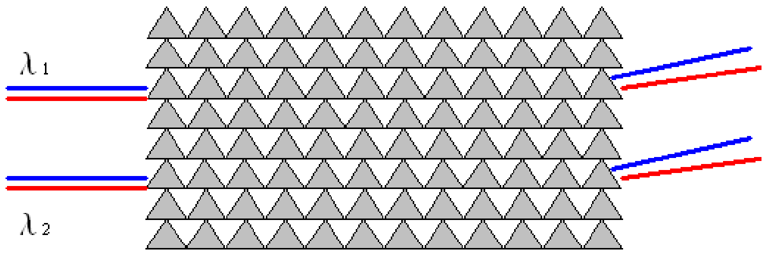
HZB Helmholtz Zentrum Berlin

Refractive neutron optics for energy analysis and focusing

Thomas Krist

Energy analysis can be achieved by **dispersive optics** like refractive crystals or a magnetic field gradient.

Idea: Use stacked prism arrays to encode the neutrons wavelengths:

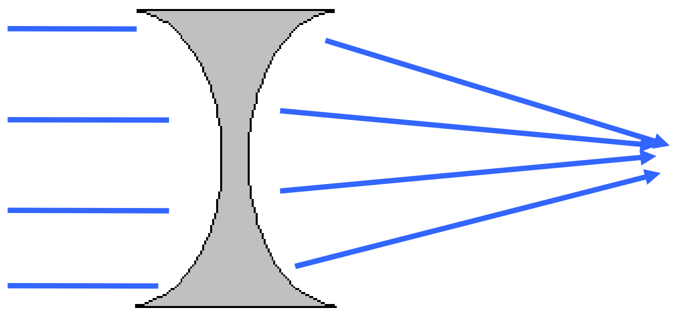


Important parameters:

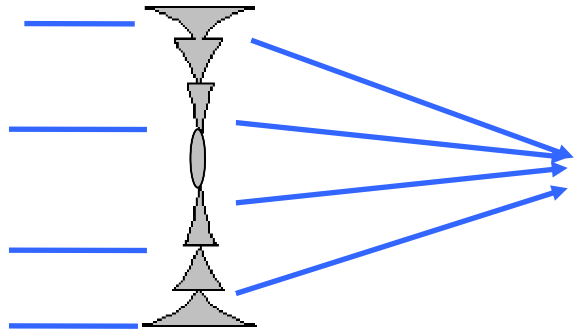
- material of the prisms
- geometry of the prisms
- height of the prisms
- length of the EA

} transmission and resolution

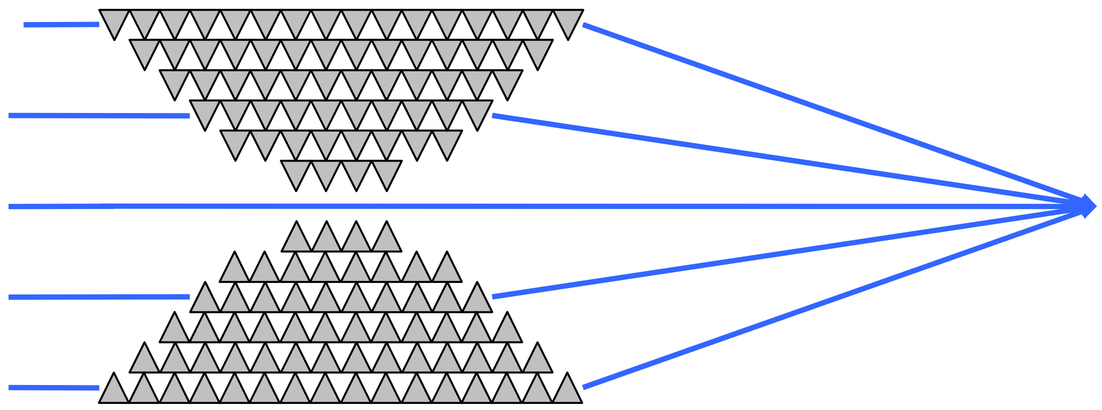
- **Types of lenses**



Biconcave focusing neutron/x-ray lens



Fresnel lens for neutrons/x-rays



Prism or „Clessidra“ lens for neutrons/ x-rays

$n = 1 - \delta - i\beta$ Index of refraction

Element	$\delta/(10^{-6})$	$\beta/(10^{-12})$	$\frac{\delta}{\beta}/(10^{5})$
C	28.7	0.44	65.12
Be	36.8	1.20	30.71
MgF_2	19.3	3.67	5.25
Pb	11.8	6.00	1.97
Si	7.9	9.16	0.86
Ni	36.9	620.77	0.06

