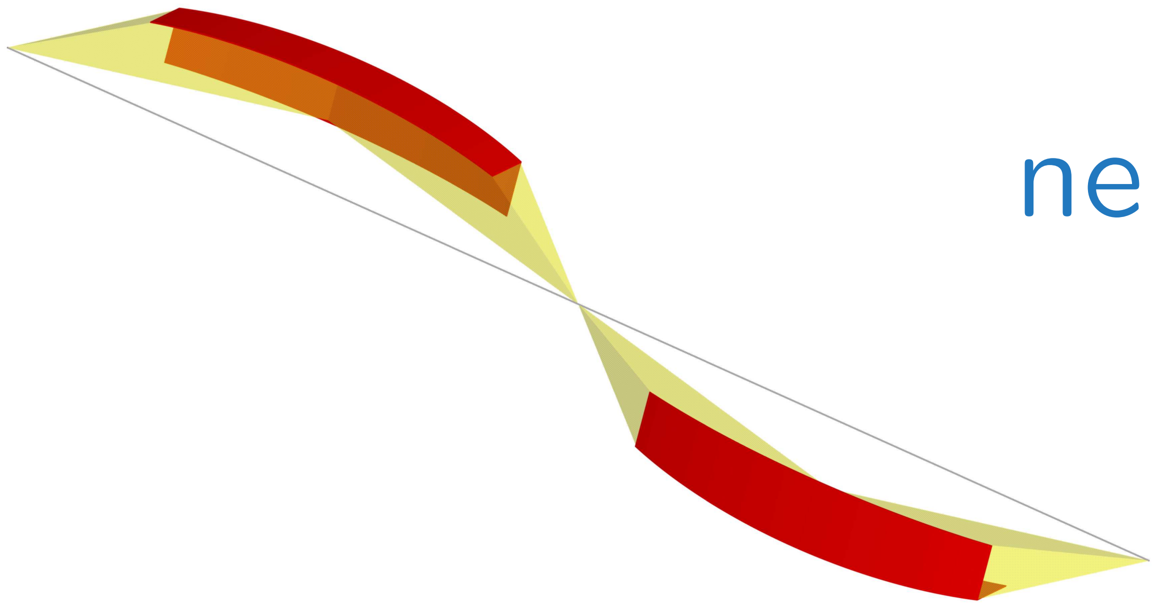
PAUL SCHERRER INSTITUT

Laboratory for Neutron Scattering and Imaging

Jochen Stahn

the *Selene* neutron guide



30. 11. 2015

ISIS, Rutherford Appleton Laboratory, Great Britain

contributors

simulations

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experiments

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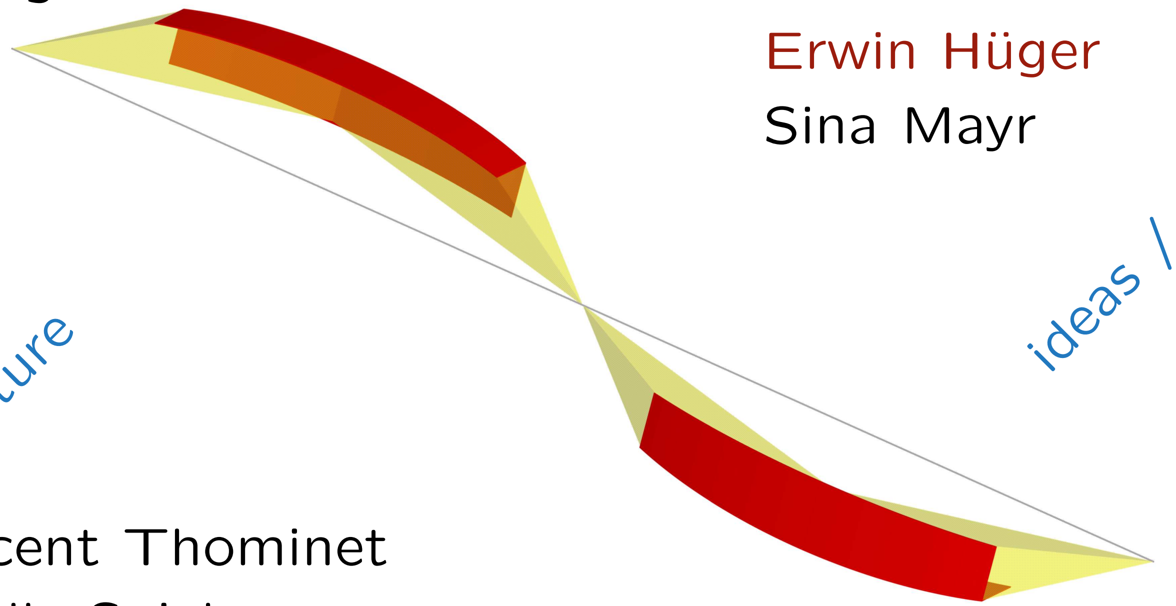

ideas / discussions

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Dieter Graf
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overview

- **Selene guide**
- **optics**
- **reflectometry**
- **experiments**
- **full guides**

overview

- **Selene guide**
- **optics**
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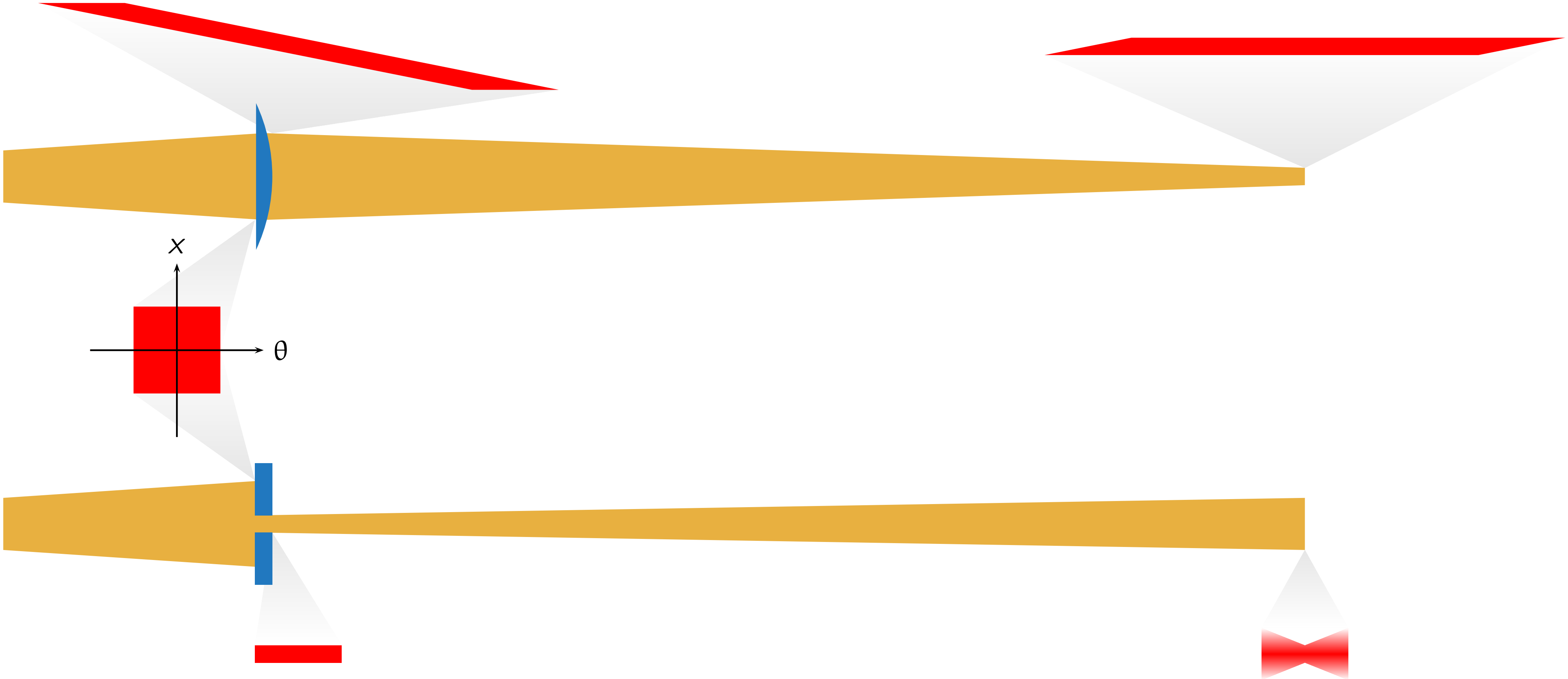
definition of focusing

focusing optics

reshapes the phase space of a n-beam (an ensemble of neutrons) to a **small spatial extent** at a given position



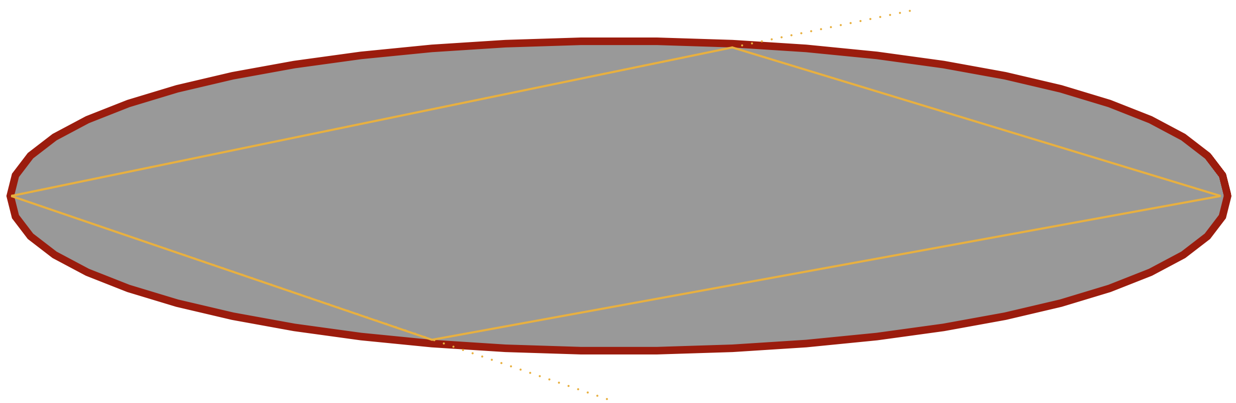
shading optics

reshapes the phase space by restricting it in space (slit)

reflective focusing optics

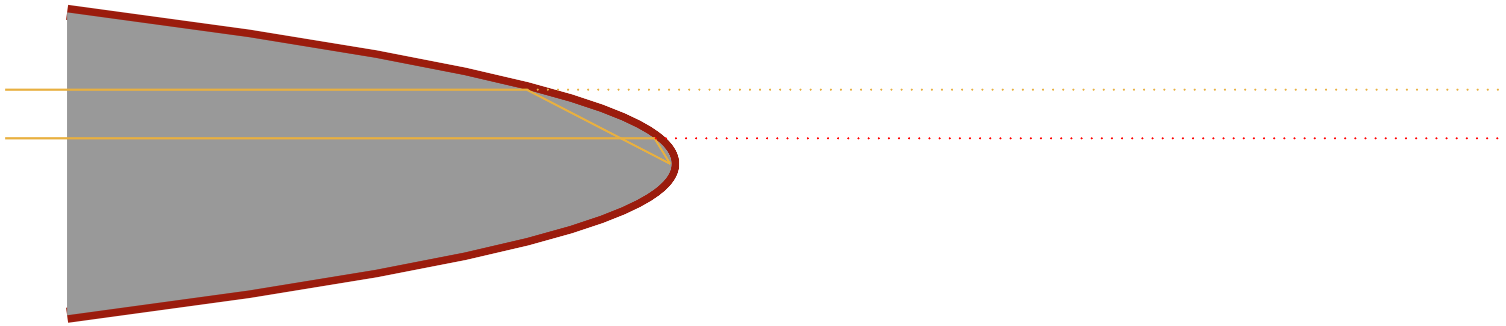
elliptic

divergent to convergent



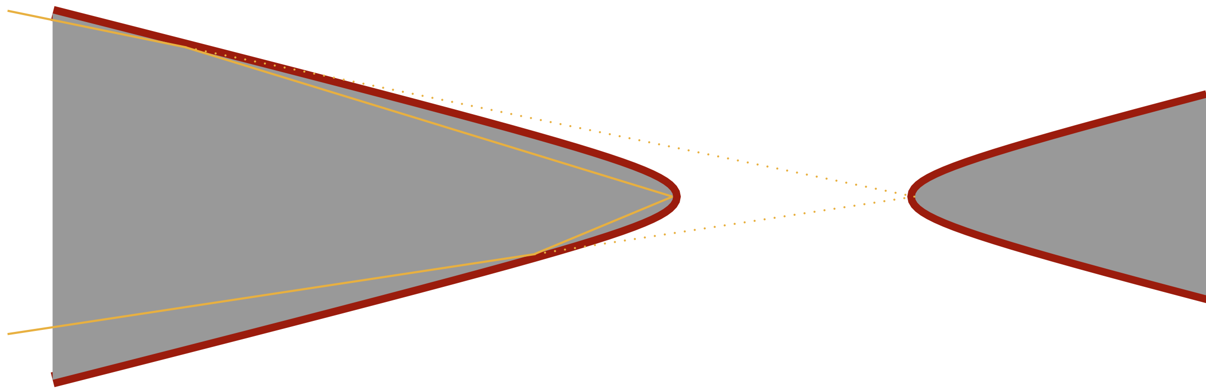
parabolic

parallel to convergent



hyperbolic

convergent to convergent

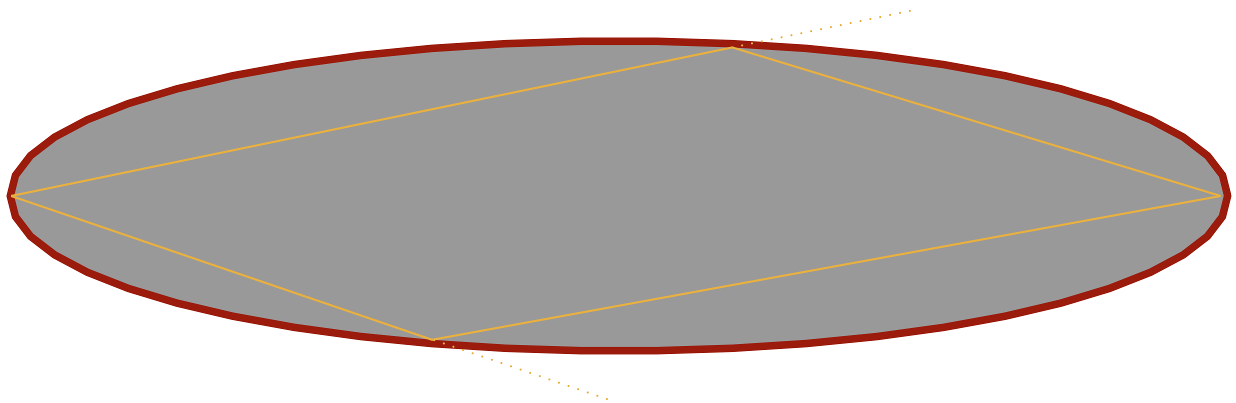


Selene guide

reflective focusing optics

elliptic

divergent to convergent

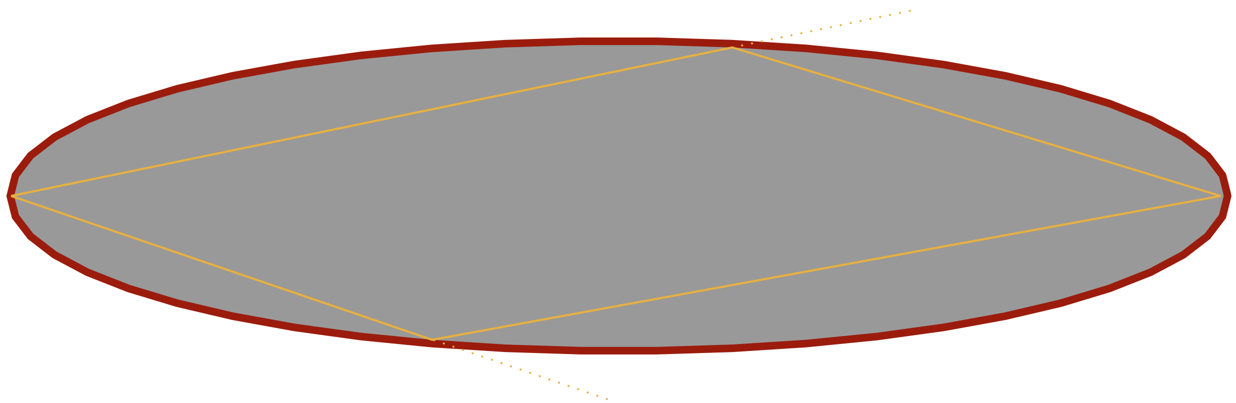


Selene guide

reflective focusing optics

elliptic

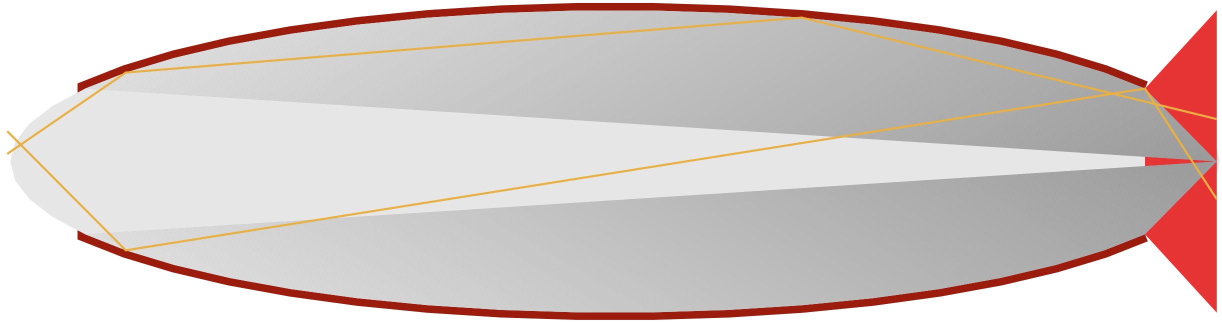
divergent to convergent ?

