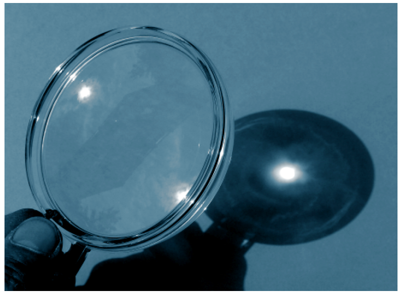
PAUL SCHERRER INSTITUT

Jochen Stahn
Tobias Panzner
Uwe Filges
Emanouela Rantsiou
Ursula B. Hansen

focusing on small samples



ICNS 2013 International Conference on Neutron Scattering
09.–12. 07. 2013, Edinburgh, Great Britain

people involved

experiments

Ursula Bengaard Hansen
Birgit Wiedemann
Anette Vickery

McStas simulations

Emanouela Rantsiou
Tobias Panzner
Panos Korelis
Uwe Filges

PSI infrastructure

Vincent Thominet
Sibylle Spielmann
Roman Bürge
Marcel Schild
Dieter Graf
Jan Krebs

ideas / discussions

Björgvin Hjörvarsson
Marité Cardenas
Beate Klösgen
Rob Dalgliesh
Frédéric Ott
Phil Bentley
Bob Cubitt
Peter Böni
Uwe Stuhr
...

inspiration

Selene

Selene picture: ceiling painting in the Ny Carlsberg Glyptotek, København

outline

- **Selene guide system**
- **prototype**
- **optics & options**
- **reflectometry**
- **discussion**

`people.web.psi.ch/stahn/publications.html#oral`

basics

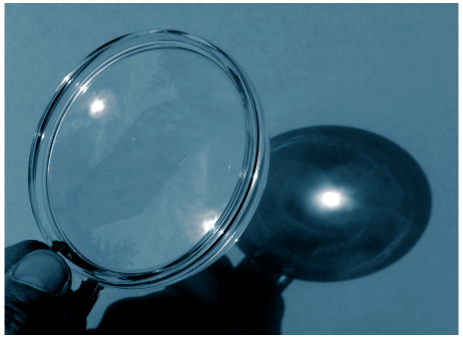
focusing on small samples

=

deal with

small samples

beam shaping



basics

focusing on small samples

=

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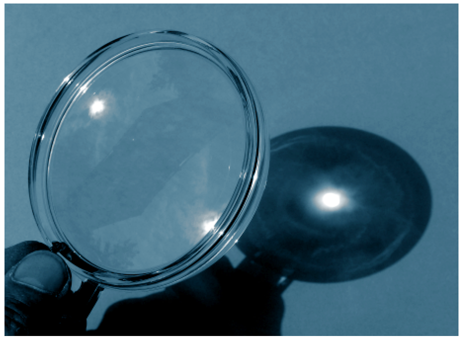
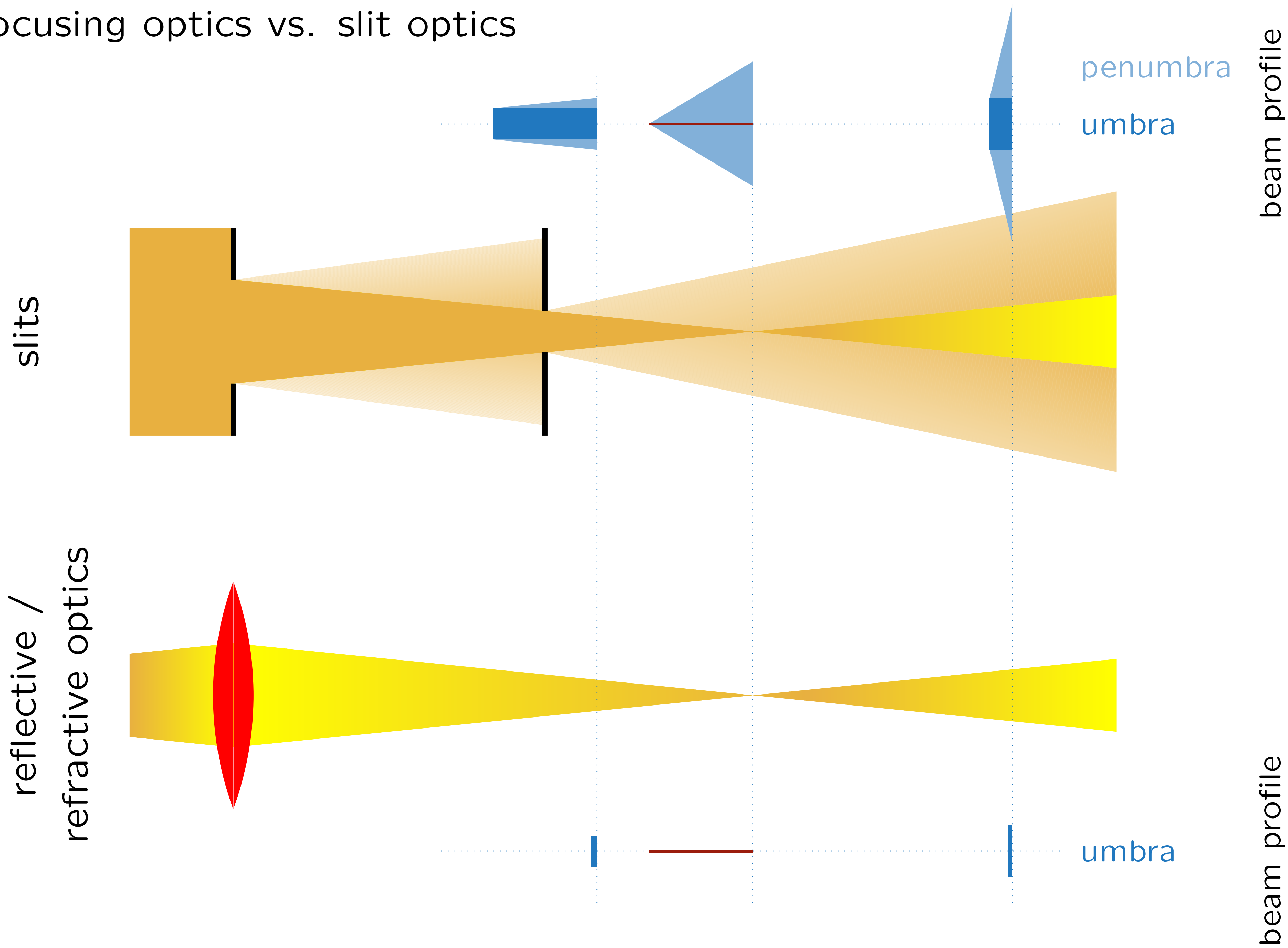


What, if the samples **are** small?

small is relative to the guide / the optics

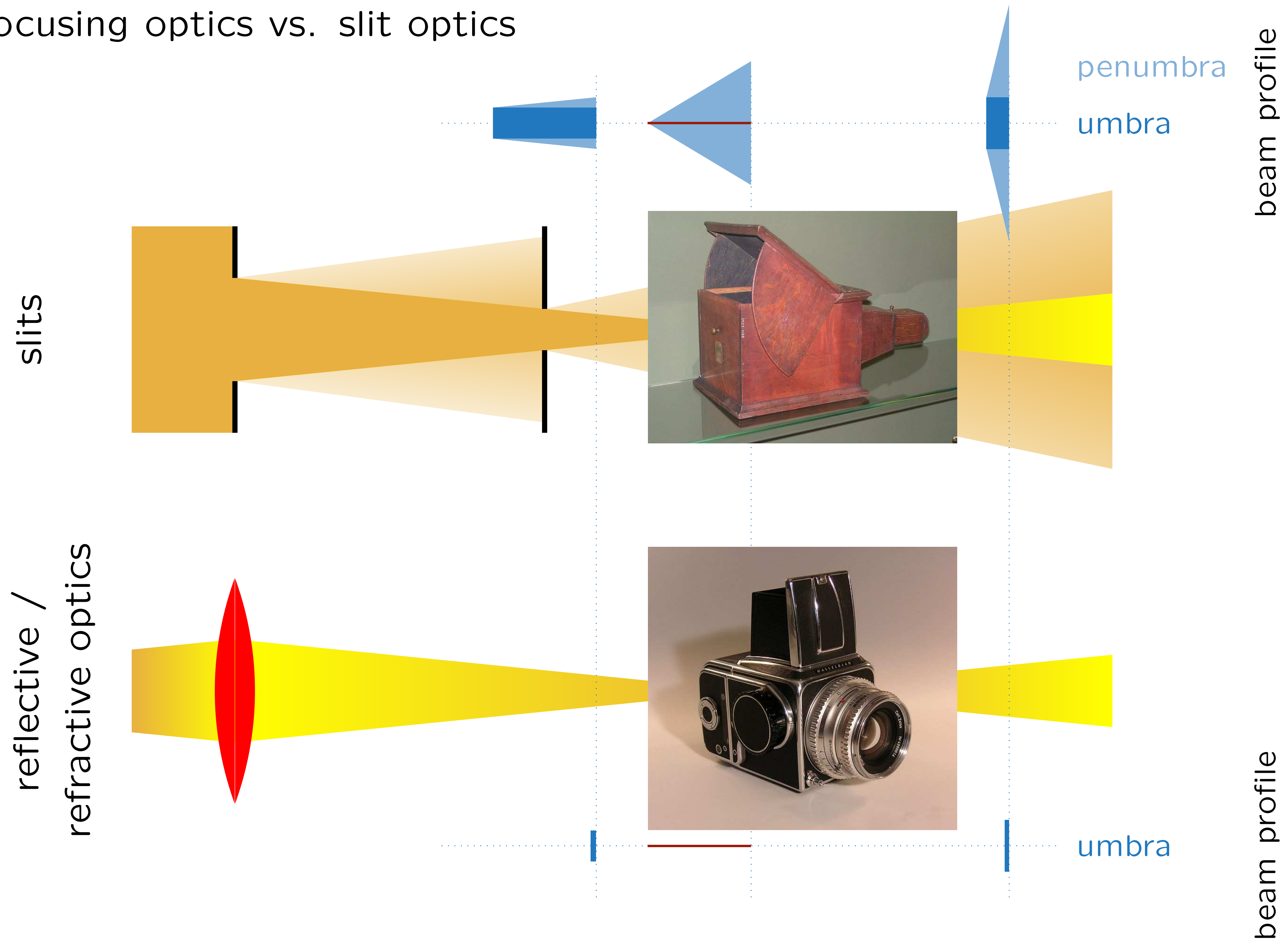
basics

focusing optics vs. slit optics



basics

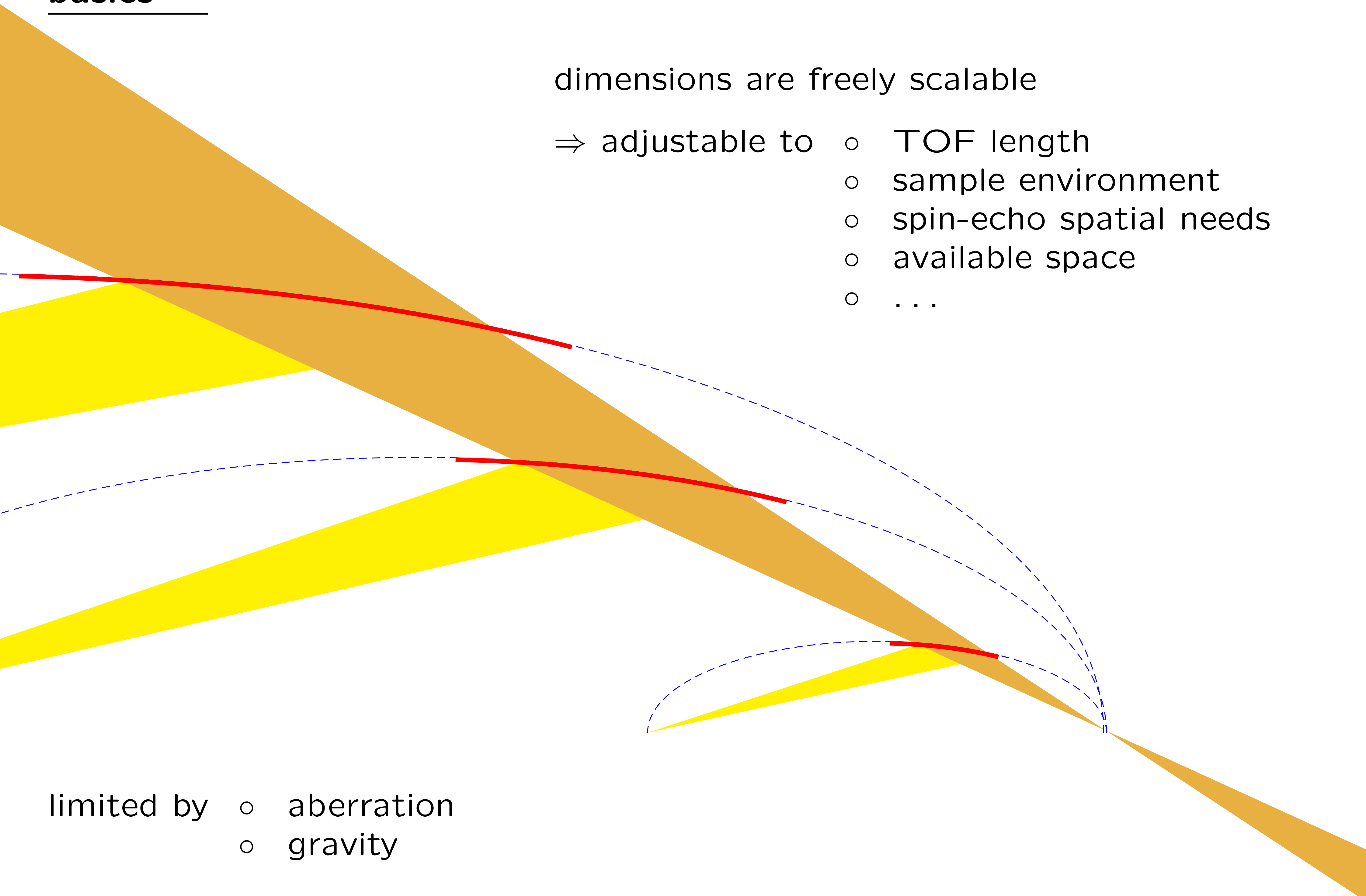
focusing optics vs. slit optics



basics

dimensions are freely scalable

⇒ adjustable to
- TOF length
- sample environment
- spin-echo spatial needs
- available space
- . . .



limited by
- aberration
- gravity

Selene guide system

- **Selene guide system**
  - **prototype**
    - **optics & options**
      - **reflectometry**
        - **discussion**

Selene guide system

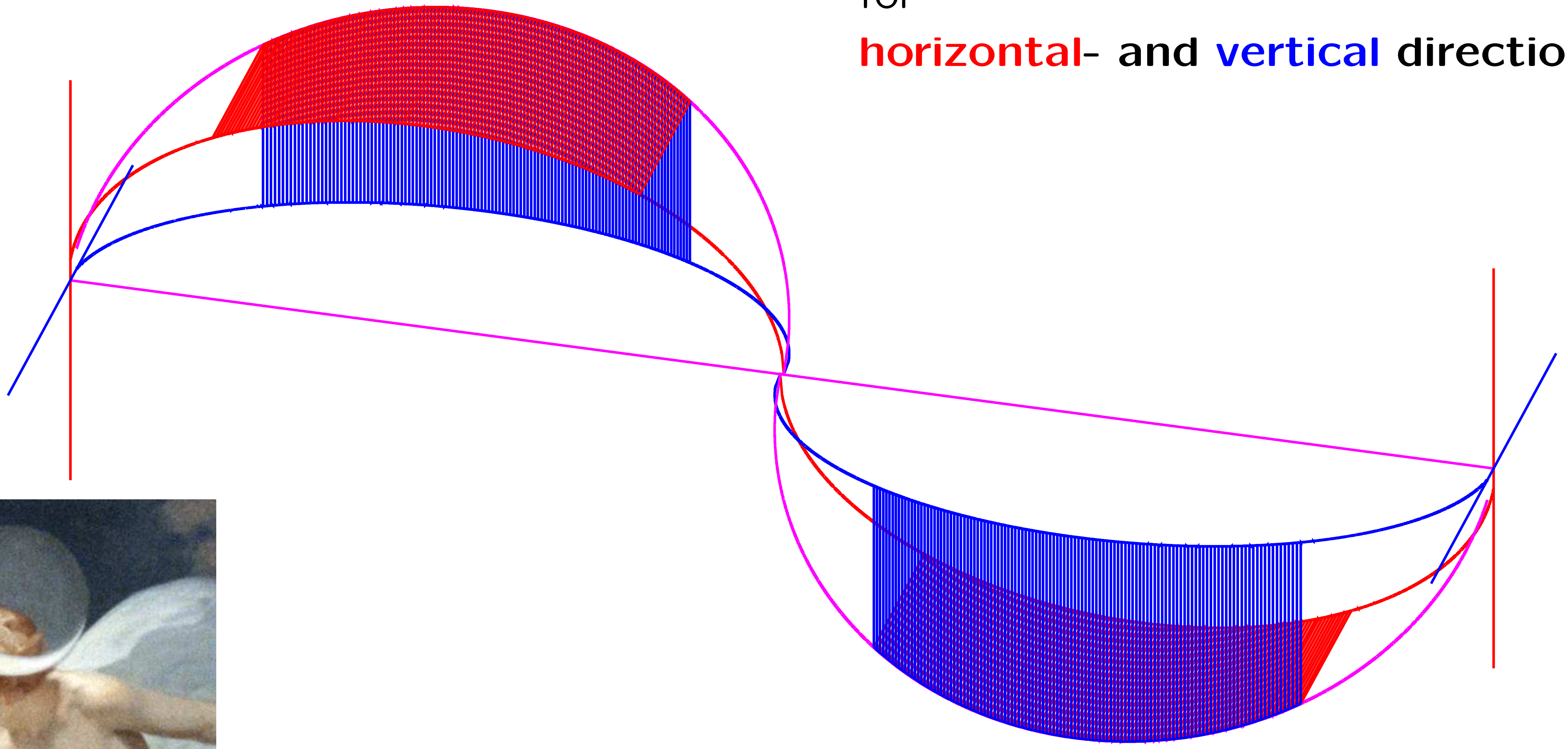
point-to-point focusing

with

2 subsequent elliptical reflectors

for

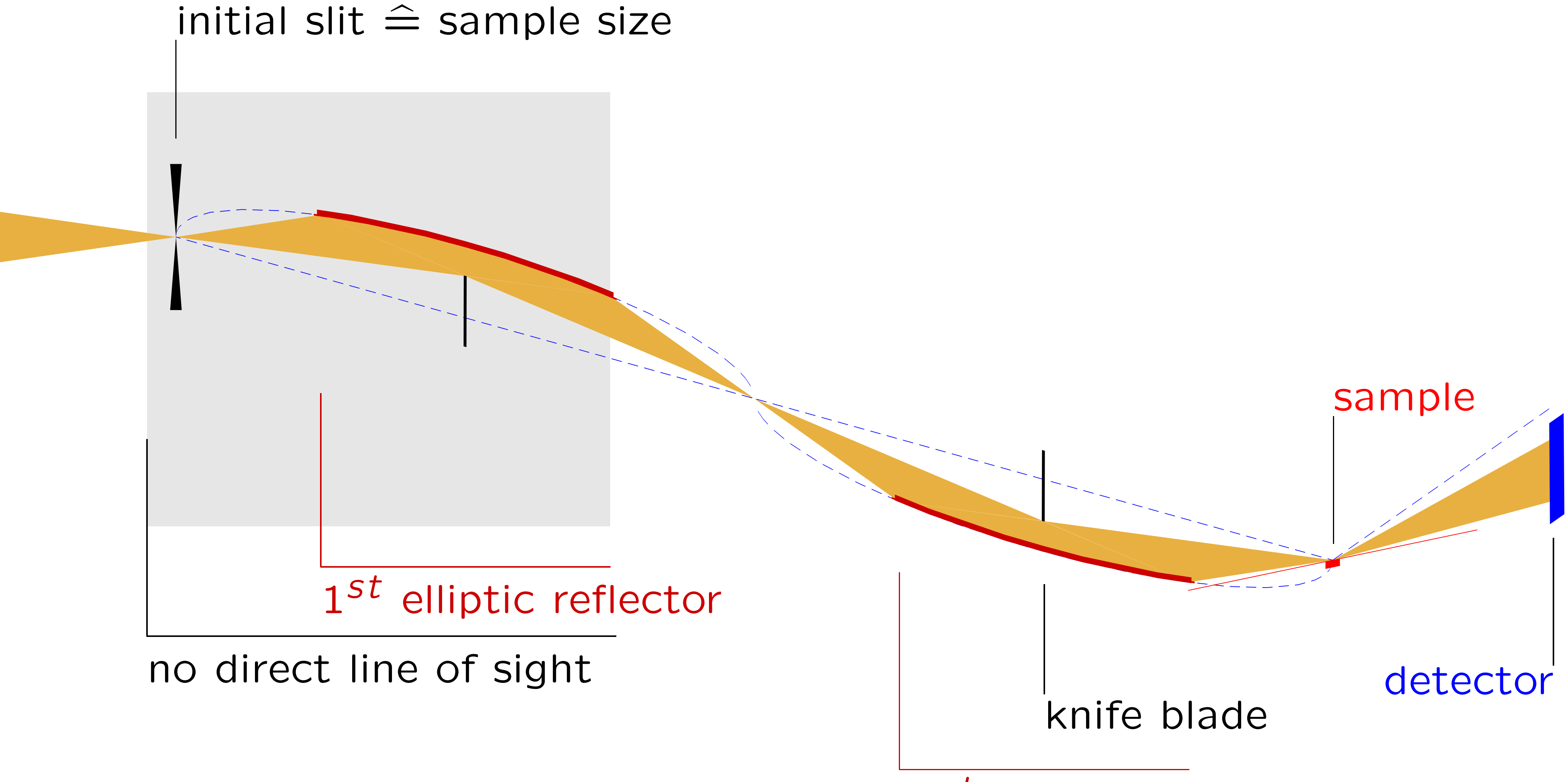
horizontal- and vertical direction



Selene guide system

generic lay-out

cut in the scattering plane stretched by 10 normal to incident beam



EPJ-AP **58**, 11001 (2012)

