Critique of Incident

"Omission of Lead glass cover from View Port on X-12C"

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Critique of Incident "Omission of Lead Glass Cover at X-12C"

Purpose - This critique was held to evaluate the causal factors that resulted in the omission of a lead glass cover from a glass view port on Beam line X-12C. This meeting was attended by: A. Ackerman (NSLS), M. Ali (DOE), L. Berman (NSLS), R. Casey (NSLS), C. Dimino (BNL PAAA Coordinator), S. Ehrlich (NSLS), A. Levine (RCD), S. Musolino (RCD), A. Saxena (X-12C local contact), P. Siddons (NSLS)

Introduction - On 2/22/02 during the commissioning of beam line X-12C, a lead glass cover was inadvertently omitted when a beam line view port was re-secured following maintenance activities. It is an expected practice at the NSLS that all hard x-ray beam line view ports be protected with a lead glass cover to reduce radiation levels through the view port from scattered radiation. Although this non-conformance did not result in any significant radiation exposure, a similar event in other beamlines could have resulted in higher exposures. The purpose of this meeting was to critique the events leading up to the incident to determine causal factors and corresponding corrective and preventive actions, and to determine if there are any other recommendations that would improve the NSLS beam line safety program.

Sequence of Events

The events relevant to this incident are as follows:

- Prior to commissioning, a beam line safety review was conducted and a safety checklist established. This list identifies all required controls which must be confirmed before the beam can be turned on.
- 2/11 - (commissioning of X-12C begins) The storage ring beam current was limited to 25mA until adequacy of the shielding along the beam line is established. Because this restriction has major impact on other operating beam lines, X-12C was scheduled for studies for a limited time period beginning at midnight.
- During the first 8 hour run, difficulties in transmitting the photon beam through the monochromator were encountered (See figures 1 and 2 for conceptual schematics of beam line and monochromator lay-out). This prompted the installation of a view port to help align the monochromator crystal. A steel flange on the beam line port was removed and replaced with a glass view port. In hard x-ray beam lines, view ports that are conventional glass are always required to be shielded with a lead glass cover[1]. However, the view port and its lead glass cover were not added to the beam line checklist following this change in the beam line configuration.
- X-12C was authorized its 2nd 8 hour shift at 25 mA at midnight on 2/19/02. Beam line personnel still had difficulty transmitting photon beam past the

[1] The glass window provided in the unprotected view port was 0.375" thick, which from a radiation protection perspective becomes increasingly transparent to x-rays with energy greater than ~ 10 keV In hard x-ray beam lines, x-ray scattering from surfaces near a view port can be significant and require the lead glass covers to reduce radiation levels.

monochromator, but shielding evaluations completed during both studies indicated that the beam line could now be operated at normal circulating beam in the ring.

- Starting on the day shift on 2/19, X-12C operated with circulating beam up to 275 mA. Radiation surveys were performed along the beam line and indicated adequate shielding for the higher intensities.
- On the morning of 2/21 a number of activities were initiated to improve photon transmission through the monochromator, including testing of the monochromator crystal for alignment and the coating of the stop with phosphor to permit observation of the white beam.
- On the morning of 2/22, the maintenance activities were completed and the beam line configuration was re-established for operation. When the view port was reinstalled by the beam line personnel, the lead glass cover was inadvertently omitted. Checklists were used by beam line and operations staff to confirm configuration before the beam line was enabled. Radiation surveys along the beamline were performed by RCTs following restart and no levels requiring shielding modifications were observed. Neither beam line, Operations, nor Health Physics personnel noticed that the lead glass cover was missing from the view port.
- In the afternoon of 2/22, a NSLS staff member came to the beam line to help diagnose the cause of the continuing difficulties in transmitting the photon beam through the monochromator. He adjusted the position of the monochromator so that the white beam[2] would strike the phosphor. In this configuration, the phosphor off-gassed because of the white light intensity and caused a vacuum spike. This promptly tripped the user interlocks and shut the beam line shutter. During this operation, the staff member recognized that the lead glass cover was missing and reported the incident to a number of personnel, including the NSLS Safety Officer. The cover was immediately restored to the view port.
- A preliminary review was done by the NSLS Safety Officer to determine the sequence of events on 2/21-22. His discussion with beam line staff working in the area indicated that the beam line had operated for about 1 hour with the unprotected view port. He determined that during this hour that one person (A) had looked through the view port for a few minutes in the routine operating position with the white beam striking the monochromator crystal, and that the staff physicist (B) had exposure of only a few seconds with the white beam striking the beam stop. His discussions with the Radiological Control Technician who had been performing surveys during the start-up activities for this beam line led him to estimate that the dose rate during the several minute period to person A would be low. Likewise person B who was exposed to a different configuration was also expected to have received a small exposure as well. None-the-less, it was determined that additional measurements were needed to determine the dose

[2] The typical photon spectrum from a bending magnet beamline extends from visible light up to photons of a few 10s of keV. This broad spectrum is often referred to as "white" light. In this beam line, the photons $> \sim 25$ keV are not transmitted past the mirror. Therefore, the photon intensity incident on the monochromator is reduced from hard X-ray beam lines without the mirror. Most of the hard x-ray beam lines do not have such a mirror.

rates that both persons experienced to confirm the amount of exposure. At this time, the Safety Officer required that the lead glass window be added to the beam line checklist.

