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a truly focusing neutron guide

Selene

International Workshop on Neutron Optics and Detectors
02.–05. 07. 2013, Munich (Ismaning), Germany

people involved

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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

motivation

losses along the beam path at Amor for a 1 cm^2 sample:

chopper $\Delta\lambda$

slit $\Delta\theta$

polariser σ

sample width

height

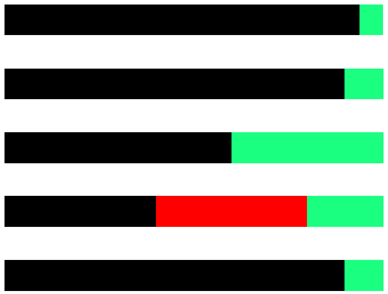
$$\left.\begin{array}{l}\Delta\lambda\\ \Delta\theta\\ \sigma\\ \text{sample width}\\ \text{height}\end{array}\right\} 6\cdot 10^{-5}$$

can we improve this?

basics

motivation

losses along the beam path at Amor for a $1\,\mathrm{cm}^2$ sample:



chopper $\Delta\lambda$
slit $\Delta\theta$
polariser σ
sample width
height

$\left.\begin{array}{l} \Delta\lambda \\ \Delta\theta \\ \sigma \\ \\ \end{array}\right\} 2\cdot 10^{-4}$

1D - focusing

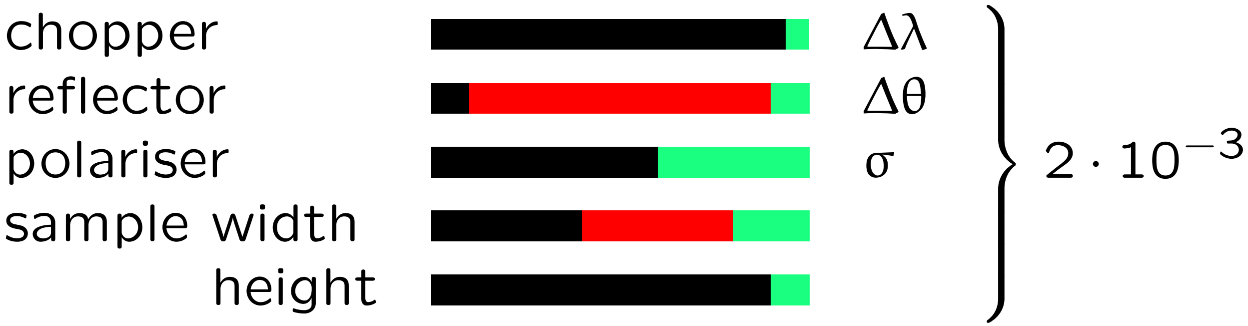
can we improve this?

○ focusing in the sample plane

basics

motivation

losses along the beam path at Amor for a $1\,\mathrm{cm}^2$ sample:



2D - focusing guide

1D - focusing

can we improve this?

∘ focusing in the sample plane

∘ new measurement schemes e.g. high-intensity specular reflectometry

F. Ott, et al.: NIM A 586, 23 (2008)

$\Rightarrow$ 99.8% of the delivered beam is not wanted!

so: why deliver it?

Selene guide system

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

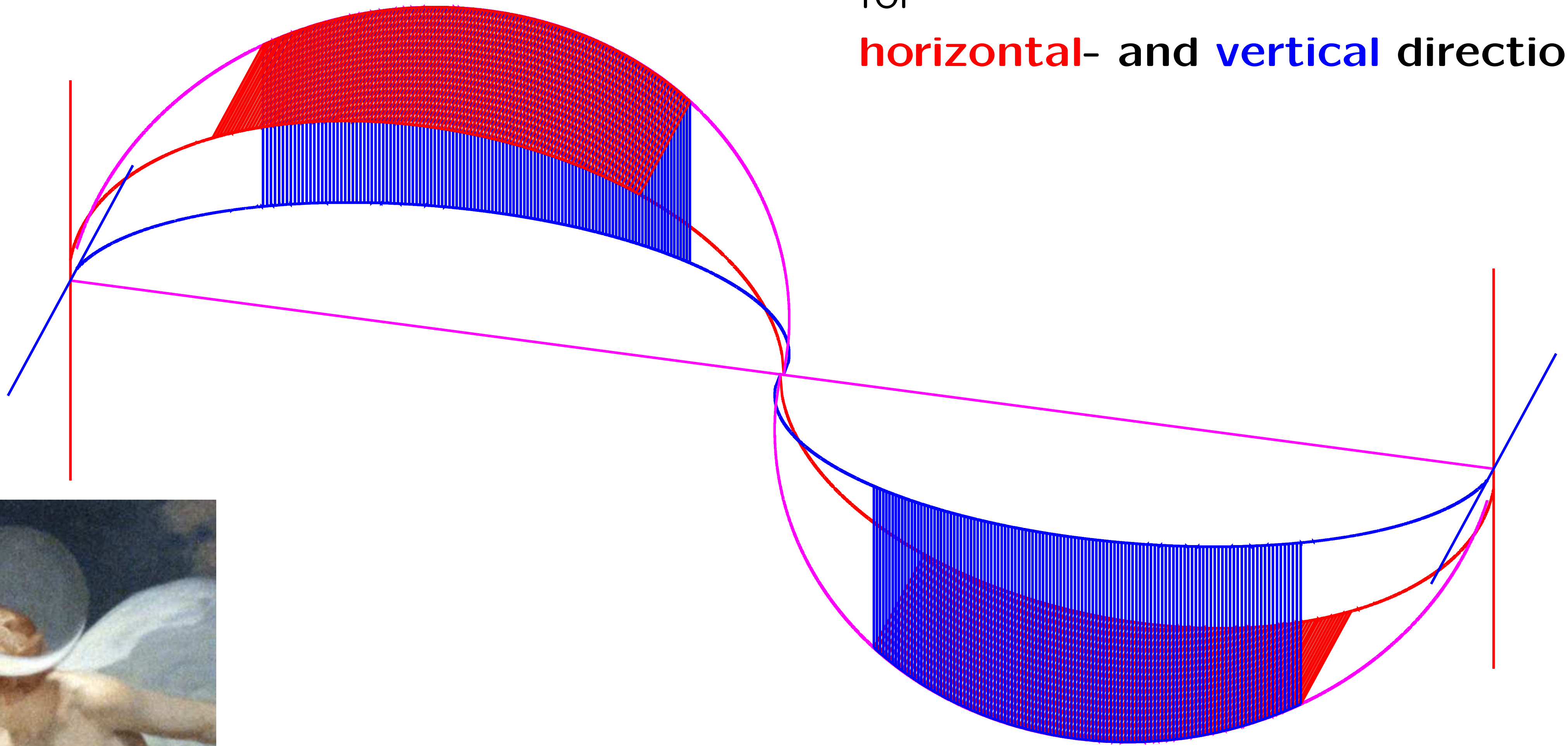
point-to-point focusing

with

2 subsequent elliptical reflectors

for

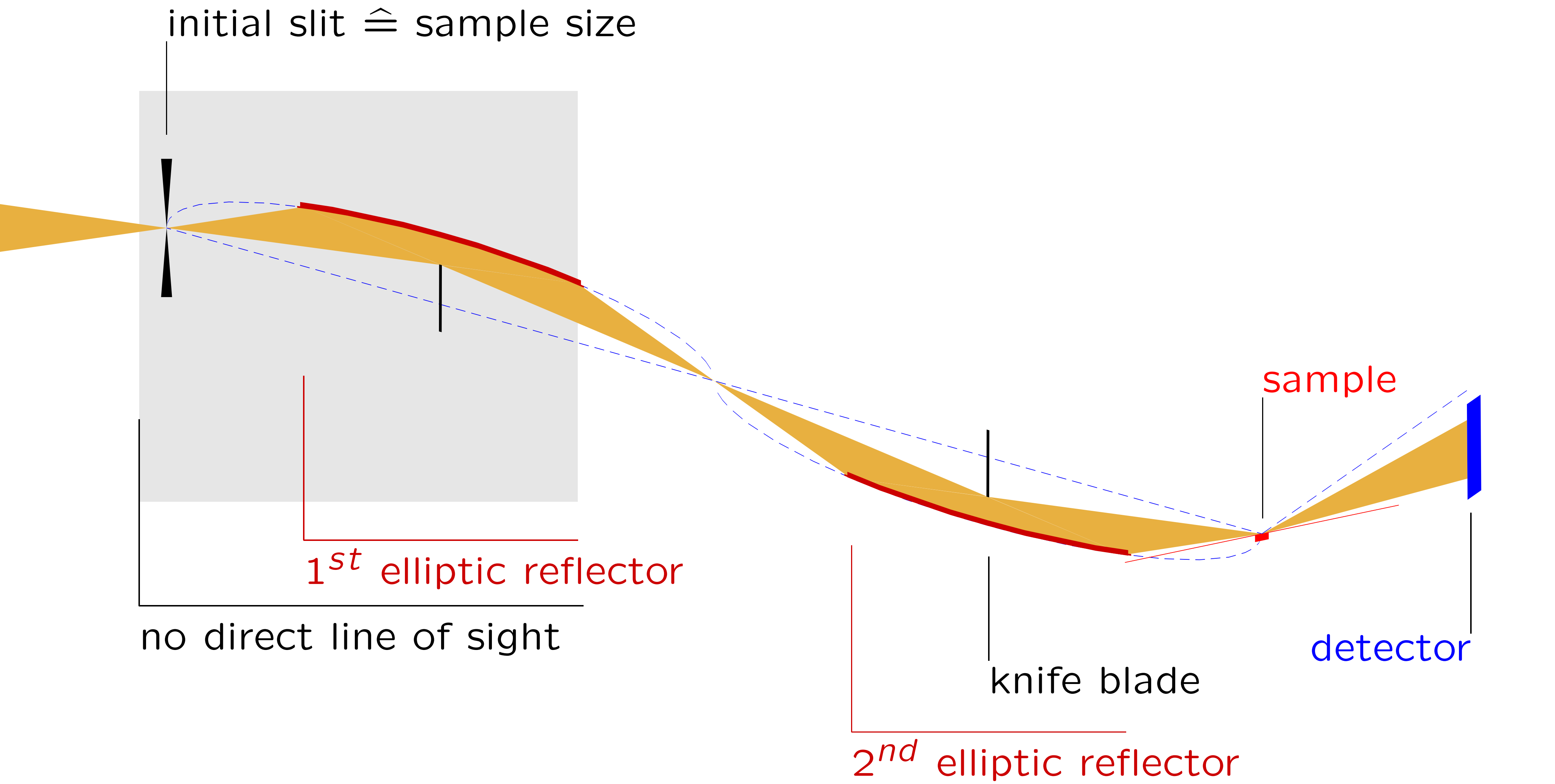
horizontal- and vertical direction



Selene guide system

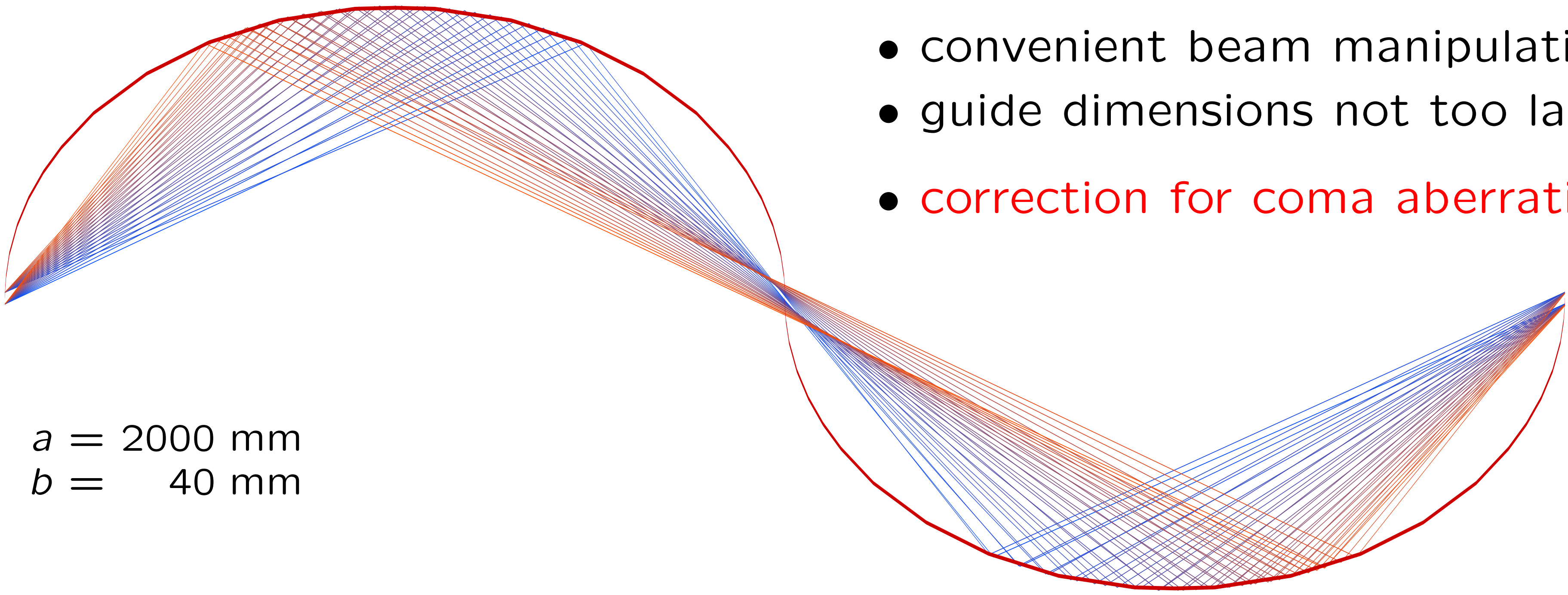
generic lay-out

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

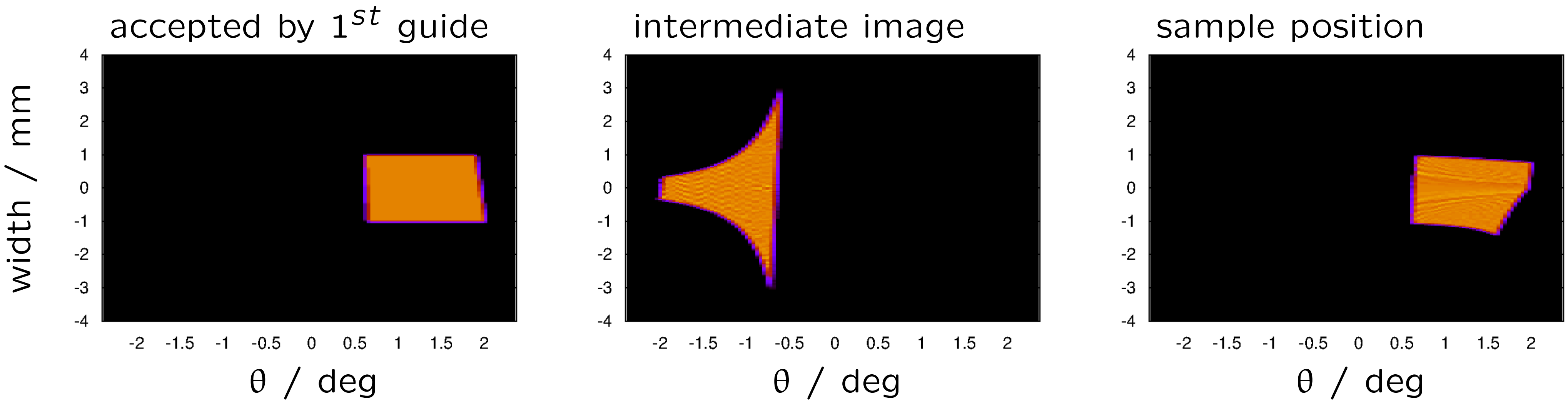


Selene guide system

why two subsequent elliptic guides?



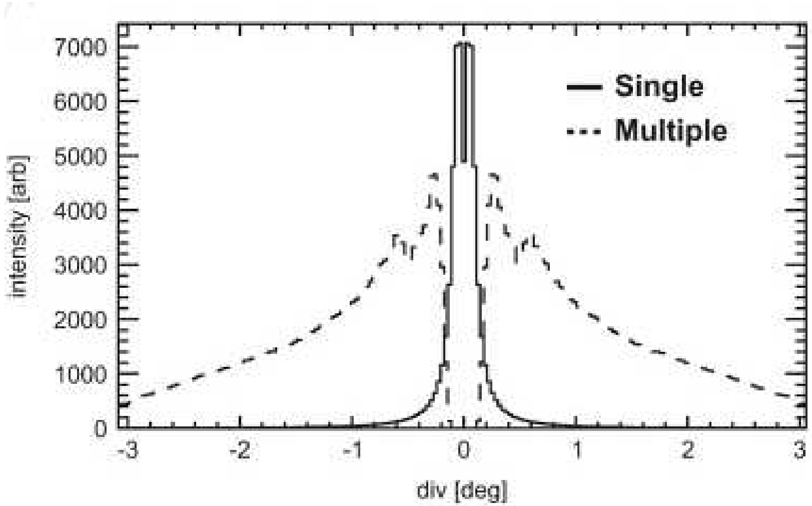
- convenient beam manipulation
- guide dimensions not too large
- correction for coma aberration!



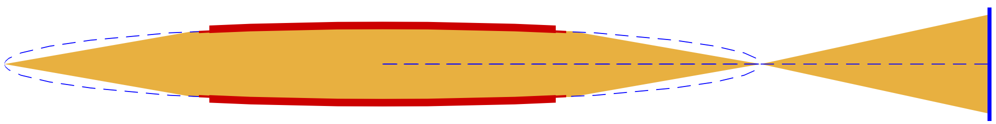
Selene guide system

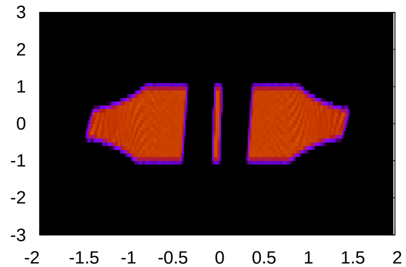
comparison to conventional and full elliptic guides

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



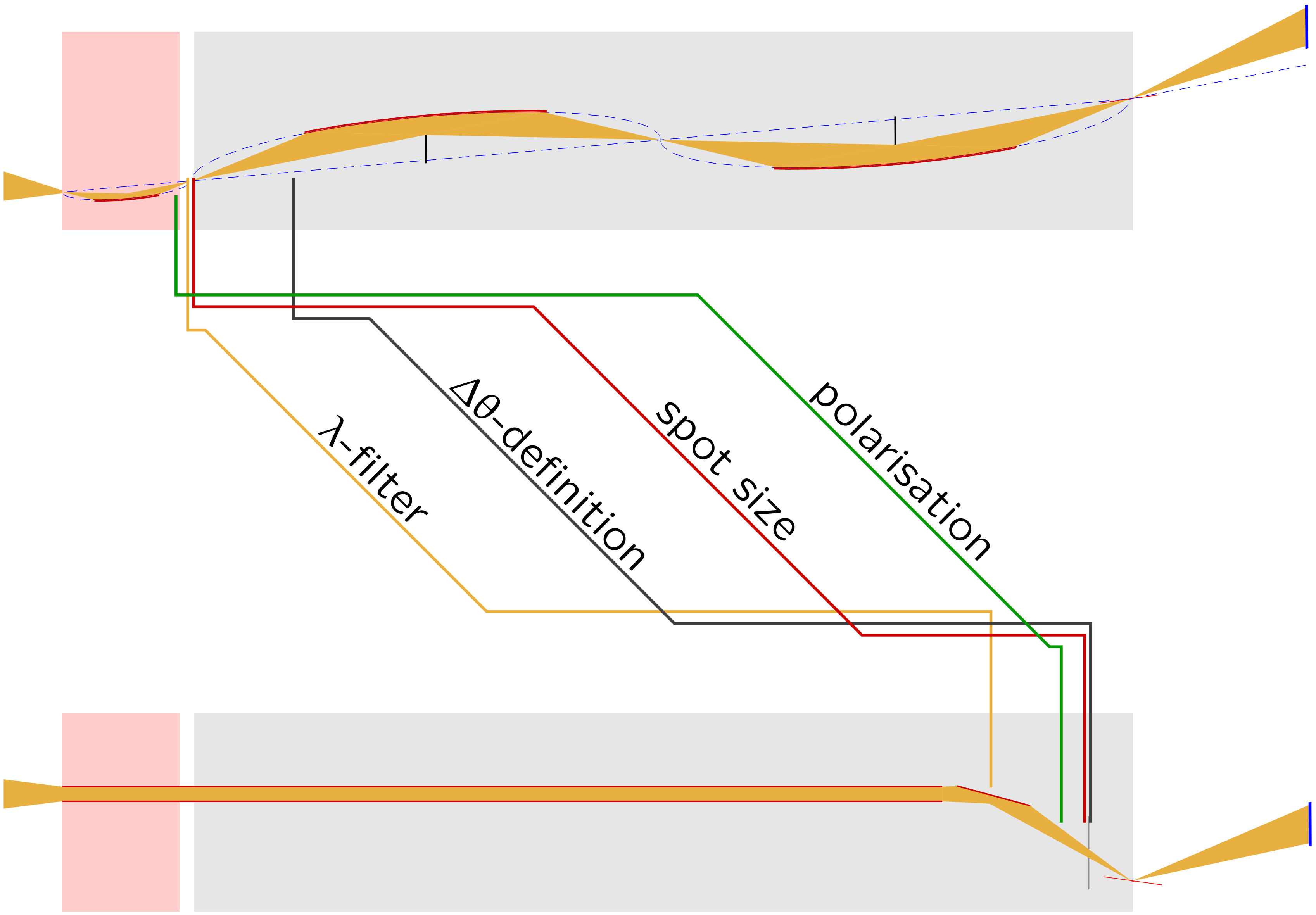
L. Cusssen *et al.*: NIM A **705**, 121 (2013)





