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Nuclear Instruments and Methods in Physics Research A 543 (2005) 375–380

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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Fixed exit DC-monochromator of *general position* for side (or top) beam line

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Available online 2 March 2005

Abstract

We develop an idea of a fixed exit double-crystal monochromator of *general position* (or skew DC-mono), in which the lines of entering and exit beams (both being fixed) do not lie in one plane, i.e., are in general position.

Both cases of identical and not identical crystals are considered, and exact solutions are obtained describing valid positions and orientations of both crystals. Special attention is paid to the case of small lattice mismatch between the first and the second crystal (e.g., due to temperature difference) and small angle of "skewness" (that is to say, an angle between skew lines of entrance and exit beams is much less than unity).

We also derive some useful formulations describing beam profile change after two reflections (whose reflection planes are nonparallel).

PACS: 07.85.Qe; 41.60.Ap

Keywords: Monochromator; Side beam line; Synchrotron radiation

1. Introduction

As a rule, side beam lines of synchrotron radiation use a single-crystal monochromator providing a monochromatic beam of fixed energy (or beam energy can vary only in a very small range) [1]. The new functionality of energy tuning in a large range would be an important feature raising user value of a side beam line (and multiplying the use of an insertion device and storage ring as well). The possible way to attain this feature is a fixed exit double-crystal monochromator of *general position* (or skew DC-mono, where lines of entering and exit beams do not lie in one plane) considered in this communication. As we will show, this results in the first and the second crystal not being identical.

Therefore, such a crystal pair as diamond (1 1 1) and Ge(2 2 0), or Si(hkl) and Ge(hkl) could be

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0168-9002/$ - see front matter
doi:10.1016/j.nima.2005.01.259

used—without third optical element (mirror or multilayer) required in plane arrangement in order to compensate the lattice mismatch between crystals [2]. The desire to use nonidentical crystals is explained by the fact that the first and the second crystals are working under very different thermal loads and should meet different requirements (especially when the second crystal is in use for sagittal focusing).

As we will see, in (slightly) skew monochromators with equal crystals, small changes of lattice spacing because of thermal expansion of the first crystal could be compensated through small corrections in crystal positions and orientations. We believe that a radiant cooling of (or heat abstraction from) the first crystal could be preferable in some conditions, especially in view of forthcoming synchrotron radiation sources of the fourth generation.

Such a non-planar approach to DC-mono setup opens up evident possibilities to have a set of skew monochromators shedding rays of different energy on the same sample.

2. Skew DC-monochromator (with fixed exit)

Let us consider two skew lines in Fig. 1, x and x', which indicate incoming and outgoing light beams and serve as guide lines (or rail guides) for two ideal mirrors placed at points A and A'. It is possible to orientate the first mirror so as to throw a reflected light spot to point A'; in turn, the second mirror can be oriented to redirect a double-reflected light beam along outgoing line x'.

If mirrors are not ideal, but instead some ordinary crystals serve to reflect X-rays, then their angles of reflection (Bragg angles) should be coordinated to match their pass bands. This requirement leads to one equation for x and x' having the form $F(x,x')=0$. So the crystal positions should be coordinated according to this equation.

Let the minimal length between skew lines x and x' (i.e., between points O and O', see Fig. 1) be taken as a unit of length; $h=1$. Then we obtain the following coordinates for the points A and A':

$$A=(x,0,0), \quad A'=(-x'\cos\alpha,\ x'\sin\alpha,\ 1). \tag{1}$$

Here x (and x') is a length measured from the origin O (and O'), that is a length of the line segment A–O; α is a skew angle formed by the projection of skew lines along the segment O–O'.

Using Eq. (1), we find the unit vectors along parts of the beam trajectory, see Fig. 1:

$$\vec{a}=(-1,\ 0,\ 0), \quad \vec{b}=\frac{(-x-x'\cos\alpha, x'\sin\alpha,\ 1)}{\sqrt{x^2+x'^2+2xx'\cos\alpha+1}},$$
$$\vec{c}=(-\cos\alpha,\sin\alpha,0). \tag{2}$$

The equations for Bragg angle θ and roll angle φ (conceived as the angle between reflection plane,

$$\{\vec{a},\vec{b}\}, \quad (0,x'\sin\alpha,1)\in\{\vec{a},\vec{b}\}$$

and xz-plane) of the first crystal are now obtained easily using Eq. (2):

$$2\sin^2\theta = 1-(\vec{a}\cdot\vec{b}) = 1-\frac{x+x'\cos\alpha}{\sqrt{x^2+x'^2+2xx'\cos\alpha+1}},$$
$$\tan\varphi = x'\sin\alpha. \tag{3}$$

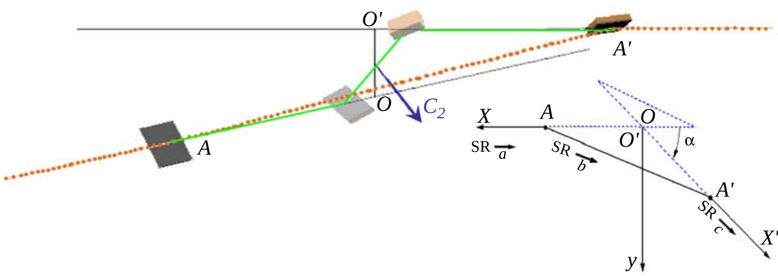

Fig. 1. Fixed exit DC-mono of general position (skew mono)—illustrating outline and top view.