A Light for Science

ESRF

European Synchrotron Radiation Facility

SHADOW (and related software)

Manuel Sánchez del Río

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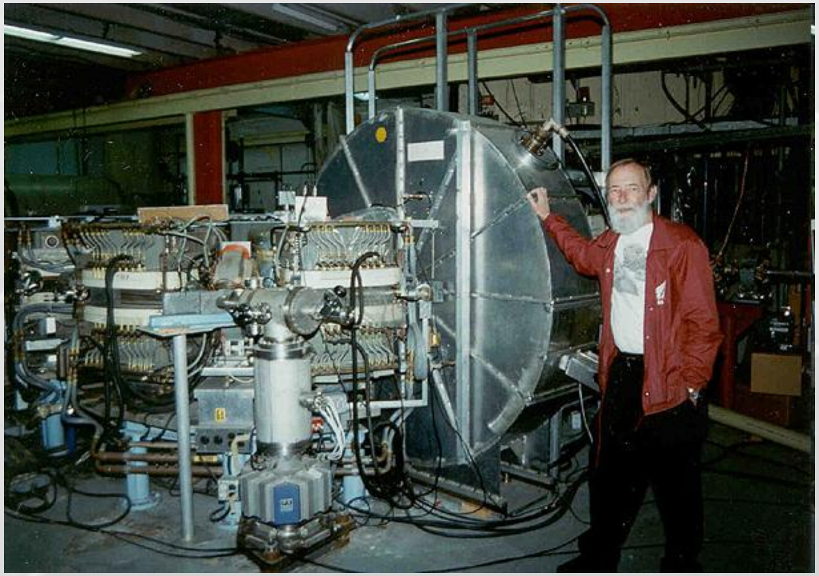
Outline

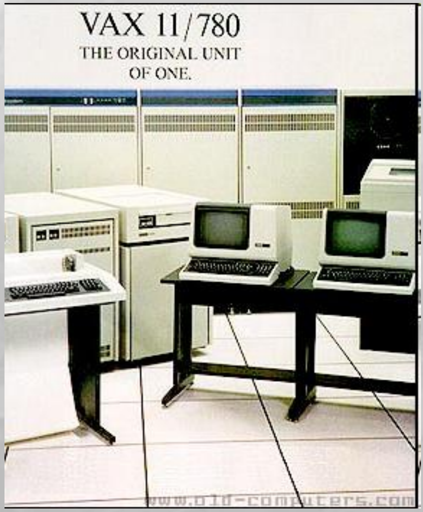
- Historical introduction
- What can SHADOW do? – functionality
- Examples
  - Classic
  - ESRF Upgrade
- New
- Future

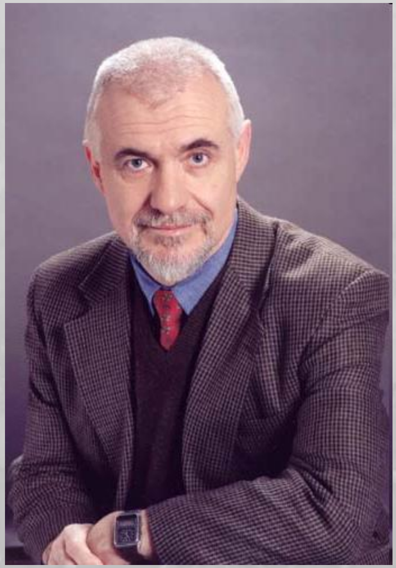
Historical introduction

Synchrotron Radiation Center, U. Wisconsin

- 1965 -1967 At the University of Wisconsin, a team led Ednor Rowe built ***Tantalus***, adapted to make synchrotron radiation available for experimentalists from all over the world
- 1977 SRC began construction on dedicated SR source, ***Aladdin***. Questions on grating monochromator design, TGM, toroidal, spherical mirrors.
- 1987 Tantalus decommissioned, Aladdin fully operational.
- 1984 Monte Carlo ray tracing program ***designed*** to simulate X-ray optical systems:
  - Two years development
  - Fortran 77+VAX/VMS extensions
  - Efficient MC approach
  - Reduced number of rays
  - Exact simulation of SR sources
  - Vector calculus
  - Modular
  - User-interface
  - Available to users







First publications

68 / SPIE Vol. 503 Application, Theory, and Fabrication of Periodic Structures (1984)

Ray tracing of recent VUV monochromator designs

F. Cerrina

Department of Electrical and Computer Engineering
University of Wisconsin, Madison WI 53706

Abstract

A new optical ray-tracing program is presented and some applications discussed. A Monte-Carlo modelling of several types of sources is implemented, and in particular the Synchrotron Radiation source is modelled exactly. The program is written specifically for grazing optics, although gaussian optics can be treated as well. Diffraction from gratings, both ruled and holographic, is included as well as Bragg diffraction from crystals. The reflectivity of mirror surfaces and transmission of filters is treated exactly and locally, solving the Fresnel equations for each ray. The interactive nature of the program and its fast execution time allow the simulation of real-life situations quickly and efficiently.
Applications
(GCM), and E

Nuclear Instruments and Methods in Physics Research A246 (1986) 337–341 337
North-Holland, Amsterdam

SHADOW: A SYNCHROTRON RADIATION RAY TRACING PROGRAM

B. LAI and F. CERRINA

Department of Electrical and Computer Engineering, University of Wisconsin, Madison, WI 53706, USA

We present the new ray-tracing program SHADOW. The program was written specifically for the XUV optics range, but is now completely general. Its capabilities are discussed in terms of the physical basis on which the program is built, with particular emphasis on the synchrotron radiation applications.

1984-1990 The kingdom of Digital VAX/VMS

Updated to include new models (several authors)

- Insertion devices (Wiggler and Undulators)
- First crystal model
- Multilayers

Documentation & Users support (C. Welnak)

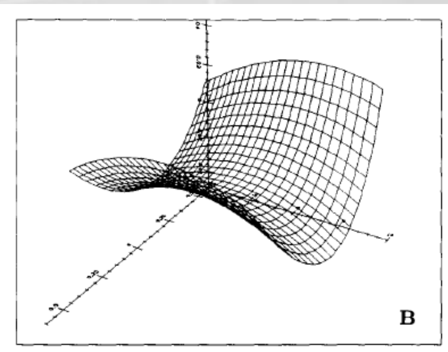
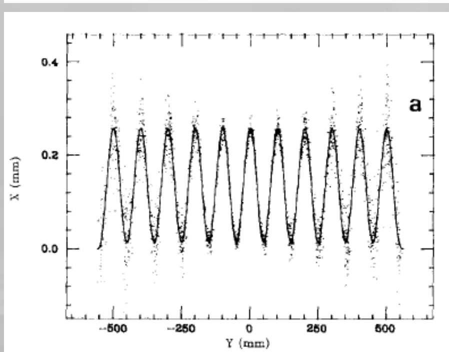
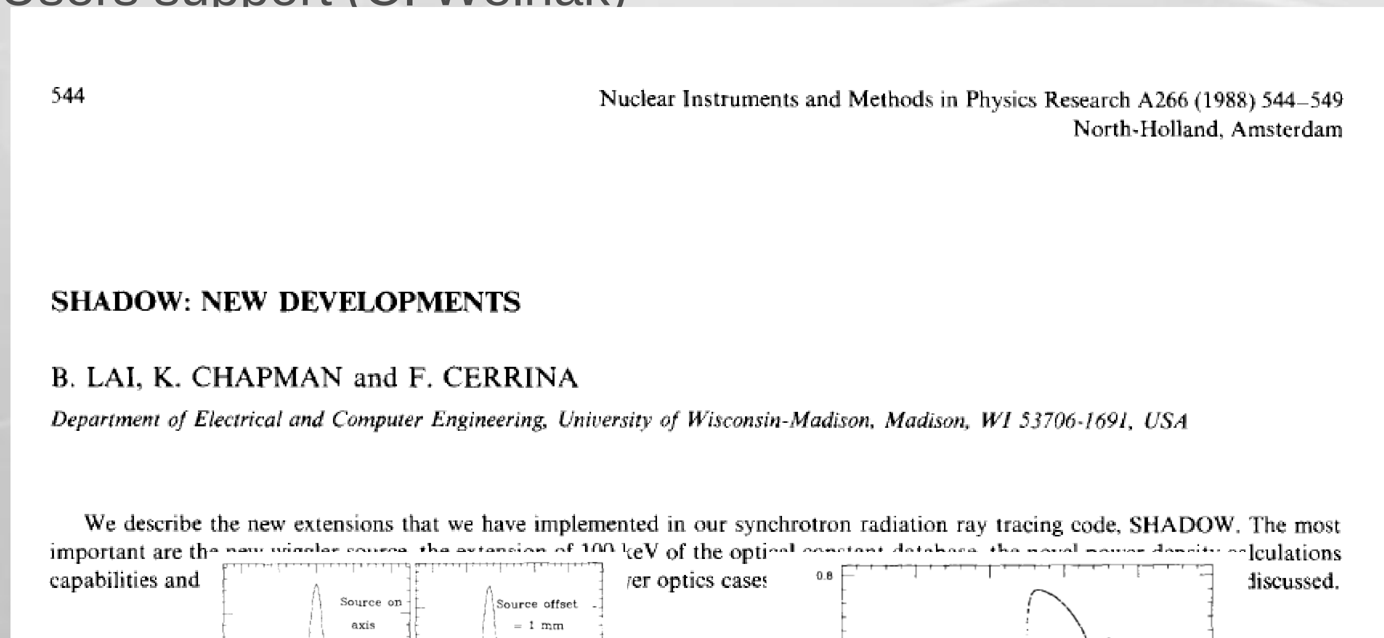


Fig. 1. Possible choices of toroidal surface regions.





544

Nuclear Instruments and Methods in Physics Research A266 (1988) 544–549
North-Holland, Amsterdam

SHADOW: NEW DEVELOPMENTS

B. LAI, K. CHAPMAN and F. CERRINA

Department of Electrical and Computer Engineering, University of Wisconsin-Madison, Madison, WI 53706-1691, USA

We describe the new extensions that we have implemented in our synchrotron radiation ray tracing code, SHADOW. The most important are the new wiggler source, the extension of 100 keV of the optical constant database, the novel power density calculations capabilities and ... yer optics cases ... discussed.

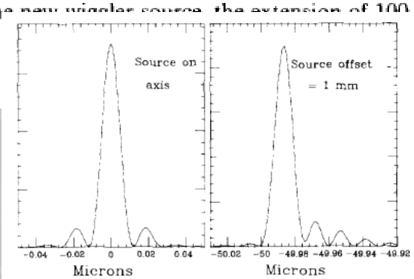
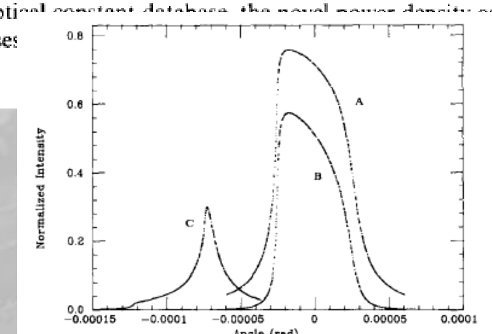


Fig. 7. Diffracted image formed by a Schwartzschild objective at 44 Å. All the physical parameters, such as phase shifts, multilayer reflectivities, and diffraction, are taken in account.



~1990 The switch to UNIX

New machines enter in the scientific computing market. Unix workstations: Digital/Ultrix, Sun, HP.

UNIX version prepared by Mumit Khan

Other scattered developments

First version installed at ESRF (1991). Twofold development: Models and Software

Recent developments in SHADOW

/I. Khan, S. Singh, and F. Cerrina
Jniversity of Wisconsin–Madison, 3731 Schneider Drive, Stoughton,

Nuclear Instruments and Methods in Physics Research A 347 (1994) 344–347
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

SHADOW: a synchrotron radiation and X-ray optics simulation tool

C. Welnak *, G.J. Chen, F. Cerrina
Center for X-ray Lithography, University of Wisconsin – Madison, 3731 Schneider Drive, Stoughton, WI 53589, USA

Nuclear Instruments and Methods in Physics Research A 347 (1994) 407–411
North-Holland

INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

Ray-tracing of X-ray focusing capillaries

Guan-Jye Chen [a,*], F. Cerrina [a], Karl F. Voss [b], K. Hyde Kim [b], Frederick C. Brown [b]

This article should be cited as Rev. Sci. Instrum. **67**, 3355 (1996).

Multilayer roughness and image formation in the Schwarzschild objective

S. Singh, H. Solak, and F. Cerrina
University of Wisconsin, 3731 Schneider Drive, Stoughton, WI 53589

(Presented on 19 October 1995)

Nuclear Instruments and Methods in Physics Research A 347 (1994) 238–243
North-Holland

IN PHYSICS RESEARCH Section A

Applications of faceted mirrors to X-ray lithography beamlines

Guan-Jye Chen, J.Z.Y. Guo, F. Cerrina
Center for X-Ray Lithography and Department of Electrical and Computer Engineering, University of Wisconsin-Madison, 3731 Schneider Drive, Stoughton, WI 53589, USA

The contribution of the ESRF: I Optics models

Asymmetrically cut crystals for synchrotron radiation monochromators

M. Sánchez del Río
European Synchrotron Radiation Facility, B.P. 220, 38043 Grenoble Cedex, France

F. Cerrina
Center for X-ray Lithography, 3731 Schneider Drive, Stoughton, Wisconsin 53589

936 Rev. Sci. Instrum. 63 (1), January 1992 0034-6748/92/010936-05$02.00 © 1992 American Institute of Physics 936

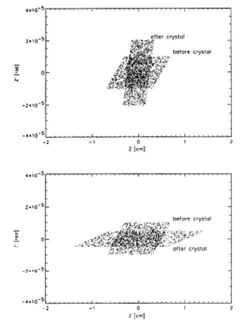


FIG. 3. Change in phase space of the photon beam of 8035 eV produced by an Si(111) asymmetrically cut crystal of $\alpha = 5$ deg (top) and $\alpha = -5$ deg (bottom). A linear and divergent source in Z direction has been considered.

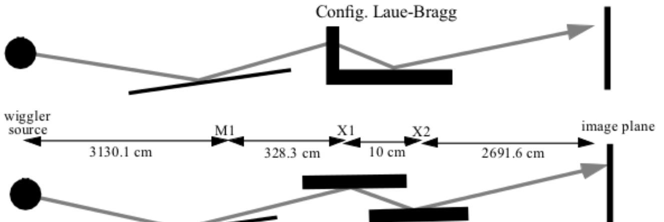
Nuclear Instruments and Methods in Physics Research A 347 (1994) 338–343
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

See: ex23_crystal_laue.ws

Modeling perfect crystals in transmission geometry for synchrotron radiation monochromator design

M. Sánchez del Río [a,*], C. Ferrero [a], G-J. Chen [b], F. Cerrina [b]
[a] *European Synchrotron Radiation Facility, BP 220, 30043 Grenoble Cedex, France*
[b] *Center for X-ray Lithography, 3731 Schneider Drive, Stoughton, WI 53589, USA*



Nuclear Instruments and Methods in Physics Research A319 (1992) 170–177
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

See: ex20b_slopeerrors.ws

Waviness effects in ray-tracing of "real" optical surfaces

M. Sánchez del Río [a] and A. Marcelli [b]
[a] *European Synchrotron Radiation Facility, B.P. 220, 38043 Grenoble Cedex, France*
[b] *INFN Laboratori Nazionali di Frascati, CP 13, 00044 Frascati, Italy*

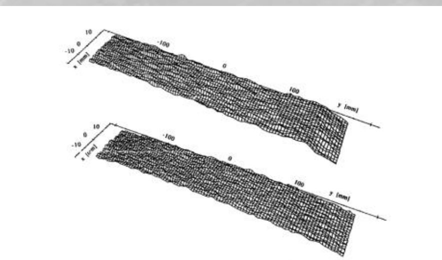
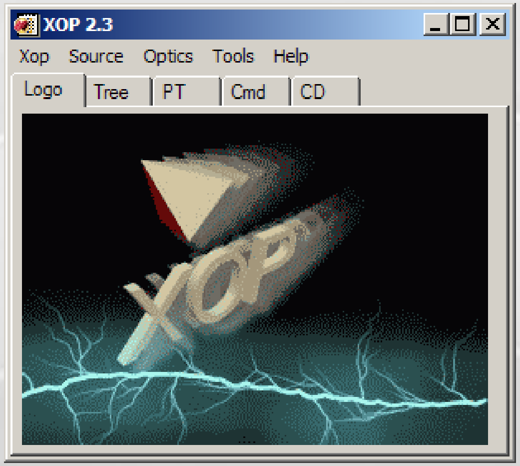


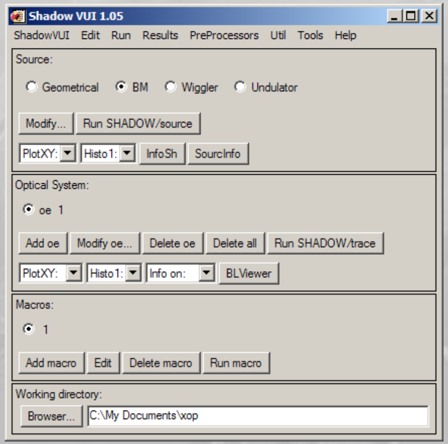
Fig. 3. Simulated waviness of optical surfaces with 0.4" slope error. The surface A has been generated considering $n_{max} = 32$, $C_n = 1$, $y_n^0 = 0$, and $f_n = 0.1$, $f_0 = f_1 = 0$. For surface B, $n_{max} = 56$ and the remaining parameters have been changed in a more complicated way. The total length of each surface is 350 mm and the width is 30 mm. The vertical length is not scaled.

