

**DISCLAIMER**

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The positioning accuracy of the control systems for the SRC six and ten meter toroidal grating monochromators required investigation due to poor system performance. Test results indicate the control system on the SRC six meter TGM has the ability to position gratings with an accuracy six times better than the theoretical resolution of the monochromator. In addition, the control system on the ten meter TGM has the ability to position the gratings with an accuracy two times better than the ten meter theoretical resolution.

Method of Testing

The monochromator grating control systems under investigation are computer interfaced and stepper motor driven. The control systems include a number of interrelated items essential to the automation of the systems. Automation of the systems allows rigorous data acquisition. Stepper motors and stepper motor drivers, directly coupled to ball screws and sinusoidal arms, control the grating displacements. Bi-directional counters indicate linear displacements of the ball screws that contact the sinusoidal arms. Grating Chamber Interface Centers (GCIC) interface the beamline computers with the stepper drivers and bi-directional counters.

A PASCAL subroutine, recently added to the existing Monochromator Control System software, carries out positioning tests and then calculates system performance from the test results. Each positioning test is a series of equal steps that consist of: (1) a destination calculation, (2) pulses sent to the stepper motor driver, (3) acquisition of the position from the bi-directional counter and (4) the response calculation.

Based on the quantity of pulses to be sent to the stepper motor driver, the destination calculation determines the expected position that the grating will occupy. Pulses are then sent to the stepper motor driver. After sending the pulses to the driver and the stepper motor has stopped turning, the grating position is acquired from the bi-directional counter and stored in memory. This grating position will be the following step's starting position.

The difference between the grating position and the expected destination is the positioning error and reflects the accuracy of the grating control system.

Results

A typical response curve for the ten meter toroidal grating control system, Figure 1, shows random error throughout the suggested displacement of the system. In this particular response curve, a single step displacement consists of 1000 pulses or 0.060 millimeters. 'Spikes', up to three times as large as the next smaller displacements, are intermittent and suggest an error in data transfer. Replacement of the bi-directional counter on the ten meter toroidal grating monochromator eliminated the 'spikes' in the response curve, as shown in Figure 2.
The six meter SRC TGM has an oscillatory response pattern, as represented in Figure 3, with 2000 pulses (0.120 millimeters) per step. Examination of the response curve reveals approximately 44 oscillations occurring in the travel distance of 66 millimeters, or a period of 1.5 millimeters for each oscillation. The ball screw pitch for the control system is 1.5 millimeters per revolution; therefore, a slight error in the ball screw pitch would explain the oscillations of position error. The amplitudes of position error shown in Figure 3 are acceptable, since the amplitudes are less than the ball screw manufacturer’s error amplitude of five microns.

The mean value of ten positioning tests per grating approached zero, on the two beamlines. Since the mean values are negligible, the standard deviations define the positioning abilities of the grating systems. Column three, of Table 1, contains the positioning abilities of the beamlines.

Columns two and one, of Table 1, contain the smallest theoretical resolutions of the 6 and 10 meter toroidal grating monochromators and the energies at which these resolutions take place, respectively. In each case, the positioning ability is smaller than the theoretical resolution. In addition, the theoretical resolution values, used for comparison, do not account for any aberrations; therefore, the differences between positioning abilities and corrected resolution values are greater still.

Conclusions

The positioning ability of the ten meter TGM approaches the theoretical resolution, defined here as greater than one fifth of the resolution. Only with an upgrade of the grating control mechanism would an increase in positioning accuracy be accomplished.

The gratings of the six meter SRC TGM control system can be positioned to within ±0.005% of a desired energy.

Modifications made to the Monochromator Control System program now allow for input of system sensitivity. System sensitivity is the largest acceptable displacement from the desired grating location, during a scan. Two limiting factors of system sensitivity are: (1) the resolution of the bi-directional counter and (2) the resolution limit of the monochromator. A system sensitivity smaller than the counter resolution is not physically acceptable for a functioning control system. System sensitivity less than one fifth the resolution of the monochromator will not allow any better data acquisition.
Figure 2

SYSTEM RESPONSE 10 m TGM LEG

HEIDENHAIN DISPLACEMENT (mm)

POSITIONING ERROR (mm)
SYSTEM RESPONSE SRC 6 m TGM LEG

Figure 3
<table>
<thead>
<tr>
<th></th>
<th>Energy</th>
<th>Energy and Displacement (1)</th>
<th>Positioning Ability</th>
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</table>
| **10 m TGM**
  LEG     | 200 eV*      | 0.0038 mm                  | 0.0018 mm***        |
  gc (2)  | 4.0605       |                            |                     |
  os (3)  | 0.03539      |                            |                     |
| **MEG**  | 310 eV*      | 0.0028 mm                  | 0.0011 mm***        |
  gc      | 2.7236       |                            |                     |
  os      | 0.0191       |                            |                     |
| **HEG**  | 660 eV*      | 0.0027 mm                  | 0.0012 mm***        |
  gc      | 1.8124       |                            |                     |
  os      | 0.04082      |                            |                     |
| **6 m TGM SRC**
  LEG     | 9 eV**       | 0.0218 mm                  | 0.0020 mm***        |
  gc      | 28.1268      |                            |                     |
  os      | -0.3523      |                            |                     |
| **MEG**  | 26 eV**      | 0.0186 mm                  | 0.0016 mm***        |
  gc      | 9.8373       |                            |                     |
  os      | -0.3057      |                            |                     |
| **HEG**  | 75 eV**      | 0.0163 mm                  | 0.0024 mm***        |
  gc      | 3.3719       |                            |                     |
  os      | -0.3268      |                            |                     |


*** Standard Deviation Data

(1) conversion equations - d mm / d eV = 12398.52 / (grating constant[ge] eV
(2) gc - grating constant (Å / mm)
(3) os - grating zero order offset (mm)