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Dynamical focusing of polychromatic beam using Bent Laue Crystal

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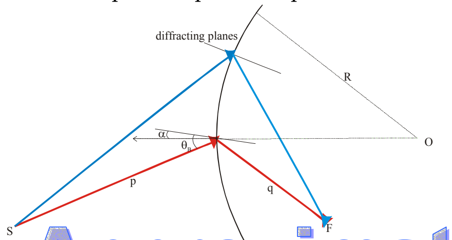
ABSTRACT

The main limitation in Laue geometry for the achievement of a small focus size, is the focus broadening due to the intrinsic Darwin width and to the spread of the beam in the Borrmann triangle caused by the propagation inside the crystal. We present here a method, based on dynamical focusing, allowing to improve the quality of high energy polychromatic focusing by bent crystals in Laue geometry. This completely wave-optical approach combines the propagation of the wave in the curved crystal, with the equations of Takagi1-Taupin, and for the propagation in the free space. Experiment performed on BM5 at ESRF show an excellent agreement with theory [1].



Geometrical focusing

Geometrical focusing is based on the lens equation presented in many articles[3]:

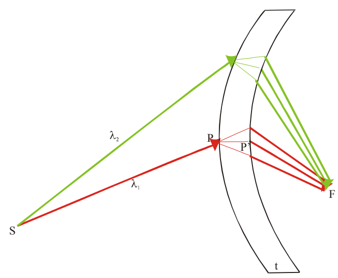
$$\frac{2}{R}=\frac{\cos(\theta_B-\alpha)}{p}+\frac{\cos(\theta_B+\alpha)}{q}=\frac{\cos\varphi_0}{p}+\frac{\cos\varphi_h}{q} \qquad (1)$$

Approximations in geometrical focusing

Infinitely narrow beams: incoherent source-poits approximation

Incident radiation on the entrance surface is considered as to be composed of rays each associated to the wavelength obeying the Bragg law at the corresponding entrance surface point.
Apparently this is an approximation because actually the crystal "sees" the whole accepted angular divergence, given approximately by the Darwin width, for every wavelength
Description of incident beam as composed by a distribution of incoherent source-point is only apparently an approximation because from polychoromaticity derive incoherence.
Incoherent source points, equivalent to consider infinitely narrow beam, correctly describe the incoherence of a polychromatic incident beam [2-6].

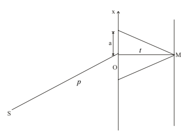
Infinitely thin crystal: spreading inside the Borrmann triangle



Considering the thickness of the crystal we have a spreading over the Borrmann trinangle.
We are interested in finding the conditions for which the diffracted wave from the point-source P located on the entrance surface converges to a distance q of the geometric focus.

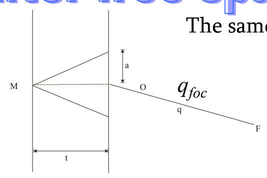
Focusing of Borrmann triangle after free space propagation

A parallel slab of perfect crystal focus a divergent beam for a suitable thickness [7,8]



$$t_{foc}=p\frac{\sqrt{\chi_h\chi_{\bar h}}}{2\sin^2\theta_B\cos\theta_B}$$

The same is true in reciprocal geometry [1]



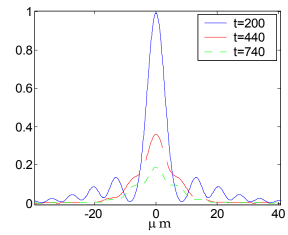
$$q_{foc}=\frac{2\sin^2\theta_B\cos\theta_B}{\sqrt{\chi_h\chi_{\bar h}}}t$$

In symmetric Laue geometry $\vec h\perp\vec u$, wave propagates inside a cylindrically bent crystal as in an unbent crystal

p, q → Geometrical focusing → Bending radius → Dynamical Focusing → Focusing thickness

Si 111
25 keV

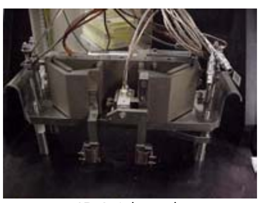
p=40 m q=1.2 m
R=2.9 m



Experimental results on wedge crystal

BM 5 - E.S.R.F.

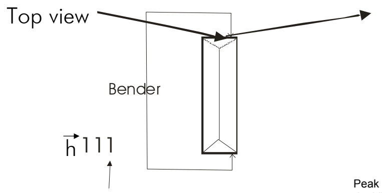
p= 40 m q=1.2 m

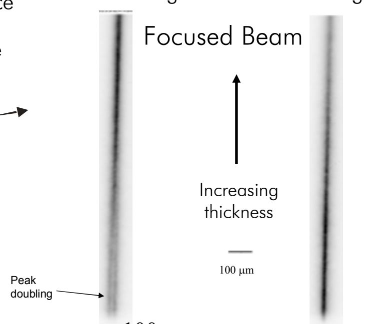


ID24 bender

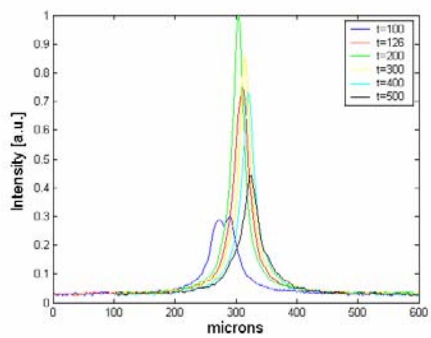
We use a wedge shaped crystal to test the thickness dependence

Focusing in the horizontal plane





Cross section plot



t=200 μm
FHWM =15 μm

Deconvoluted source size FHWM 6 µm

References

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