12.39842

Radian <=> Arc sec

Microradian and arc seconds relationship:

Microradian = 1.e+6 * Arc seconds * π /180/60/60

Arc degree and arc seconds relationship:

Arc degree = Arc seconds * 3600

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X-Ray Optics Calculator

Unit Conversion
Energy <=> Wavelength
radian <=> arc sec

Energy <=> Wavelength

Photon energy, 0.01 - 10000 keV	12
Wavelength, Å	1.0332
Characteristic line	Select line

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X-Ray Optics Calculator

Unit Conversion
Energy <=> Wavelength
radian <=> arc sec

Energy <=> Wavelength

Photon energy, 0.01 - 10000 keV	12
Wavelength, Å	1.0332
Characteristic line	Select line

Select line
Ag K_alpha_1
Ag K_alpha_2
Ag K_beta_1
Ag K_beta_2
Au L_alpha_1
Co K_alpha_1
Co K_alpha_2
Co K_beta_1
Cr K_alpha_1
Cr K_alpha_2
Cr K_beta_1
Cu K_alpha_1
Cu K_alpha_2
Cu K_beta_1
Fe K_alpha_1
Fe K_alpha_2
Fe K_beta_1
Ge K_alpha_1
Ge K_alpha_2
Ge K_beta_1
Ge K_beta_2
Mo K_alpha_1
Mo K_alpha_2
Mo K_beta_1
Mo K_beta_2
Ni K_alpha_1
Ni K_alpha_2
Ni K_beta_1
Zn K_alpha_1

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X-Ray Optics Calculator

Unit Conversion
Energy <=> Wavelength
radian <=> arc sec

Energy <=> Wavelength

Photon energy, 0.01 - 10000 keV	8.04799
Wavelength, Å	1.540562
Characteristic line	Cu K_alpha_1

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X-Ray Optics Calculator

Unit Conversion
Energy <=> Wavelength
radian <=> arc sec

Radian <=> Arc

radian	2
microradian	2000000
arc seconds	412529.6125
arc degree	114.59155902616464

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X-Ray Optics Calculator

Refractive Optics

Refraction Index Decrement

The Refraction Index Decrement and related parameters are calculated from the atomic scattering factors and Compton and Rayleigh cross-sections.

First part of the atomic scattering data is given on a uniform logarithmic mesh with 500+ points from 0.01 keV to 30 keV. The atomic scattering factors are based upon experimental measurements of the atomic photoabsorption cross section. The absorption measurements provide values for the imaginary part of the atomic scattering factor. The real part, which describes the dispersion of radiation as it interacts with matter, is calculated from the absorption measurements using the Kramers-Kronig integral relations.
Source: http://www-cxro.lbl.gov/optical_constants/
B. L. Henke, E. M. Gullikson, and J. C. Davis, Atomic Data and Nuclear Data Tables Vol. 54 No. 2, 181-343 (July 1993).

The atomic scattering factors for energies above 30 keV up to 10 MeV are taken from data set calculated by Lynn Kissel. The original data is available from http://www-phys.llnl.gov/V_Div/scattering/elastic.html These data are computed for neutral atoms, only, entirely within a local relativistic self-consistent potential with the Slater local-exchange coefficient and Latter tail. For a detailed discussion of the underlying validity of the information contained in these directories see, for example:
Validity of Form-Factor, Modified-Form-Factor and Anomalous-Scattering-Factor Approximations in Elastic Scattering Calculations, by Lynn Kissel, B. Zhou, S. C. Roy, S. K. Sen Gupta and R. H. Pratt, Acta Crystallographica Vol. A51, 271-288 (1995).

