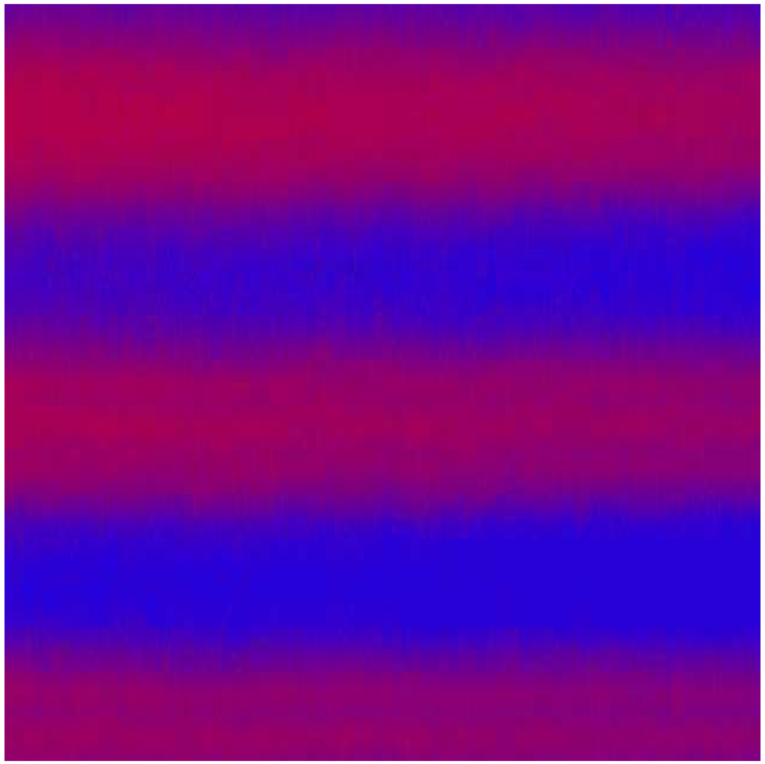
laterally graded and complex multilayers for neutron optical elements



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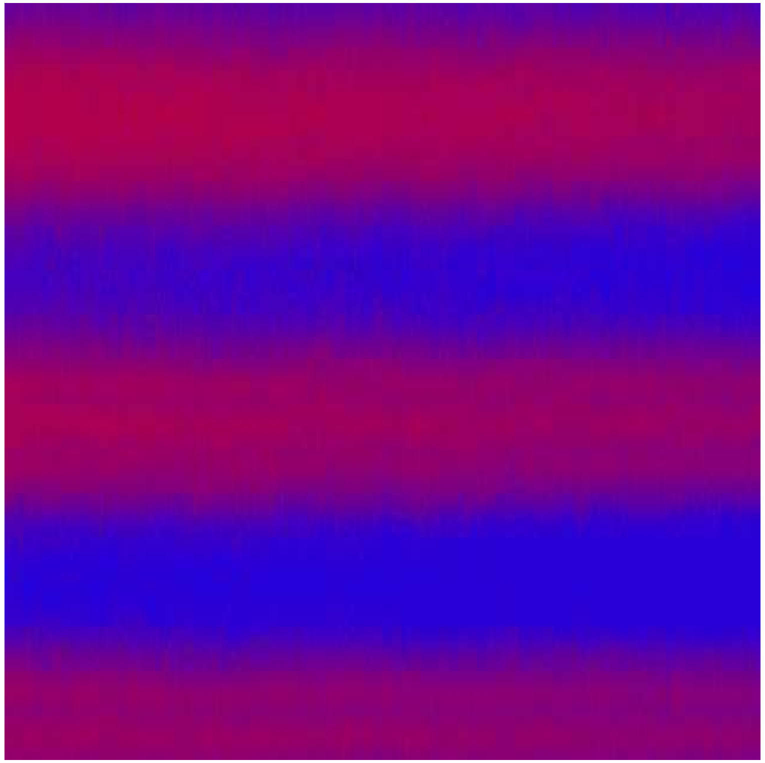
conventional multilayers (should) have:

– sharp interfaces	⇒	high reflectivity, no losses
– lateral homogeniety	⇒	high reflectivity, no losses
– 2 layers per *period*	⇒	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 controll of the density profile
– sinusoidal profile to get a monochromator without higher orders

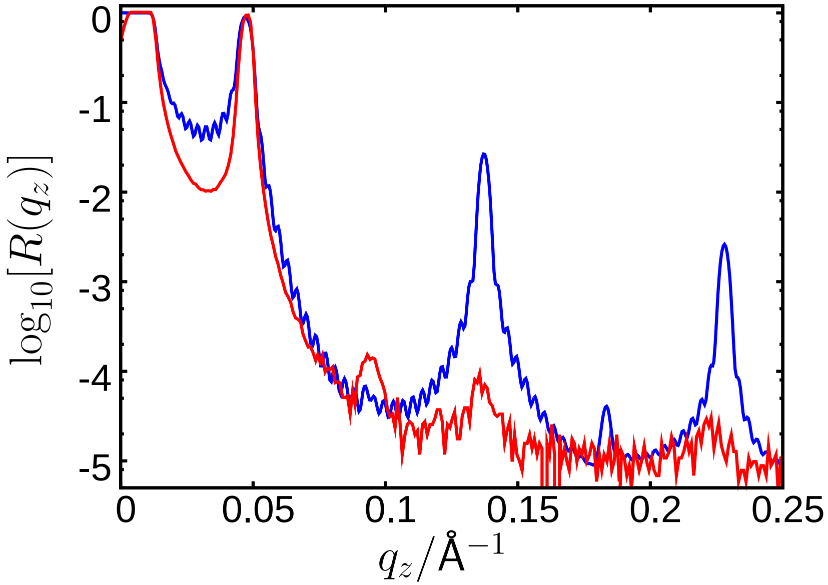
complex multilayers

blured interfaces

attempt to create a
sinusoidal density profile
by:

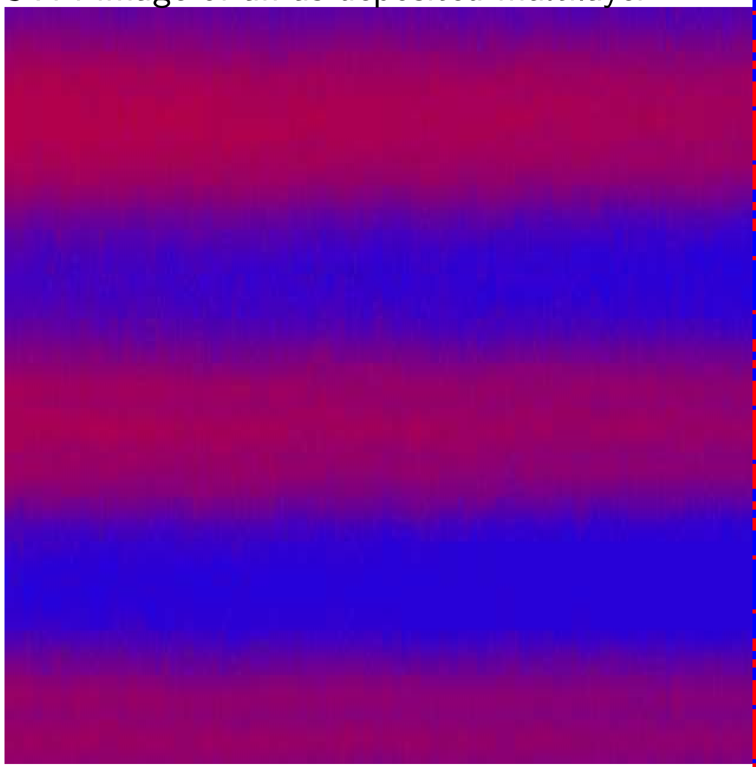
– deposition of thin films
  (up to 22 per period)

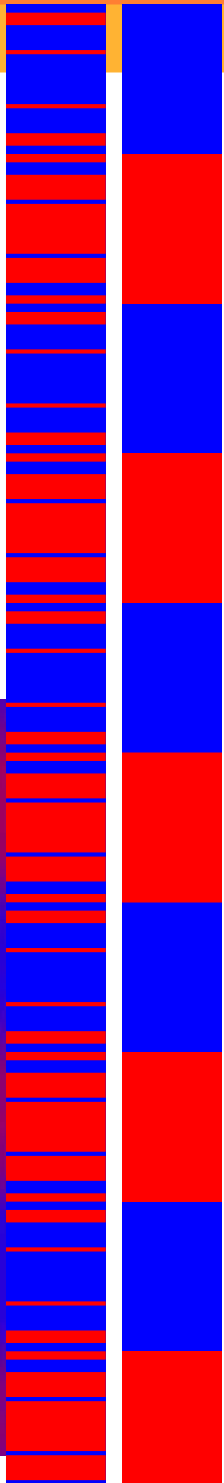
– subsequent annealing
  to get interdiffustion



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

STM image of an as-deposited multilayer





problem:
annealing leads to grain-formation
and thus to rough interfaces

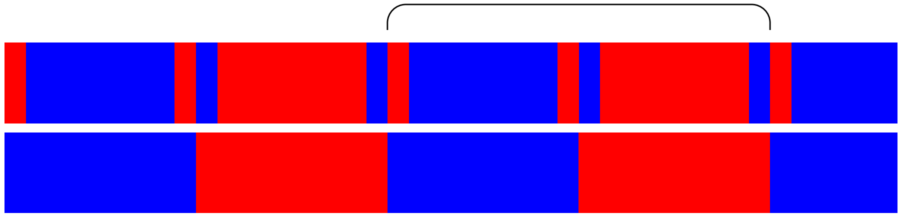
but:

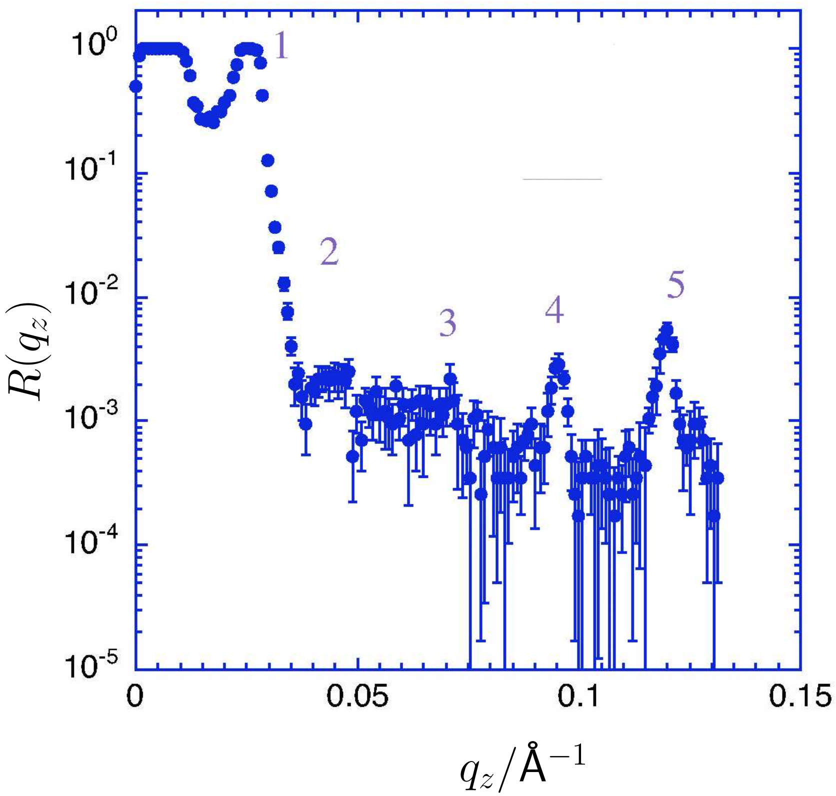
the as-depositded film shows no higher order reflections!

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 rations 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

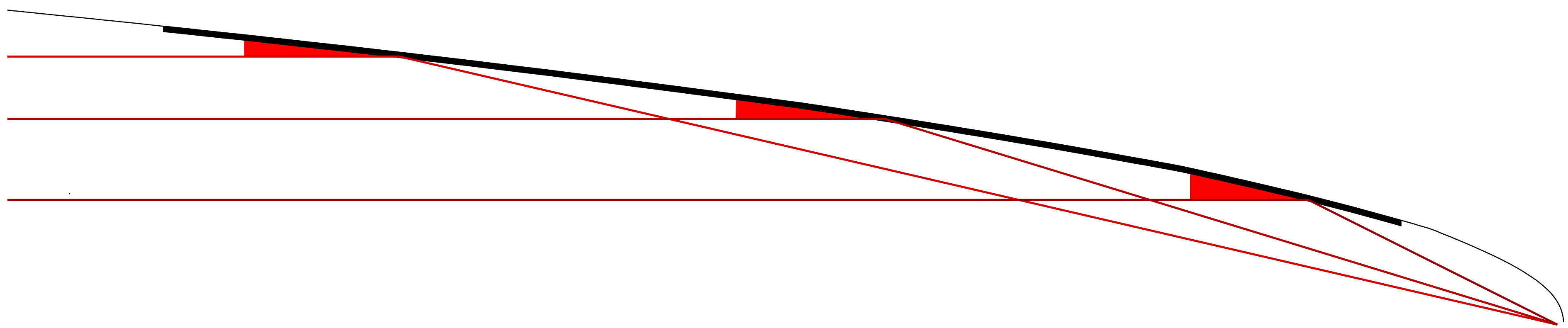
if the *necessary* q range varies spacially

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

$\Rightarrow$ higher reflectivity of the coating

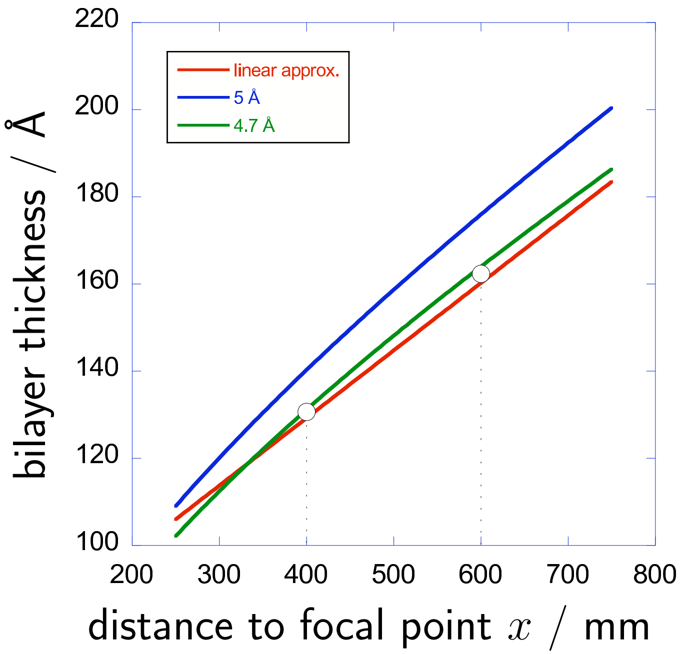
example:

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



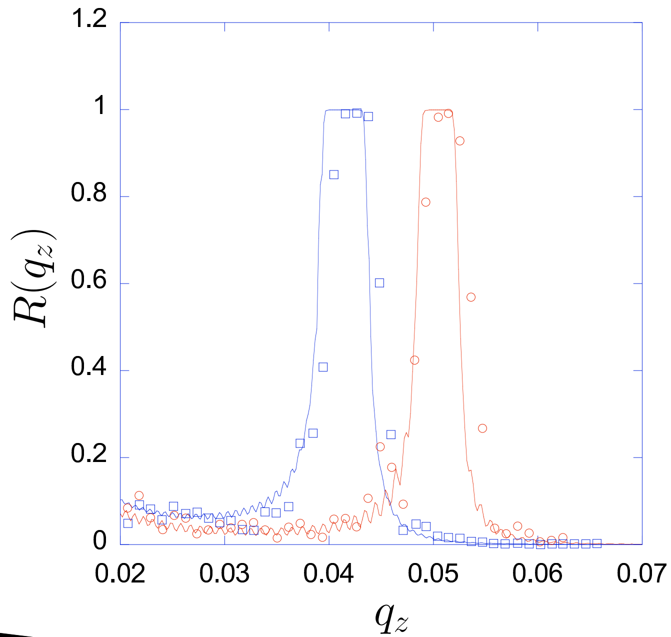
design

linear approximation for period vs. x



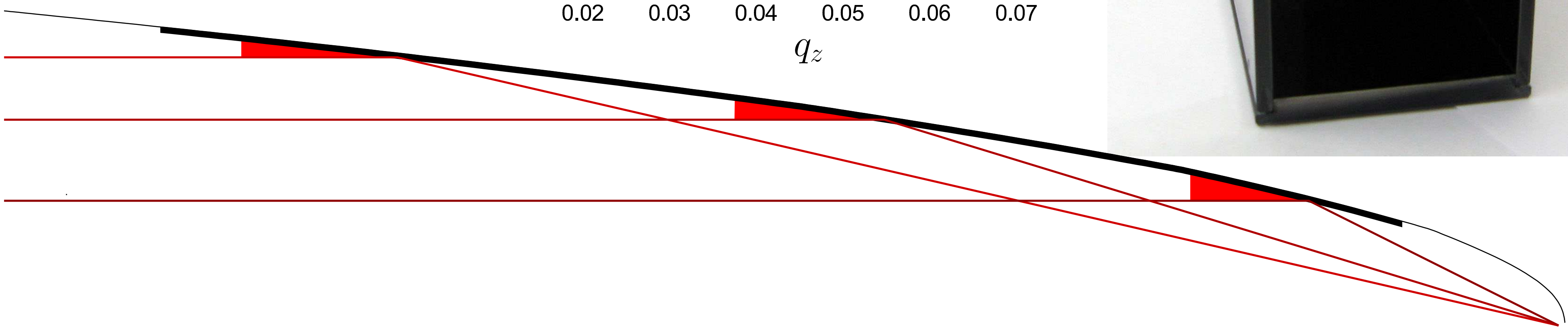
test measurements

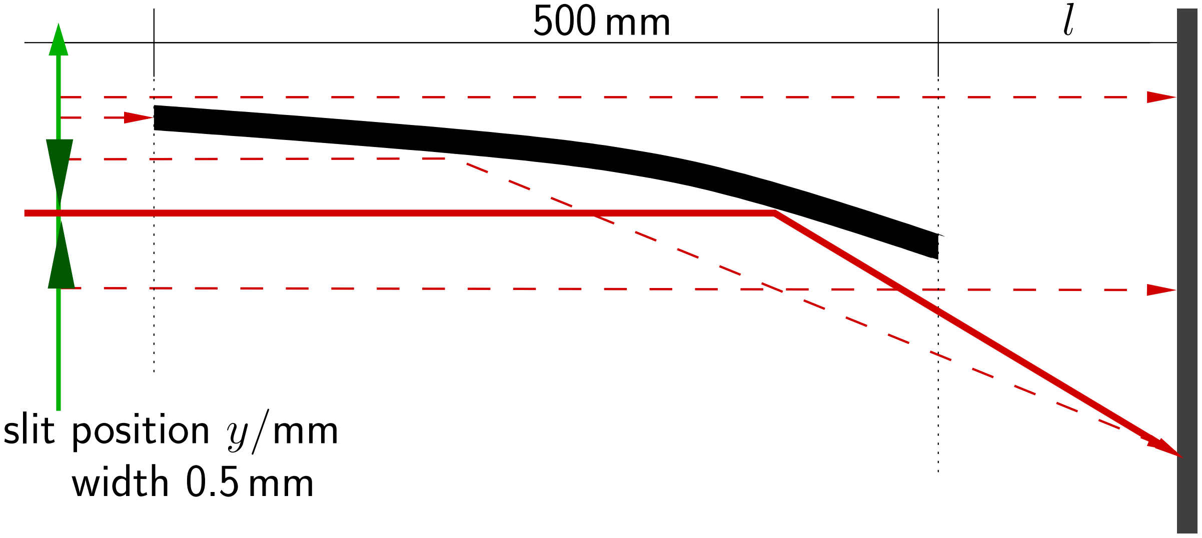
$R(q_z)$ at various positios x

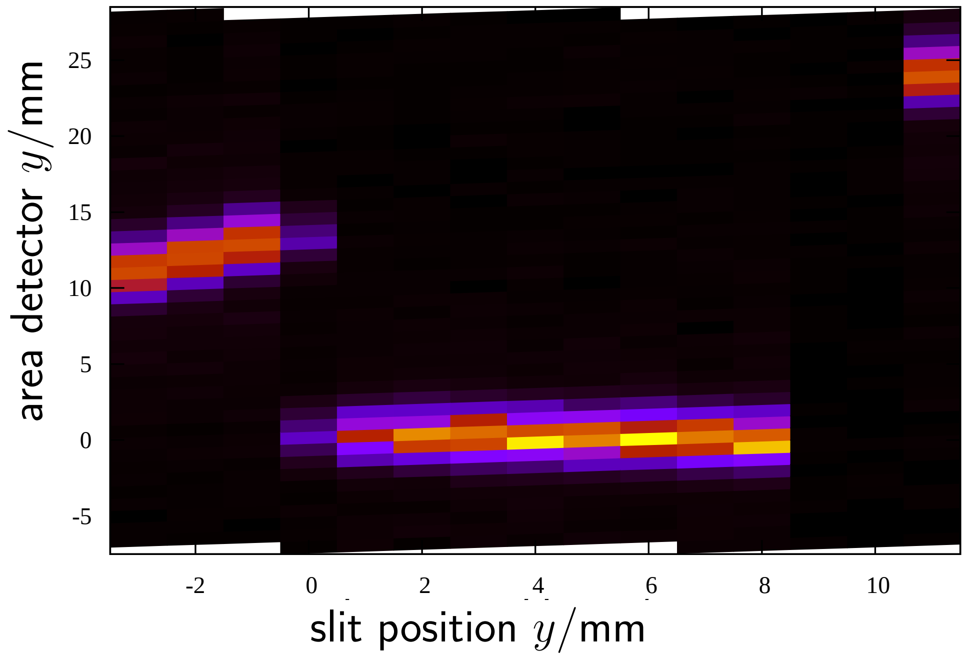


assembled device

(only one branch was used here)