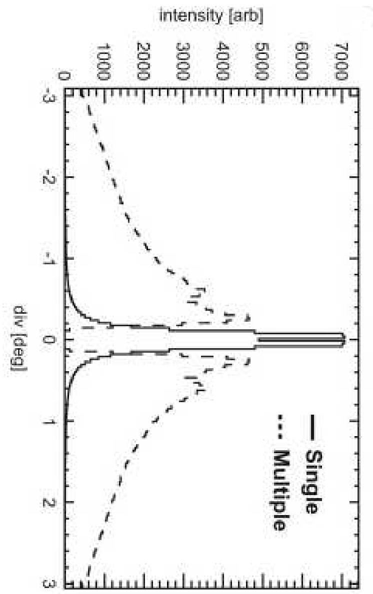


early reflections suffer the most from coma aberration

⇒ multiple reflections

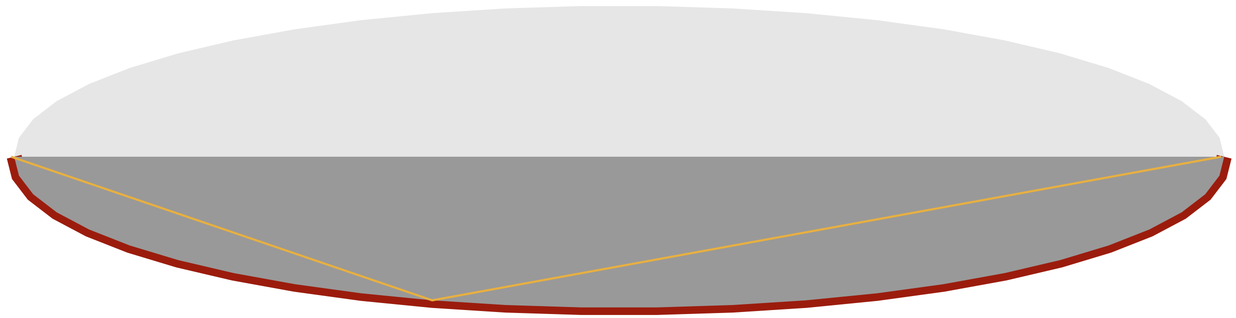
⇒ non-convergent beam behind guide exit



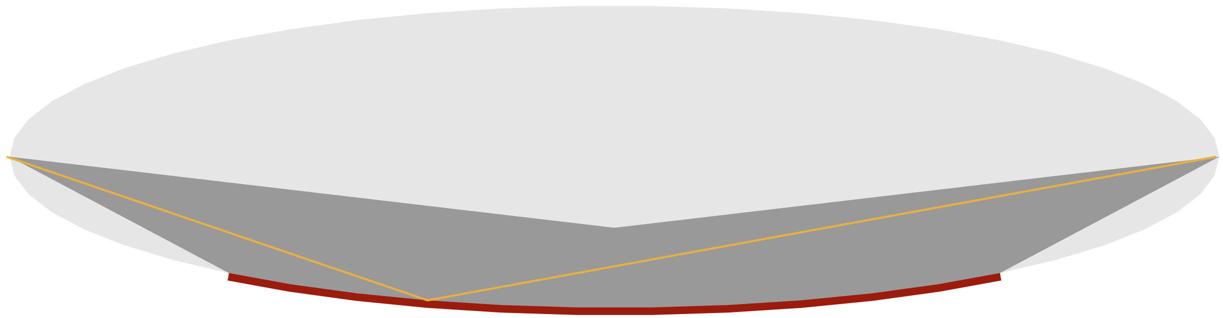


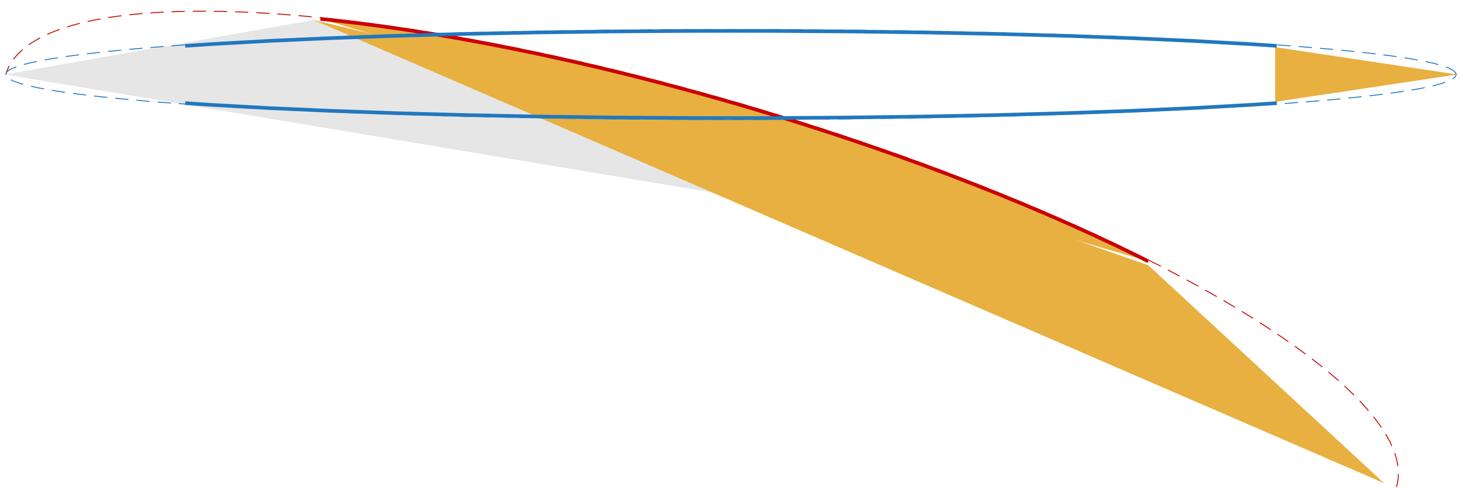
L. Cusssen *et al.*: NIM A **705**, 121 (2013)