Compton and Rayleigh cross-sections data has been extracted from the file raycomin.f of the library by Brennan and Cowan
S. Brennan and P.L. Cowan, Rev. Sci. Instrum. 63,1, 850 1992
The file raycomin.f is available by ftp from the authors from http://www-ssrl.slac.stanford.edu/absorb.html

Compound Refractive Lens (cylindrical)

The calculation of Cylindrical Compound Refractive Lens parameters is based on the formulae from
A. Snigirev, V. Kohn, I. Snigireva & B. Lengeler "A compound refractive lens for focusing high-energy X-rays", Nature, v.384, No.6604, 1996, pp.49-51

Compound Refractive Lens (parabolical)

The calculation of Parabolical Compound Refractive Lens parameters is based on the formulae from
B. Lengeler, J. T?mmler, A. Snigirev, I. Snigireva, and C. Raven "Transmission and gain of singly and doubly focusing refractive x-ray lenses", Journal of Applied Physics, v.84, No.11, 1998, pp.5855-5861

Planar Parabolic Refractive Lens

The calculation of Planar Parabolic Refractive Lens parameters is based on the formulae from
V.V. Aristov, M.V. Grigoriev, S.M.Kuznetsov, L.G. Shabelnikov, V.A. Yunkin, M. Hoffman, E. Voges "X-ray focusing by planar parabolic refractive lenses made of silicon", Optical Communications, v.177, 2000, pp.33-38

X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Refractive Index Decrement

Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Characteristic line	Select line

Material Name

Chemical Formula — Select element

Choose Material Type — Single Element

Delta	
Beta	
Total linear attenuation coefficient, μm^{-1}	
Linear attenuation coefficient (photoelectric part), μm^{-1}	
Linear attenuation coefficient (Compton scattering part), μm^{-1}	
Linear attenuation coefficient (Rayleigh scattering part), μm^{-1}	
Pi-shift length, μm	
Indexes ratio	
Critical angle for total external reflection, rad	
Brewster angle, rad	

Calculate

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Refractive Index Decrement

Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Characteristic line	Select line

Material Name

Chemical Formula — Select element

Choose Material Type — Sing

Delta	
Beta	
Total linear attenuation coefficient, μm^{-1}	
Linear attenuation coefficient (photoelectric part), μm^{-1}	
Linear attenuation coefficient (Compton scattering part), μm^{-1}	
Linear attenuation coefficient (Rayleigh scattering part), μm^{-1}	
Pi-shift length, μm	
Indexes ratio	
Critical angle for total external reflection, rad	
Brewster angle, rad	

Select element
H
He
Li
Be
B
C
N
O
F
Ne
Na
Mg
Al
Si
P
S
Cl
Ar
K
Ca
Sc
Ti
V
Cr
Mn
Fe
Co
Ni
Cu

Calculate

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Refractive Index Decrement

Photon energy, 0.01 - 10000 keV	12
Wavelength, Å	1.0332
Characteristic line	Select line

Material Name **Silicon**

Chemical Formula: Si

Choose Material Type: Single Element

Delta	3.3820999210893E-06
Beta	3.5698688424793E-08
Total linear attenuation coefficient, μm^{-1}	0.0044842921910069
Linear attenuation coefficient (photoelectric part), μm^{-1}	0.004341872101695
Linear attenuation coefficient (Compton scattering part), μm^{-1}	2.7136090767853E-05
Linear attenuation coefficient (Rayleigh scattering part), μm^{-1}	0.00011528399854402
Pi-shift length, µm	15.274558569723
Indexes ratio	15.078366859502
Critical angle for total external reflection, rad	0.0026008075365506
Brewster angle, rad	0.78539647234749

Calculate

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Refractive Index Decrement

Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Characteristic line	Select line

Material Name

Chemical Formula — Select element

Choose Material Type — Single Element (Single Element / Compound Material / Custom Material)

Delta	
Beta	
Total linear attenuation coefficient, μm^{-1}	
Linear attenuation coefficient (photoelectric part), μm^{-1}	
Linear attenuation coefficient (Compton scattering part), μm^{-1}	
Linear attenuation coefficient (Rayleigh scattering part), μm^{-1}	
Pi-shift length, μm	
Indexes ratio	
Critical angle for total external reflection, rad	
Brewster angle, rad	