Selene guide system

comparison to a straight guide

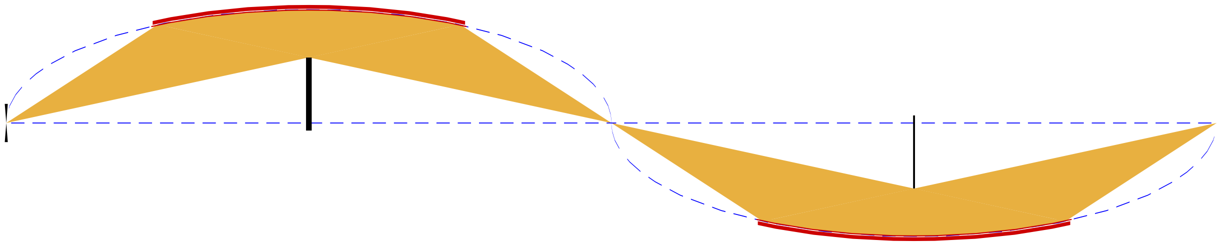


Selene guide system

chromatic aberration due to gravity

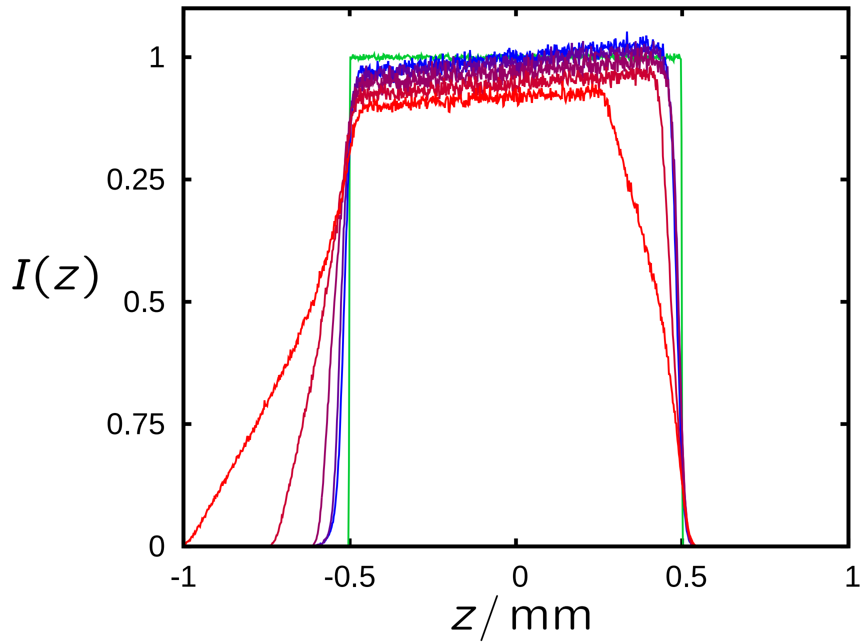
simulations (McStas) with (1 mm) tapered guides (40 m long, $b/a = 0.022$)