reflective focusing optics

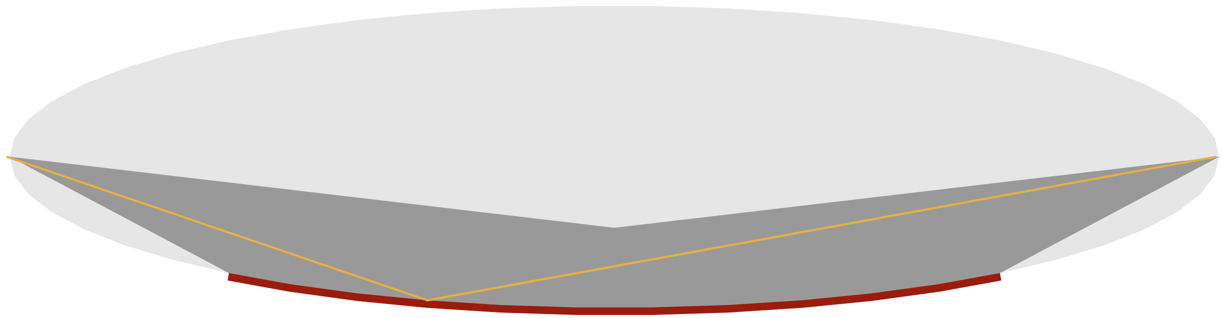


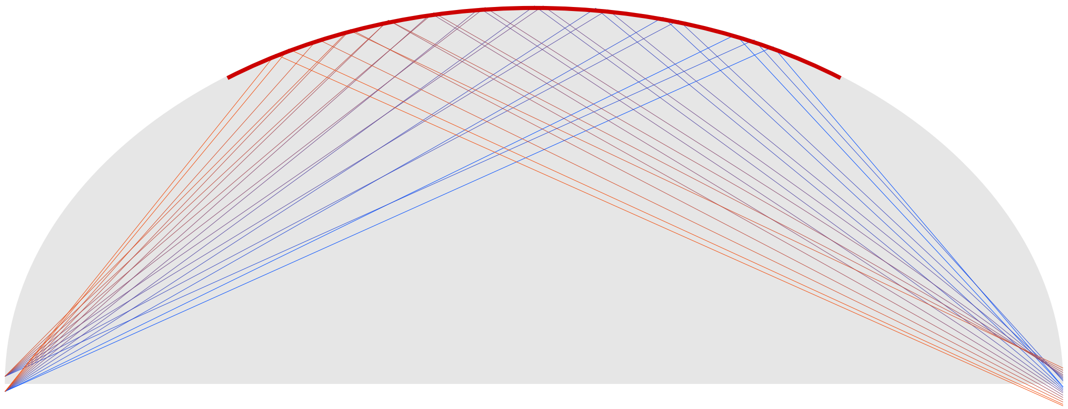
reflective focusing optics





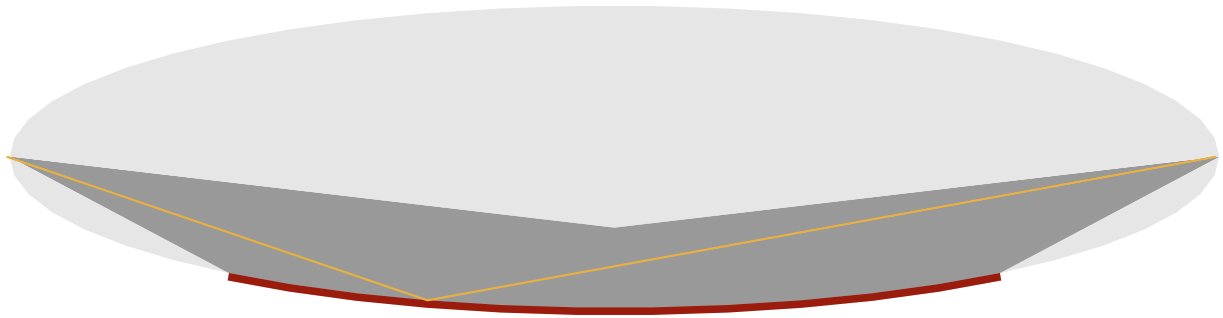
coma aberration

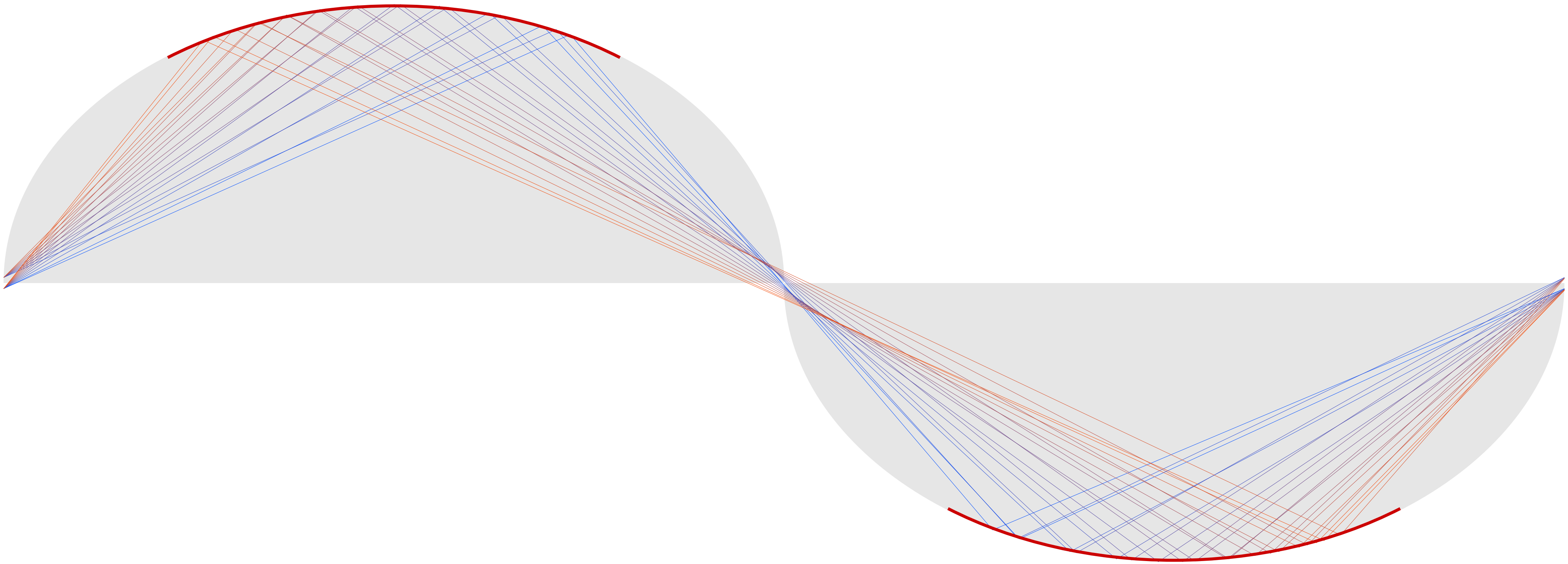




coma aberration

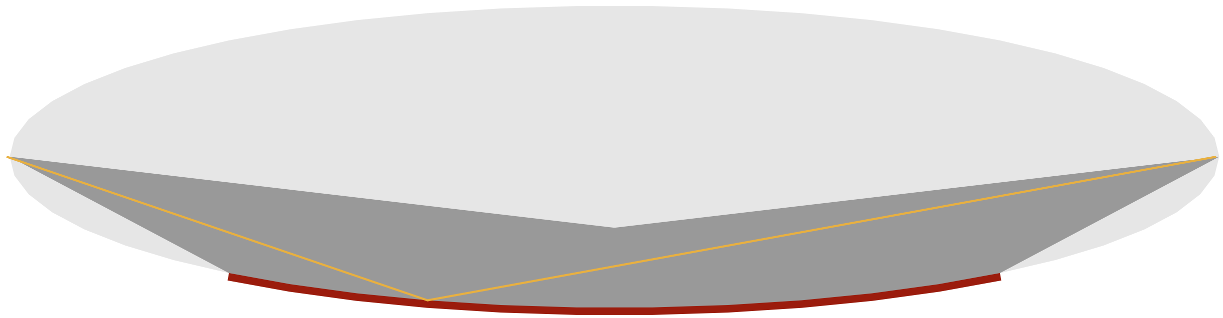
. . . and its correction

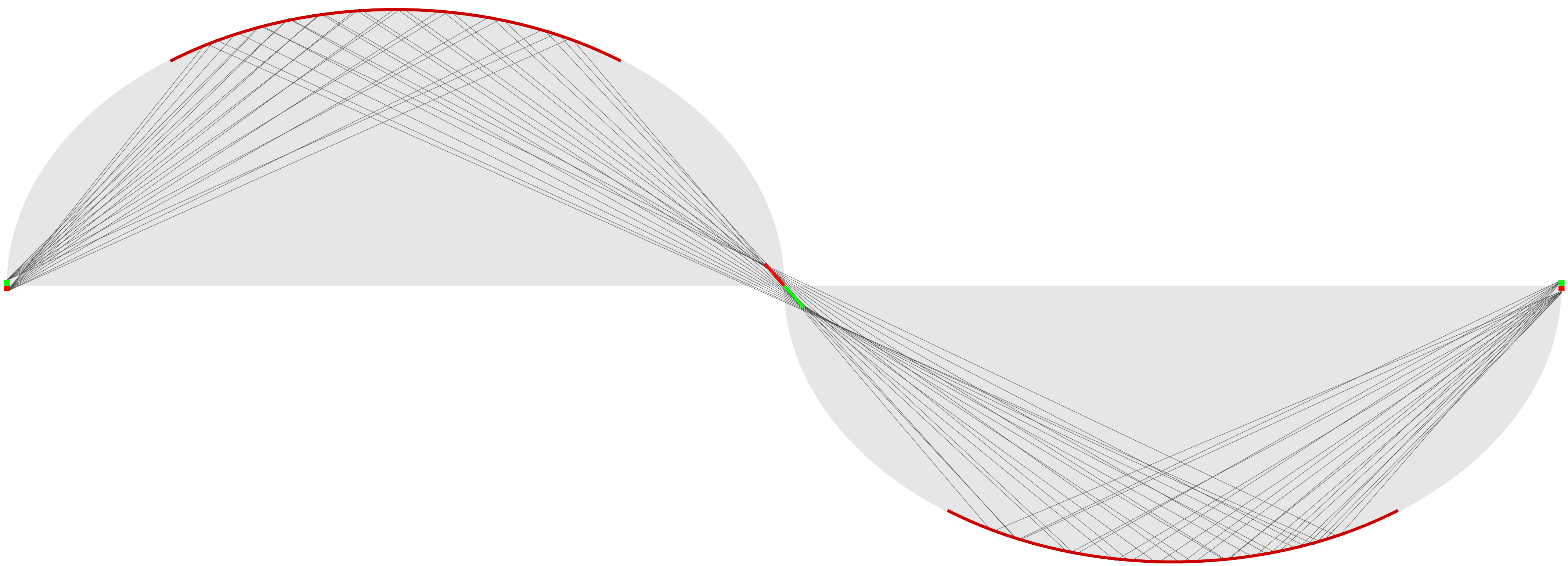




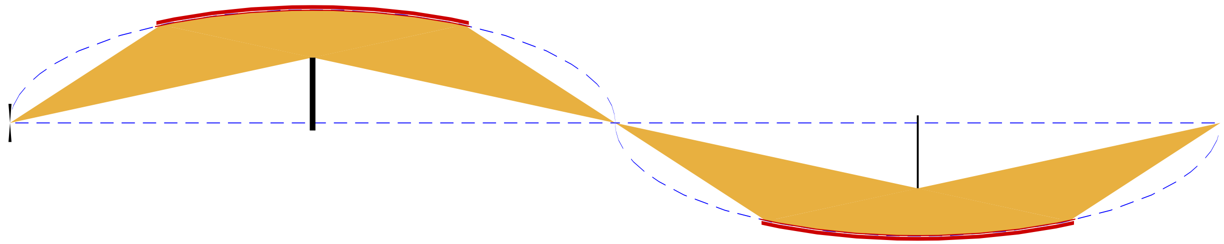
coma aberration

. . . and its correction





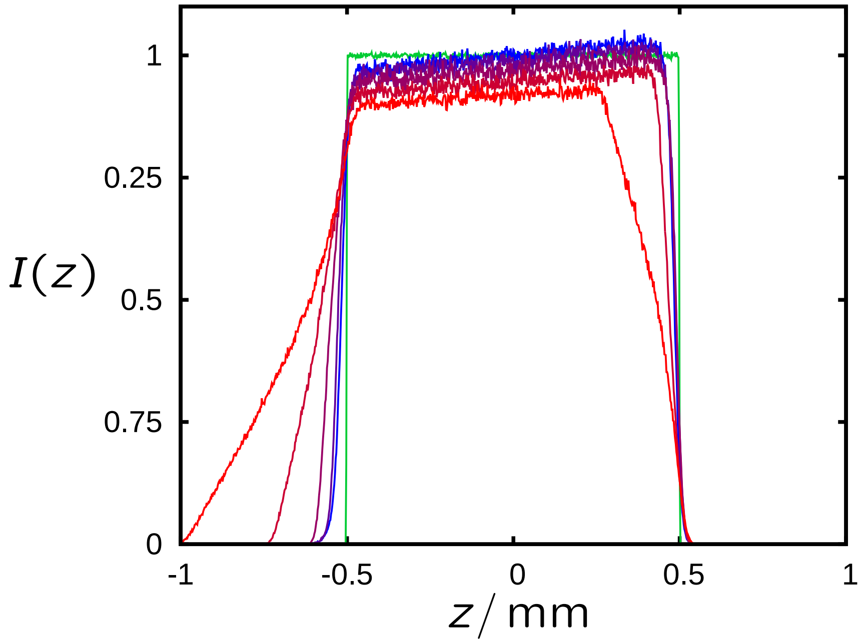
chromatic aberration



due to gravity → limits *length* × *wavelength* to ≈ 400 m Å

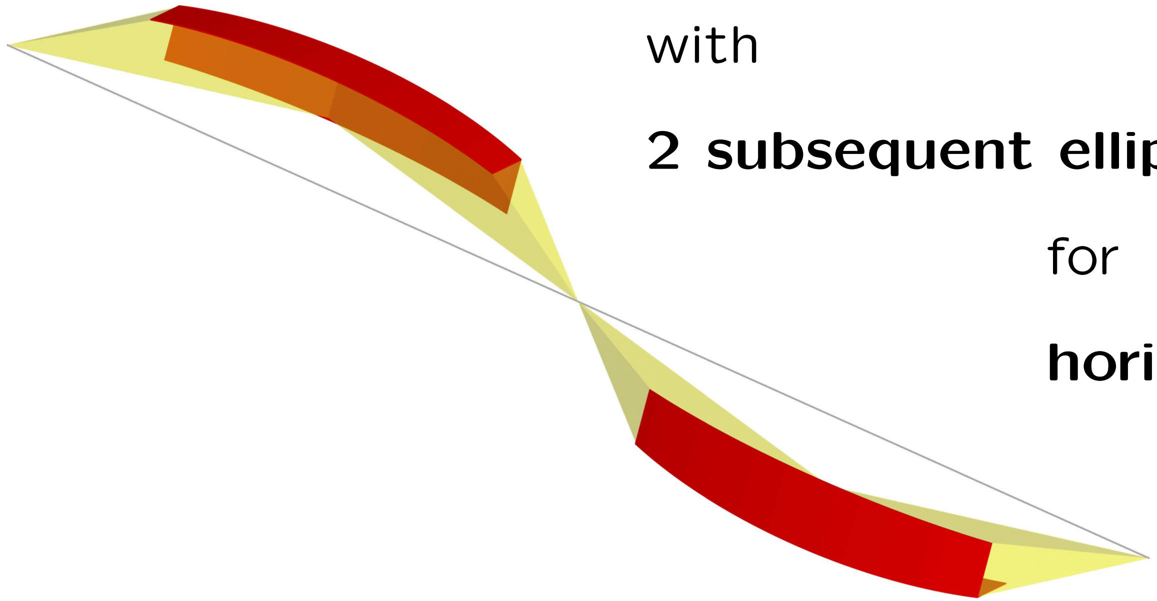
$I(z, \lambda)$ area normalised to 1

λ = 0 Å
3 Å
5 Å
7 Å
9 Å



due to λ-dependend reflectivity of coating → 4 reflections

$$m \approx 8 \frac{\Delta\theta/\mathrm{deg}}{\lambda_{\mathrm{min}}/\text{Å}}$$



Selene guide

point-to-point focusing

with

2 subsequent elliptical reflectors

for

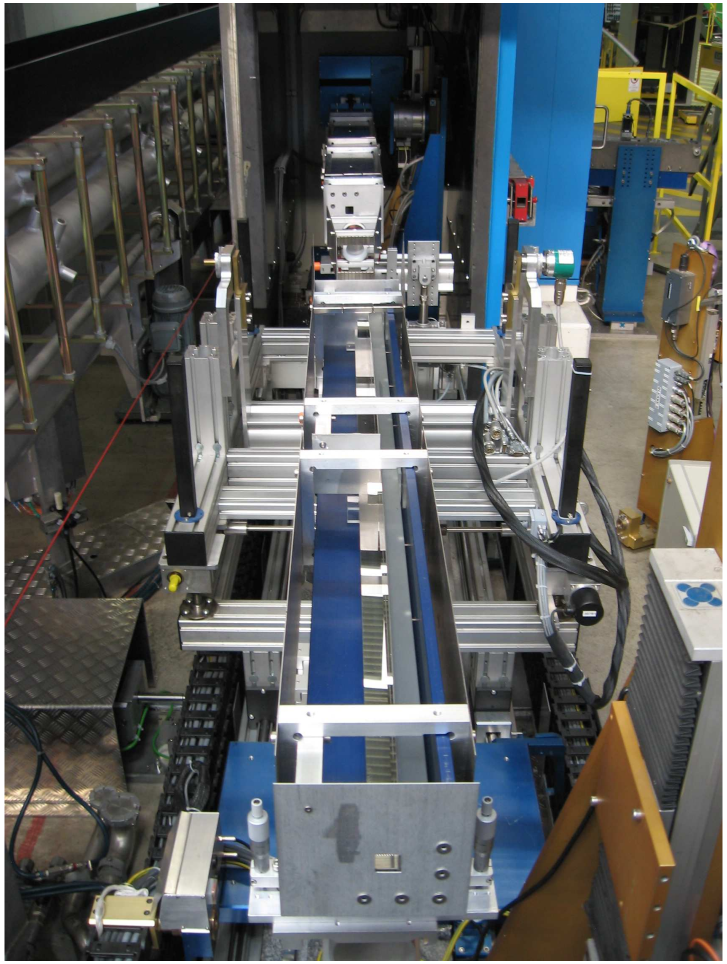
horizontal and vertical direction

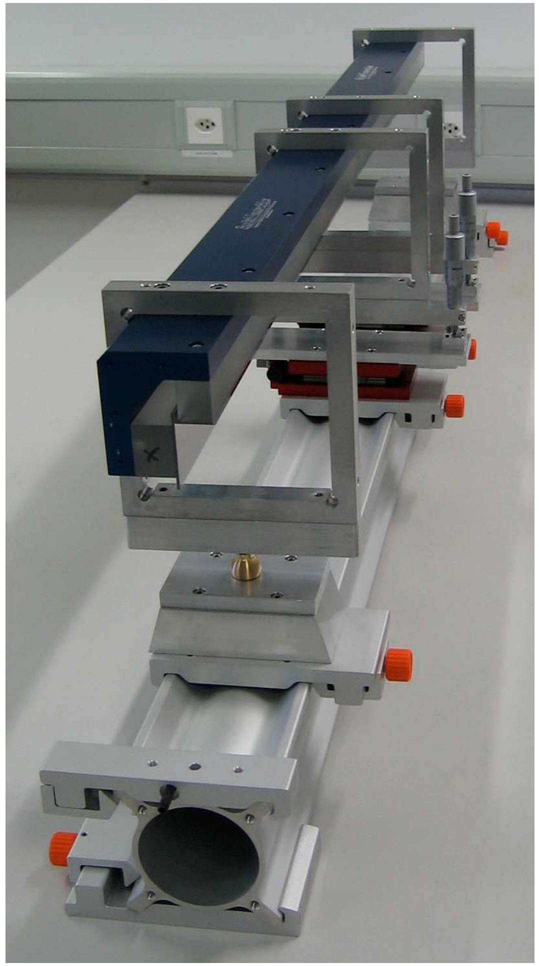
Selene picture
ceiling painting in the Ny Carlsberg Glyptotek, København

Selene guide

demonstrator

- total length $= 4\,\mathrm{m}$
- divergence $\approx 1.8^\circ \times 1.8^\circ$
- max spot size $\approx 2 \times 2\,\mathrm{mm}^2$
- wavelength $\geq 4\,\mathrm{\AA}$





overview

- Selene guide
- optics
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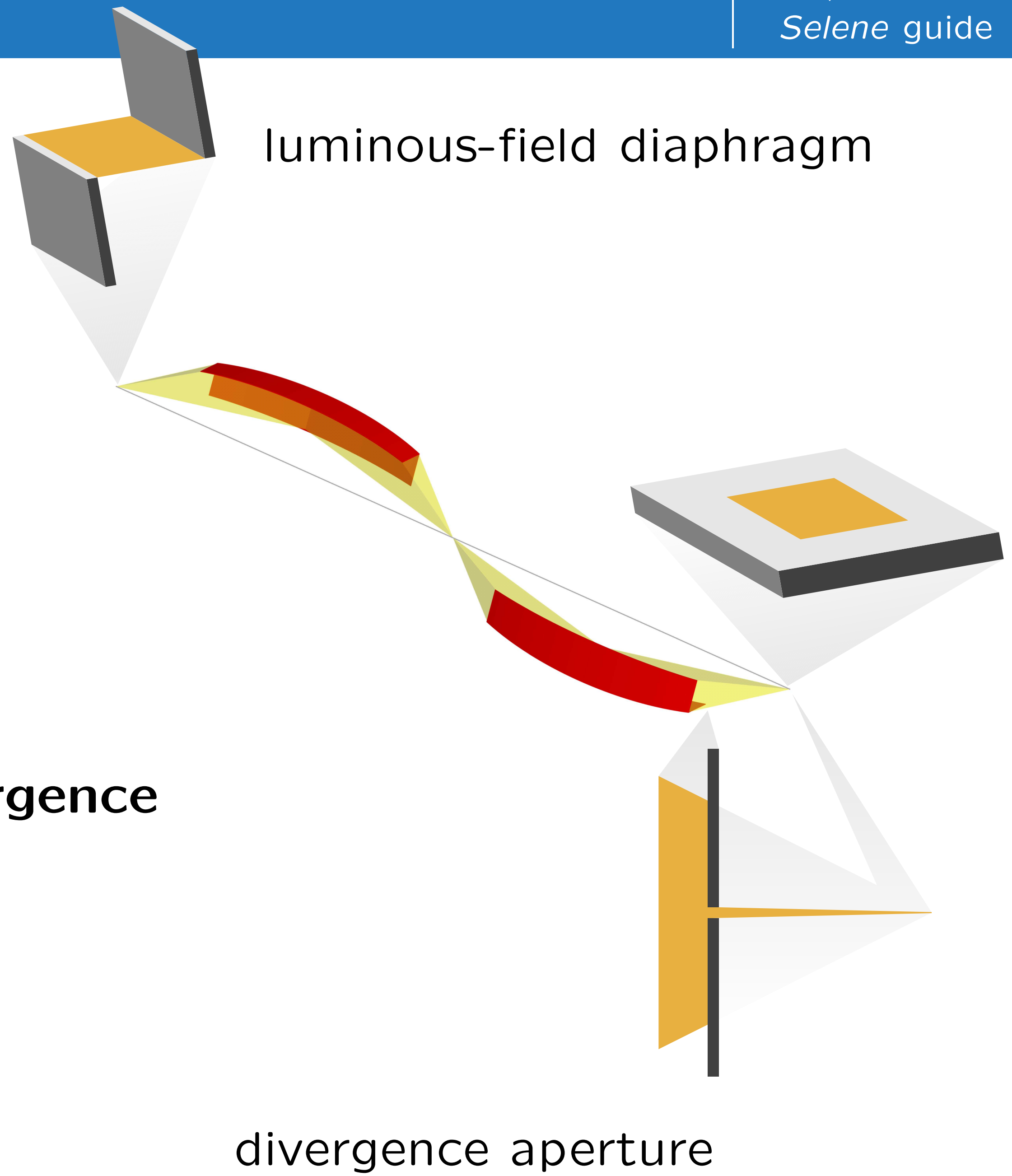
properties of a Selene guide

imaging system

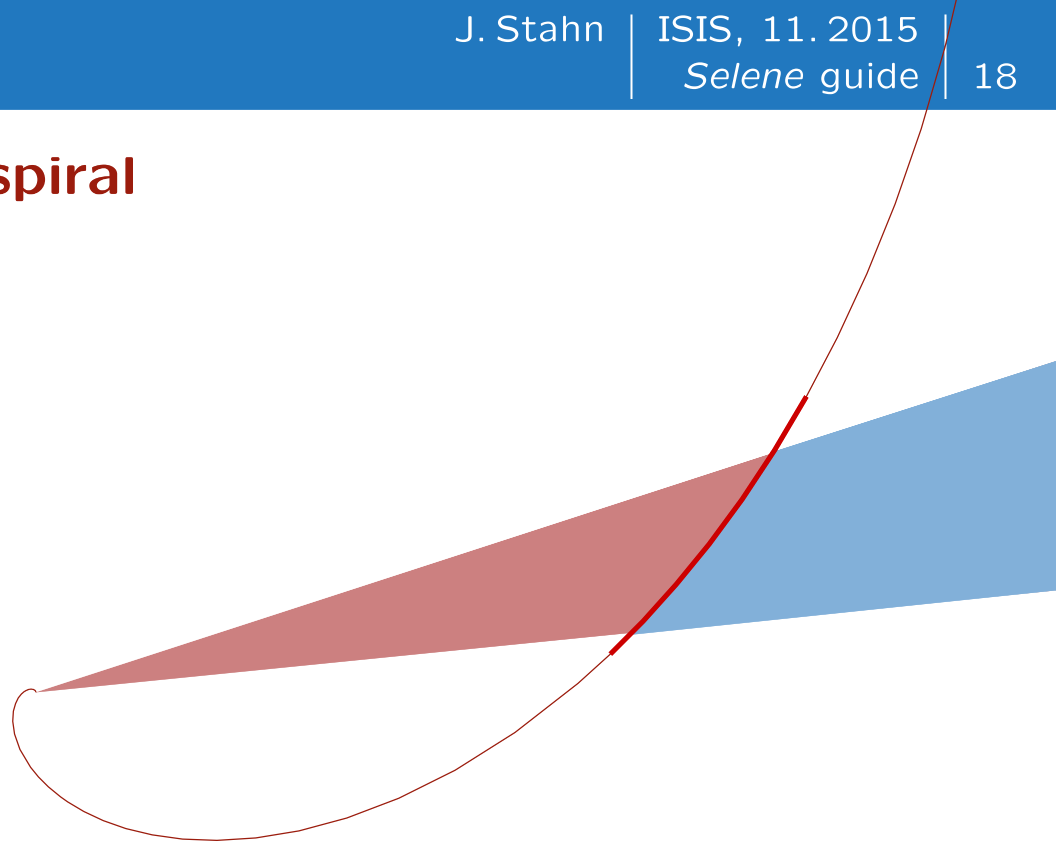
decoupling of spot-size and divergence



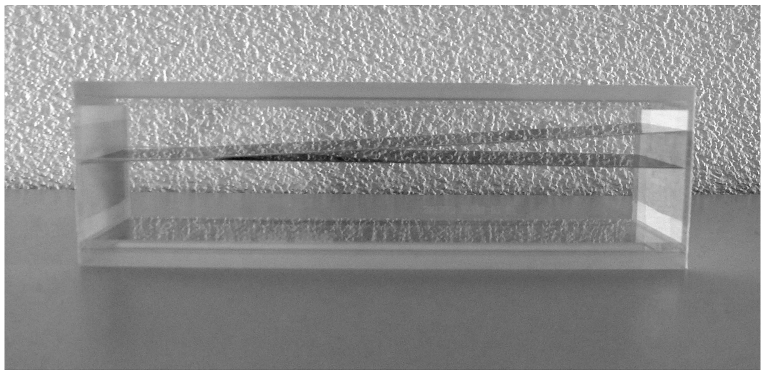
transmission filter using a logarithmic spiral

for convergent or divergent beams with small focus spot

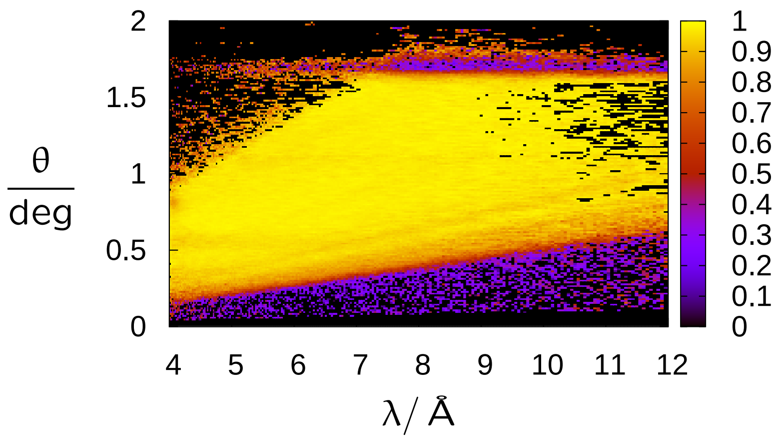
e.g. as analyser for any beam reflected on small or moderate-sized samples!



