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Design of a High-Precision
Double Crystal Tunable Monochromator

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ABSTRACT

This paper describes a UHV-compatible double crystal monochromator with independent drives for 2 linear and 2 angular crystal motions. Precise angular crystal positioning is achieved by using a spindle with a double gimbal mechanism, which converts linear motion of 0.1 micron to an angular motion of 0.042 arcsec. In order to decrease thermal distortions, the crystal intercepting white beam, is watercooled.

1. INTRODUCTION

The design of double crystal monochromators has received considerable attention in recent years. Various monochromators have been designed \1-5\ to meet a large number of requirements for specific experiments. The design requirements include:

- rapid tunability with a fixed exit beam position;
- good energy resolution and repeatability;
- cooling option for the first crystal;
- remote computer controlled operation;
- high vacuum compatibility.

In this paper we describe a design for a high precision crystal monochromator with an angular crystal positioning accuracy up to .042 arcsec.

A universal spindle design employs a double-axis gimbal mechanism to provide crystal rotations with high angular resolution. The monochromator includes 2 spindles: a watercooled one, whose crystal intercepts white beam, and a spindle without water-cooling.

The monochromator is equipped with a digital feedback system to adjust and maintain the required energy level.

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2. DESIGN CRITERIA

The following criteria were established:

- a. The alignment of each crystal is achieved by stepper motors independently controlling angular and linear position of the crystals. The advantage of independent steppers over the conventional system of mechanical linkages, supplemented by correcting piezoelectric actuators, is based on the ability to easily control angular and linear crystal position using a digital feedback system. This feedback system could also be used to correct the beam position due to closed orbit distortions of the storage ring \6\.
- b. Angular positions of the crystals will be accurate to within 0.042 arcsec. This is accomplished by using a double-axis gimbal mechanism, manipulated by precision linear actuator with an accuracy 0.1 micron via a long connecting bar.
- c. Exit beam position must be maintained within 1 micron. It can be controlled by the translation of the crystal along the beam axis, or perpendicular to it.
- d. In order for the monochromator to provide a range of different energies, the longitudinal distance between spindles should be adjustable by a least 100 mm.
- e. Each spindle should have the capability of withdrawing the crystal from the line of the beam.
- f. The spindle mounting a crystal, intercepting white beam, will be provided with a crystal water cooling system.
- g. The monochromator should be UHV compatible.

3. MECHANICAL DESIGN

Figure 1 shows the general layout of the monochromator, which consists of a watercooled crystal spindle, intercepting the white beam (1), and non-watercooled crystal spindle intercepting reflected beam (2), positioned in the housing (3), 2 side plates (4,5) and 2 shoe plates (6,7) are used for installation on the supporting stand.

A water-cooled spindle (fig. 2) is mounted on a 13.25" dia. conflat flange (8) fixed to a mating flange on the housing (9).

The spindle design includes three mechanisms:

- a mechanism for crystal horizontal linear motion along the beam axis, which provides the proper distance between crystals according to a required energy level;
- a mechanism for crystal vertical linear motion, which is used to retract the crystal from the beam line or to correct vertical position of the crystal;

- and a double-axis gimbal mechanism for changing the Bragg angle or the tilting angle by rotation about two perpendicular axes.

Linear horizontal motion is provided by a slide (10). The fixed base of the slide (10) is rigidly bolted to the flange (8) by means of plate (11) and extender (12). The remainder of the spindle assembly is attached to the movable slide carriage (10).

Vertical motion of the crystal is provided by the stepper motor (13), driving an actuator (14) with a lead screw (15). The lead screw in turn drives a cage (16), which is guided by the ball bushings (17) riding on two shafts (18), secured to the frame (19). The frame also supports the stepper motor (13) and the actuator (14). A tubular column (20) connected to the top plate of the cage (16), transmits both vertical and horizontal motion to the gimbal mechanism and crystal (25). A bellows (26) is welded to both the stationary housing and the column (20) to provide a vacuum boundary, while allowing both horizontal and vertical motion. The travel range of each crystal horizontally is ± 25.4 mm and vertically 25.4 mm. For the monochromator the range of adjustment along the beam axis is ± 50.8 mm, or over 100 mm. The accuracy of the motion in both directions is 1 micron. Two angular motions of the crystal are provided by the double gimbal mechanism, mounted on the base (21) plate (fig. 3). The gimbal mechanism also includes an intermediate plate and a crystal plate.

The intermediate plate (22) is mounted on the base plate (21) via two flexure pivots (27). The crystal plate (23) is mounted on the intermediate plate via identical set of flexure pivots with their axis perpendicular to the first set. A water-cooled molybdenum block (24), supporting the crystal (25) is fixed to the crystal plate.

A liquid indium-gallium eutectic alloy interface is used between the molybdenum block (24) and crystal (25) to improve the thermal conductance.

The molybdenum block (24) is rigidly fixed to the connecting bar (28) through the flange (29). A welded bellows (30) between the flange (29) and the base plate (21) provides a vacuum seal and allows angular motion of the crystal (25). Two tubes (35) for water cooling of the molybdenum block (24) are installed inside connecting bar (28). Angular motions of the crystal are produced by two precise linear actuators (33), orthogonally positioned (fig. 4) on the bottom plate of the cage (16). The actuators move the bar (28) through a spherical ball (32), positioned on its end. In order to eliminate any play, the V-shape plate (31), ball (32) and pivots (27) are preloaded during the assembly of the spindle. The angular crystal position accuracy is defined by the accuracy of a linear actuator (0.1 micron) and the length of the arm (488 mm), which result in an accuracy of .0423 arcsec.

Each spindle can move the crystal along the beam axis ± 25.4 mm and rotate it ± 2.5 grads. In other words, a monochromator can provide a total 101.6 mm distance change between crystals. For the design, shown in fig. 1, the vertical offset between incoming and outgoing beam is 15 mm; the size of crystal support plates will accommodate a 120 x 120 mm Bragg or Laue crystal, and the design is UHV compatible.

A position monitor sensing the location of the output beam provides feedback to the actuators through a digital control system to maintain a proper crystal positioning.

4. REFERENCES

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