The contribution of the ESRF: II Software



- Need of tools « before » using SHADOW => XOP
  - XOP
    - quick calculations (synchrotron spectra, reflectivities, rocking curves, attenuation coeffs. etc.)
    - generic data visualization and analysis
    - specific applications ("extensions")
    - Collaboration work ESRF (M Sanchez del Rio)-APS (Roger Dejus)
    - Freely available to users (>10 years)
    - Large user community (>400 users in tens of laboratories)
    - Multiplatform (Windows, Unix, MacOSX)
    - Written in IDL (using Fortran and C modules). Embedded license

- Improve the « speed » of interaction with user (more than speed of calculation) => ShadowVUI
- Spreading the use of SHADOW and related tools at ESRF and outside
- SHADOW code « frozen », suffering from oldness
  - ShadowVUI: interface that uses the standard SHADOW calculation engine
    - "Easy" to use
    - High performance graphics
    - Macro language
    - Tutorials
    - BLViewer

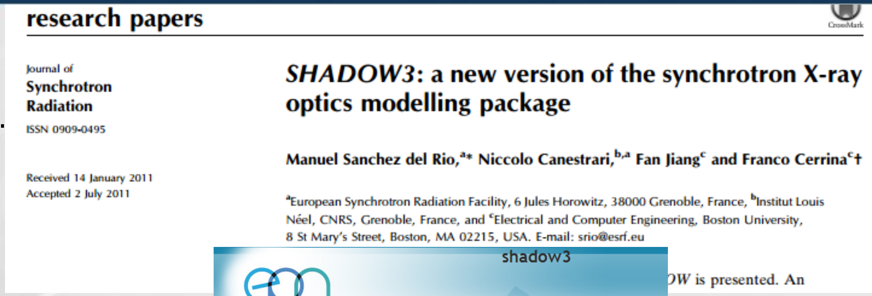


2008-now

- 1998-2008 Reduced interest in Optics simulations
- ESRF Upgrade programme 2008-2017
- Double implication
  - New trends in optics: CRL, transfocators, nanofocusing, partial coherence
  - Need to evolve following the new available computer environments
- Actions
  - Urgent renewal of SHADOW
  - Need of complementarities (other codes)
  - Consolidating collaborations
  - Software development programme

SHADOW3

- Renew the internals
- Prepare the framework for the "new challenges"
- Fully compatible with existing version (only Kernel, no graphics, menu, etc.
- Maintain Shadow's flavor: SHADOW users will feel "comfortable" with it
- Remove present limitations in:
  - Dimensions (number of rays, optical elements, mesh points, etc.)
  - Old programming techniques (Common blocks, etc).
- API (C, Python, IDL)
- Transform f77 to f95 and full use of modular structure
- Supported for Windows, Linux and MacOS
- Full compatibility of ShadowVUI
- New "basic" graphics (gnuplot)
- In conclusion: first a lot of cleaning and modernisation of the code (mostly done, but still thinks to cleaned), then (on going), upgrade physical models)


research papers

Journal of Synchrotron Radiation

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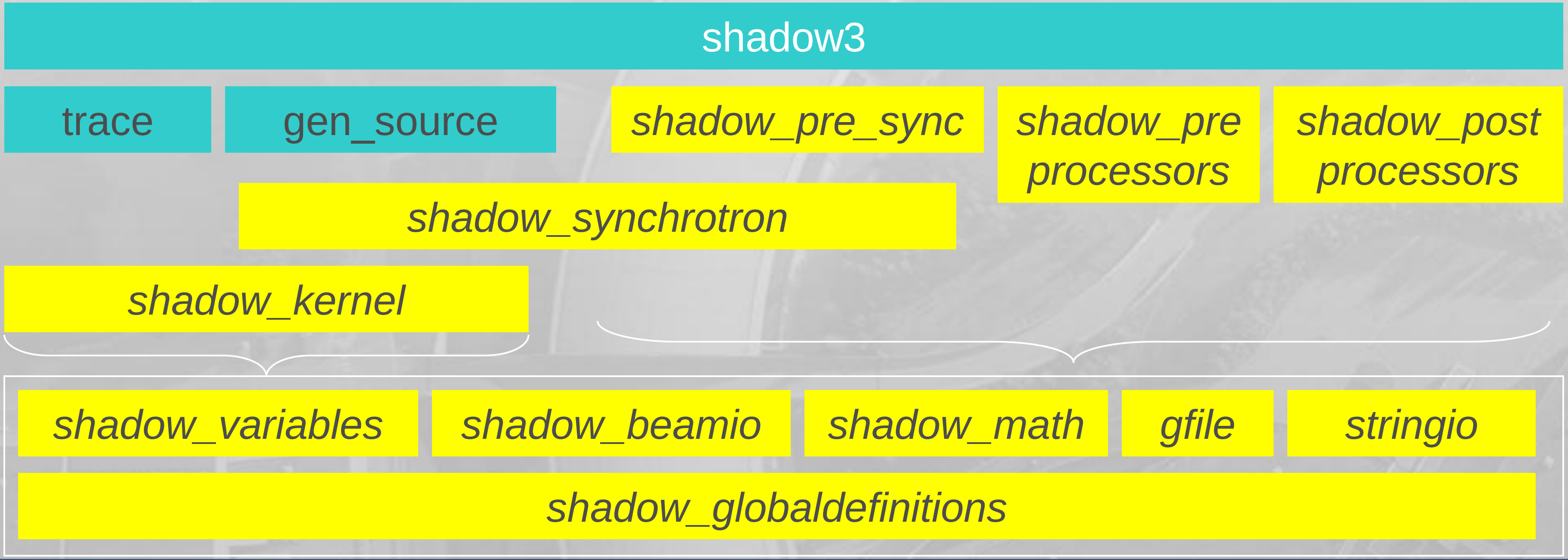
Accepted 2 July 2011

SHADOW3: a new version of the synchrotron X-ray optics modelling package

Manuel Sanchez del Rio,[a*] Niccolo Canestrari,[b,a] Fan Jiang[c] and Franco Cerrina[c†]

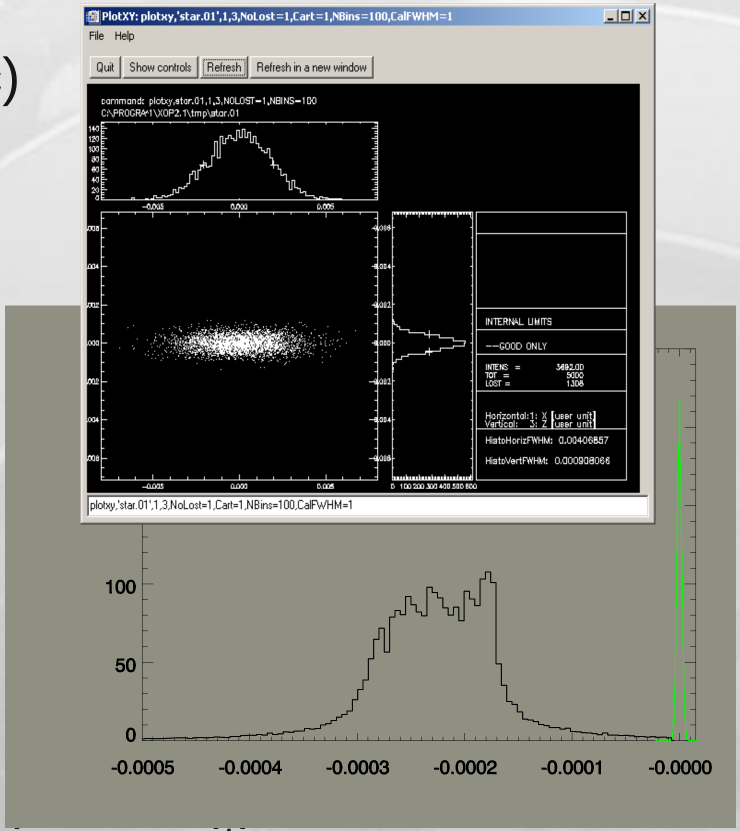
[a]European Synchrotron Radiation Facility, 6 Jules Horowitz, 38000 Grenoble, France, [b]Institut Louis Néel, CNRS, Grenoble, France, and [c]Electrical and Computer Engineering, Boston University, 8 St Mary's Street, Boston, MA 02215, USA. E-mail: srio@esrf.eu

...OW is presented. An



What can SHADOW do?

- Beam cross sections (focal spot, PSF, etc)
    - source characteristics (dimensions, depth, emittances)
    - vignetting (apertures, dimension of oe's)
    - effect of mirror shape: aberrations, errors…
    - effect of mirror imperfections (slope errors, roughness?)
    - dump of intensity because of reflectivity of elements

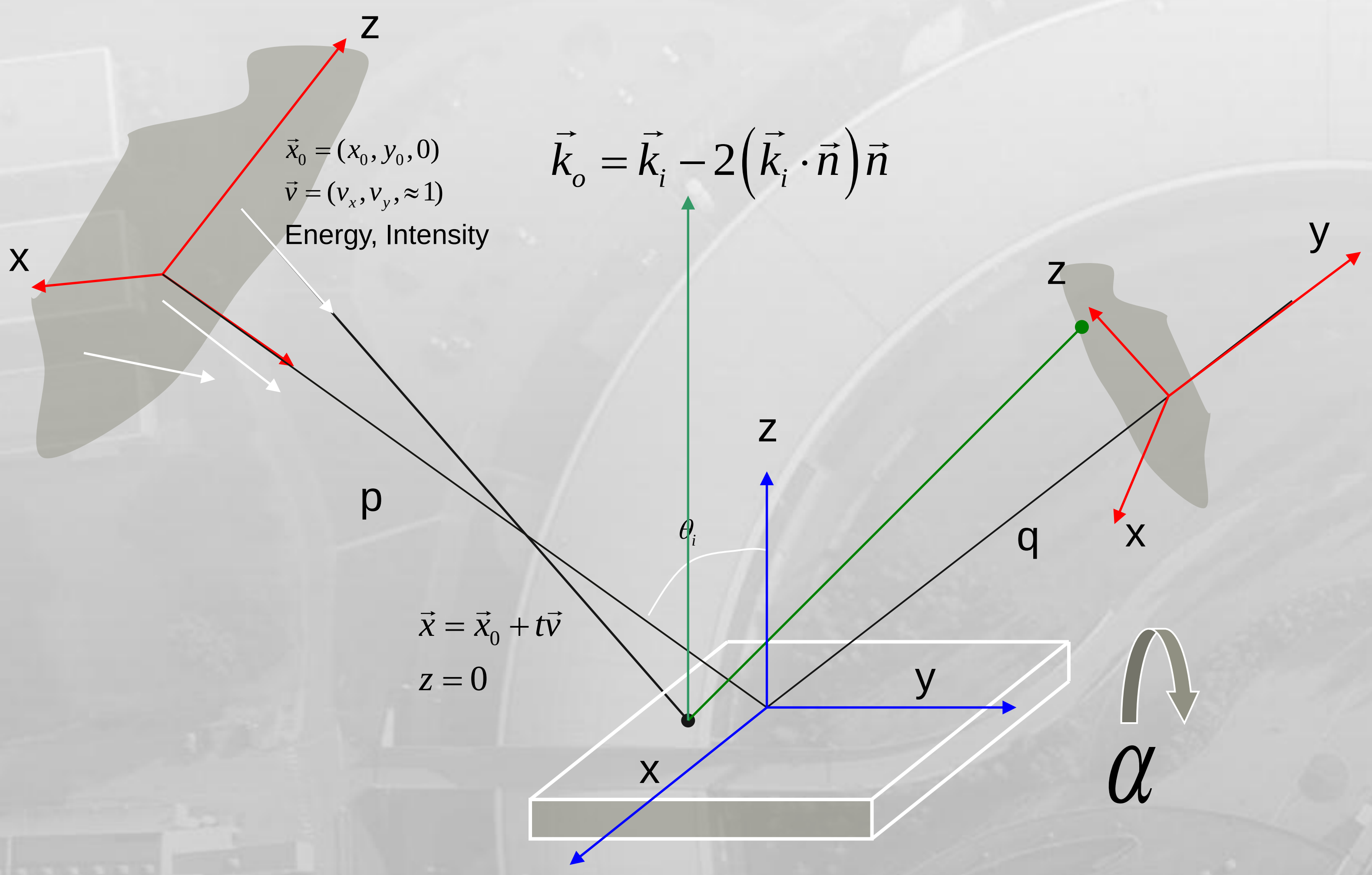


- Energy resolution

- Flux and power (number of photons at a given position, absorbed/transmitted power, etc)

- Other aspects? (polarization, coherence effects, etc.)

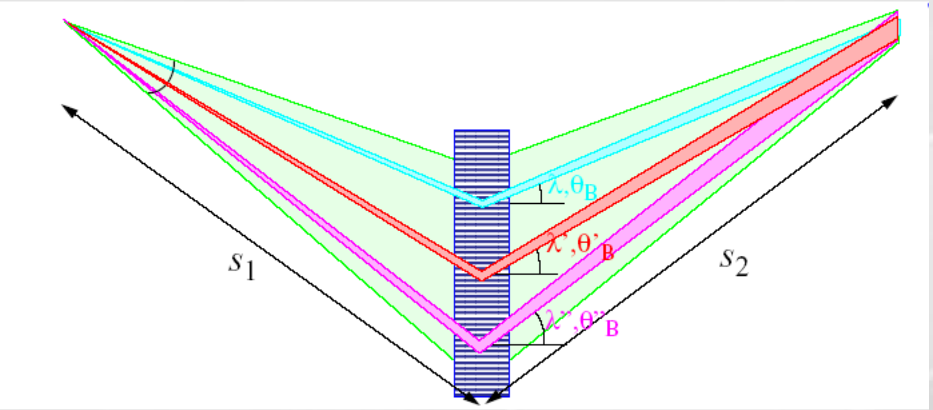
How SHADOW works?



Examples of applications

- Crystals
- Gratings
- Mirrors

*Pseudo*focusing with *plane* Laue crystal



Focusing characteristics of diamond crystal x-ray monochromators. An experimental and theoretical comparison [a)]

M. Sánchez del Río and G. Grübel
European Synchrotron Radiation Facility, BP220 38043 Grenoble Cedex 9, France

J. Als-Nielsen
European Synchrotron Radiation Facility, BP220 38043 Grenoble Cedex 9, France
and Risö National Laboratory, Roskilde, Denmark

M. Nielsen
Risö National Laboratory, Roskilde, Denmark

(Received 21 July 1994; accepted for publication

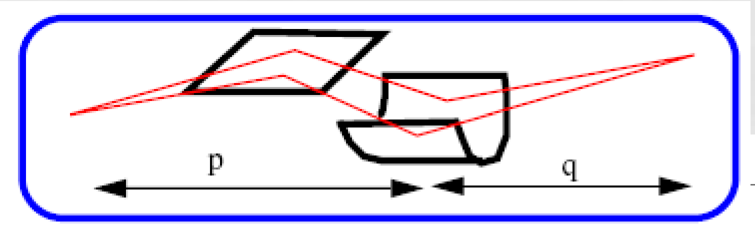
N·H
ELSEVIER
Nuclear Instruments and Methods in Physics Research B 94 (1994) 306–318
NIM B
Beam Interactions with Materials & Atoms

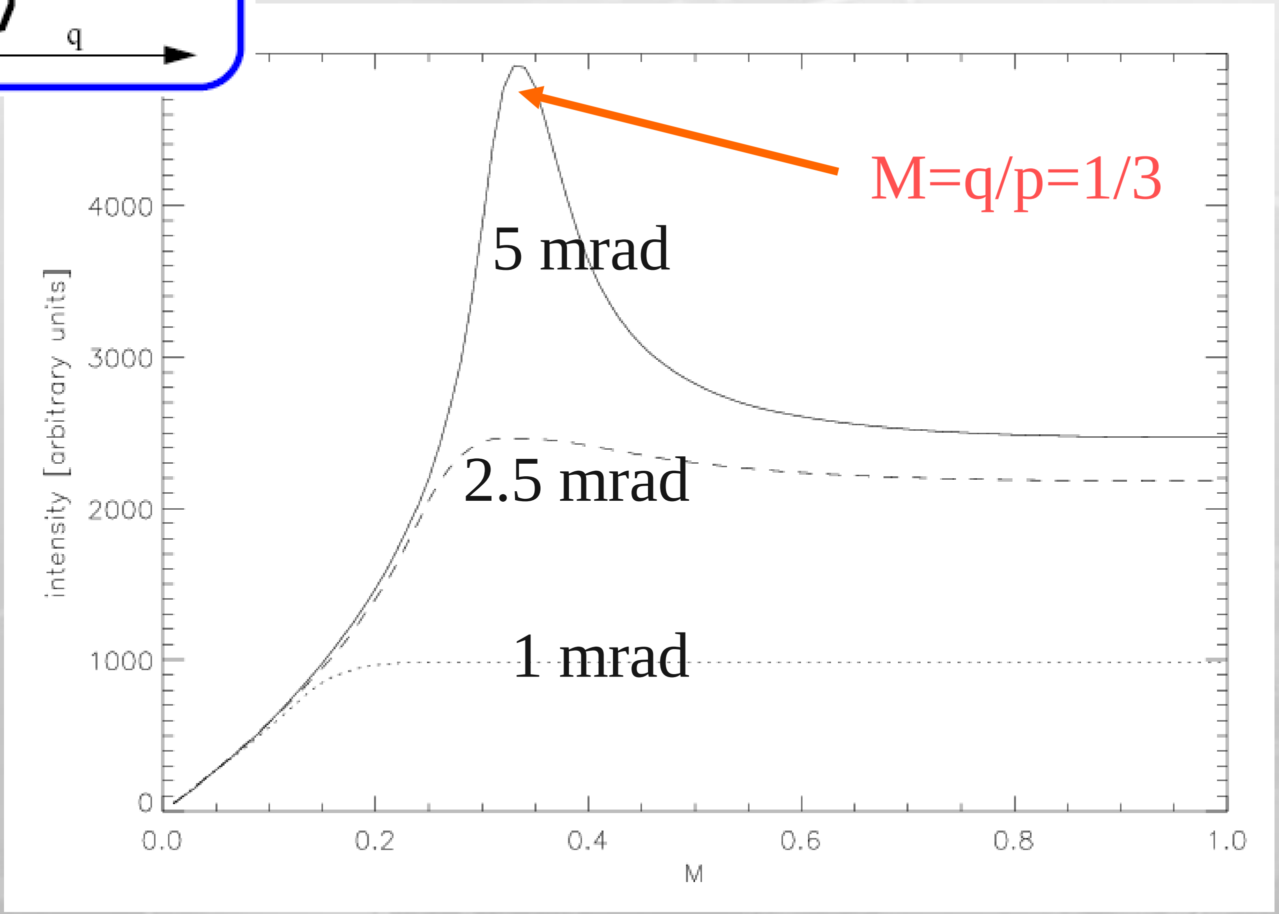
Multiple station beamline at an undulator X-ray source

J. Als-Nielsen [a,b,*], A.K. Freund [b], G. Grübel [b], J. Linderholm [a,b], M. Nielsen [a], M. Sanchez del Rio [b], J.P.F. Sellschop [c]

See: ex23_crystal_laue.ws

sagittal focusing



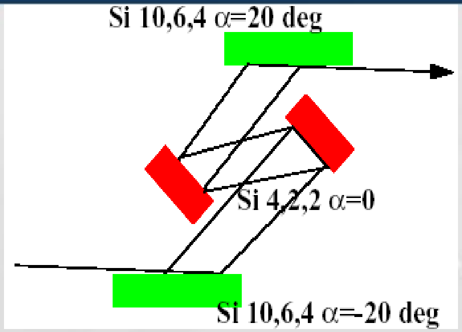


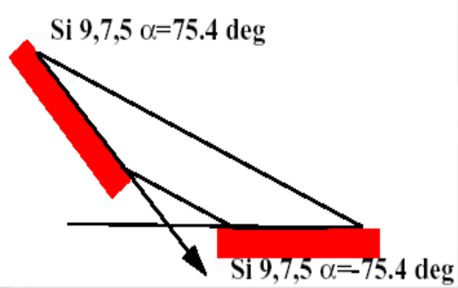
Shape effects:
•Anticlastic curvature
•Cylindrical vs Conic
(Ice&Sparks, JOSA A11 (1994) 1265)

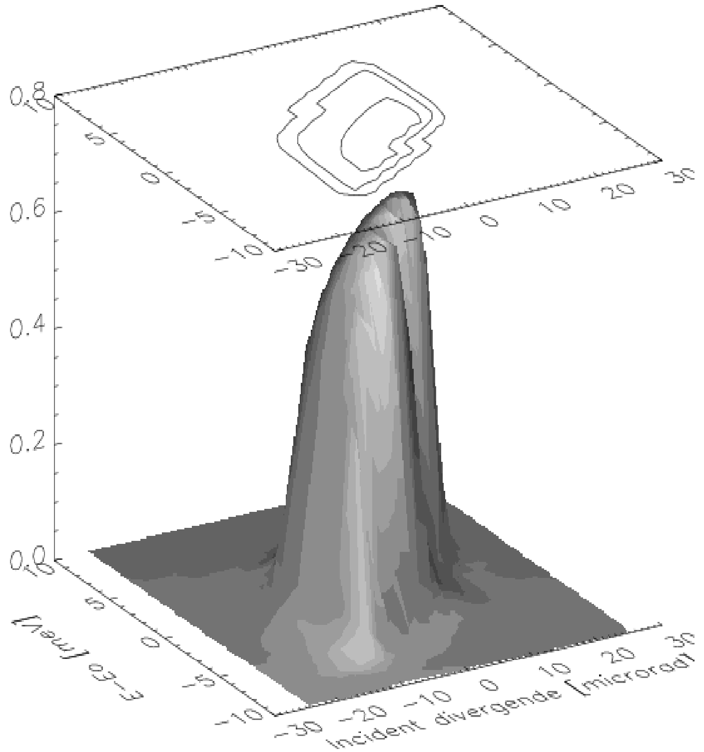
Diffracted beam intensity vs accepted divergence: Sparks & Borie, NIM 172 (1980) 172