prototype

- Selene guide system
  - **prototype**
    - optics & options
      - reflectometry
        - discussion

prototype

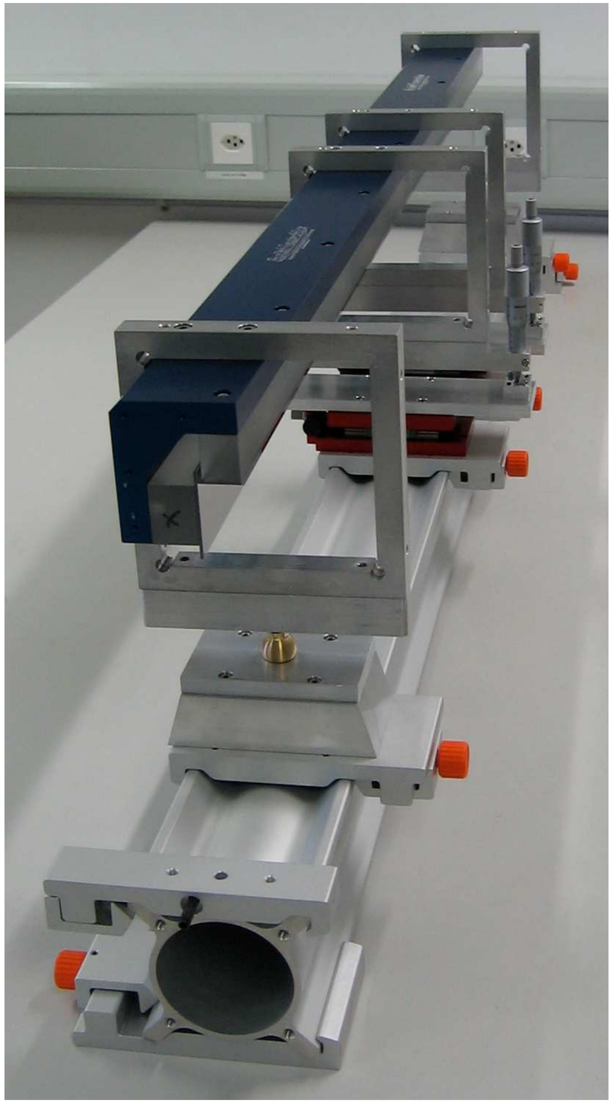
guides

by *SwissNeutronics*

2 guides
1200 mm each,

made of
2 elements,

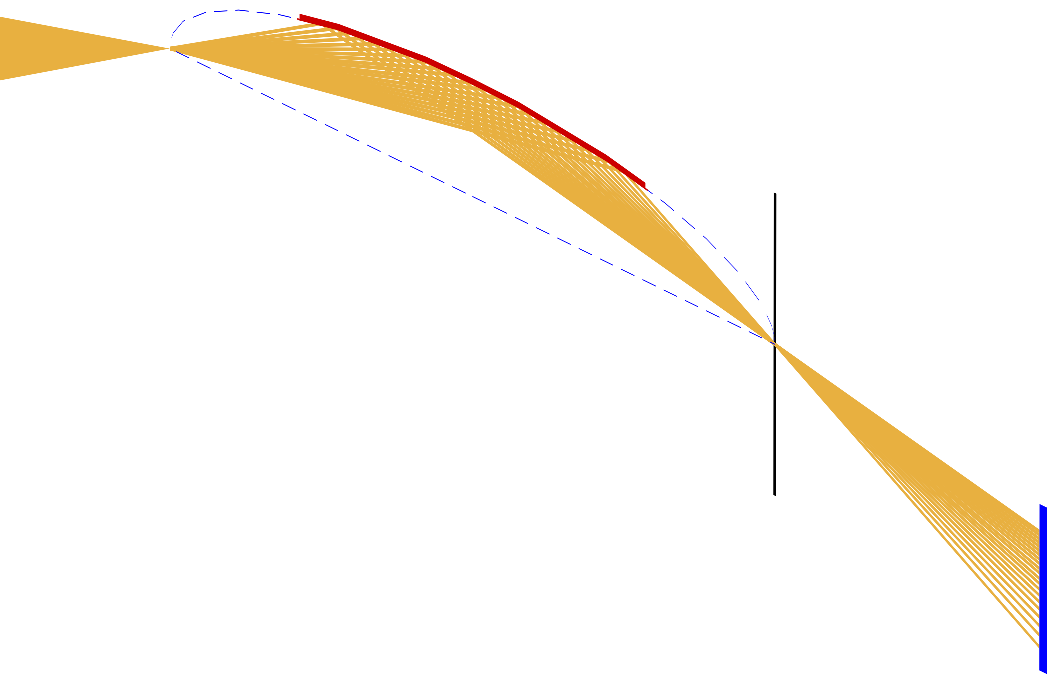
made of
2 elliptically bent reflectors.
coating: Ni/Ti SM, $m = 4$



$a = 1000\,\text{mm}$
$b/a = 0.0206$

prototype

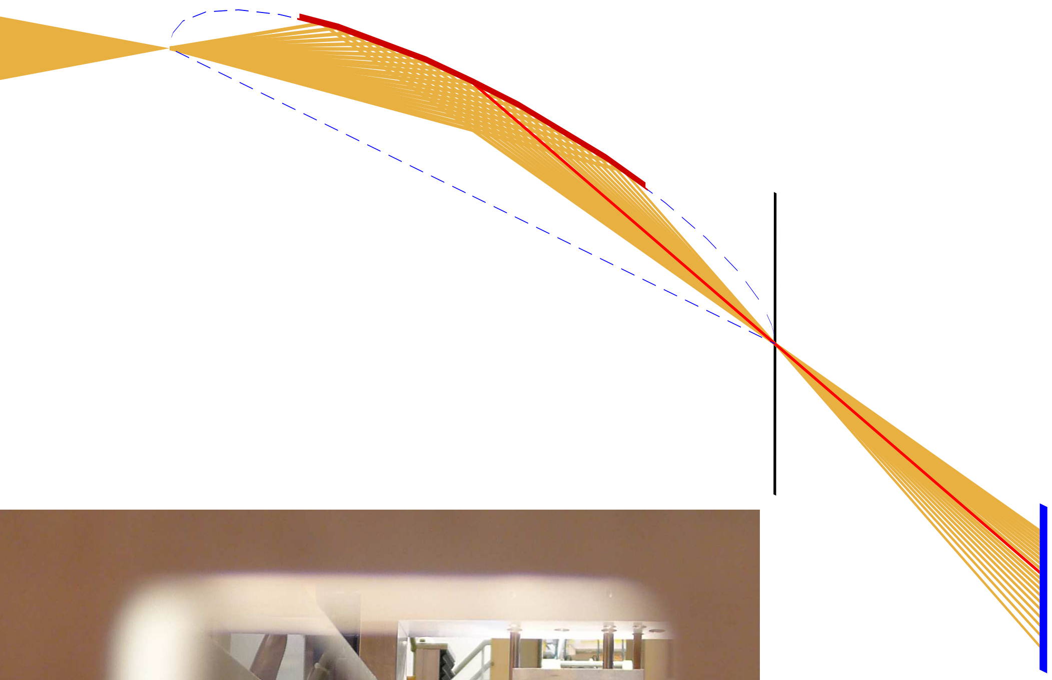
quality characterisation with pin-hole



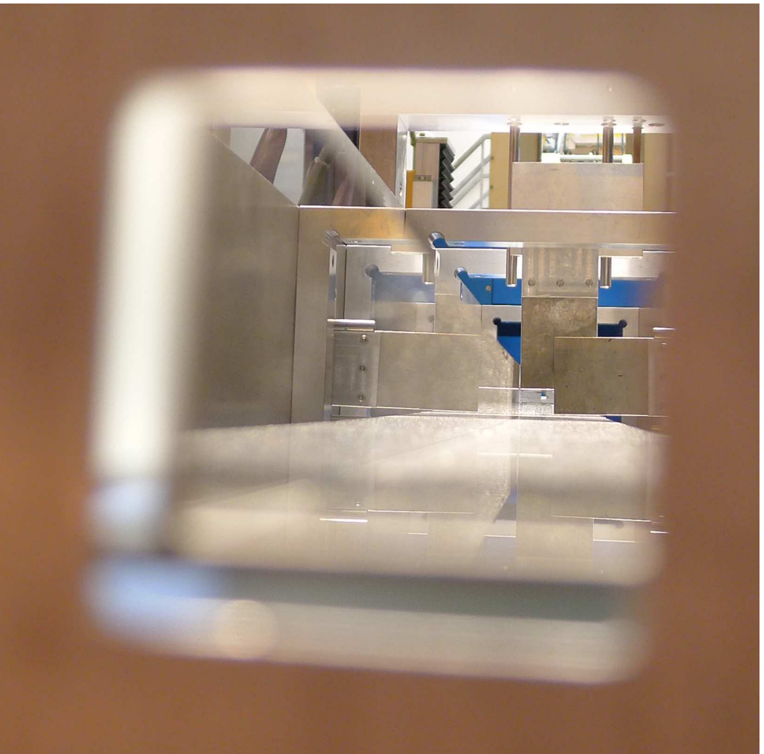
using light & CCD camera, or neutrons

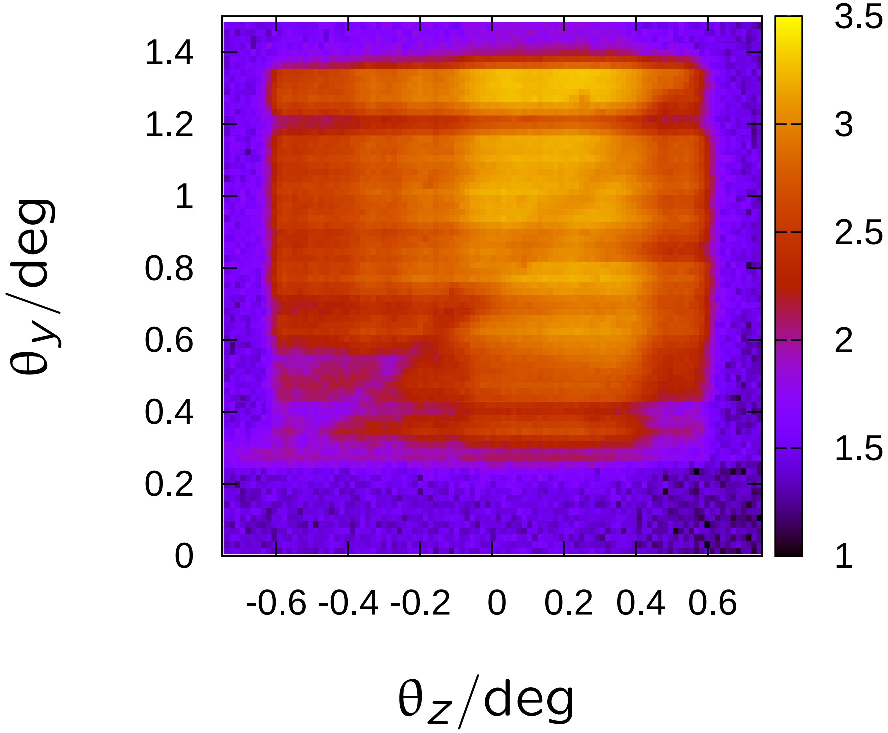
prototype

quality characterisation with pin-hole



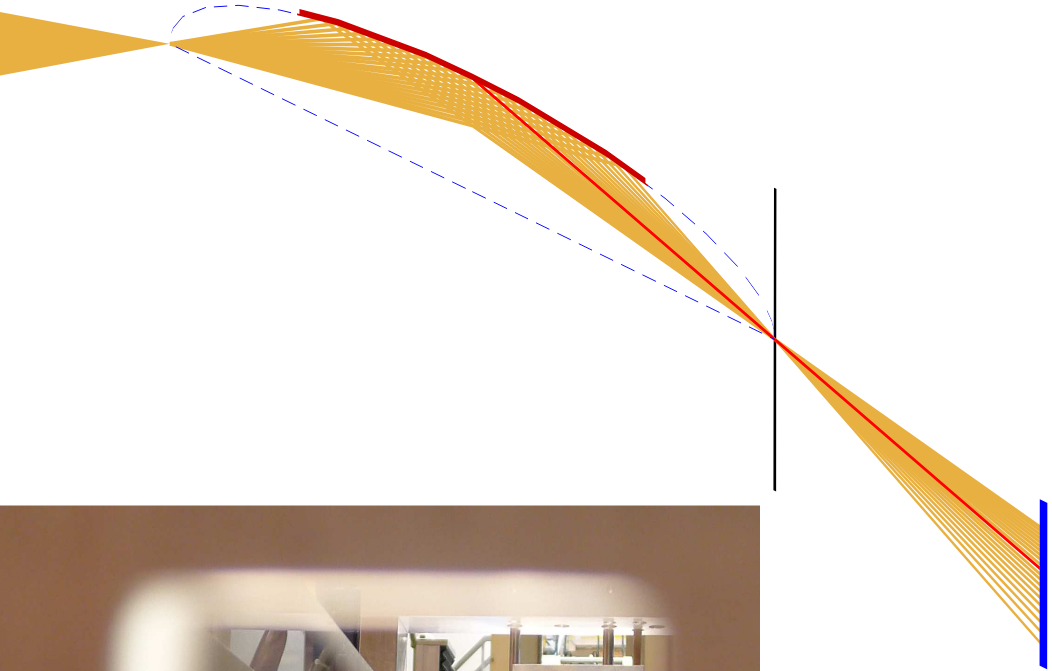
using light & CCD camera, or neutrons



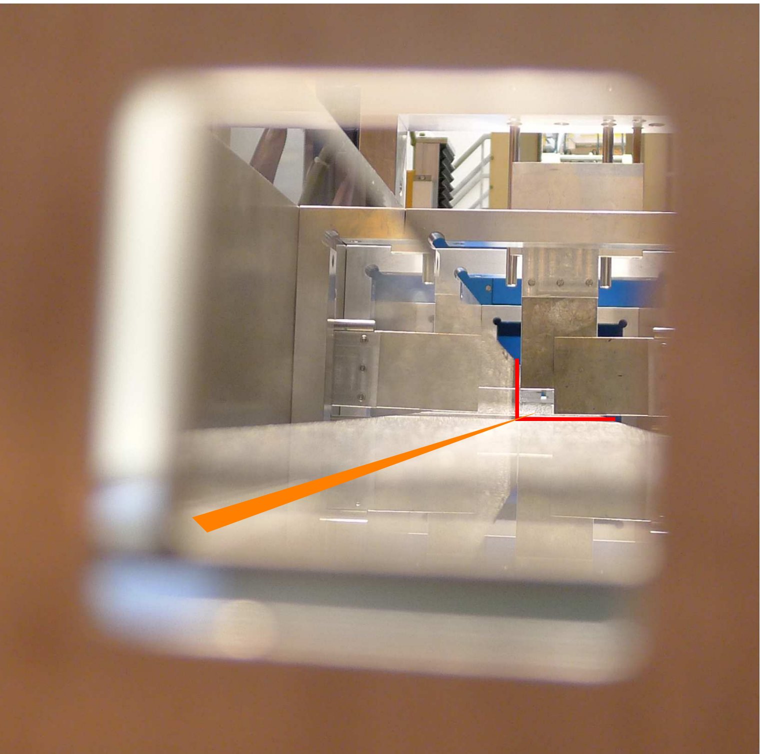


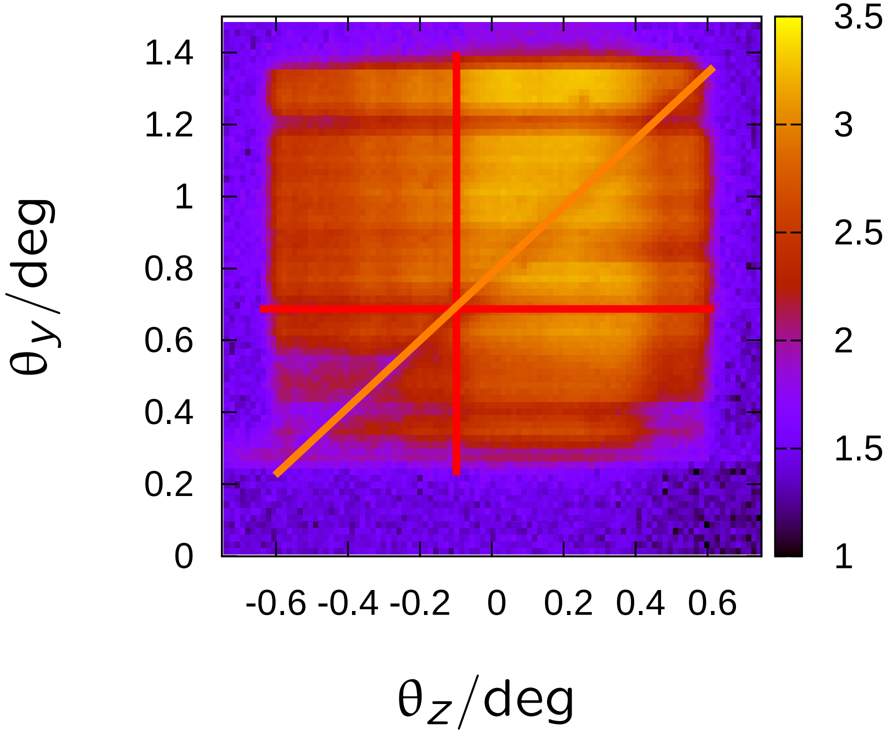
prototype

quality characterisation with pin-hole



using light & CCD camera, or neutrons





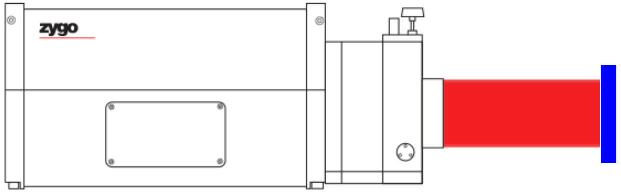
prototype

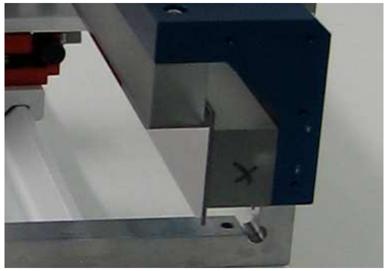
quality characterisation by interferometry:

