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Radiation shielding study against gas bremsstrahlung for the BMIT POE3 at the Canadian light source

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ABSTRACT

A dose rate study is undertaken when gas bremsstrahlung strikes a monochromator, a copper absorber and a tungsten beam stop in the third primary optical enclosure (POE3) of the BioMedical Imaging and Therapy (BMIT) insertion device (ID) beamline 05ID-2. In the POE3, computed tomography, diffraction enhanced imaging and K-Edge subtraction monochromators are housed to conduct various diagnostic and therapeutic studies in the experimental hutch. The safety features of this beamline must be examined with great care, as this multipurpose beamline is intended for use in vivo on animals and humans.

A tungsten beam stop, two safety shutters, and a lead movable wall are placed in the POE3 for the safe operation of the BMIT beamline. However, for one particular mode of operation, gas bremsstrahlung and monochromatic X-ray beams propagate closely together until the former is stopped by the tungsten beam stop while the safety shutters remain open to allow the passage of the latter to the experimental area SOE1. It is thus imperative to know the anticipated dose rate around the POE3, especially behind the back wall and on the roof. The dose rate estimates are presented based on a realistic model of the POE3 with its safety features.

1. Introduction

The Canadian Light Source (CLS) is a 2.9 GeV, 500 mA, third-generation synchrotron facility. At present, the CLS operates with a maximum current of 250 mA. Seven beamlines in Phase I are currently in operation, and seven additional beamlines are being developed in Phase II.

The BMIT-ID beamline (Chapman, 2006; Wysokinski et al., 2011) is one of the Phase II beamlines being presently commissioned. The POE3 houses three monochromators, listed in order of location (from upstream): the computed tomography (CT) monochromator, diffraction enhanced imaging (DEI) monochromator and the K-Edge subtraction (KES) monochromator. The bremsstrahlung beam stop is placed outside the KES monochromator. This beam stop must be small enough vertically for the KES beam to be deflected above or below and for the CT and DEI beam to pass over the top of the beam stop. However, the beam stop must be thick enough to stop gas bremsstrahlung. At present the vertical distance between the CT monochromatic beam and the gas bremsstrahlung beam is 1.5 cm, centre to centre (ctc).

High-energy electrons interacting with residual molecules in the vacuum chamber generate gas bremsstrahlung. When produced in the ID straight section, highly forward-peaked gas bremsstrahlung may travel with synchrotron radiation to the experimental area. The purpose of this report is to assess the radiation levels when the gas bremsstrahlung strikes a beam stop placed in the POE3 of the BMIT ID beamline.

The monochromatic beam propagates toward the 13 cm-thick lead movable wall to which two safety shutters are attached. There are two holes on the movable wall to accommodate wide angle range of the higher and the lower energy X rays of the KES. When the DEI or CT mode is in operation, the movable wall is shifted downward so that only one window is opened to the SOE1, as shown in Fig. 1.

If various possible settings are considered, the worst case scenario might be that the CT rays are passing over the gas bremsstrahlung stop which is only 1.5 cm ctc above the gas bremsstrahlung beam. These X-rays propagate through the movable wall to the experimental area, whereas the gas bremsstrahlung is stopped by the beam stop. This bremsstrahlung stop consists of a copper absorber followed by a tungsten beam stop, as shown in Fig. 2. The dimension of the tungsten stop is (X(width), Y(height), Z(thickness))=(21.4, 1.8, 18.0) in units of cm. The hole of the movable wall has a dimension (X, Y)=(21.4, 3.0). Hence there exists an open area (X, Y)=(21.4, 0.6) over the