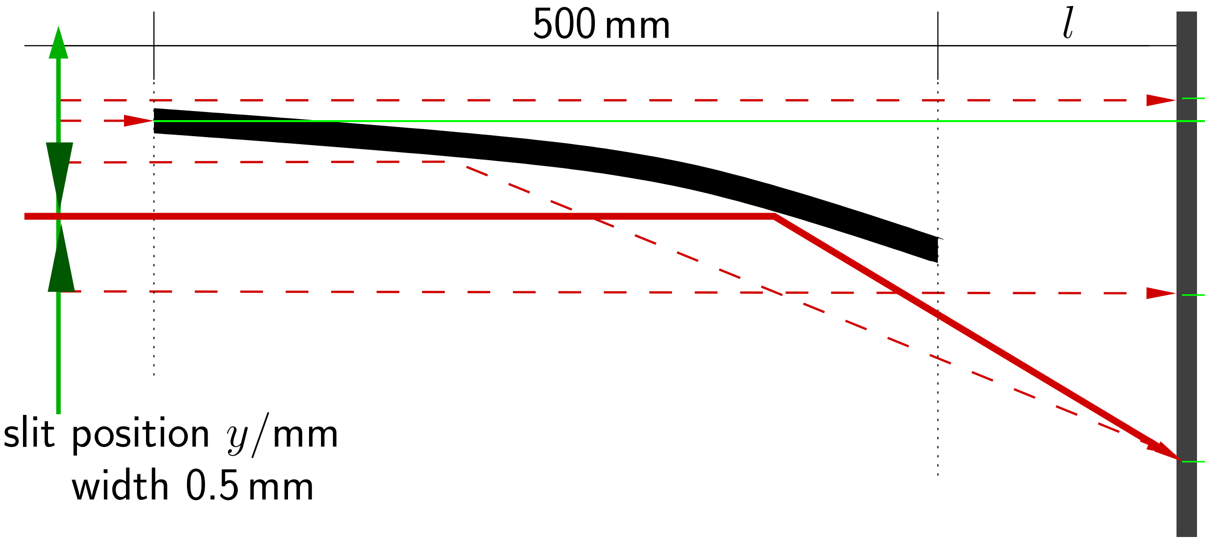


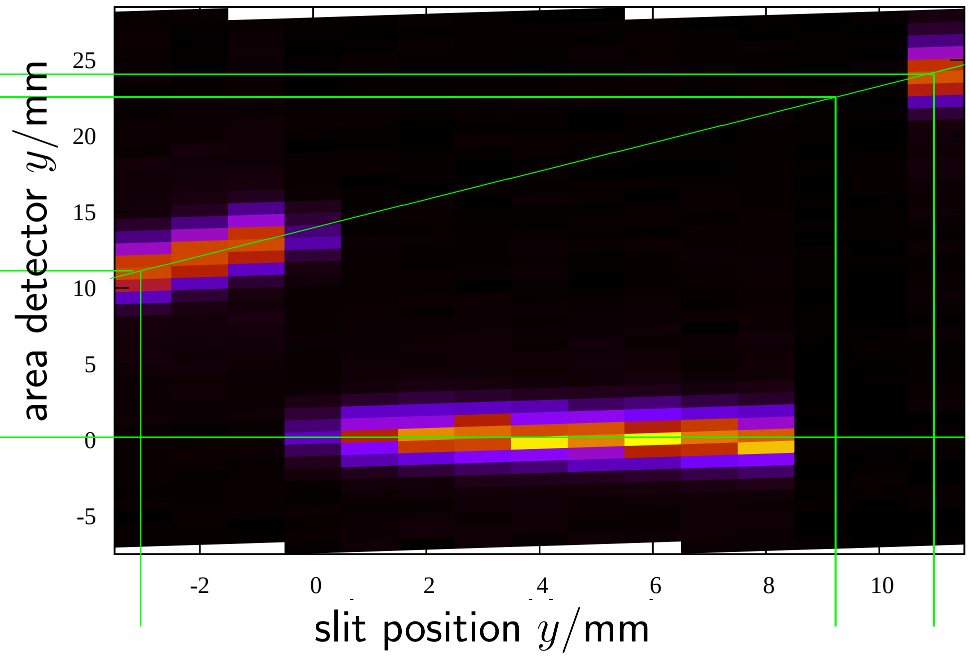
instrument: Morpheus at SINQ, PSI

$\lambda = 4.5 \ldots 5$ Å

various tilt angles

various distances l (optimum 250 mm)





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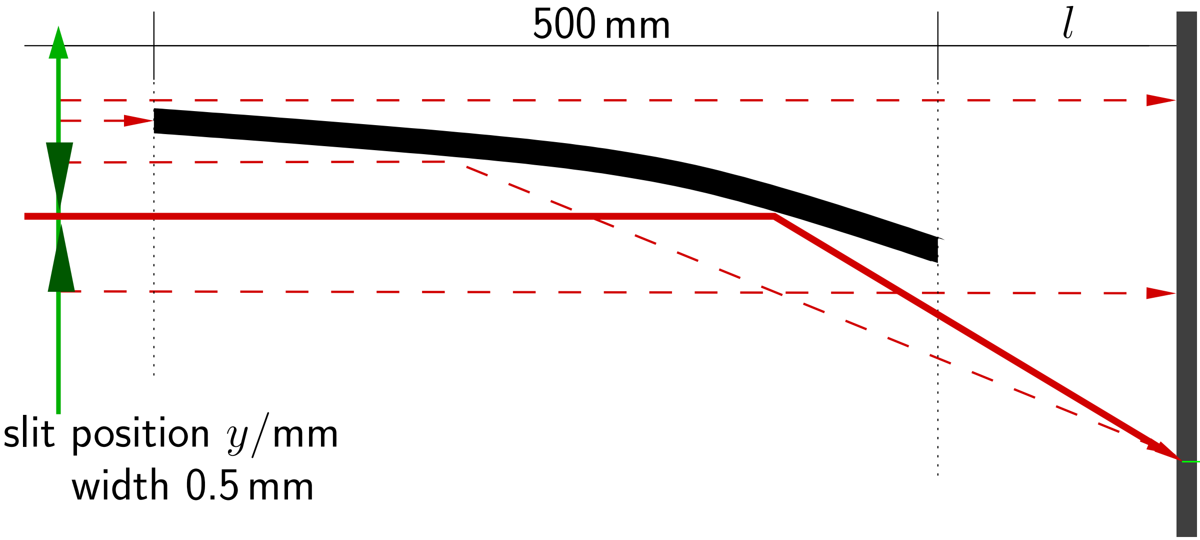