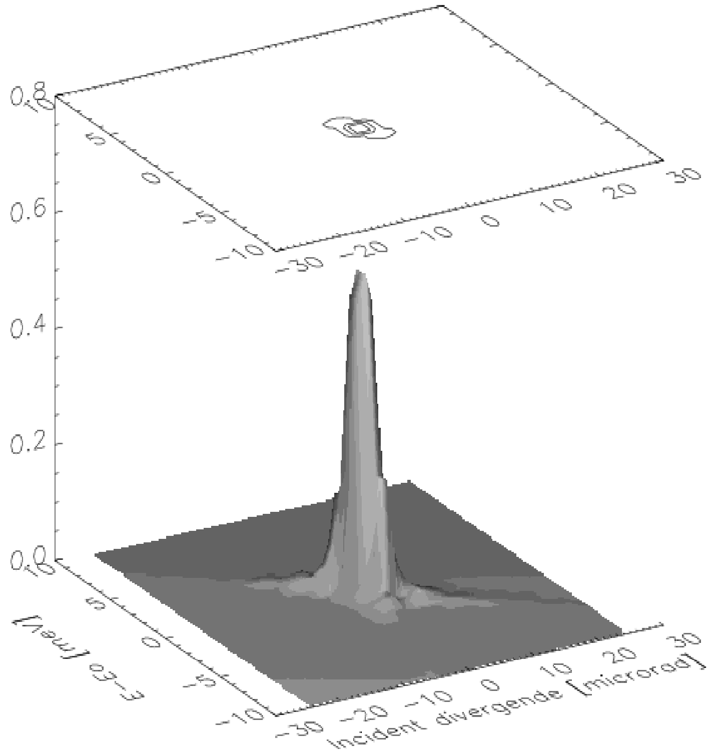
See: ex18b_sagittalfocusing.ws

High resolution monochromators









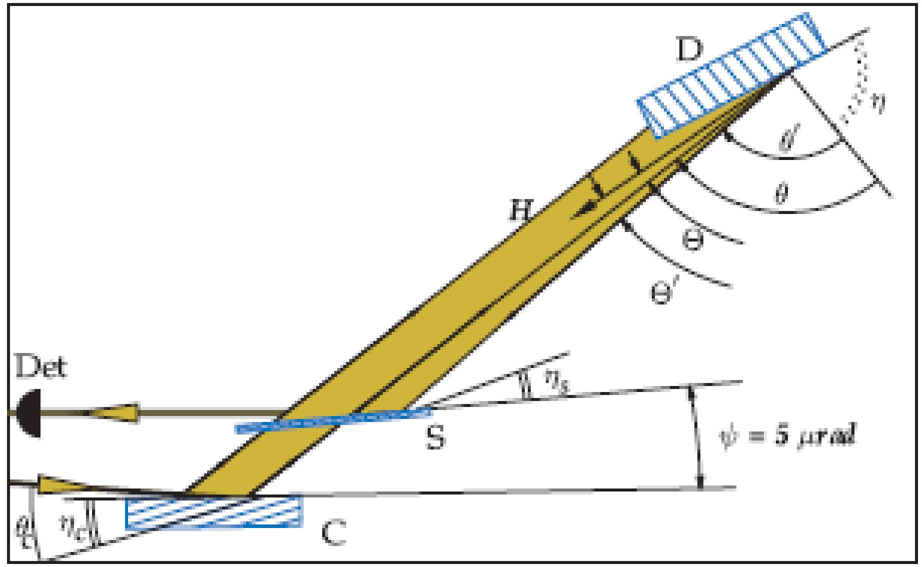
Energy resolution in backscattering

PRL 97, 235502 (2006) PHYSICAL REVIEW LETTERS week ending 8 DECEMBER 2006

X-Ray Bragg Diffraction in Asymmetric Backscattering Geometry

Yu. V. Shvyd'ko*
Advanced Photon Source, Argonne National Laboratory, A
M. Lerche
University of Illinois at Urbana-Champaign, Urbana
Advanced Photon Source, Argonne National Laboratory, A
U. Kuetgens
Physikalisch-Technische Bundesanstalt (PTB), Braunsch
H. D. Rüter
Institut für Experimentalphysik, Universität Hambu
A. Alatas and J. Zhao
Advanced Photon Source, Argonne National Laboratory, A
(Received 9 May 2006; published 8 Dece

We observe three effects in the Bragg diffraction of x rays in t metrically cut crystals. First, exact Bragg backscattering takes plac flecting atomic planes. Second, a well-collimated (≃1 μrad) beam i tion into a strongly divergent beam (230 μrad) with reflection angle effect of angular dispersion. The asymmetrically cut crystal thus beh an incident collimated polychromatic beam. The dispersion rate is ≃ reflections accompanying Bragg backreflection are suppressed. Thes for monochromatization of x rays not limited by the intrinsic width of the Bragg reflection.



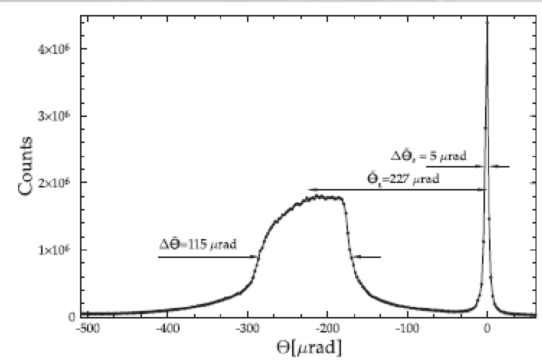
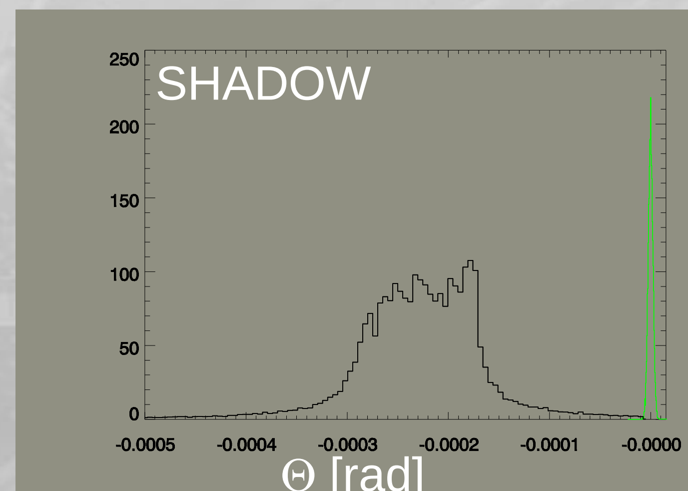


FIG. 4. Bragg reflectivity from crystal *D* of 9.1315 keV x rays, exactly backwards, as a function of the angle of incidence $\Theta = \pi/2 - \theta$ to the reflecting atomic planes.

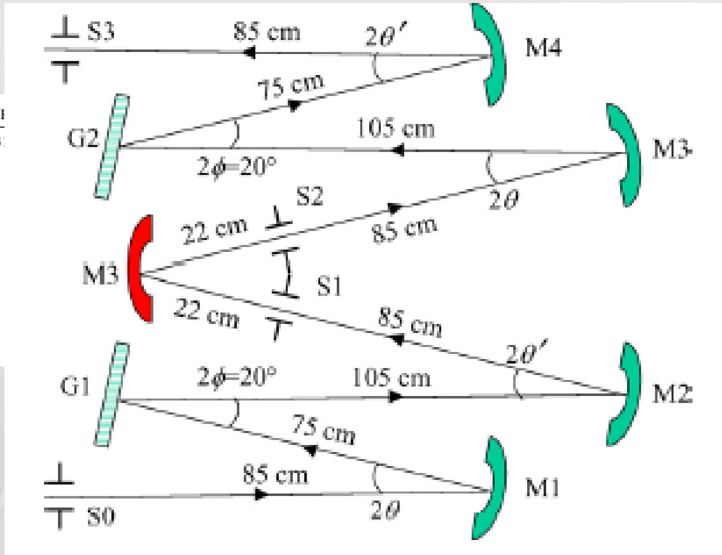


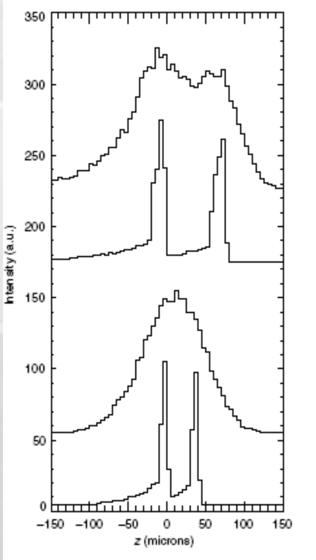
gratings

Institute of Physics Publishing
Phys. Scr. 73 (2006) 499–505 doi:10.1088/003

Computer modelling of the optics of a dispersive Raman spectrometer

M Sánchez del Río[1], E Haro-Poniatowski and M Picquart





Journal of
Synchrotron

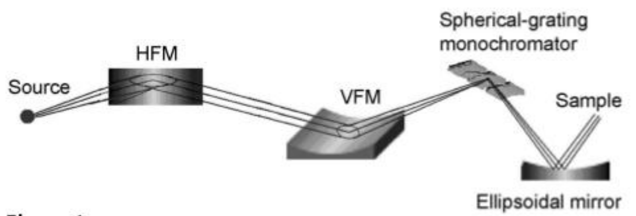


Figure 1
D09 beamline optical components layout.

2010
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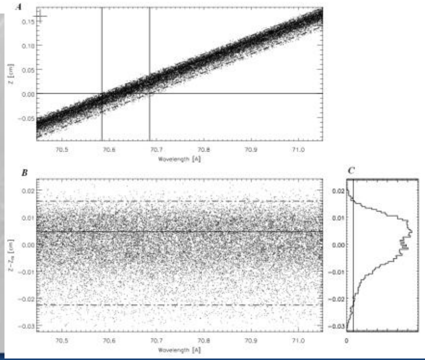
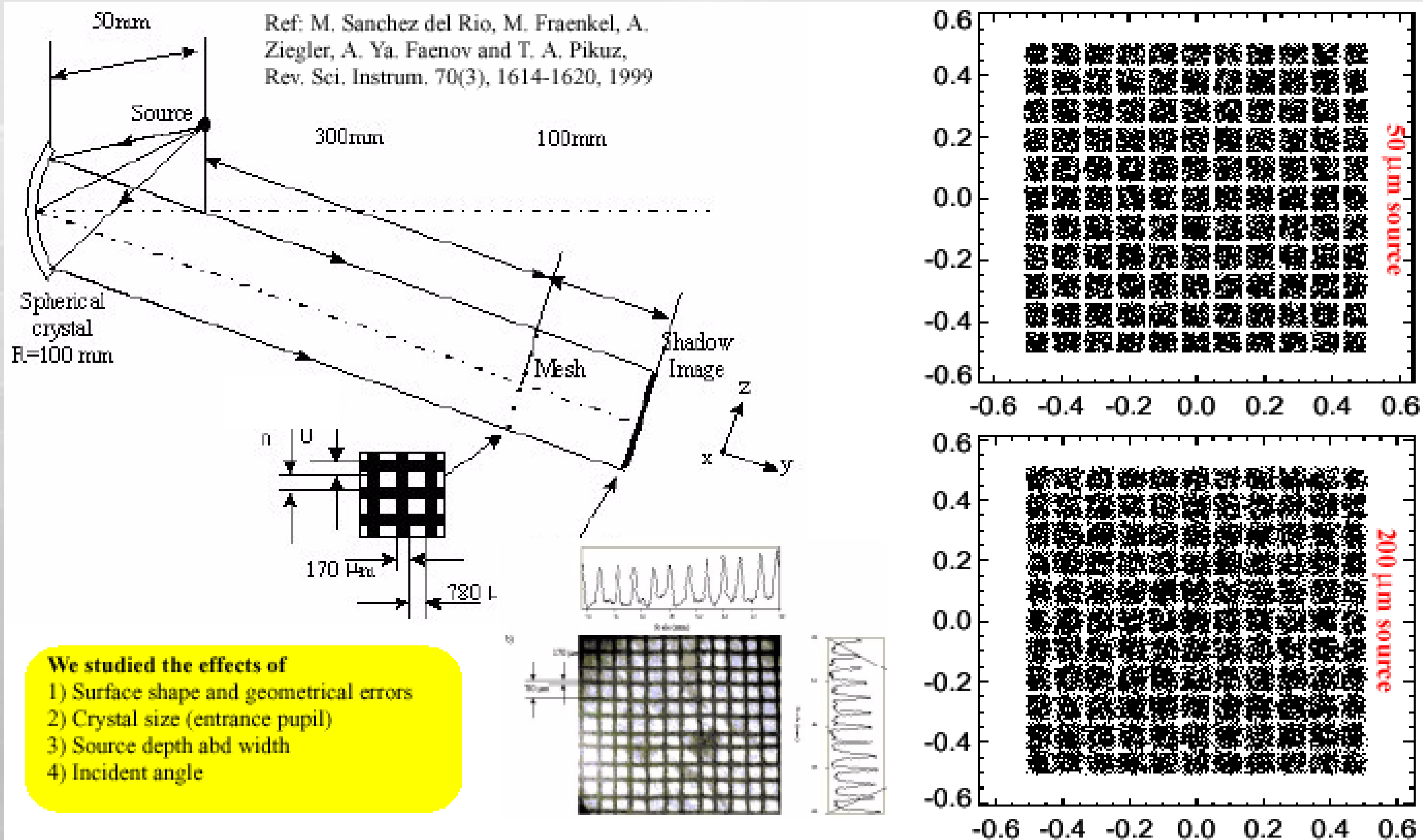
Geometrical layout and optics modelling of the surface science beamline station at the SESAME synchrotron radiation facility

Wa'el Salah[a,b]* and Manuel Sanchez del Rio[c]



See: example_respower.ws

Vignetting/Spatial resolution



See: example_grid_pattern.ws

Using LTP data (slopes/profiles)

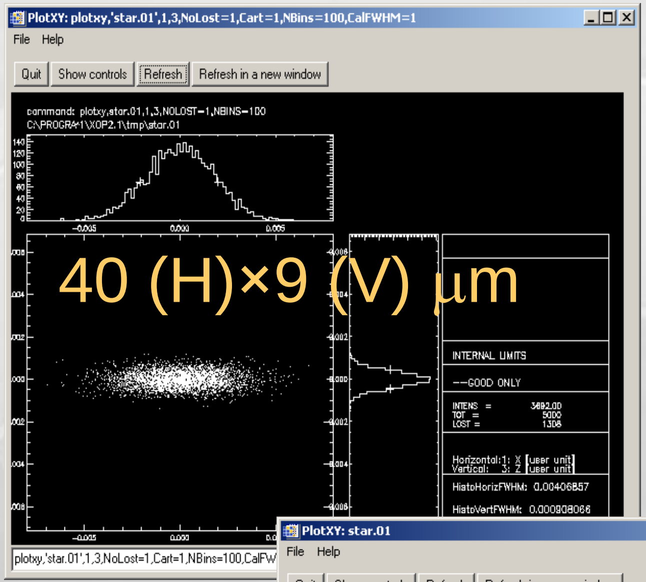
Toroidal mirror M~1/3 (p=31 m, q=10 m q=3.5 mrad)

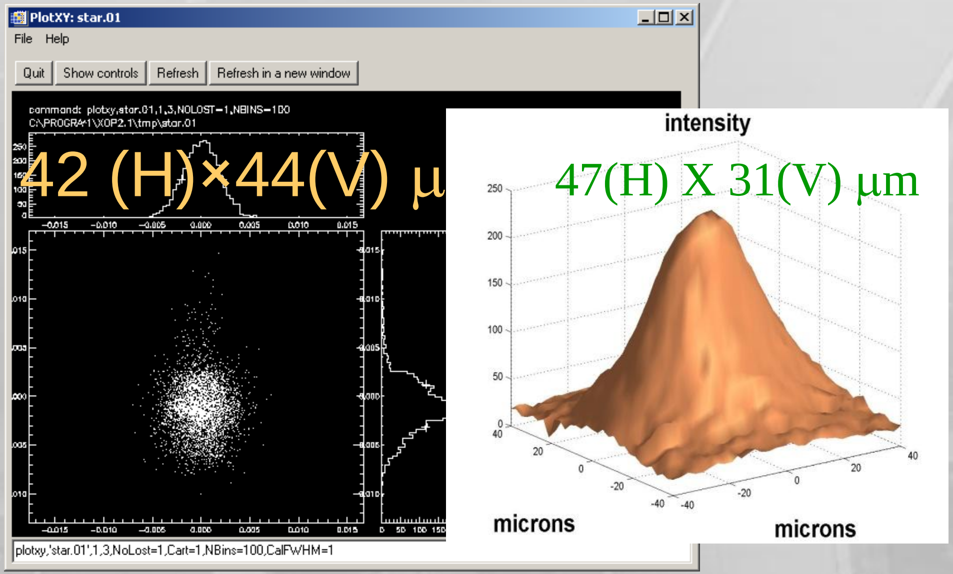
Gaussian source

- Size: 134 (H) × 25 (V) μm² FWHM
- Divergence: 6.8 (H) × 85.1 (V) μrad RMS

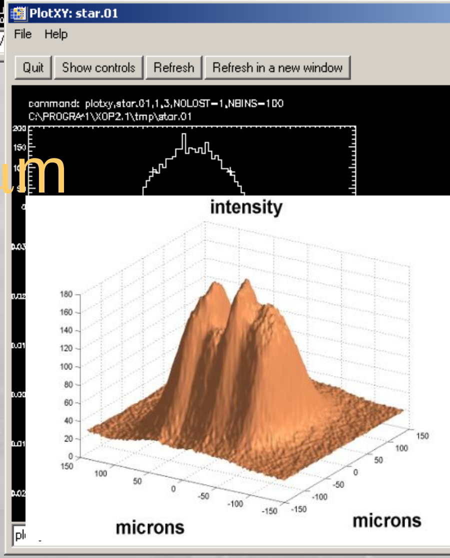
Expected:

- 134/3=45 (H) μm² FWHM
- 25/3=8.3 (V) μm² FWHM





140 ×160 μm

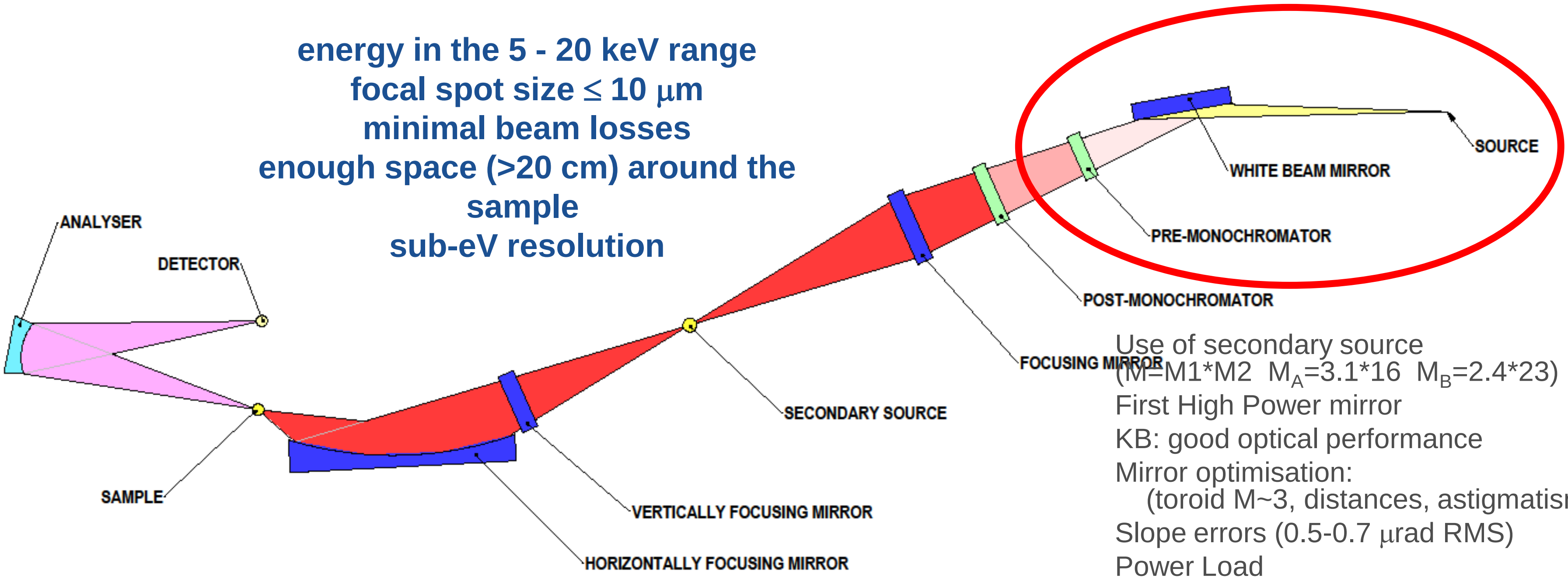


See: macro_metrology_mirror_profile.ws, macro_metrology_hfm_slope.ws

ESRF Upgrade – Examples

- Inelastic scattering UPBL6
- TEXAS ID24
- MASSIF
- Soft X-rays UPBL7

energy in the 5 - 20 keV range
focal spot size ≤ 10 μm
minimal beam losses
enough space (>20 cm) around the sample
sub-eV resolution



- Use of secondary source ($M=M1*M2$ $M_A=3.1*16$ $M_B=2.4*23$)
- First High Power mirror
- KB: good optical performance
- Mirror optimisation:
  (toroid M~3, distances, astigmatism)
- Slope errors (0.5-0.7 μrad RMS)
- Power Load
- Tolerances
- Monochromator(s) optimization

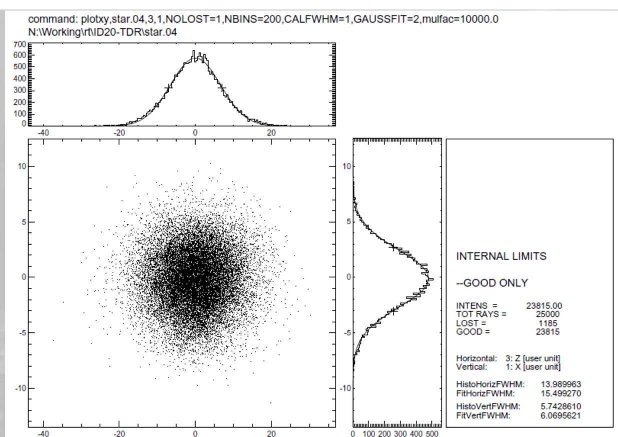
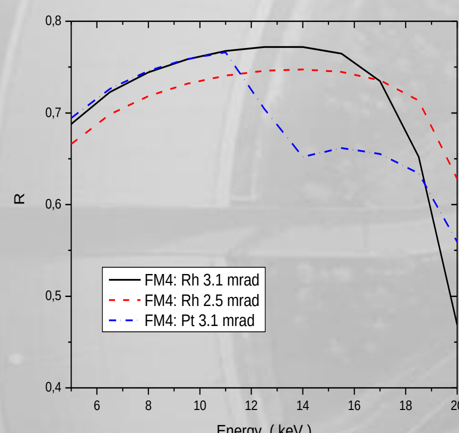
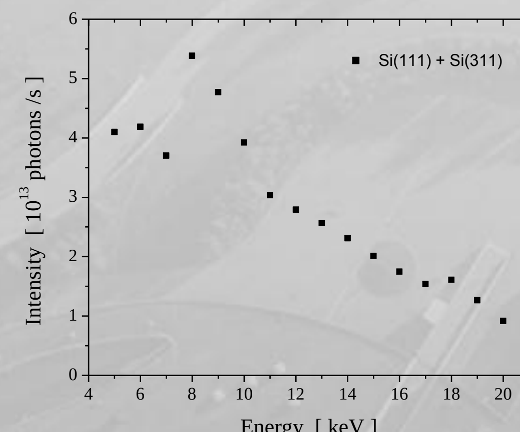
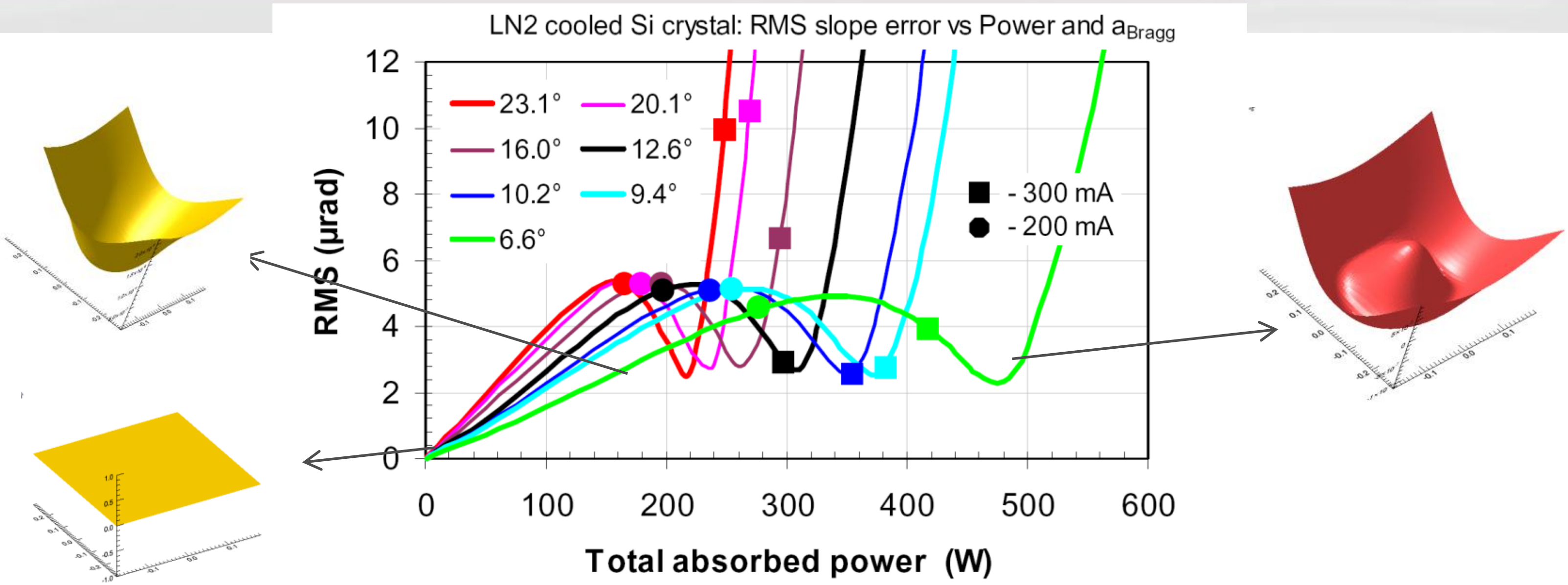


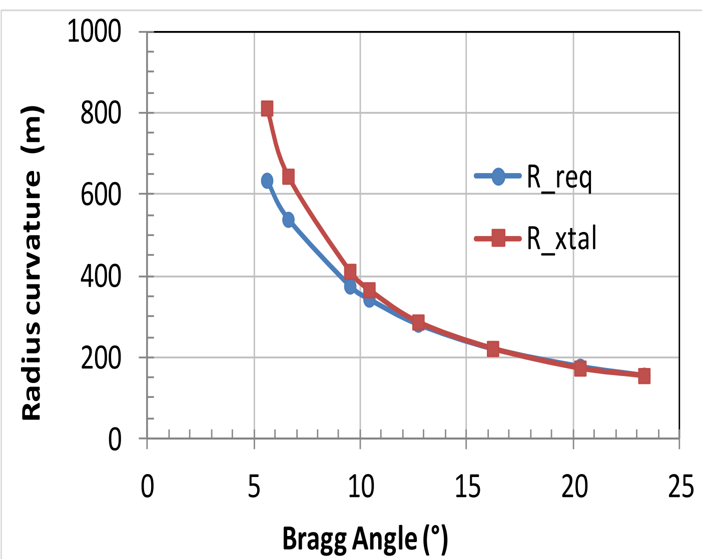
Figure 20: Geometrical contribution (including slope error effects) to the focal spot size at the sample position (optimized design option) on station UPBL06-A. FWHM = 6 x 15 μm^2 V x H.



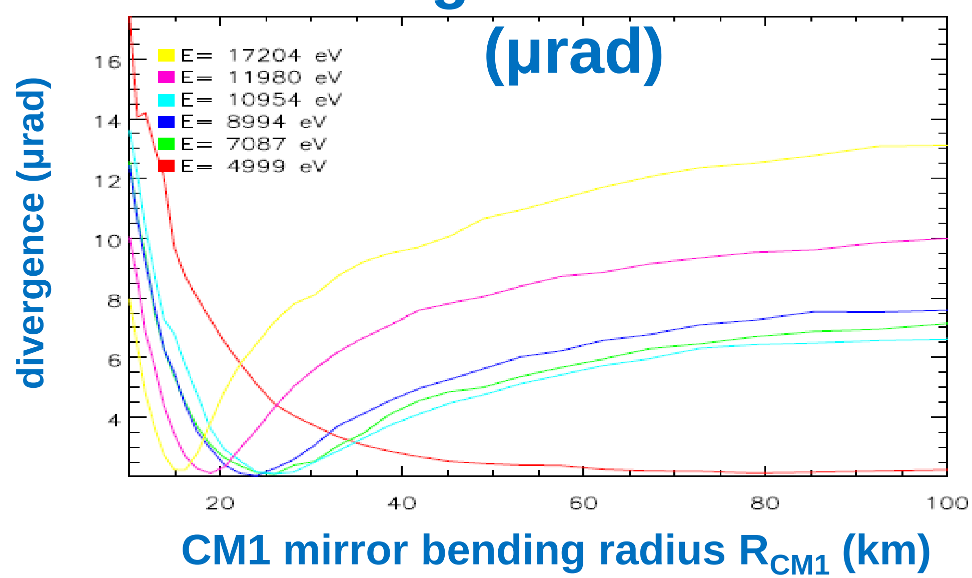


Crystal curvature and white mirror correction





Beam divergence before HRM (µrad)



TEXAS - Hyperbolic LAUE crystals

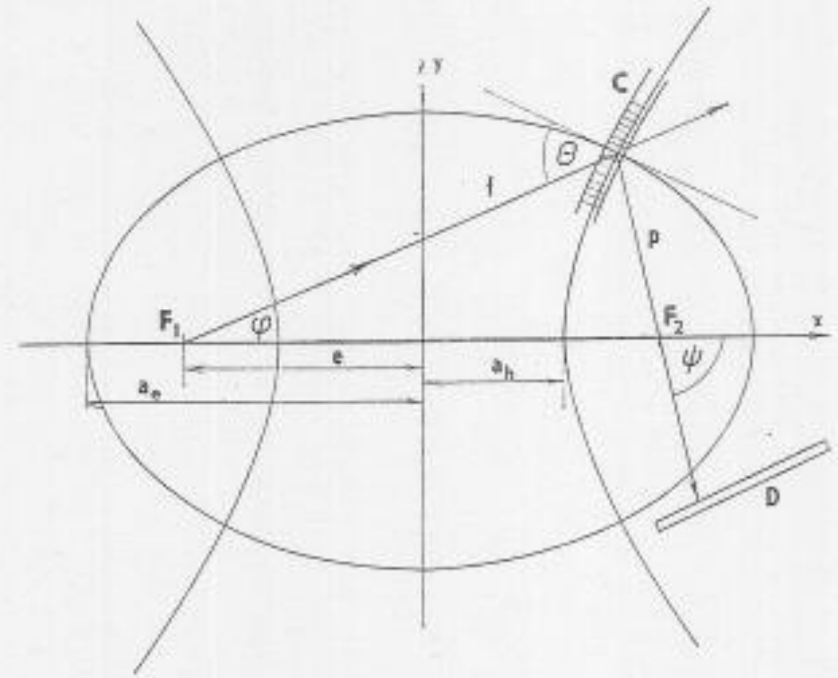


Fig. 1. A schematic drawing of the hyperbolical spectrograph. X-rays with the source in the focus F_1 are, after diffraction on the crystal C, focused into the focus F_2 and registered by the position sensitive detector D.

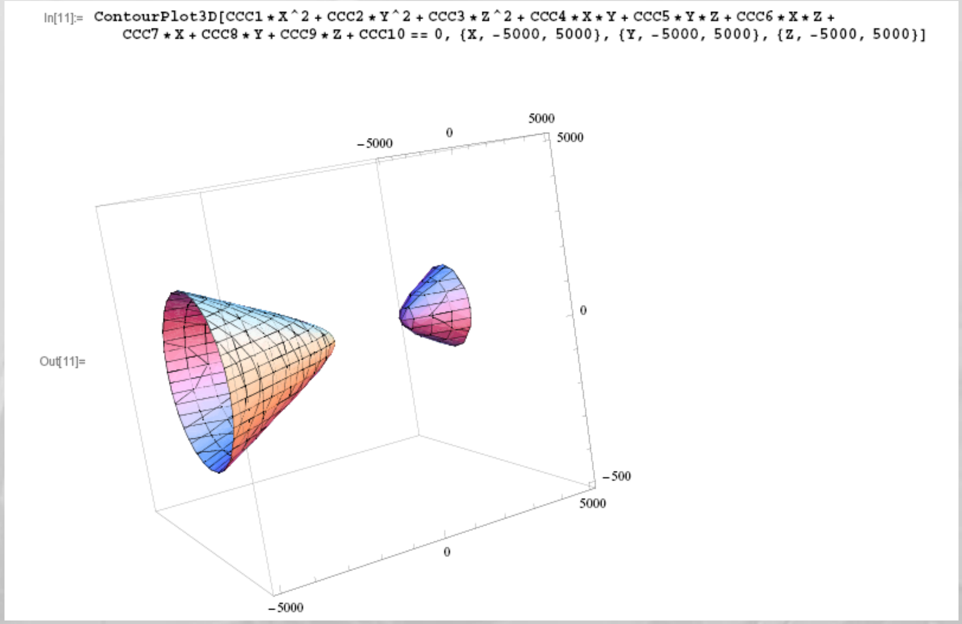
Hrdy has shown that for focusing x-rays using a Laue crystal with atomic planes perpendicular to the crystal surface, the crystal surface must follow an hyperbola.

Hrdy, J., 1990. POLYCHROMATIC FOCUSING OF X-RAYS IN LAUE-CASE DIFFRACTION - (HYPERBOLICAL SPECTROGRAPH). Czechoslovak Journal of Physics 40, 1086-1090.

Conic equation

$$c_0\, x^2 + c_1\, y^2 + c_2\, z^2 + c_3\, xy + c_4\, yz + c_5\, xz + c_6\, x + c_7\, y + c_8\, z + c_9 = 0$$

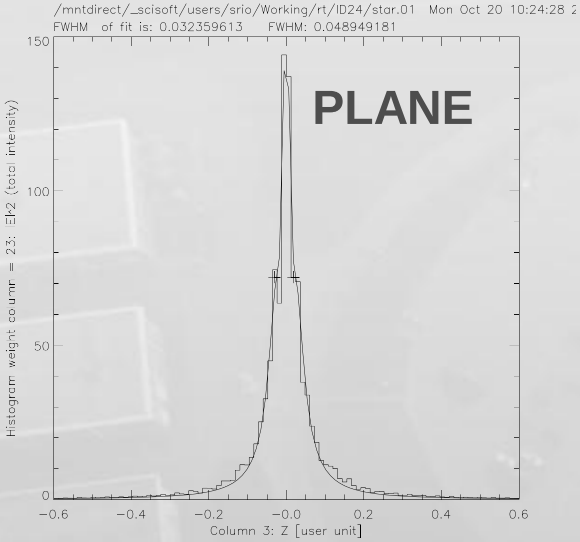
	plane	sphere	ellipse1	ellipse2	hyperbola1	hyperbola2
c0	0	1	2.99E-06	2.99E-06	-3E-06	-3E-06
c1	0	1	2.81E-06	2.81E-06	-2.8E-06	-2.8E-06
c2	0	1	6.01E-07	6.01E-07	3.1E-07	3.1E-07
c3	0	0	0	0	0	0
c4	0	0	-1.3E-06	1.32E-06	-1.6E-06	1.55E-06
c5	0	0	0	0	0	0
c6	0	0	0	0	0	0
c7	0	0	0	0	0	0
c8	-1	476.1324	0.001336	1.34E-03	-0.00145	-0.00145
c9	0	0	0	0	0	0

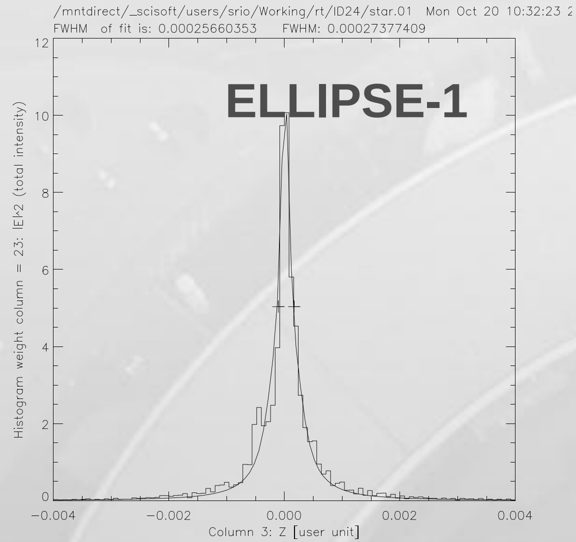


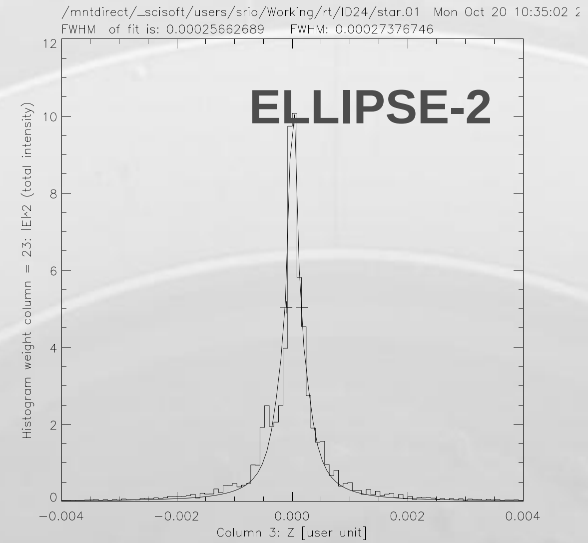
p=2790, q=120 and θ_B=14.3deg.

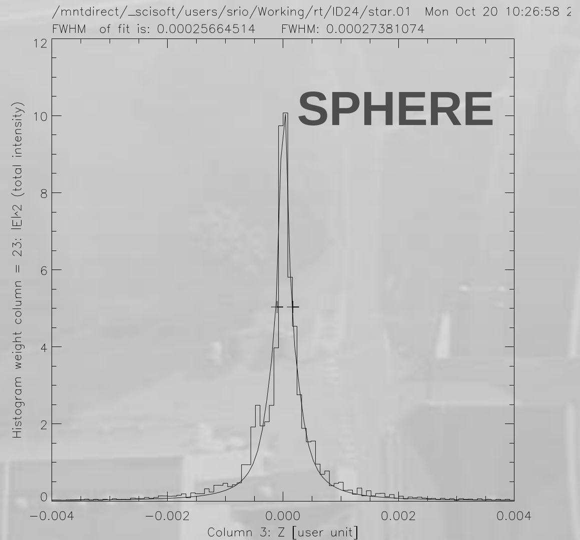
Ellipse2 (Hyperbola2) is obtained from ellipse1 (Ellipse1) by symmetry with respect to the (x,z) plane (i.e., y->-y).

