SOS - WORKSHOP

Simulating Hard X-ray beamline optics by ray-tracing using ShadowOui

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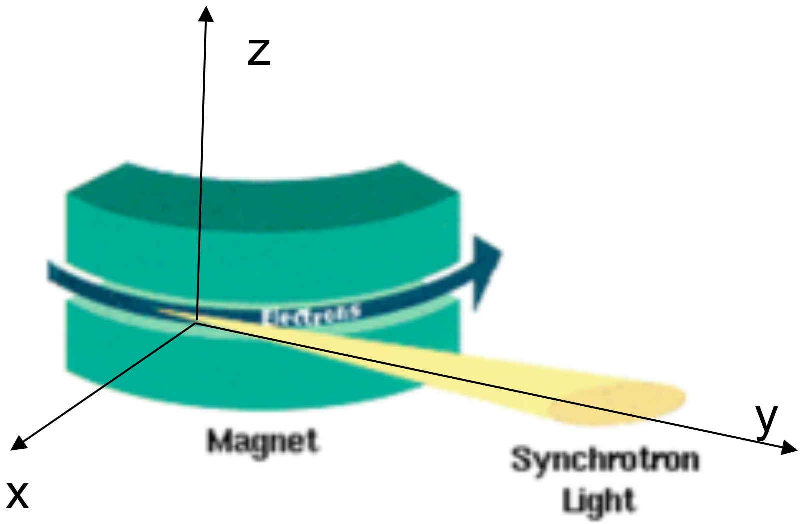
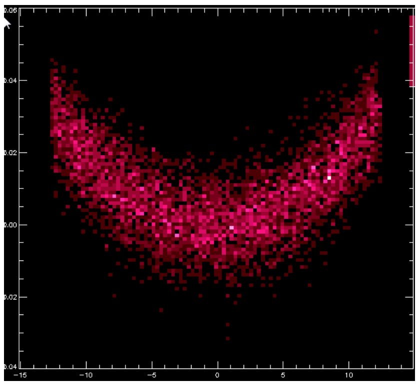
Oasys+ShadowOui

- Install Oasys+ShadowOui:
  - https://github.com/srio/oasys-installation-scripts/wiki
- Download Tutorial Examples:
  - https://github.com/srio/ShadowOui-Tutorial

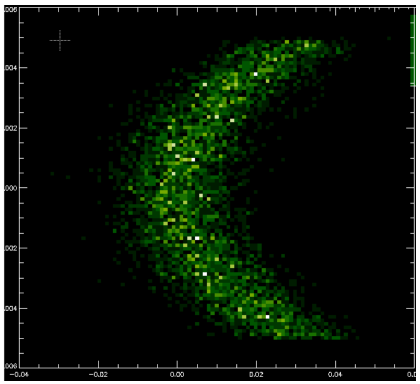
BM – Emission by N incoherent e^-



Real Space (top)

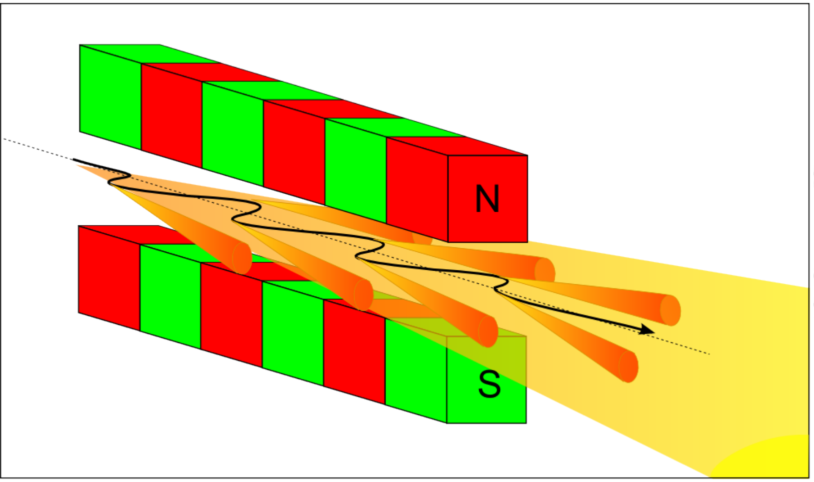


Phase Space (H)