in agreement with analytical calculations



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

λ = 0 Å, 3 Å, 5 Å, 7 Å, 9 Å

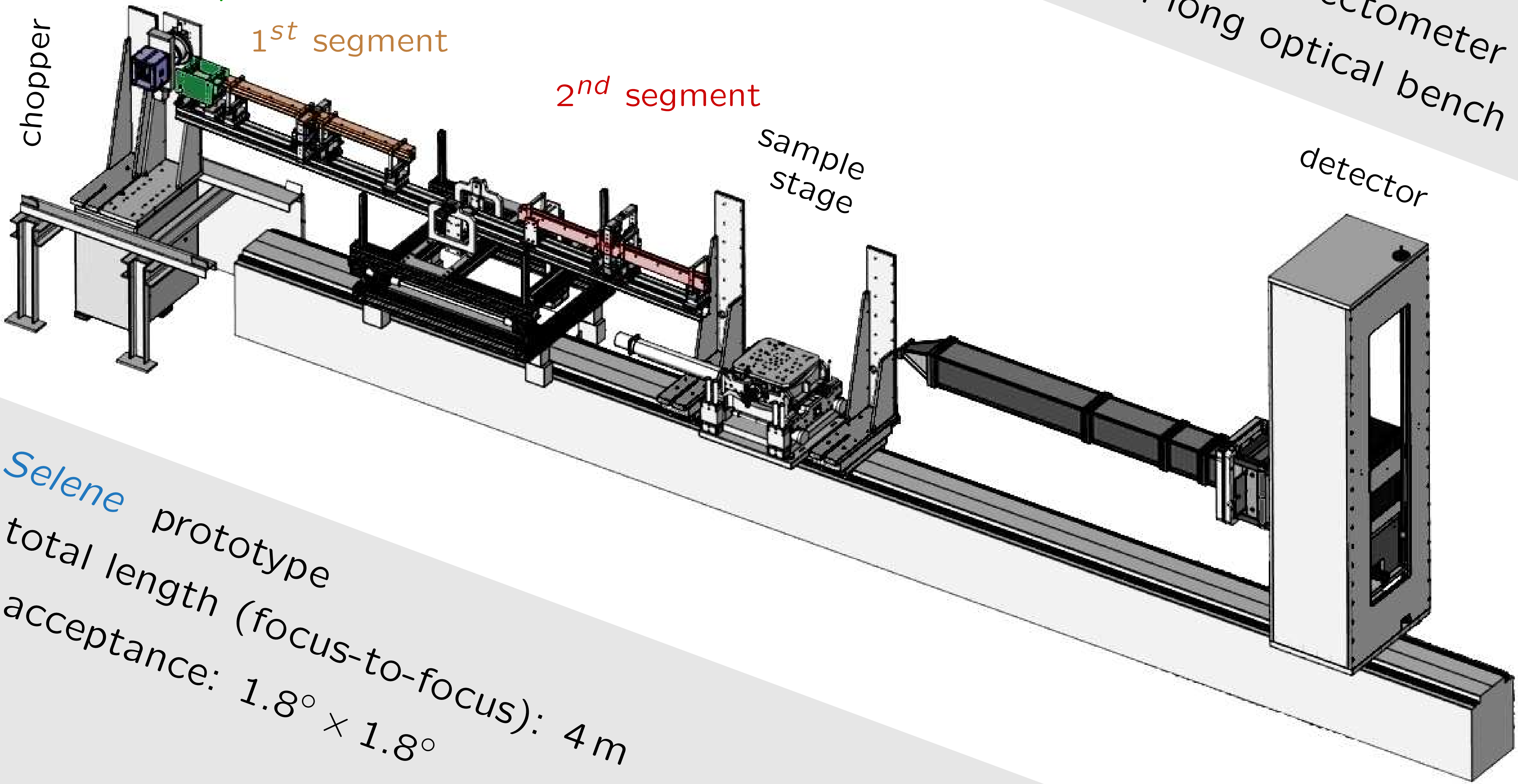


prototype

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

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

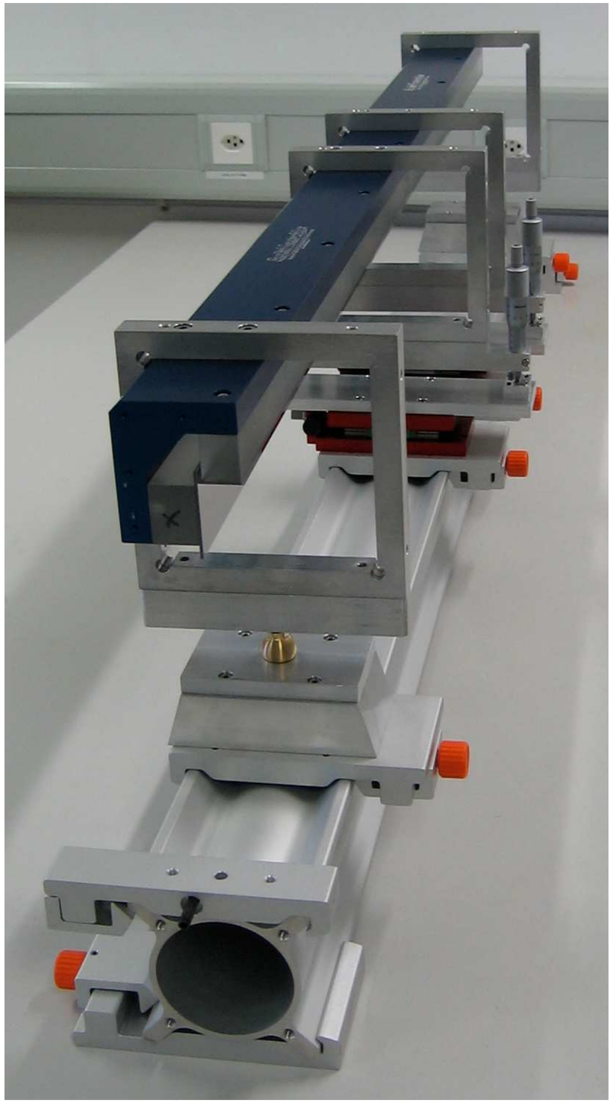
guides

by *SwissNeutronics*

2 guides
1200 mm each,

made of
2 elements,

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

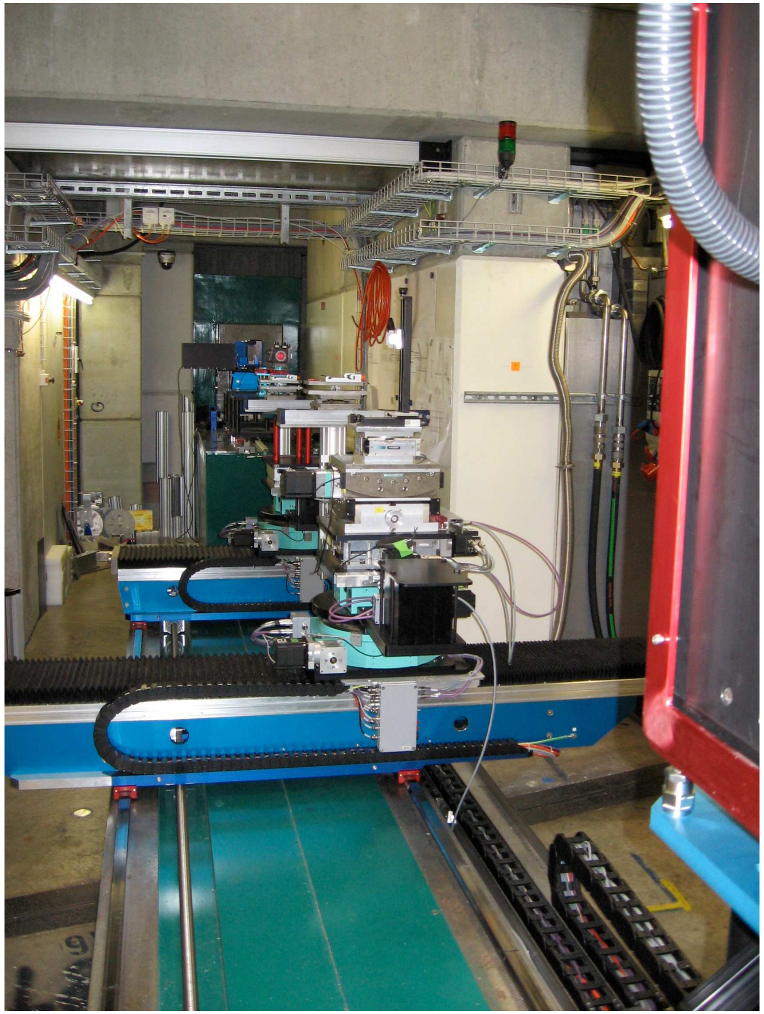


$a = 1000\,\mathrm{mm}$
$b/a = 0.0206$

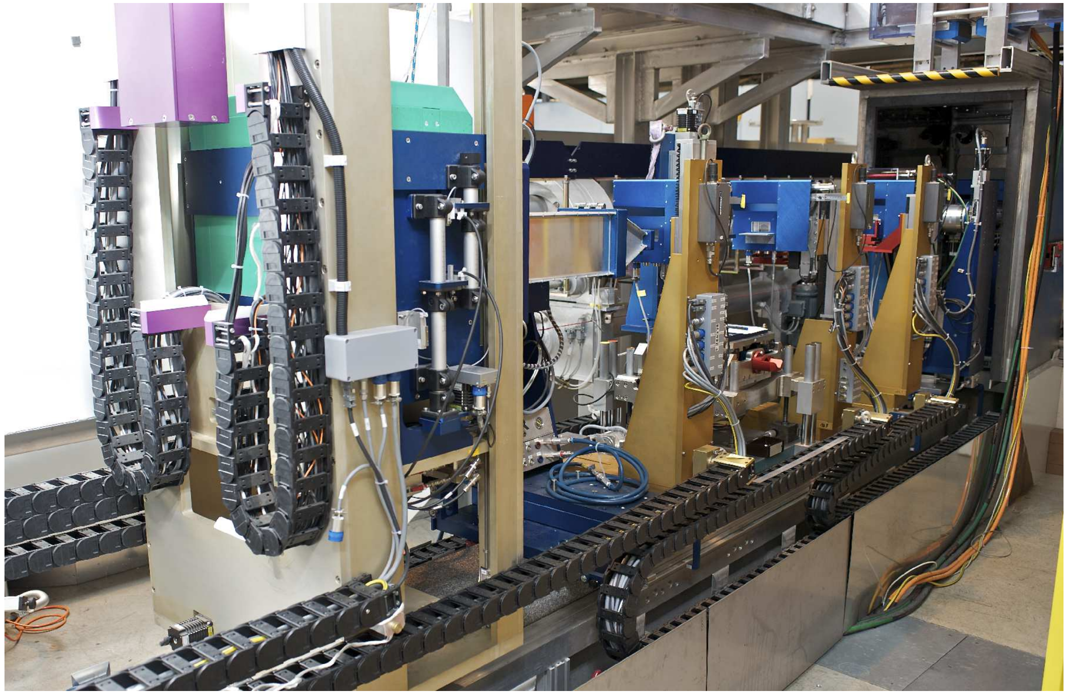
prototype

set-up realised several times

on the optical bench BOA@PSI



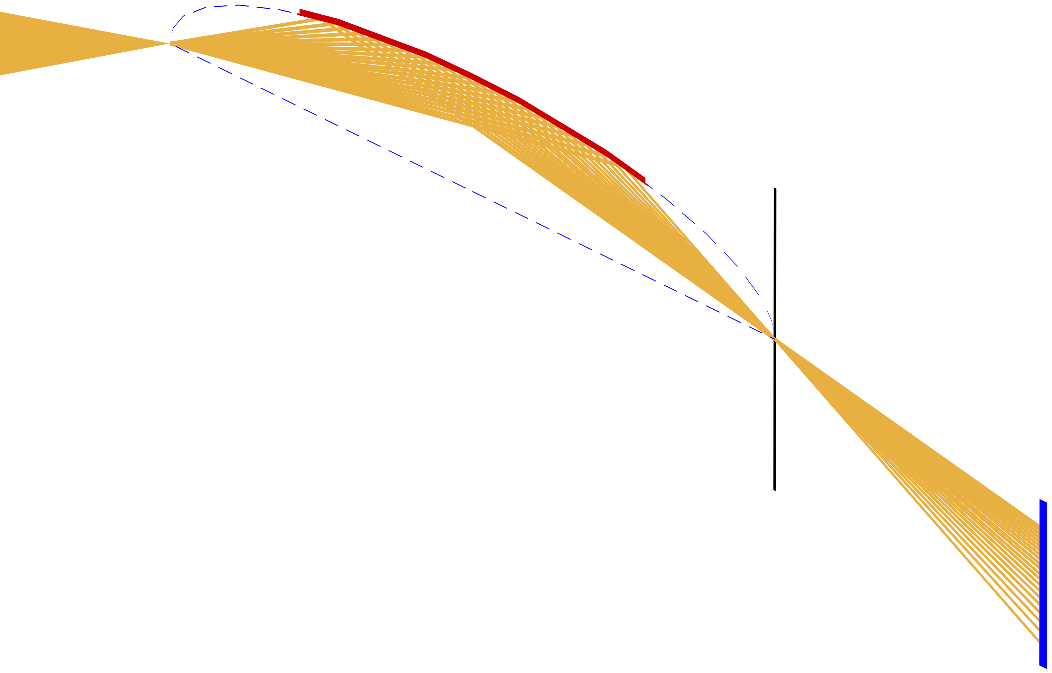
on the TOF reflectometer Amor@PSI



→ details, optics and measurements on the following slides

prototype

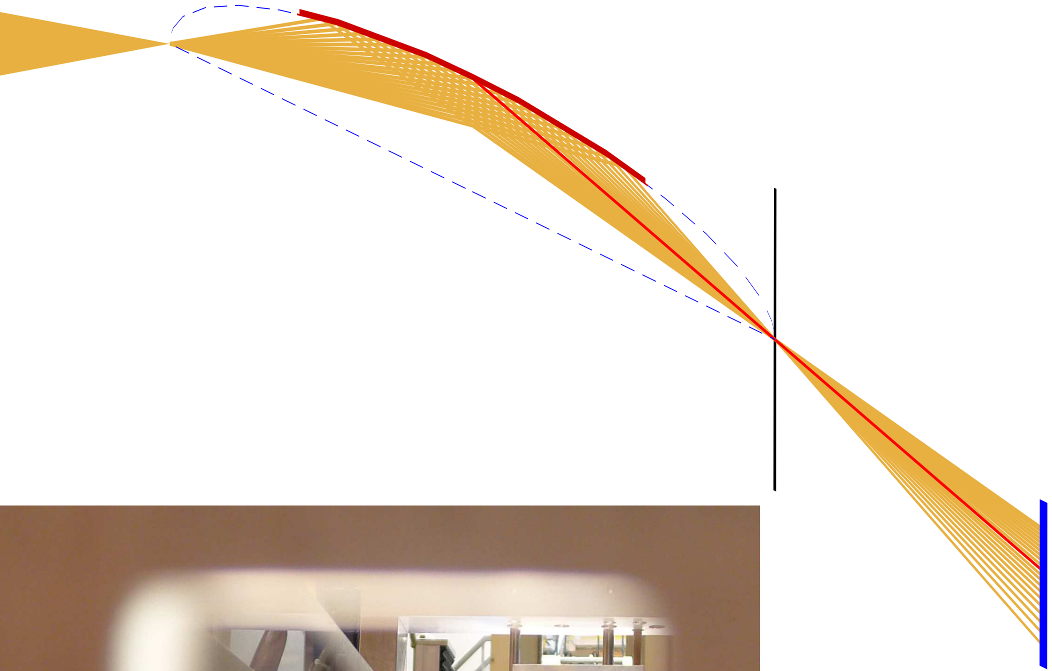
quality characterisation with pin-hole



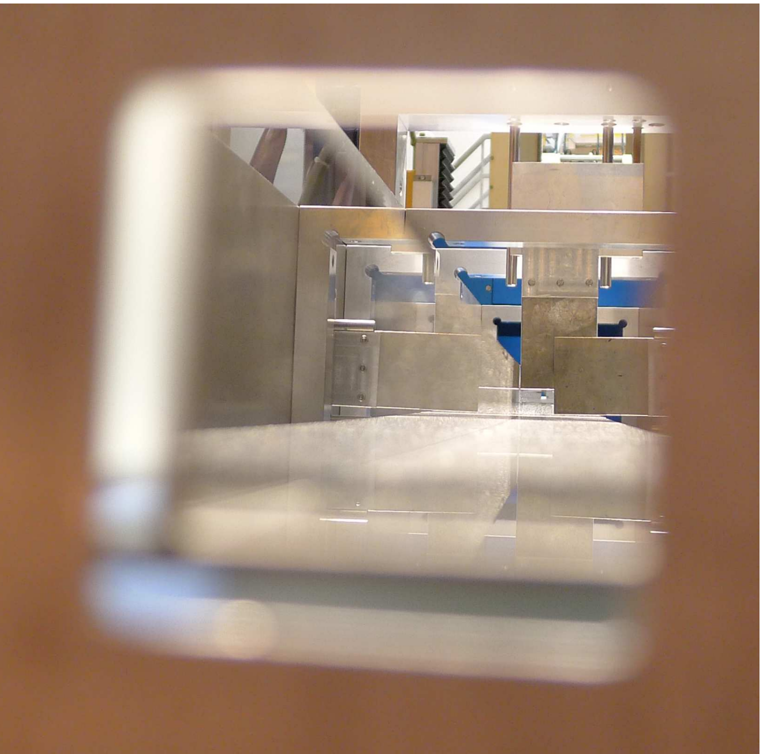
using light & CCD camera, or neutrons

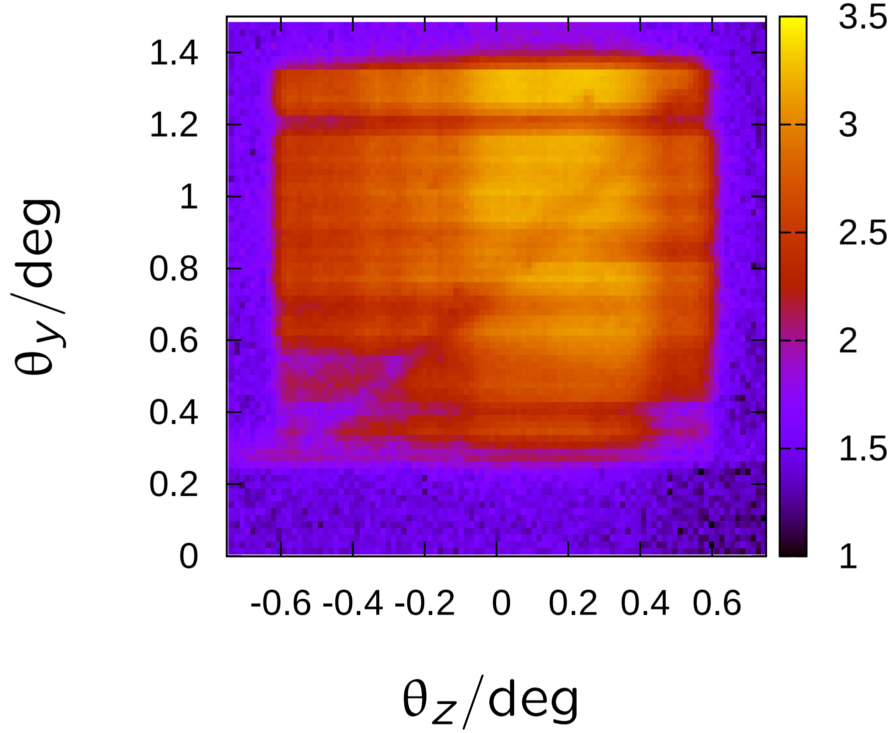
prototype

quality characterisation with pin-hole



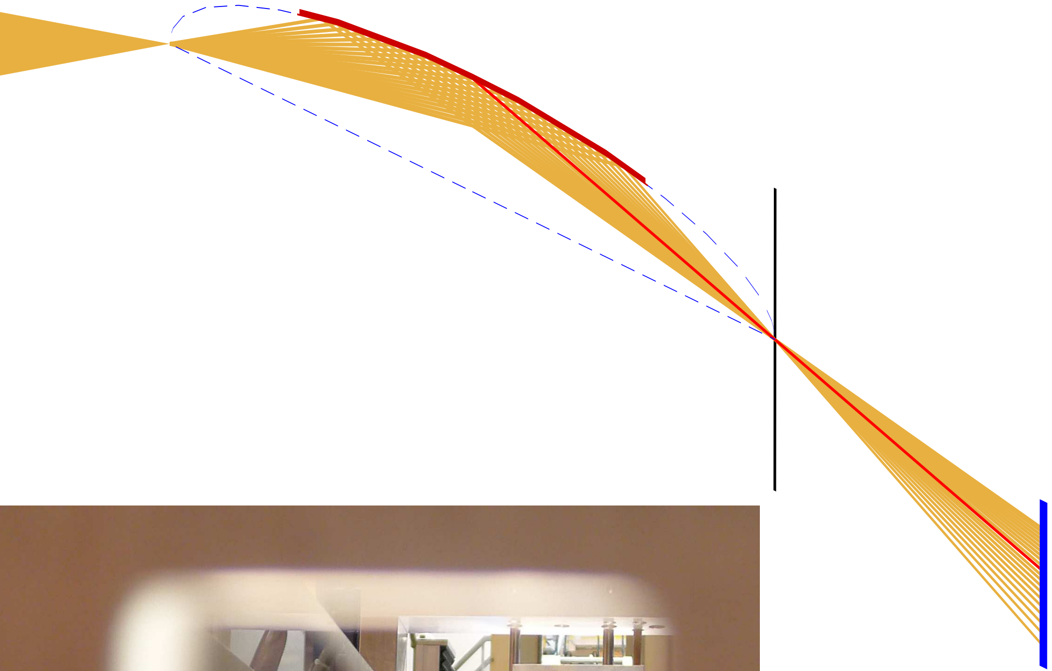
using light & CCD camera, or neutrons



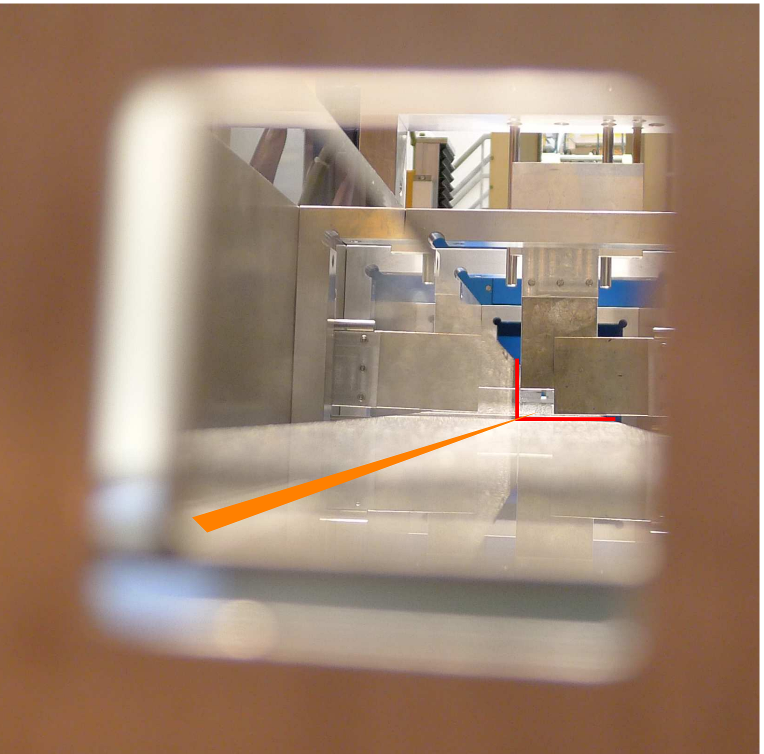


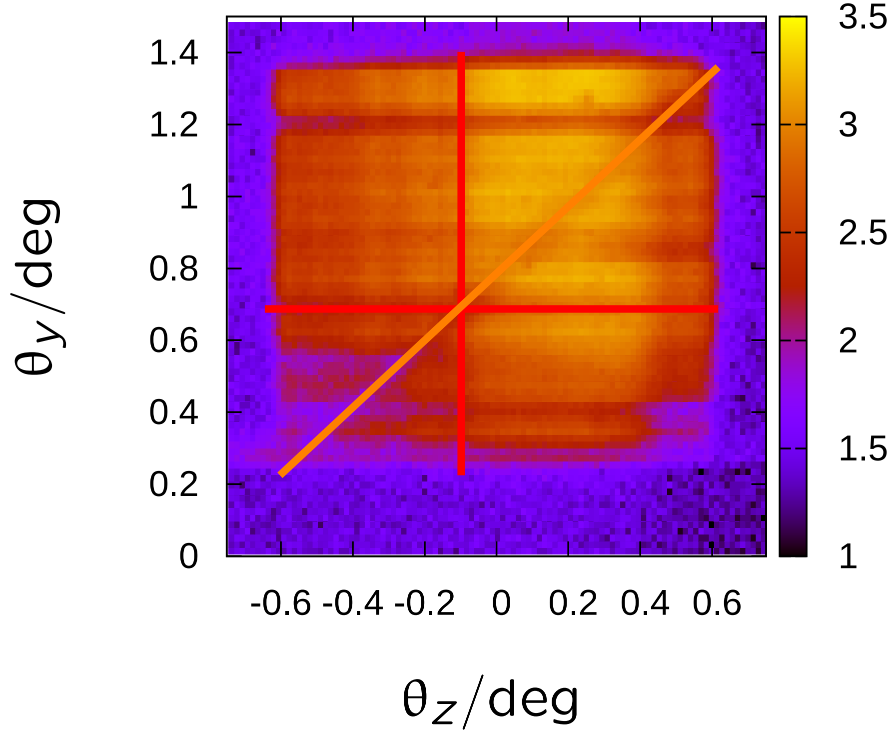
prototype

quality characterisation with pin-hole



using light & CCD camera, or neutrons



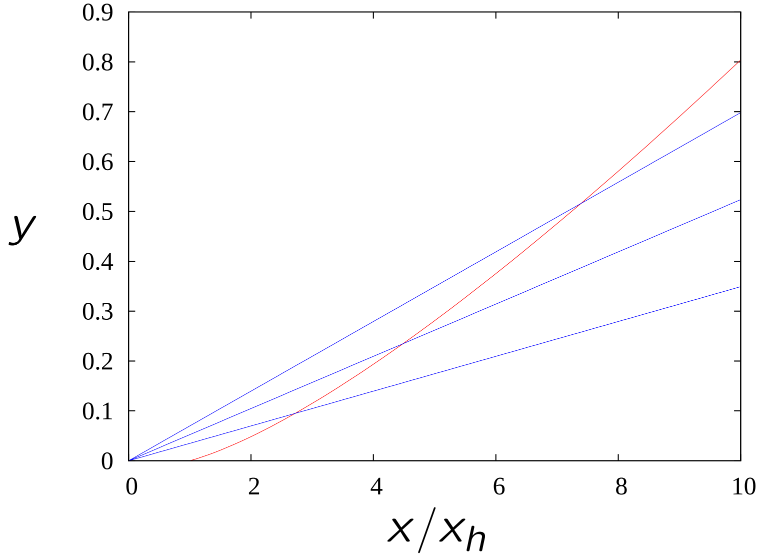


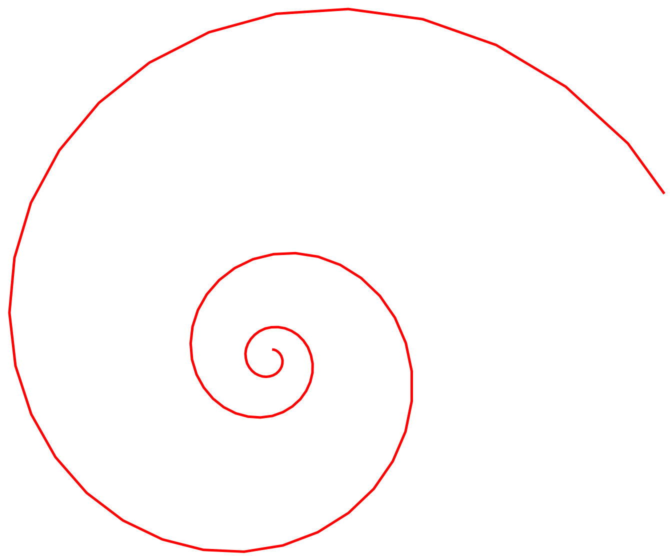
optics & options

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

optics & options

polariser



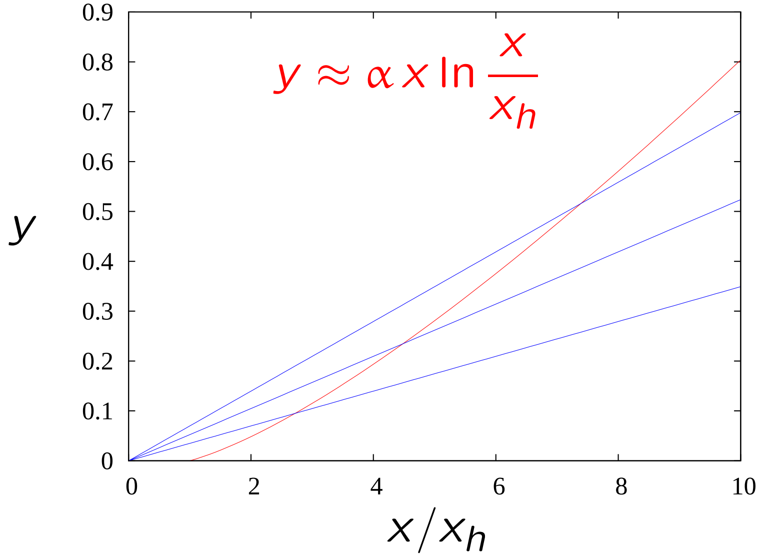


requested:

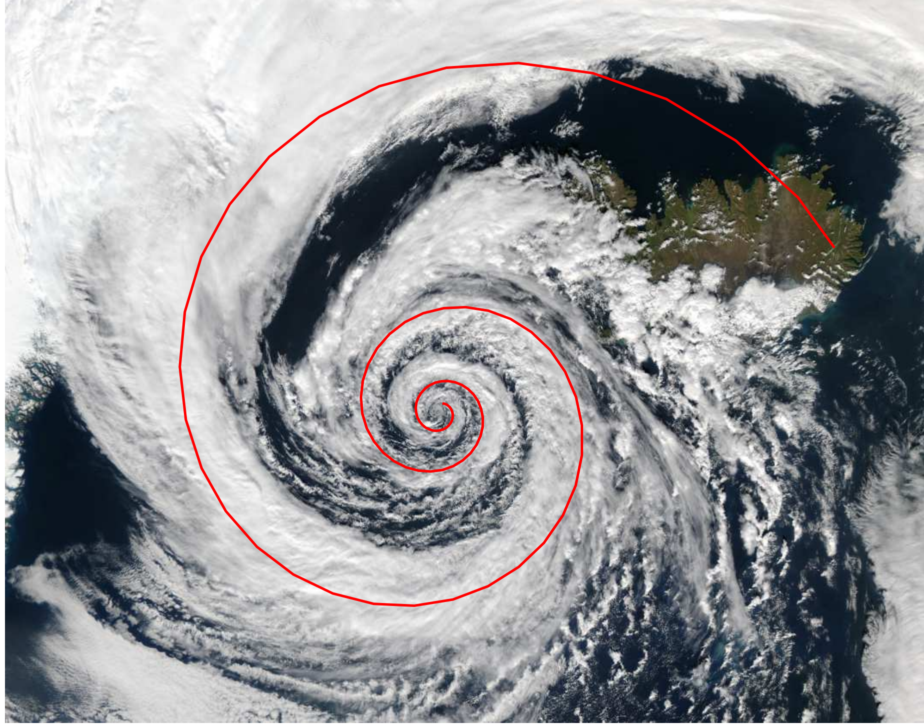
a surface hit by all trajectories from a point source at the same angle α

optics & options

polariser



NASA: low-pressure system centred at Iceland



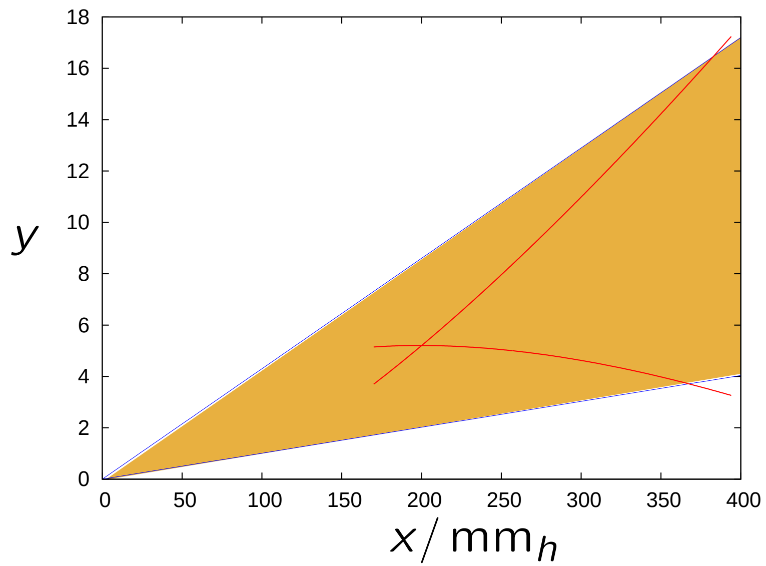
requested:

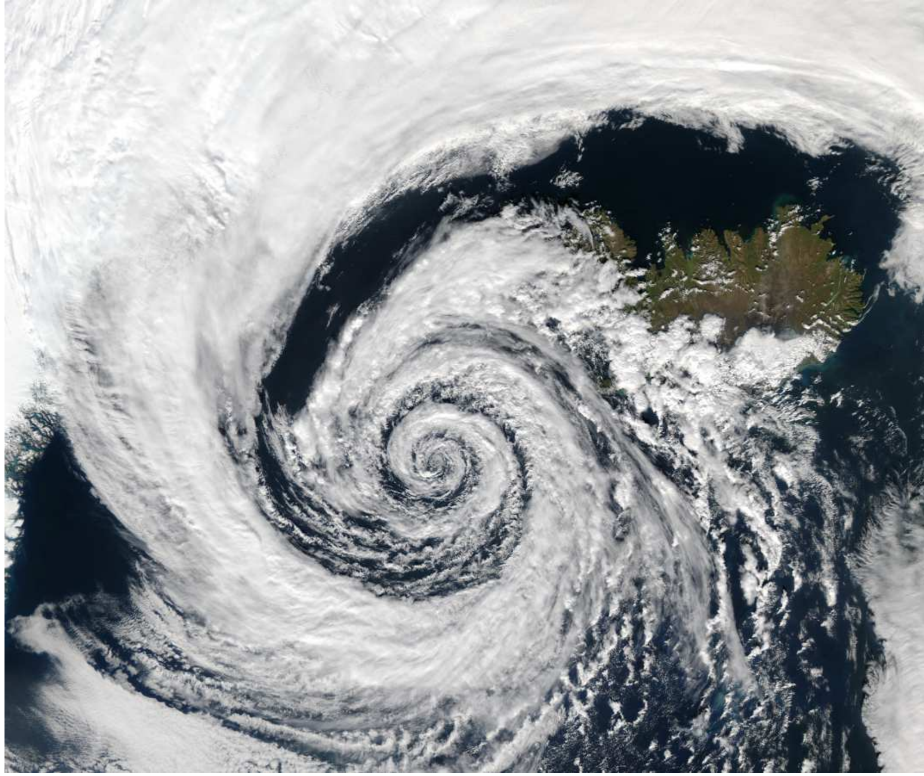
a surface hit by all trajectories from a point source at the same angle α