- On February 27, the two configurations were reestablished by Operations in conjunction with ES&H staff to estimate the exposures. The x-ray ring was again operating under normal conditions. The machine current was approximately 230 mA. With beam on the silicon crystals of the monochromator and then with beam on the copper beam stop, approximately 2 mrem/hr and 20 mrem/hr were found, respectively. Under these conditions the maximum exposure to the face of person A would be ~0.2 mrem and to person B ~ 6 x 10^{-3} mrem.

Discussion

- While this incident produced small radiation exposures, other beam lines have a higher potential for radiation exposure through an unprotected view port. As noted previously, the photon spectrum incident on the X12C monochromator did not include higher energy components. Most beamlines at the NSLS do not have an upstream mirror; therefore, higher energy photons will be present at the monochromator. In this circumstance, radiation levels could be a factor of 10 higher than the levels measured in this event. These potential radiation levels make it important to maintain configuration control of lead glass covers and other shields on the beam lines.

- There are two checklists used at the NSLS that are used to confirm beam line configuration following maintenance. Both checklists are the responsibility of the beam line staff and are reviewed with the operations and ES&H staff prior to implementation. The Beam Line Safety Committee confirms the existence of approved checklists during its beam line walk-downs for new beam lines, but does not review nor approve the content of the checklists. The beam line safety checklist is implemented by the beam line staff and is used to ensure that certain safety related items such as lead shields, lead glass covers, and exclusion barriers are in place prior to the enabling of a beam line following maintenance or modifications. The padlock checklist is implemented by the Operations Coordinators and is used to confirm that all access points to the interior of a beam line are in-place and padlocked prior to enabling of the beam line. In addition, the Operation Coordinator also confirms that the beam line staff has completed the beam line safety checklist and that the checklist is posted at the beam line.

- The X-12C beam line is managed by members of the BNL Biology Department. Beam line personnel conducting the commissioning were experienced in operating the beam line and appear knowledgeable in safety issues and NSLS requirements.

- As expected, beam line staff installed a lead glass cover when the steel flange was replaced with a view port. However, the replacement of the steel flange was not discussed with operations personnel nor the NSLS Safety Officer. Such a

discussion should have resulted in the lead glass cover being added to the beam safety checklist that was developed for this beam line. Since the view port was not on the beam line checklist, the presence of the lead glass cover was not confirmed by beam line staff when the beam was re-enabled on 2/22.

- Although beam line staff were aware that the lead glass cover was needed, it was overlooked when the beam view port was closed up following the maintenance activity. It should be noted that a near-by view port located directly above the monochromator was fitted with a lead glass cover from the beginning of the commissioning and was properly applied following the maintenance period.

- On some beamlines, the lead glass cover has been provided with a padlocking mechanism and is subject to confirmation through the padlock checklist. It may not be possible in all cases to provide a padlocking mechanism because of the physical geometry of the view port and beam line.

Causal Analysis

Following the discussion of the sequence of events, a brainstorming session including physicists, users, and ES&H Staff analyzed the event to determine the causes of this incident and to establish corrective and preventative actions.

Direct Cause

The lead glass plate was not reinstalled on the view port window at the end of maintenance on 2/22.

Contributing Causes

1. The beam line staff did not advise the NSLS Safety Officer nor the Operations Coordinators of the beam line configuration change. As a result the beam line configuration check-list was not changed and there was no required confirmation that the lead glass cover was in place when the photon beam was delivered to X12C following the maintenance period.

2. The beamlines are complex and congested. See Figure 3. These conditions, coupled with the location of the view port made it easy to overlook the lack of the lead glass cover without a rigorous inspection of beam line configuration following the maintenance activities.

3. Although the process for developing beam line checklists is well understood, the guidance for check-lists provided in NSLS PRM 1.3.5b is general and does not provide information for the content, review, approval and control of the check-lists.

Root Cause

Inadequate configuration control was exercised following the installation of the view-port and the subsequent maintenance activity.

Corrective Actions

1. Remind all responsible beam line staff of the importance of beam line configuration requirements and the importance of beam line safety and padlock checklists in the control of radiological hazards.
2. Review current NSLS policy and requirements for beam line configuration management and ensure that the following issues are adequately addressed:
    a. Items to be included in the configuration checklist
    b. Assignment of responsibility to prepare and to approve the checklist
    c. The review and approval process for changes in beam line configuration.
    d. Annual review of padlock and beamline checklists to confirm completeness of content.
    e. Coordination and integration of beamline safety and padlock checklists
3. Where possible, provide padlocks for existing and future lead glass covers and include them in the padlock checklist.
4. Conduct a review of all existing beam line safety checklists to ensure completeness.

