Nuclear Instruments and Methods in Physics Research A 649 (2011) 97–100

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Photon-beam stabilization systems for the MX2 beamline at LNLS

Lucas Sanfelici *, Fernando de Mattos

Brazilian Synchrotron Light Laboratory, National Center for Energy and Materials Research, Campinas – SP, CEP 13.083-100, Brazil

ARTICLE INFO

Available online 16 December 2010

Keywords:
Beam stability
Control systems
Ground motion
LNLS
Beamline
Diagnostics
Protein crystallography

ABSTRACT

The MX2, a wiggler beamline dedicated to macromolecular crystallography, started routinely operating for users in 2007. Late in the commissioning phase, several experiments started to be conducted in order to characterize photon-beam stability. At that time, position movements of typically 150 μm per shift and severe energy drifts reaching 0.8 eV/h were observed at sample position, which would certainly spoil the MAD experiments. The severity of this scenario for a recently delivered beamline led us to install temperature sensors and inclinometers along the optical hutch, besides performing exhaustive tests to clarify the disturbance paths. To elucidate the main instability mechanisms, three control systems for beam stabilization were considered—position stabilization, ground motion canceling and, the most important of all, temperature control for the optical hutch. Results and perspectives are presented hereafter.

1. Photon-beam instabilities

Photon-beam characteristics [1,2] such as position, intensity, energy, resolution, etc. may be affected by both endogenous factors (heating of optical elements, mechanical limitations, etc.) and exogenous (storage ring, room temperature, ground motion, etc.) to the beamline. The MX2 beamline [3] was the first LNLS beamline to be employed in large scale homemade diagnostics devices to evaluate its performance and beam stability. This uniqueness made the characterization processes more laborious and the reaction time to the stability problems longer. Since the first stability measurements (mainly vertical position and energy), 24 h patterns of recurrence were found when our team expected to find drift profiles directly related to the injections, which take place every 12 h. In fact, the observed pattern directly reflected the room temperature influence over the storage ring and/or the beamline, but drifts as large as those seen in Fig. 1 could not be understood purely in terms of girders and supports' expansion or e-beam movements; the real cause seemed to come from the floor.

In order to get more information about the optical elements' dependence on room temperature and ground motion, a set of experiments were conducted trying to clarify the instability paths. Initially, the experimental hutch was covered with a thermal insulating material, substantially reducing the presented drifts. Then a rudimentary temperature control was implemented allowing one to observe further improvements for both energy and position. Concomitantly, the monochromator and the collimating mirror were equipped with high resolution biaxial inclinometers model 711-2 A from Applied Geomechanics Inc. to quantify the contribution of each optical element to energy drifts. Naturally, a strong correlation was found between the energy drifts and the mirror pitch angle. A control system based on this correlation will be presented in a section ahead.

The crucial experiment [4] consisted of thermally isolating collimating mirror, monochromator and optical hutch, separately creating temperature ramps on each element while keeping the optical hutch temperature stable, thus evaluating the impact on energy measurements for each intentional disturbance action. These experiments revealed that the collimating mirror was about 13 times more sensitive to temperature than the monochromator considering the energy changes (1.65 eV/°C against 0.13 eV/°C). In this way, the most sensitive element in the beamline was then identified, and the installation of a definitive temperature controller for the optical hutch could finally put the drifts within acceptable levels.

2. Optical hutch temperature control

The definitive temperature control system [5] recently installed makes use of a couple of commercial fan coils, 1500 W heating/1400 W cooling capacity, to implement a current duplex control through a Honeywell UDC3500 process controller. The fan coils are supplied with chilled water from the same circuit shared by the beamlines. A dedicated electrical panel was assembled to provide power to the fan coils heaters, interface with the beamline interlock system, and equipments' protection.

According to Fig. 2, a temperature stability of 0.05 °C was achieved at the most critical points—collimating mirror and monochromator. This result is capable of enormously simplifying cause

* Corresponding author.
E-mail address: lsanfelici@lnls.br (L. Sanfelici).

0168-9002/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2010.12.069

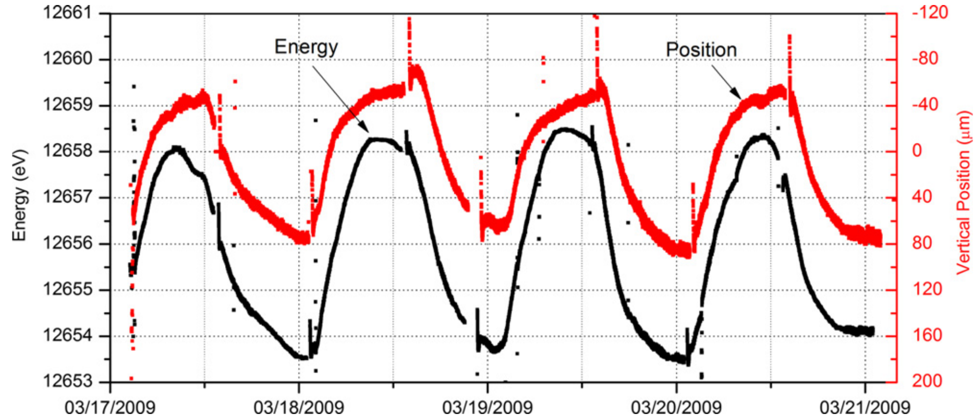

Fig. 1. Instability example. Photon-beam energy measured at SeKα absorption edge, and vertical position measured 0.5 m upstream of sample using Quad-BPM.