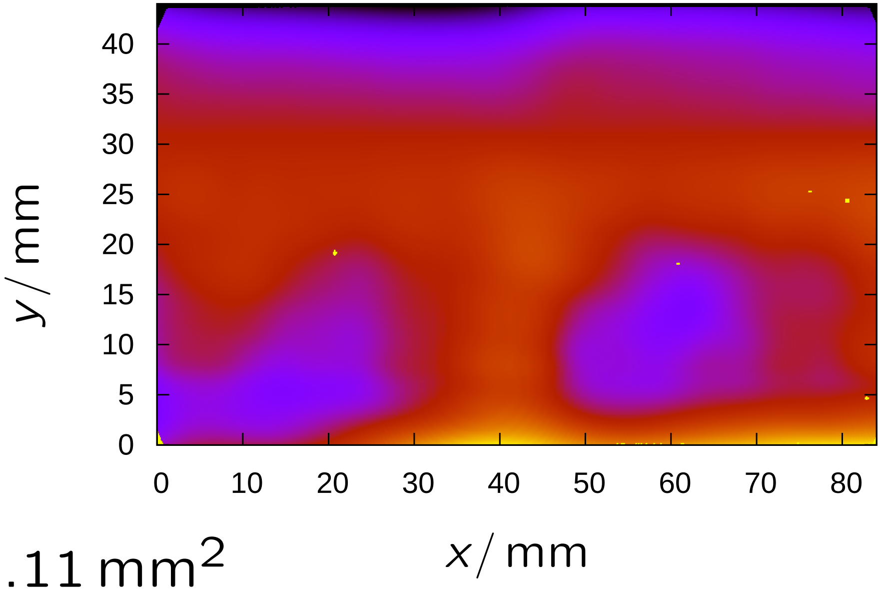
ZYGO Verifire ATZ

metrology-lab @ PSI

parallel beam *normal* to the surface







dynamic range: 1.5 µm

resolution: $0.11 \times 0.11\,\text{mm}^2$

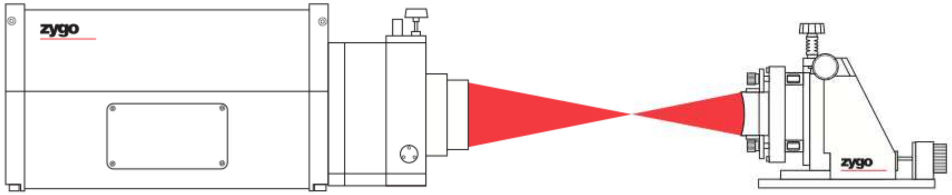
prototype

quality characterisation by interferometry:

ZYGO Verifire ATZ

metrology-lab @ PSI

focused beam

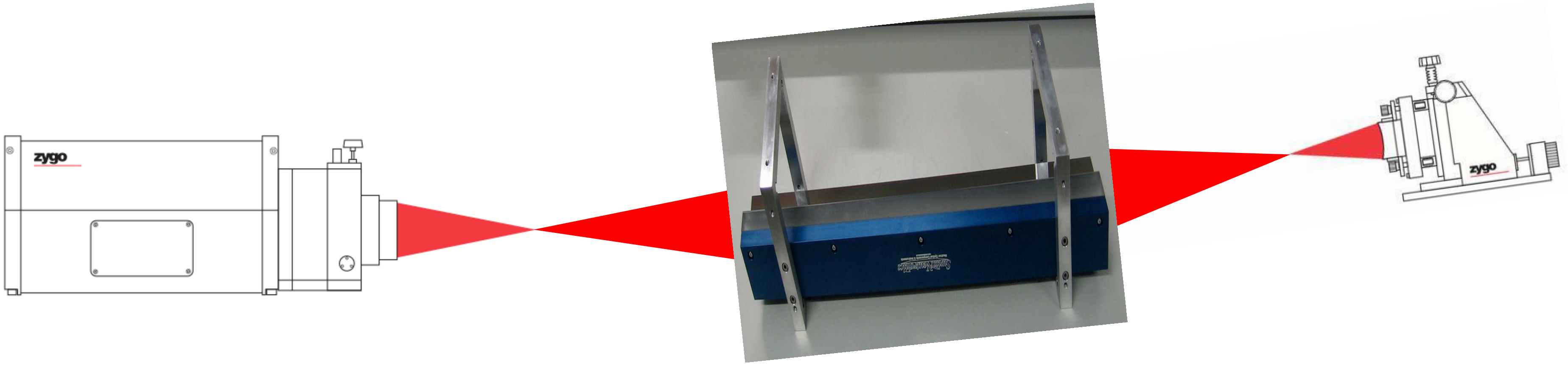


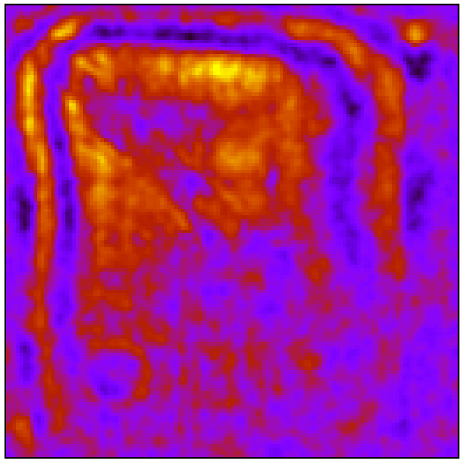
prototype

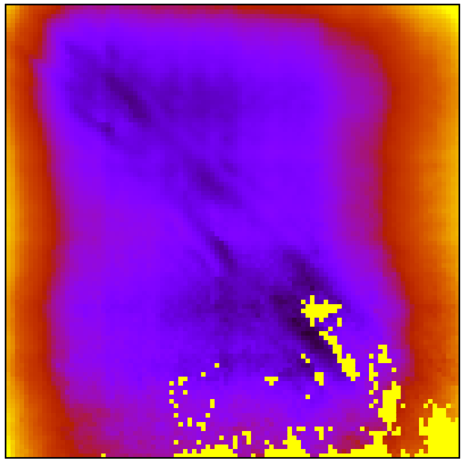
quality characterisation by interferometry:

ZYGO Verifire ATZ
metrology-lab @ PSI

focused beam fed into guide







not yet analysed

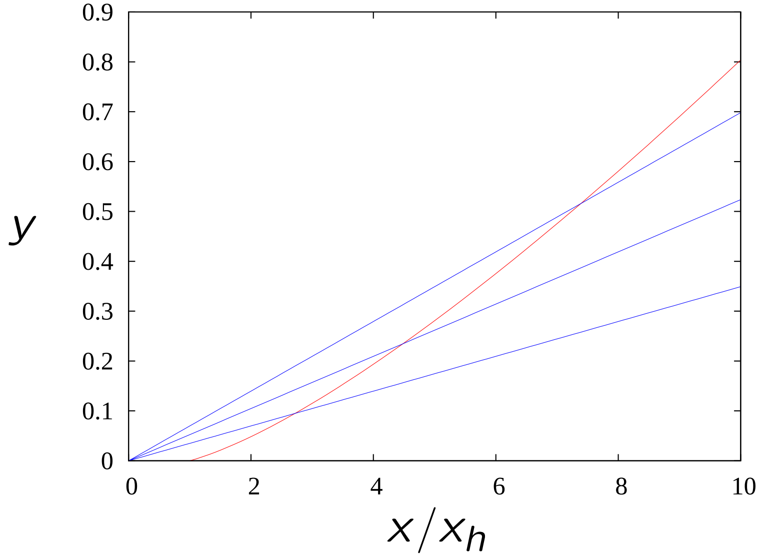
light optics not adapted
⇒ low intensity

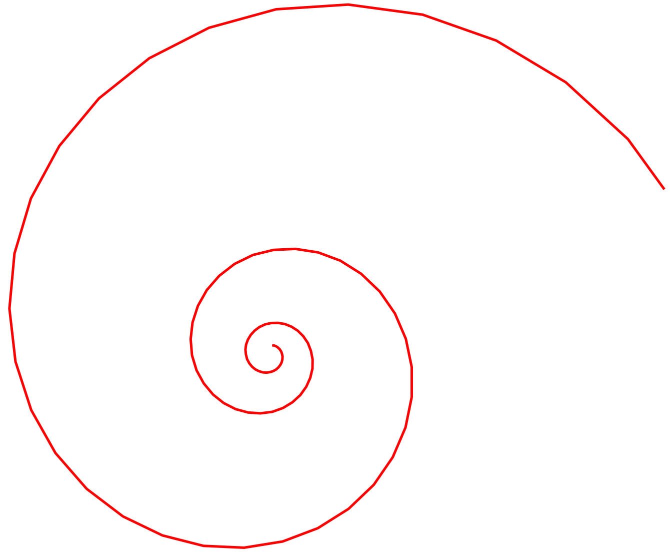
optics & options

- Selene guide system
- prototype
- optics & options
  - reflectometry
  - discussion

optics & options

polariser



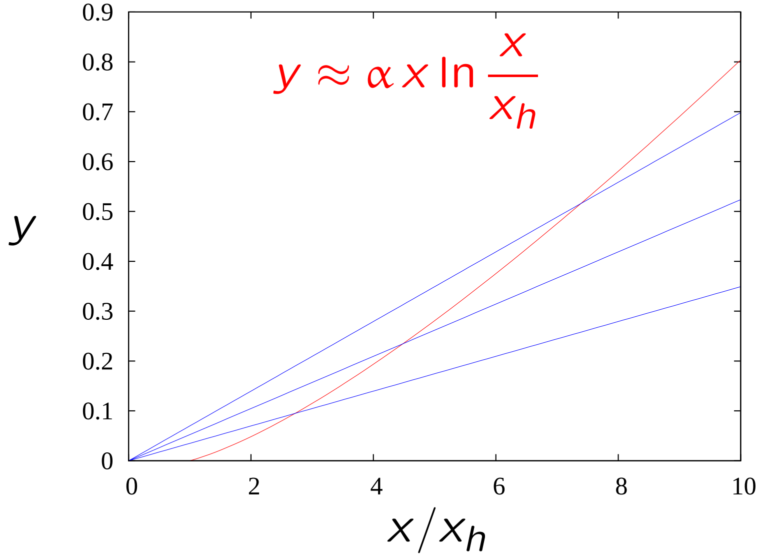


requested:

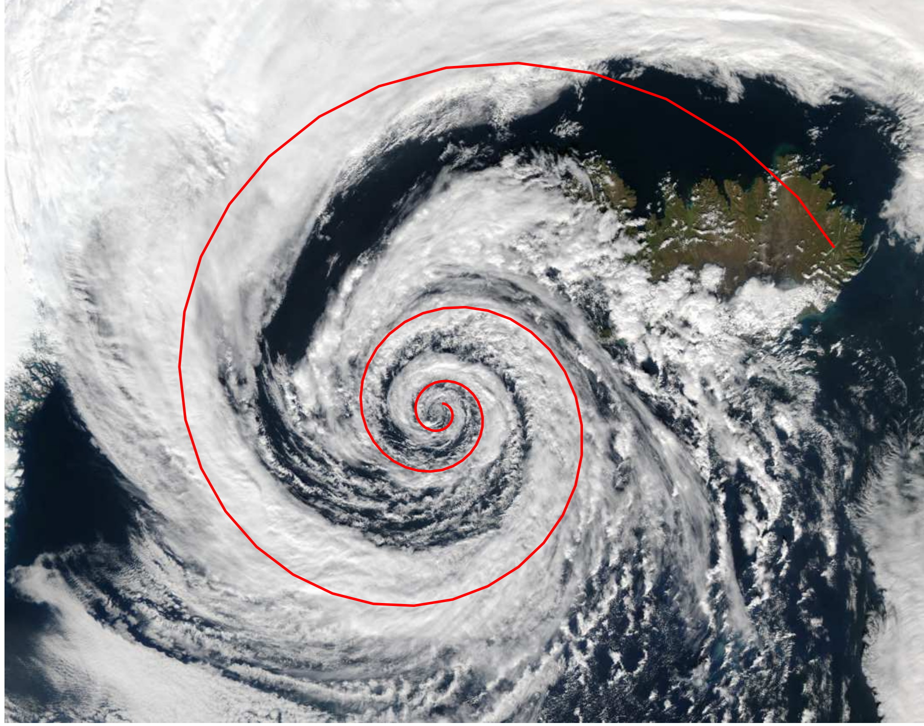
a surface hit by all trajectories from a point source at the same angle α

optics & options

polariser



NASA: low-pressure system centred at Iceland



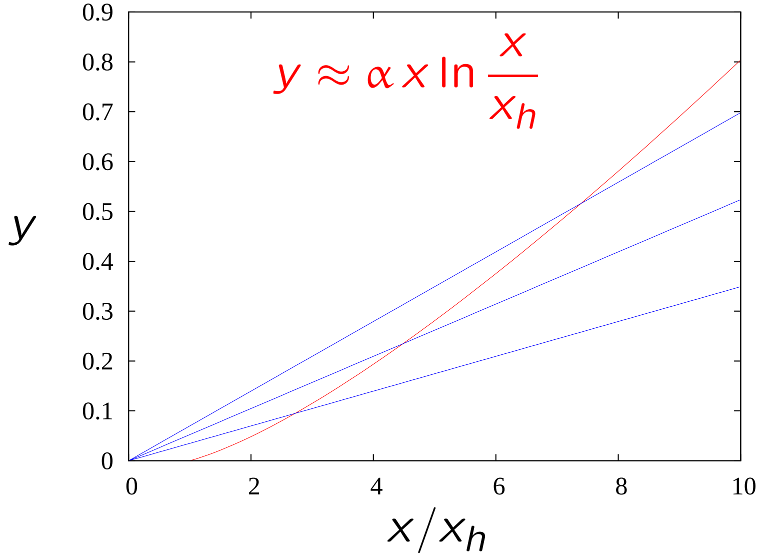
requested:

a surface hit by all trajectories from a point source at the same angle α

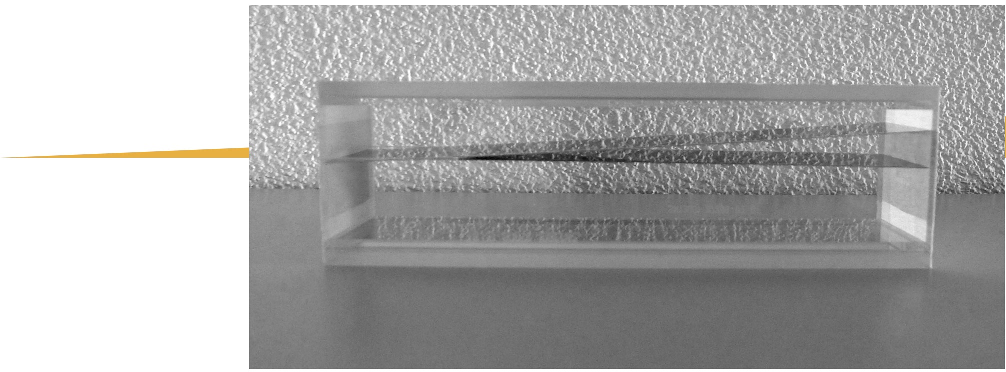
$\Rightarrow$ the logarithmic spiral

optics & options

polariser: logarithmic spiral

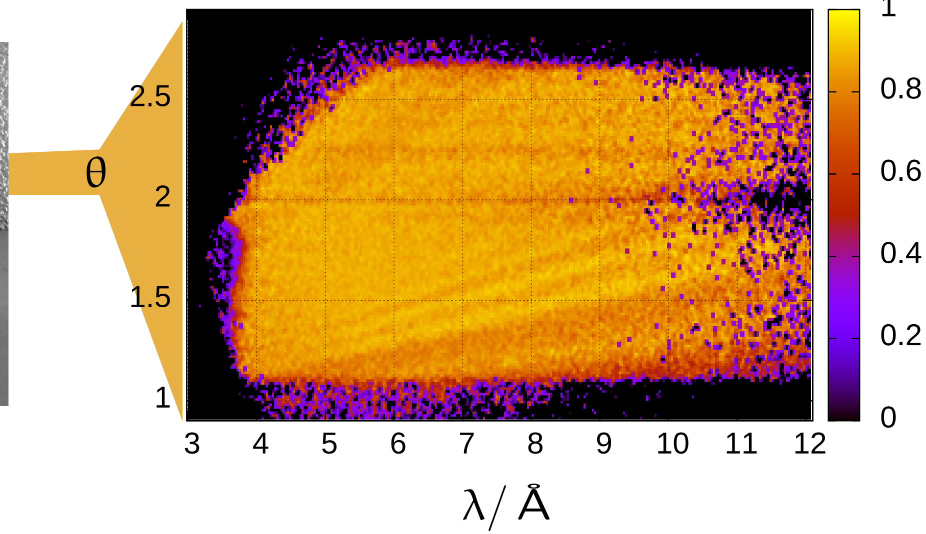


polariser
215 mm long, 1.8° acceptance



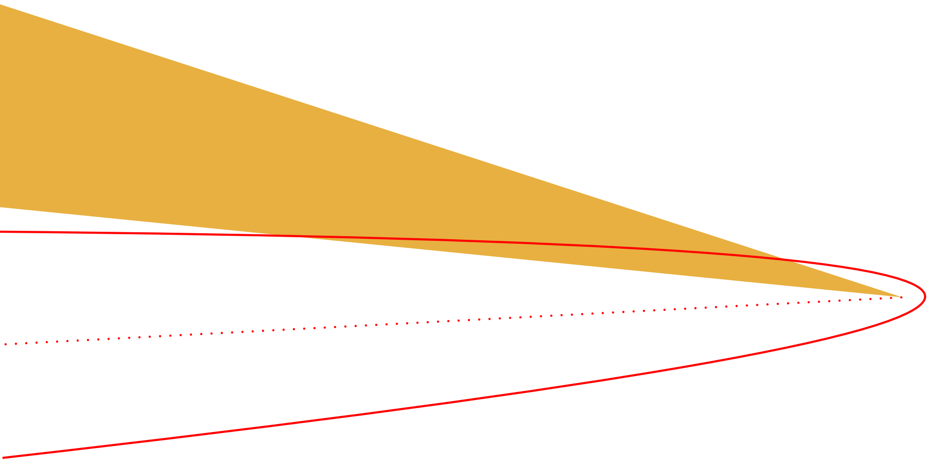
(by SwissNeutronics)

polarisation efficiency



optics & options

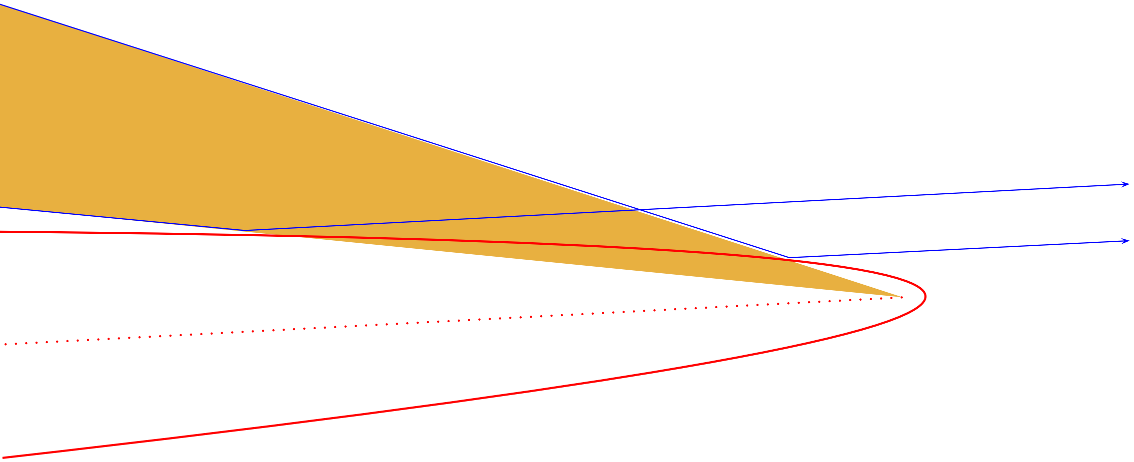
condenser: parabolic deflector to generate a parallel beam



parabola axis ⇒ beam direction

optics & options

condenser: parabolic deflector to generate a parallel beam

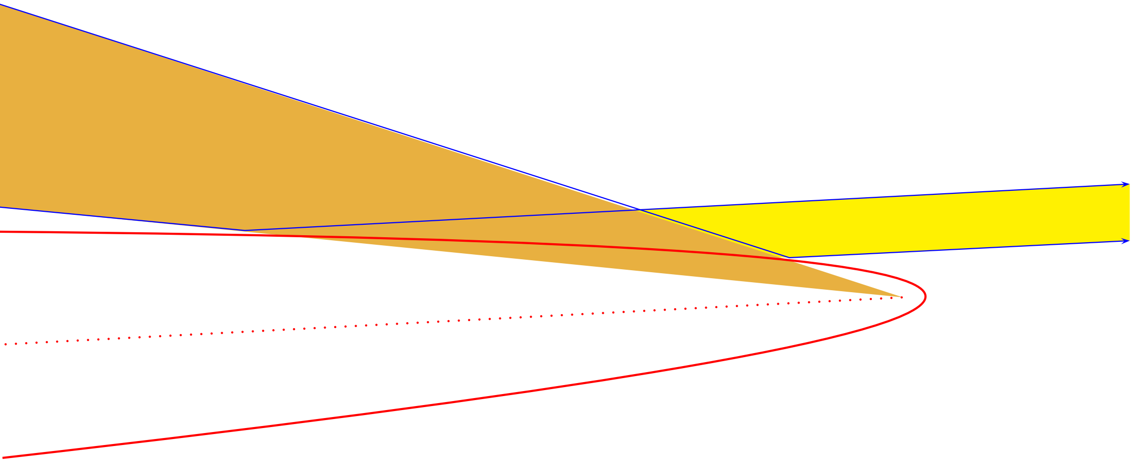


parabola axis ⇒ beam direction

focal length ⇒ beam width

optics & options

condenser: parabolic deflector to generate a parallel beam



parabola axis ⇒ beam direction

focal length ⇒ beam width

beam width & spot size ⇒ divergence

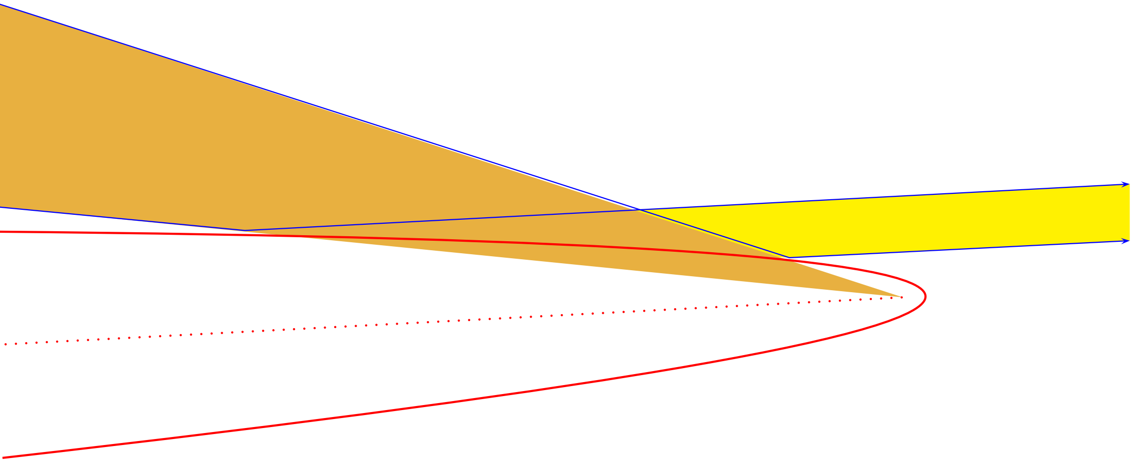
no collimator needed

tunable

(not yet realised)