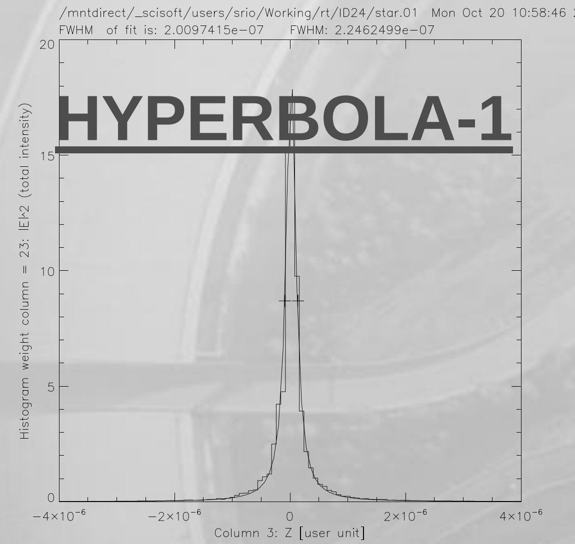
Spot profiles

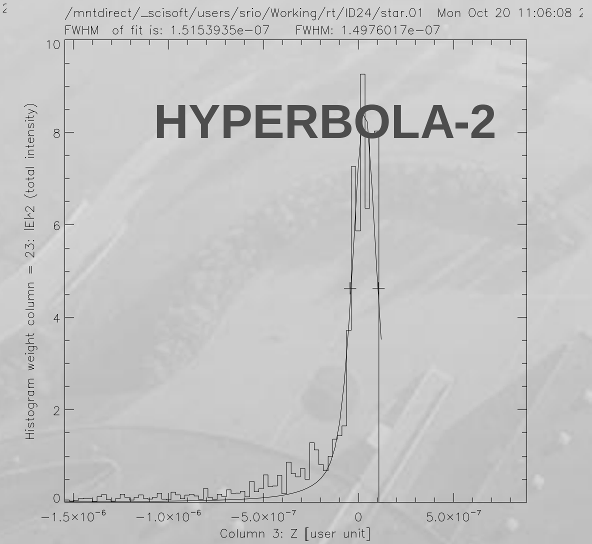




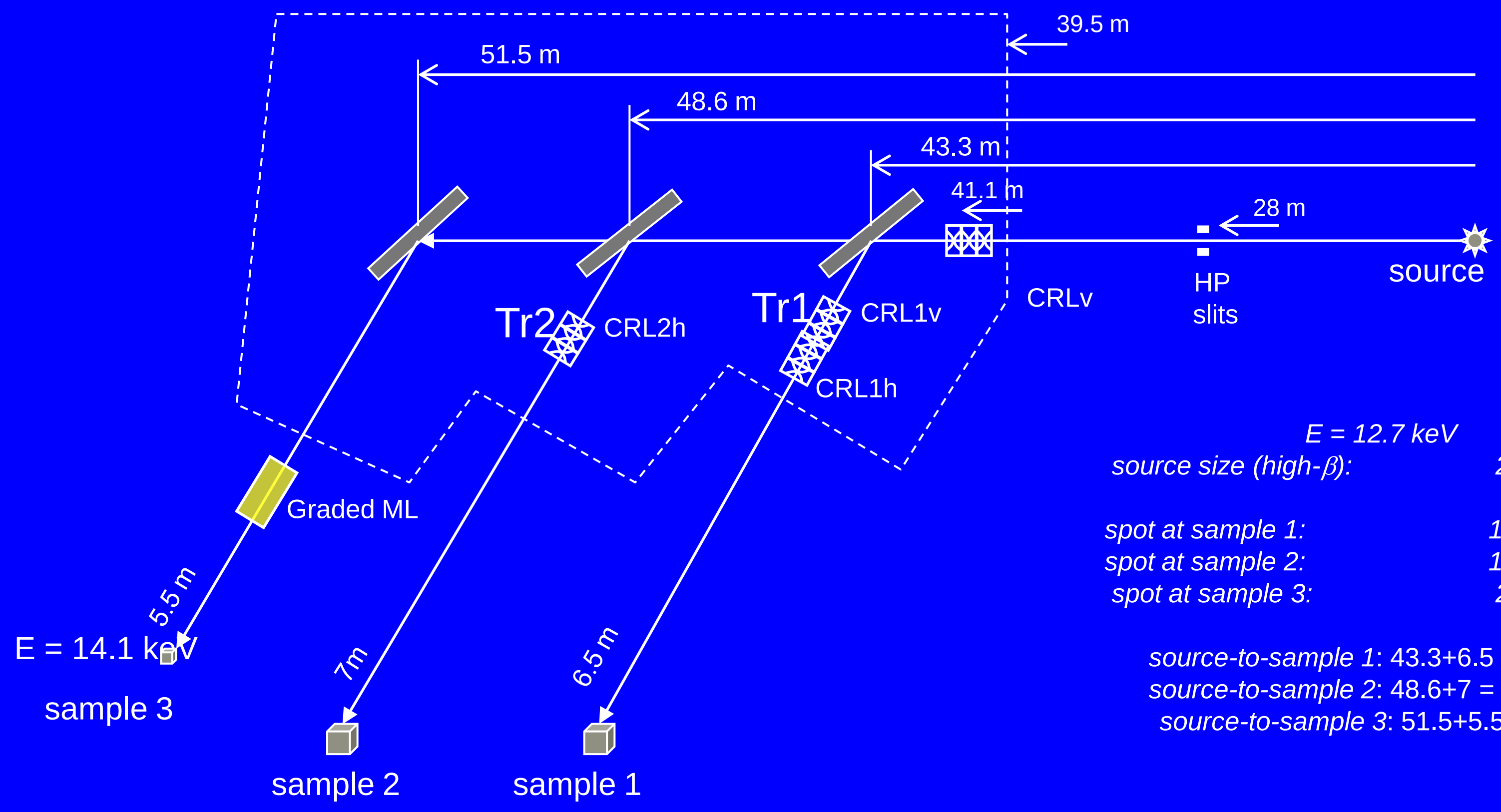








MASSIF layout based on linear CRLs



E = 12.7 keV

source size (high-β): *25 x 900 μm²*

spot at sample 1: *100 x 100 μm²*

spot at sample 2: *100 x 100 μm²*

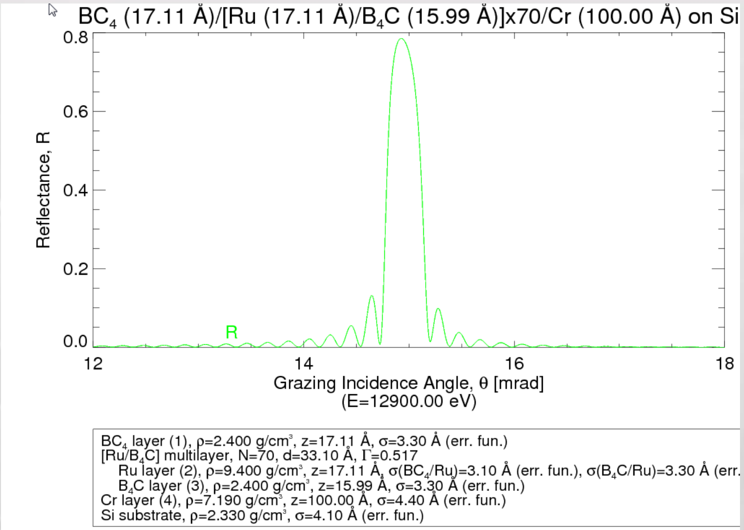
spot at sample 3: *20 x 20 μm²*

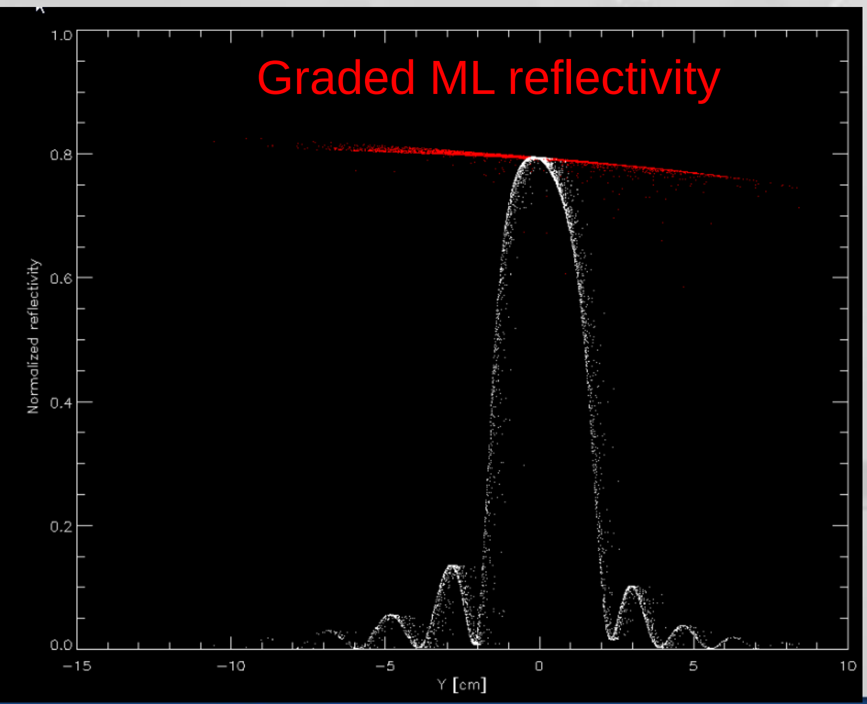
source-to-sample 1: 43.3+6.5 = 49.8 m

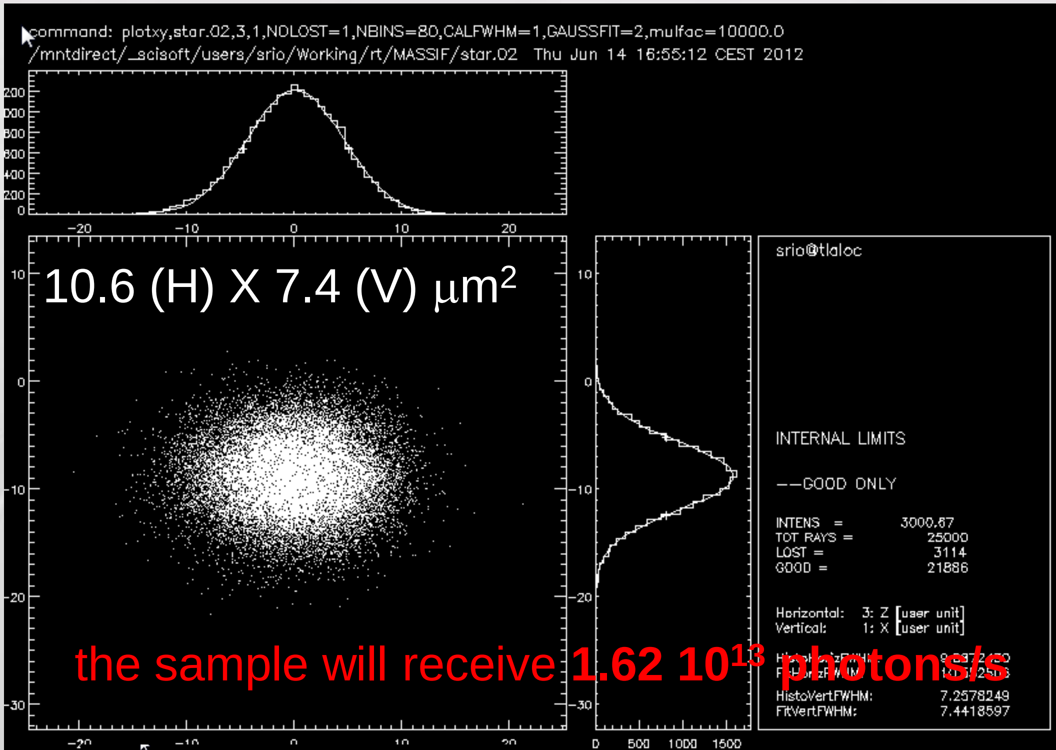
source-to-sample 2: 48.6+7 = 55.6 m

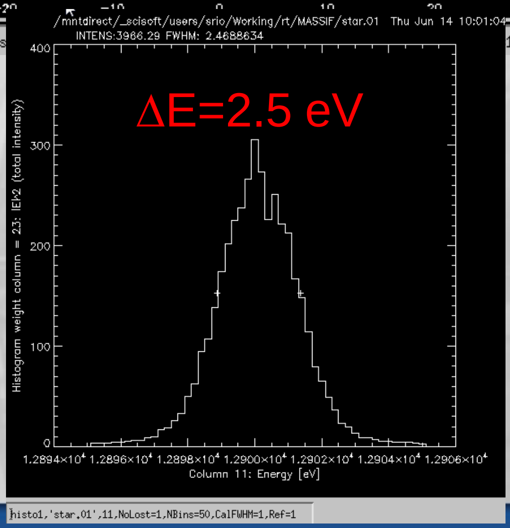
source-to-sample 3: 51.5+5.5 = 57 m

MASSIF Branch A Station 3









VLS gratings – Soft X-ray - UPBL07

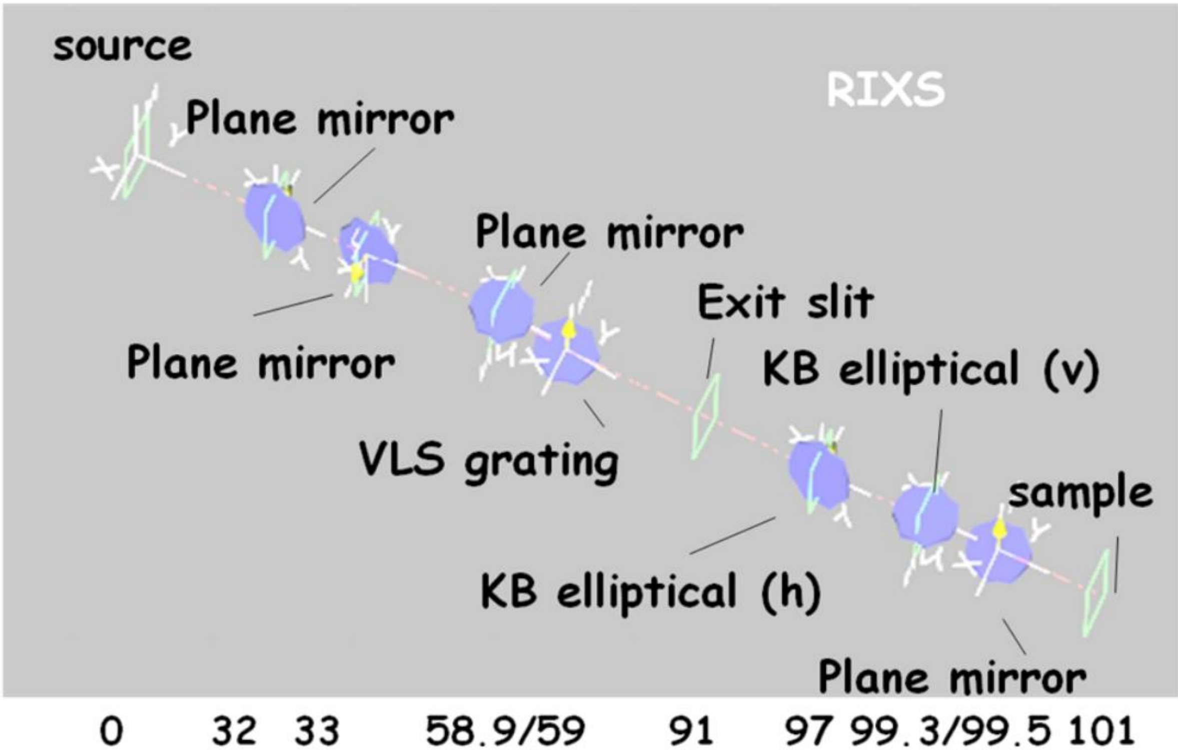
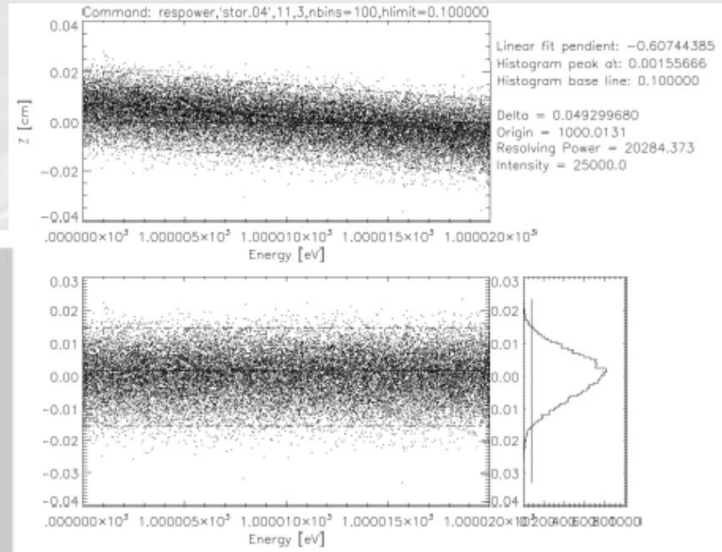


Figure 18: Optical layout with a horizontal monochromator exit arm



ure 28: Ultimate resolution with a 1000 l/mm grating

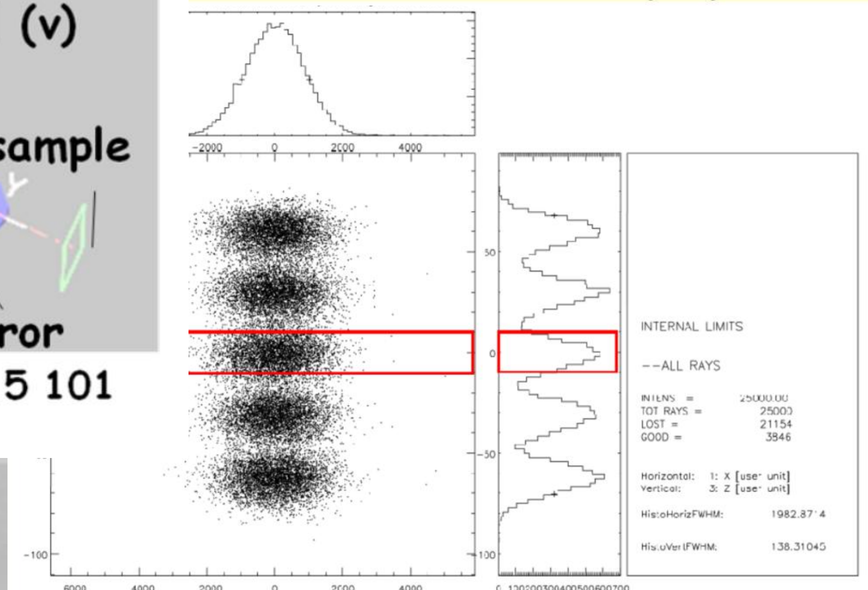
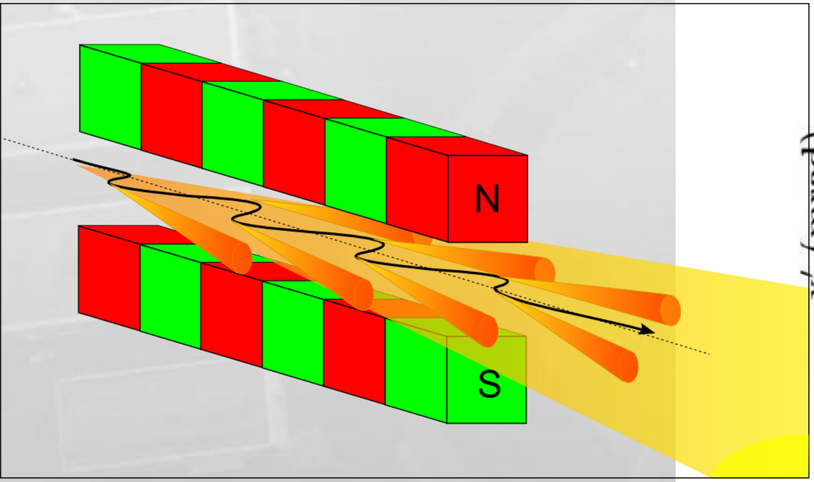