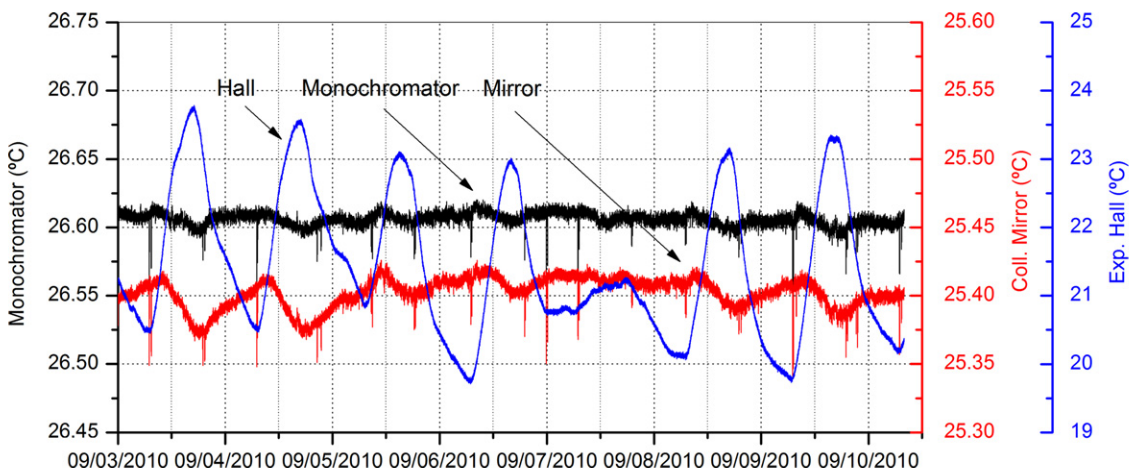

Fig. 2. Control system operating. Temperature measurements of sensors installed on energy-affecting optical elements' concrete stands, and outside optical hutch, representing experimental hall temperature.

analysis for instabilities and, of course, improving the beamline stability itself. By simplifying cause analysis we mean it makes support stands and electronics devices more reliable since there is essentially no temperature variation along time. Therefore, considering the beamline optical elements are minimally (compared to Fig. 1 drifts) affected by heat load, one can believe the remaining instabilities are associated only to ground motion nearby the beamline and e-beam motion. Energy measurements with this system operating are shown in the next section.

3. Ground motion canceling

As mentioned before, other beamline diagnostics do not agree to explain the large drifts observed, but adding ground motion as a potential cause, it could explain them. After equipping the energy-affecting optical elements supports with inclinometers the result found was made clear—as the temperature outside the optical hutch changed, the tilt of the collimating mirror could sense it proportionally, as observed during the first two days in the bottom graph of Fig. 3. During all the graph period the temperature inside the hutch was stabilized. The first day in the bottom graph depicts the influence of a tilt change in the collimating mirror due to thermally induced ground motion from outside the optical hutch. The highlighted region marks a calm ground motion period minimally impacting energy (top graph)—note its correspondence to external temperature. Extrapolating these observations one can say from the previous section's data that controlling the temperature inside the hutch softens temperature-induced ground motion around the optical elements, but there is still a remaining contribution due to outside temperature variations.

Based on the observed correlation between mirror inclination, temperature and energy, a ground motion canceling system is proposed in order to completely eliminate the effect of tilt variations of the collimating mirror, and consequently, changes in the incidence angle over the monochromator's first crystal associated to the mirror. This system would consist of feeding back the mirror's step motors to provide a small angle correction opposite to the inclination change detected by the inclinometer. A positive side-effect related to this control system operation is that beam position at the sample would also benefit from it since the angle corrections would eliminate the mirror contribution to the position drift at the experimental hutch.

The left axis of the top graph of Fig. 3 presents an energy measurement along 4 days only with the optical hutch temperature control turned on. The maximum energy variation reaches about 0.19 eV/h in the period. The right axis presents how energy would evolve if corrections to the mirror attack angle were applied based on the inclinometer readings. It is clear that day/night cycles in the energy drift are replaced by shift to shift cycles, indicating that the causes for the observed remaining drift (about 0.045 eV/h) would be now related to heat load issues originating at the storage ring