Calculate

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Refractive Index Decrement

Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Characteristic line	Select line

Material Name

Chemical Formula: Select formula

Choose Material Type: Compound Material

Delta	
Beta	
Total linear attenuation coefficient, μm^{-1}	
Linear attenuation coefficient (photoelectric part), μm^{-1}	
Linear attenuation coefficient (Compton scattering part), μm^{-1}	
Linear attenuation coefficient (Rayleigh scattering part), μm^{-1}	
Pi-shift length, μm	
Indexes ratio	
Critical angle for total external reflection, rad	
Brewster angle, rad	

Calculate

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Refractive Index Decrement

Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Characteristic line	Select line

Material Name

Chemical Formula — Select formula

Choose Material Type

Delta
Beta
Total linear attenuation coefficient, μm^{-1}
Linear attenuation coefficient (photoelectric part), μm^{-1}
Linear attenuation coefficient (Compton scattering part), μm^{-1}
Linear attenuation coefficient (Rayleigh scattering part), μm^{-1}
Pi-shift length, μm
Indexes ratio
Critical angle for total external reflection, rad
Brewster angle, rad

Select formula
AgBr
AgCl
Al2O3
AlPO4
B4C
BaF2
BaTiO3
BeO
BN
C10H8O4
C16H14O3
C16H14O3
C22H10N2O5
C2F4
C3H6
C3H8O3
C5H8O2
C8H7Cl
C8H8
CaF2
CdS
CdSe
Cr2O3
CsBr
CsCl
CsI
GaAs
GaP
Hg2Cl2

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Refractive Index Decrement

Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Characteristic line	Select line

Material Name **Polyimide**

Chemical Formula C22H10N2O5

Choose Material Type Compound Material

Delta	
Beta	
Total linear attenuation coefficient, μm^{-1}	
Linear attenuation coefficient (photoelectric part), μm^{-1}	
Linear attenuation coefficient (Compton scattering part), μm^{-1}	
Linear attenuation coefficient (Rayleigh scattering part), μm^{-1}	
Pi-shift length, μm	
Indexes ratio	
Critical angle for total external reflection, rad	
Brewster angle, rad	

Calculate

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Refractive Index Decrement

Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Characteristic line	Select line

Density, g/cm^3 0

Chemical Formula

Choose Material Type Custom Material

Delta	
Beta	
Total linear attenuation coefficient, μm^{-1}	
Linear attenuation coefficient (photoelectric part), μm^{-1}	
Linear attenuation coefficient (Compton scattering part), μm^{-1}	
Linear attenuation coefficient (Rayleigh scattering part), μm^{-1}	
Pi-shift length, μm	
Indexes ratio	
Critical angle for total external reflection, rad	
Brewster angle, rad	

Calculate

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Compound Refractive Cylindrical Lens

Lens Parameters	
Radius of Holes, μm	
Number of Holes	
Space between Holes, μm	0
Lens Length, mm	

Lens Material

Material Name

Chemical Formula: Select element

Choose Material Type: Single Element

Source	
Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Source-Lens Distance, m	
Source size, μm	

Lens characteristics	
Focus distance, cm	
Focus Depth, mm	
Image distance, cm	
Effective Aperture, μm	
transparent	
absorbing	
Resolution, μm	
Diffraction limit	
Source size limit	
Ideal Gain	
+ Source account	
++ Roughness account	Total RMS Roughness, μm

Calculate Clear

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Compound Refractive Cylindrical Lens

Lens Parameters	
Radius of Holes, μm	200
Number of Holes	235
Space between Holes, μm	5
Lens Length, mm	95.17

Lens Material

Material Name	**Beryllium**
Chemical Formula	Be
Choose Material Type	Single Element

Source	
Photon energy, 0.01 - 10000 keV	20
Wavelength, Å	0.61992
Source-Lens Distance, m	50
Source size, μm	50