Dispersion and absorption of different elements for wavelength 4.9Å

Properties of the material:

- high refraction power
- small absorption
- small incoherent scattering
- easy to treat and fabricate
- inexpensive

⇒ Magnesium fluoride and silicon might be good candidates for a focusing and energy analysing device.

Properties of the sample

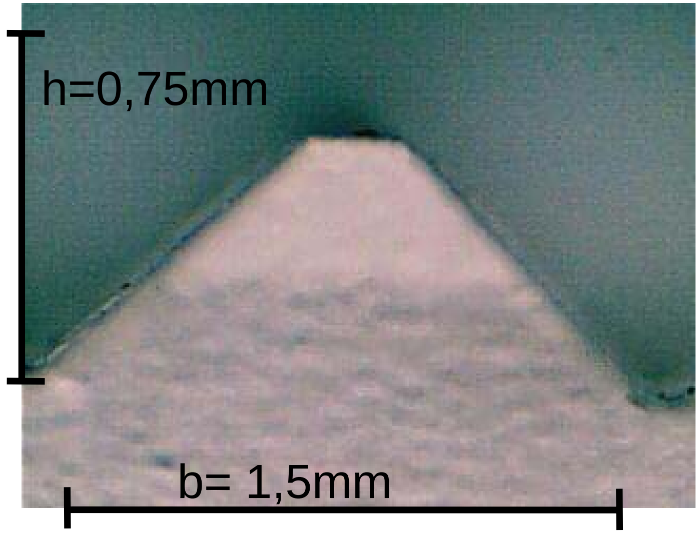
- $50x20x2mm^3$ single crystal block
- Upper 0.5mm with a prism structure
- 33 prisms, each with an angle of 45 deg to the basis of 1.5mm width

(for wavelength 4.9Å)

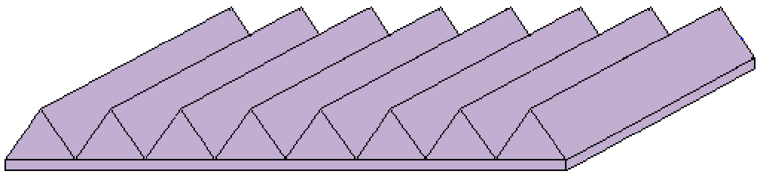
Index of refraction: n = 0.9999804 critical angle: $\Theta_{\chi\rho\iota\tau}$= 0.358 deg