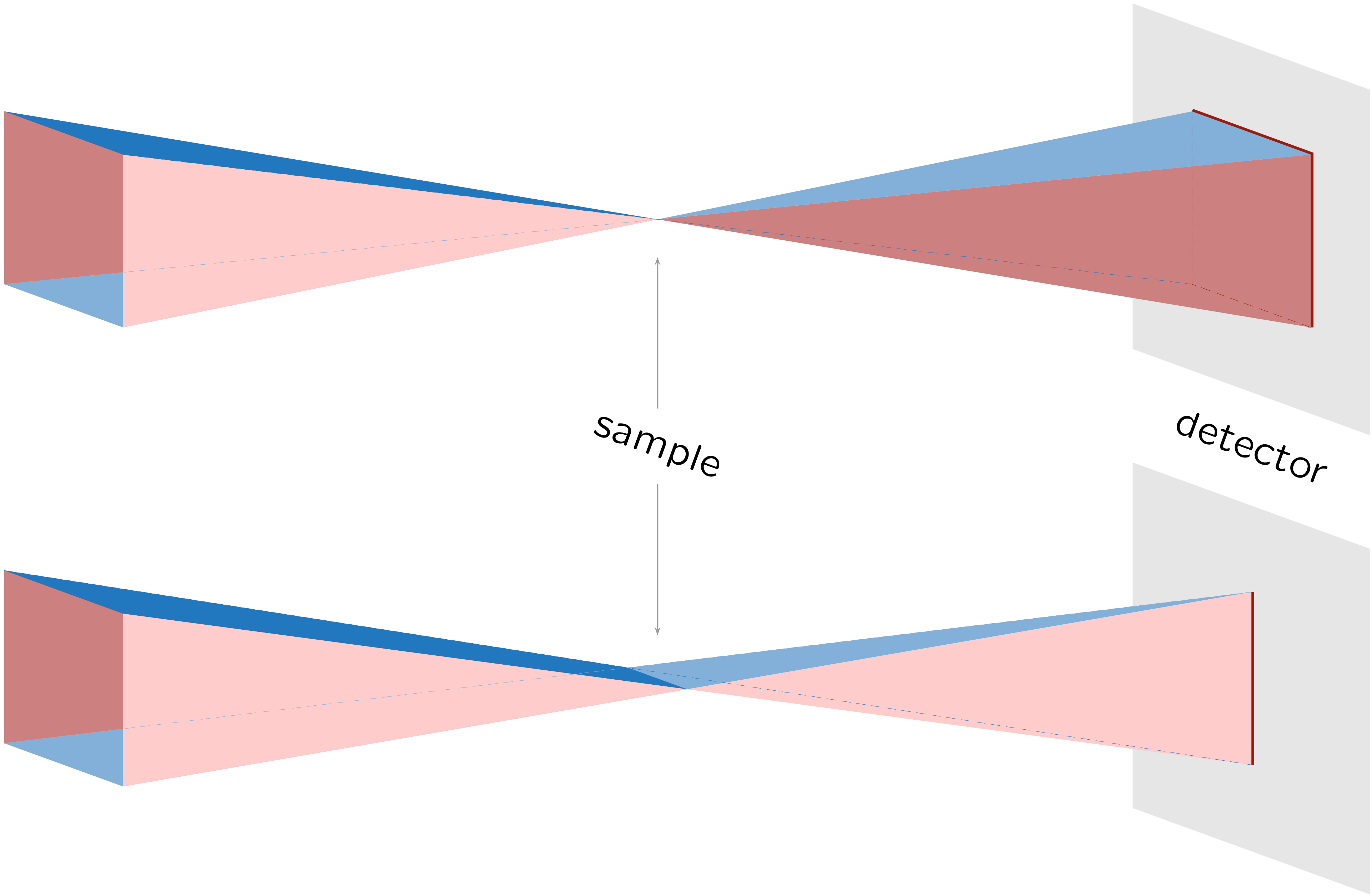
polariser, frame-overlap mirror



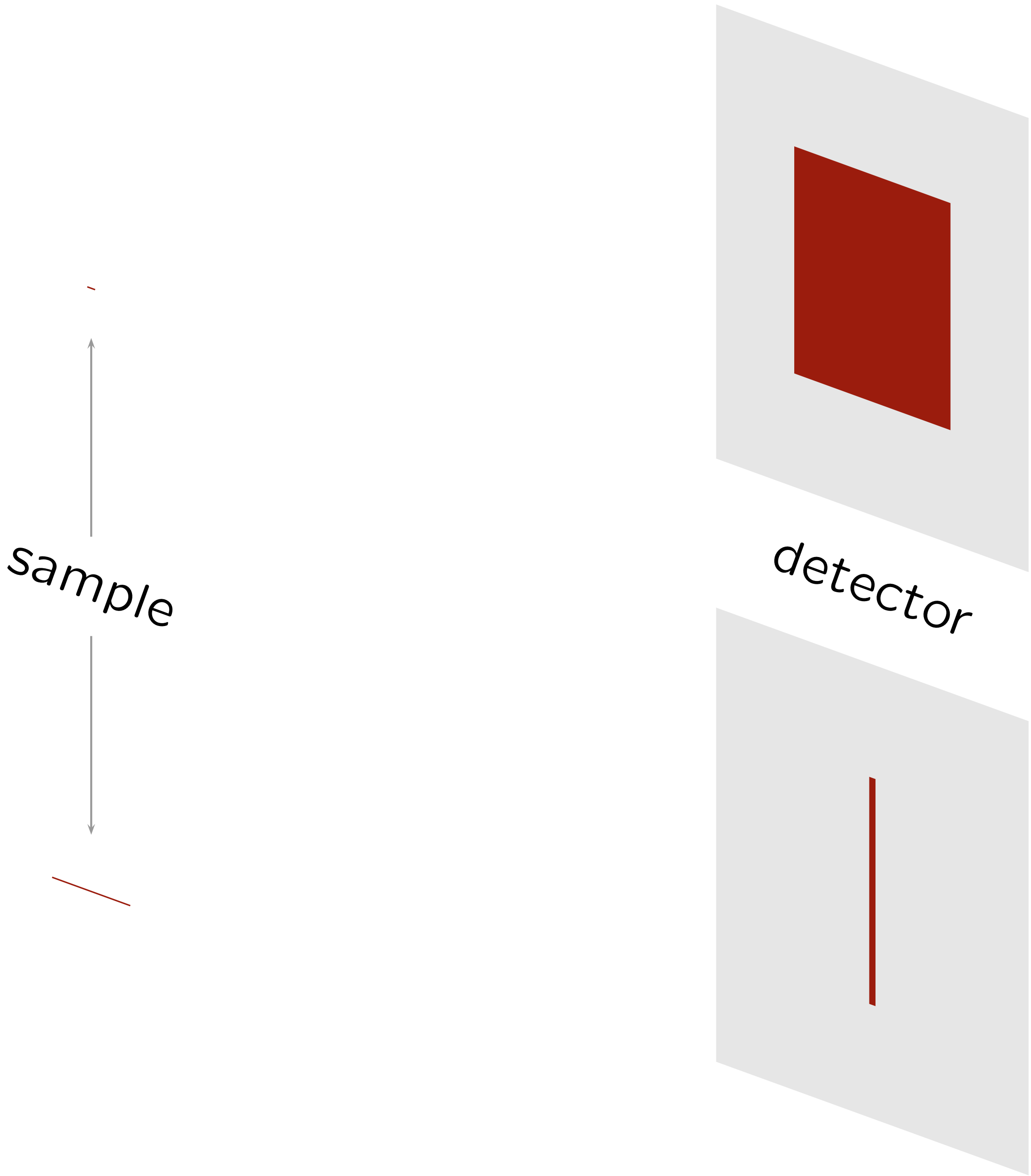
polarisation efficiency measured with a Fe/Si supermirror



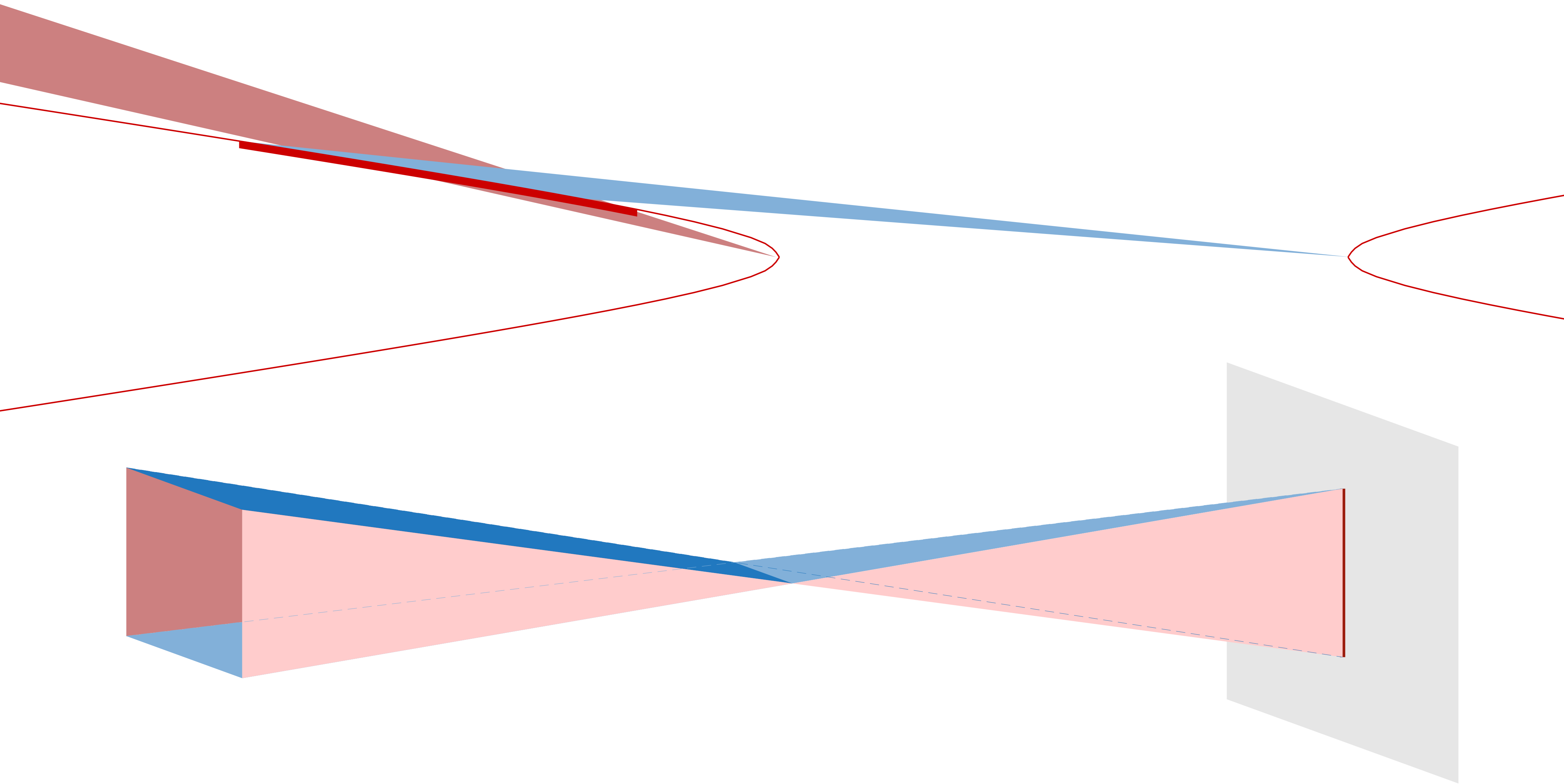
astigmatic focusing



astigmatic focusing



astigmatic focusing using a hyperbolic deflector



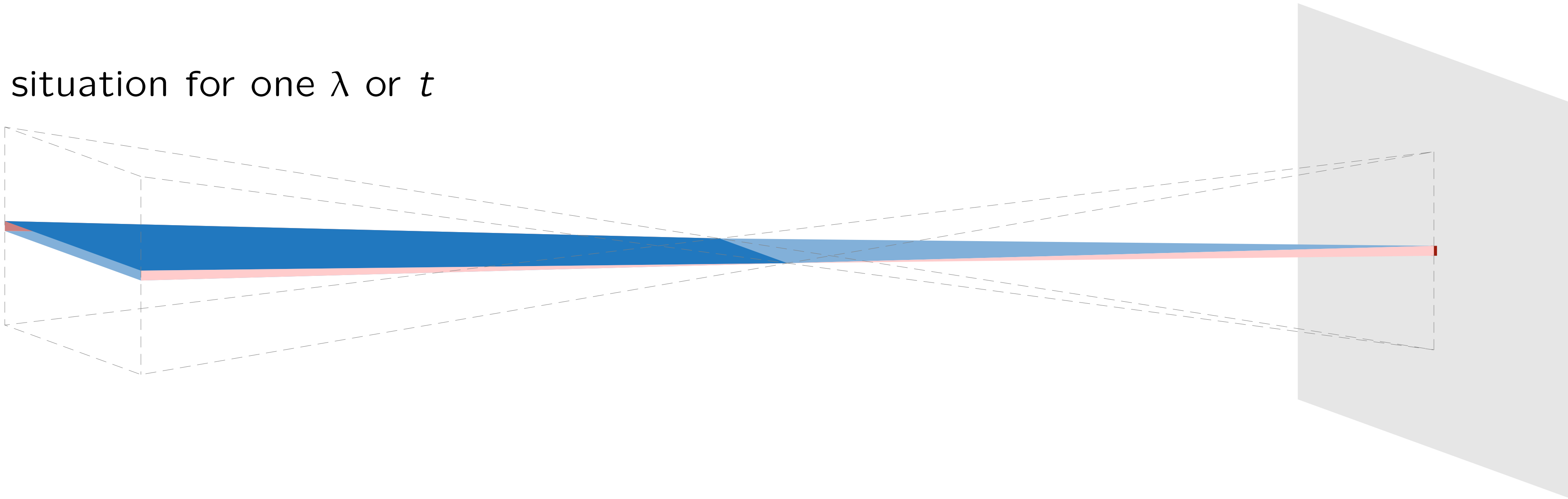
astigmatic focusing

in combination with TOF and
a chopper / scanning aperture / dispersive monochromator

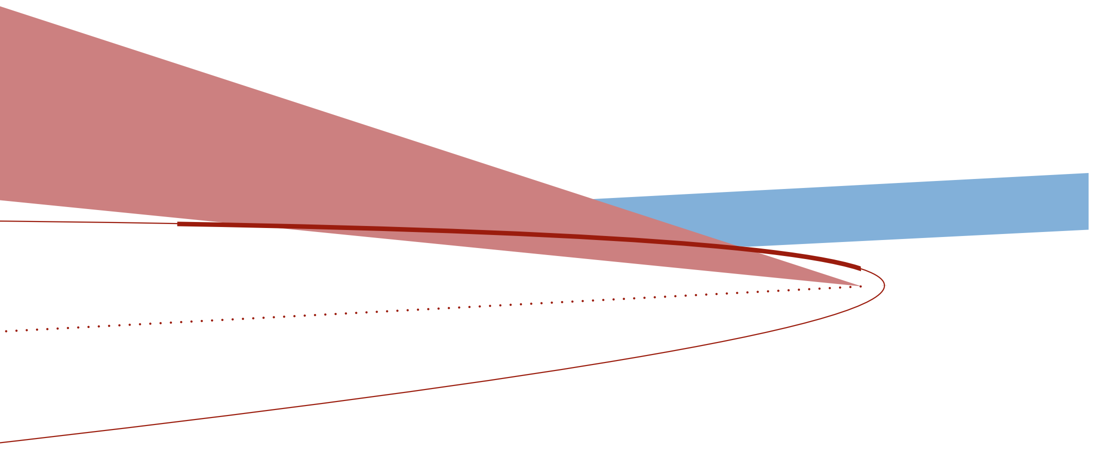
specular intensity concentrated on a small spot

⇒ focusing GISANS configuration

situation for one λ or t



condenser using a parabolic deflector to generate a parallel beam



parabola axis ⇒ beam direction

focal length ⇒ beam width

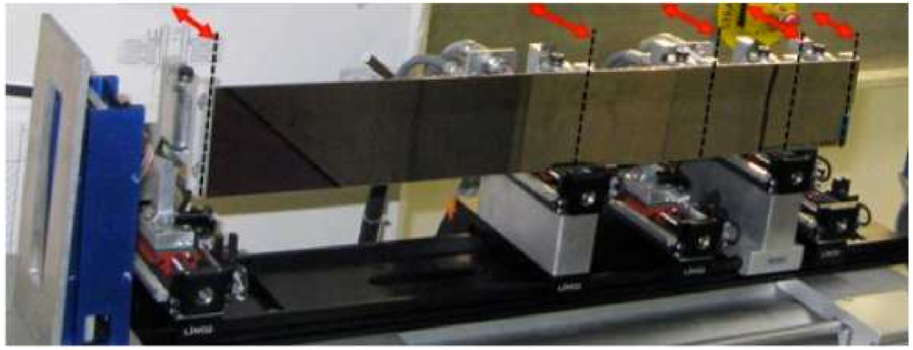
beam width & spot size ⇒ divergence

no collimator needed

tunable

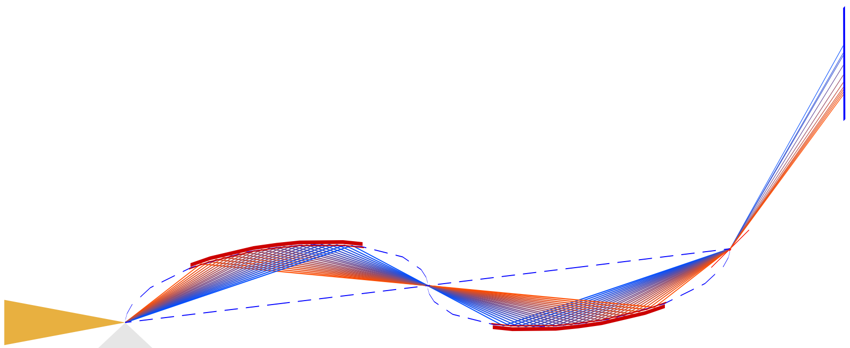
adaptive parabola (convex)
focal spot with 170 µm reached

