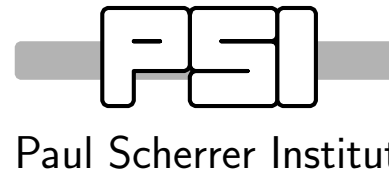
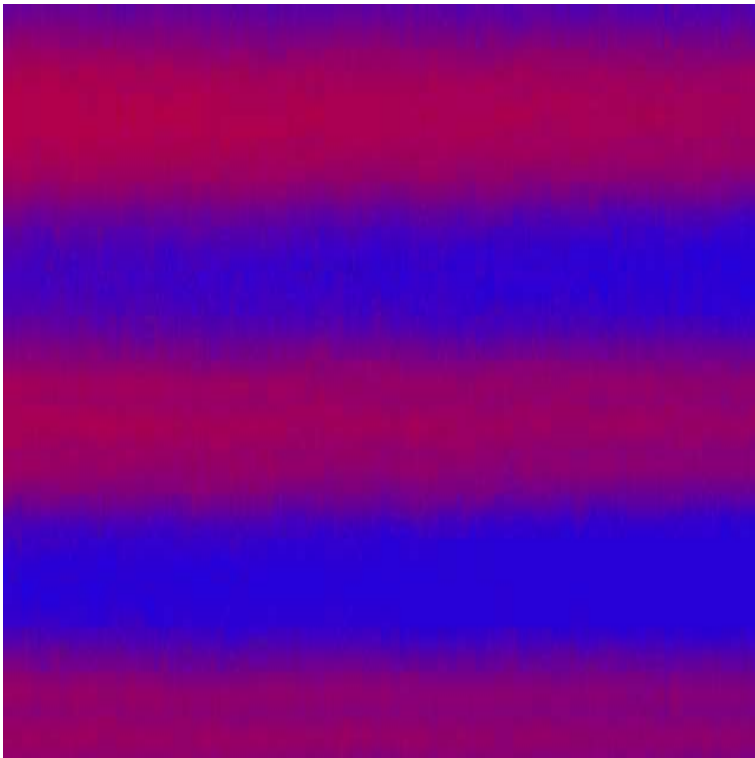


laterally graded and complex multilayers for neutron optical elements



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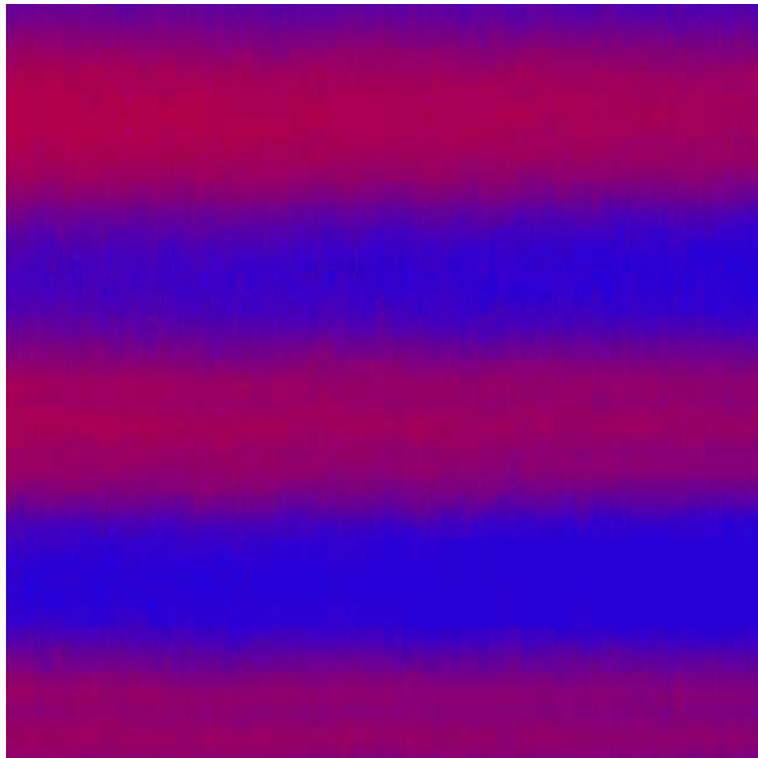
Peter Böni

SwissNeutronics

conventional multilayers (should) have:

- sharp interfaces $\Rightarrow$ high reflectivity, no losses
- lateral homogeneity $\Rightarrow$ high reflectivity, no losses
- 2 layers per *period* $\Rightarrow$ cheap to produce