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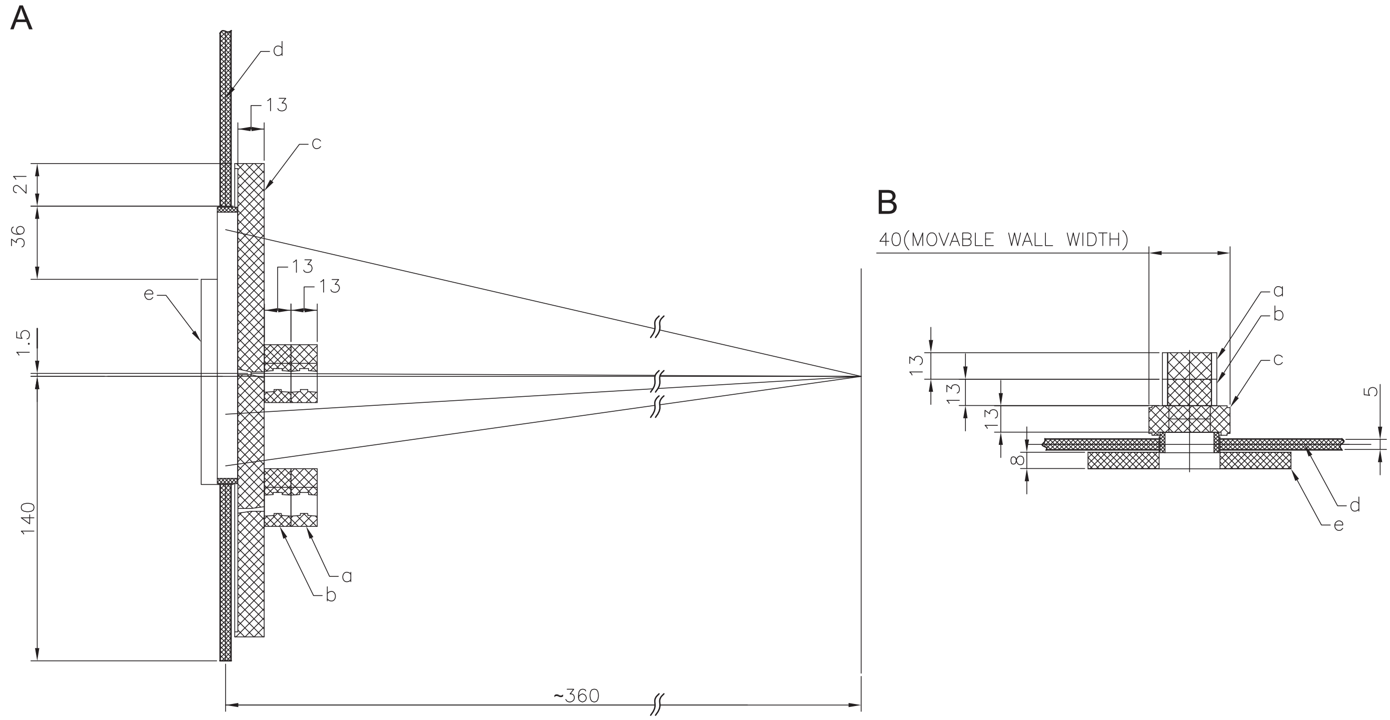

Fig. 1. Shielding setting for the CT operation. Safety shutters are in open position. (a) safety shutter SS1, (b) Safety shutter SS2, (c) lead movable wall, (d) lead back wall and (e) lead centre reinforcement. Note the small opening on the lead movable wall. The length is in units of cm.

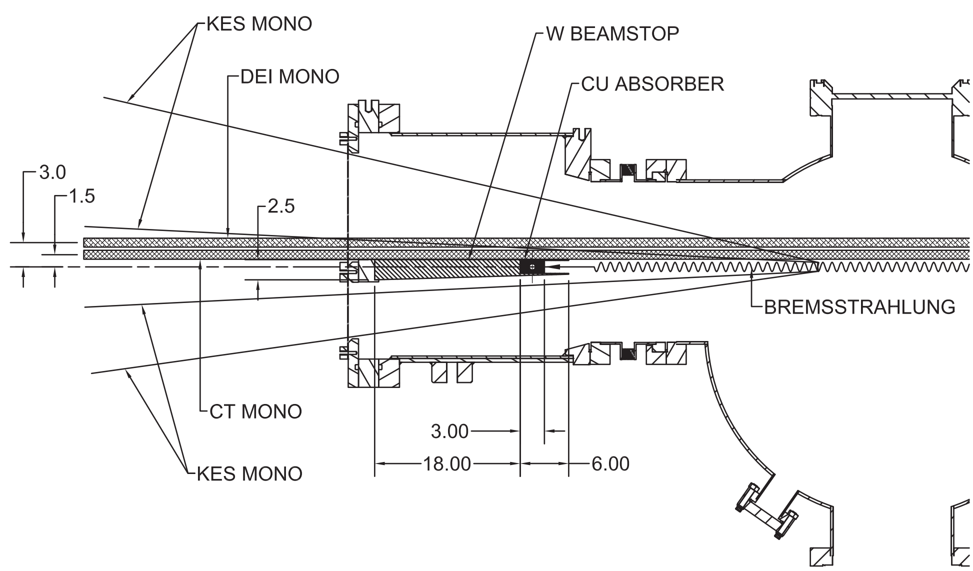

Fig. 2. Copper absorber and tungsten beam stop. Note the CT and DEI beams pass over the top of the beam stop. The length is in units of cm.

top surface of the beam stop when the CT rays are in use. The radiation that originates from the copper absorber tungsten unit could travel through that opening to the experimental floor.

Although the optical elements and the movable lead wall in the POE3 are yet to be installed, the aim of this paper is to estimate the expected dose rate behind the back wall, side wall and the roof top of the POE3. These assessments will allow for safe operation of the BMIT beamline, as this multipurpose beamline is intended for use on animals and humans.

In Section 2, the model of the POE3 structure, the beam stops and the shielding is constructed as close as possible to the planned construction of the POE3. Section 3 gives the dose rate estimates behind the back wall. The dose rates along the side wall and the roof top are given in Section 4, and Section 5, respectively. Section 6 gives the summary and conclusions.

2. Model and parameters used for dose rate estimates

The width, height and length inside the POE3 are taken as 224 cm, 360 cm and 360 cm, respectively. The elements considered from upstream in the POE3 include a silicon crystal, a copper absorber followed by a tungsten stop. There are two lead safety shutters (SS1 and SS2) which are attached to the lead movable wall. The back wall is a 5 cm-thick lead wall reinforced by an 8 cm-thick lead centre piece. The side is a 3 cm-thick lead wall