Lens characteristics	
Focus distance, cm	50
Focus Depth, mm	3.4796282128986
Image distance, cm	50.505050505051
Effective Aperture, μm	94.381397664055
transparent	94.381397664055
absorbing	404.46442569726
Resolution, μm	0.60425197815462
Diffraction limit	0.33172946877237
Source size limit	0.50505050505051
Ideal Gain	273.64387001997
+ Source account	202.83059201542
++ Roughness account	Total RMS Roughness, μm
202.83059201542 >>	0

Calculate Clear

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Compound Refractive Parabolical Lens

Lens Parameters	
Radius at parabola apex, µm	
Number of single lenses	
Full Aperture, µm	
Space between apexes, µm	0
Lens Length, mm	

Lens Material

Material Name

Chemical Formula: Select element

Choose Material Type: Single Element

Source	
Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Source-Lens Distance, m	
Source vertical size, µm	
Source horizontal size, µm	

Lens characteristics	
Focus distance, cm	
Focus Depth, mm	
Image distance, cm	
Effective Aperture, µm	
Intensity Transmission, %	
Resolution, µm	
Diffraction limit	
+ Horizontal source size limit	
+ Vertical source size limit	
Ideal Gain	
+ Source account	
++ Roughness account	Total RMS Roughness, µm

Calculate Clear

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Compound Refractive Parabolical Lens

Lens Parameters	
Radius at parabola apex, μm	200
Number of single lenses	84
Full Aperture, μm	900
Space between apexes, μm	10
Lens Length, mm	85.89

Lens Material

Material Name	**Beryllium**
Chemical Formula	Be
Choose Material Type	Single Element

Source	
Photon energy, 0.01 - 10000 keV	12
Wavelength, Å	1.0332
Source-Lens Distance, m	40
Source vertical size, μm	40
Source horizontal size, μm	200

Lens characteristics	
Focus distance, cm	50
Focus Depth, mm	0.23197052394264
Image distance, cm	50.632911392405
Effective Aperture, μm	471.9117590791
Intensity Transmission, %	13.196365734488
Resolution, μm	
Diffraction limit	0.11085530937546
+ Horizontal source size limit	2.5340714650133
+ Vertical source size limit	0.51832236226488
Ideal Gain	4019.8615112399
+ Source account	83388.000030802
++ Roughness account	Total RMS Roughness, μm
79605.12180441014 <	1.5

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Planar Parabolic Refractive Lens

Lens Parameters	
Full Aperture, µm	
Single Profile Length, µm	
Number of Profiles	
Radius at parabola apex, µm	
Space between apexes, µm	0
Lens Length, mm	

Lens Material

Material Name

Chemical Formula: Select element

Choose Material Type: Single Element

Source	
Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Source-Lens Distance, m	
Source size, µm	

Lens characteristics	
Focus distance, cm	
Focus Depth, mm	
Image distance, cm	
Effective Aperture, µm	
Intensity Transmission, %	
Resolution, µm	
Diffraction limit	
Source size limit	
Gain	
Source account	
+ Roughness account	Total RMS Roughness, µm

Calculate Clear

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Planar Parabolic Refractive Lens

Lens Parameters	
Full Aperture, µm	50
Single Profile Length, µm	50
Number of Profiles	103
Radius at parabola apex, µm	6.25
Space between apexes, µm	5
Lens Length, mm	5.66

Lens Material

Material Name	**Silicon**
Chemical Formula	Si
Choose Material Type	Single Element

Source	
Photon energy, 0.01 - 10000 keV	20
Wavelength, Å	0.61992
Source-Lens Distance, m	40
Source size, µm	50