- but
- interfaces are not sharp due to roughness or interdiffusion
 - (almost) sharp interfaces cause higher order Bragg reflections



initial idea:

accept a non-sharp profile step but with low roughness

- intermediate layers
- controlled interdiffusion

next step:

full control of the density profile

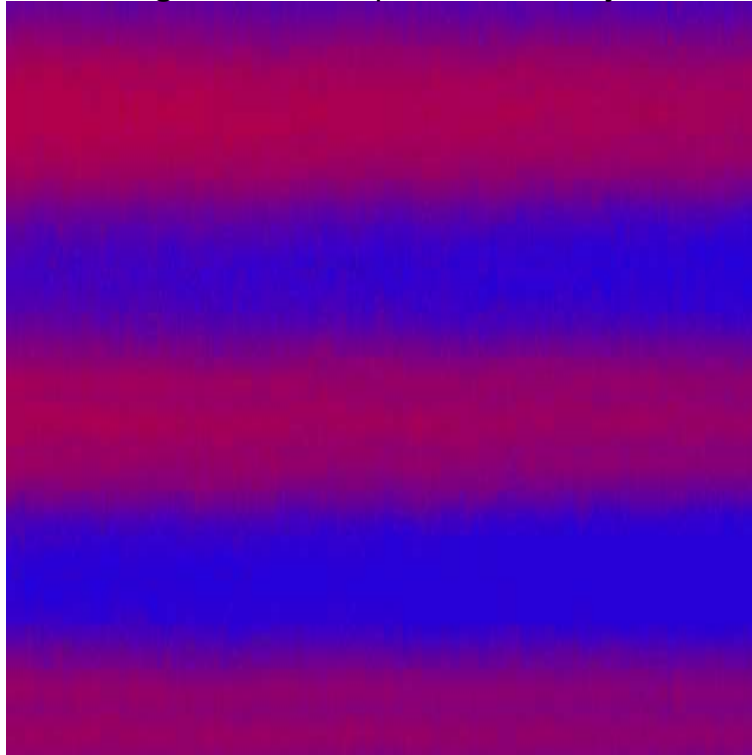
- sinusoidal profile to get a monochromator without higher orders

complex multilayers

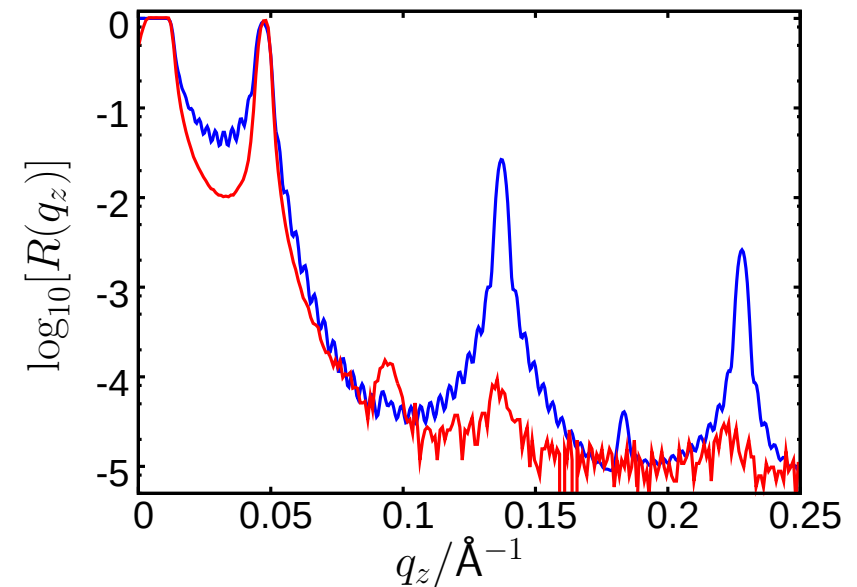
attempt to create a
sinusoidal density profile
by:

- deposition of thin films
(up to 22 per period)
- subsequent annealing
to get interdiffusion

STM image of an as-deposited multilayer



blurred interfaces



reflectivity of the annealed multilayer compared
to the calculated multi-bilayer

problem:

annealing leads to grain-formation

and thus to rough interfaces

but:

the as-deposited film shows no higher order reflections!

next step:

reduce number of layers and still suppress higher orders

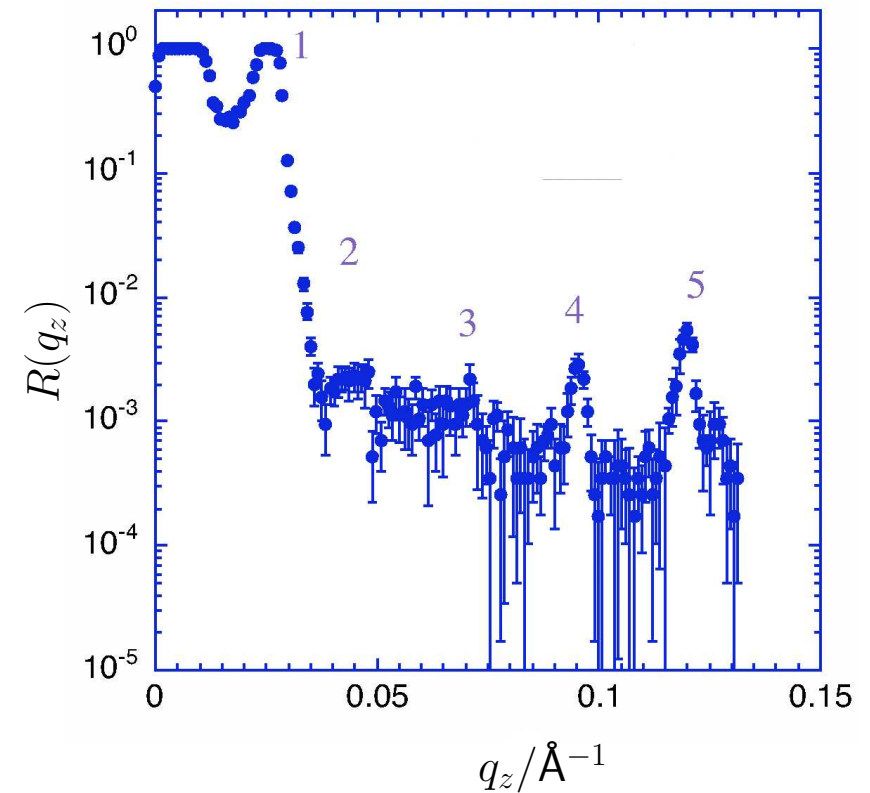
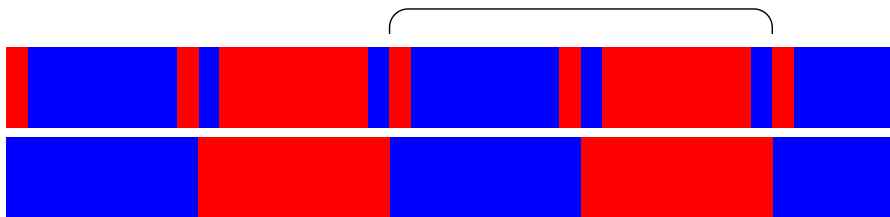
aim:

starting from the quasi-sinusoidal profile

reduce number of layers and still suppress higher orders

example:

suppression of orders 2, 3 and 4 is possible with 6 layers per period
with (approximate) thickness ratios 1:7:1:1:7:1



reflectivity of a Ni-Ti-multilayer, period: 27 nm,
6 sublayers/period, 10 repetitions

a short-wavelength filter of this type is used on the neutron reflectometer Narziss, SINQ

discrete layers allow for the application of the principle for polarising monochromators

conventional supermirror coatings cover a *large* angular / q range

but reflectivity decays with q

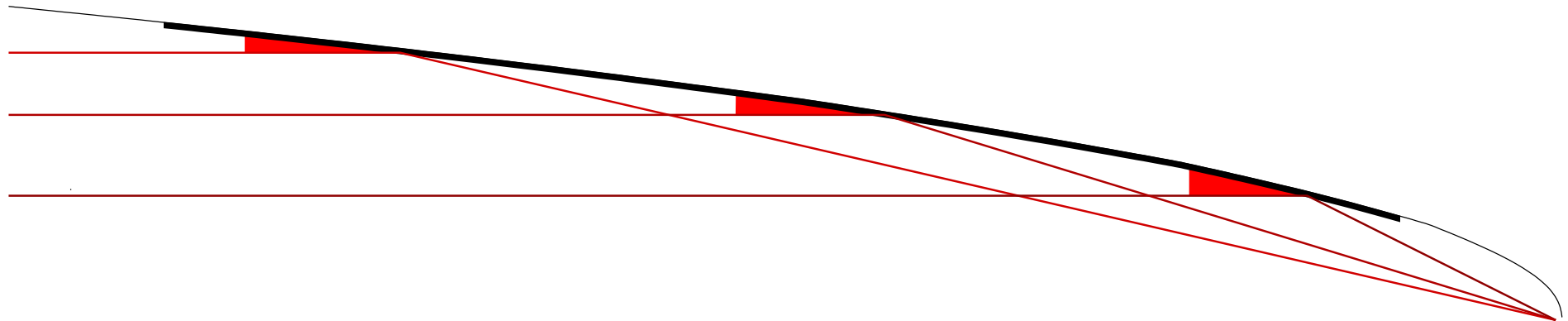
if the *necessary* q range varies spacially

one can skip the needless layers (better: periods).

⇒ higher reflectivity of the coating

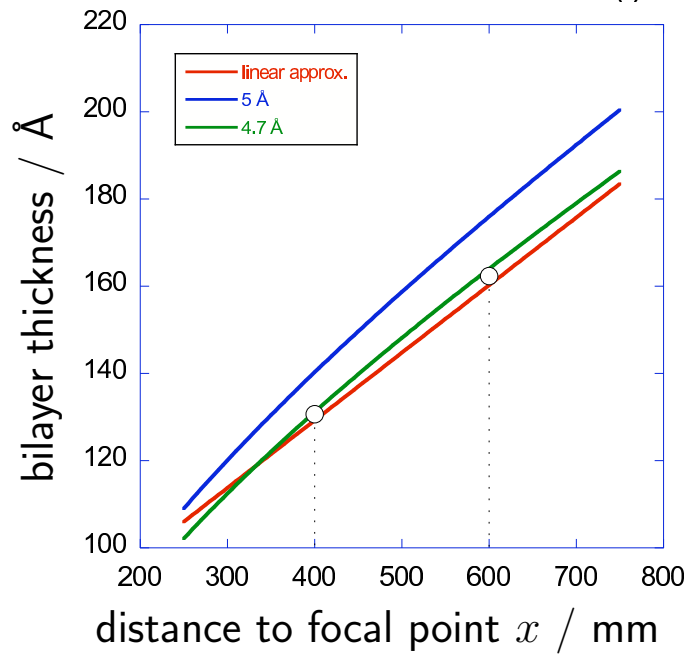
example:

focusing element (parabula-branch) for a wavelength band $\lambda = 4.7 \text{ \AA} \pm 10\%$