- Monte Carlo (SHADOW)
  - Energy (and polarisation) sampled from spectrum
  - Angular Distribution ($1e^-$, σ'_x, σ'_z)
  - Geometry (along the arc, σ_x, σ_z)
  - Limitation: Computer time and memory
    - Typically: 10^3 - 10^9 rays
    - Desirable: one ray per photon, i.e., 10^{14} -10^{20}

Wiggler: Like BM, but a bit more complex



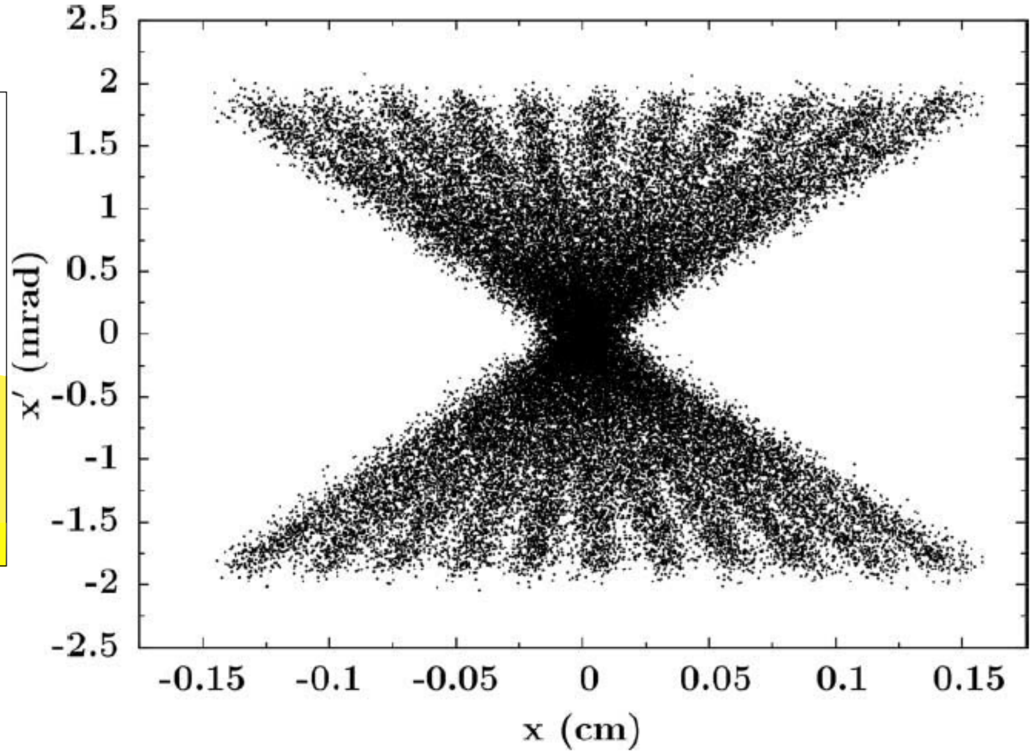
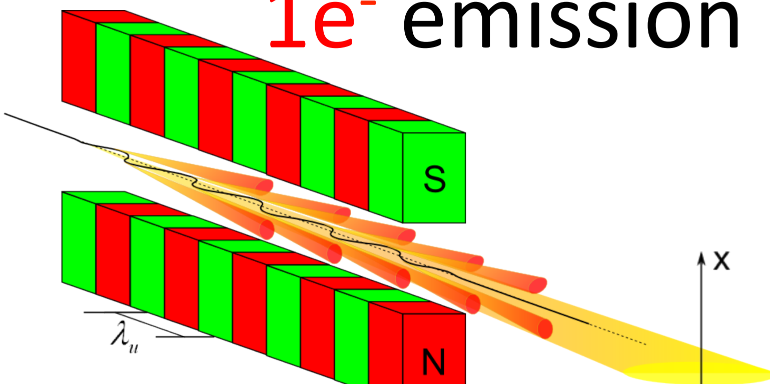
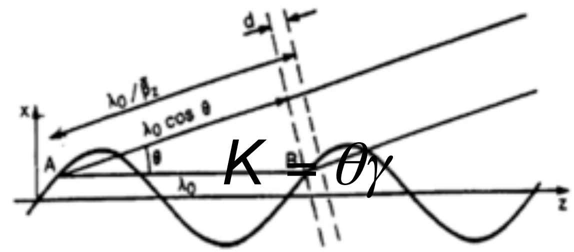