Lens characteristics	
Focus distance, cm	5
Focus Depth, mm	0.41463849148876
Image distance, cm	5.0063438705994
Effective Aperture, µm	27.341697464425
Intensity Transmission, %	22.924815389148
Resolution, µm	0.095389982860318
Diffraction limit	0.071993612522548
Source size limit	0.062579298382492
Gain	
Source account	120.16364141043
+ Roughness account	Total RMS Roughness, µm
100 >>	3.49404231348235

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Planar Kinoform Refractive Lens

Lens Parameters	
Full Aperture, µm	
Number of phase drops, M	
Number of Lenses, p	
Number of segment pairs, N	
Single Lens Length, µm	
Last segment width, µm	
Lenses Total Length, µm	

Lens Material

Material Name

Chemical Formula: Select element

Choose Material Type: Single Element

Source	
Photon energy, 0.01 - 10000 keV	
Wavelength, Å	
Source-Lens Distance, m	
Source size, µm	

Lens characteristics		
Focus distance, cm		
Focus Depth, mm		
Image distance, cm		
Phase-matching number		
Intensity Transmission, %		
Resolution, µm		
Diffraction limit		
Source size limit		
Gain		
Source account		
+ Roughness account	Total RMS Roughness, µm	

Calculate Clear

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X-Ray Optics Calculator

Refractive Optics
Refraction Index decrement
Compound Refractive Lens (cylindrical)
Compound Refractive Lens (parabolical)
Planar Parabolic Refractive Lens
Planar Kinoform Refractive Lens

Planar Kinoform Refractive Lens

Lens Parameters	
Full Aperture, µm	77.144228559238
Number of phase drops, M	2
Number of Lenses, p	12
Number of segment pairs, N	20
Single Lens Length, µm	51.223907262612
Last segment width, µm	0.28193969326983
Lenses Total Length, µm	614.68688715134

Lens Material

Material Name	**Silicon**
Chemical Formula	Si
Choose Material Type	Single Element

Source	
Photon energy, 0.01 - 10000 keV	20
Wavelength, Å	0.61992
Source-Lens Distance, m	50
Source size, µm	50

Lens characteristics	
Focus distance, cm	5
Focus Depth, mm	0.052083333333333
Image distance, cm	5.005005005005
Phase-matching number	12
Intensity Transmission, %	76.461821681222
Resolution, µm	0.064207601649673
Diffraction limit	0.04021950521315
Source size limit	0.05005005005005
Gain	
Source account	5250.7418306466
+ Roughness account	Total RMS Roughness, µm
5250.7418306466 >>	0

Calculate Clear

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X-Ray Optics Calculator

Fresnel Optics

1-st Fresnel zone radius

- Radius of the first (central) zone R_1

  $R_1 = (F*\lambda)^{1/2}$
- Focal distance F of the Fresnel lens

  $F = R_1*R_1/\lambda$

Fresnel Zone Plate

The calculation of Fresnel Zone Plate parameters is based on the formulae from
A.Michett "Optical Systems for Soft X-Rays", Plenum Press New York, 1986.
Relative fabrication error is the ratio of fabricated and theoretical widths of processed (etching, deposition etc) zones.

Composite Fresnel Zone Plate

It is assumed that Composite Fresnel Zone Plate consists of even and odd zones made of different materials (like so-called "roulette" zone plate).
The calculation of Composite Fresnel Zone Plate parameters is based on the same formulae as for Fresnel Zone Plate.

S. Kuznetsov, IMT RAS, Chernogolovka, Russia.

X-Ray Optics Calculator

Fresnel Optics
1-st Fresnel zone size
Fresnel Zone Plate
Composite Fresnel Zone Plate

First Fresnel zone radius

Photon energy, 0.01 - 10000 keV	12
Wavelength, Å	1.0332
Characteristic line	Select line

Zone Plate Focal distance, cm	25	◉
1-st Fresnel zone radius, μm	5.0823	○

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X-Ray Optics Calculator

Fresnel Optics
1-st Fresnel zone size
Fresnel Zone Plate
Composite Fresnel Zone Plate