$\Rightarrow$ the logarithmic spiral

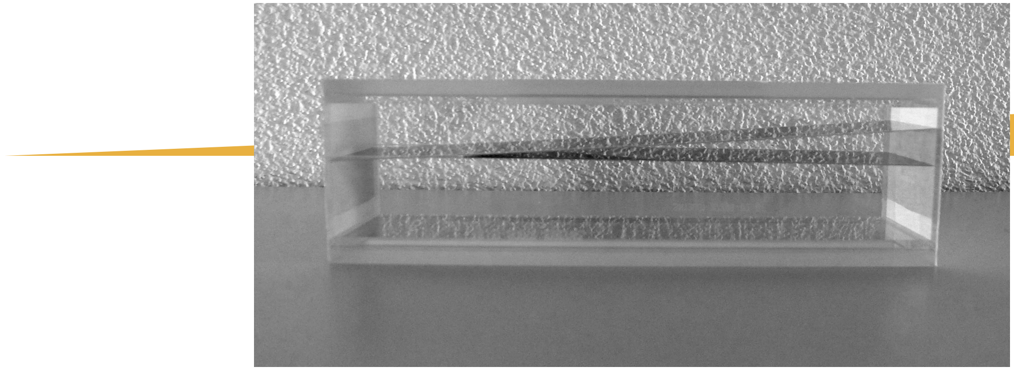
optics & options

polariser: logarithmic spiral



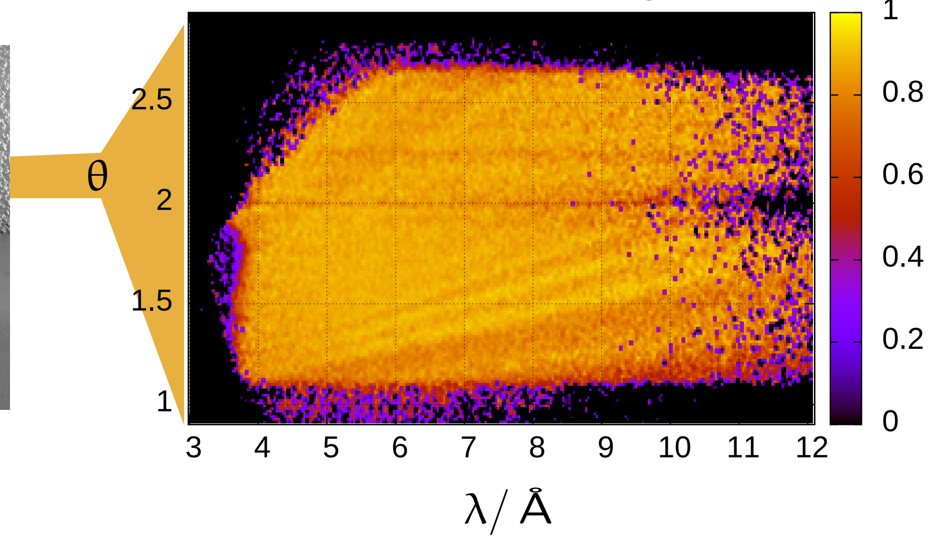


polariser
215 mm long, 1.8° acceptance



(by SwissNeutronics)

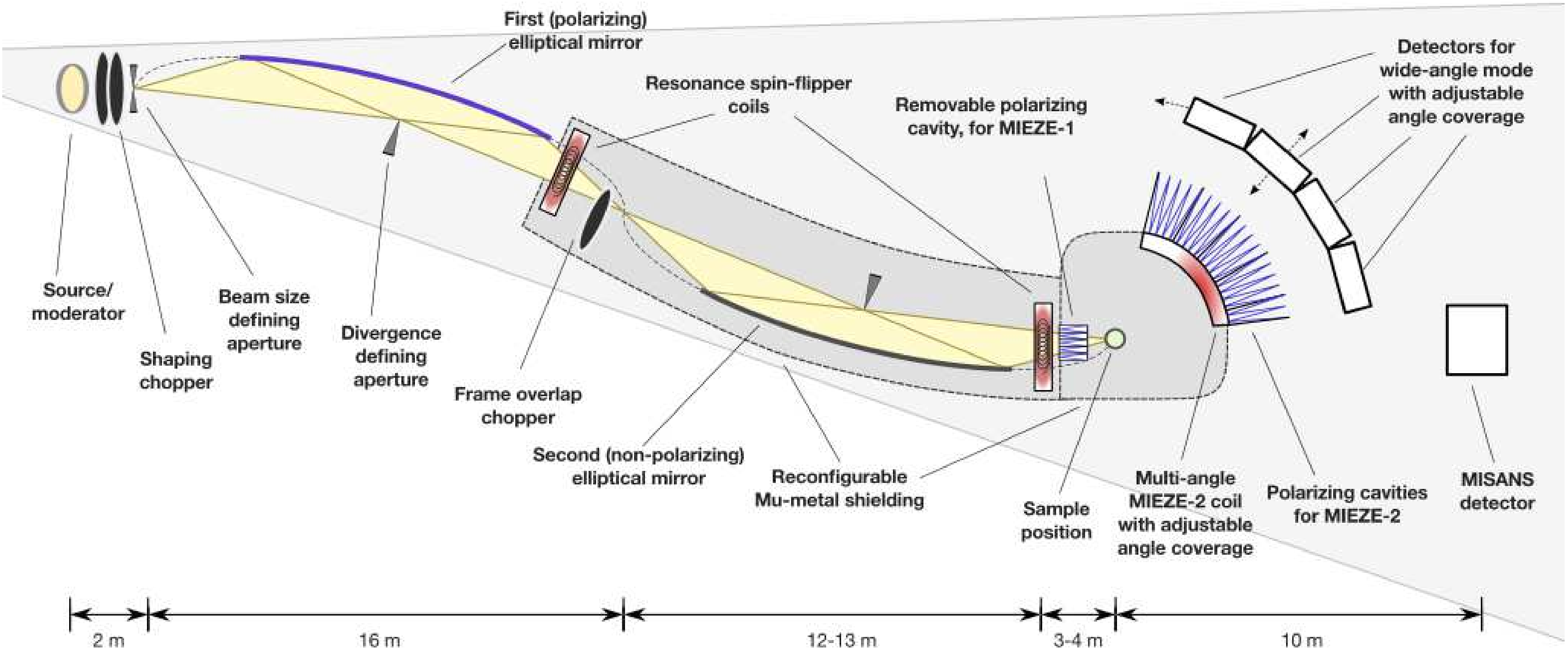
polarisation efficiency



optics & options

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

all trajectories have the same length



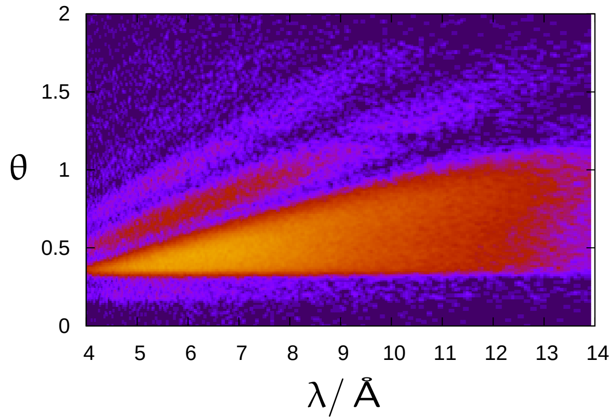
G. Brandl, A. Chacón, R. Georgii, W. Häußler, *et al.* FRM II & TU Munich

reflectometry

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

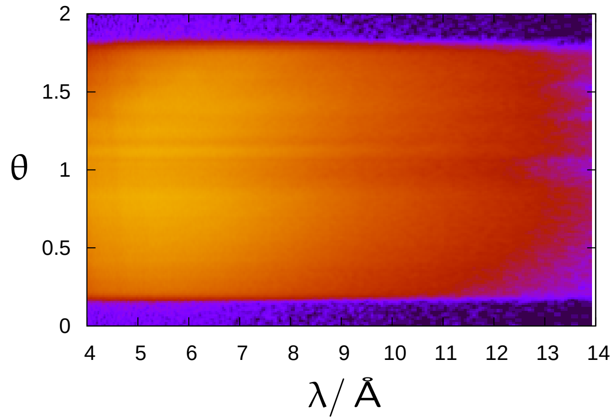
reflectometry

high-intensity specular reflectivity



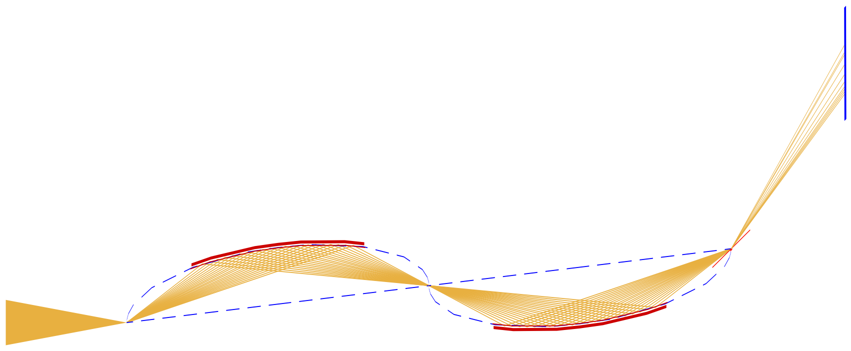
Si/Fe/Cu film on Si

sample by
Birgit Wiedemann
TU Munich



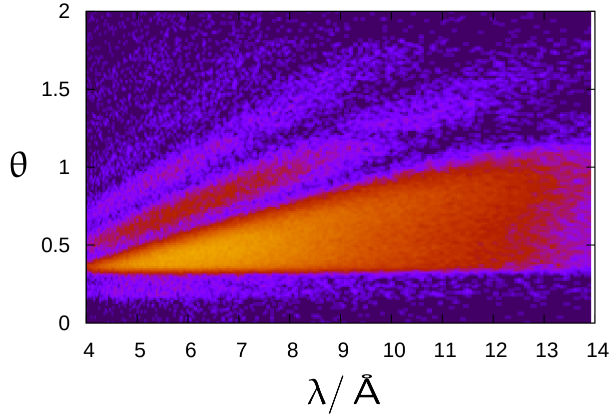
supermirror $m = 5$

sample by
SwissNeutronics



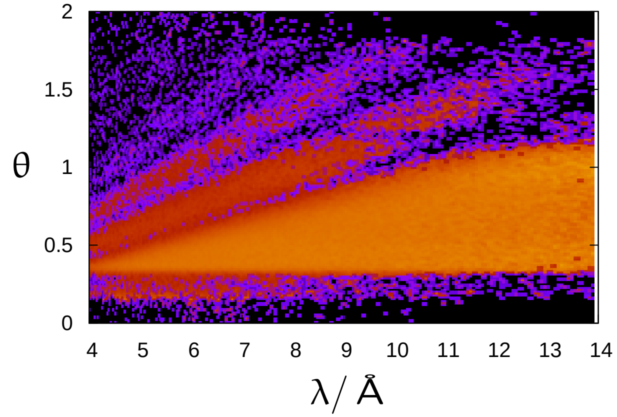
reflectometry

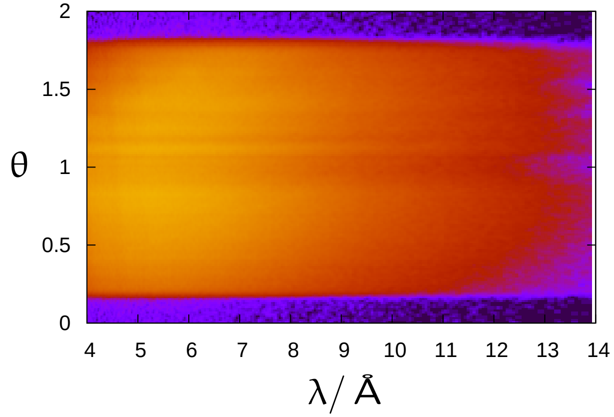
high-intensity specular reflectivity



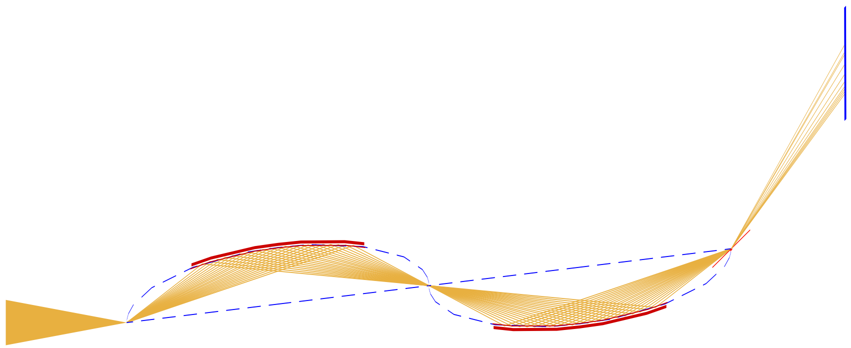
Si/Fe/Cu film on Si

Si/Fe/Cu / SM



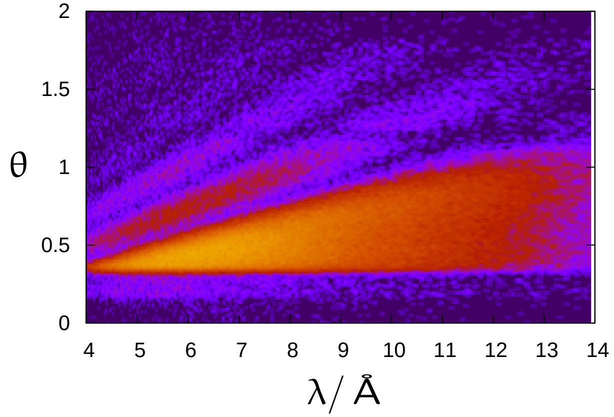


supermirror $m = 5$



reflectometry

high-intensity specular reflectivity



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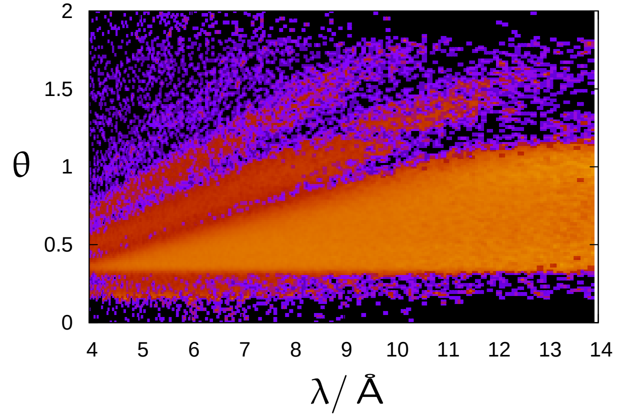
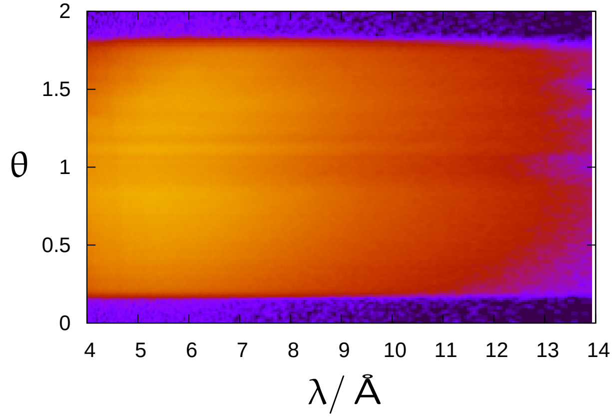
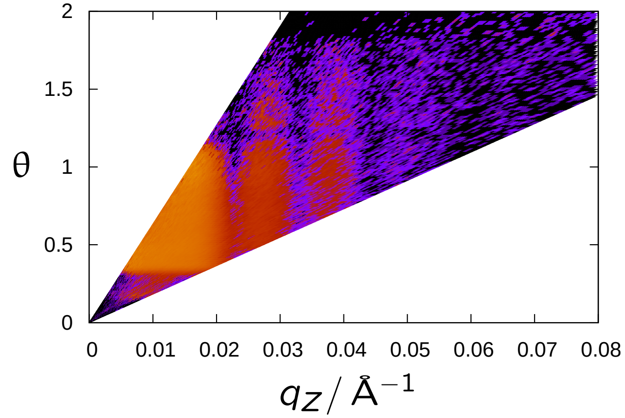


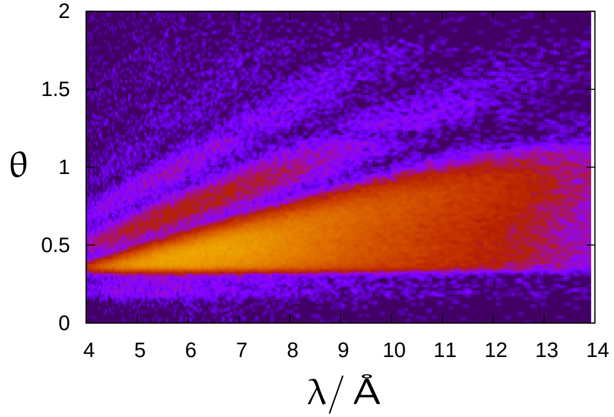


supermirror $m = 5$



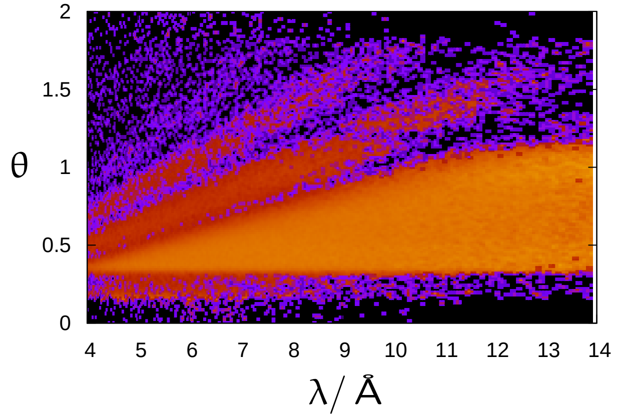
reflectometry

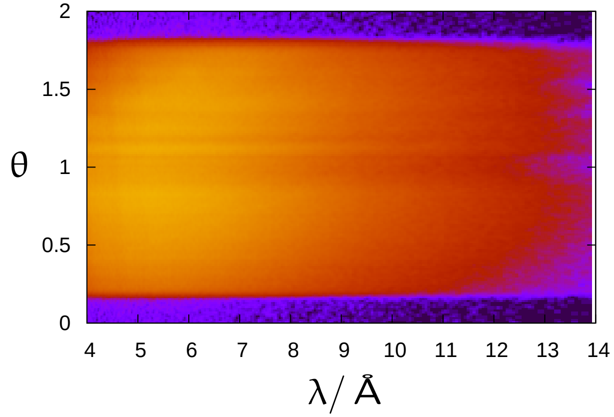
high-intensity specular reflectivity



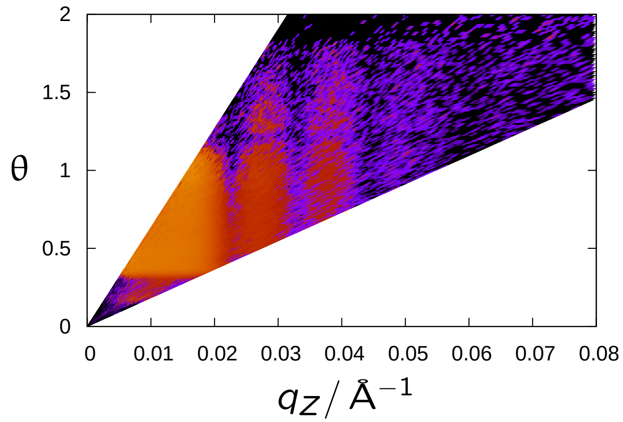
Si/Fe/Cu film on Si

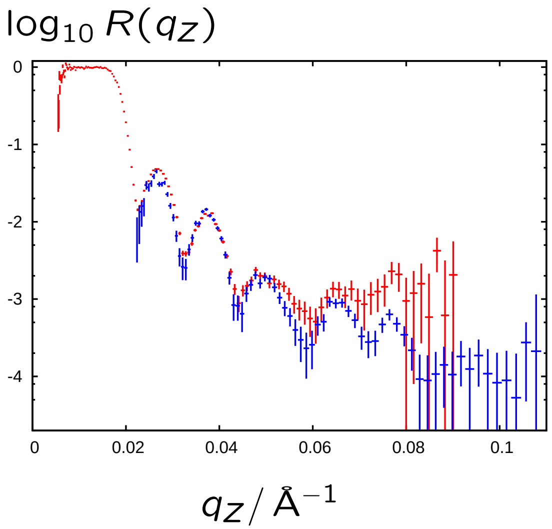
Si/Fe/Cu / SM





supermirror $m = 5$





reflectometry

instrument concept for ESS

focusing reflectometer

two Selene guide sections

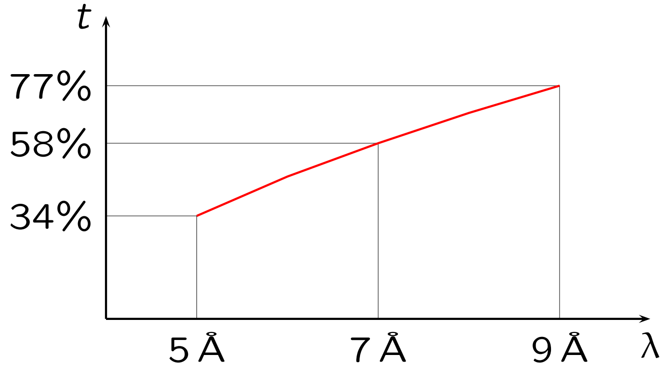
- ◦ background reduction
- ◦ convenient beam manipulation