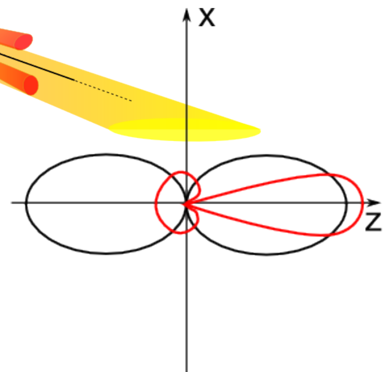
Figure 5

Plot of the horizontal phase space for a wiggler (ID17 at the ESRF) with 11 periods of 0.15 m length, K = 22.3 and electron beam energy of 6.04 GeV.

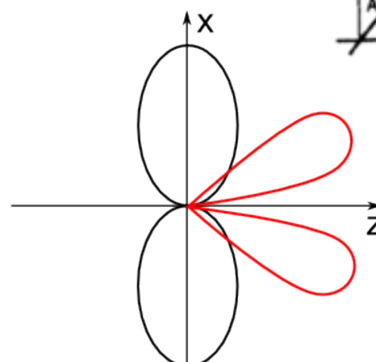
Undulator: Much more complex: 1e$^-$ emission interferes with itself





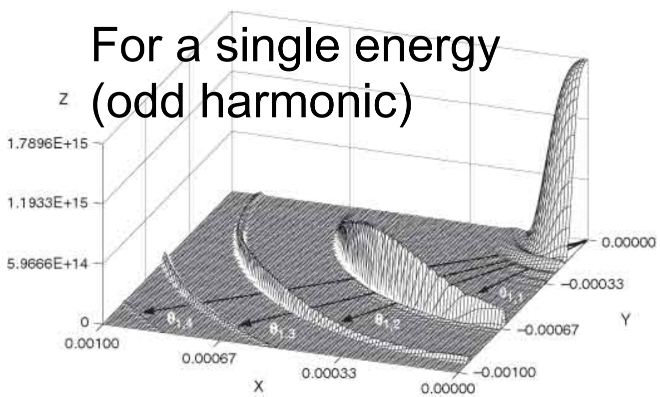


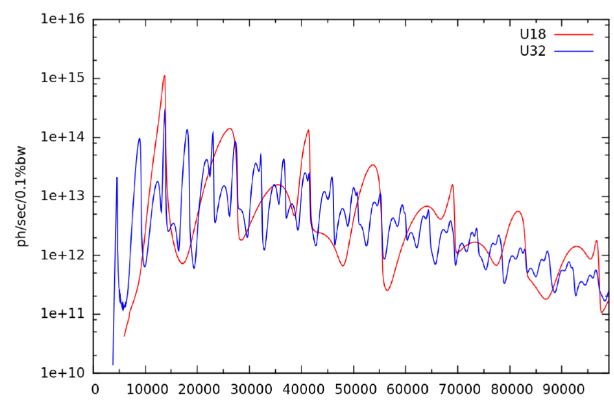
uneven harmonics



even harmonics

For a single energy (odd harmonic)