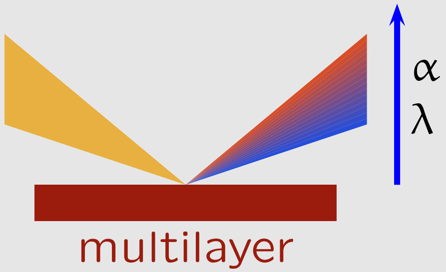
(PSI, early version)

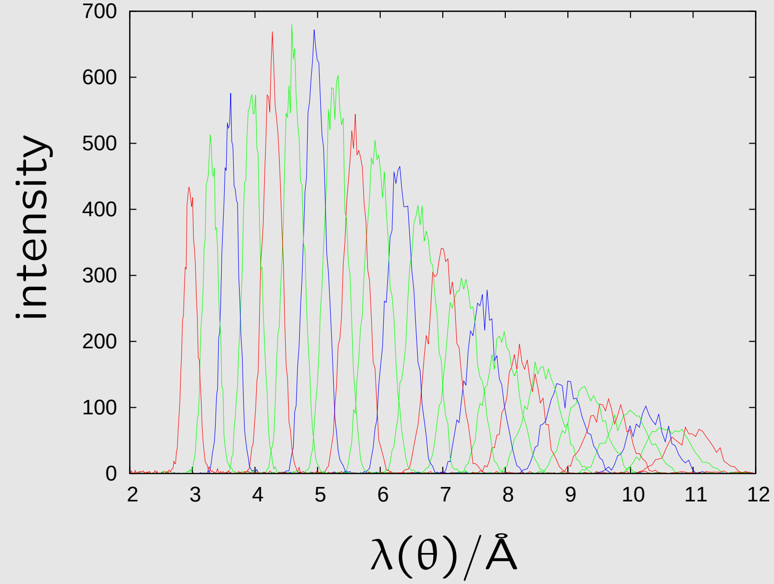


spectral analysis using a multilayer monochromator

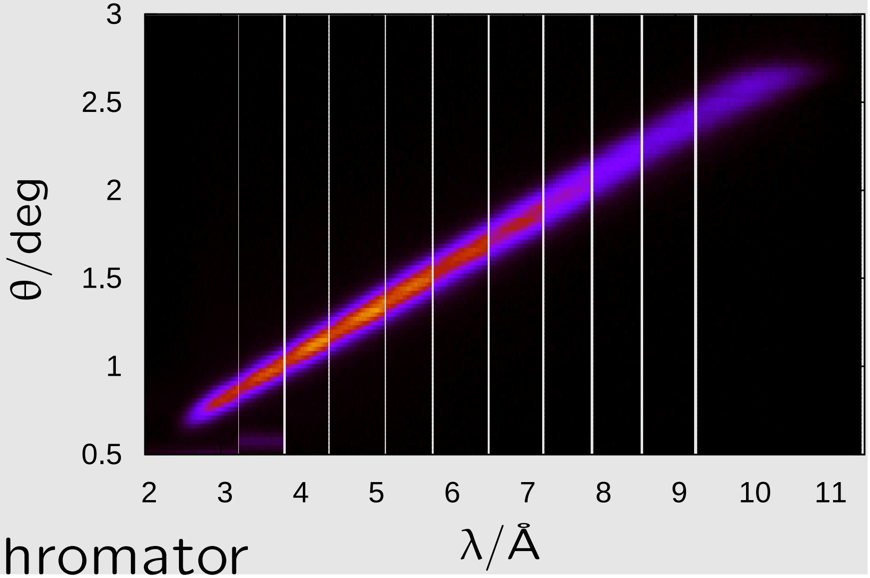
λ-θ encoding

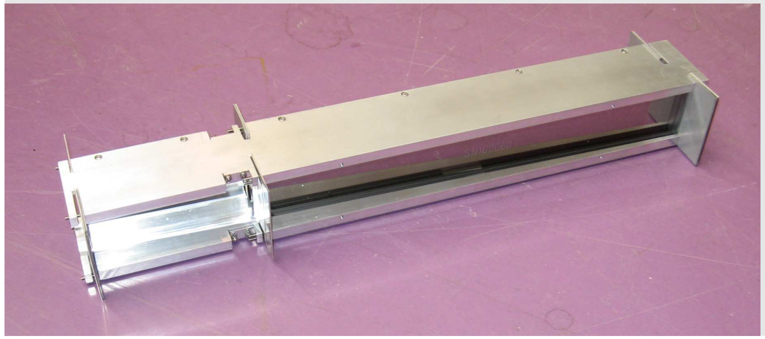






$I(\lambda, \theta)$ measured on Amor



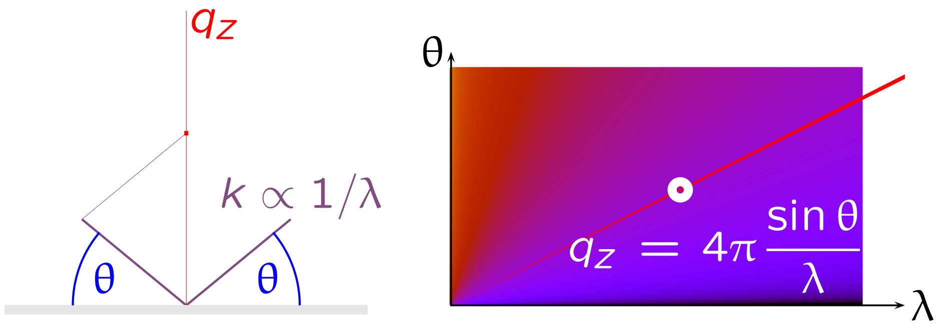


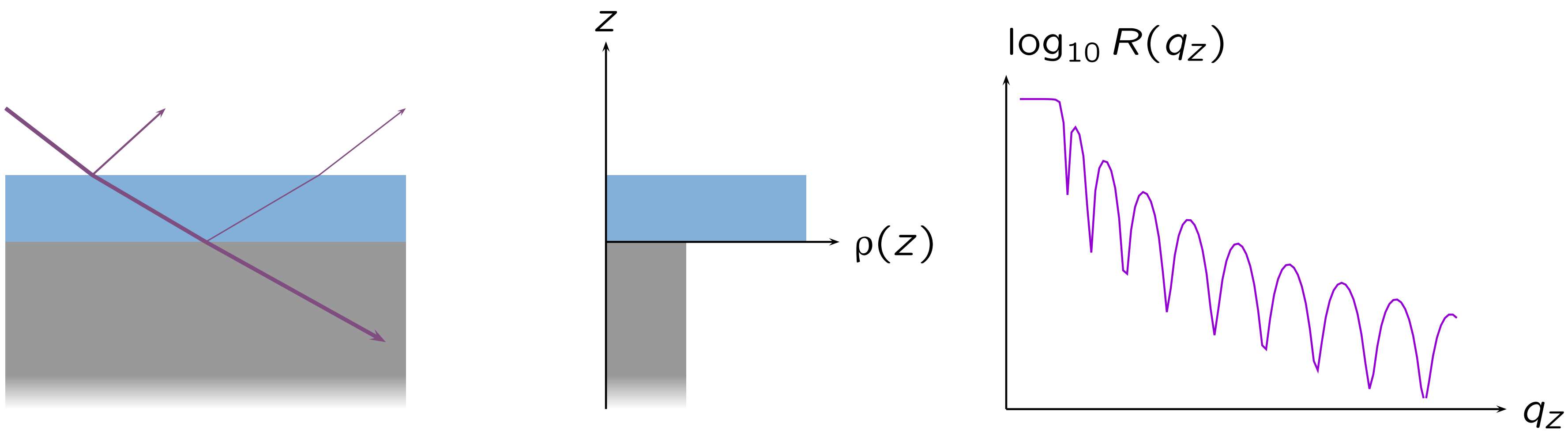
double ML monochromator

overview

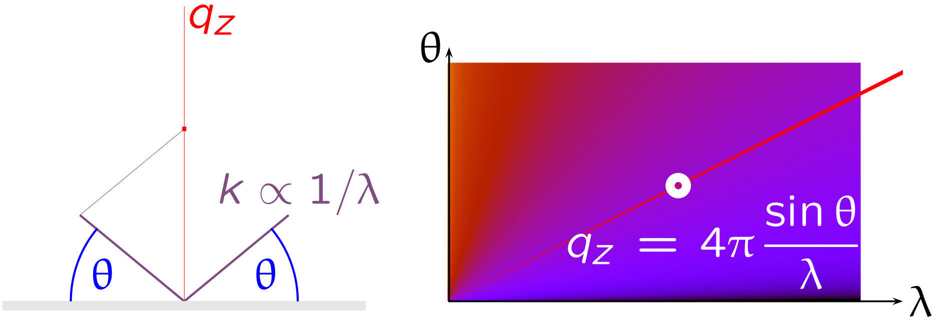
- Selene guide
- optics
- **reflectometry**
- experiments
- full guides