Fresnel Zone Plate

Zone Plate Topology & Parameters	
Central zone radius, μm	5
Last zone width, μm	.3
Full aperture, μm	83.33333333333334
Number of zones	69
Zone height, μm	2
Relative fabrication error, %	10
Membrane thickness, μm	20

Lens Material

Material Name	**Silicon**
Chemical Formula	Si
Choose Material Type	Single Element

Source	
Photon energy, 0.01 - 10000 keV	12
Wavelength, Å	1.0332
Source-Lens Distance, m	40
Source size, μm	50

Zone Plate characteristics	
Zone Phase shift, 1/pi	0.13093668081279
Zone Attenuation, %	0.89284865921136
Focus distance, cm	24.196670538134
Focus depth, cm	0.17745498881326
Image distance, cm	24.343931057987
Focal spot FWHM, μm	0.36277268724367
Peak/background ratio	629.4119151207
Focusing Efficiency, %	1.7471154443531
Intensity Transmission, %	82.836611470292
Membrane attenuation, %	16.420481308416

Calculate Clear

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X-Ray Optics Calculator

Fresnel Optics
1-st Fresnel zone size
Fresnel Zone Plate
Composite Fresnel Zone Plate

Composite Fresnel zone plate

Lens Topology & Parameters	
Central zone radius, microns	5
Last zone width, microns	.3
Lens full aperture, microns	83.33333333333334
Number of zones	69
Relative fabrication error, %	0

Lens characteristics	
Focus distance, cm	24.196670538134
Focus depth, cm	0.17745498881326
Image distance, cm	24.343931057987
Focal spot FWHM, µm	0.36531397799459
Peak/background ratio	1801.8450874968
Focusing Efficiency, %	5.0576661982431

Lens Material			
Odd zones	Zone height, µm	2	
Material Name	**Boron**		
Chemical Formula	B		
Choose Material Type	Single Element		
Zone Phase shift, 1/π	0.12090488990459	Zone Attenuation, %	0.035969722539297
Even zones	Zone height, µm	2	
Material Name	**Gold**		
Chemical Formula	Au		
Choose Material Type	Single Element		
Zone Phase shift, 1/π	0.69502540306925	Zone Attenuation, %	49.980380048806

Source	
Photon energy, 0.01 - 10000 keV	12
Wavelength, Å	1.0332
Source-Lens Distance, m	40
Source size, µm	50

Calculate Clear

S. Kuznetsov, IMT RAS, Chernogolovka, Russia.

X-Ray Optics Calculator

Transmission through matter

X-ray attenuation in air

The calculation is based on the extrapolation function derived from the data presented in
Wm. J. Veigele "X-Ray Attenuation Cross Sections of Air between 0.1 keV and 1 MeV", Journal of Applied Physics, v.41, 1970, pp.3178

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X-Ray Optics Calculator

Transmission through matter
X-ray attenuation in air

Transmission through air

Photon energy, 0.01 - 10000 keV	8.04799
Wavelength, Å	1.540562
Characteristic line	Cu K_alpha_1

Distance through air, m	1
Intensity transmission, %	33.4326
Intensity loss, %	66.567

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X-Ray Optics Calculator

Table data used in the X-ray Optics Calculator

Elements

These table lists several important properties of the elements. Data were taken mostly from *X-ray data booklet*, January 2001, LBL, University of California. [this reference refers to : D.R.Lide, Ed. *CRC Handbook of Chemistry and Physics*, 80th ed. CRC Press, Boca Raton, Florida, 1999]

- Atomic weights apply to elements as they exist naturally on earth.
- Densities for solids and liquds are given at 20°C; densities for gaseous elements are given for liquids at their boiling points.
- Specific heat and thermal conductivity are given for the elements at 25°C and a pressure of 100 kPa.

Compounds

These table lists chemical formula and density for several compound materials. The data is taken from the **Center for X-Ray Optics** at Lawrence Berkeley National Laboratory.