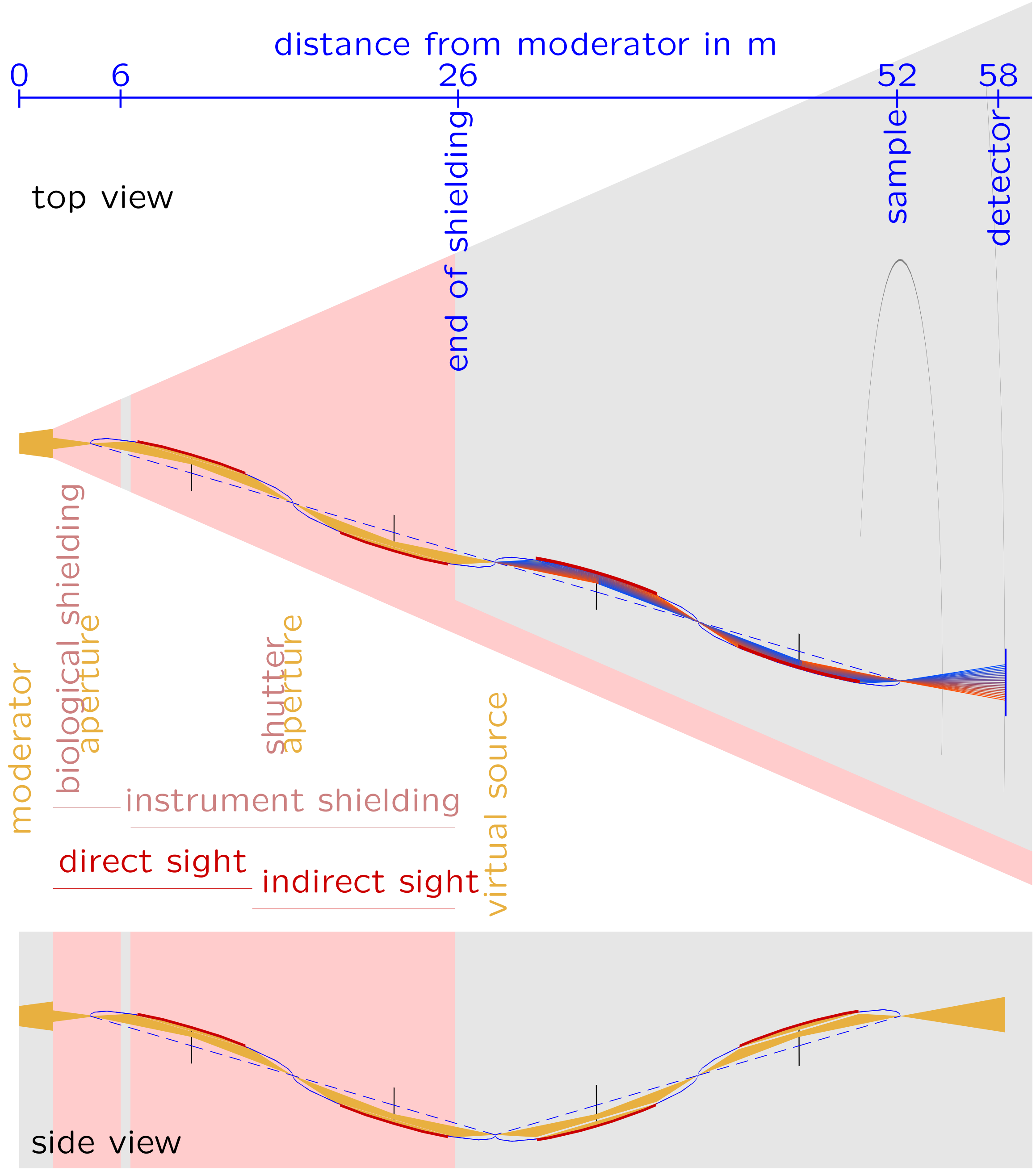
$\lambda \in [5, 9.4]$ Å

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

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

transmission





discussion

- **Selene guide system**
- **prototype**
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discussion

general limits of *Selene* guides

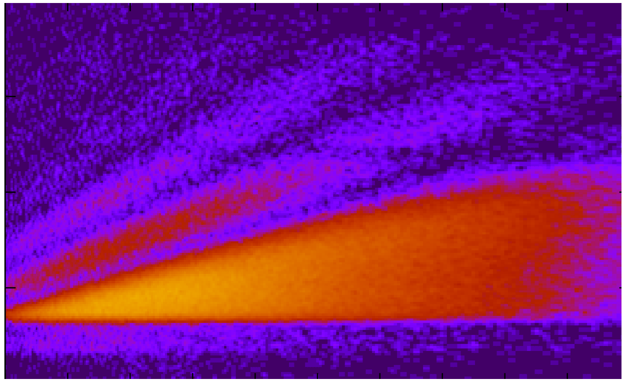
- max. spot-size / guide-length $\approx 5 \cdot 10^{-4}$ — i.e. 1 cm / 20 m
- gravity gets important for large guide $\times$ wavelengths — e.g. 40 m $\times$ 10 Å
- finite reflectivity / m — $\Delta\theta/\lambda < 0.6\,\mathrm{deg}/\text{Å}$

technical limits (to be pushed)

- guide assembly and alignment
- ground settling

successes

+ guide quality sufficient for high-intensity and conventional reflectometry
+ successfully applied to real samples



discussion

focusing results in:

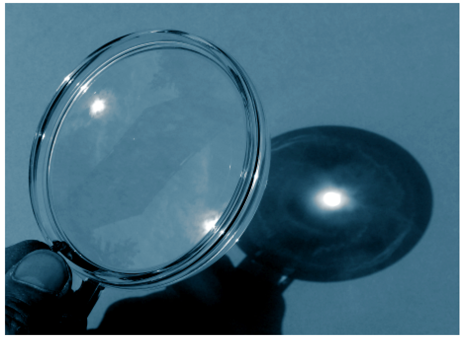
no gain in brilliance

defined footprint

clean beam

homogeneous

uni-modal angular or spatial distribution



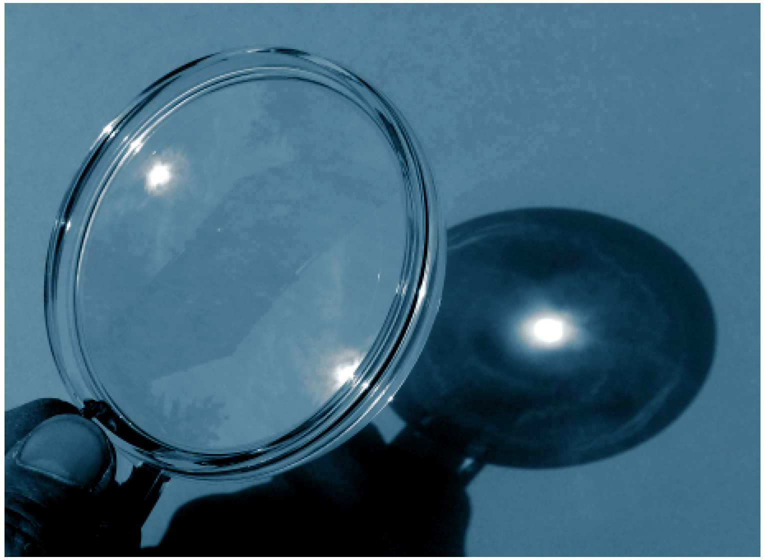
non-perfect optics

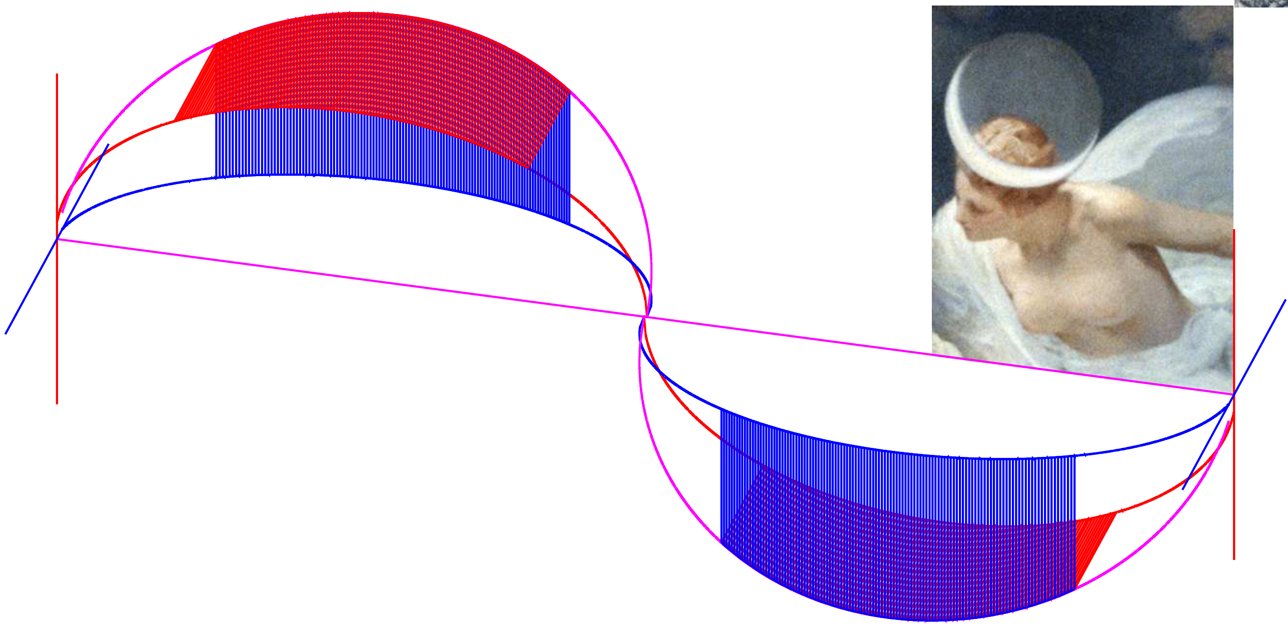
⇒ reduction of resolution / transmission