specular reflectometry

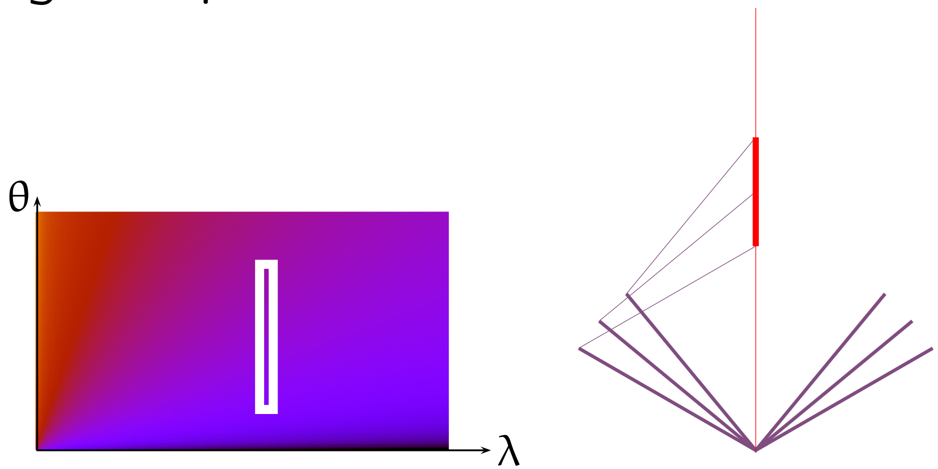




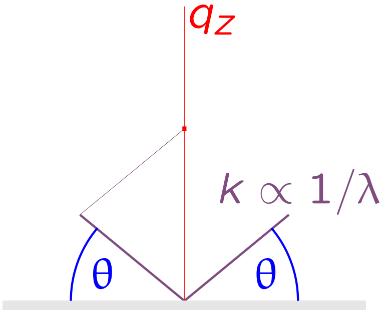
specular reflectometry

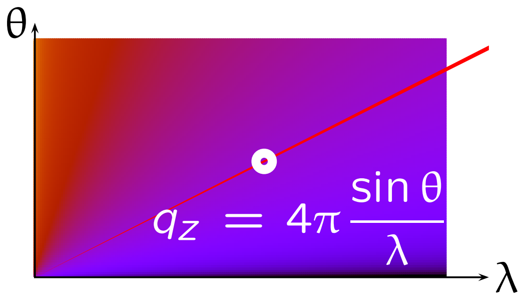


angle-dispersive

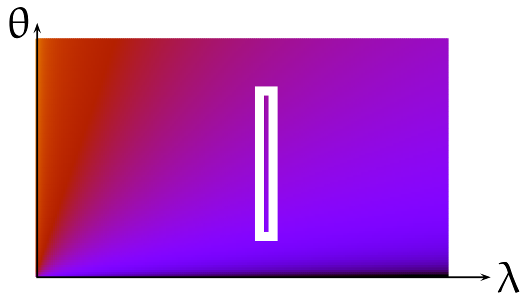


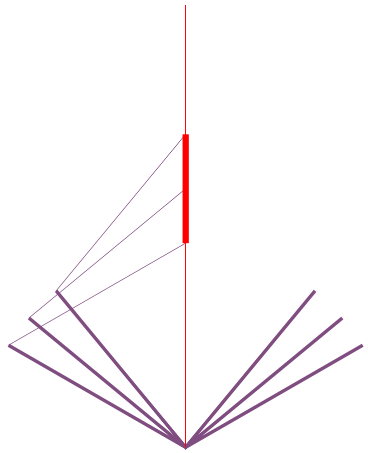
specular reflectometry



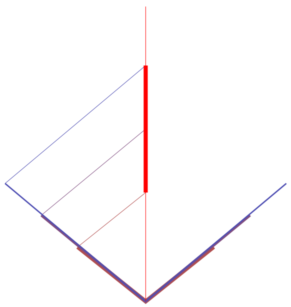


angle-dispersive

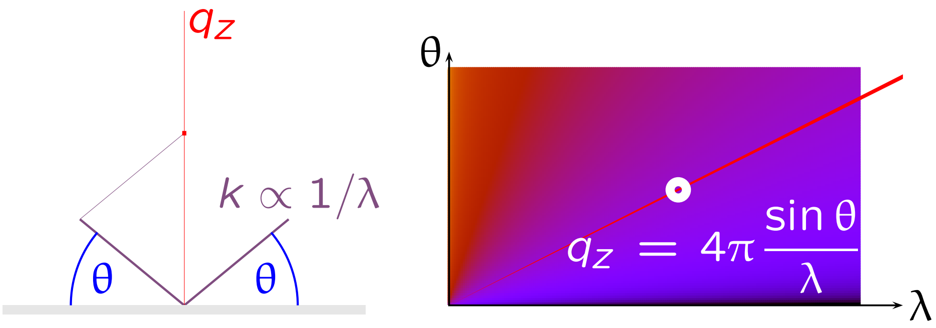




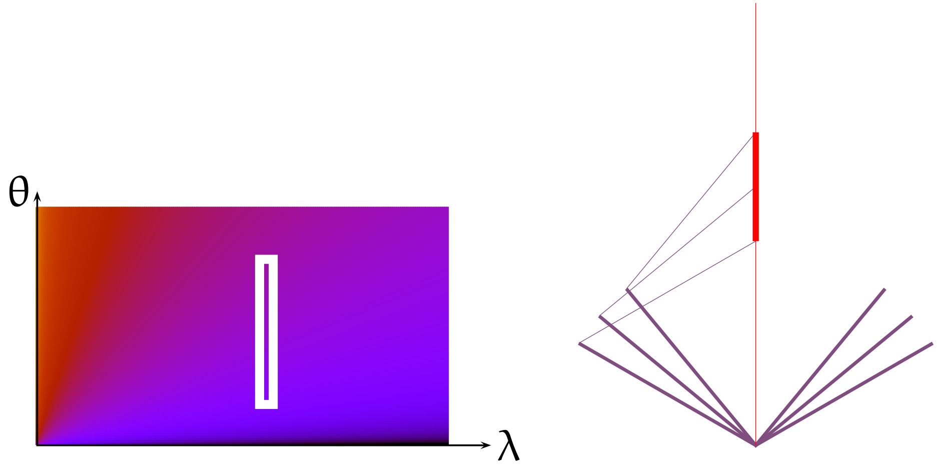
energy-dispersive



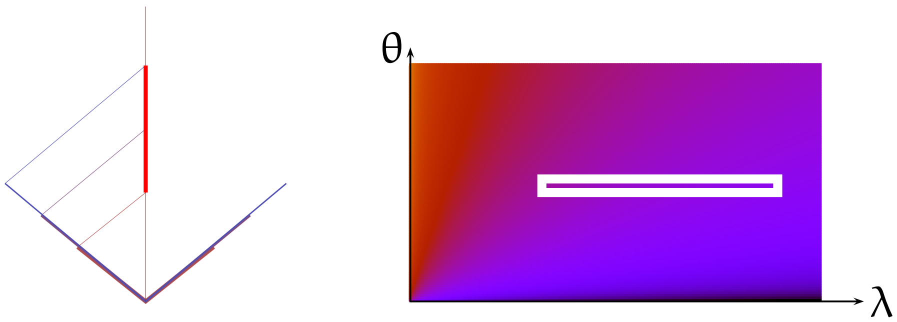
specular reflectometry

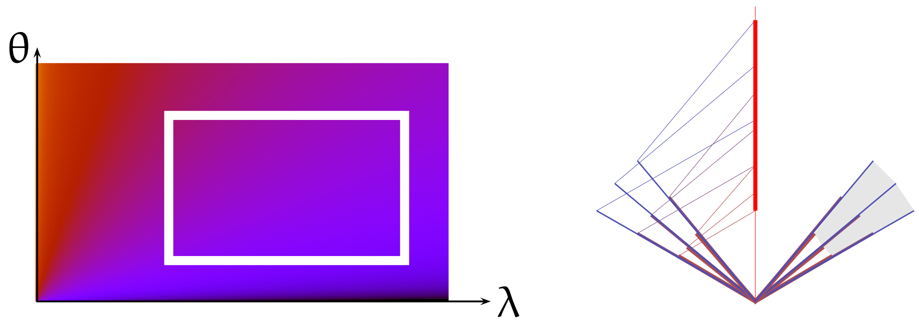


angle-dispersive



energy-dispersive





specular reflectometry

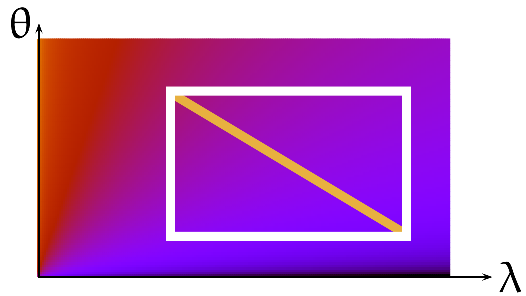
angle-dispersive

energy-dispersive

λ-θ-encoding

ML monochromator

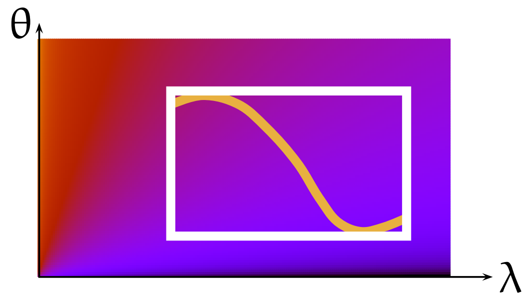
continous sources



scanning aperture

adaption to $R(q)$ and $I(\lambda)$

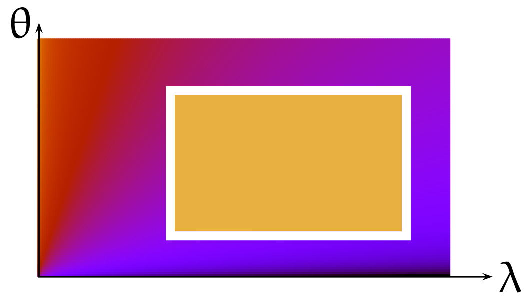
pulsed sources



high-intensity mode

no off-specular signal

pulsed sources



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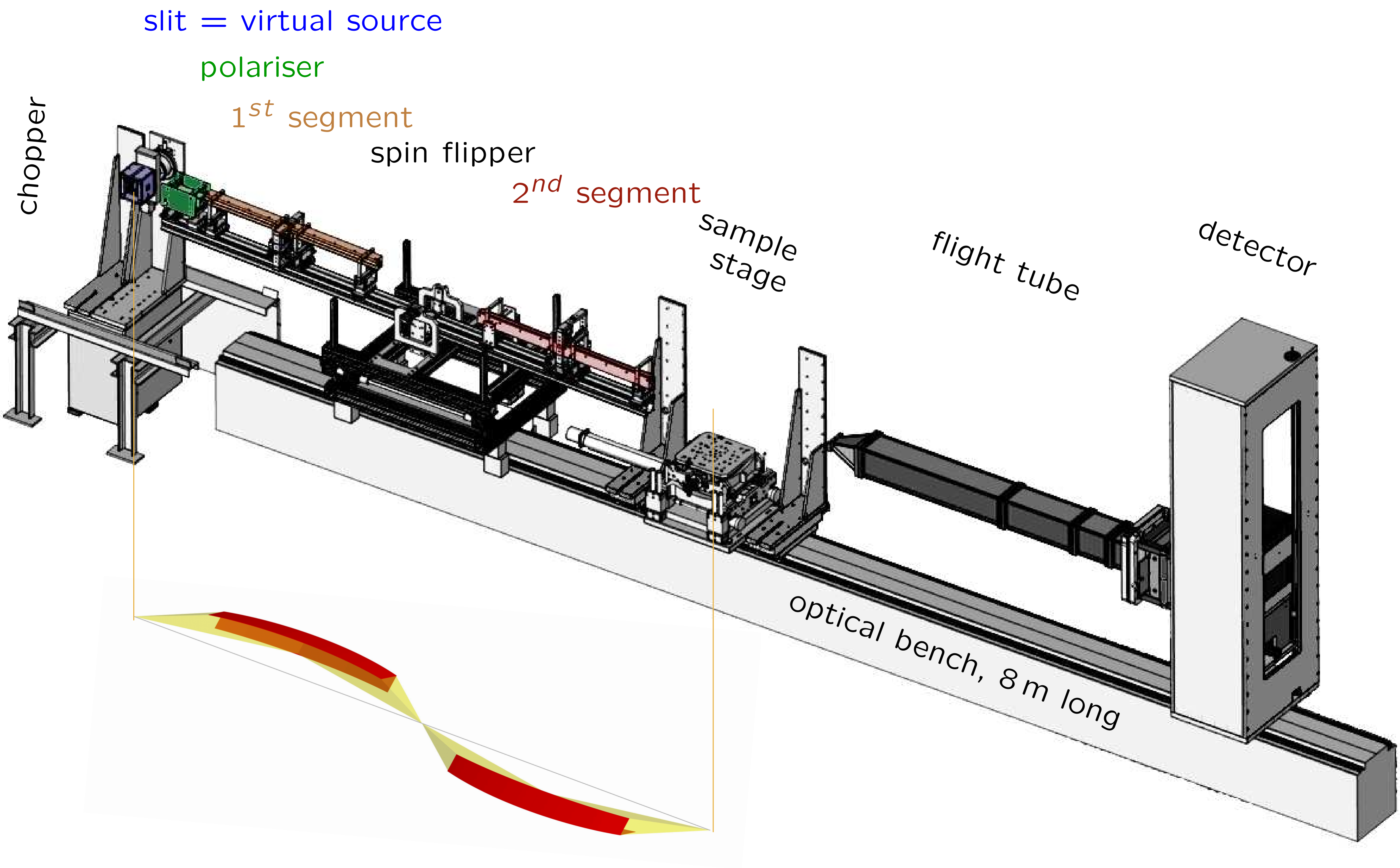
demonstrator on Amor @PSI



Li transport through thin silicon films

in-situ study in cooperation with E. Hüger, F. Strauß and H. Schmidt, TU Clausthal

technological motivation:

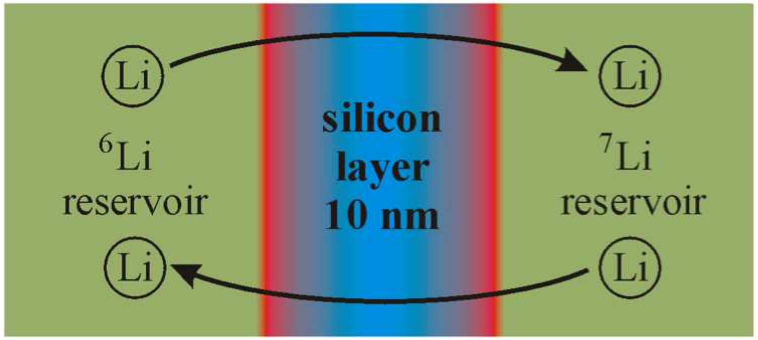
- Si layers can be used in Li batteries to prevent oxidation of the electrodes
- Si films can be used as elecrodes in Li batteries

⇒ How fast does Li difuse through thin amorphos Si films?

⇒ What is the solubility of Li in Si?

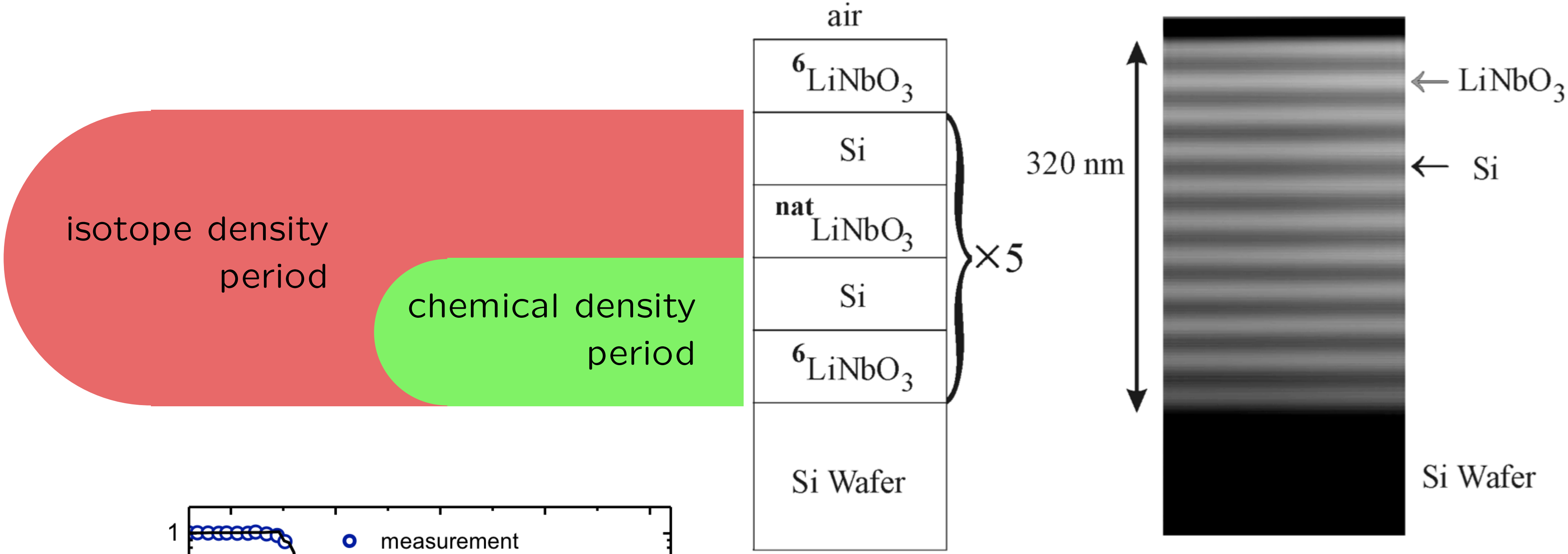
⇒ What is the influence of the Si:O:Li interface layer?

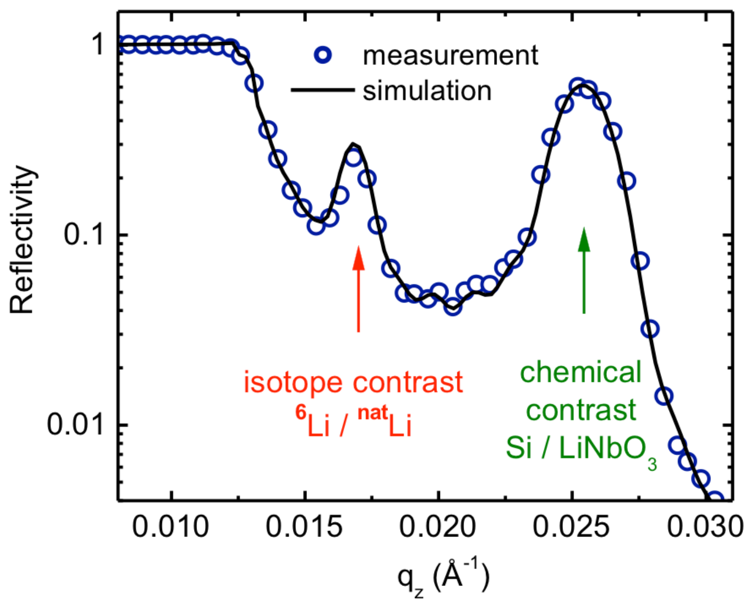
E. Hüger, *et al.*, Nano Letters 13 (2013) 1237.

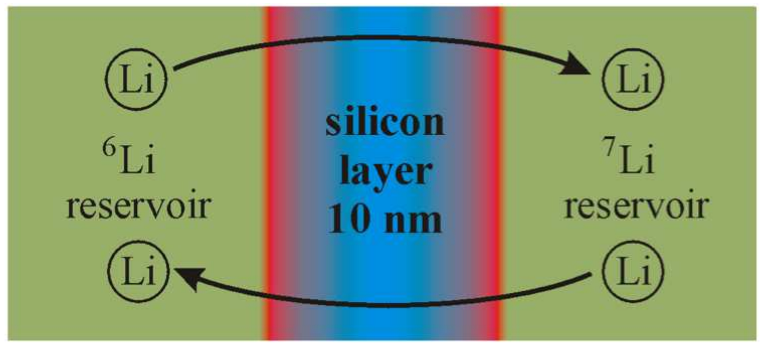


Li transport | the sample

multilayer structure using the different densities of ^{6}Li and ^{7}Li



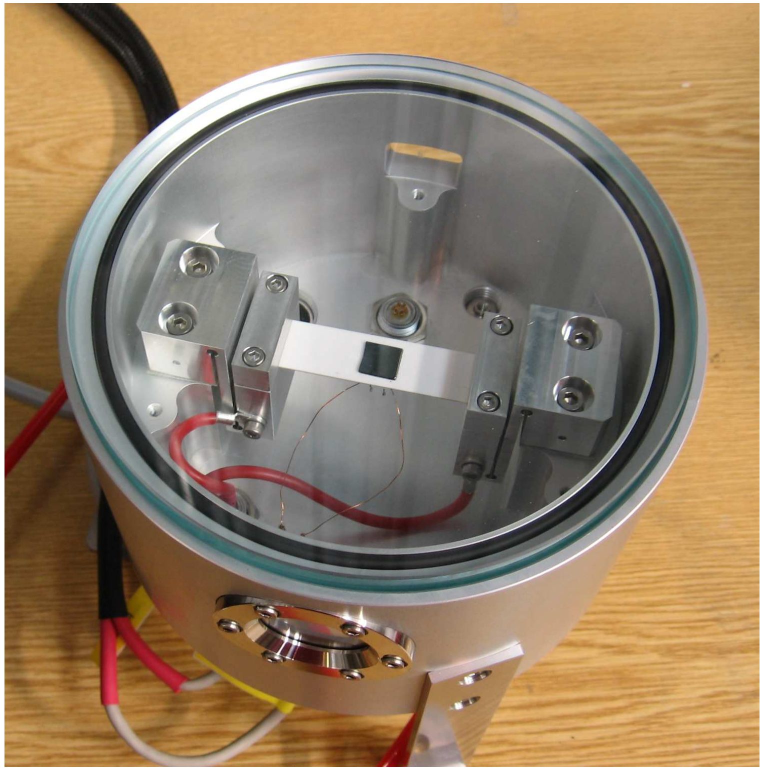




Li transport | experimental set-up

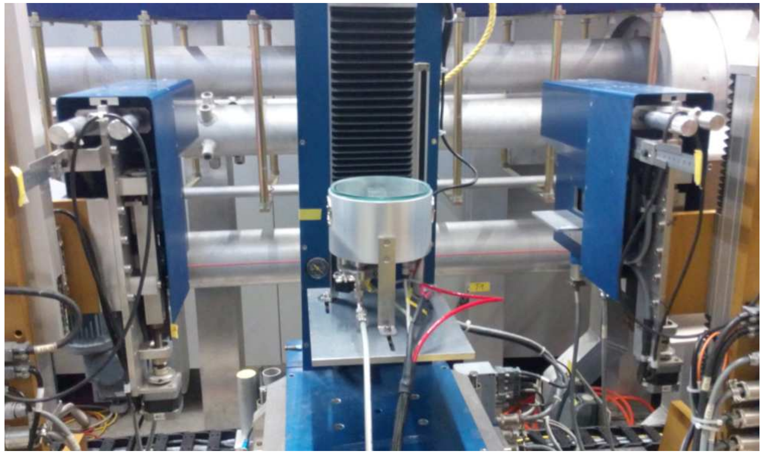
in-situ furnace

- $T \in [25^\circ\mathrm{C}, 500^\circ\mathrm{C}]$ here: $T = 240^\circ\mathrm{C}$
- $\dot{T} = 50\,\mathrm{Ks}^{-1}$ for heating
- $\dot{T} = 12\,\mathrm{Ks}^{-1}$ for cooling



time-structure

- interval
  (measurements at RT in between annealing periods)
- continous measurement

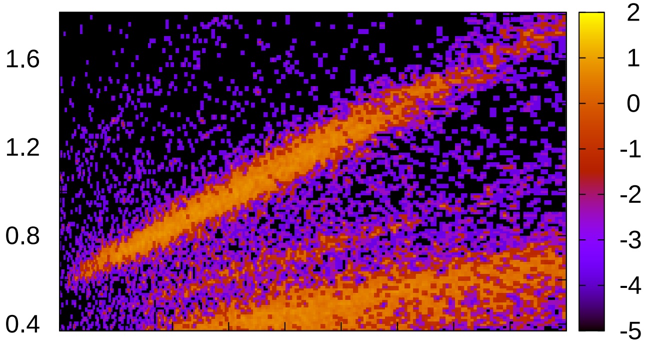


experiments

Li transport | measurements

raw data

$\frac{\theta}{\text{deg}}$



$\log_{10} I(\lambda, \theta)$

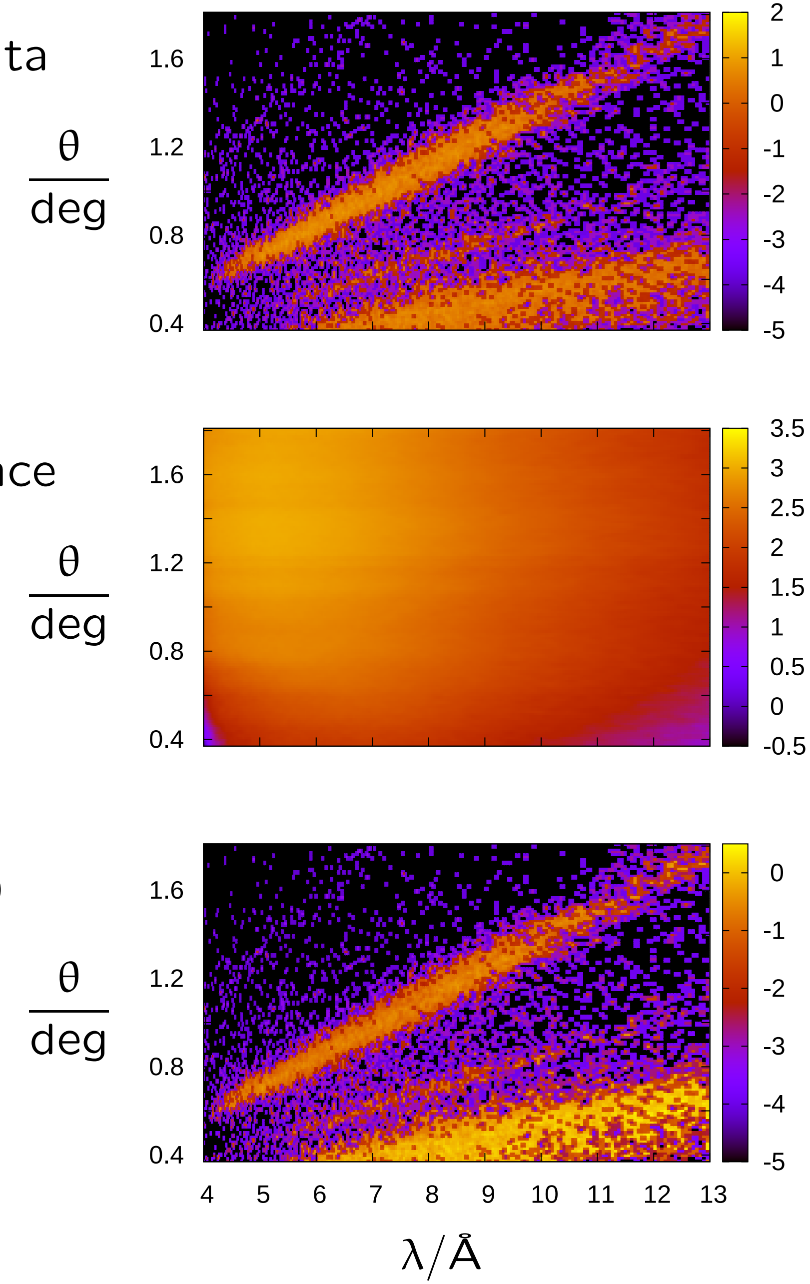
$^{6}LiNbO_3/Si/^{7}LiNbO_3/Si$ multilayer
counting time 1.5 min

