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**study on a**  
**focusing, low-background neutron delivery system**
approach:

define the beam, starting at the sample, by:
– size at the sample position
– divergence
– wavelength, \( \Delta \lambda / \lambda \)

and avoid everything else!

small samples (i.e. in the mm\(^2\), mm\(^3\) range)

**focusing**

**low-background**

filtering / beam-profiling far from the sample
define the beam, starting at the sample

⇒ beam line lay-out
  − shading optics
  − focusing optics

→ aberration

application to a specular reflectometer

McStas simulations on the performance

extention to diffraction / spectroscopy

next steps

prototype for amor
Amor – polarised reflectometer in TOF mode

losses between guide (50 \times 50 \text{mm}^2) and sample:

- chopper: 96%
- first diaphragm: > 80%
- frame overlap filter: \approx 5%
- polariser: > 60%
- sample (10 \times 10 \text{mm}^2): 20%
- \Pi: > 99.75%
beam defined by • required beam divergence

shading / guide

source

aperture  sample

focusing
beam defined by • finite source size

guide

source

aperture

lense

sample

shading / guide

focusing
beam defined by • filtering (polarisation / monochromatisation)
beam defined by • background / radiation issues
background / radiation issues

shading vs. focusing

shading / guide

source aperture guide filter

focusing

input aperture lense sample
effect of optical elements on the phase space

non-focusing elements: (shading optics)
- diaphragm cuts phase space
- plain mirror alters direction, $\lambda$ filter
- (long) guide, can be seen as diaphragm + translation

... limit and dilute phase space

focusing elements:
- lense distorts phase space, aberration
- bent mirror, $\lambda$ filter
- focusing guide, open end $\Rightarrow$ shading + focusing effects

... alter and dilute phase space
realisation

shading / guide

(source) (curved) straight guide monochromator aperture sample

double monochromator aperture half elliptic guide

focusing
selene
titan goddess of the moon
coma aberration  (distortion of the image of an off-axis point source)

inhomogeneous illumination

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"
coma aberration

analytic calculations for selene

slit: high emittance
aperture = 0.2 mm
coma aberration

analytic calculations for selene

slit: high emittance
aperture = 0.6 mm

\[ \alpha / \text{deg} \]

\[ y / \text{mm} \]

\[ \alpha / \text{deg} \]

\[ y / \text{mm} \]

J. Stahn, Garching, 04.05.2010
coma aberration

analytic calculations for selene

slit: high emittance
aperture = 2.0 mm

⇒ a *nice* phase space element requires a sample aperture
coma aberration

comparison to a straight guide / diaphragm set-up

guide: emittance = ±0.5°
slit: aperture = 2.0 mm
McStas simulations for selene — reflectometer

- monochromator
  - aperture = 1\textsuperscript{st} focal point
- half elliptic guide
- sample & knife aperture = 2\textsuperscript{nd} focal point
McStas simulations for selene — reflectometer

the model device:

- guide: 80 × 50 mm²
- coating $m = 5$

monochromator:
- PG
- ml

sample: $[\text{Ni}(160 \text{ Å})/\text{Ti}(240 \text{ Å})]_{20}/\text{Si}$
new McStas component
- true curvature
- all surfaces with individual properties
- individual shapes
- neutrons can pass by
- nesting of devices

to come:
- off-specular reflectivity
high-intensity specular reflectometer – principle

incoming beam with known $\lambda/\alpha_i$ relation
detection of $I$ vs. $\alpha_f$
conversion to
$q_z = 4\pi \frac{\sin \alpha_f}{\lambda}$

gain:
$\Delta \alpha_i = 1.4^\circ$ compared to $\Delta \alpha/\alpha = 7\%$ gives a gain factor 20

but:
off-specular scattering leads to background
$\Rightarrow$ method is limited to 5 orders of magnitude
high-intensity specular reflectometer – implementation

ReFOCUS concept by F. Ott

the elliptic guide
has a (graded)
monochromating coating

encode $\lambda$ in $\alpha_i$
resolve $q_z(\lambda, \alpha_i)$ with
an area detector
McStas simulations for **selene — reflectometer** using a double **ml monochromator** \((m = 3)\)

incident angle on the ml: \(0\ldots2^\circ\)

with \(\lambda \propto \sin \alpha_i\)

acceptance of the guide: 
\(\Delta \alpha = 1.3^\circ\)

\[\Rightarrow \lambda \text{ vs. } \alpha_i \text{ at sample position:}\]
McStas simulations for **selene — reflectometer**

using a double ml monochromator \( m = 6, \Delta q_z/q_z \approx 1\% \)