Figure 29: Energy separation of lines. The red rectangle represents the exit slit (20 µm)

On-going developments

Upgrade sources (IDs etc)



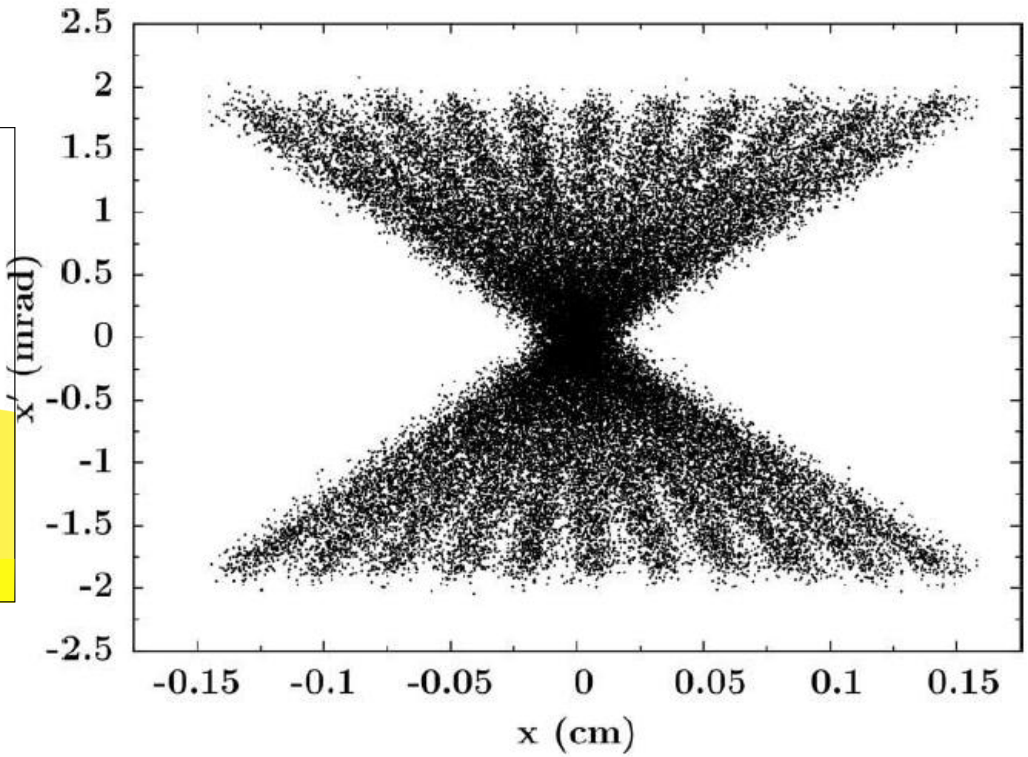


Figure 5
Plot of the horizontal phase space for a wiggler (ID17 at the ESRF) with 11 periods of 0.15 m length, $K = 22.3$ and electron beam energy of 6.04 GeV.

See: macro_source_spectrum.ws

SRW-SHADOW

11th International Conference on Synchrotron Radiation Instrumentation (SRI 2012) IOP Publishing
Journal of Physics: Conference Series **425** (2013) 162007 doi:10.1088/1742-6596/425/16/162007

Improved models for synchrotron radiation source in SHADOW

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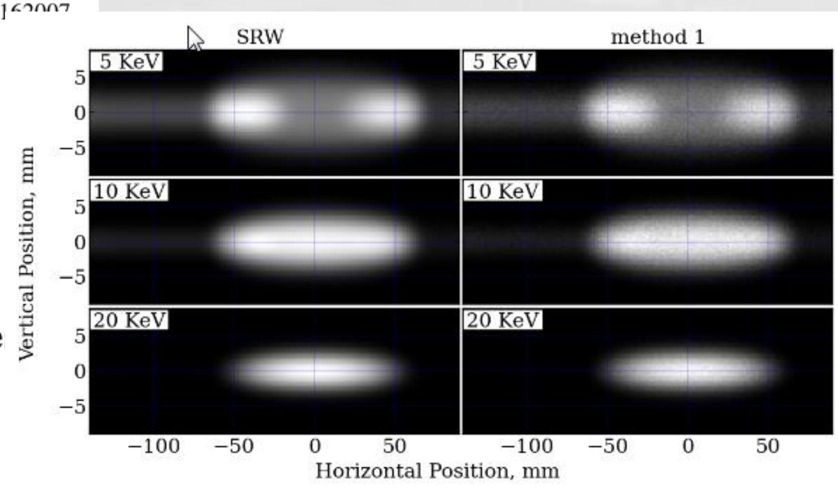
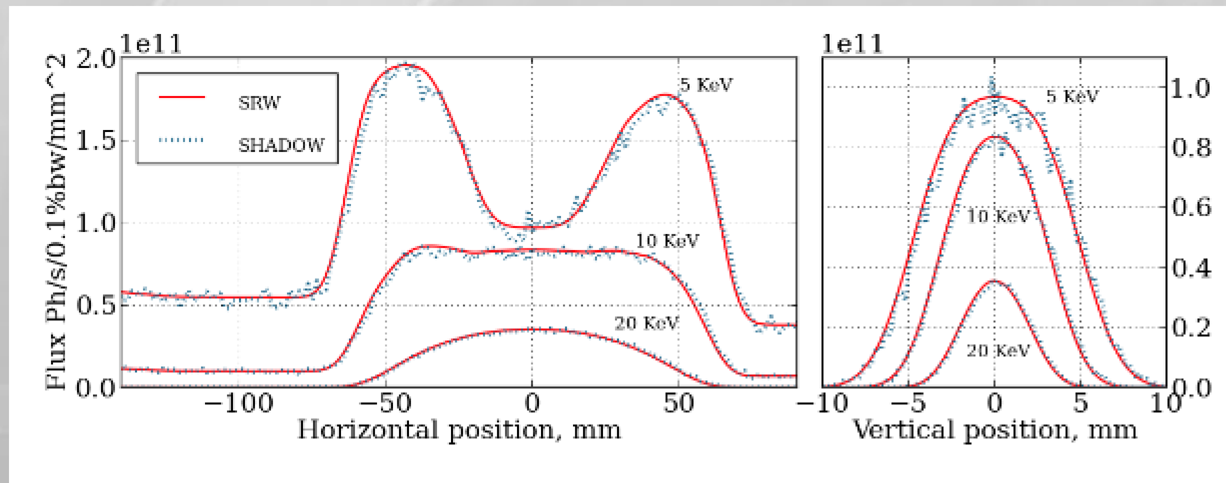
[2] European Synchrotron Radiation Facility, Grenoble, France 38043





See:
shadow3/README_PYTHON.txt
shadow3/SRW2SHADOW_Example01.py

Single lenses

	$n_1 < n_2$	$n_1 > n_2$
Collimated to convergent	Ellipse c)	Hyperbola a)
Convergent to collimated	Hyperbola	Ellipse
Divergent to convergent	Cartesian oval d)	Cartesian oval b)

Figure 4
Ideal surface shape for different focusing conditions.

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Aspherical lens shapes for focusing synchrotron beams

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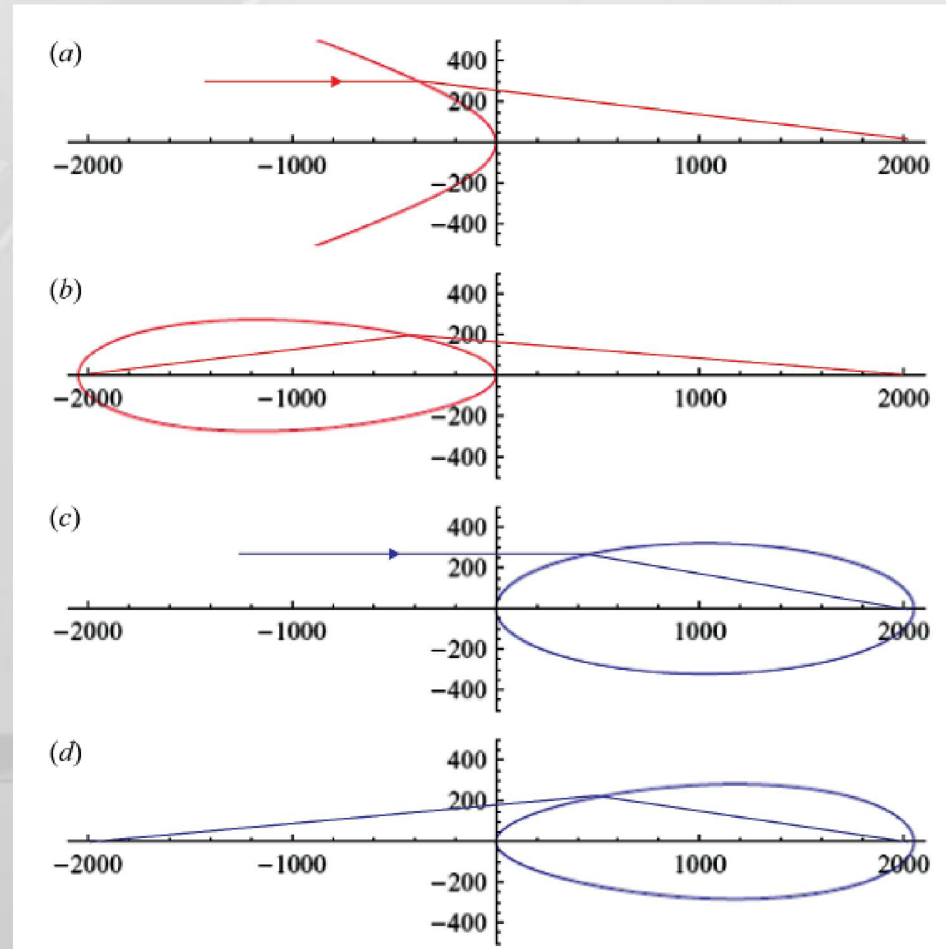
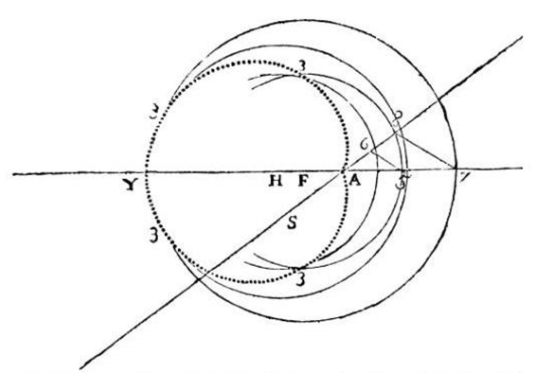
[a]European Synchrotron Radiation Facility, France, and [b]Diamond Light Source Ltd, UK.

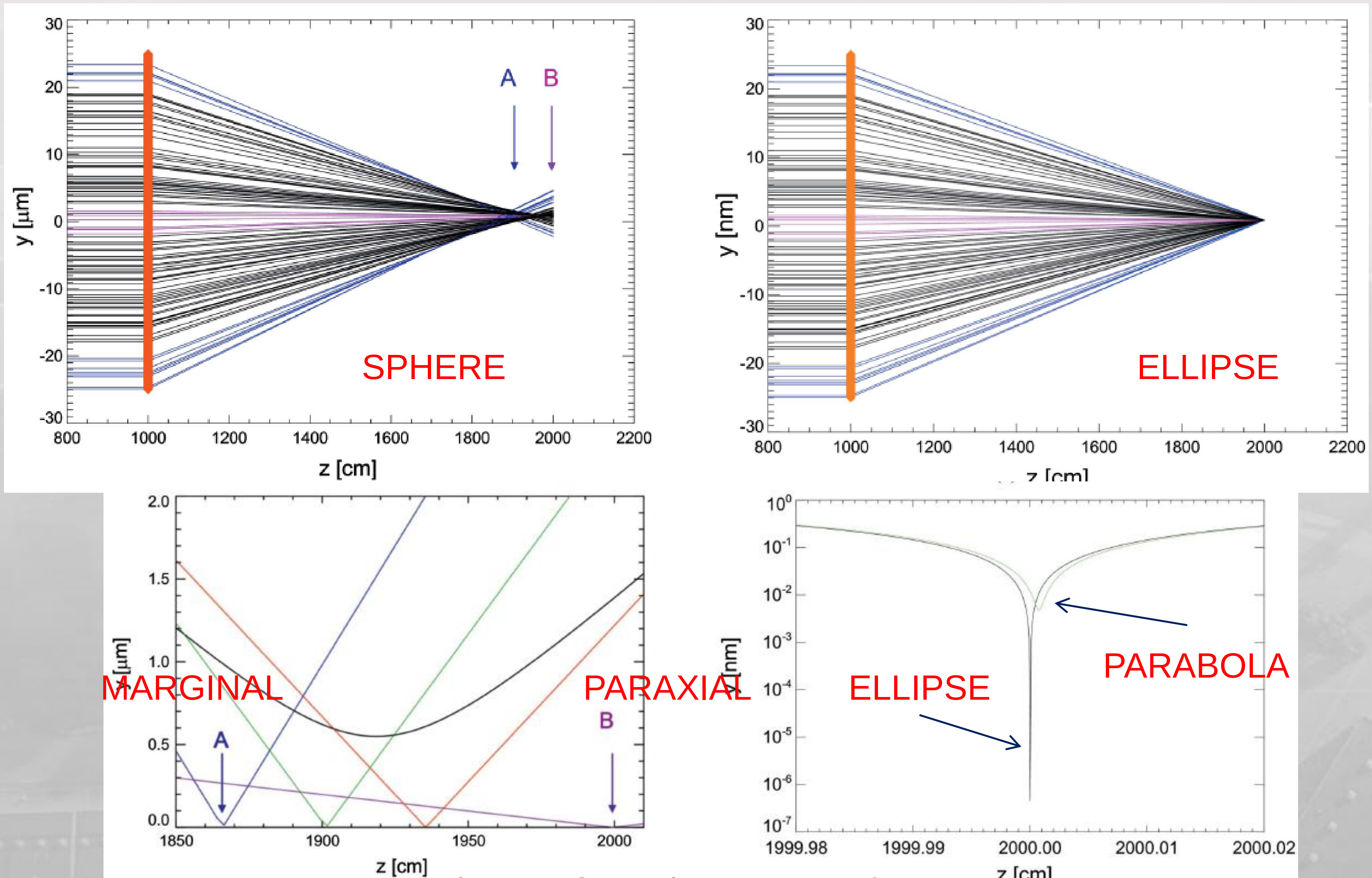




eſgal à S 6, qui coupe au point 3 celuy du centre F, qui paſſe par le point 5; & vn autre dont le rayon eſt eſgal a S 8, qui coupe celuy qui paſſe par le point 7, au point auſſy marqué 3; & ainſi des autres. Enfin pour la derniere

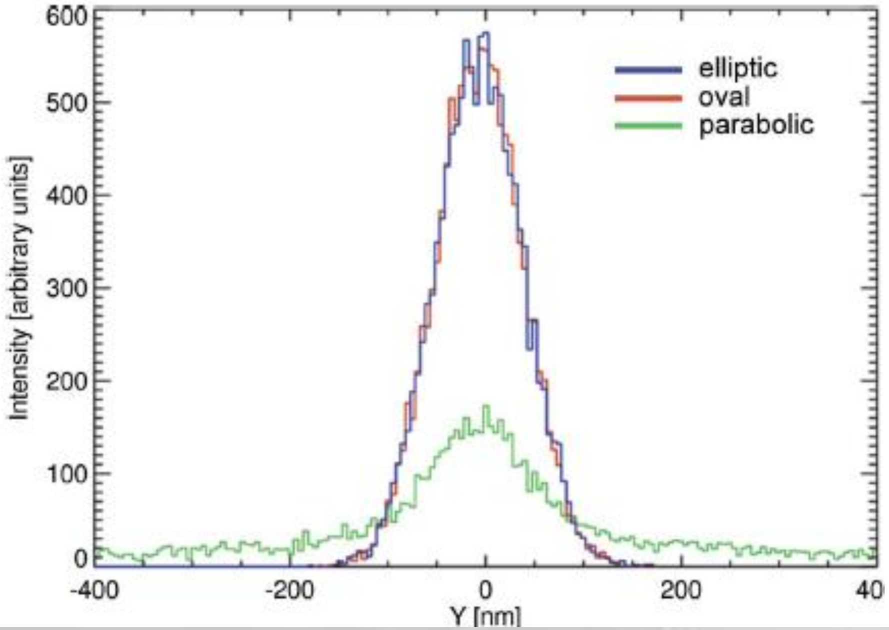
Descartes 1637

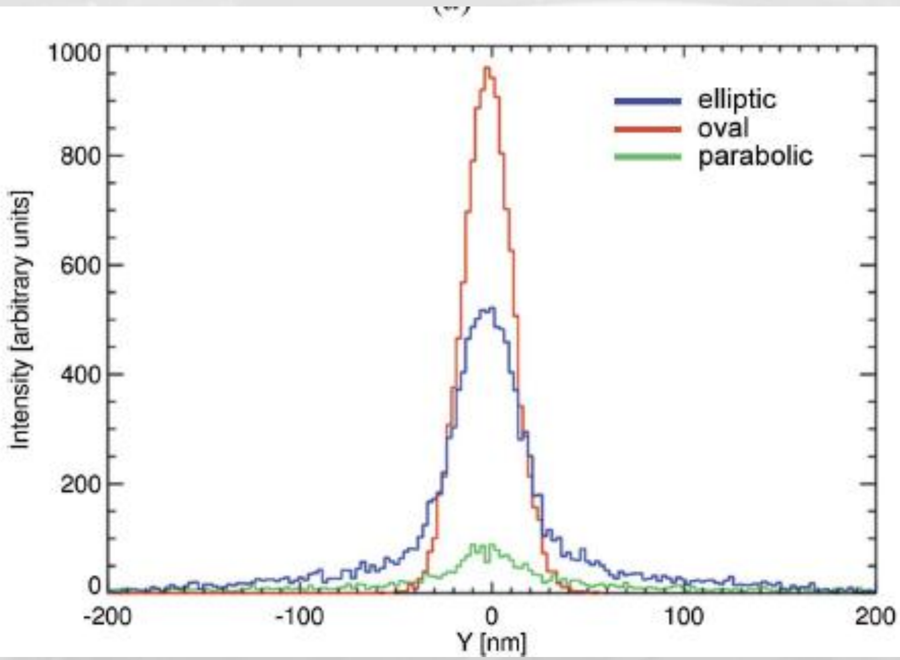
Ideal interface shape for focusing a collimated beam