optics & options

condenser: parabolic deflector to generate a parallel beam



parabola axis ⇒ beam direction

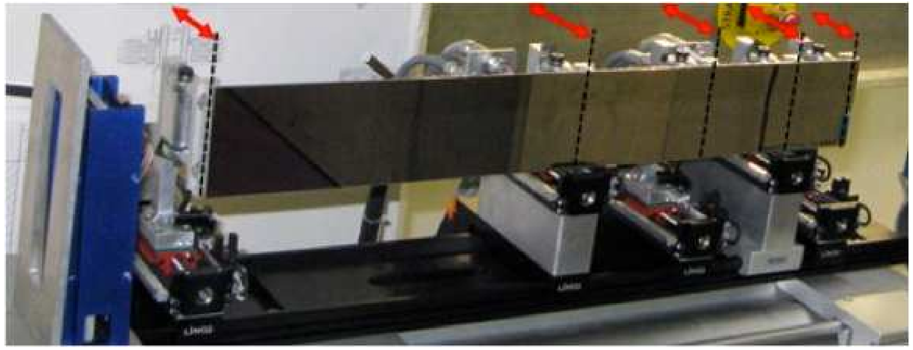
focal length ⇒ beam width

beam width & spot size ⇒ divergence

no collimator needed

tunable

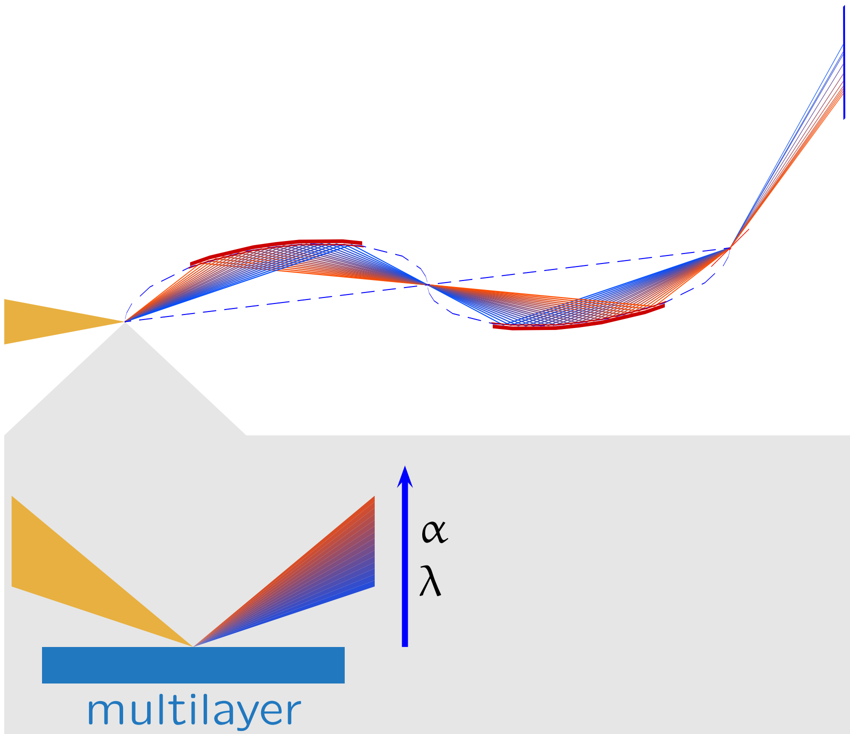
adaptive convex parabola
(PSI, early version)

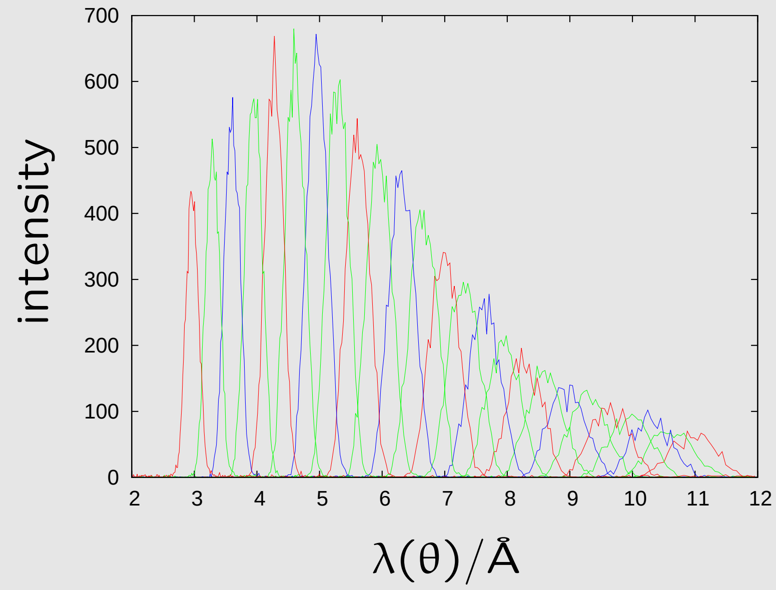


optics & options

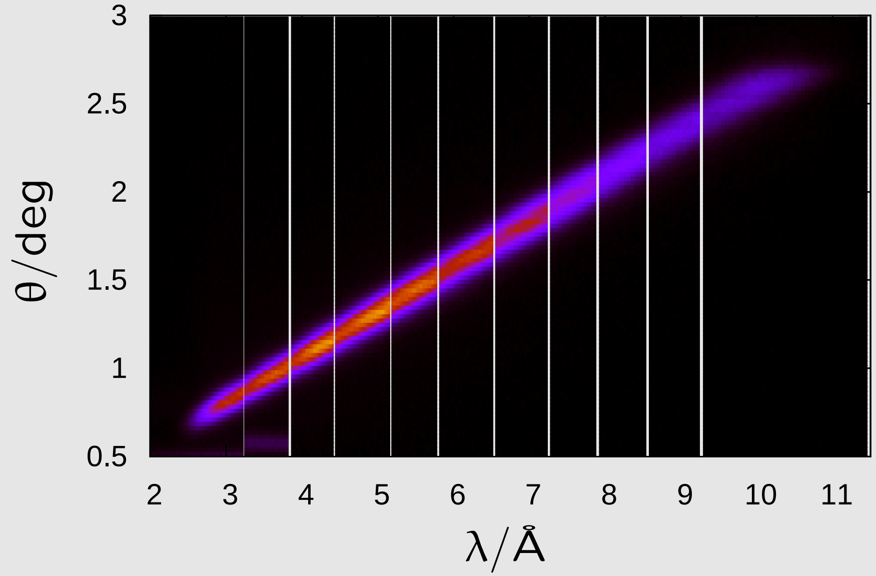
spectral analysis

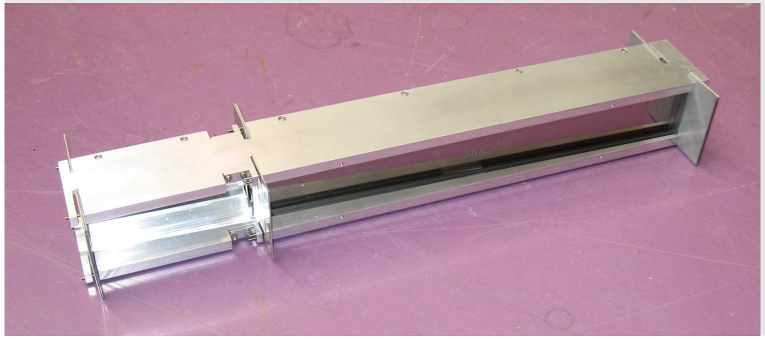
using a multilayer monochromator





$I(\lambda, \theta)$ measured on Amor





double ML monochromator

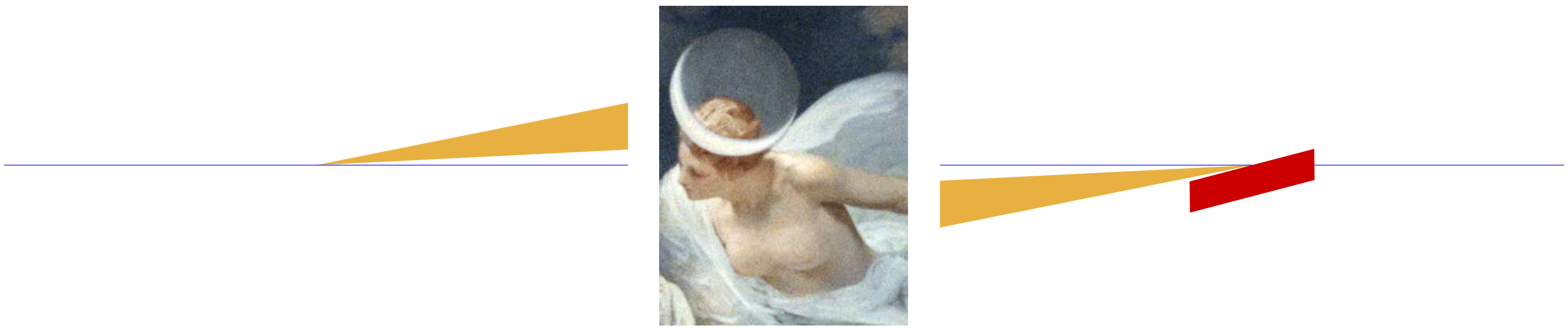
optics & options

3D footprint definition using the imaging property of the *Selene* guide

point source $\Rightarrow$ illuminates sample centre

source

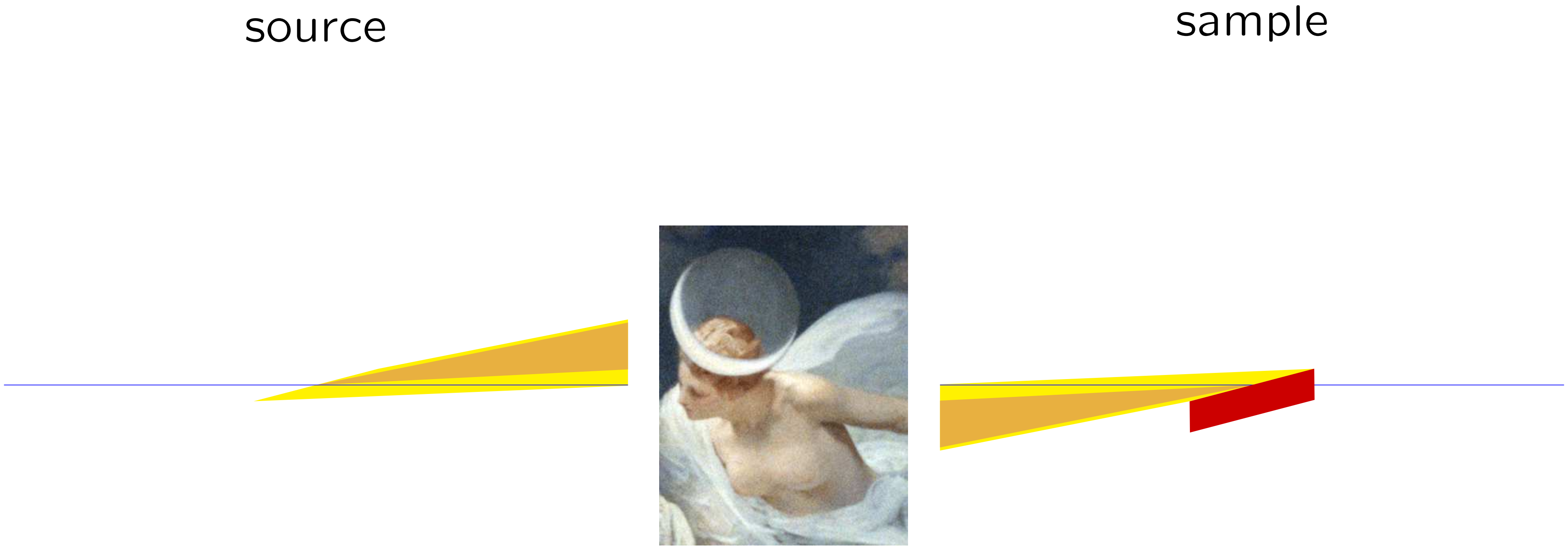
sample



optics & options

3D footprint definition using the imaging property of the *Selene* guide

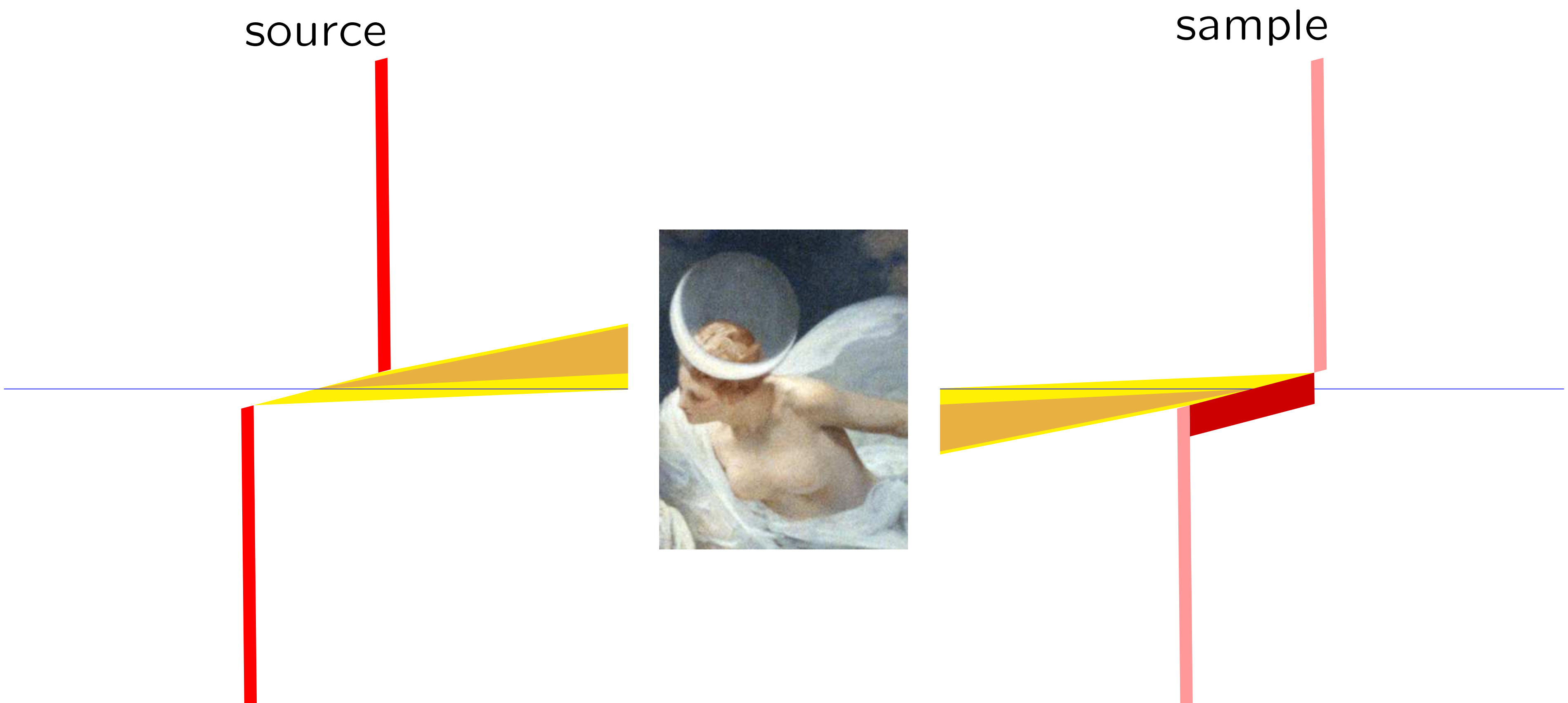
point source	$\Rightarrow$	illuminates sample centre
finite sample	$\Rightarrow$	needs finite source



optics & options

3D footprint definition using the imaging property of the *Selene* guide

point source	⇒	illuminates sample centre
finite sample	⇒	needs finite source
source shape & orientation	=	image of footprint



optics & options

3D footprint definition using the imaging property of the *Selene* guide

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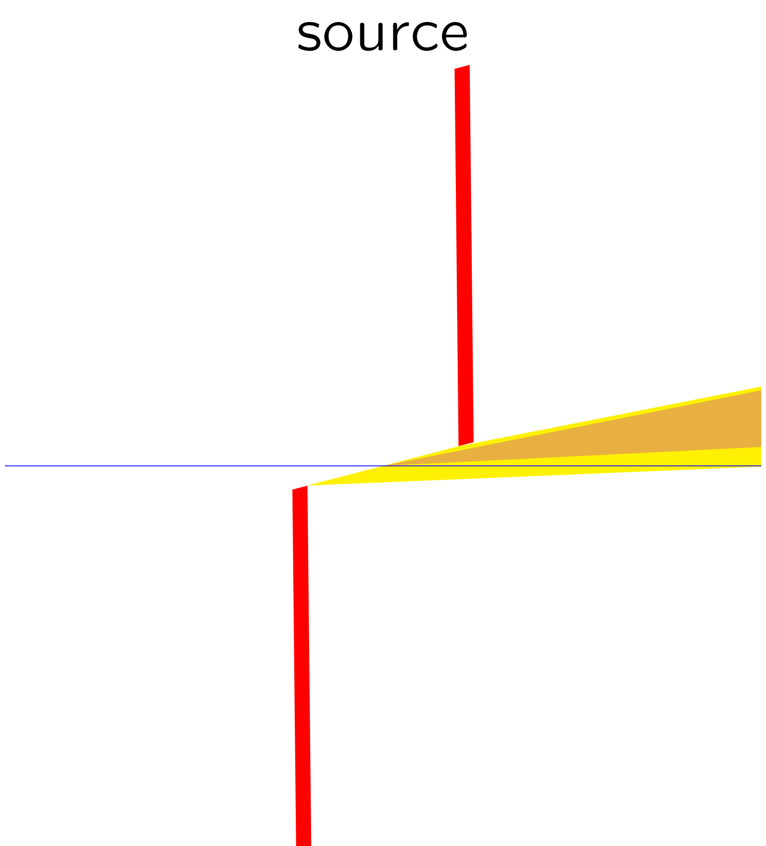
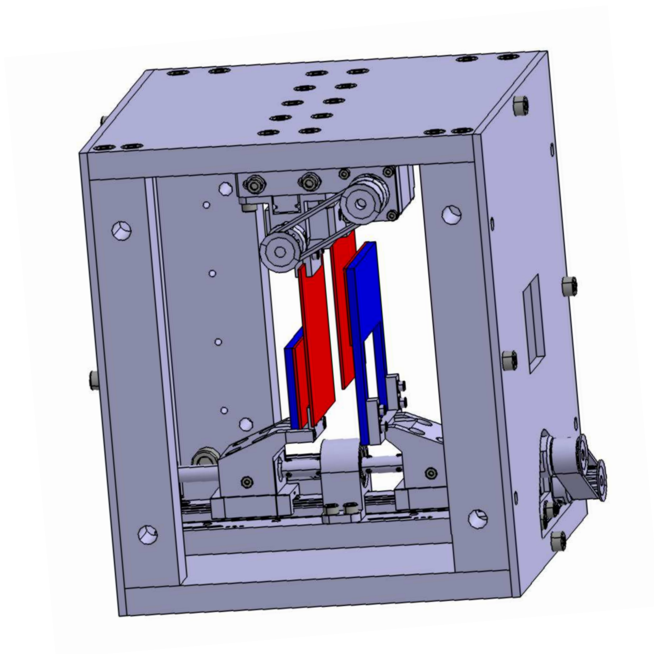




optics & options

3D footprint definition using the imaging property of the *Selene* guide

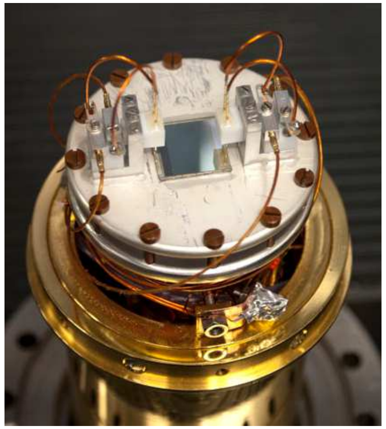
applications:

- exclude sample holder, etc.
- concentrate on one crystallite

reflectometry

- inner region within a trough
- inner region of a solid-liquid cell:

- samples with electrical contacts:



- partially coated substrates
- bent substrates

optics & options

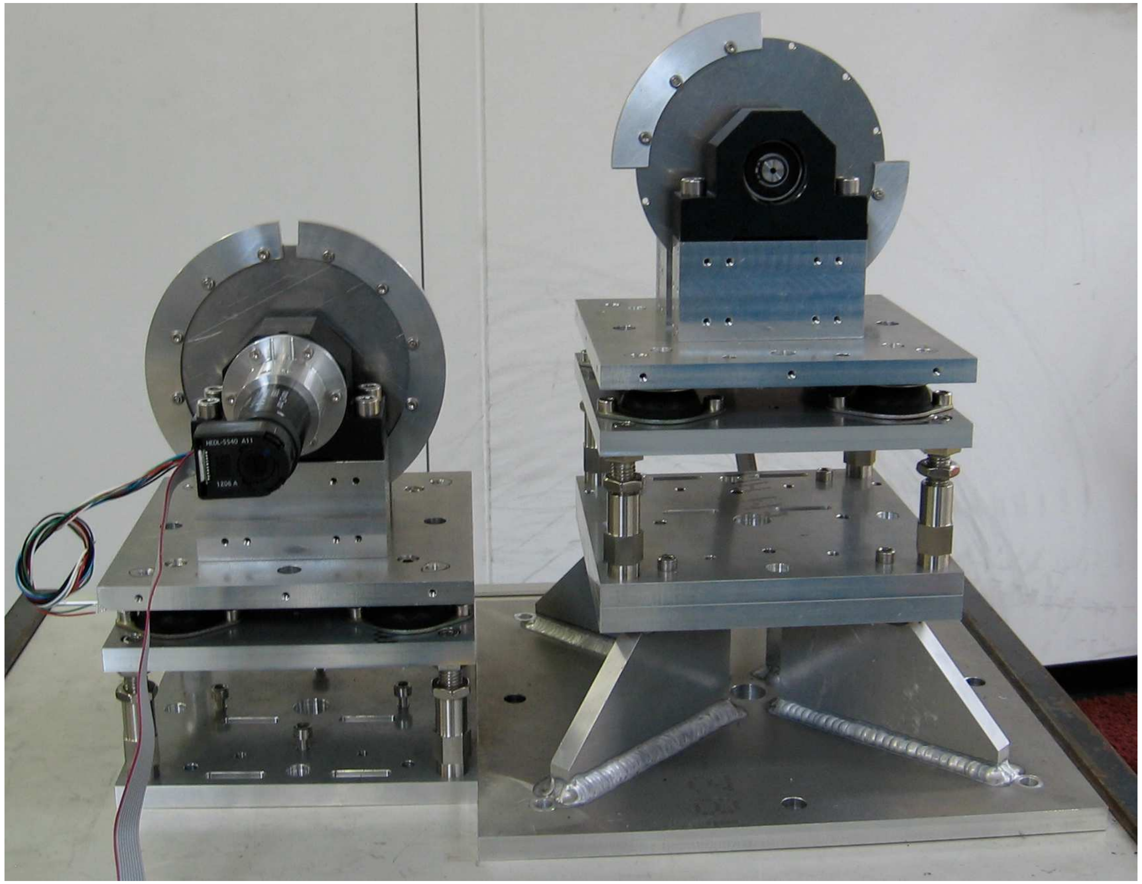
choppers

$\nu = 60\,\mathrm{s}^{-1}$
gives $\lambda = 0 \ldots 10\,\text{Å}$

$\varnothing = 150\,\mathrm{mm}$

Al:B and Cd absorber

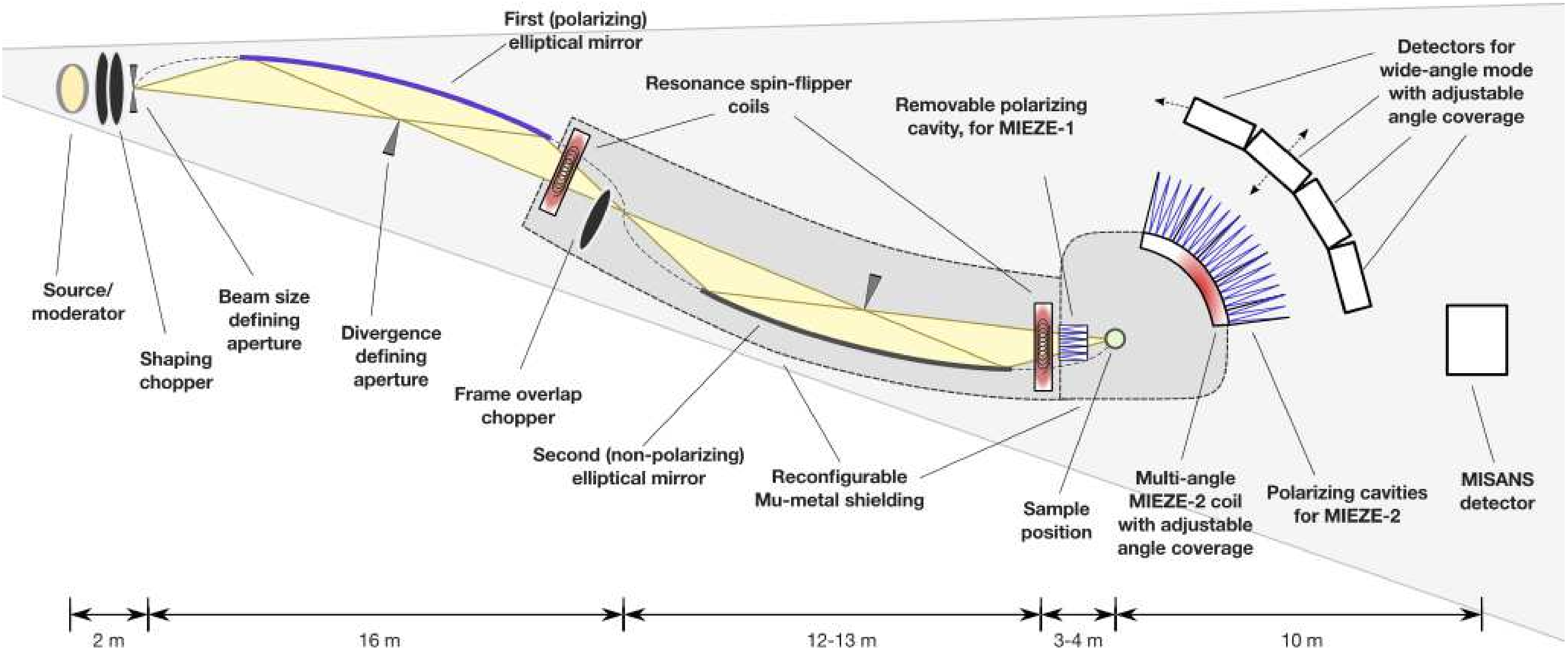
- frame-overlap suppression
- pulse generation



optics & options

MIEZE (NRSE) compatibility with *Selene* guide under investigation

all trajectories have the same length



G. Brandl, A. Chacón, R. Georgii, W. Häußler, *et al.* FRM II & TU Munich

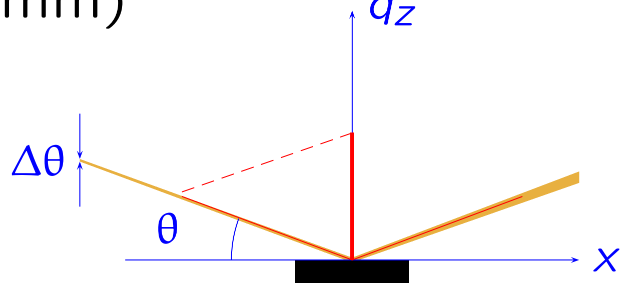
reflectometry

- Selene guide system
- prototype
- optics & options
- reflectometry
- ◦ discussion

reflectometry

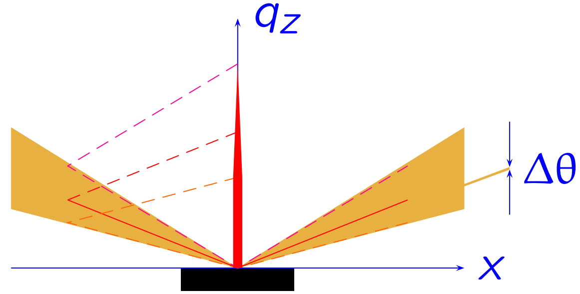
why?

- samples are *small* in at least one direction ($\ll 10\,\mathrm{mm}$)



- typically $\lambda > 3\,\text{Å}$

- large dynamic range requires a low background
  no illumination of sample environment



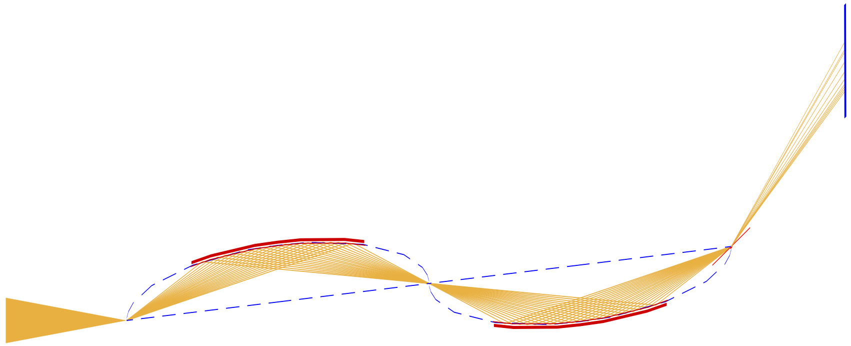
- reflectometry can profit from
  - large $\Delta\theta$
  - λ-θ encoding
  - changing θ without rotating the sample