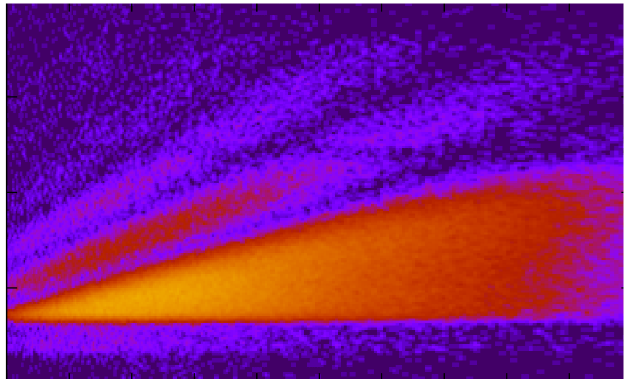
works best for small samples

weak aberration

discussion



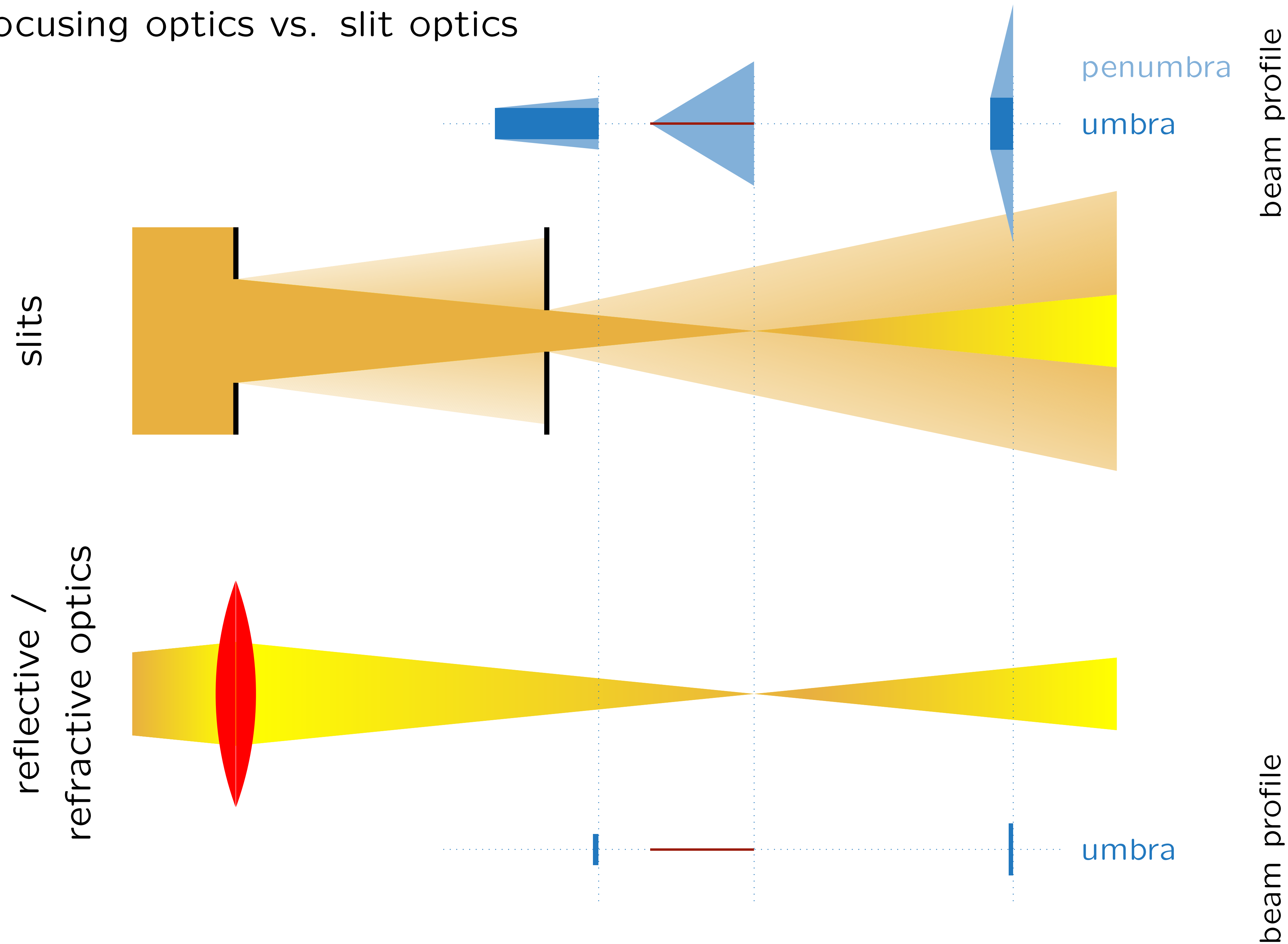




appendix

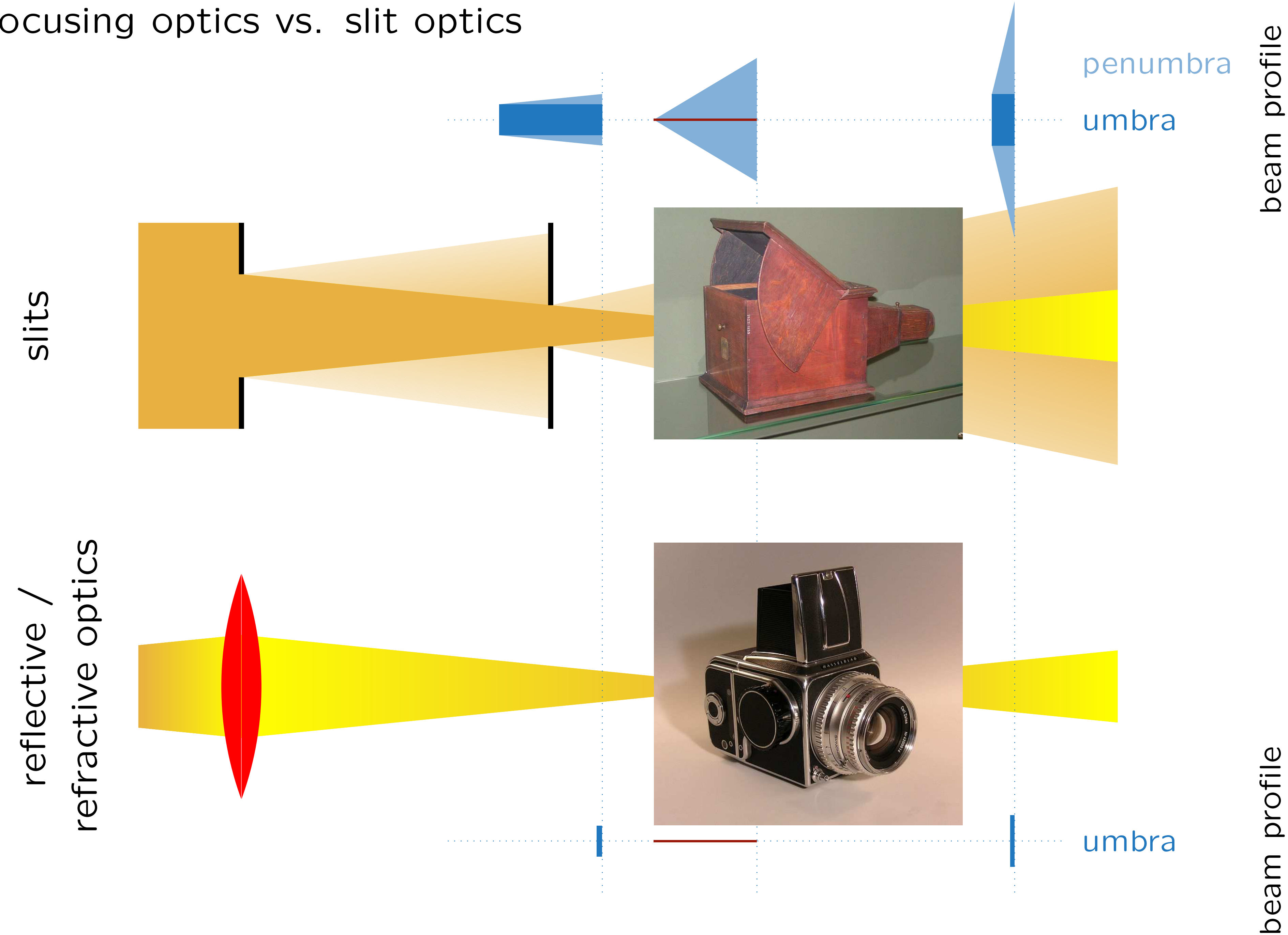
basics

focusing optics vs. slit optics



basics

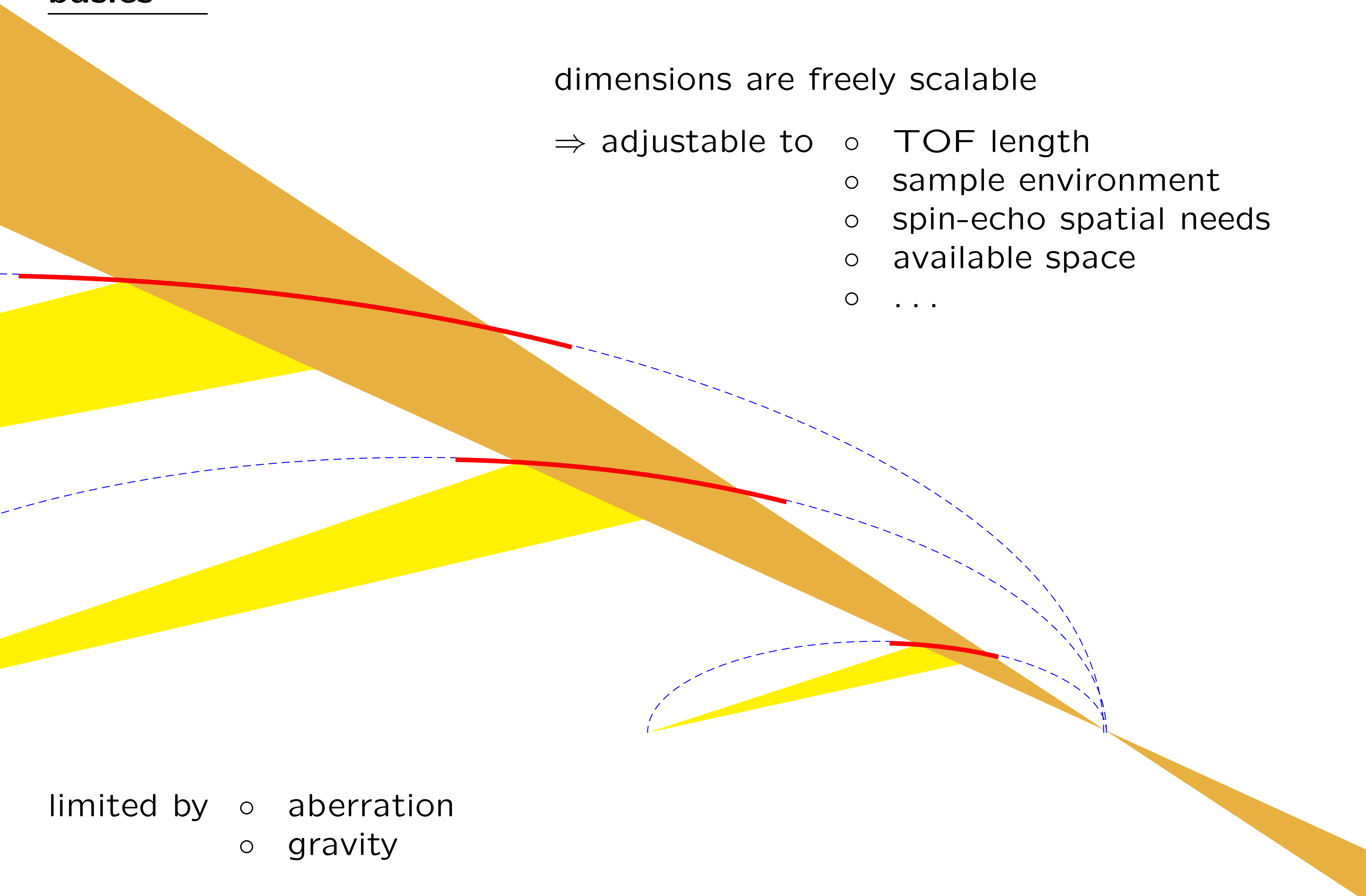
focusing optics vs. slit optics



basics

dimensions are freely scalable

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



limited by
- aberration
- gravity

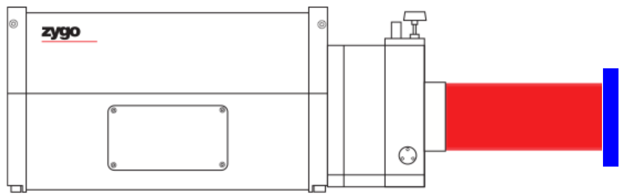
prototype

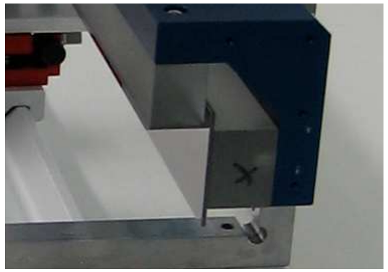
quality characterisation by interferometry:

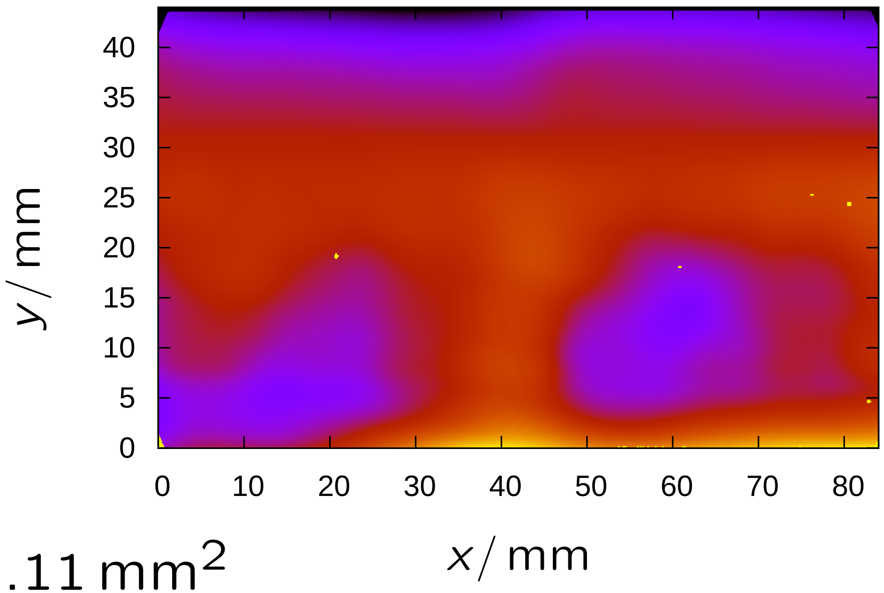
ZYGO Verifire ATZ

metrology-lab @ PSI

parallel beam *normal* to the surface







dynamic range: 1.5 μm

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

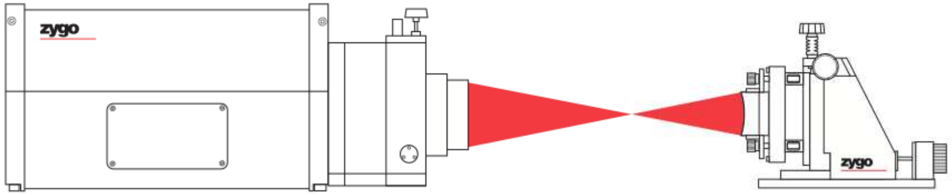
prototype

quality characterisation by interferometry:

ZYGO Verifire ATZ

metrology-lab @ PSI

focused beam

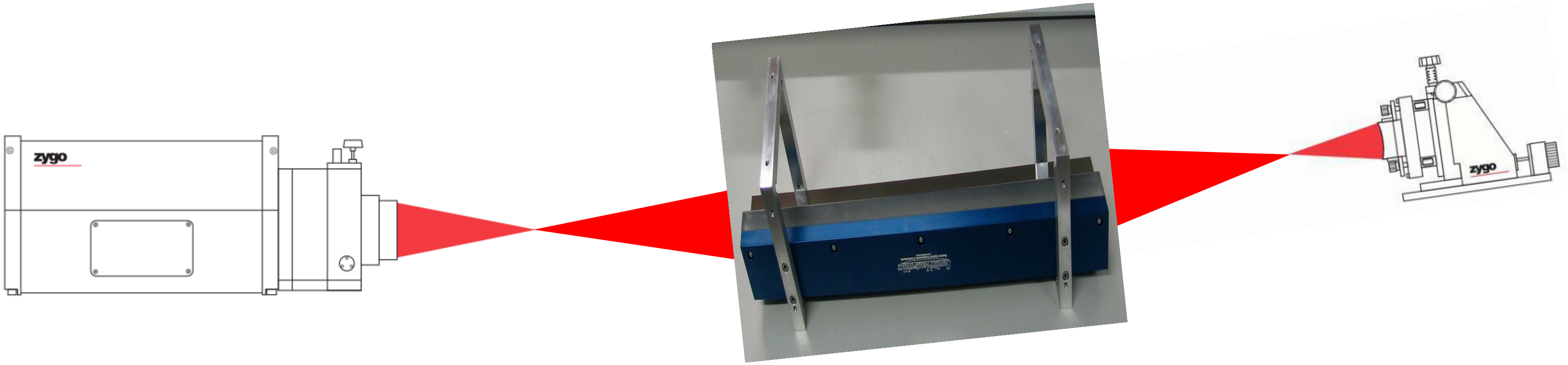


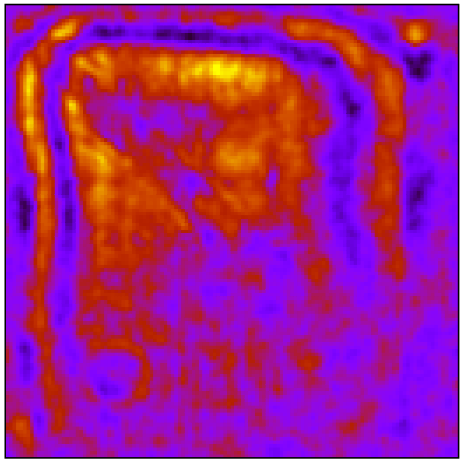
prototype

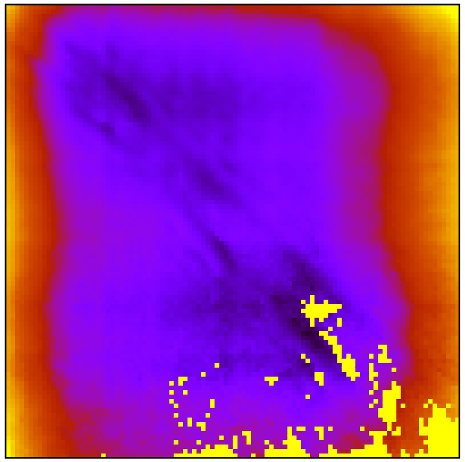
quality characterisation by interferometry: ZYGO Verifire ATZ

metrology-lab @ PSI

focused beam fed into guide





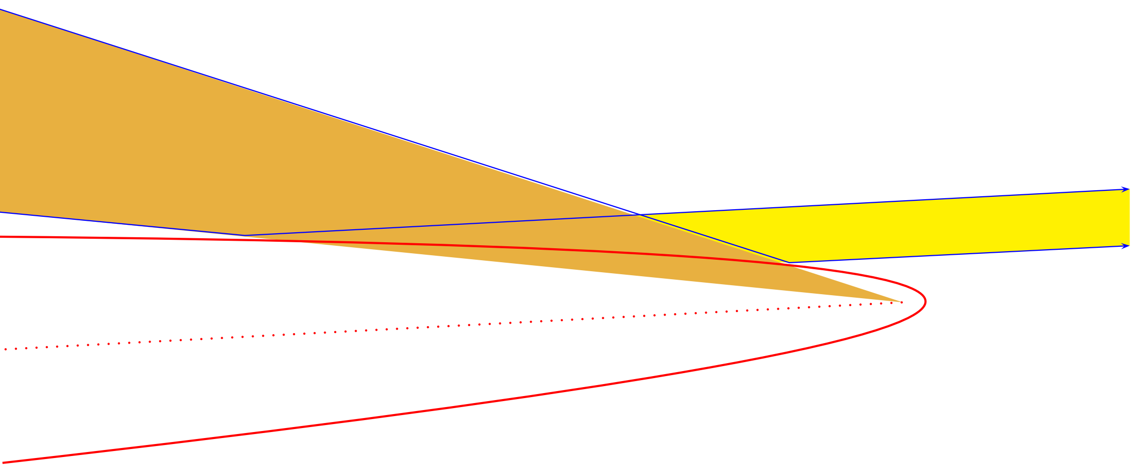


not yet analysed

light optics not adapted
⇒ low intensity

optics & options

condenser: parabolic deflector to generate a parallel beam



parabola axis ⇒ beam direction

focal length ⇒ beam width

beam width & spot size ⇒ divergence

no collimator needed

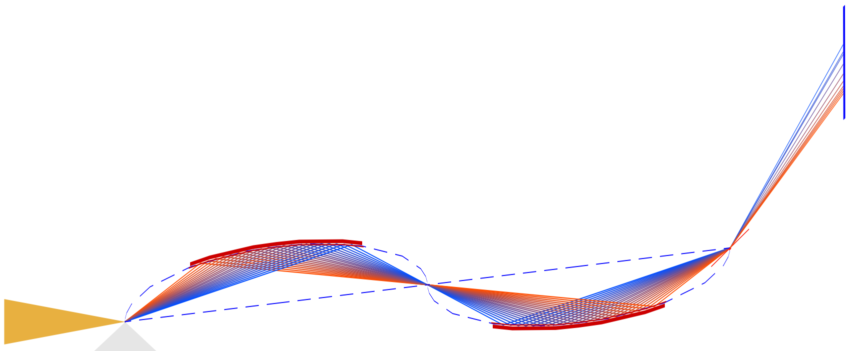
tunable

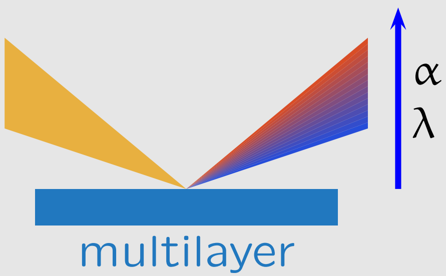
(not yet realised)