Using **sysplot** and **ray_prop** tools

Microfocusing/Nanofocusing





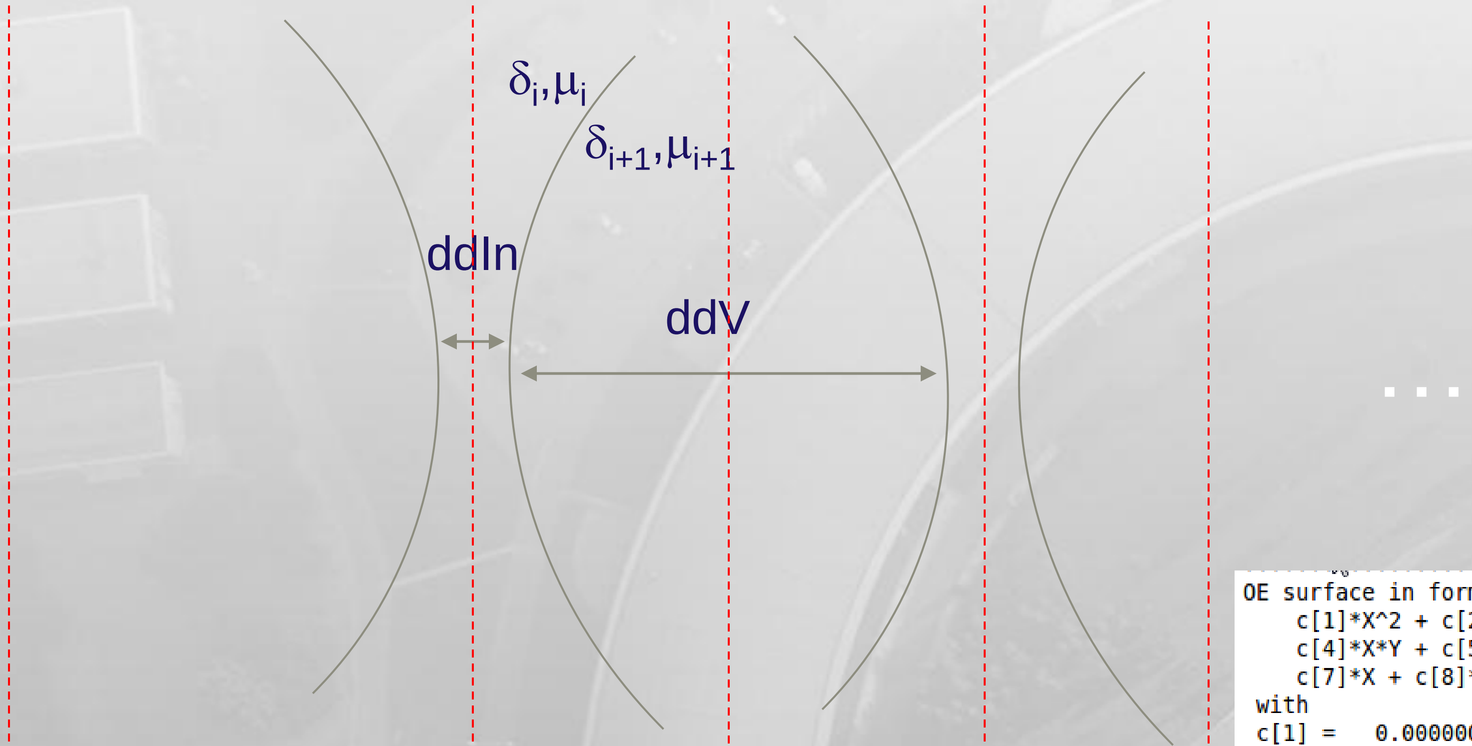
E=8 keV
Si Lens
p=47 m
h=0.3 mm

q=30 cm
M=157

q=10 cm
M=470

We may need in the future to shape lenses following the Cartesian oval…

CRL/Transfocator: Stack of interfaces



See:
shadow3/README_CRL.txt
lens_single_sysplot.ws
lens_chromatic_aberrations.ws
crl_snigirev1996.ws

```
OE surface in form of conic equation:
    c[1]*X^2 + c[2]*Y^2 + c[3]*Z^2 +
    c[4]*X*Y + c[5]*Y*Z + c[6]*X*Z  +
    c[7]*X + c[8]*Y + c[9]*Z + c[10] = 0
 with
 c[1] =   0.0000000000000000
 c[2] =   1.0000000000000000
 c[3] =   0.0000000000000000
 c[4] =   0.0000000000000000
 c[5] =  -0.0000000000000000
 c[6] =   0.0000000000000000
 c[7] =   0.0000000000000000
 c[8] =   0.0000000000000000
 c[9] = -0.10000000000000001
 c[10] =   0.0000000000000000
```

Crystals

- Allow any crystal structure (e.g., quartz)
- Calculate diffraction profiles for bent crystals (ML & PP)
- Allow the possibility to use external diffraction profiles
- X-ray polarisers (changes in phase)
- UPBL2 High energy X-rays

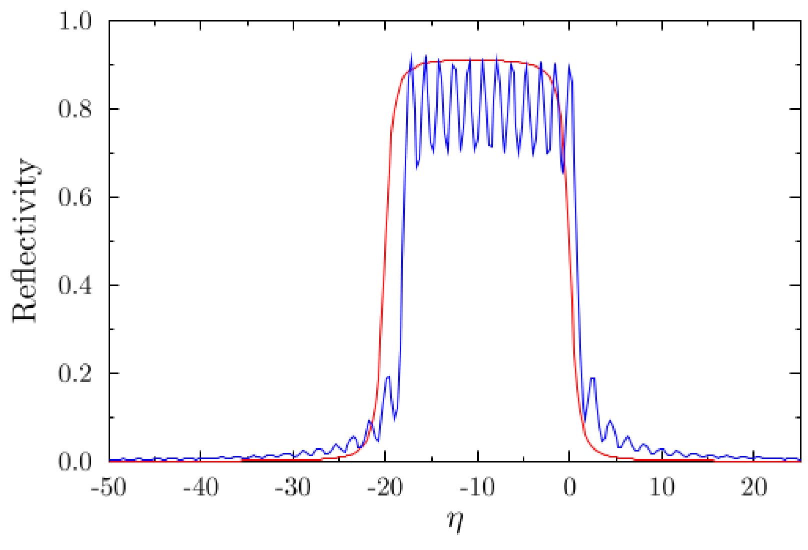


Fig. 14. Diffraction profiles for a crystal with parameters in Table 4 calculated using the Penning-Polder (red) and multilamellar (blue) models. $1\eta = 2.57\ \mu rad$.

See: macro_crystal_with_external_diffraction_profile.ws

Optical constants

- Current limitations
  - The current data is quite old (new tabulations are available)
  - Only covers 30eV-100keV
  - It does not include Compton scattering (important in many cases)

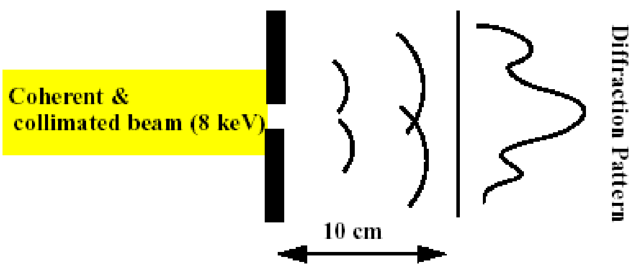
- Good points
  - SHADOW optic library is decoupled from the kernel
  - Re-write the preprocessors with using your preferred data

- Ideas
  - Rebuild the existing database with new data and perhaps more points
  - Use xraylib

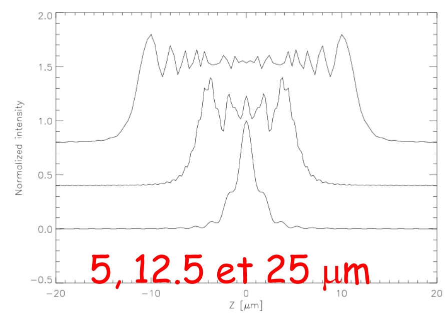
See:
shadow3/README_PYTHON.txt
shadow3/ShadowPreprocessorsXraylib.py

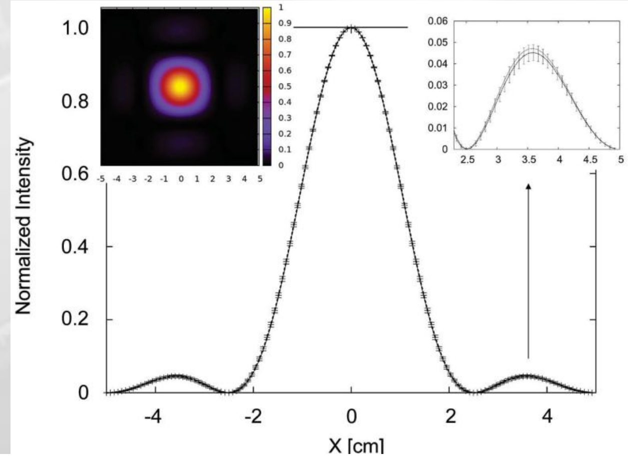
Fresnel-Kirchhoff propagator in Shadow

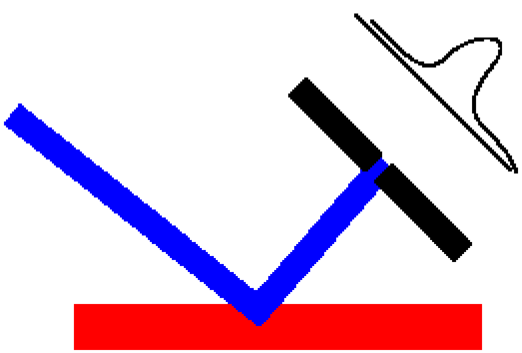
$$u(\mathbf{x}) = \frac{ikI}{4\pi} \int_{\mathrm{A}} u_{\mathrm{inc}}(\mathbf{r}) \frac{e^{iks}}{s}\, dS$$



Fraunhofer Diffraction by a slit

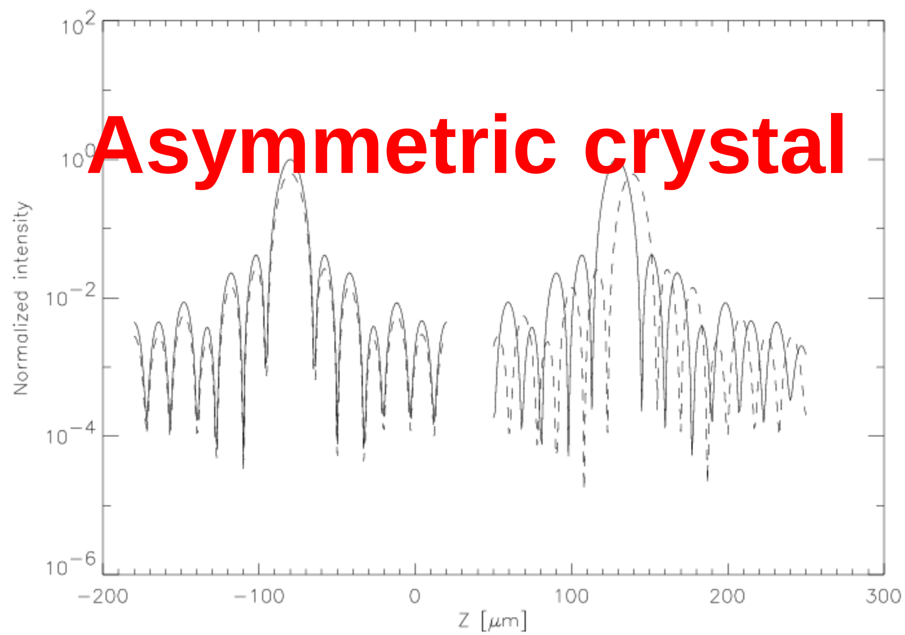






Si 111, α=0, α=0.15 deg

8 keV, ΔE~ 1 eV



Two slits experiment

Coherence by propagation

Thomson & Wolf, JOSA 47, 895 (1957)

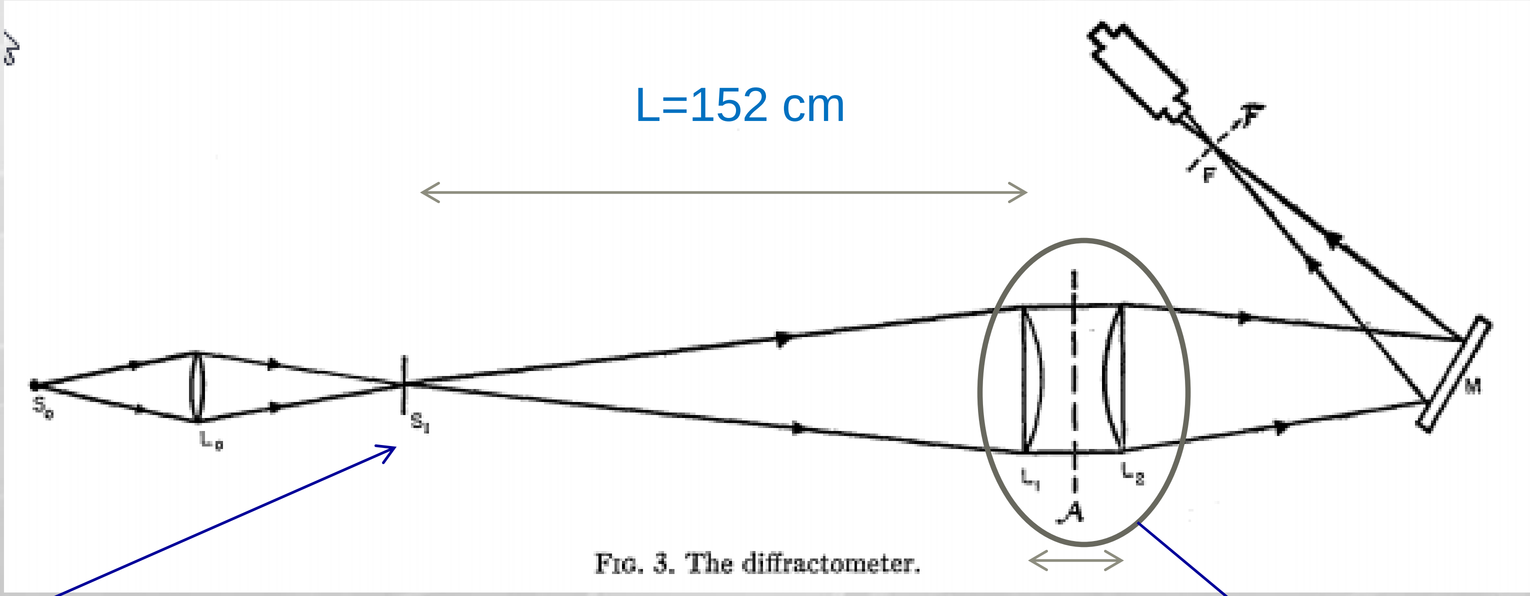
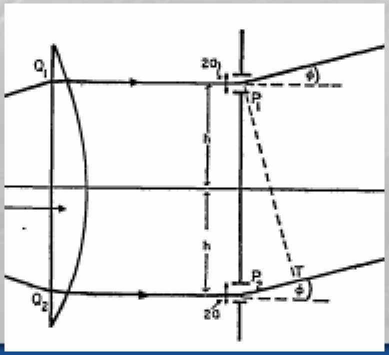


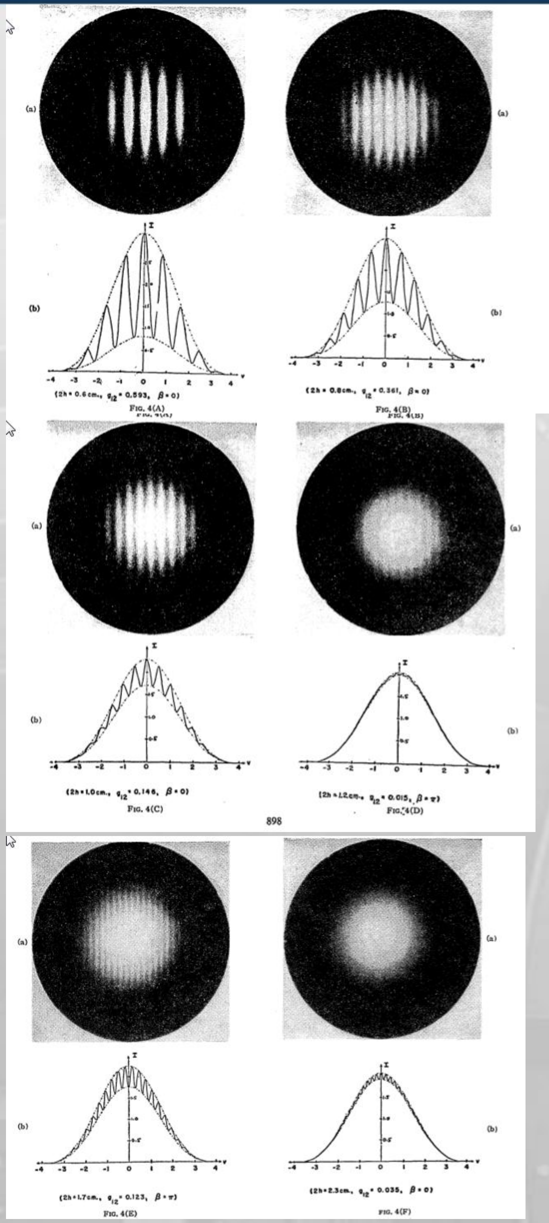
FIG. 3. The diffractometer.