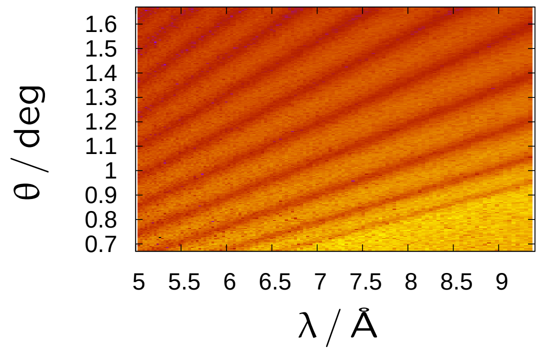
- it's my area of interest

reflectometry

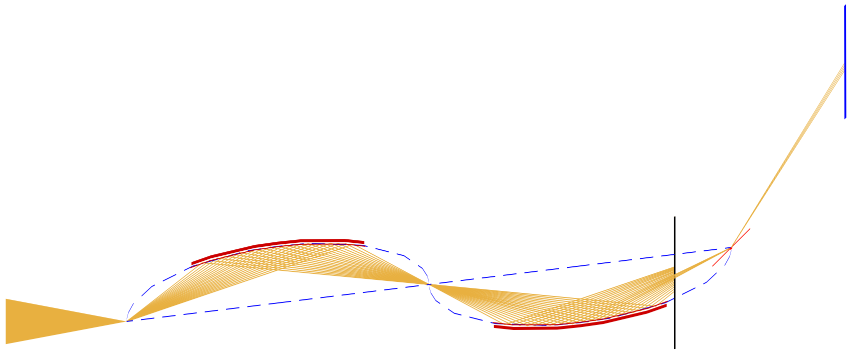
operation modes

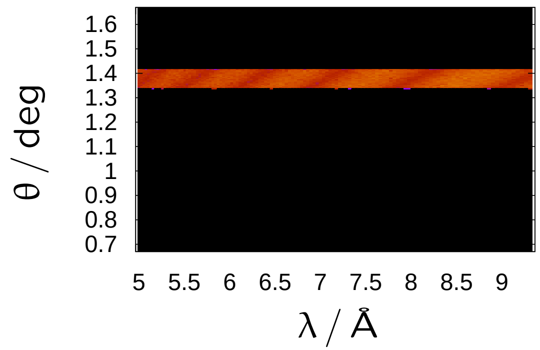
high-intensity
specular reflectivity



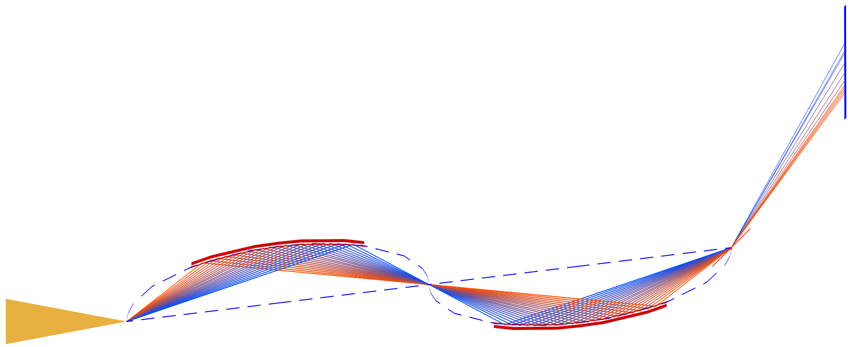


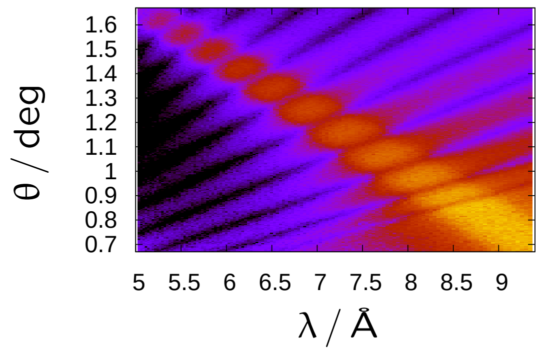
almost conventional
reflectivity





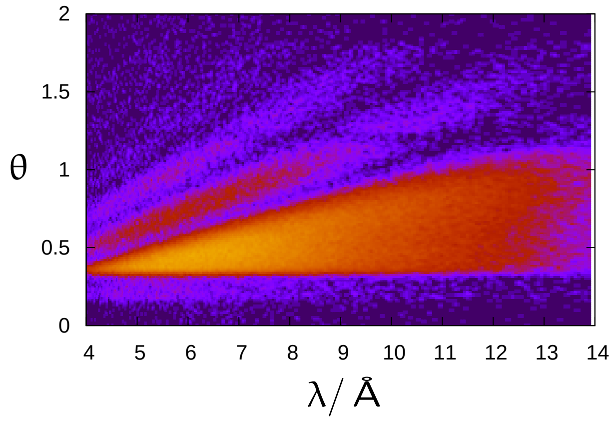
λ-θ encoding





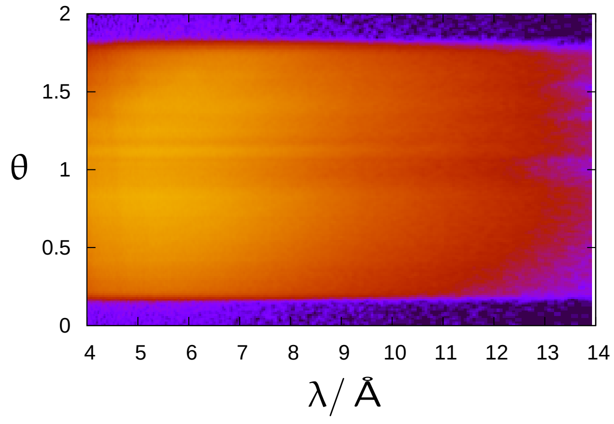
reflectometry

high-intensity specular reflectivity



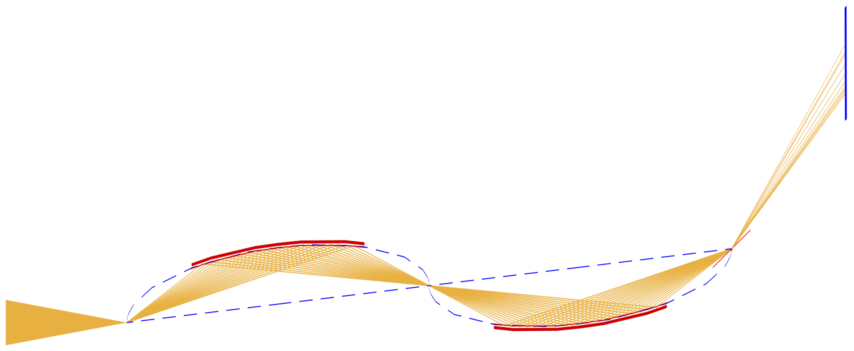
Si/Fe/Cu film on Si

sample by
Birgit Wiedemann
TU Munich



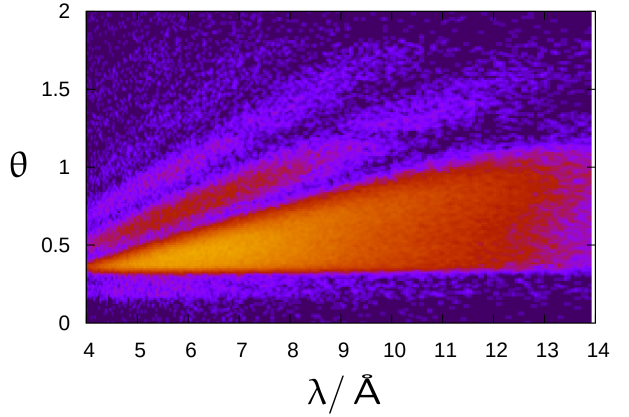
supermirror $m = 5$

sample by
SwissNeutronics



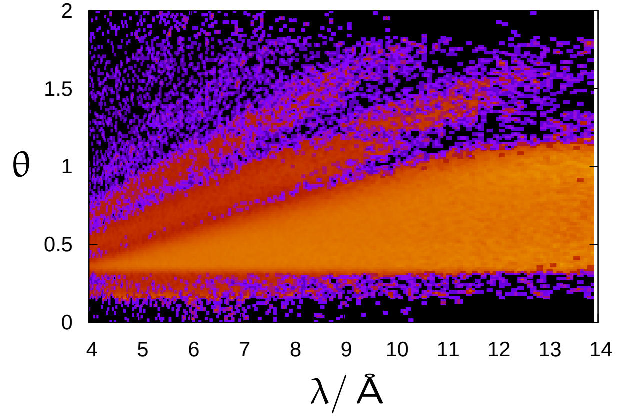
reflectometry

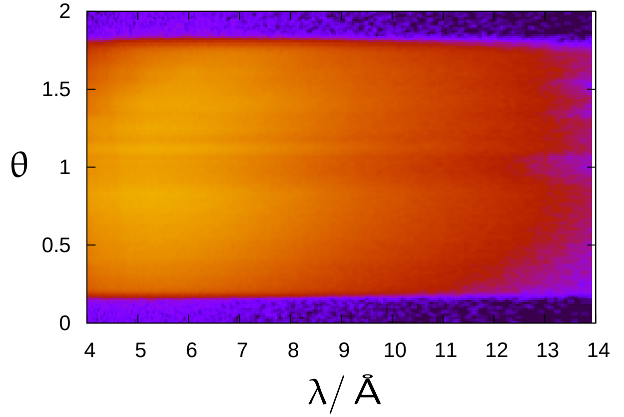
high-intensity specular reflectivity



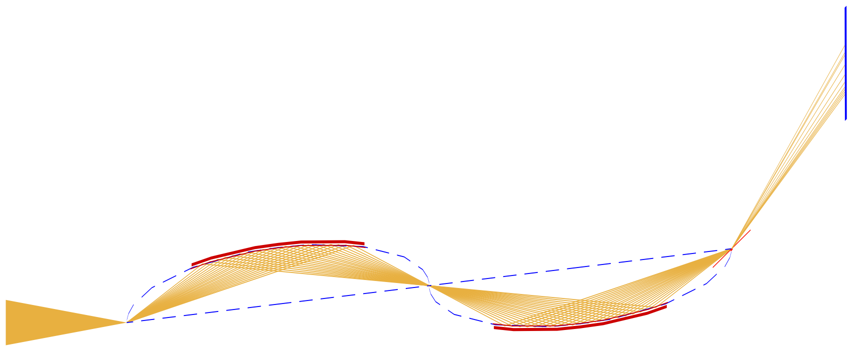
Si/Fe/Cu film on Si

Si/Fe/Cu / SM



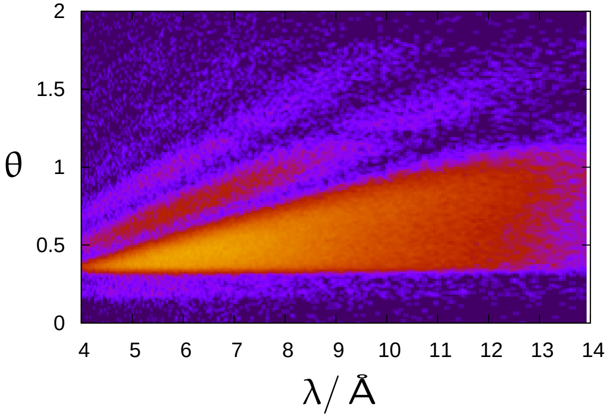


supermirror $m = 5$



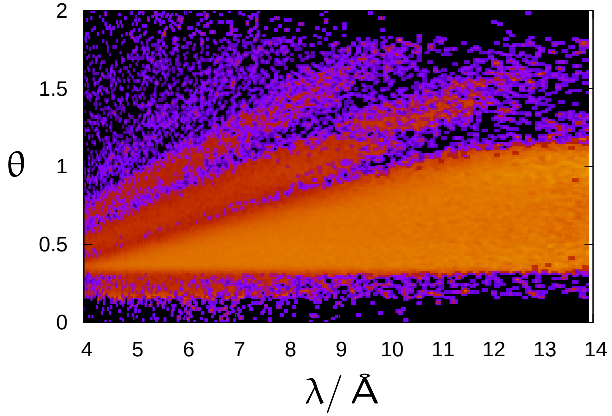
reflectometry

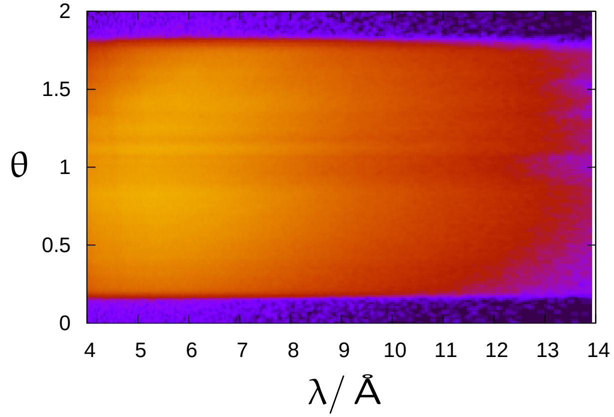
high-intensity specular reflectivity



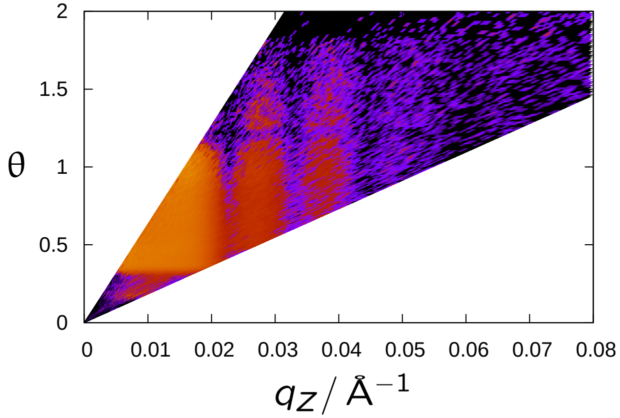
Si/Fe/Cu film on Si

Si/Fe/Cu / SM



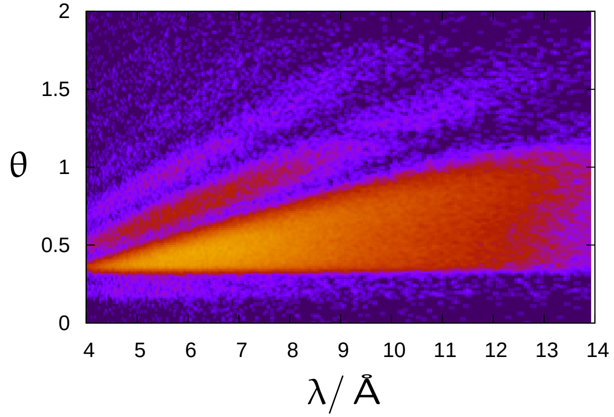


supermirror $m = 5$



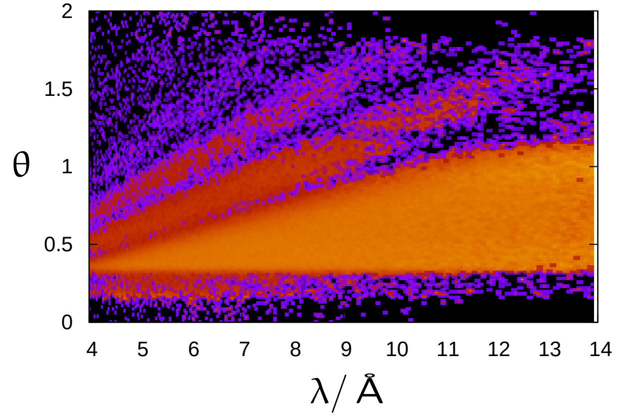
reflectometry

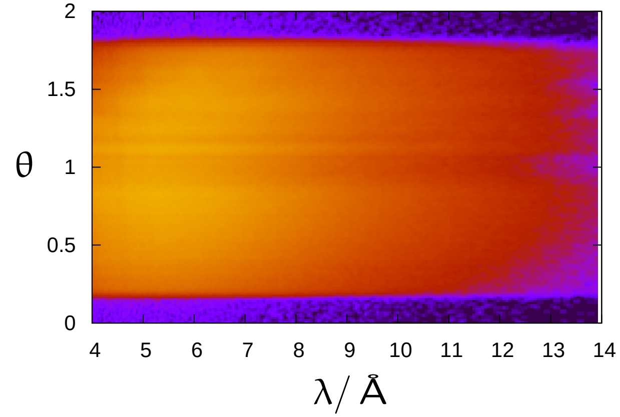
high-intensity specular reflectivity



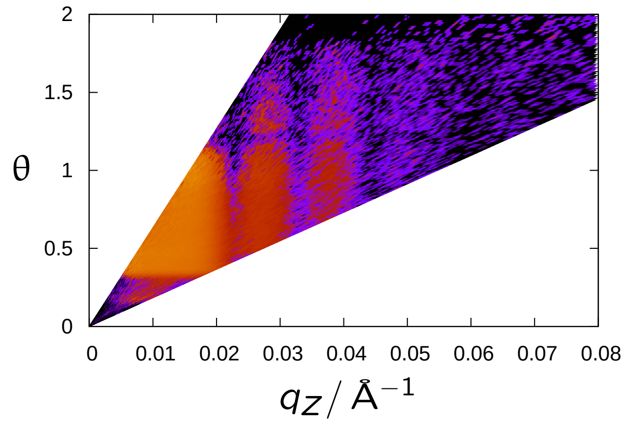
Si/Fe/Cu film on Si

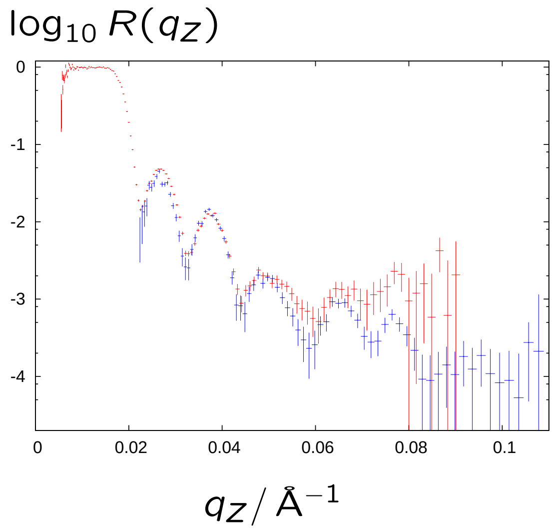
Si/Fe/Cu / SM





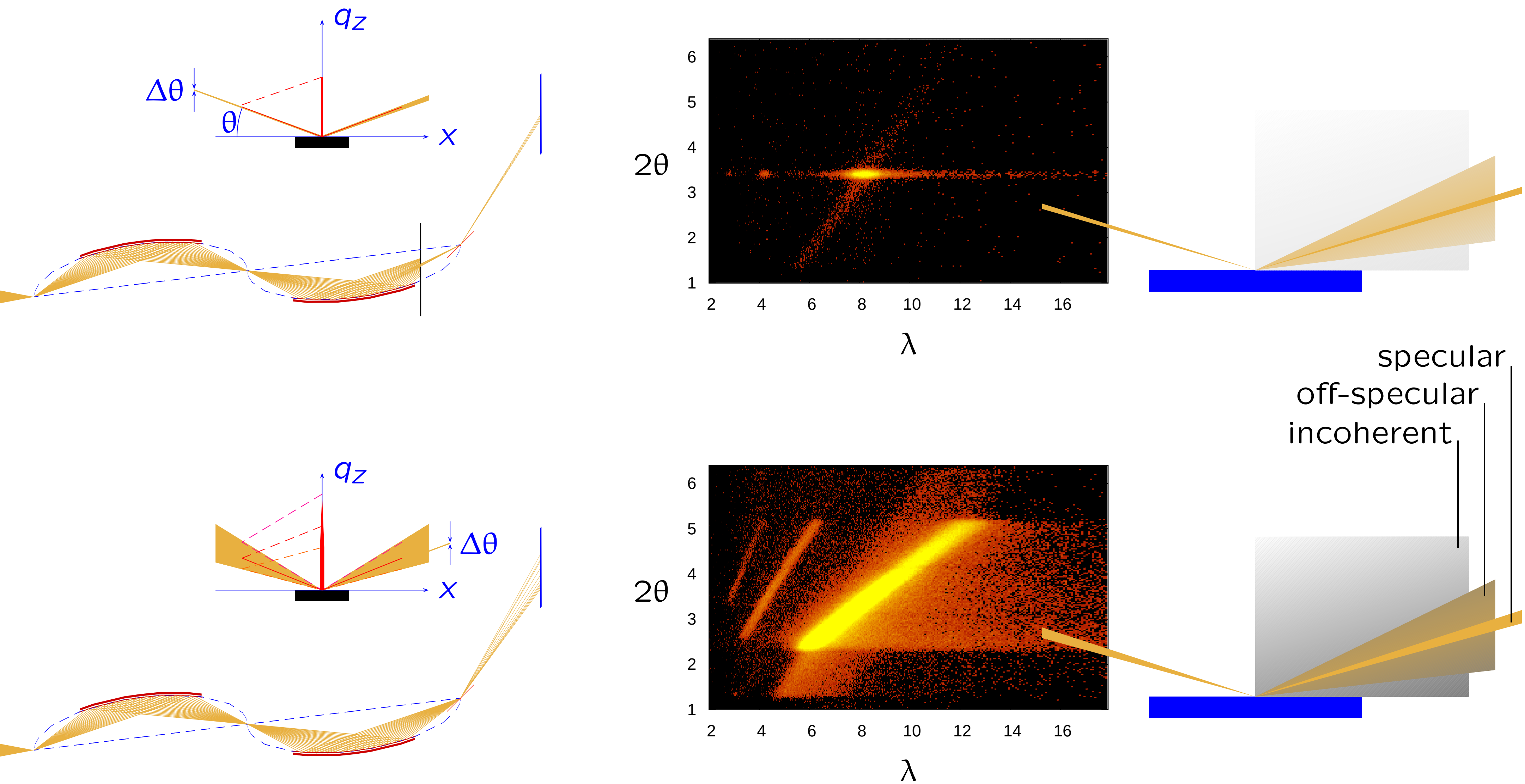
supermirror $m = 5$





reflectometry

high-intensity specular reflectometry vs. almost conventional

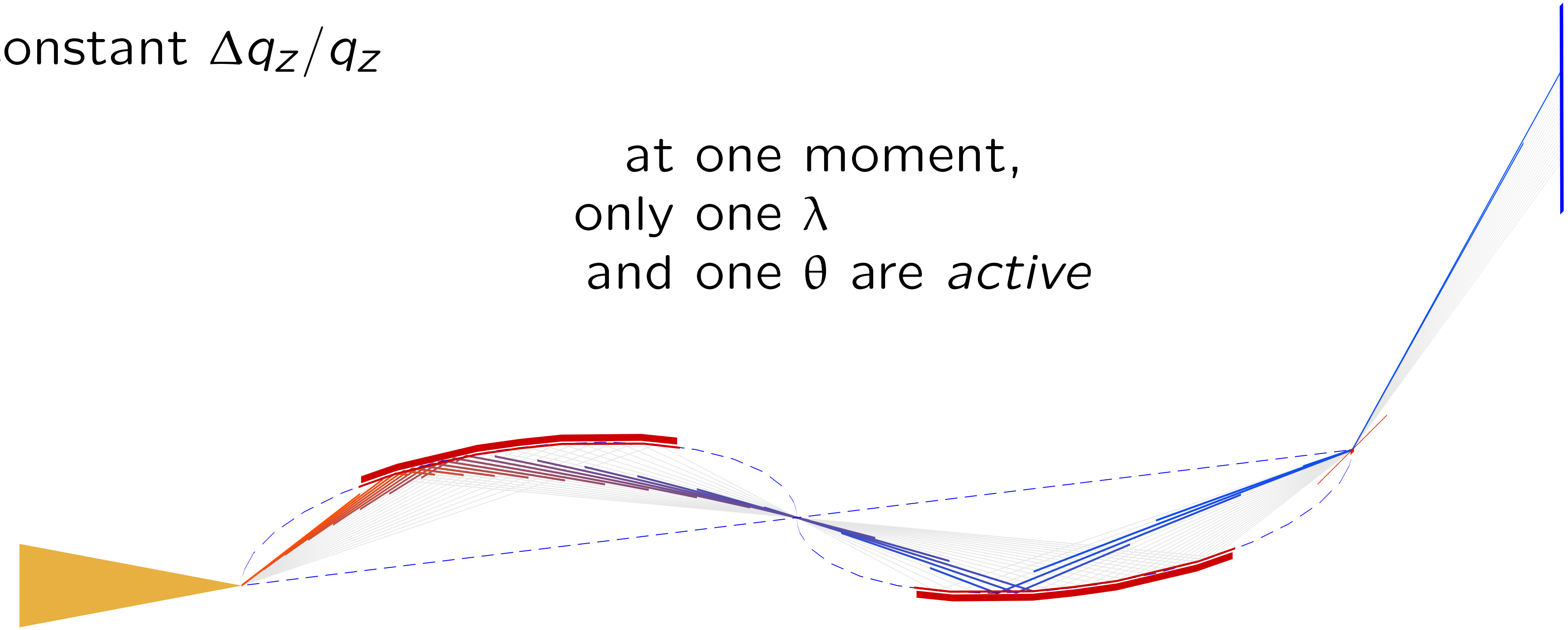


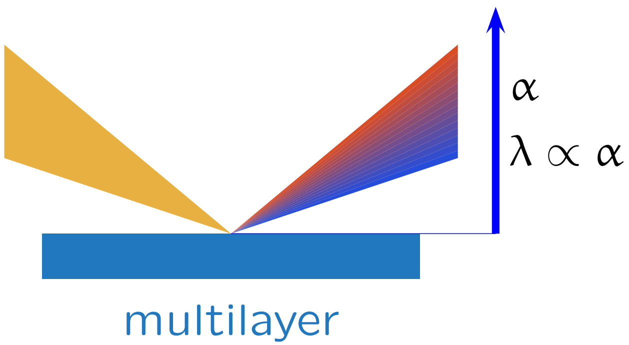