Onuki & Elleaume Undulators, Wigglers and their applications, CRC press, 2002

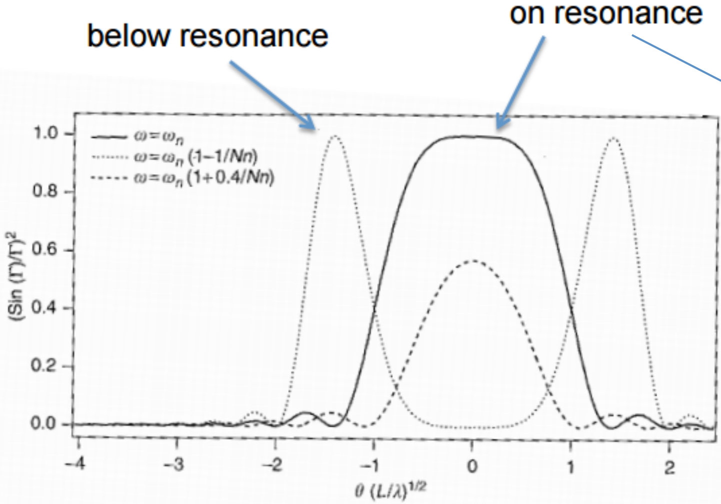


Figure 3.3 Graph of $(\sin(\Gamma)/\Gamma)^2$ as a function of the angle $\theta = \sqrt{\theta_x^2+\theta_z^2}$ for three different frequencies. ω_n is an abbreviation for $n\omega_1\,(0,0)$.

78 *P. Elleaume*

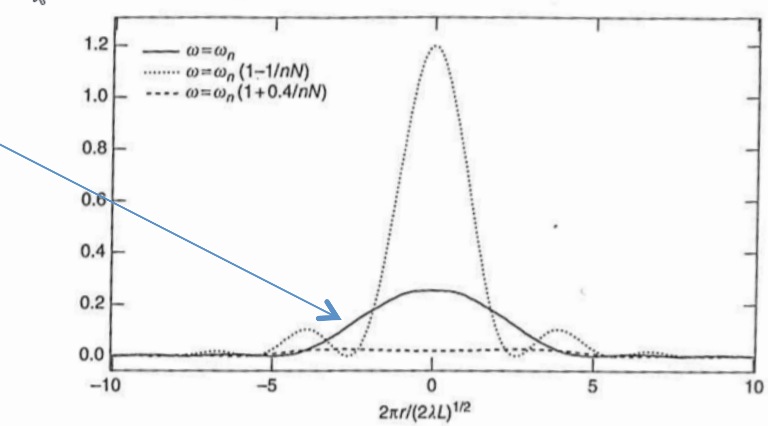


Figure 3.4 Spectral flux per unit surface in the middle of the undulator for three frequencies close to the on-axis resonant frequency $\omega_n = n\omega_1(0,0)$.

Even on resonance, beam is not fully Gaussian
But for resonance, can be reasonably approximated as Gaussian

$$\sigma_r = \frac{2.704}{4\pi}\sqrt{\lambda L} \approx \sqrt{\frac{\lambda L}{2\pi^2}}$$

$$\sigma_{r'} = 0.69\sqrt{\frac{\lambda}{L}} \approx \sqrt{\frac{\lambda}{2L}}$$

$$\sigma_r \sigma_{r'} = \frac{1.89\lambda}{4\pi} \approx \frac{\lambda}{2\pi}$$

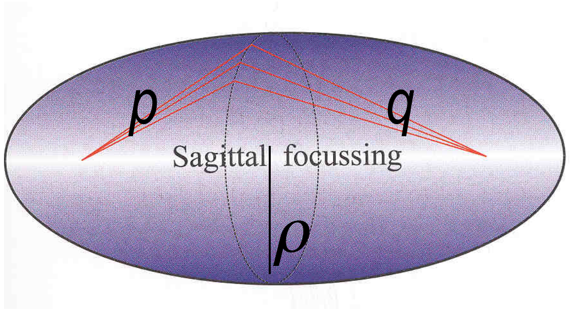
- Undulator beams have not Gaussian profiles (even at resonances)
- BY NOW, WE APPROXIMATE UNDULATORS BY GEOMETRIC SOURCES WITH GAUSSIAN SIZES AND DIVERGENCES

ex15_aberration.ows

Non-imaging system:

BL as a concentrator: which shape (in reflection)?