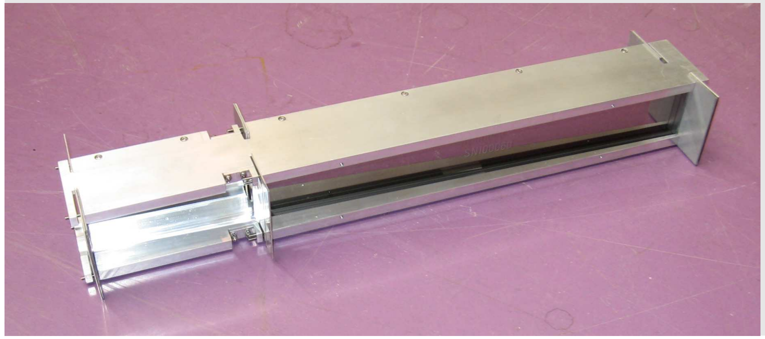
optics & options

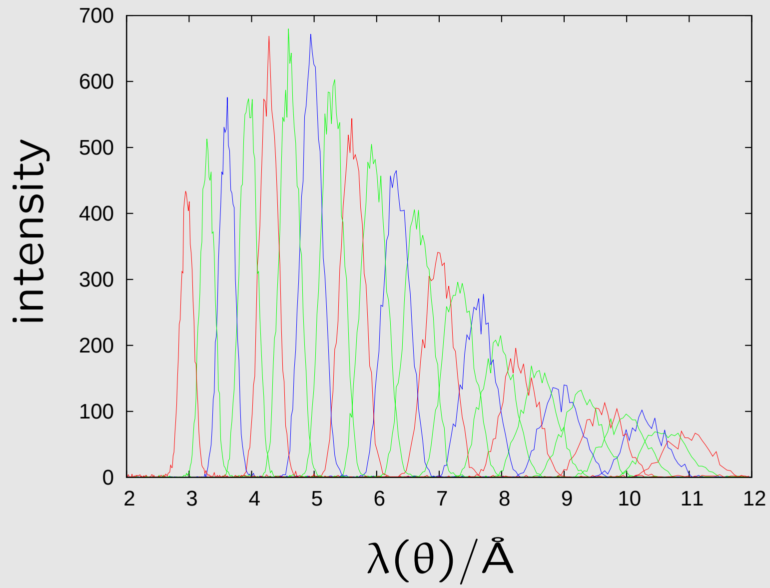
spectral analysis

using a multilayer monochromator

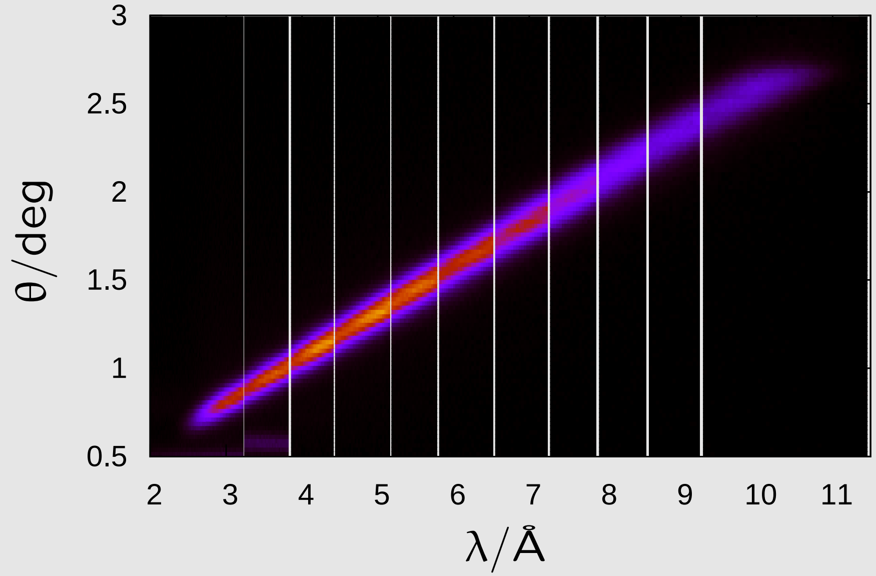








$I(\lambda, \theta)$ measured on Amor

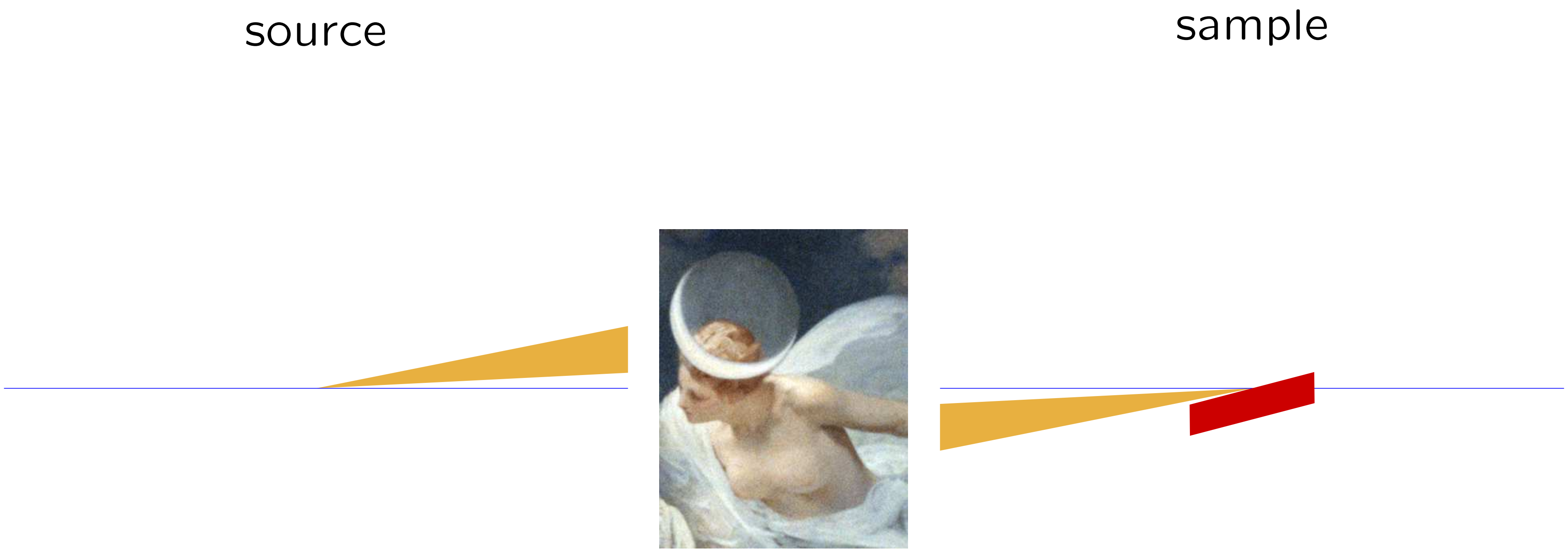


double ML monochromator

optics & options

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

point source $\Rightarrow$ illuminates sample centre



optics & options

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

point source ⇒ illuminates sample centre

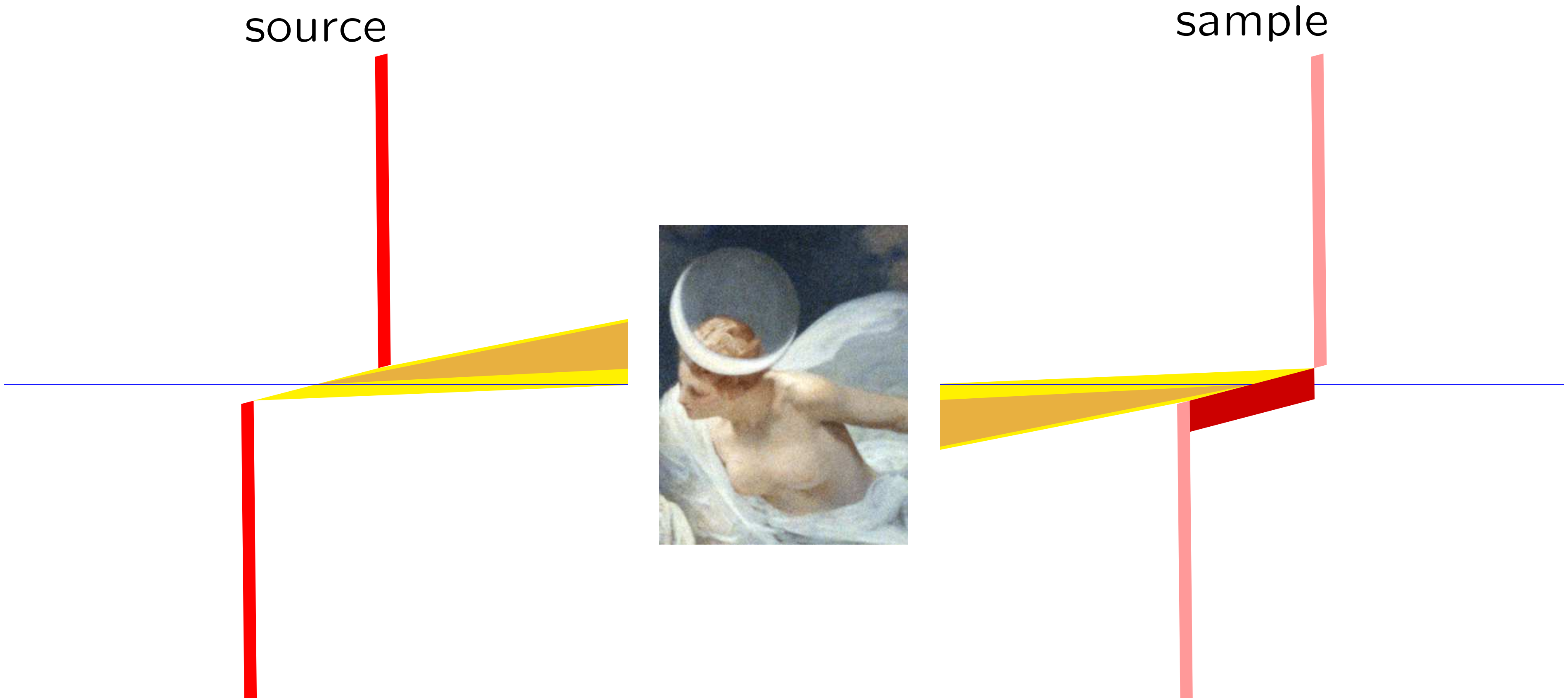
finite sample ⇒ needs finite source

source sample

optics & options

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

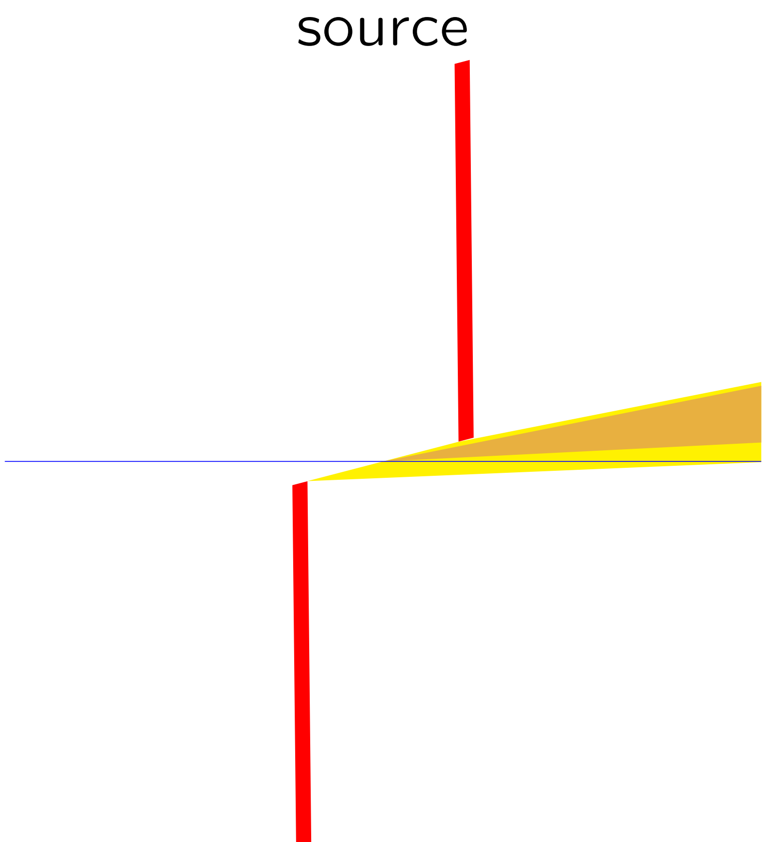
point source	$\Rightarrow$	illuminates sample centre
finite sample	$\Rightarrow$	needs finite source
source shape & orientation	$=$	image of footprint

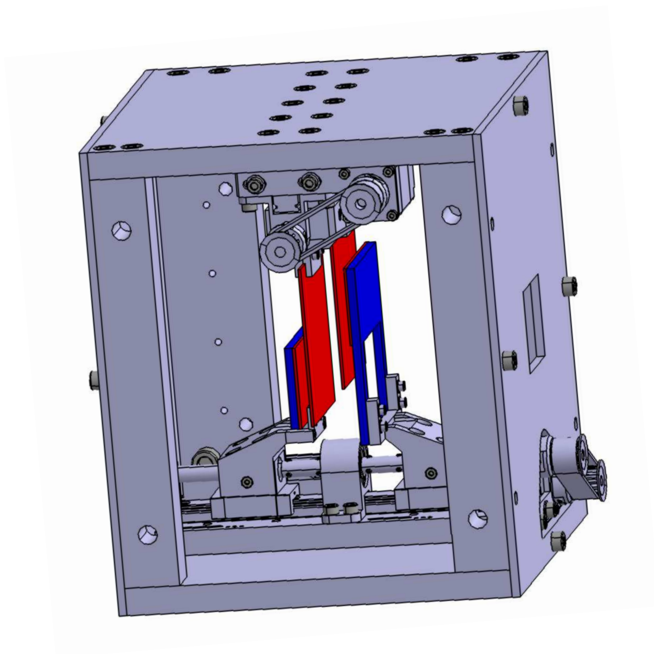


optics & options

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

point source	$\Rightarrow$	illuminates sample centre
finite sample	$\Rightarrow$	needs finite source
source shape & orientation	$=$	image of footprint





optics & options

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

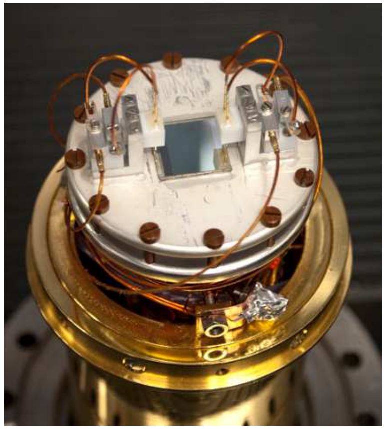
applications:

- 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

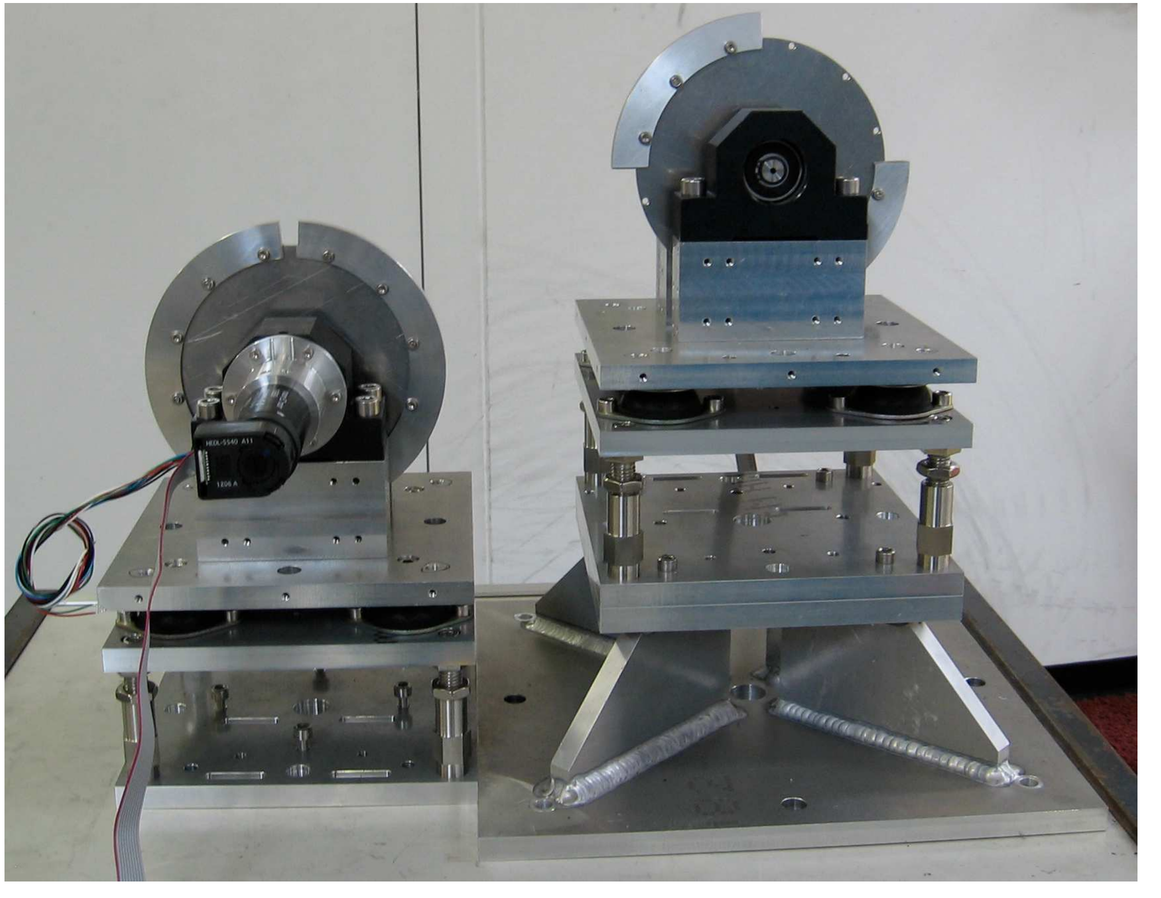
$\nu = 60\,\mathrm{s}^{-1}$
gives $\lambda = 0 \ldots 10\,\text{Å}$

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

Al:B and Cd absorber

- frame-overlap suppression

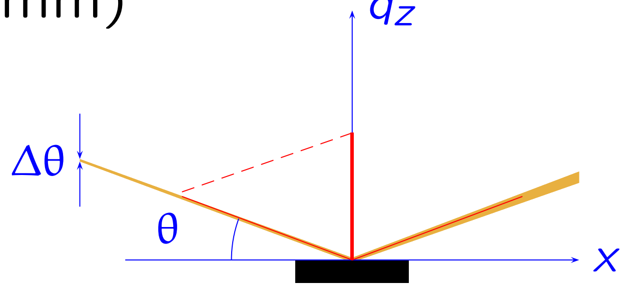
- pulse generation



reflectometry

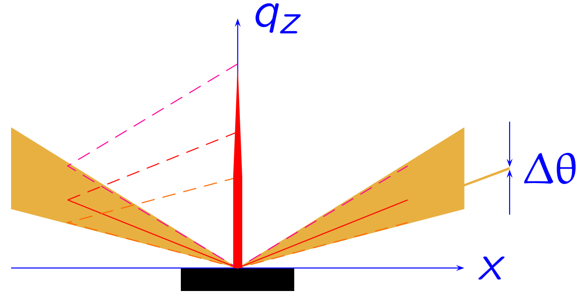
why?

- 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



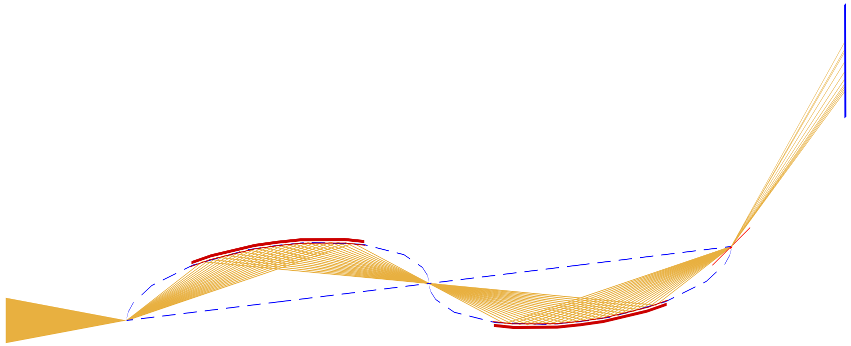
- reflectometry can profit from
  - large $\Delta\theta$
  - λ-θ encoding
  - changing θ without rotating the sample