Figure 1
Conceptual Schematic of X-12C Beam Line
Not to scale

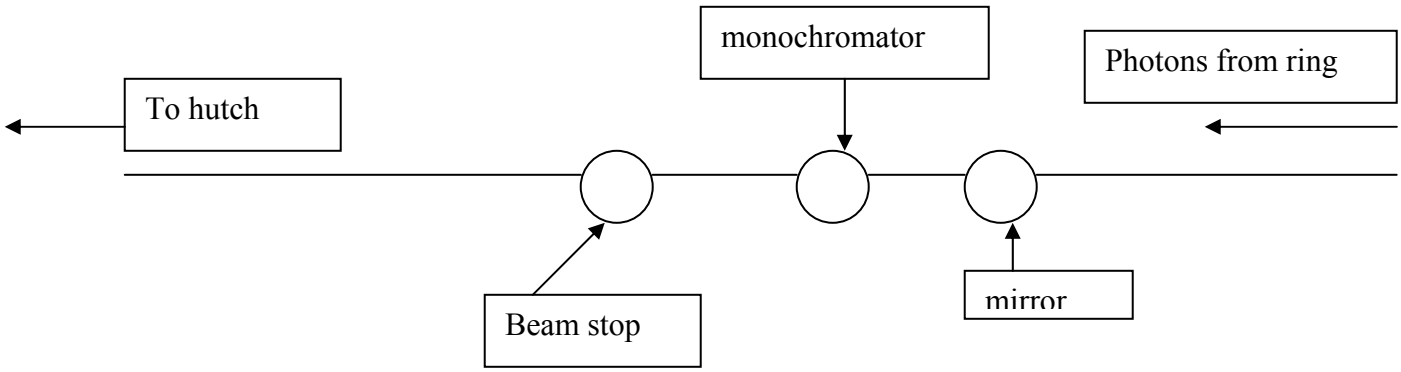

Figure 2
Schematic of Monochromator and beam stop
Not to scale

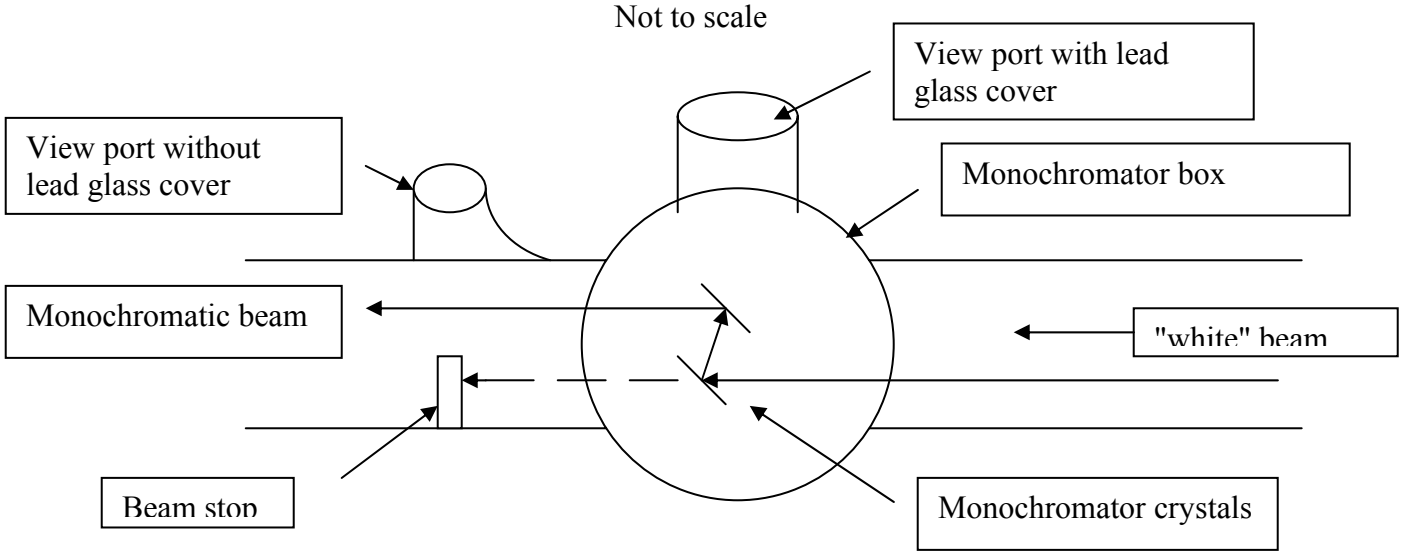

Figure 3

Photograph of X-12C Monochromator Box and View Port