- S1 INCOHERENT source (90 μm)
- λ=579 nm

- 2xPinhole Ø=0.14 cm
- 2h=0.6-2.5 cm



Thomson & Wolf, JOSA 47, 895 (1957)



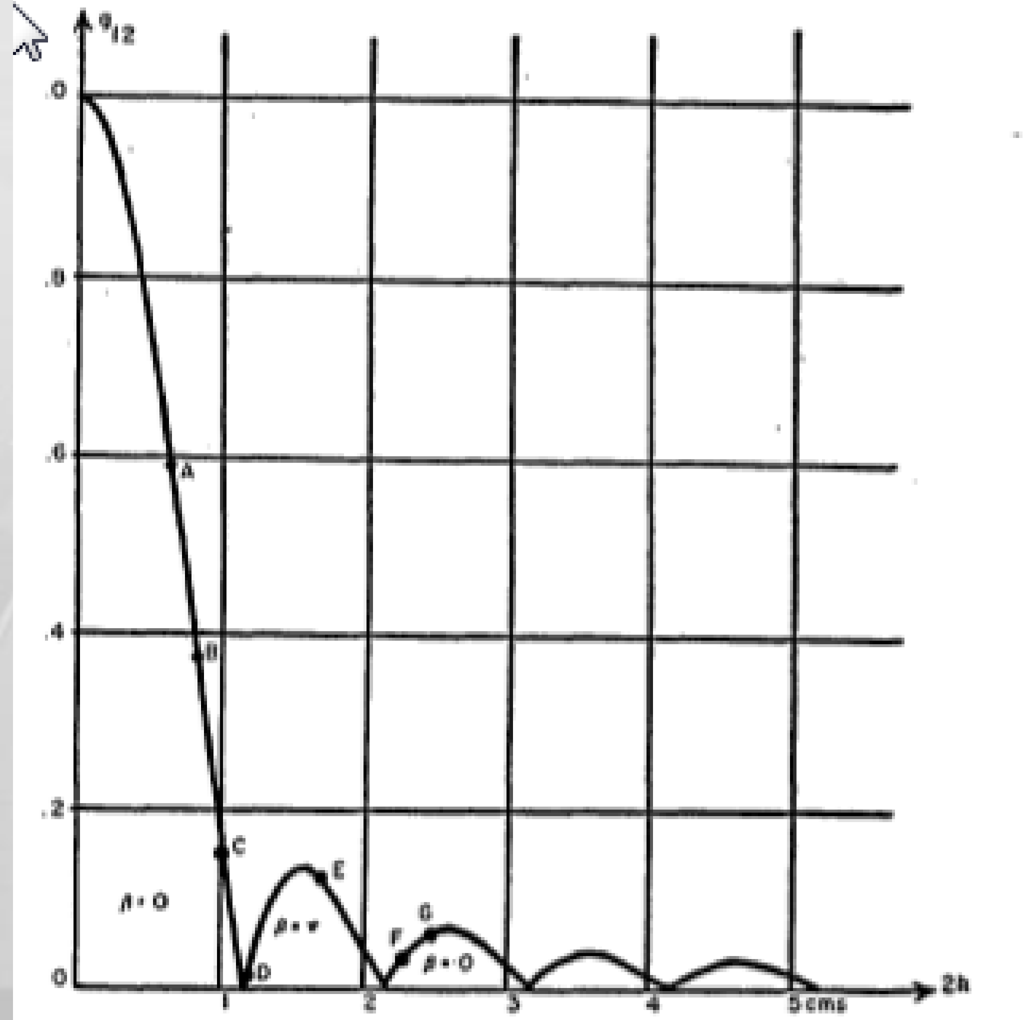
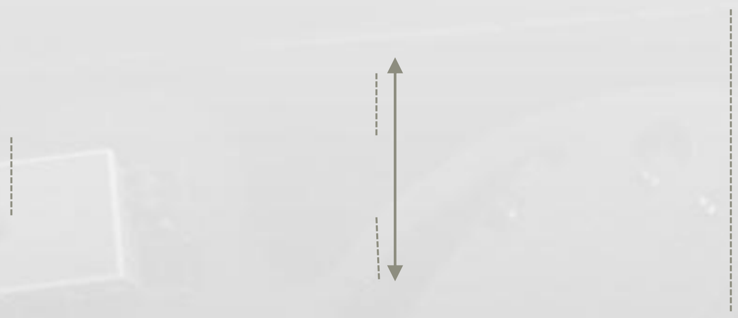
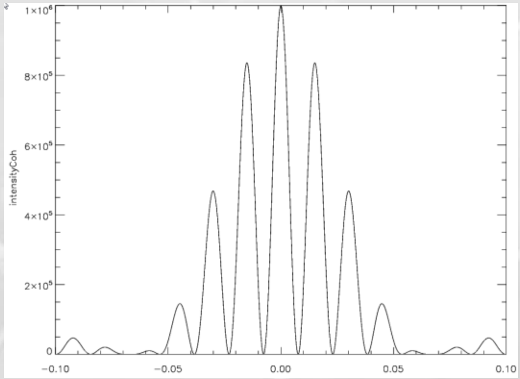


FIG. 6. The degree of coherence, as function of the separation $2h$ of the apertures at P_1 and P_2.

Hybrid Model



x_i, U_i $\qquad x_j$ $\qquad x_k$



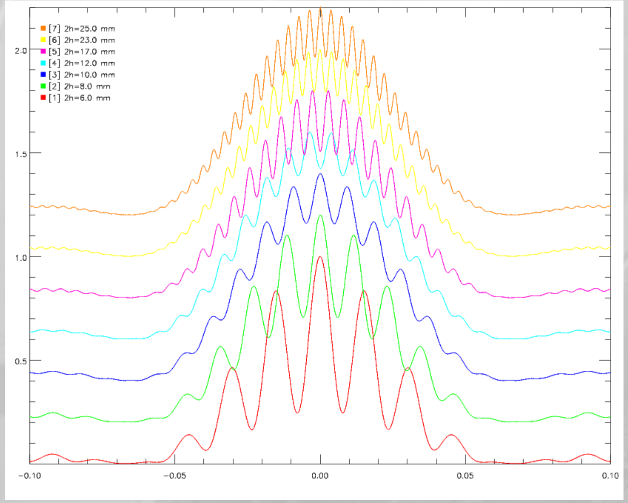
Coherent: $U_i = 1$

$$r_{mn} = \sqrt{(x_m - x_n)^2 + y_{mn}^2}$$

$$M_{nm} = e^{i\,k\,r_{nm}}$$

$$U_k = U_i \left(M_{ij} M_{jk} \right)$$

$$I_k = \left| U_k \right|^2$$



Fully incoherent: Use ensemble average

$$U_i = e^{i 2\pi\zeta} \qquad \zeta = random$$

$$I_k = \sum_{\rho \in realisations} \left| U_k^{\rho} \right|^2$$

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Double pinhole diffraction of white synchrotron radiation

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[b] Institut für Festkörper- und Werkstoffforschung, P.O. Box 270016, D-01171 Dresden, Germany
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Received 26 September 2002; accepted 12 December 2002

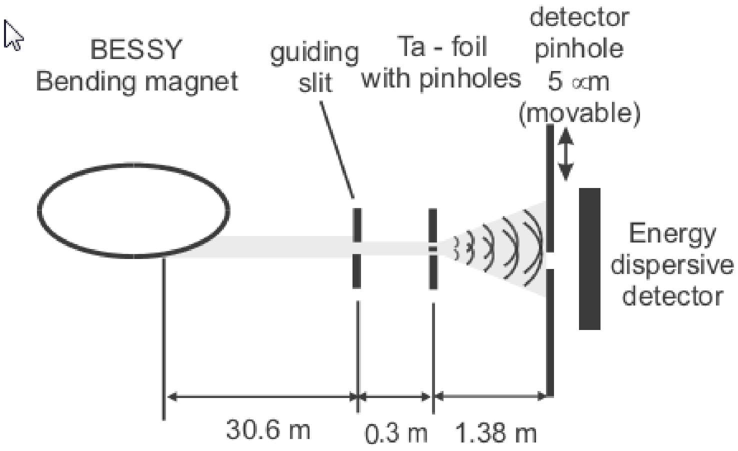


Fig. 1. Experimental set-up at the EDR-beamline at BESSY II.

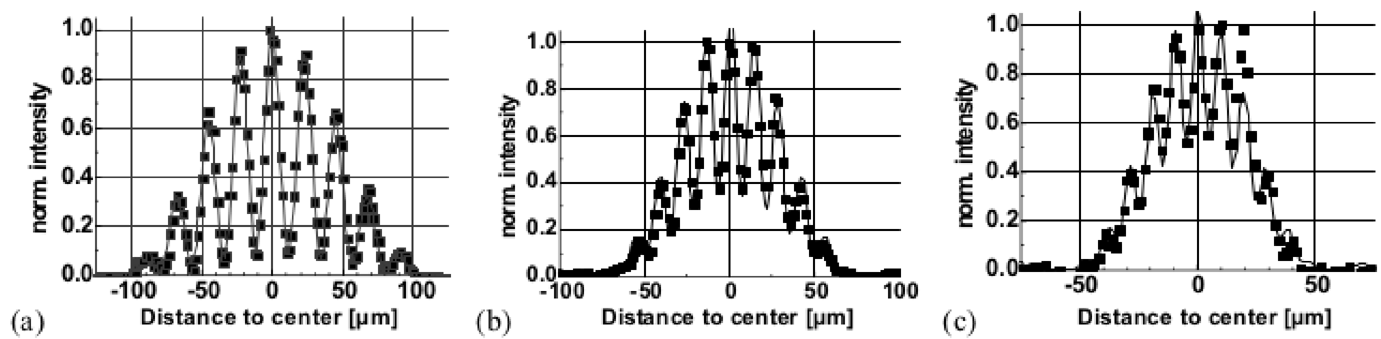
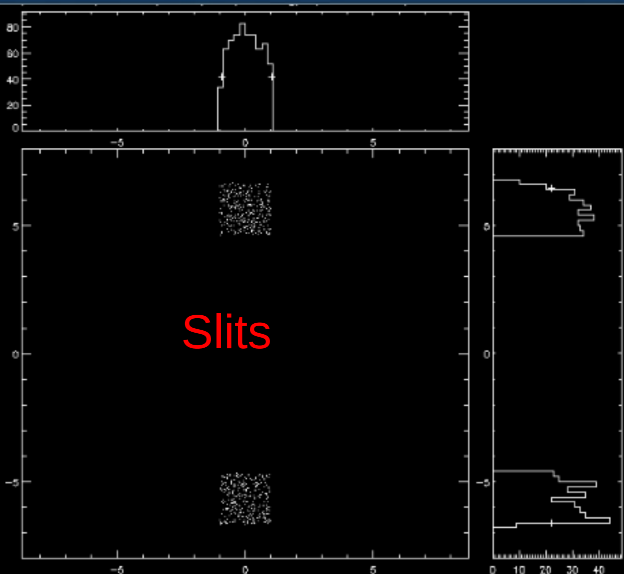
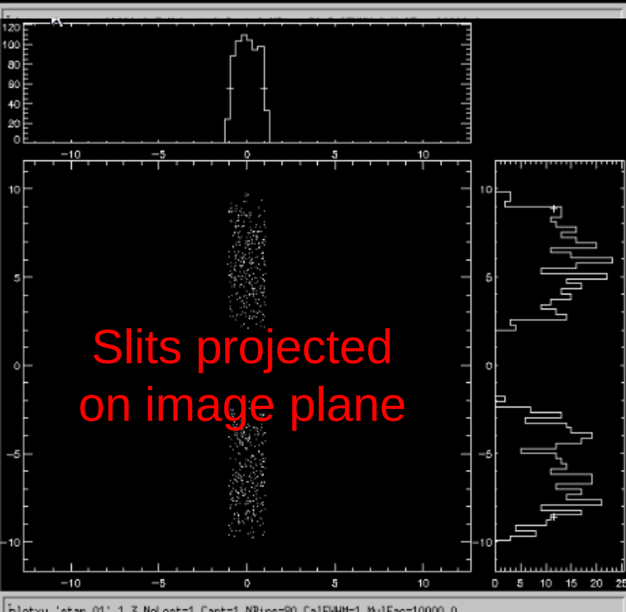
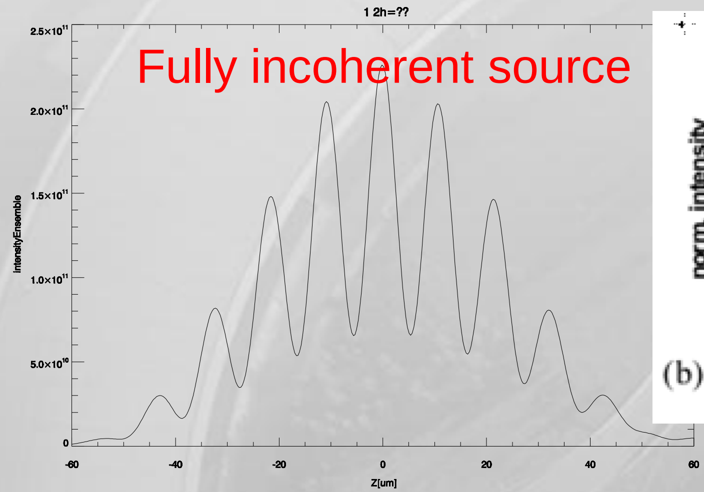
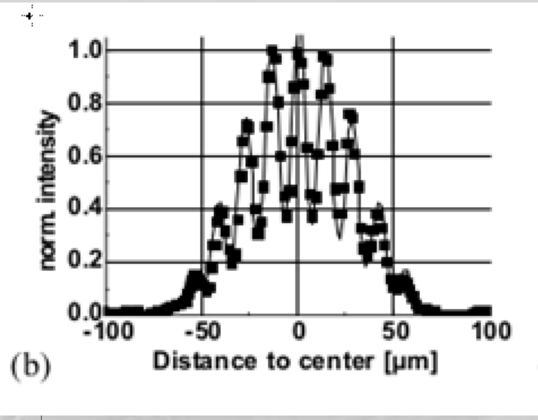


Fig. 4. Normalized interference fringes obtained with the double pinhole at three different energies (a)–(c) 6 keV, 10 keV and 14 keV. The squares indicate the measured data from Fig. 3 and the lines indicate the results of the best fit of Eq. (1).





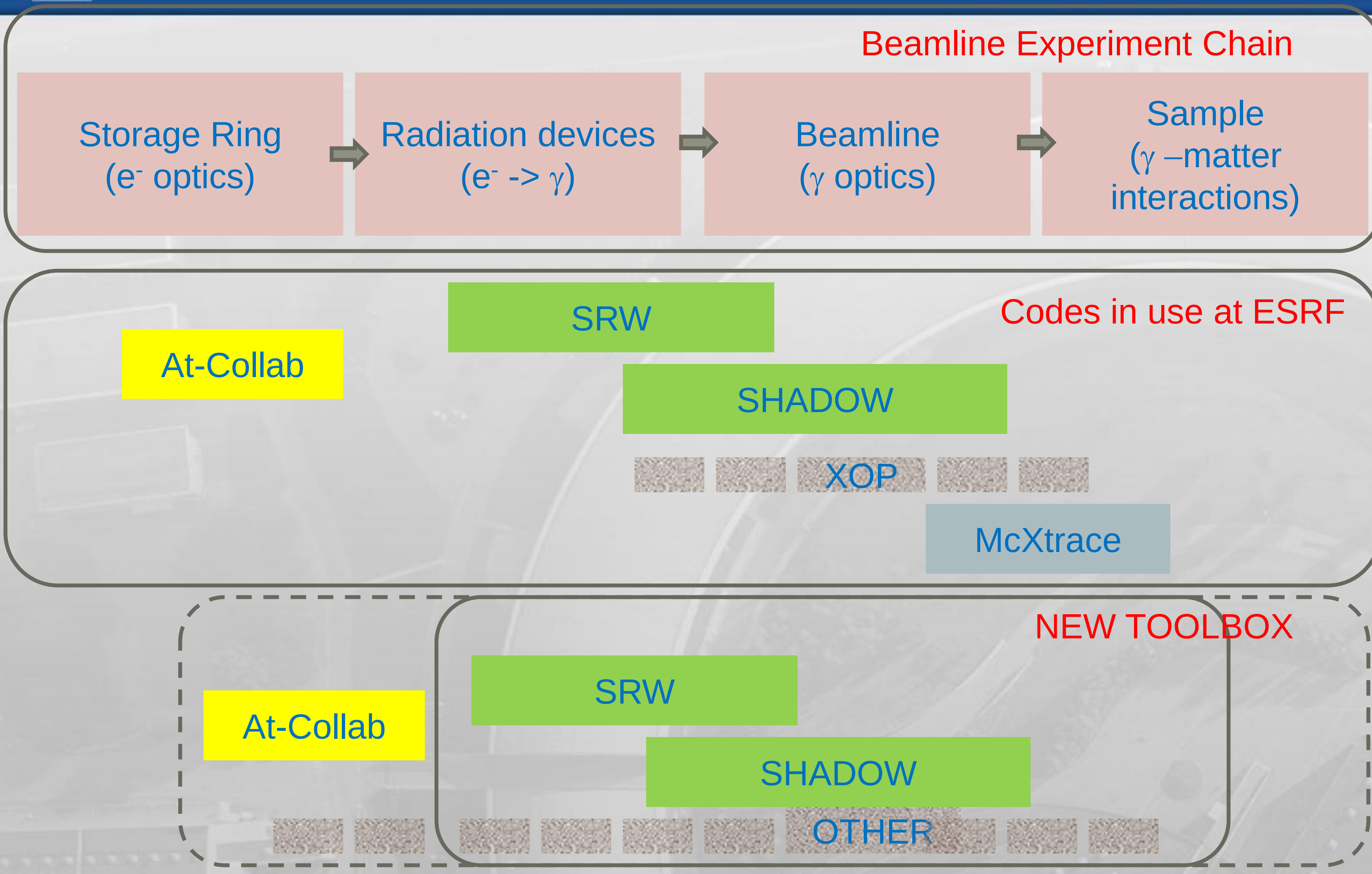




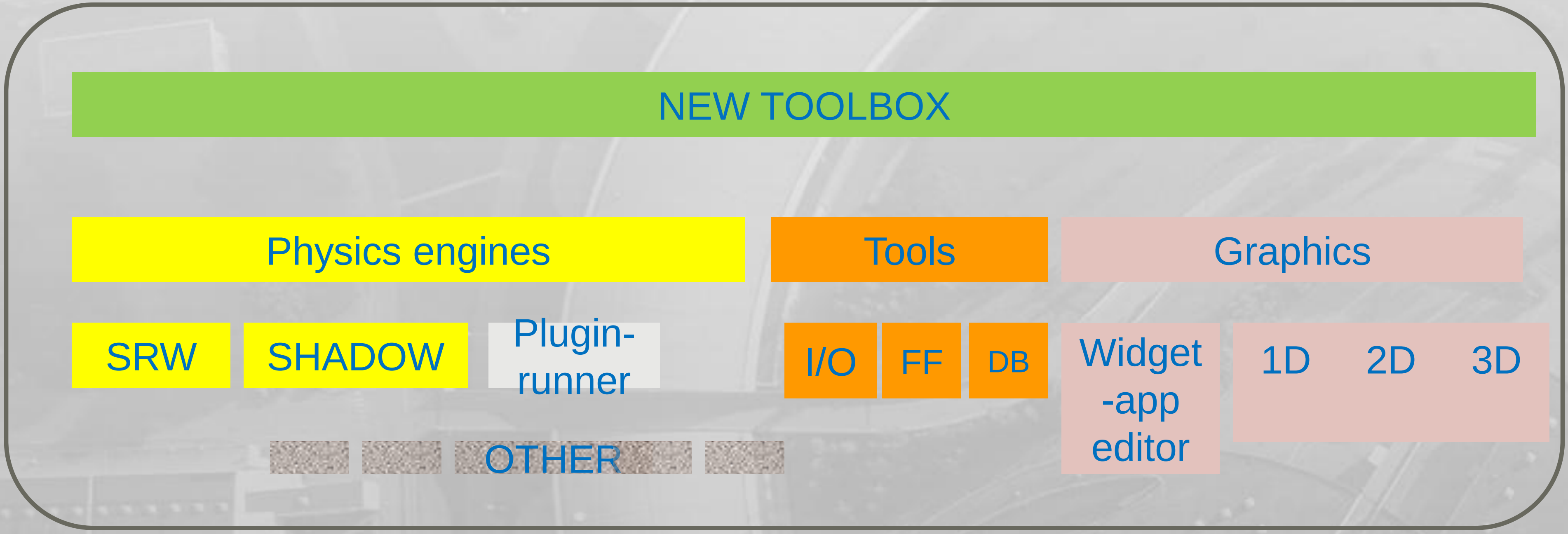
=>Use ray tracing for *gridding*, and a postprocessor for calculating *M* matrices and the ensemble average over many source realisations

Future

- SHADOW
  - Compound Refractive Lenses and Transfocators
  - Crystals
  - Optical constants
  - Partial Coherence
  - Global optimization
  - Model samples
- Towards a new hybrid (ray-tracing+wave-optics) optics toolbox?
  - SPIE Conference 2011 (to be followed…)
  - Collaborative work
    - NSLS-II
      - Cross talk SHADOW-SRW
      - API in python for ray tracing and wave optics (python)
  - Switch Ray optics <-> Wave optics
  - New GUI
  - McXtrace


Beamline Experiment Chain
Storage Ring
(e- optics)
Radiation devices
(e- -> γ)
Beamline
(γ optics)
Sample
(γ –matter
interactions)
Codes in use at ESRF
SRW
At-Collab
SHADOW
XOP
McXtrace
NEW TOOLBOX
SRW
At-Collab
SHADOW
OTHER

- Timing:
  - Alpha1 Version: Defining basic tools, making the skeleton, prototype an XOP clone
  - Alpha2 Version: Define SHADOW+SRW inputs, basic use of them
  - Alpha3 Version: Allow to use most SHADOW+SRW functionality, advanced visualization tools, beta test version
- Tools (dependencies): based on python, Qt4 and many other tools to be defined
- Personnel: MSR+PhD+SE (2 y.)+collaborators
- Document in preparation



Thank you

(more tomorrow)