Characteristic lines

These table lists several important characteristic lines of X-Ray emission in hard X-Ray range (5 - 30 keV).
Values are given from J.A.Bearden, "X-Ray Wavelengths", *Review of Modern Physics*, **39** 1967.
Wavelength and photon energy relationship:

Wavelength (Å) * Energy (keV) = 12.39842

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X-Ray Optics Calculator

Table Data
Elements data table
Compounds data table
Characteristic lines

Elements table data used in the X-ray Optics Calculator

Atomic number Z	Symbol	Name	Atomic weight	Density, g/cm^3	Specific heat, J/(g*K)	Thermal conductivity, W/(m*K)
1	H	Hydrogen	1.00794	0.0708	14.304	0.1805
2	He	Helium	4.0026	0.122	5.193	0.1513
3	Li	Lithium	6.941	0.533	3.582	85
4	Be	Beryllium	9.01218	1.845	1.825	190
5	B	Boron	10.811	2.34	1.026	27
6	C	Carbon (diamond	12.011	3.51	0.709	2300
7	N	Nitrogen	14.0067	0.81	1.042	0.02583
8	O	Oxygen	15.9994	1.14	0.92	0.02658
9	F	Fluorine	18.998403	1.108	0.824	0.0277
10	Ne	Neon	20.179	1.207	1.03	0.0491
11	Na	Sodium	22.98977	0.969	1.23	140
12	Mg	Magnesium	24.305	1.735	1.02	160
13	Al	Aluminum	26.98154	2.6941	0.9	235
14	Si	Silicon	28.0855	2.3283	0.7	150
15	P	Phosphorus	30.97376	1.82	0.769	0.236
16	S	Sulfur	32.066	2.07	0.71	0.205
17	Cl	Chlorine	35.4527	1.56	0.48	0.0089
18	Ar	Argon	39.948	1.4	0.52	0.01772
19	K	Potassium	39.0983	0.86	0.757	100
20	Ca	Calcium	40.078	1.55	0.647	200
21	Sc	Scandium	44.9559	2.98	0.568	16
22	Ti	Titanium	47.88	4.53	0.523	22
23	V	Vanadium	50.9415	6.1	0.489	31
24	Cr	Chromium	51.996	7.18	0.449	94

X-Ray Optics Calculator

Table Data
Elements data table
Compounds data table
Characteristic lines

Compounds table data used in the X-ray Optics Calculator

No	Name	Chemical formula	Density, g/cm^3
1		AgBr	6.476
2		AgCl	5.571
3	Sapphire	Al2O3	3.974
4	Berlinite	AlPO4	2.618
5		B4C	2.52
6		BaF2	4.893
7		BaTiO3	6.02
8		BeO	3.01
9		BN	2.25
10	Mylar	C10H8O4	1.4
11	Polycarbonate	C16H14O3	1.2
12	Kimfol	C16H14O3	1.2
13	Polyimide	C22H10N2O5	1.43
14	Teflon	C2F4	2.2
15	Polypropylene	C3H6	0.9
16	Glycerine	C3H8O3	1.26003
17	PMMA	C5H8O2	1.19
18	Parylene-C	C8H7Cl	1.29
19	Parylene-N	C8H8	1.11
20	Fluorite	CaF2	3.18
21		CdS	4.82
22		CdSe	5.74
23		Cr2O3	5.21
24		CsBr	4.455

X-Ray Optics Calculator

Table Data
Elements data table
Compounds data table
Characteristic lines

Compounds table data used in the X-ray Optics Calculator

No	Name	Chemical formula	Density, g/cm^3
1		HgS	8.1
2		PbTiO3	7.95
3		LiTaO3	7.454
4		TlBr	7.45292
5		TlCl	7
6		Hg2Cl2	6.97
7		NiO	6.67
8		AgBr	6.476
9		MoSi2	6.31
10		BaTiO3	6.02
11		TeO2	5.93
12	YGG	Y3Ga5O12	5.79
13		CdSe	5.74
14		InSb	5.74
15		ZnO	5.642
16		AgCl	5.571
17		ZnSe	5.42
18		GaAs	5.316
19		TiN	5.22
20		Cr2O3	5.21
21	YIG	Y3Fe5O12	5.17
22		SrTiO3	5.122
23		BaF2	4.893
24		CdS	4.82