reflectometry

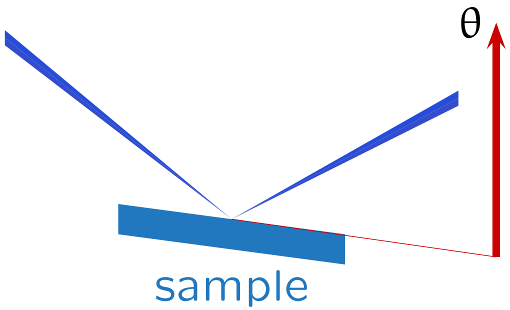
λ-θ-**encoding** & TOF

$\Rightarrow$ constant $\Delta q_z / q_z$

at one moment,
only one λ
and one θ are *active*





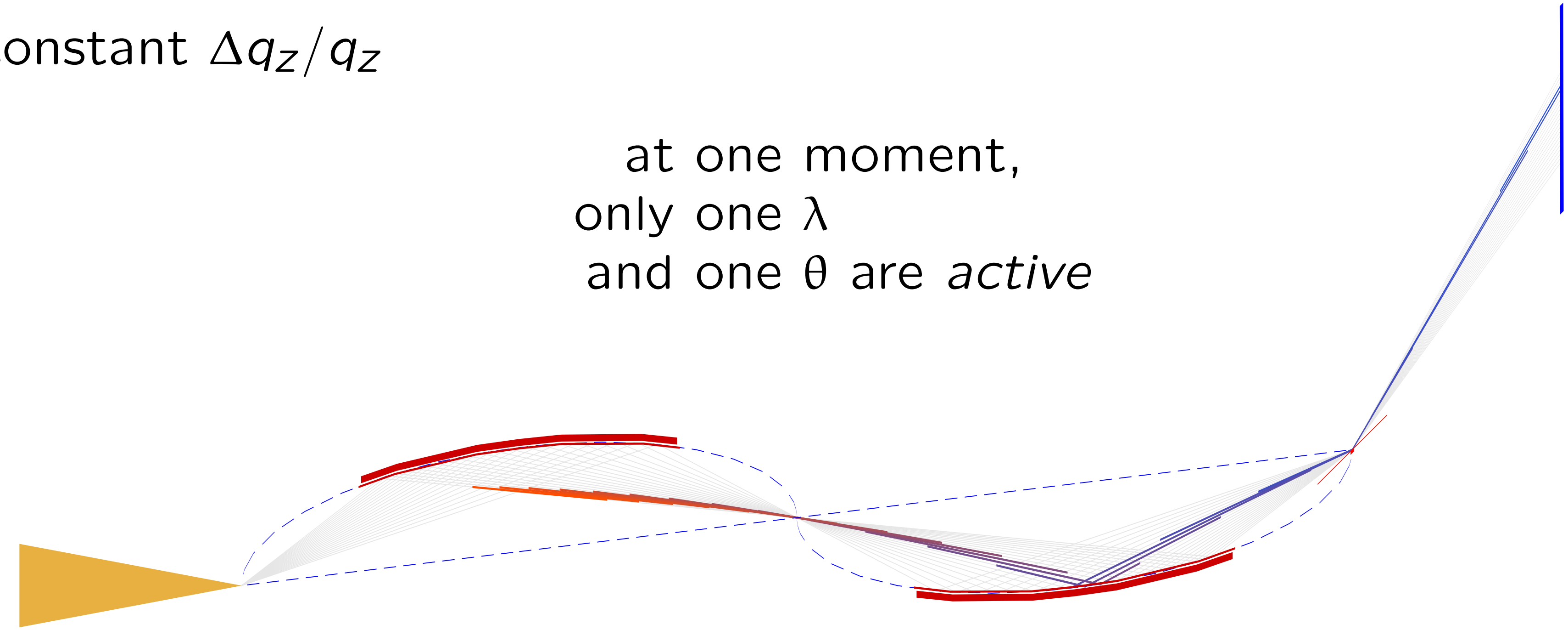


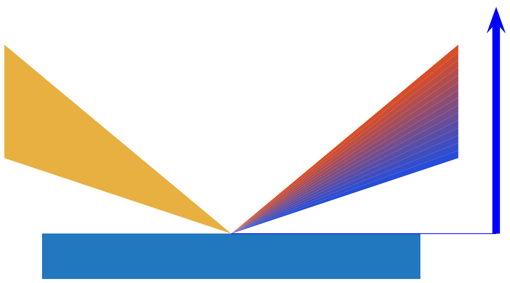
reflectometry

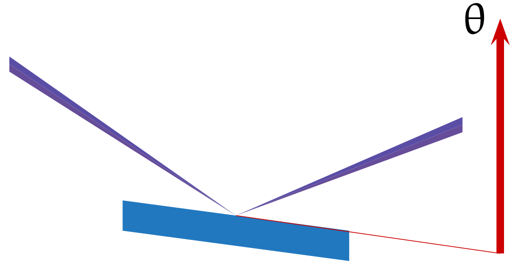
λ-θ-**encoding** & TOF

⇒ constant $\Delta q_z / q_z$

at one moment,
only one λ
and one θ are *active*







reflectometry

λ-θ-**encoding** & TOF

⇒ constant $\Delta q_z / q_z$

at one moment,
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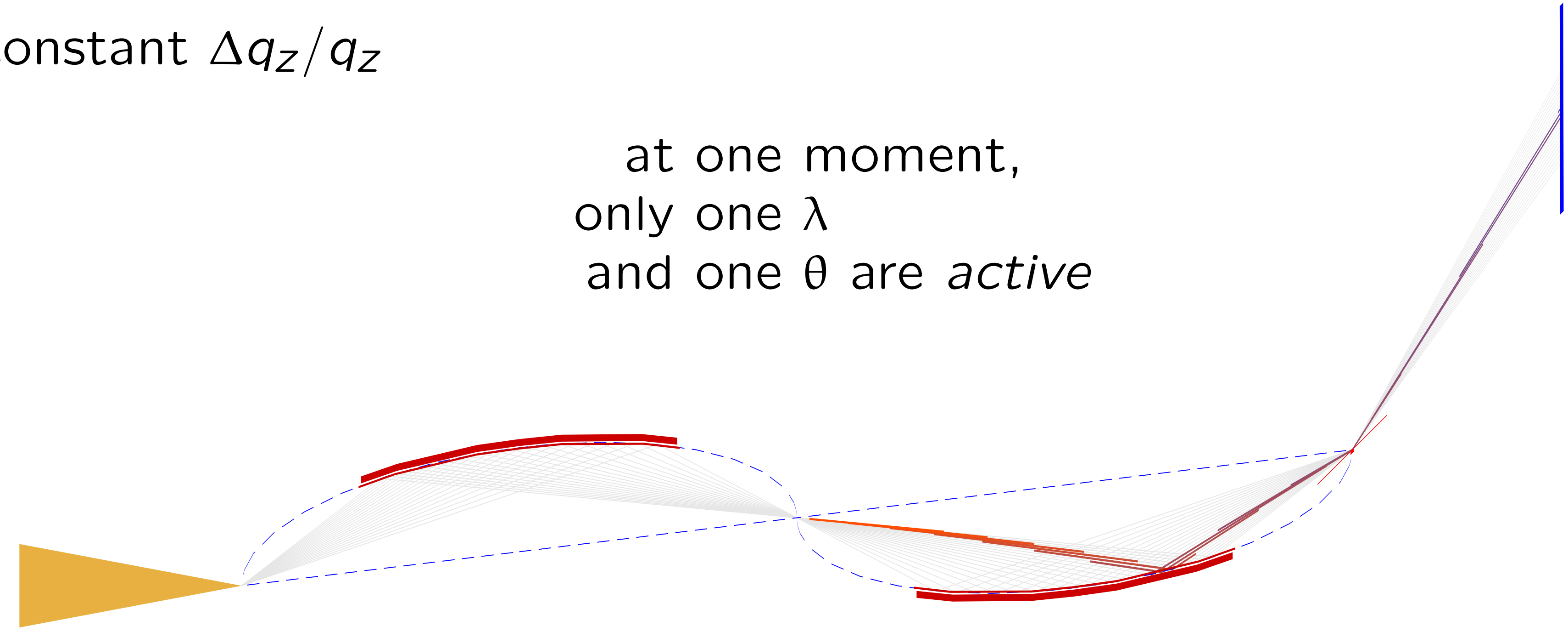
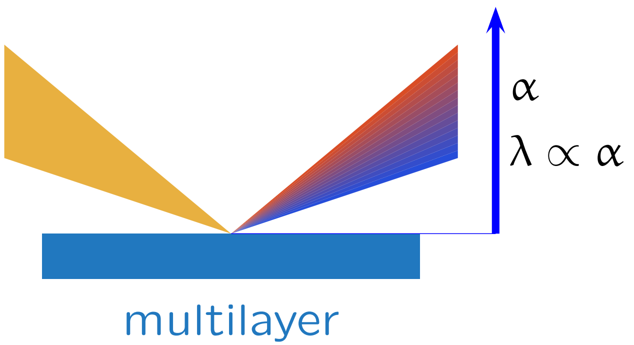
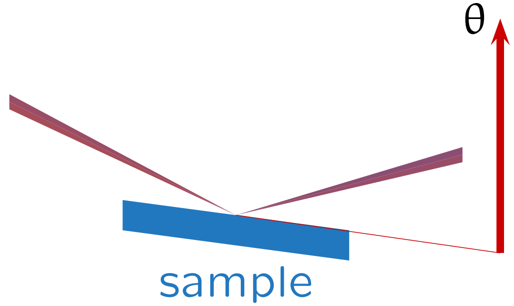






reflectometry

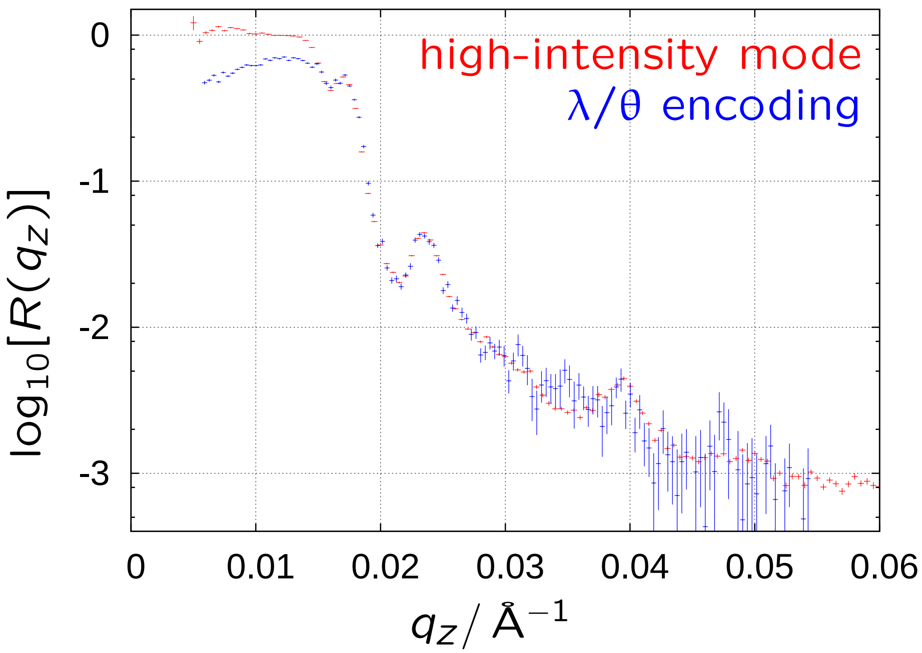
λ/θ **encoding** & TOF

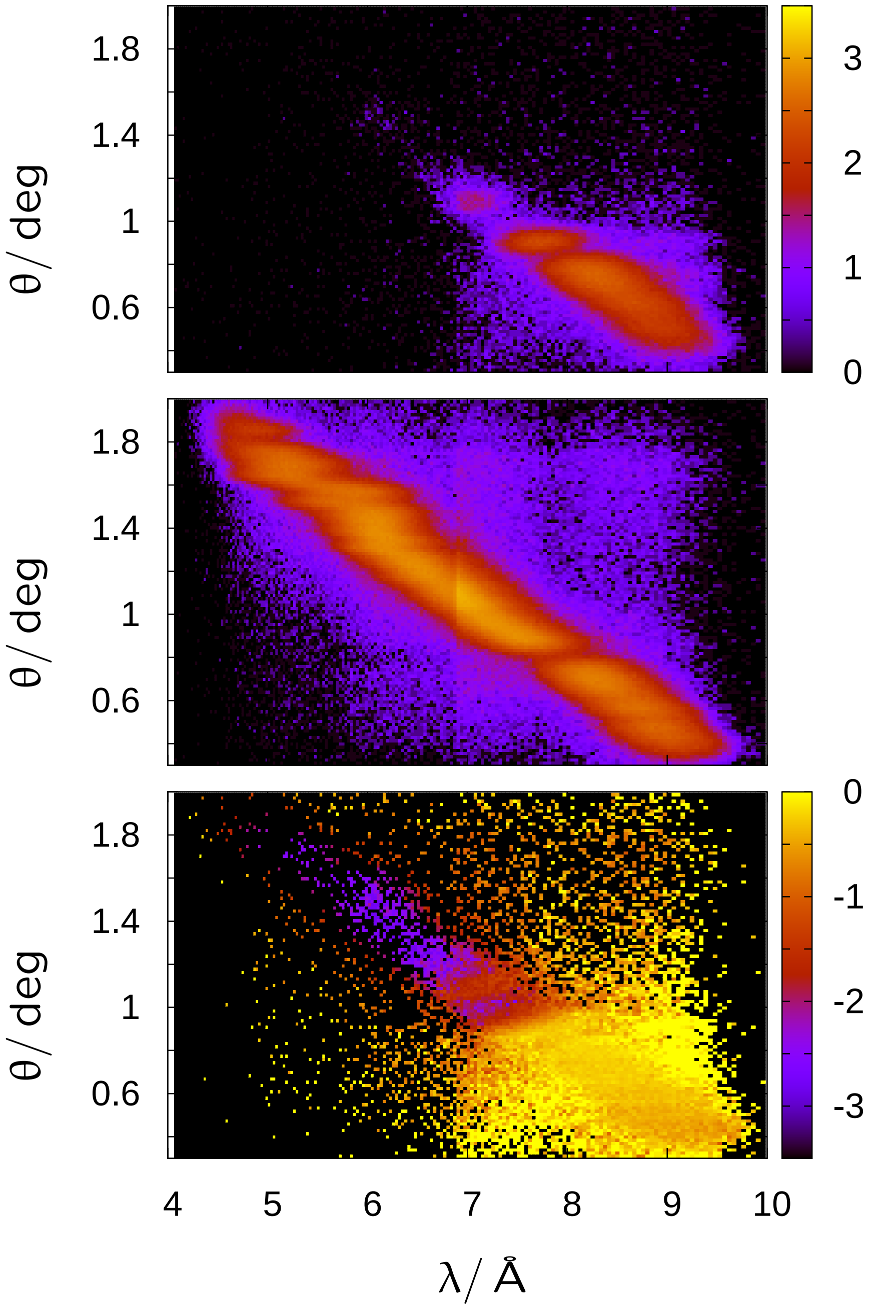
[LCMO(200 Å)/YBCO(400 Å)]$_5$

$10 \times 10\,\mathrm{mm}^2$

SM

$m = 5$





problems of data-analysis:

– absolute error of 0

reflectometry

instrument concept for ESS

focusing reflectometer

two Selene guide sections

to reduce background

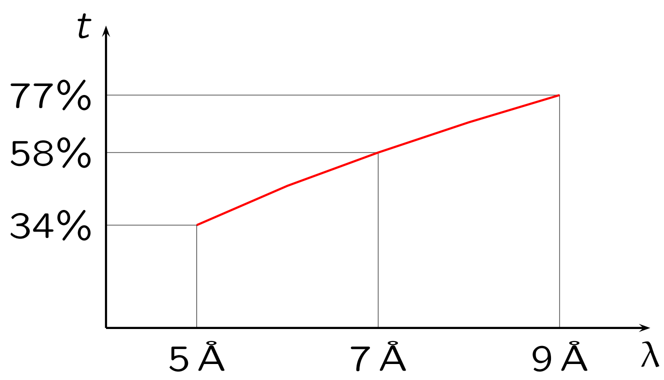
for convenient beam manipulation

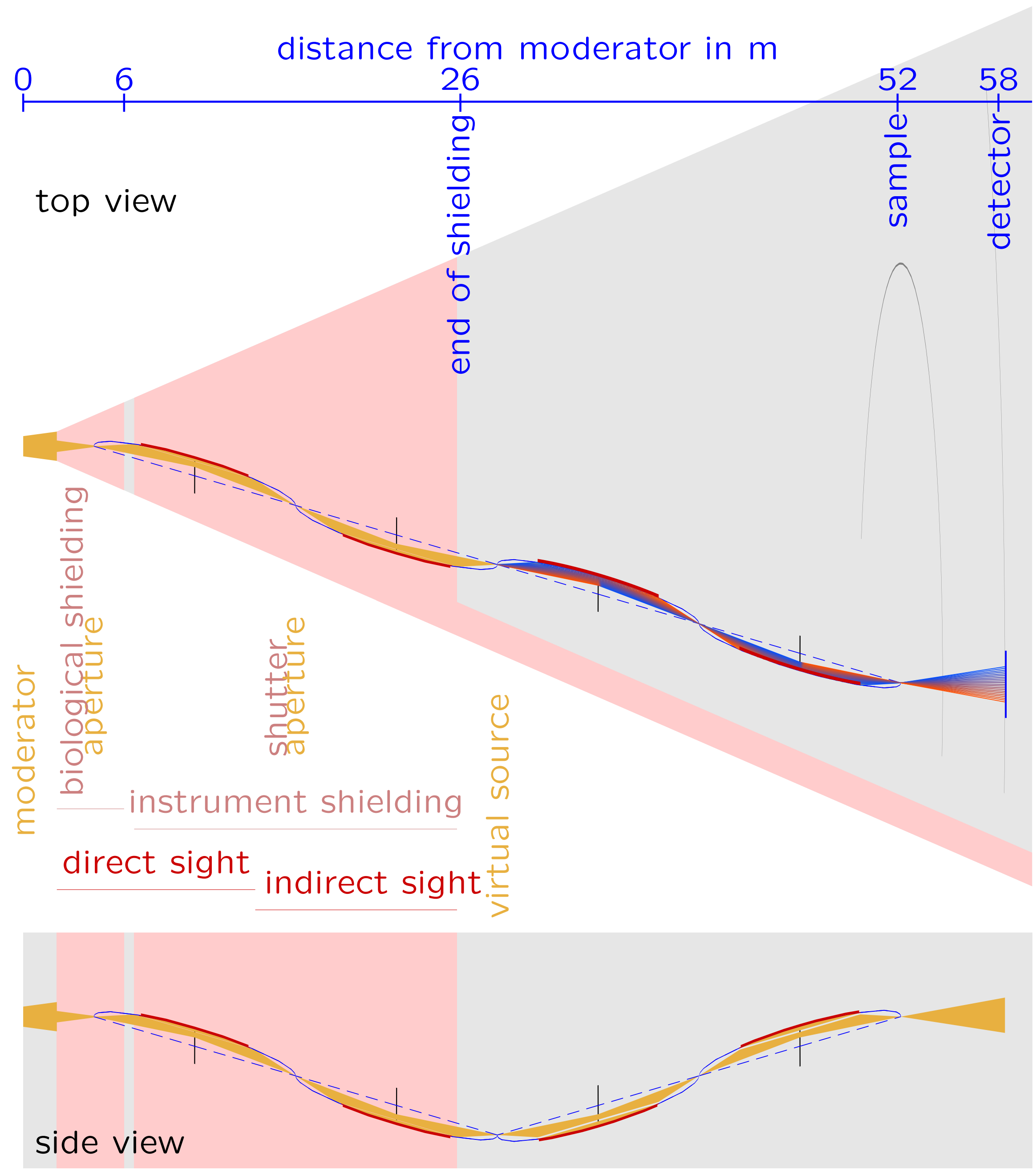
$\lambda \in [5, 9.4]$ Å

$\Delta\theta_{xy} = 1.5^\circ$

$\Delta\theta_{xz} = 1.5^\circ$

transmission





discussion

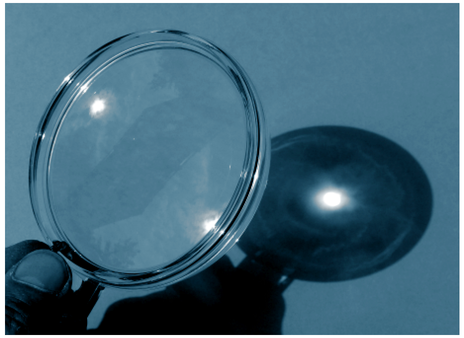
- Selene guide system
- prototype
- optics & options
- reflectometry
- discussion

discussion

focusing results in:

no gain in brilliance

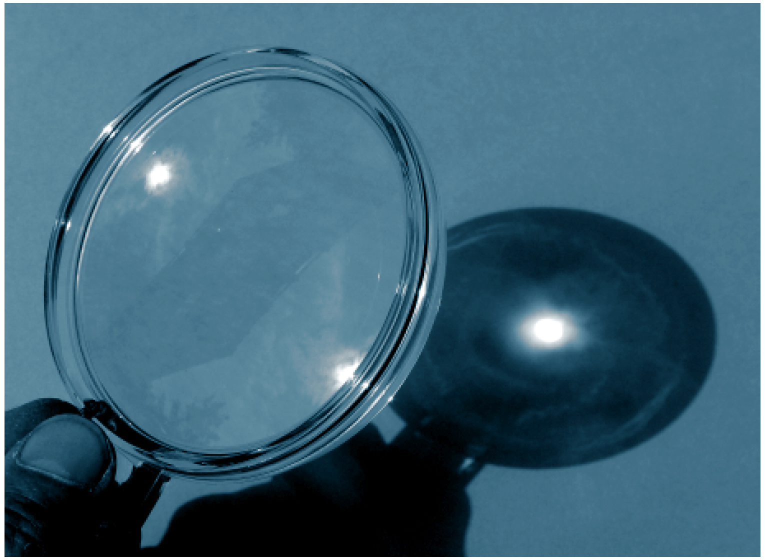
defined footprint
clean beam
homogeneous
uni-modal angular or spatial distribution

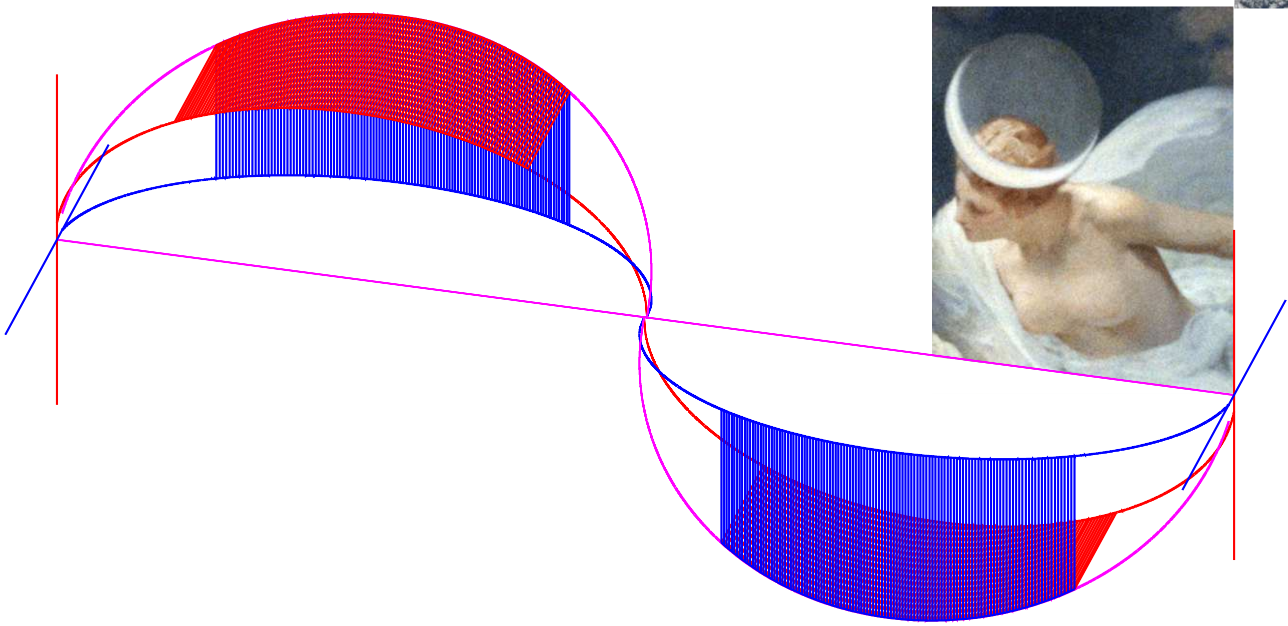


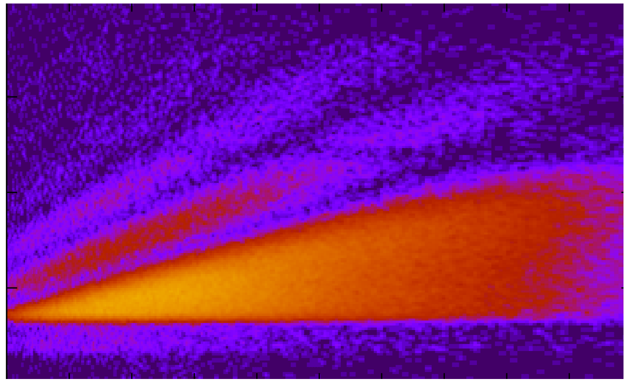
non-perfect optics
⇒ reduction of resolution / transmission