- Point to point focusing (ellipsoid)
- Collimating (paraboloid)
- Focalization in two planes
  - Tangential or Meridional (ellipse or parabola)
  - Sagittal (circle)
- Demagnification: M=p/q
- Easier manufactiring:
  - 2D: Ellipsoid => Toroid
  - Only one plane: cylinder Ellipsoid (ellipse)=> cylinder (circle)
  - Sagittal radius: non-linear (ellipsoid) => constant (cylinder) or linear (cone),
- Aberrations



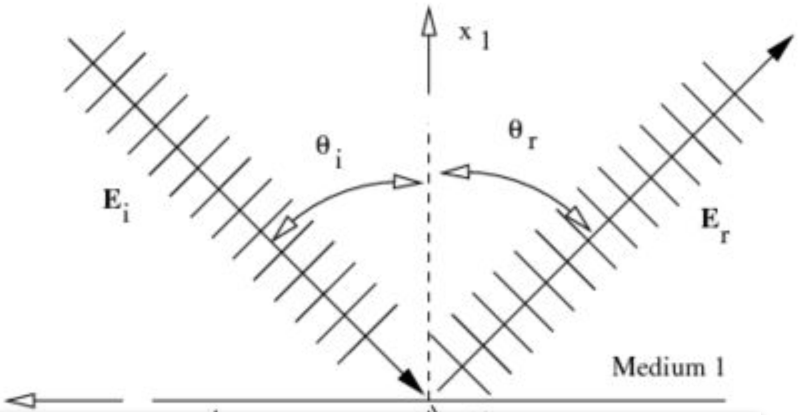
$$\frac{1}{p}+\frac{1}{q}=\frac{2}{R\sin\theta}$$

$$\frac{1}{p}+\frac{1}{q}=\frac{2\sin\theta}{\rho}$$

ex15_aberration.ows

Mirrors

Geometrical model

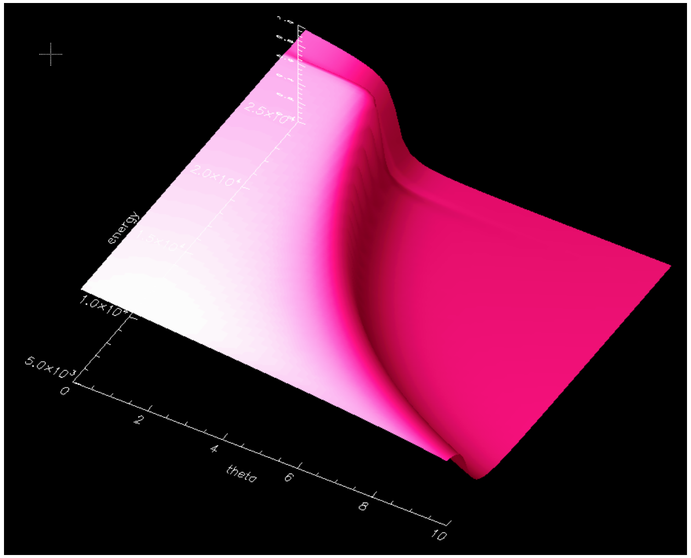


$$\hat{\mathrm{d}}_{\mathrm{s}} = 2\left(\hat{\mathrm{d}}_{\mathrm{n}} \cdot \hat{\mathrm{d}}_{\mathrm{i}}\right)\hat{\mathrm{d}}_{\mathrm{n}} - \hat{\mathrm{d}}_{\mathrm{i}},$$

Physical model

Fresnel equations give the reflectivity as a function of angle and photon energy. As a consequence, one gets the critical angle:

$$1 = \left(\frac{n_1}{n_2}\right)^2 \cos^2\theta_c \quad \Leftrightarrow \quad \sin\theta_c = \sqrt{2\delta - \delta^2} \approx \sqrt{2\delta}$$