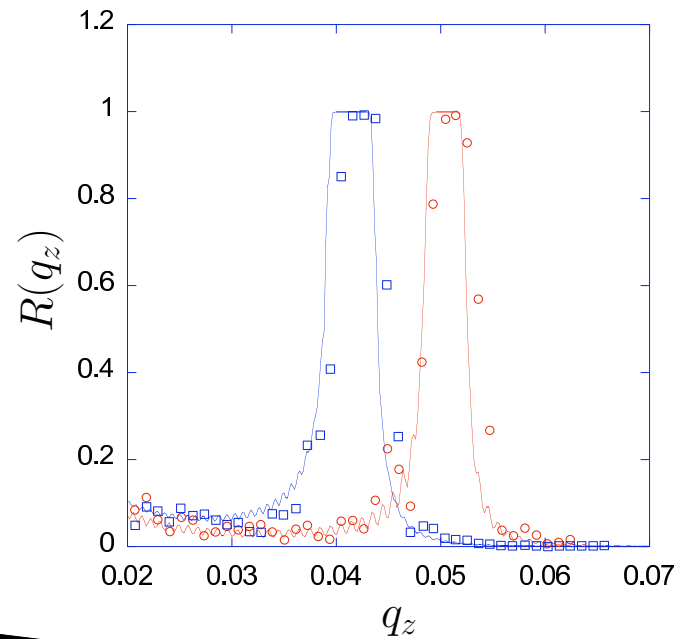
design

linear approximation for period vs. x



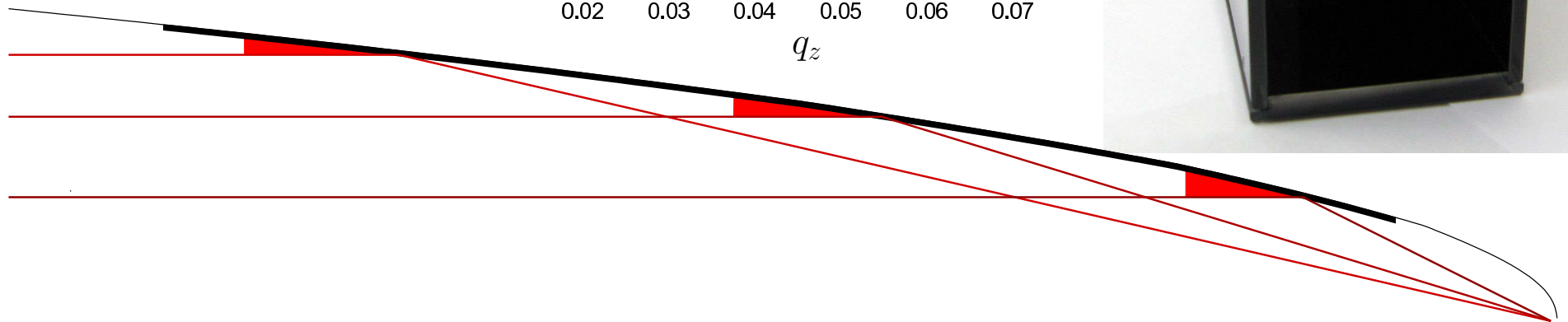
test measurements

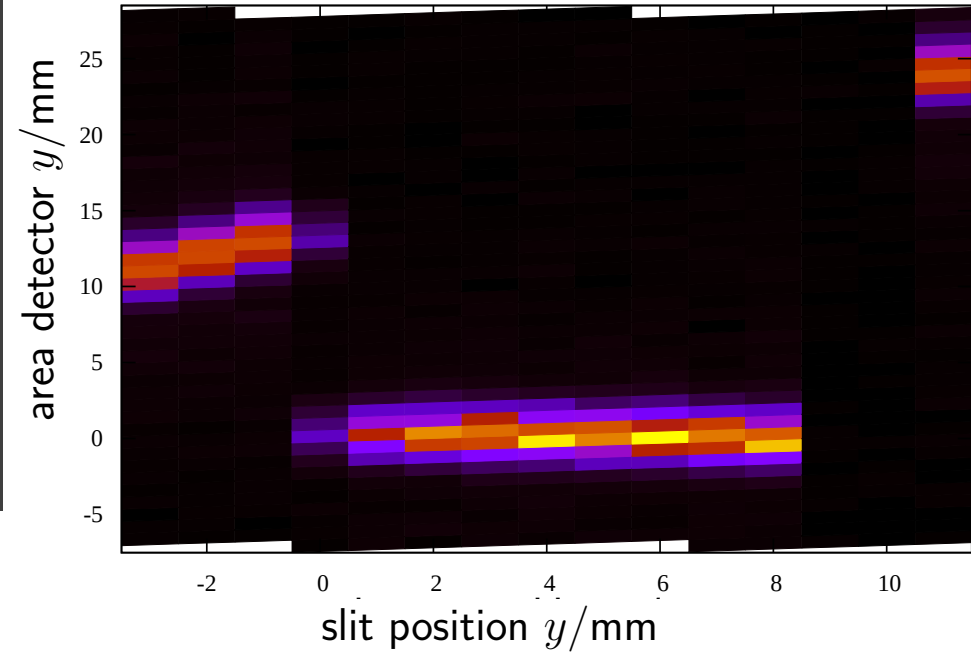
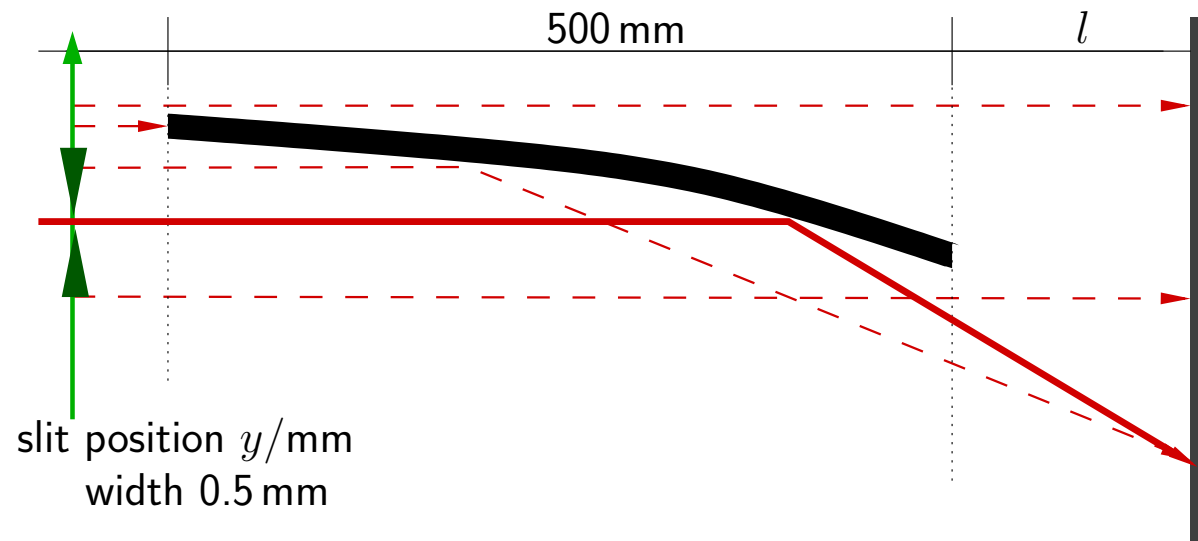