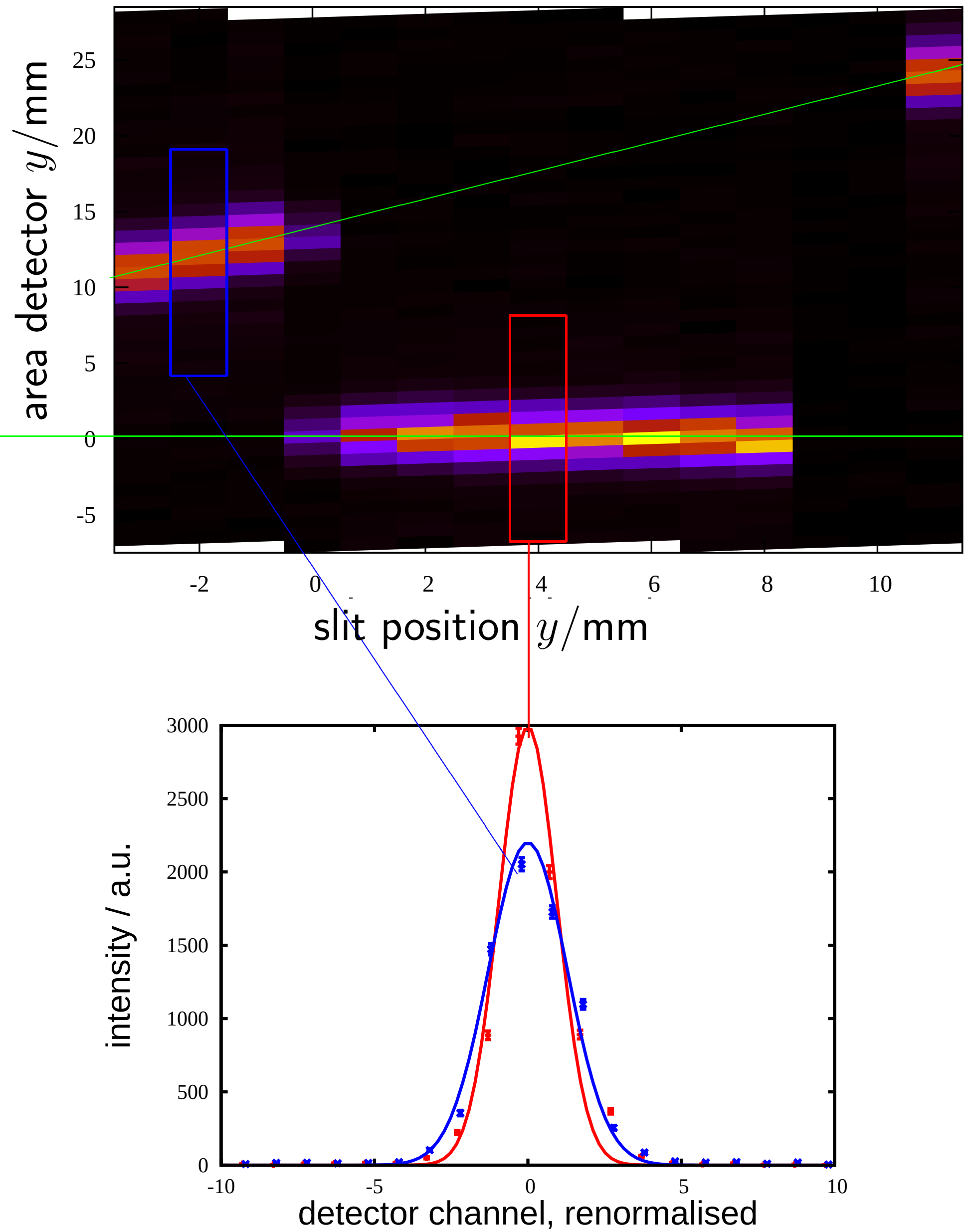

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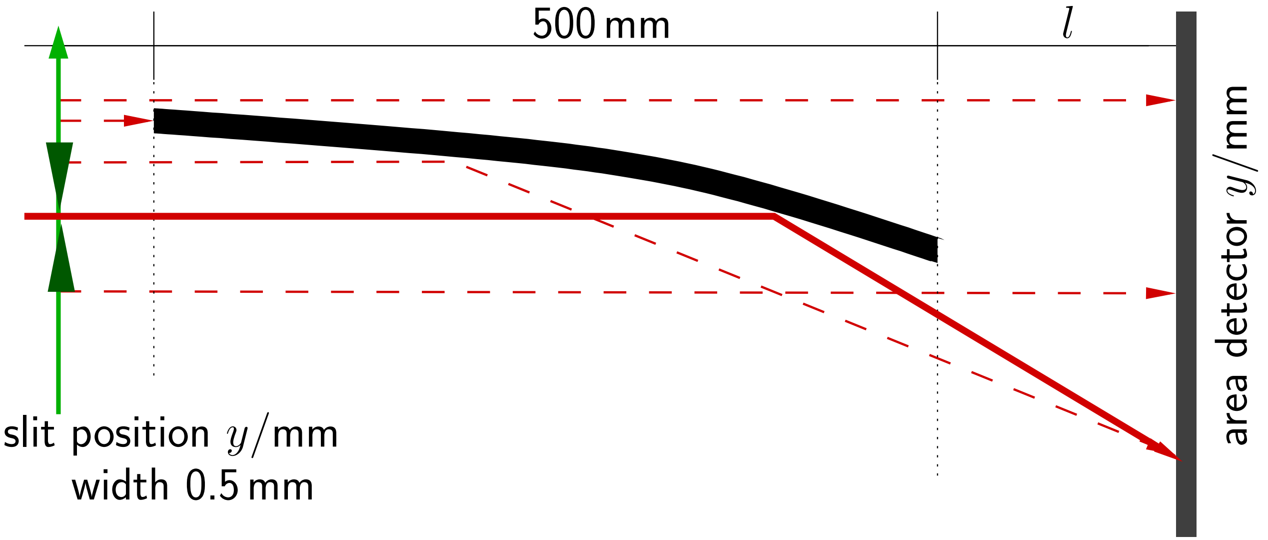