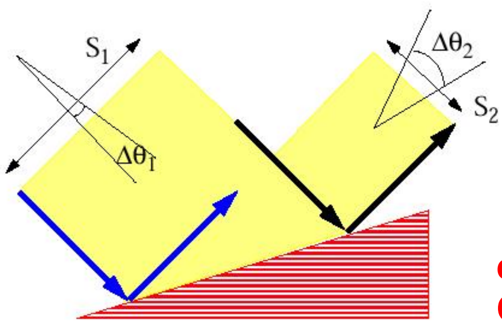
Crystals

Geometrical model

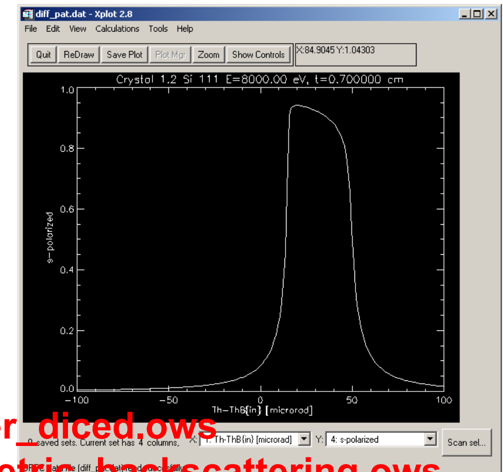
like a grating originated by the truncation of the Bragg planes with the crystal surface. Crystals are dispersive elements, except for the most used case of Bragg-Symmetric reflection.

Physical model

(crystal reflectivity) is given by the Dynamical Theory of Diffraction and gives the “Darwin width”



BRAGG or reflection



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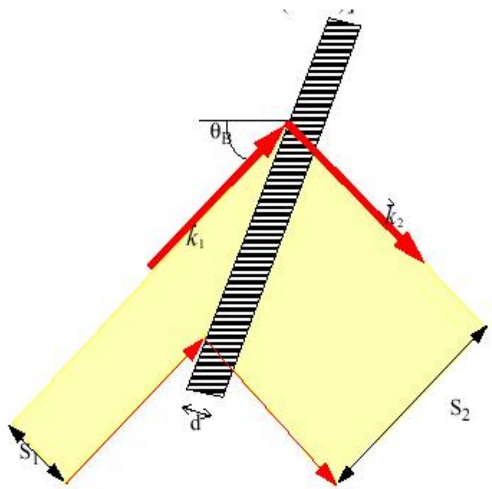
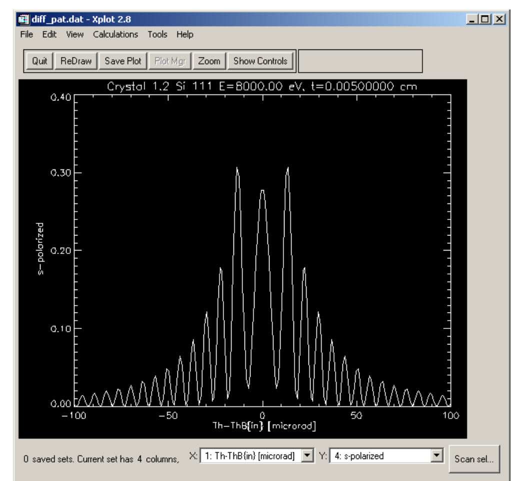


LAUE or transmission

(ex23_crystal_laue.ows)