$R(q_z)$ at various positions x



assembled device

(only one branch was used here)



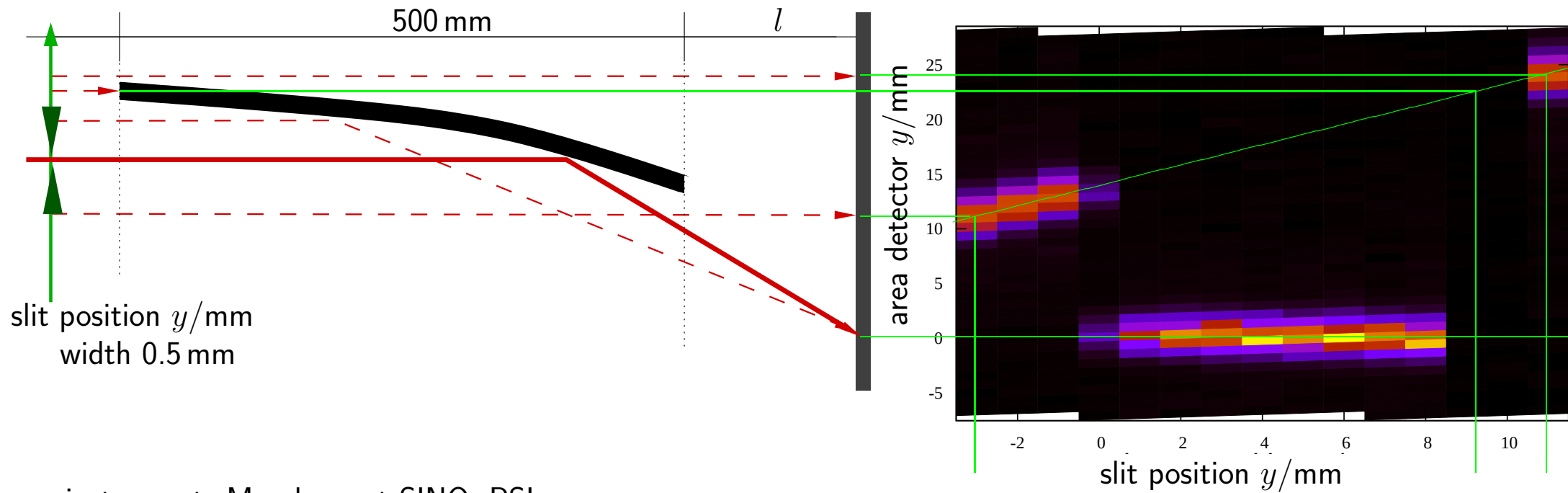


instrument: Morpheus at SINQ, PSI

$\lambda = 4.5 \dots 5 \text{ \AA}$

various tilt angles

various distances l (optimum 250 mm)