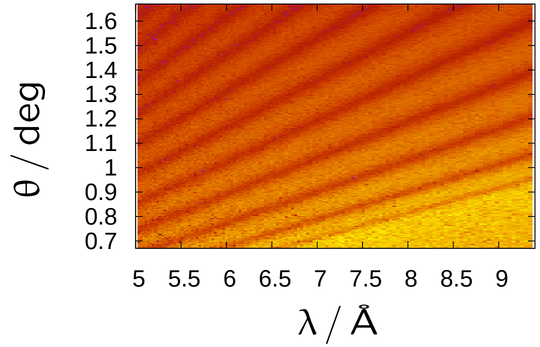
- it's my area of interest

reflectometry

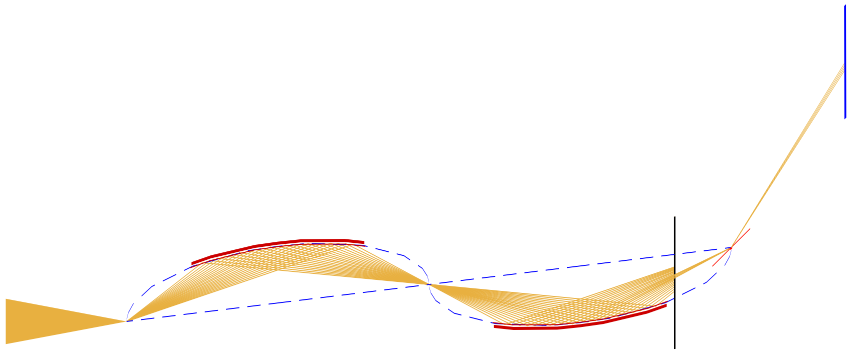
operation modes

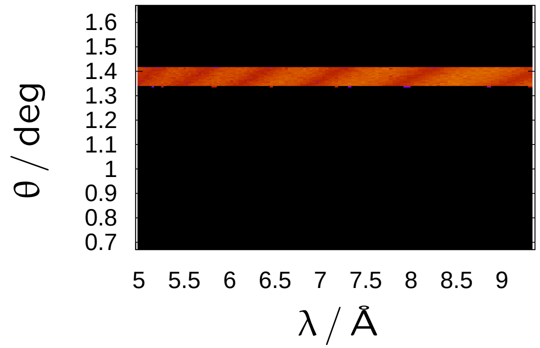
high-intensity
specular reflectivity



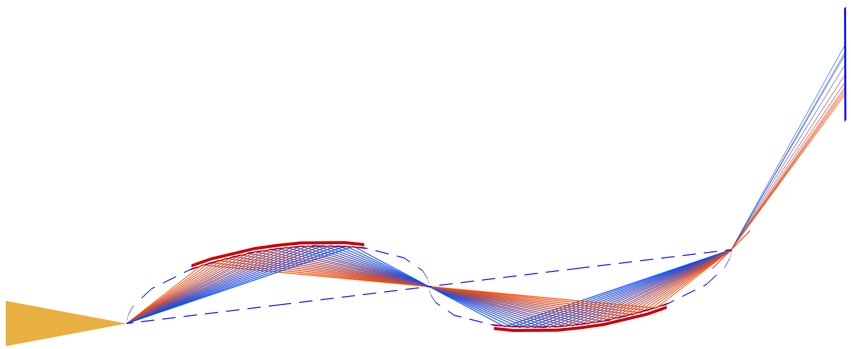


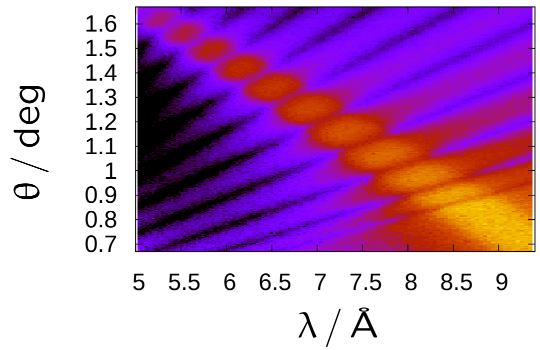
almost conventional
reflectivity





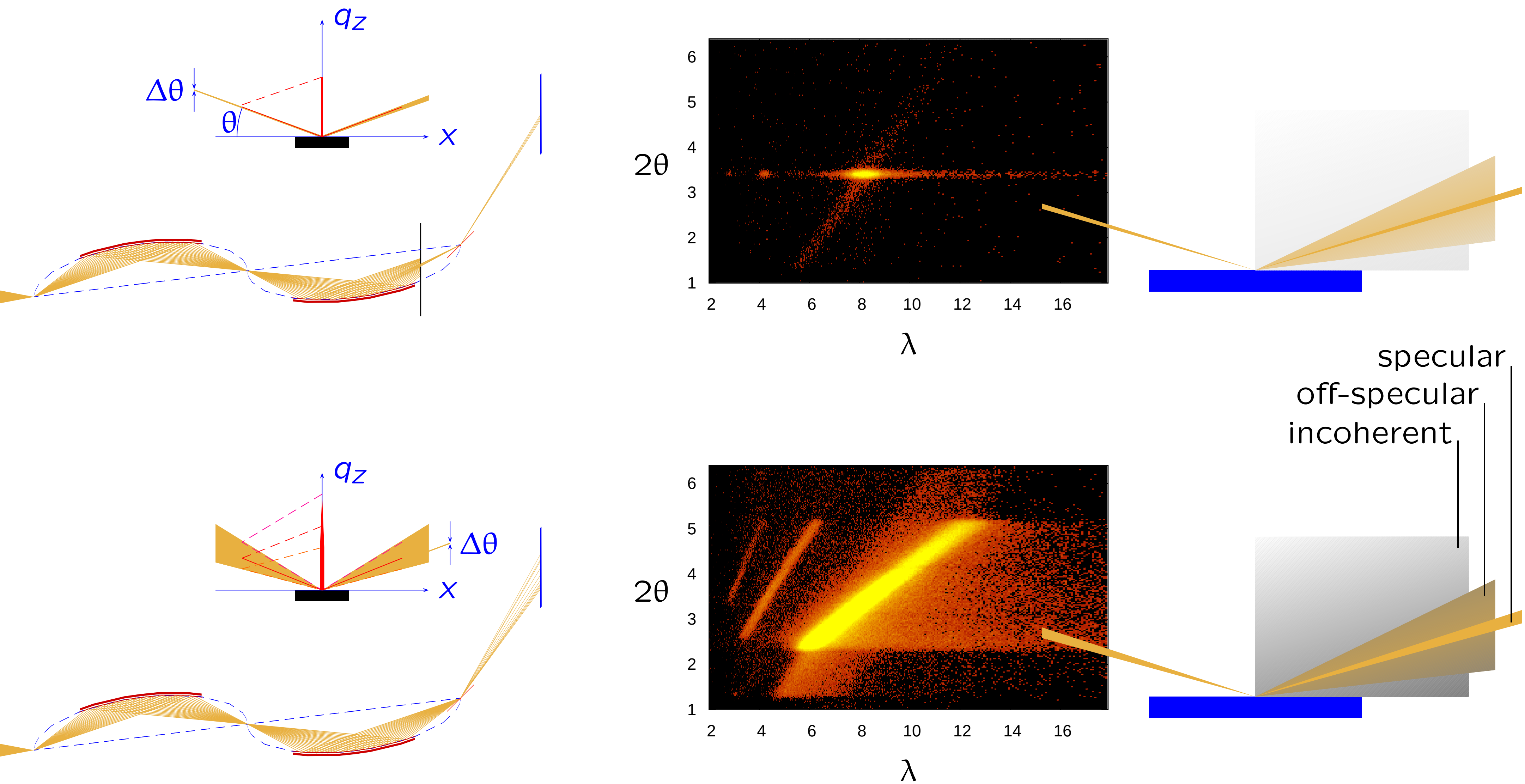
λ-θ encoding





reflectometry

high-intensity specular reflectometry vs. almost conventional

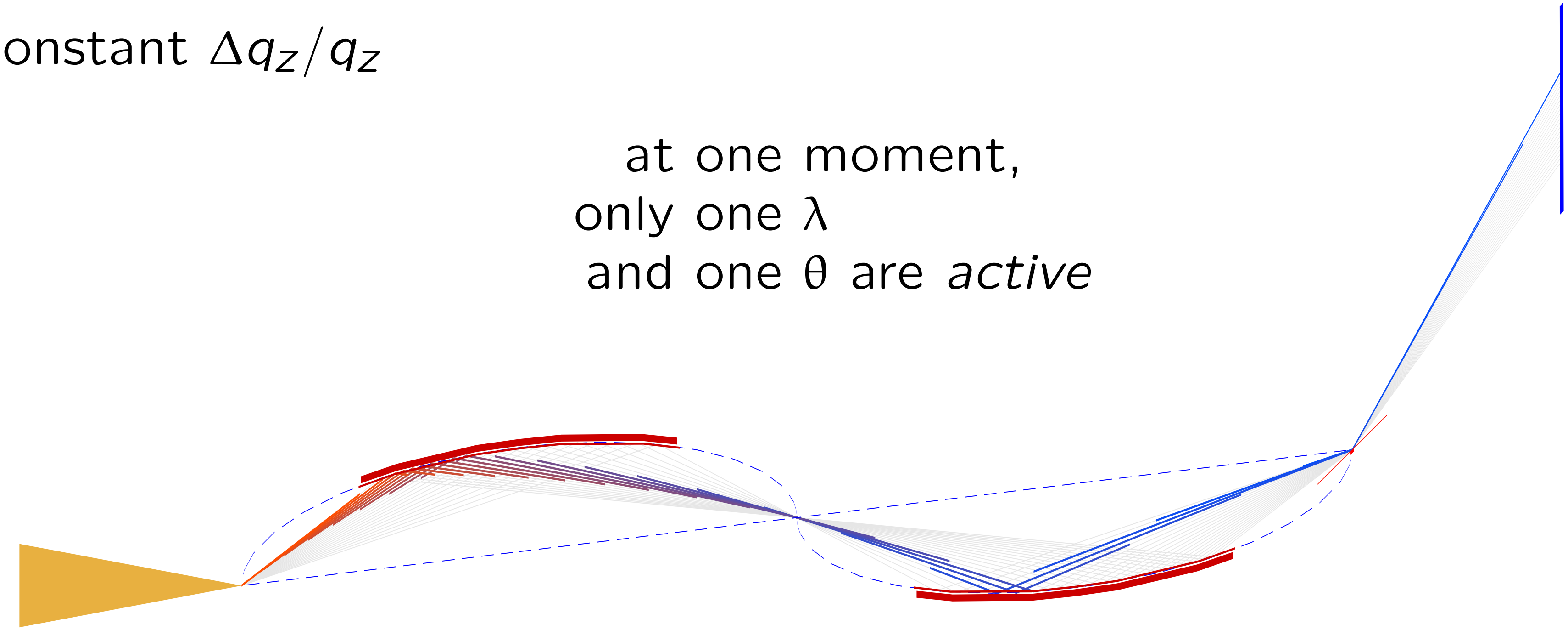


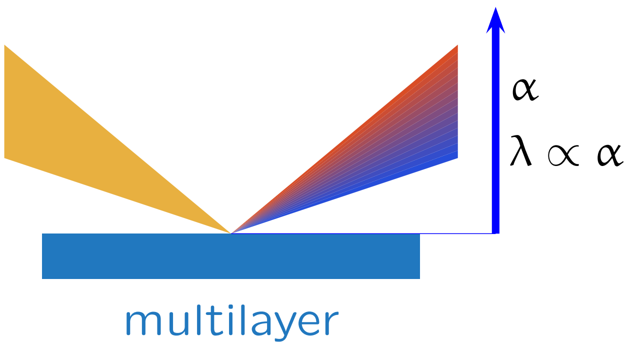
reflectometry

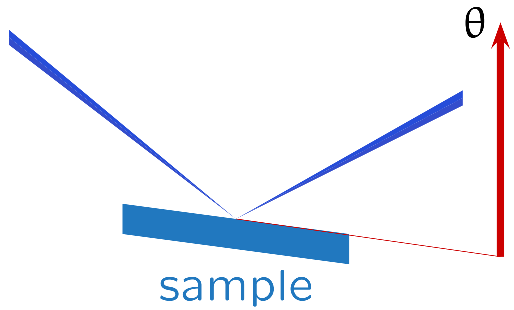
λ-θ-**encoding** & TOF

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

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



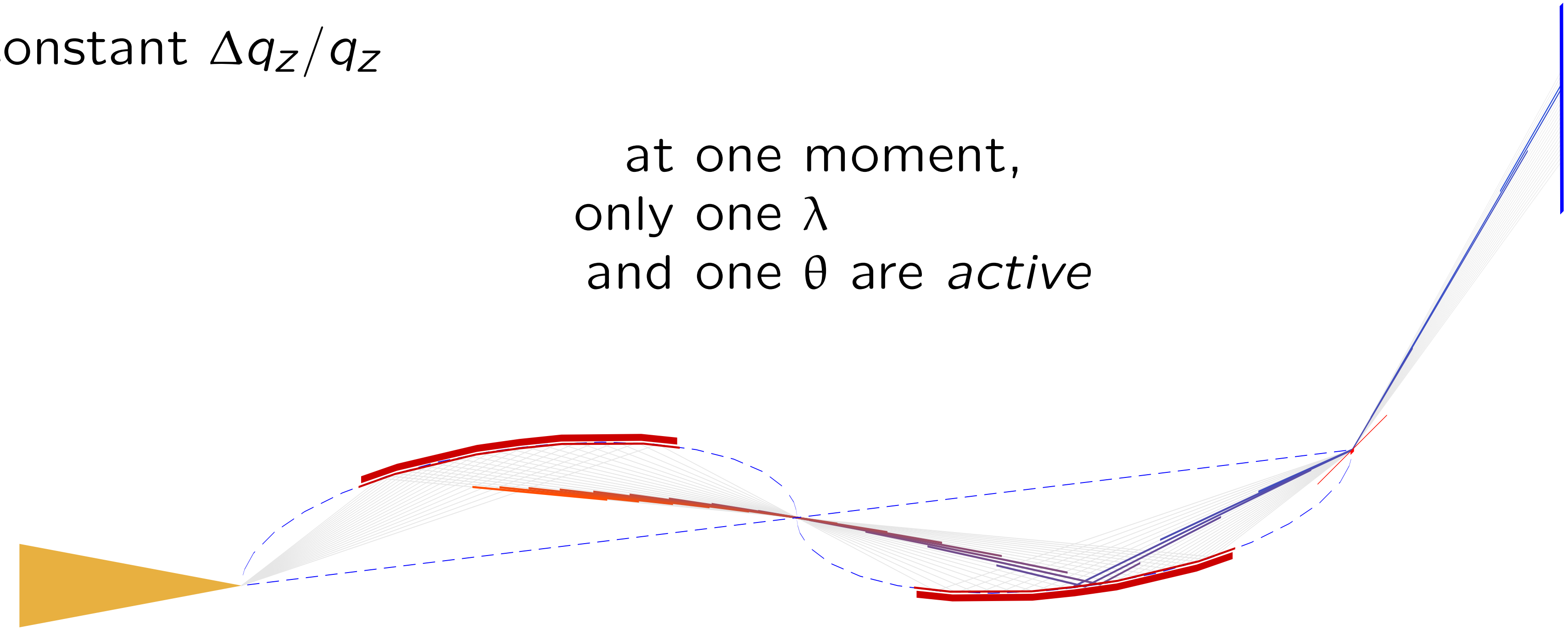


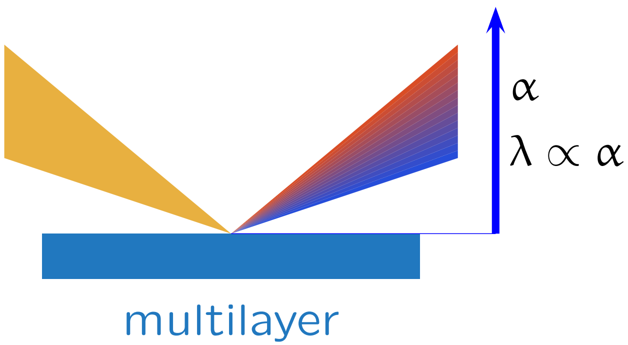


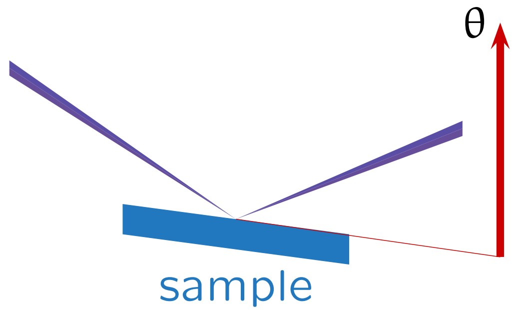
reflectometry

λ-θ-**encoding** & TOF

⇒ constant $\Delta q_z / q_z$



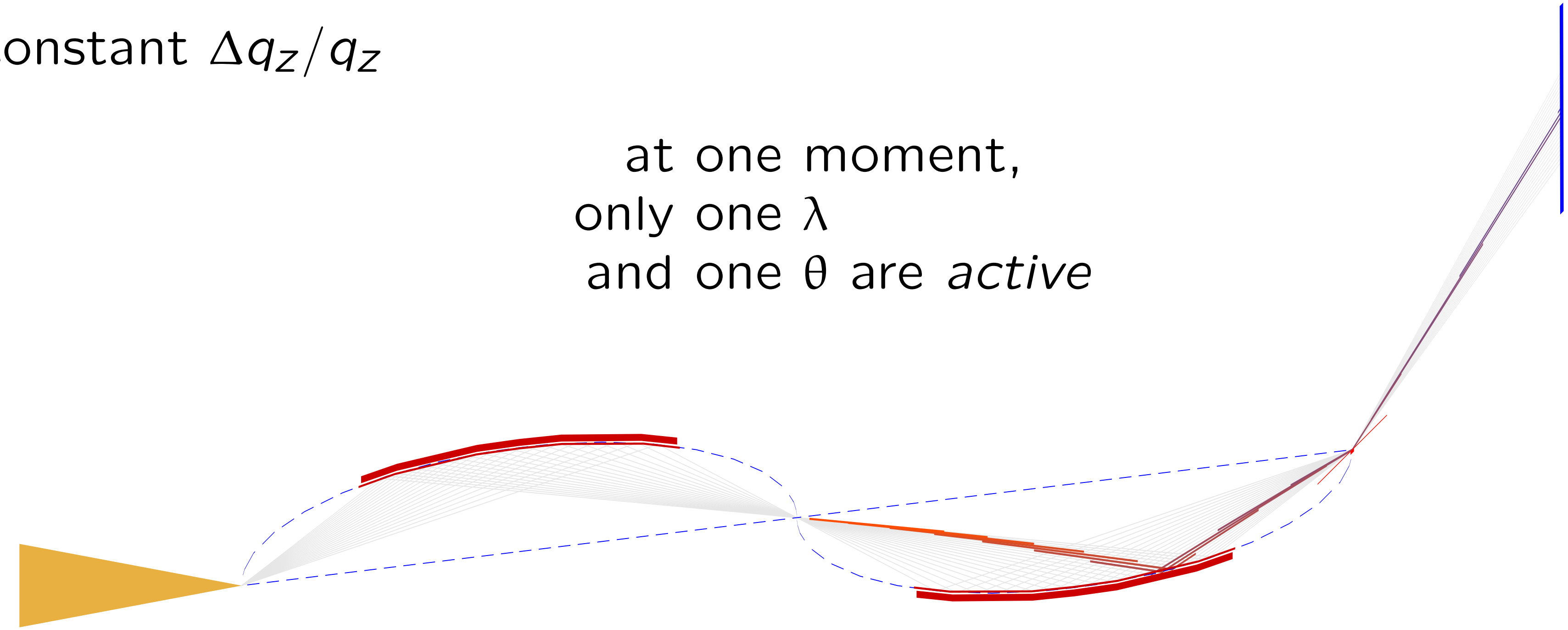


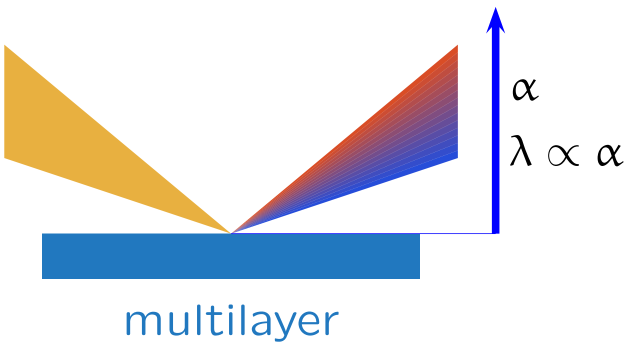


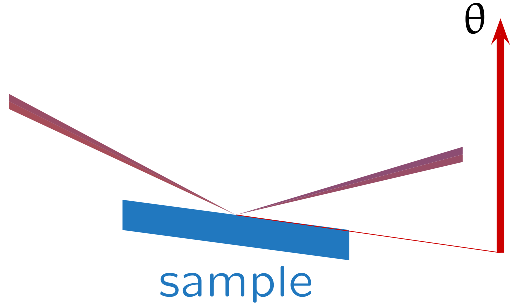
reflectometry

λ-θ-**encoding** & TOF

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





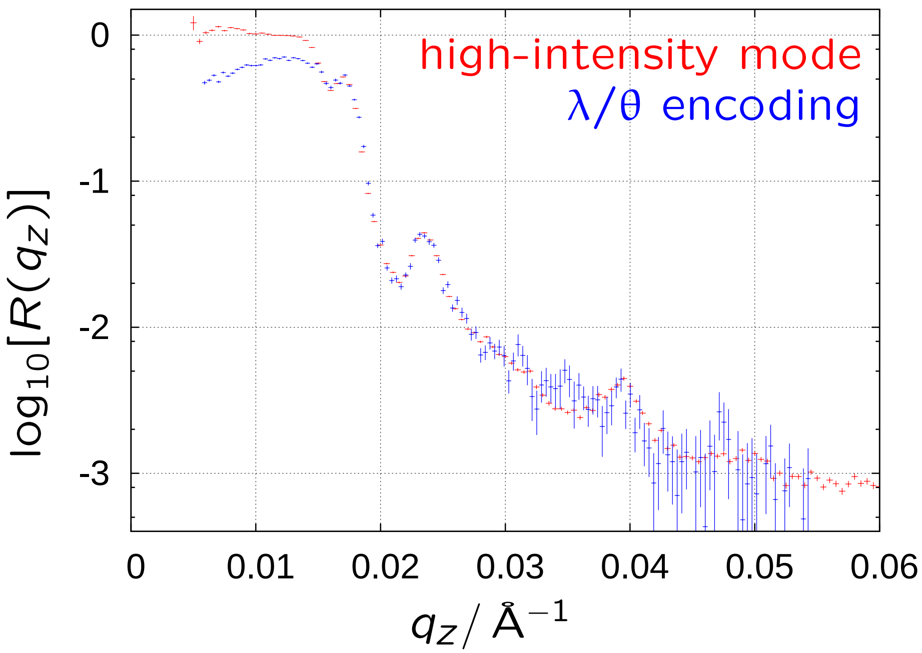


reflectometry

λ/θ **encoding** & TOF

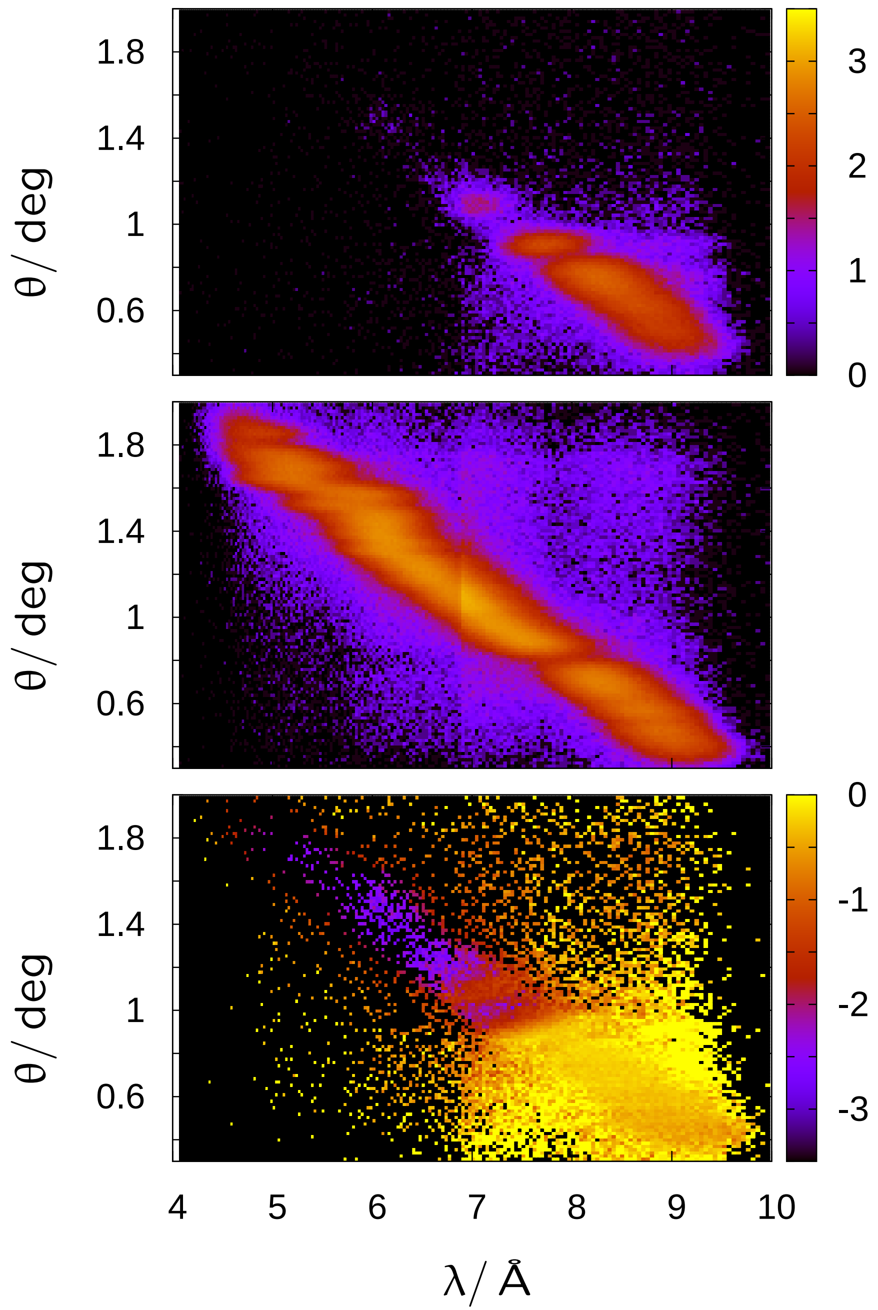
$[\mathrm{LCMO}(200\,\text{Å})/\mathrm{YBCO}(400\,\text{Å})]_5$

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



SM

$m = 5$



problems of data-analysis:

– absolute error of 0