a 8 mm wide beam is focused to <0.8 mm
with a yield of almost 100%



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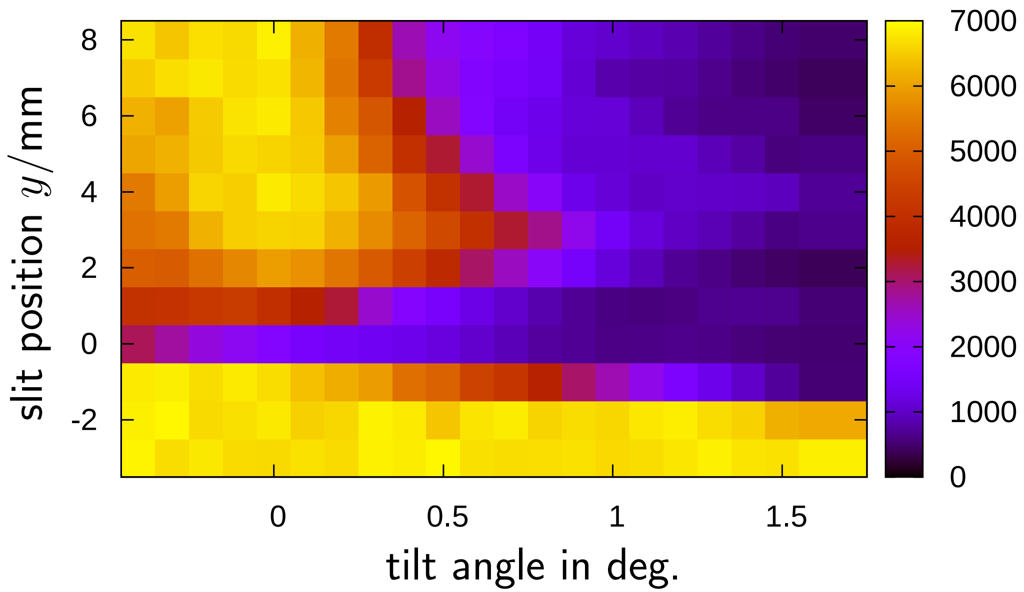