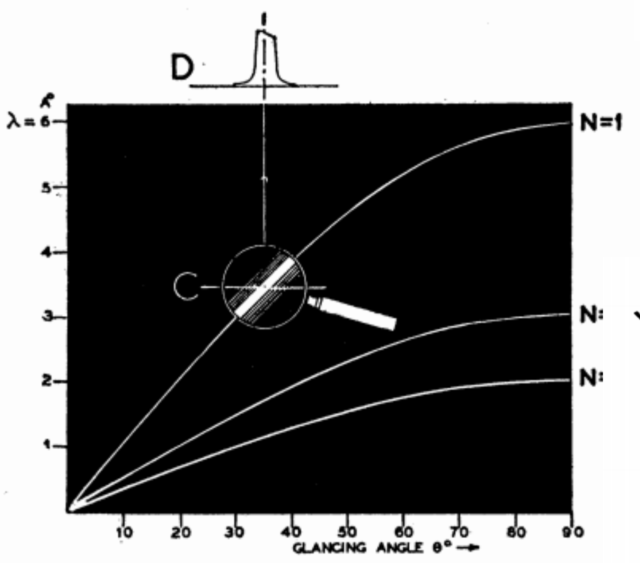


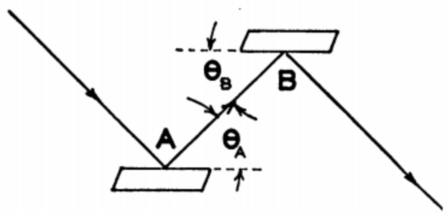
ex17_crystalmono.ows

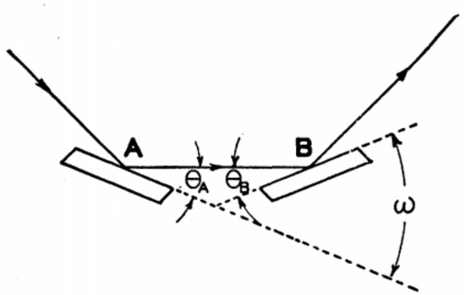
Theory of the Use of More Than Two Successive X-Ray Crystal Reflections to Obtain Increased Resolving Power

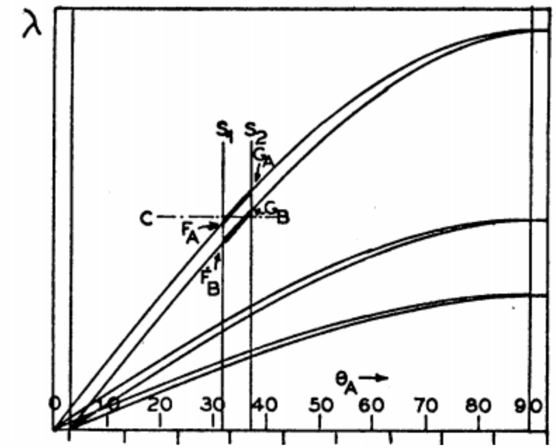
J W. M. DuMond Phys. Rev. **52**, 872 – (1937)

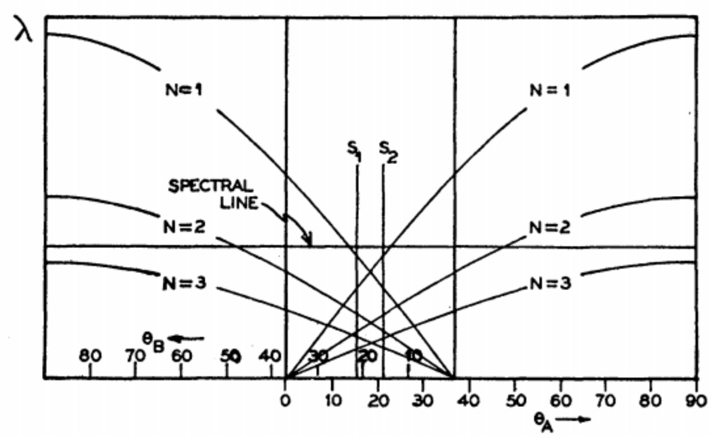
http://dx.doi.org/10.1103/PhysRev.52.872