Li transport | measurements & data reduction

raw data

reference

$R(\lambda, \theta)$



$\log_{10} I(\lambda, \theta)$

$\log_{10} I^0(\lambda, \theta)$

$\log_{10} R(\lambda, \theta)$

$^6LiNbO_3/Si/^7LiNbO_3/Si$ multilayer
counting time 1.5 min

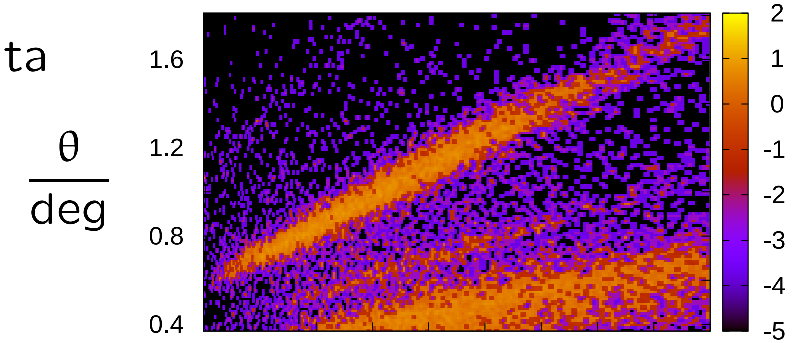
$m = 5$ supermirror

quotient

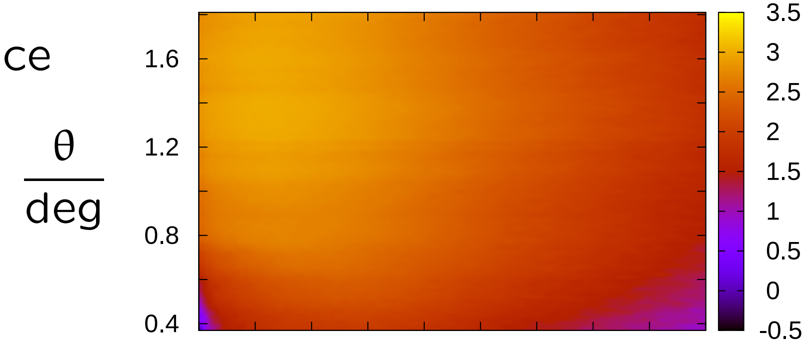
Li transport | measurements & data reduction

$^6LiNbO_3/Si/^7LiNbO_3/Si$ multilayer
counting time 1.5 min

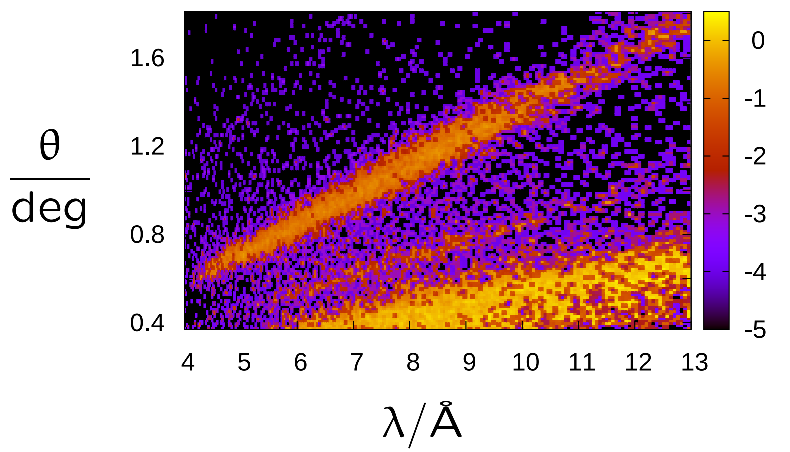
raw data



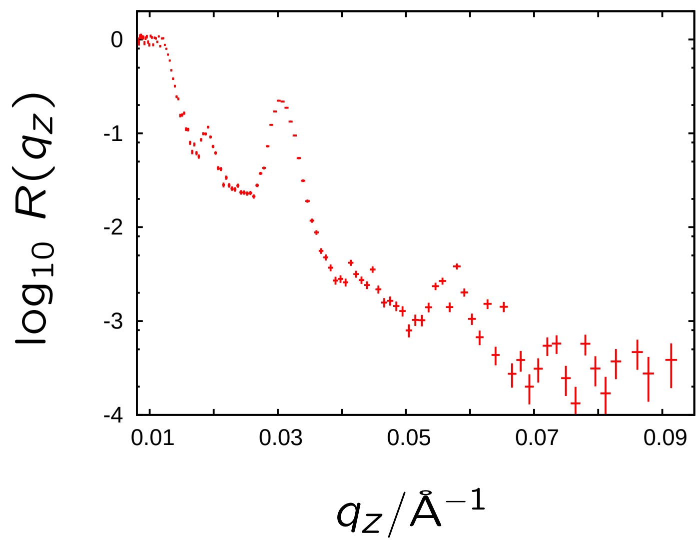
reference



$R(\lambda, \theta)$

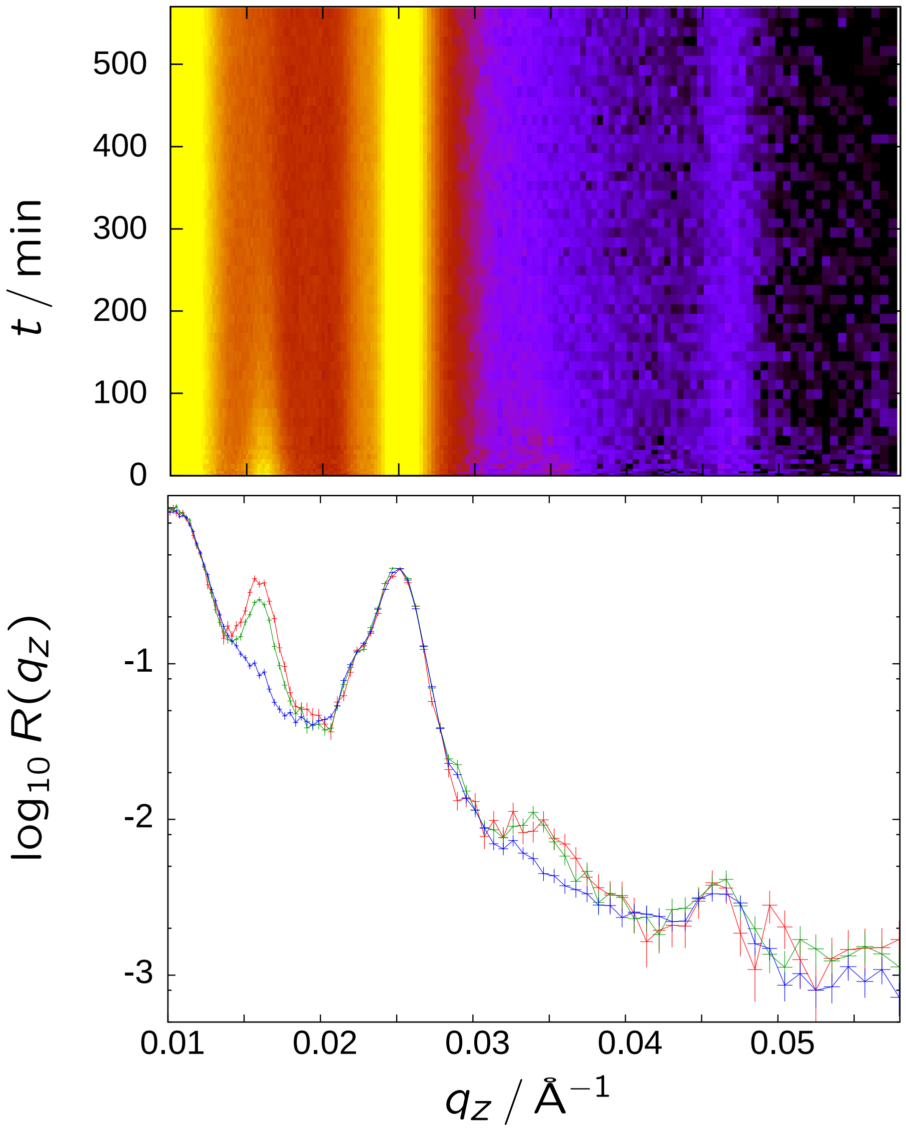


averaging along q_z



Li transport | reflectivity curves

recent measurements on a $^{6}Li_3NbO_4/Si/^{7}Li_3NbO_4/Si$ multilayer



anealing at $T = 240^\circ$C

ml is chemically stable

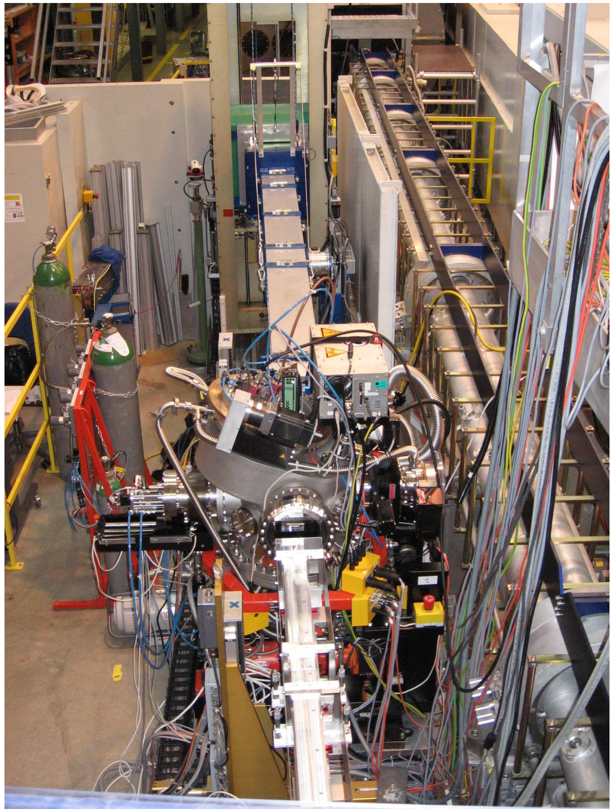
Li contrast is vanishing

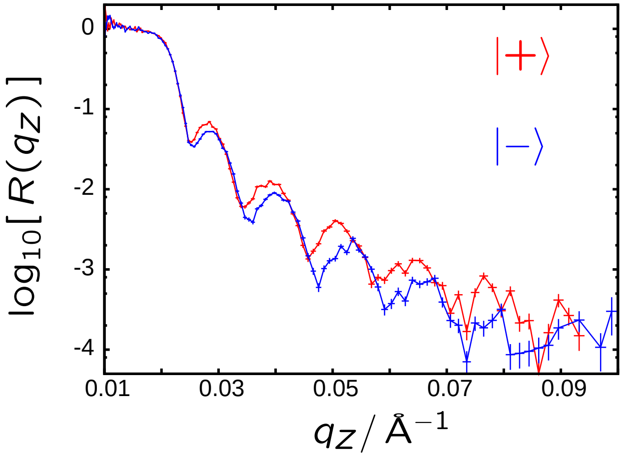
t = 0→ 3 min
18→ 24 min
558→570 min

quasi in-situ reflectmetry during sample growth

sample: Si/Cu(50 nm)/Fe(0 . . . 20 layers)

by B. Wiedemann, S. Mayr, W. Kreuzpaintner, TU Munich

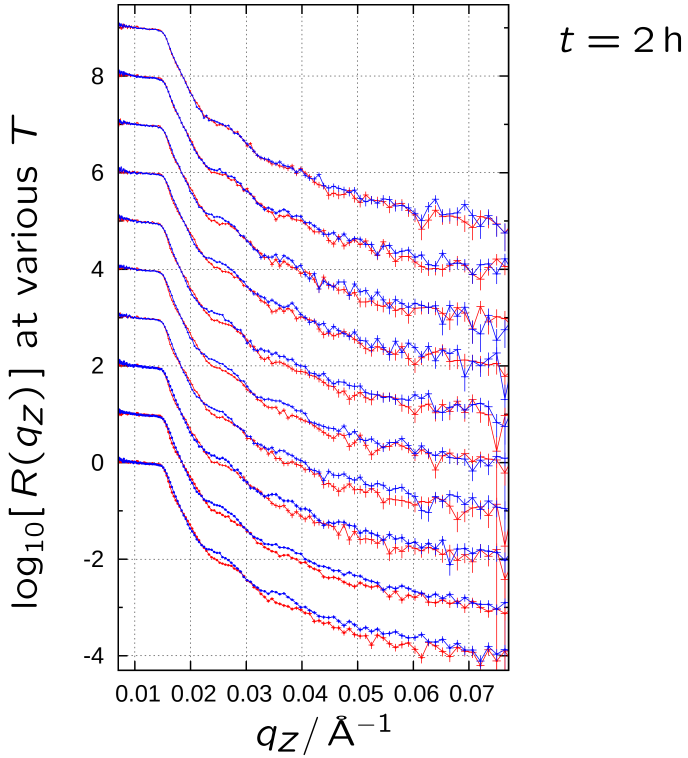




counting time per spin state = 10 min

further projects

small multiferroic samples with electrical contacts



in-operando studies on electrochemical cells

very nice data

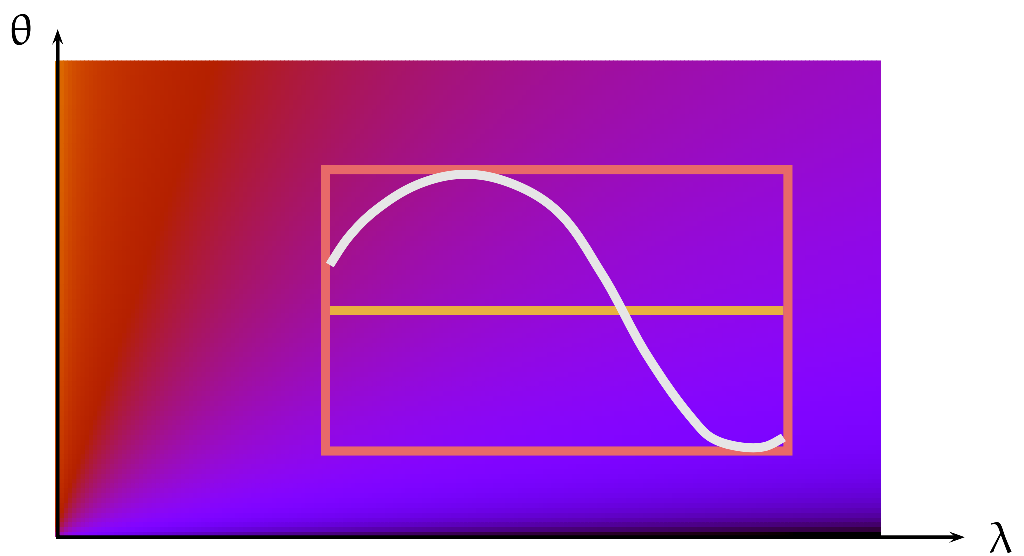
top secret until published . . .