\( R(q_z) \) of the sample

\( \omega = -0.5^\circ, 1.5^\circ \text{ and } 3.5^\circ \)

no off-specular scattering included, yet
McStas simulations for **selene — reflectometer**

using a double ml monochromator $m = 5$, $\Delta q_z/q_z = 7\%$

\[
\log_{10}[R(q_z)]
\]

$\omega = 0^\circ$

\[
q_z/\text{Å}^{-1}
\]

J. Stahn Garching, 04. 05. 2010
McStas simulations for **selene — reflectometer** using a double ml monochromator $m = 3$, $\Delta q_z/q_z \approx 4\%$

![Graphical representation of McStas simulations for selene — reflectometer using a double ml monochromator](image)
McStas simulations for **selene — reflectometer** using a double **PG monochromator** ($\Delta \alpha = 0.16^\circ$)

simulated data ($\omega = -1^\circ, 0^\circ, 1^\circ, \ldots, 7^\circ$)

no illumination correction applied yet
McStas simulations for **selene — reflectometer**

using a double **PG monochromator**

comparison: **mosaicity** of PG

- 1.40°
- 0.50°
- 0.16°

sample
McStas simulations for selene — reflectometer using a double PG monochromator ($\Delta \alpha = 0.16^\circ$)

comparison: sample sizes

- $10 \times 10 \text{ mm}^2$
- $8 \times 8 \text{ mm}^2$
- $6 \times 6 \text{ mm}^2$
- $4 \times 4 \text{ mm}^2$
- $2 \times 2 \text{ mm}^2$

\[ \log_{10}[I(q_z)] \]

$q_z/\text{Å}^{-1}$
reflectometer – resume

*maximum* flux on the sample for a given $\Delta \alpha_i$

allows for high-intensity reflectometry:

– ml monochromator: $q_z$-range e.g. 0.01 to 0.1 Å$^{-1}$

– PG monochromator: $q_z$-range $\propto \Delta \alpha_i$

reduction of $\Delta \alpha_i$ leads to a *conventional* angle-dispersive reflectometer

$\Rightarrow$ off-specular measurements are possible

$\Rightarrow$ a diaphragm-scan results in a $q_z$-scan
some thoughts on focusing monochromators

typical set-up:
source – guide – monochromator – sample

monochromator: array of flat crystals (mirrors)
⇒ divergence is transported
some thoughts on focusing monochromators

modified set-up:
source – guide – monochromator + lense – sample

lense: mirror with continuous curvature
⇒ divergence is transformed to convergence
some thoughts on focusing monochromators

modified set-up:

aperture: reduces un-wanted flux
⇒ reduced background
some thoughts on focusing monochromators

modified set-up:

guide: reduced to the necessary length
⇒ selene-type set-up

- double monochromator needed
- same usable intensity on the sample
+ strongly reduced background
+ fix sample position
McStas simulations for **selene** — **diffractometer**

using a double **PG monochromator**

($\Delta \alpha = 0.5^\circ$)

![Graph showing spot size and wavelength resolution](image)

- **Spot**: $0.8 \times 8 \text{ mm}^2$
- **Wavelength Resolution**: $\Delta \lambda / \lambda < 4\%$
- **First Aperture**: $2 \text{ mm}$
next steps

a prototype of 4 m length (monochromator to sample) is under construction
to be tested on BOA
to be used on AMOR
Amor – polarised reflectometer in TOF mode
Amor with selene in TOF mode

horizontal focusing
gain factor $\approx 6$

enables high-intensity specular reflectivity
gain factor $\approx 20$
Amor with selene in monochromator mode

chopper stopped
double monochromator (ml or PG)
same flux, but different $q_z$-range
polarising ml possible
replacement of the guide of e.g. RITA II, SINQ
- old insert / first part of the straight guide can be reused
- monochromator in the 1st part of guide bunker
- guide ends within guide bunker

⇒ fixed sample position
⇒ large 2θ-range accessible
filter first:

+ reduction of radiation entering the guide to < 1%
+ reduced n-background: saves shielding material
+ reduced radiation level: saves life!
  o no gain in flux!
  - mechanical parts close to source

focusing guide:

+ reduces illumination of sample surroundings
+ no direct view to source
+ allows for small monochromators . . .
  o no gain in flux!
  + allows for $q_Z/\alpha_i$ encoding
  - (coma) aberration
  - does not work for large samples
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YOU