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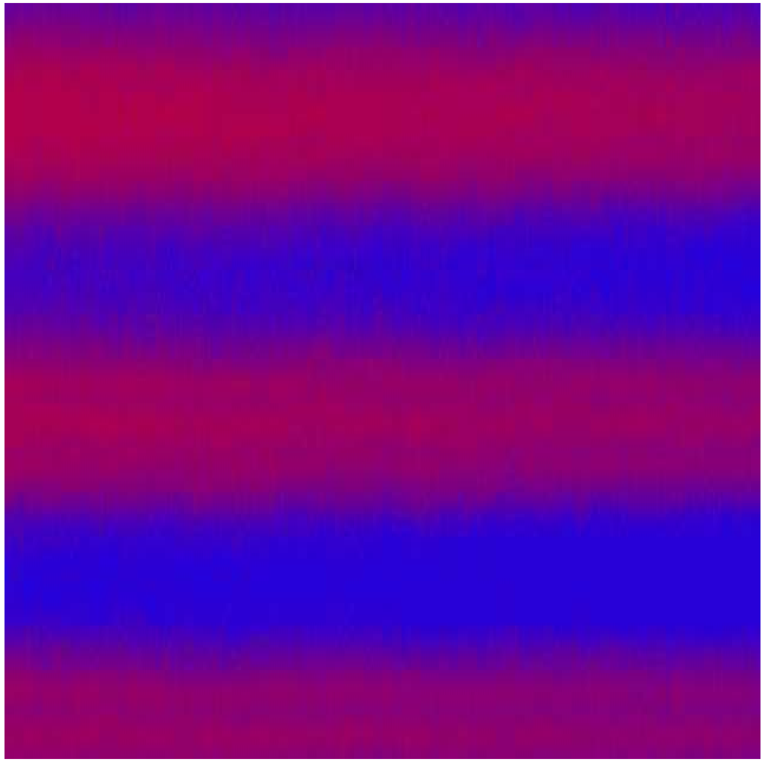
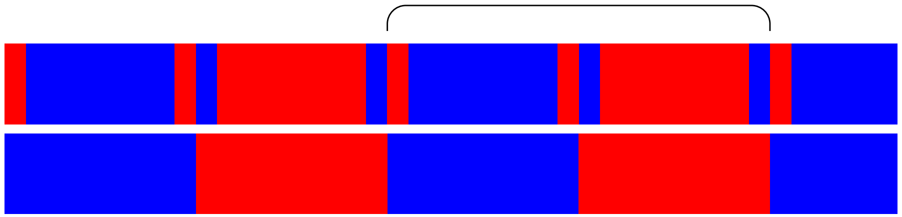
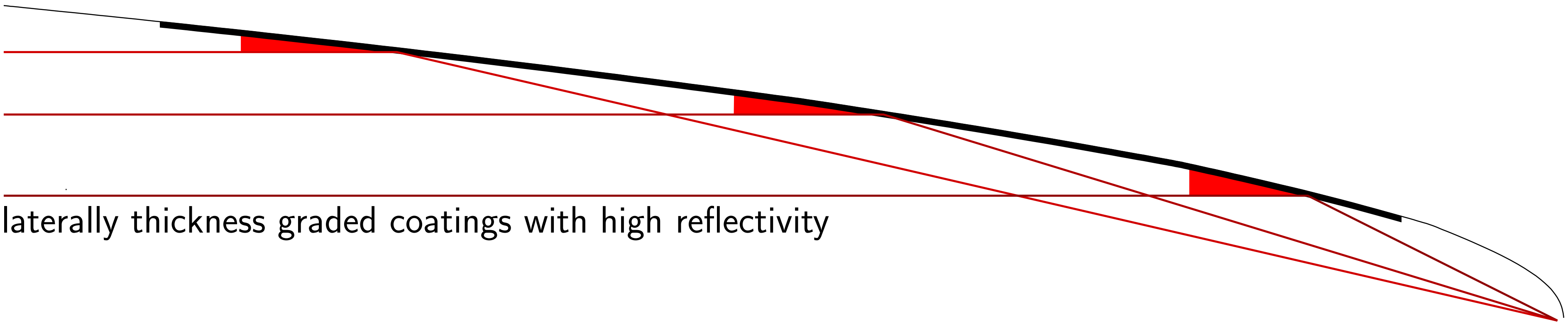


quasi-sinusoidal density profile

monochromator with suppressed higher orders





laterally thickness graded coatings with high reflectivity