deflection per prism: Θ=0.0022 deg

Attenuation: μ = 0.03 cm^{-1}



Microscopy picture of a single prism of the magnesium fluoride prism array



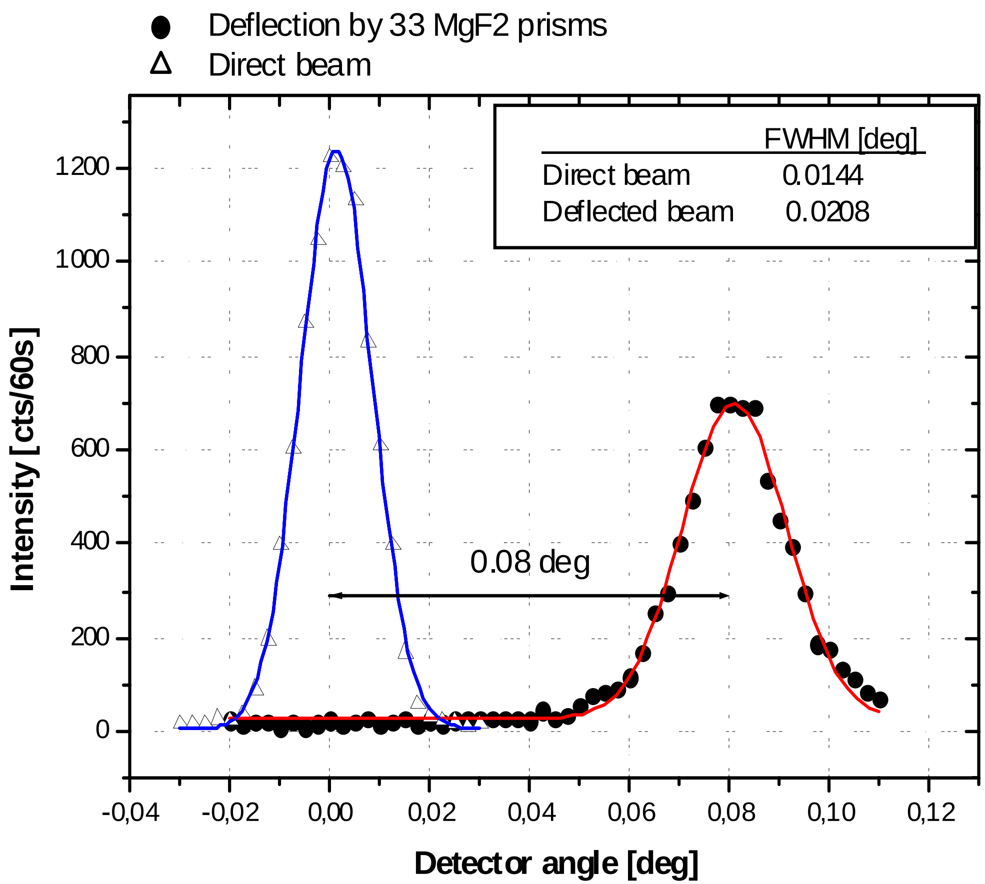
Schematic description of the whole sample

Refraction and transmission

- Angle of refraction: 0.08 deg
- Increase of the beam width: 0.015 deg
- Angular resolution: 0.02 deg
- Total transmission: 86%
- Peak transmission: 54%
- Refr. angle* Peak

Transmission:

- **0.047°**
- Attenuation: 0.055 cm^{-1}
- Attenuation by the pure material: 0.03 cm^{-1}



Good refraction, but increase of the beam width.

Properties of the sample

- 40 x 65 x 0.5 mm^3 single crystal block
- 92 prisms, each with an angle of 54.7 deg to the basis of 0.7mm width

➡

(for wavelength 4.9Å)