works best for small samples
weak aberration

discussion





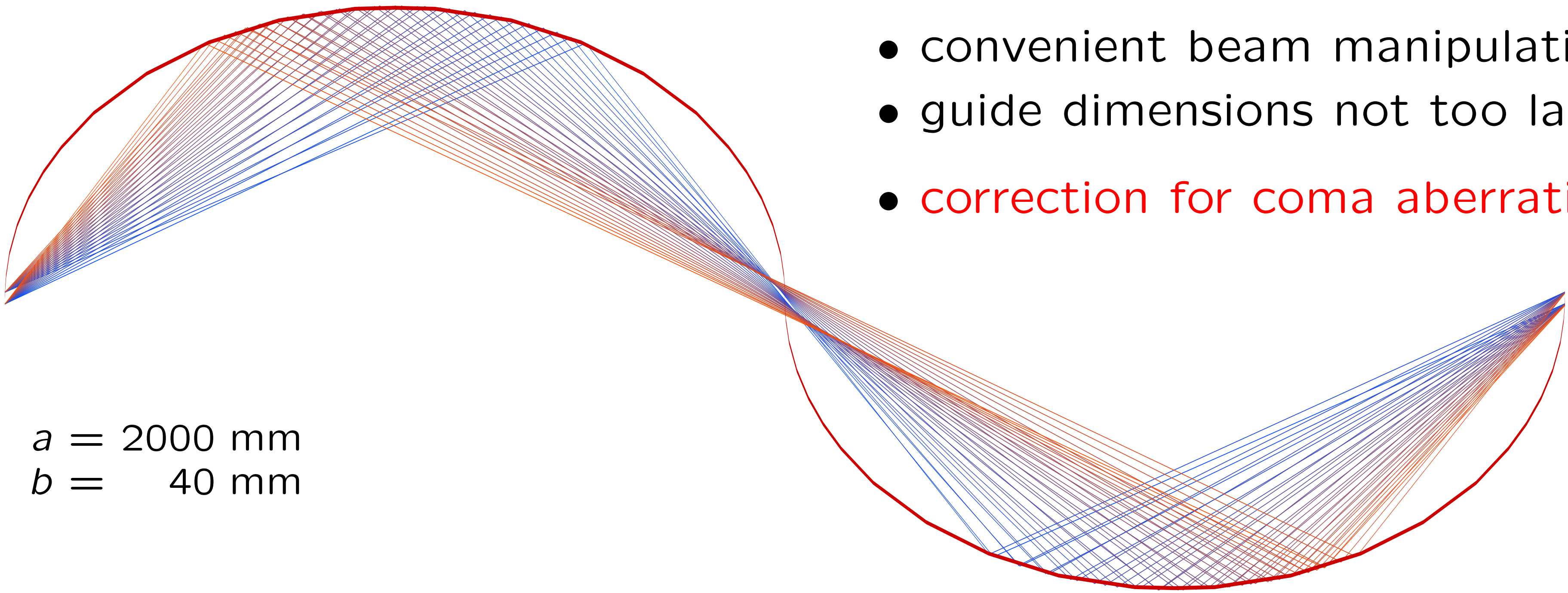


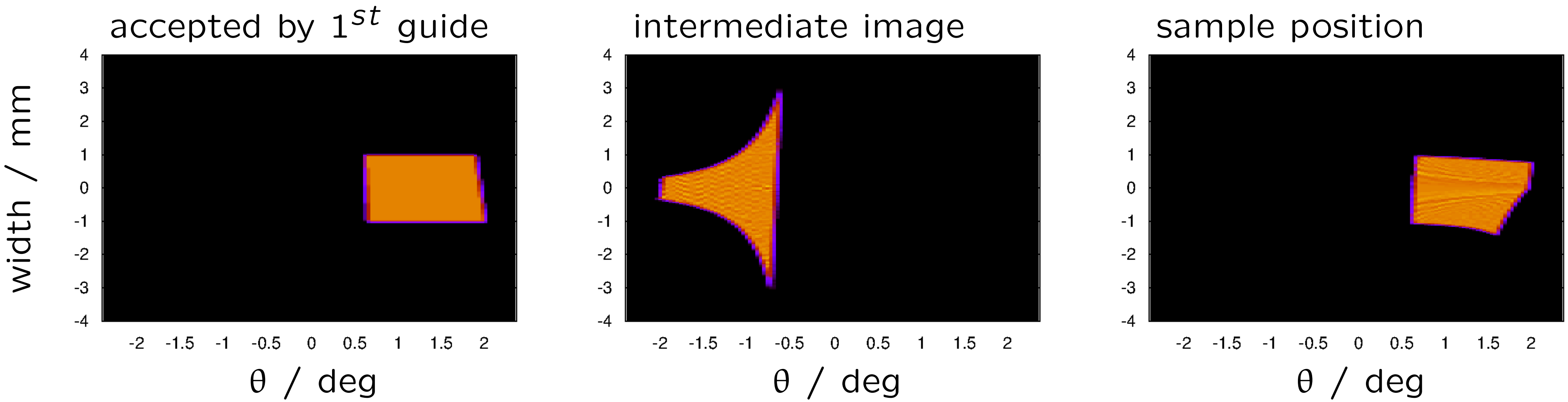
appendix

Selene guide system

why two subsequent elliptic guides?

- convenient beam manipulation
- guide dimensions not too large
- correction for coma aberration!

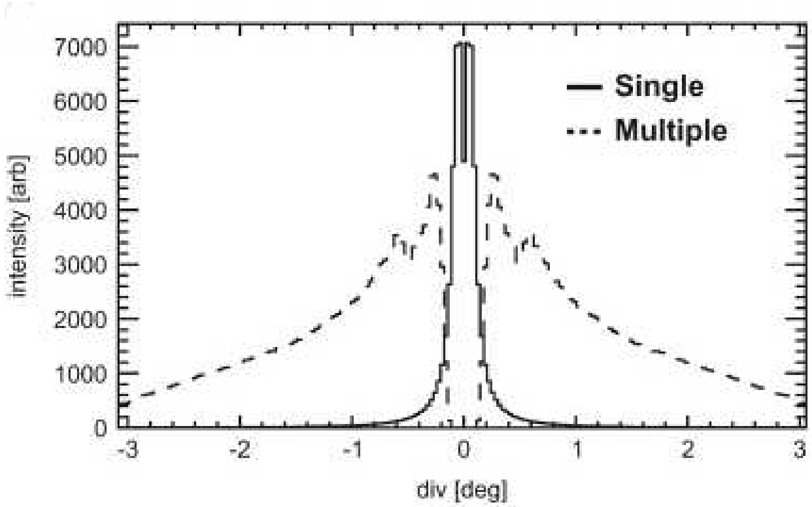




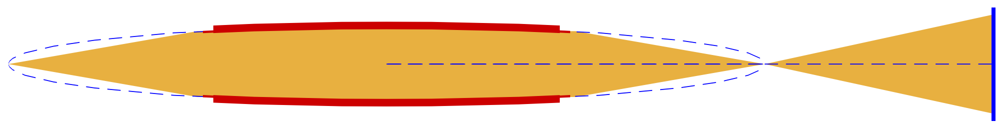
Selene guide system

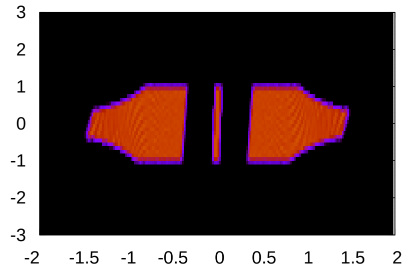
comparison to conventional and full elliptic guides

guide	straight	elliptic	*Selene*
focusing	0%	5% – 50%	100%
divergence	smooth	multi-modal	almost rectangular



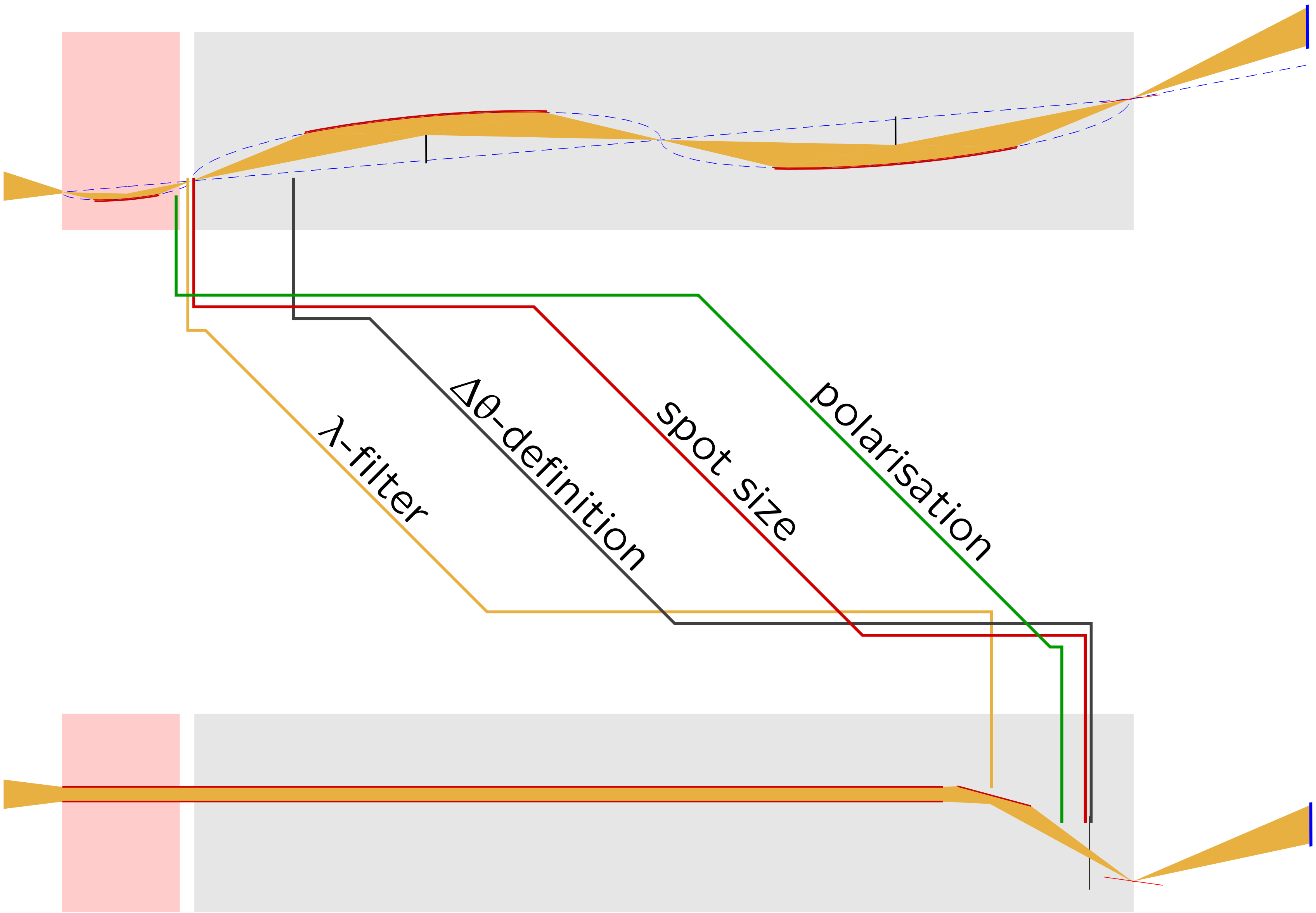
L. Cusssen *et al.*: NIM A **705**, 121 (2013)





Selene guide system

comparison to a straight guide

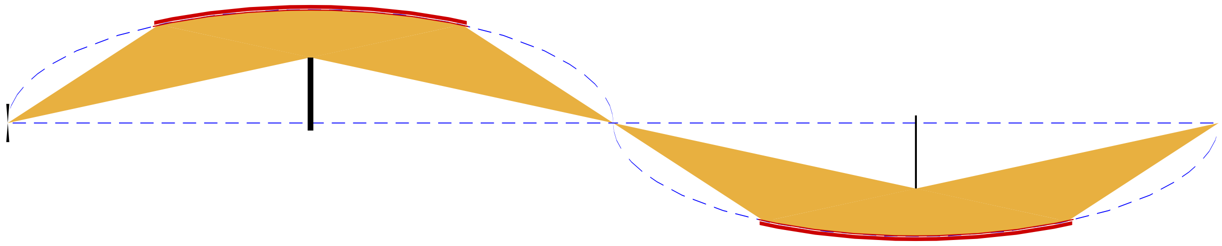


Selene guide system

chromatic aberration due to gravity

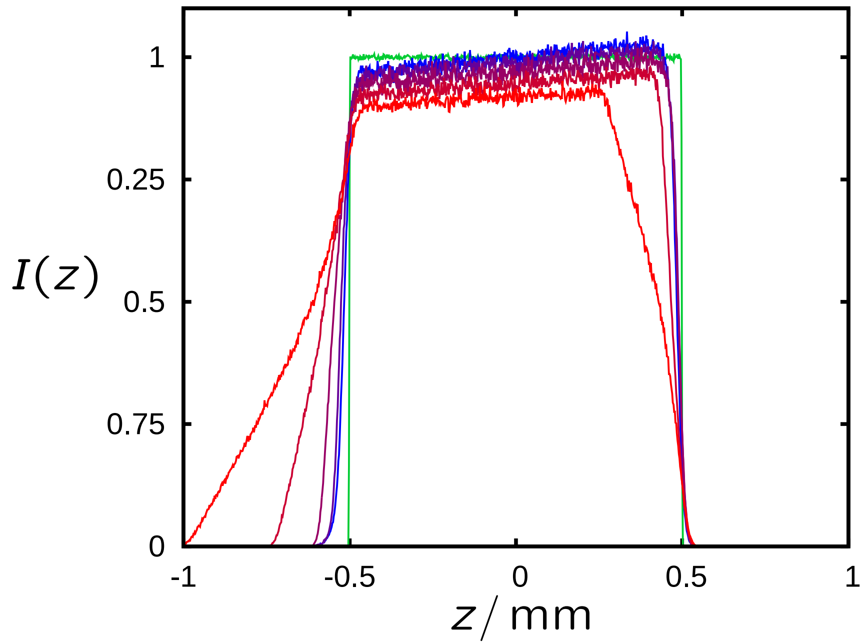
simulations (McStas) with (1 mm) tapered guides (40 m long, $b/a = 0.022$)

in agreement with analytical calculations



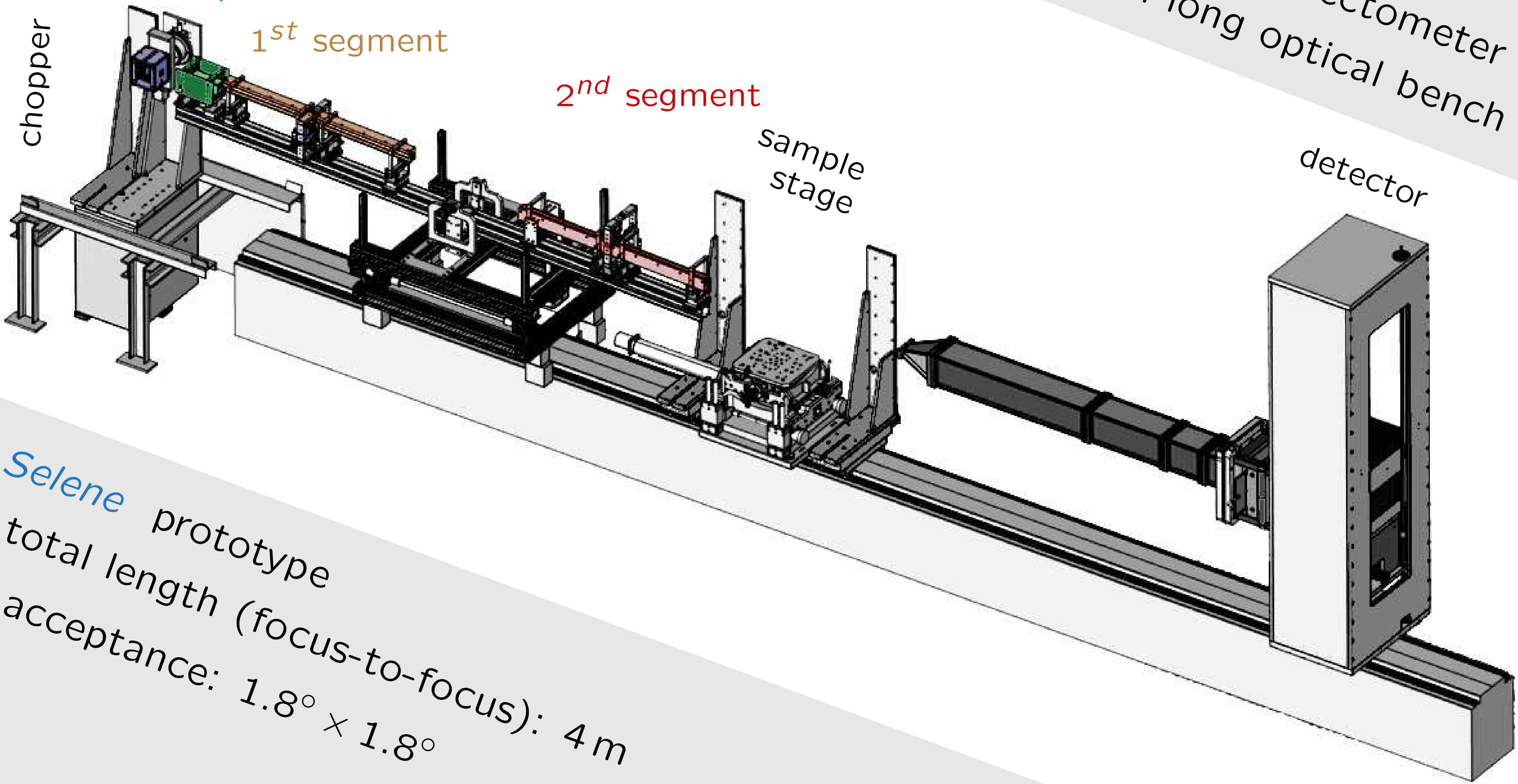
$I(z, \lambda)$ area normalised to 1

λ = 0 Å
3 Å
5 Å
7 Å
9 Å



prototype

Amor
at SINQ, PSI
TOF reflectometer
on an 8 m long optical bench

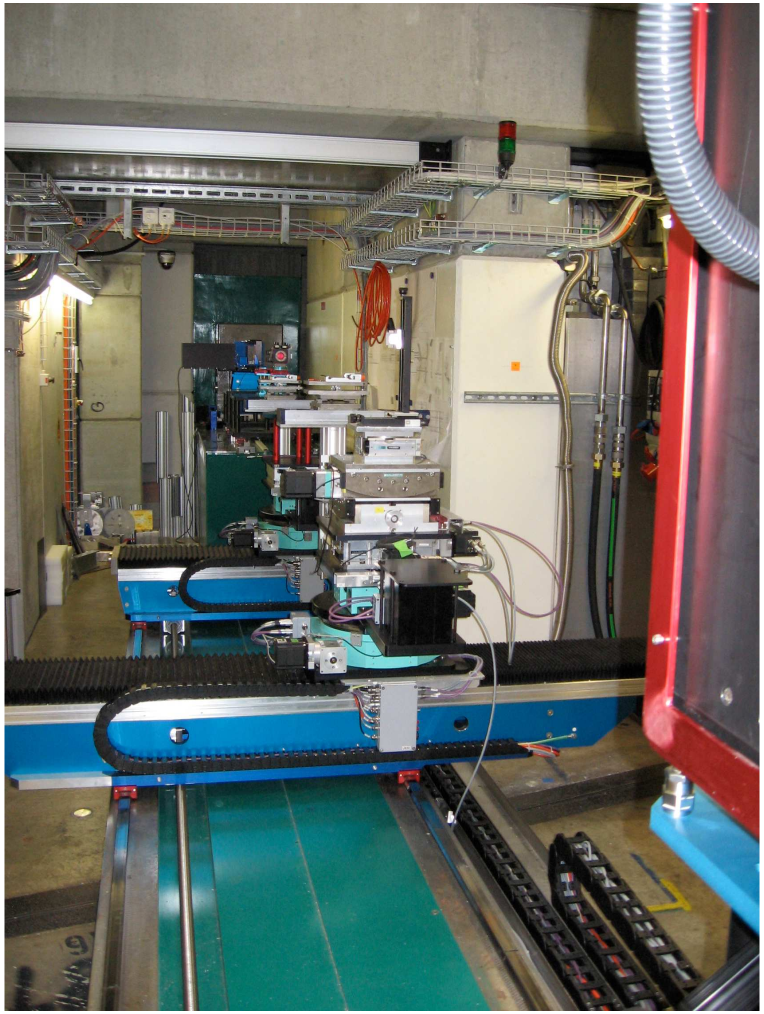


Selene prototype
total length (focus-to-focus): 4 m
acceptance: $1.8^\circ \times 1.8^\circ$

prototype

set-up realised several times

on the optical bench BOA@PSI



on the TOF reflectometer Amor@PSI