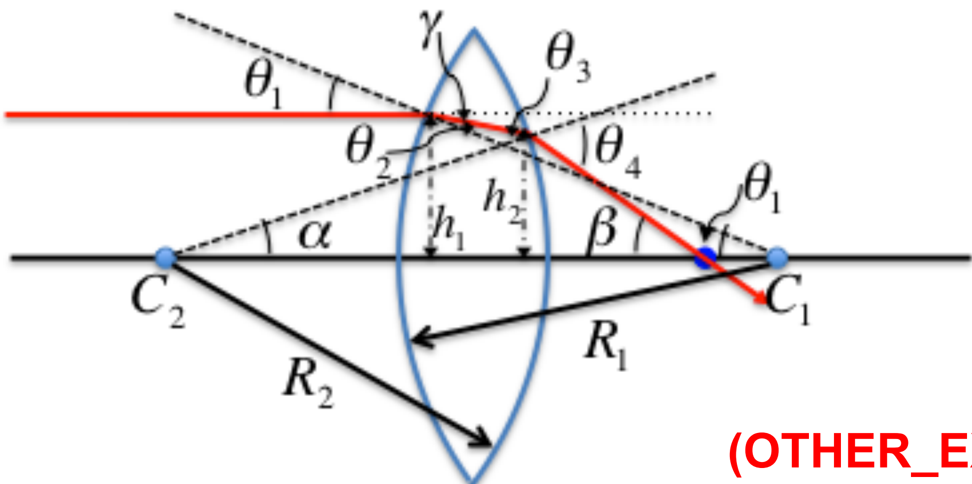


LENSE = TWO INTERFACES

Geometrical model

Law of Refraction (Snell's Law)

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$



Physical model

absorption in media

$I/I_0 = \exp(-\mu\ t)$

(OTHER_EXAMPLES/lens_elliptical.ows)
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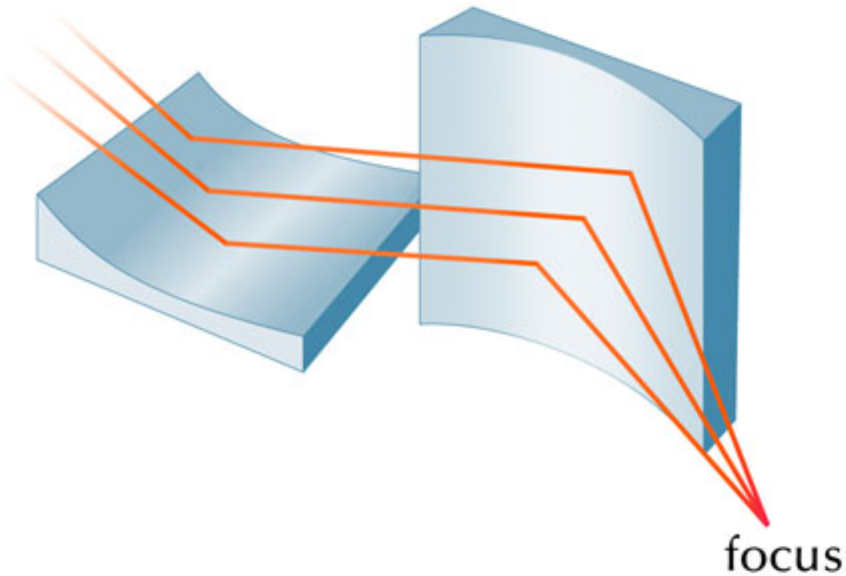
ex24_transfocator.ows

CRL = *n* identical Lenses

TRANSFOCATOR = *m* different CRLs

Other



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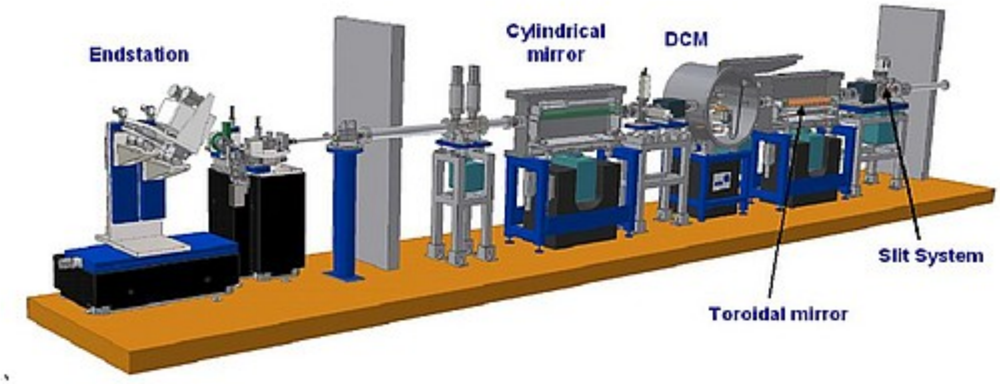

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