overview

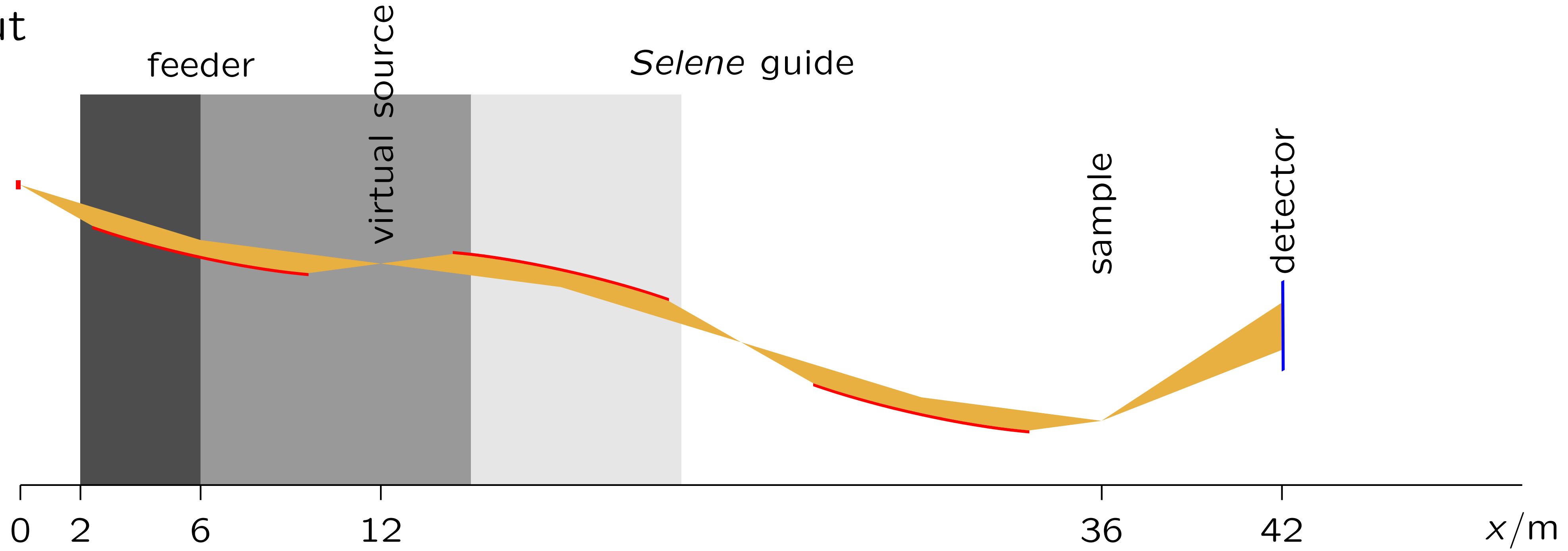
- Selene guide
- optics
- reflectometry
- experiments
- **full guides**

Estia: a reflectometer for the ESS

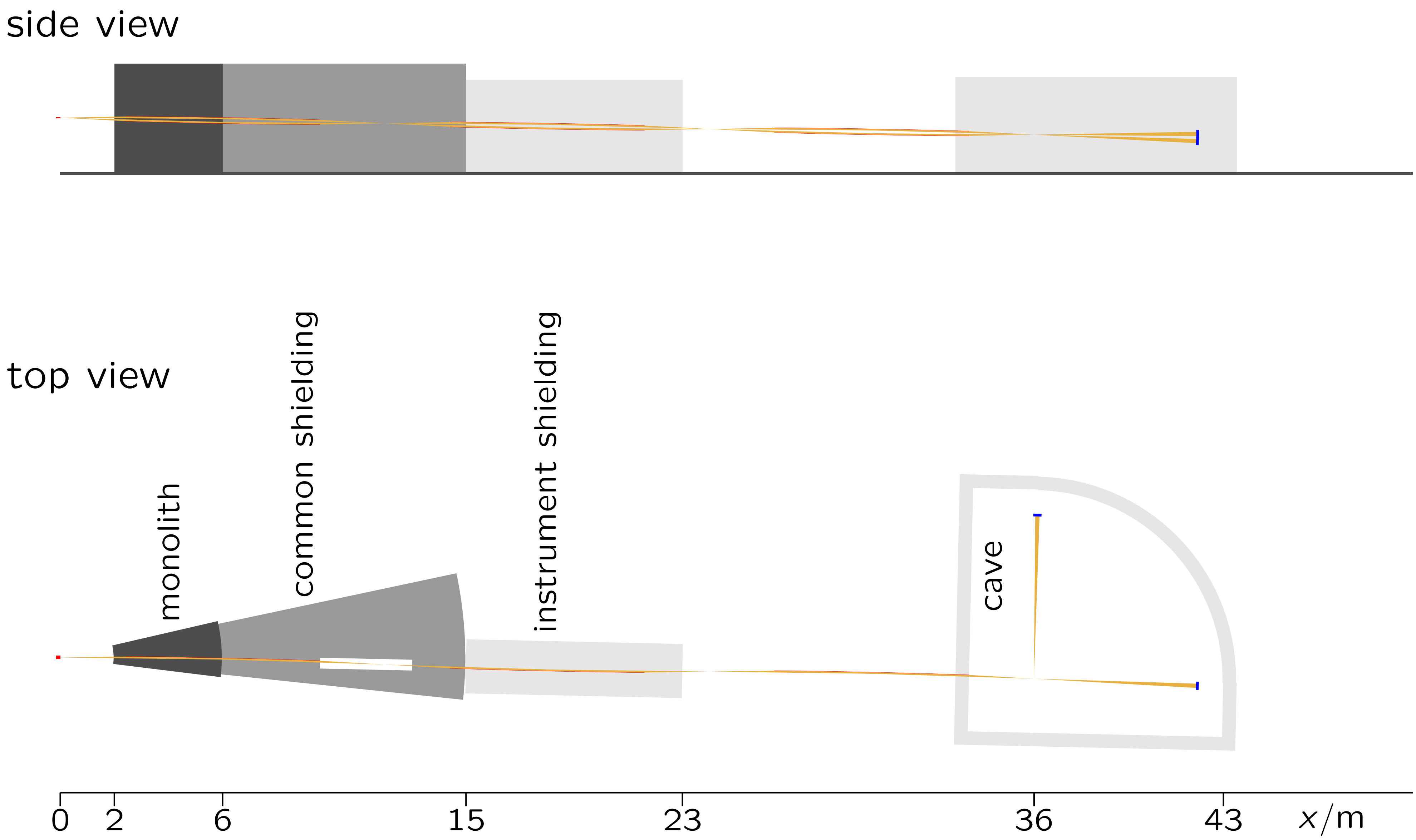
- horizontal scattering plane
- sample size $< 10 \times 50\,\mathrm{mm}^2$
- divergence $1.5^\circ \times 1.5^\circ$
- $\lambda \in [4, 10]\,\text{Å}$



- principle operation modes: classical, optimised, high-intensity
- lay-out

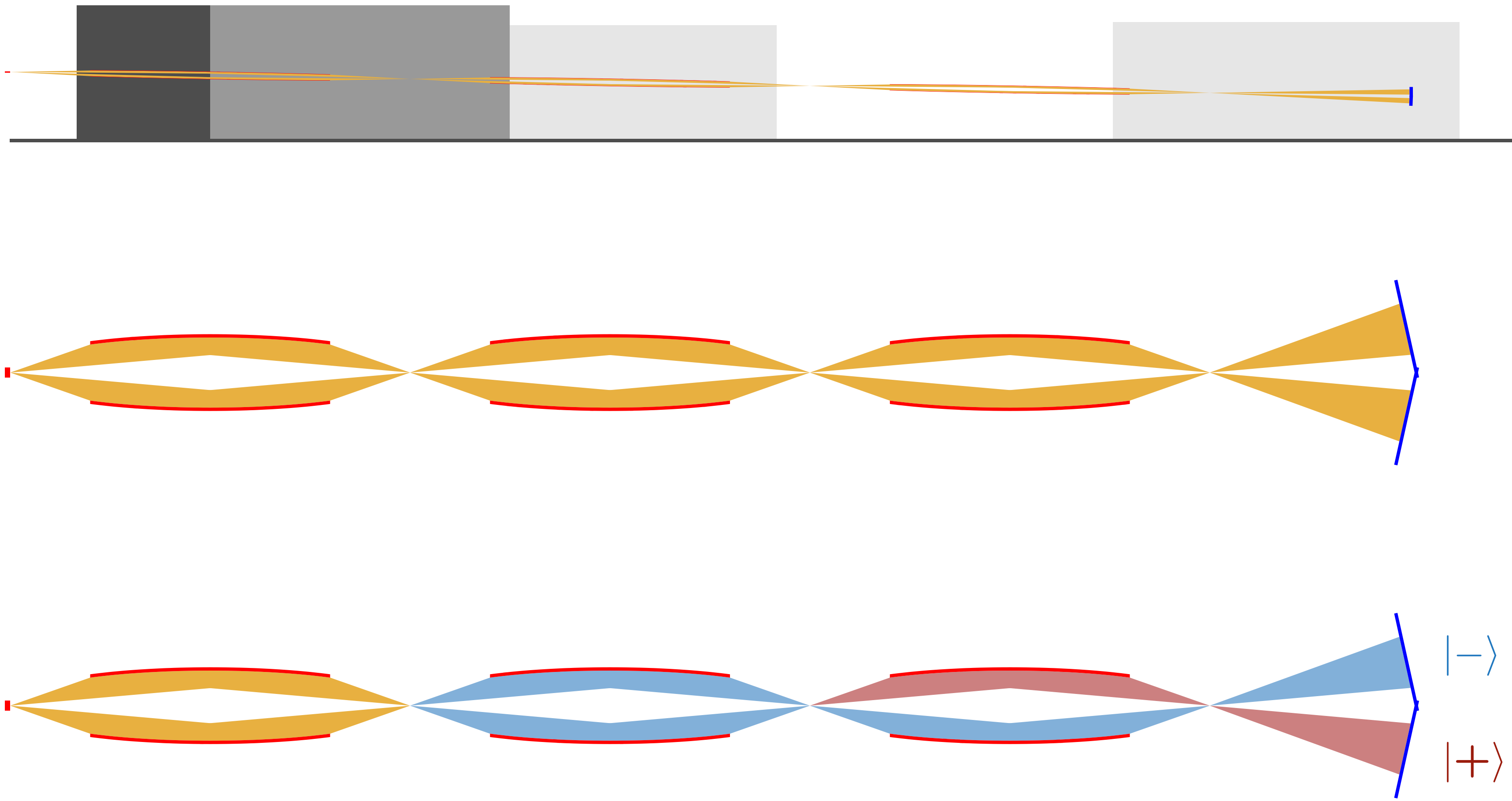


Estia: a reflectometer for the ESS — guide lay-out



Estia: a reflectometer for the ESS — guide lay-out

side view

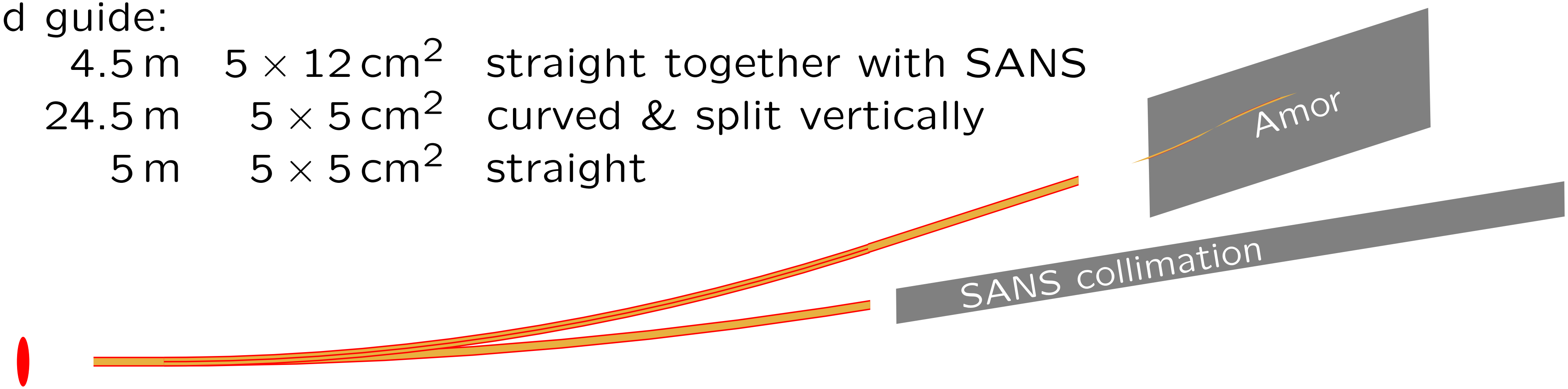


full guide projects

Amor: replacement of beam guide

old guide:

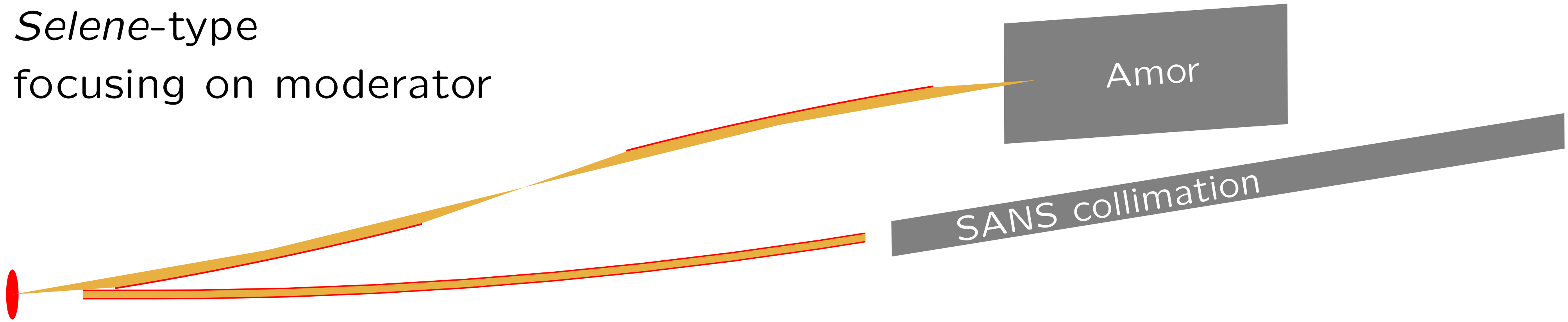
4.5 m	$5 \times 12\,\mathrm{cm}^2$	straight together with SANS
24.5 m	$5 \times 5\,\mathrm{cm}^2$	curved & split vertically
5 m	$5 \times 5\,\mathrm{cm}^2$	straight



new guide:

Selene-type

focusing on moderator



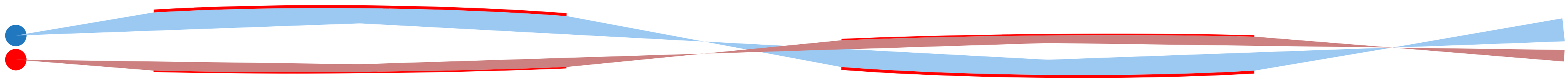
Werner Schweika's thermal & cold guide

two individually optimised *Selene* guides with

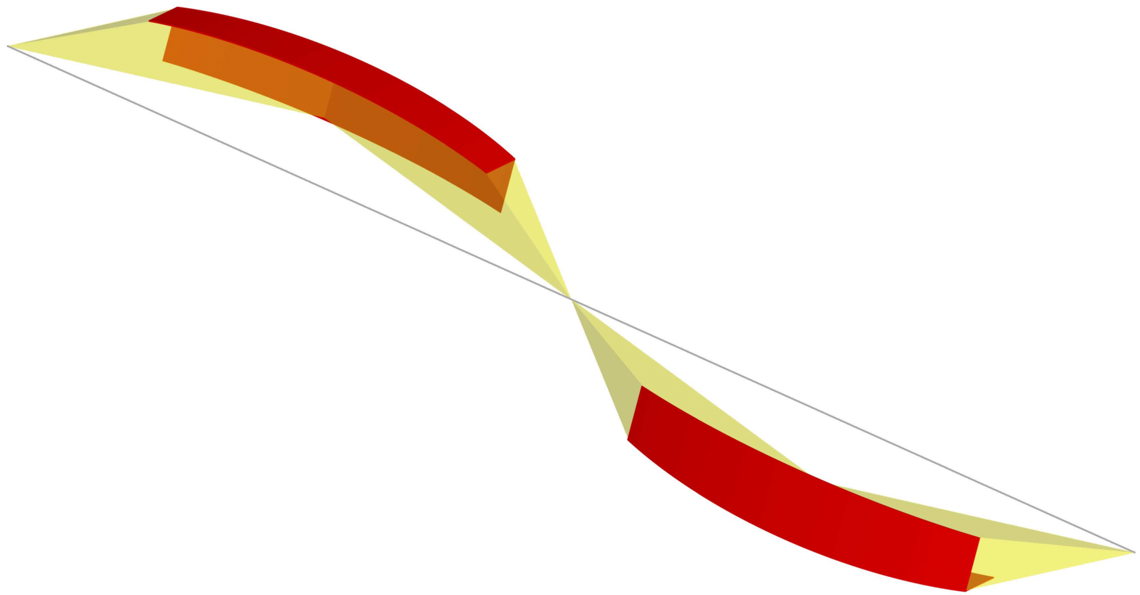
a common focal point on the sample

and

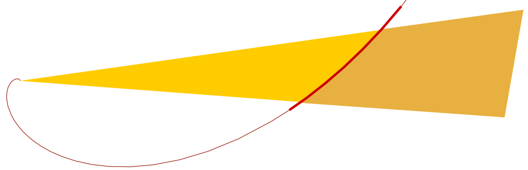
a focal point on a thermal / cold moderator



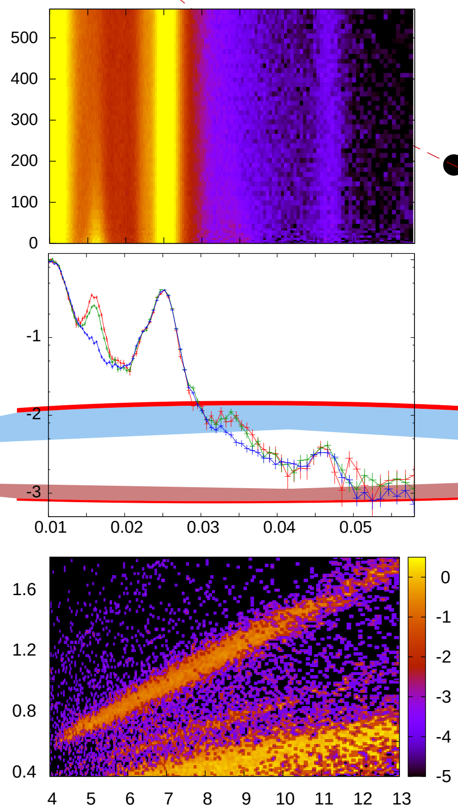
conclusion



- Selene guide
- optics



- reflectometry



- experiments
- full guides