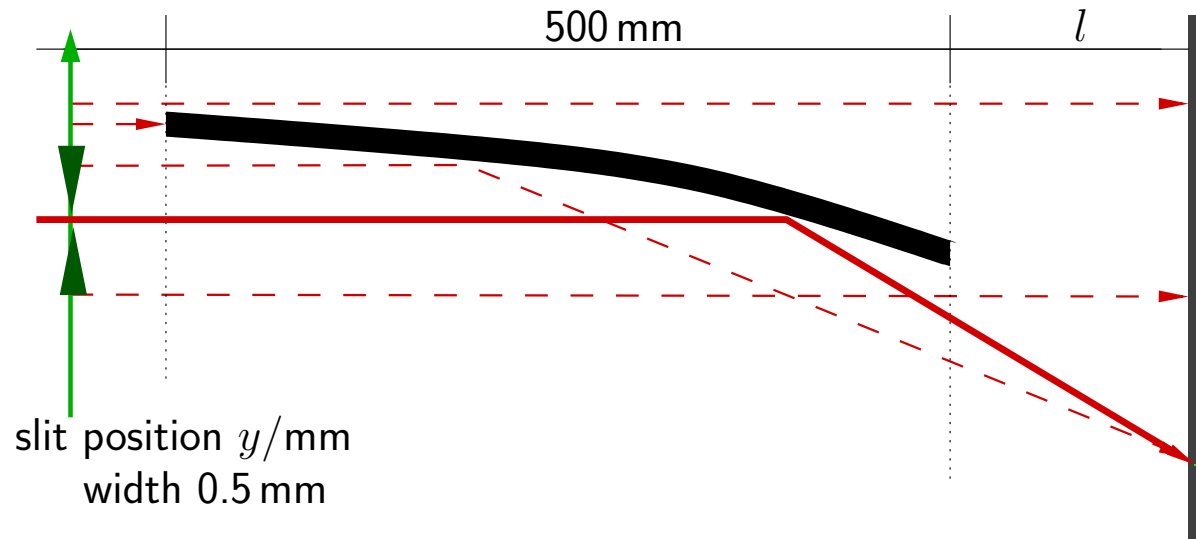


instrument: Morpheus at SINQ, PSI

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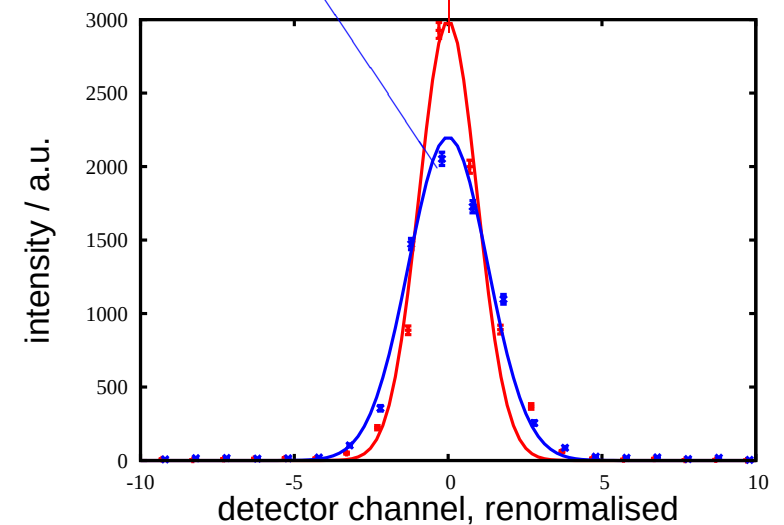
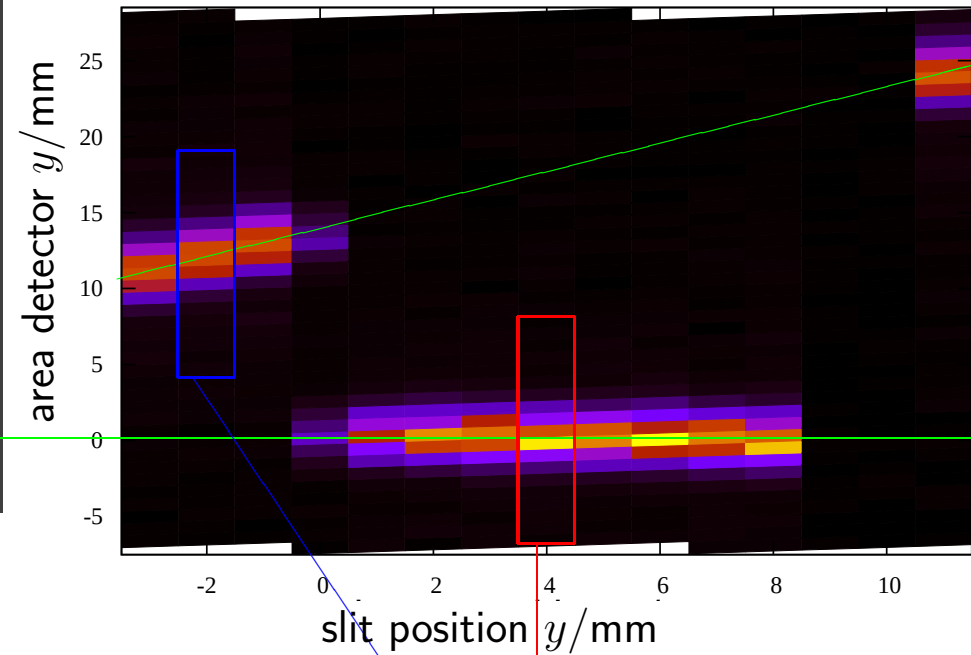
instrument: Morpheus at SINQ, PSI