X-Ray Optics Calculator

Table Data
Elements data table
Compounds data table
Characteristic lines

Characteristic lines table data used in the X-ray Optics Calculator

No	Line Name	Wavelength, Å	Energy, keV
1	Ag K_alpha_1	0.5594075	22.163
2	Ag K_alpha_2	0.563798	21.991
3	Ag K_beta_1	0.497069	24.943
4	Ag K_beta_2	0.497685	24.912
5	Au L_alpha_1	1.2736	9.735
6	Co K_alpha_1	1.788965	6.93
7	Co K_alpha_2	1.79285	6.915
8	Co K_beta_1	1.62079	7.65
9	Cr K_alpha_1	2.2897	5.415
10	Cr K_alpha_2	2.293606	5.406
11	Cr K_beta_1	2.08487	5.947
12	Cu K_alpha_1	1.540562	8.048
13	Cu K_alpha_2	1.544398	8.028
14	Cu K_beta_1	1.392218	8.906
15	Fe K_alpha_1	1.936042	6.404
16	Fe K_alpha_2	1.93998	6.391
17	Fe K_beta_1	1.75661	7.058
18	Ge K_alpha_1	1.254054	9.887
19	Ge K_alpha_2	1.258011	9.856
20	Ge K_beta_1	1.0573	11.726
21	Ge K_beta_2	1.05783	11.721
22	Mo K_alpha_1	0.7093	17.48
23	Mo K_alpha_2	0.71359	17.375
24	Mo K_beta_1	0.632288	19.609

X-Ray Optics Calculator

Table Data
Elements data table
Compounds data table
Characteristic lines

Characteristic lines table data used in the X-ray Optics Calculator

No	Line Name	Wavelength, Å	Energy, keV
1	Ag K_beta_1	0.497069	24.943
2	Ag K_beta_2	0.497685	24.912
3	Ag K_alpha_1	0.5594075	22.163
4	Ag K_alpha_2	0.563798	21.991
5	Mo K_beta_1	0.632288	19.609
6	Mo K_beta_2	0.63286	19.591
7	Mo K_alpha_1	0.7093	17.48
8	Mo K_alpha_2	0.71359	17.375
9	Ge K_beta_1	1.0573	11.726
10	Ge K_beta_2	1.05783	11.721
11	Ge K_alpha_1	1.254054	9.887
12	Ge K_alpha_2	1.258011	9.856
13	Au L_alpha_1	1.2736	9.735
14	Zn K_beta_1	1.29525	9.572
15	Cu K_beta_1	1.392218	8.906
16	Zn K_alpha_1	1.435155	8.639
17	Zn K_alpha_2	1.439	8.616
18	Ni K_beta_1	1.500135	8.265
19	Cu K_alpha_1	1.540562	8.048
20	Cu K_alpha_2	1.544398	8.028
21	Co K_beta_1	1.62079	7.65
22	Ni K_alpha_1	1.65791	7.478
23	Ni K_alpha_2	1.661747	7.461
24	Fe K_beta_1	1.75661	7.058

X-Ray Optics Calculator – A Web-based application for X-Ray Scientists

Future possible additions:

- Composite Compound Refractive Lens (CRL consisting of a number of individual lenses made of different materials) aka “Transfocator”
- List of atomic scattering factors for selected element
- Refraction Index Decrement for the energy range
- X-Ray attenuation in different materials
- Mirrors?
- Multilayers?
- Version for pocket computers?
- …..