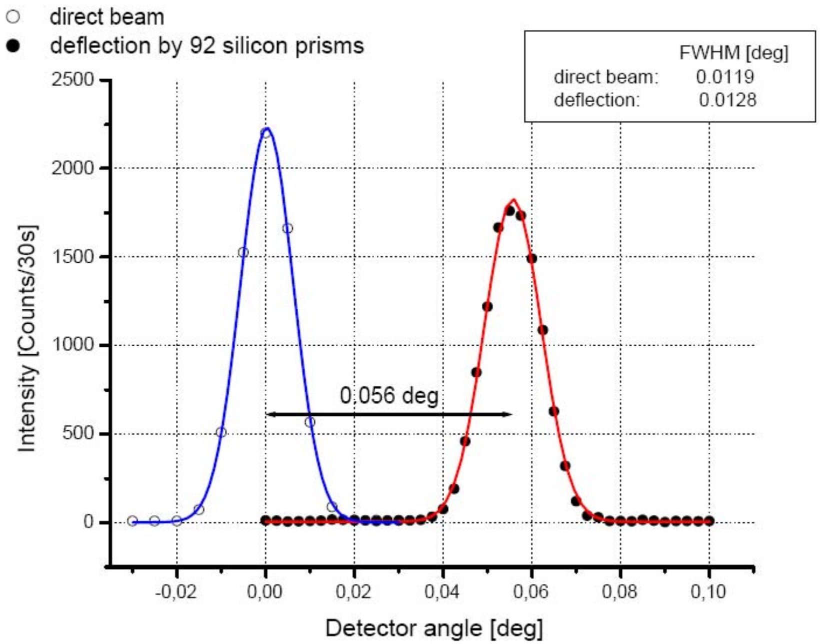
Index of refraction: n = 0.999992

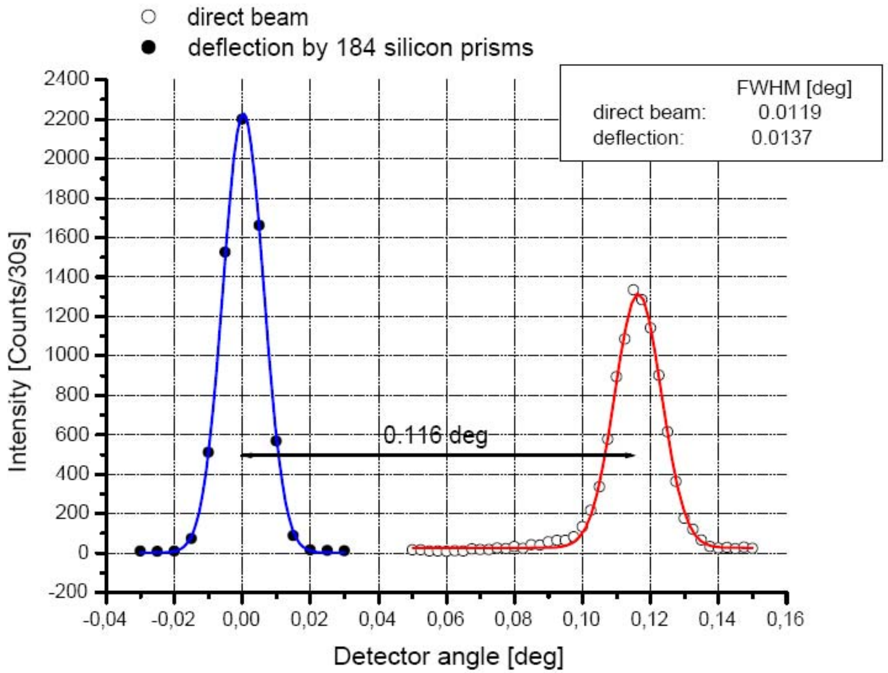
critical angle: Θ_{crit}= 0.23 deg

deflection per prism: Θ=0.00064 deg

Attenuation: μ = 0.032 cm^{-1}

Refraction and transmission



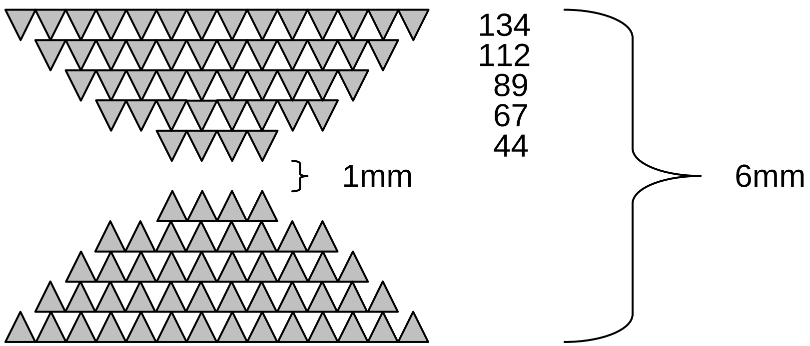


- deflection: 0.056 deg
- increase of the beam width: 0.005 deg
- total transmission: 88%
- peak transmission: 82%
- attenuation coefficient: 0.029 cm^{-1}
- defl. angle* peak transmission: **0.046°**

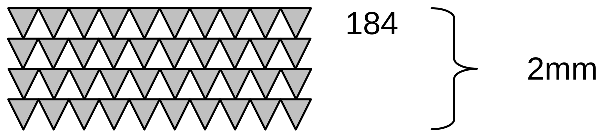
- deflection: 0.116 deg
- increase of the beam width: 0.007 deg
- total transmission: 77%
- peak transmission: 59%
- attenuation coefficient: 0.030 cm^{-1}
- defl. angle* peak transmission: **0.070°**

Conclusion and Outlook

- Silicon prisms are good candidates for optical devices, because of the high transmission and the easy fabrication process.
- Going to finer structures (250µm – 150µm thickness) will allow us to achieve higher deflections at the same transmission rate.
- Design of the first prototypes:



Focal length: 200cm



Angular resolution: 0.11 deg

Thanks for your attention!