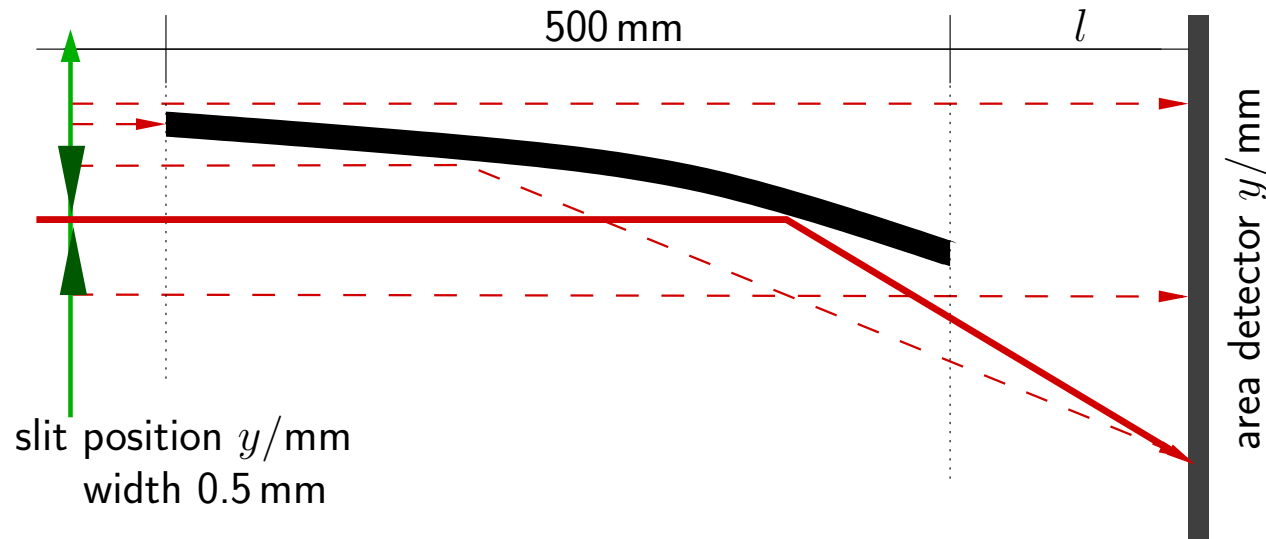
$\lambda = 4.5 \dots 5 \text{ \AA}$

various tilt angles

various distances l (optimum 250 mm)

a 8 mm wide beam is focused to $< 0.8 \text{ mm}$
with a yield of almost 100%





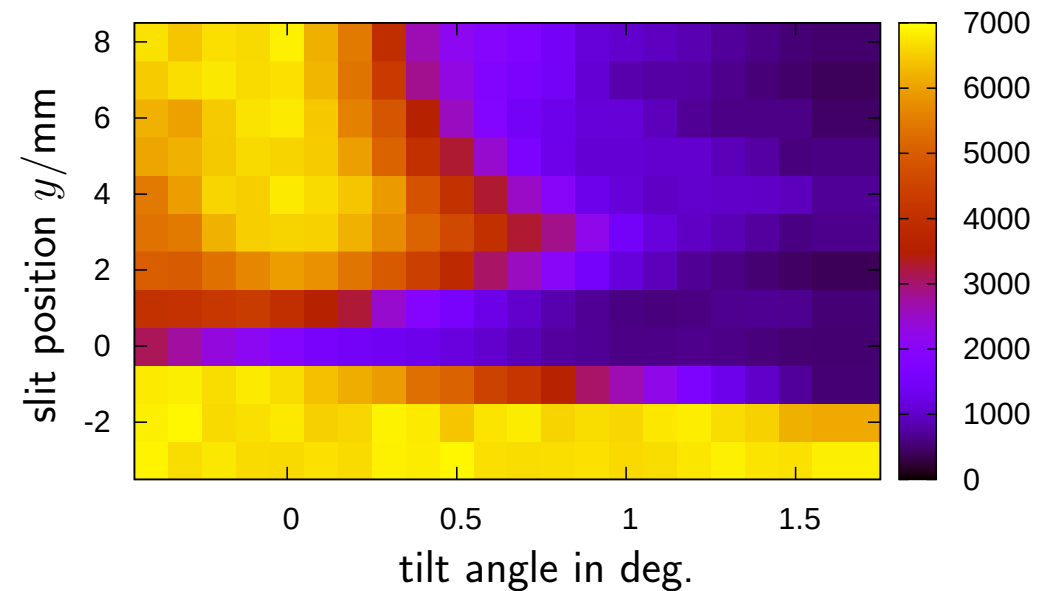
instrument: Morpheus at SINQ, PSI

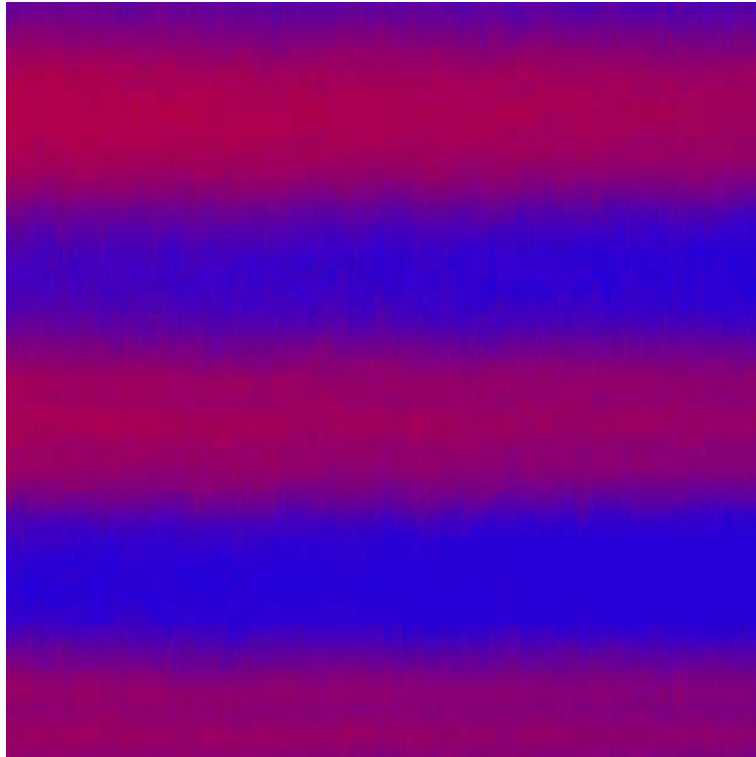
$\lambda = 4.5 \dots 5 \text{ \AA}$

various tilt angles

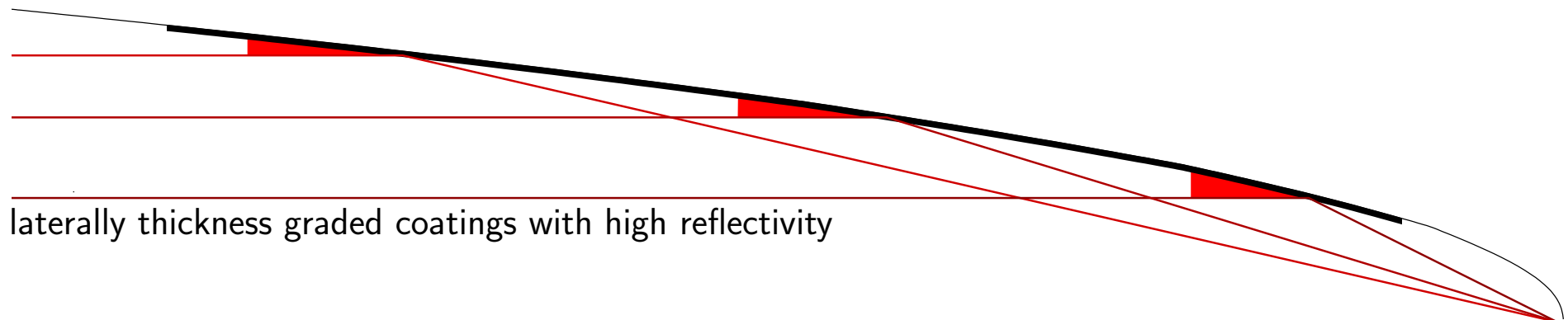
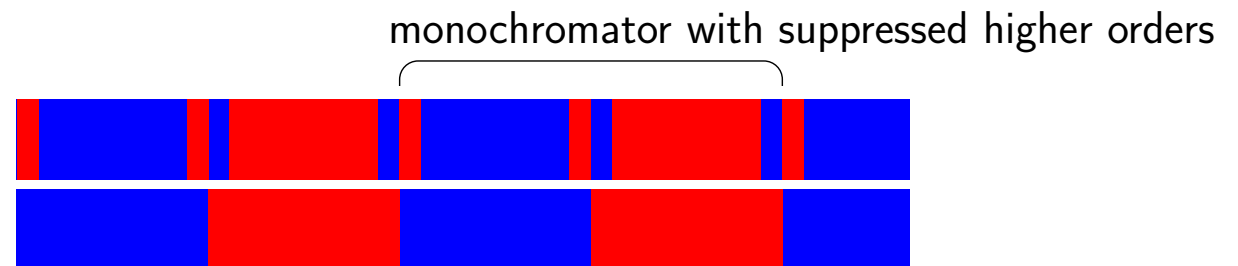
various distances l (optimum 250 mm)

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with a yield of almost 100%





quasi-sinusoidal density profile



laterally thickness graded coatings with high reflectivity