BEAMLINE SCIENTIST:
**Tomasz W. Wysokinski**
tomasz.wysokinski@lightsource.ca
306-657-3710 / 306-657-3629

BEAMLINE TEAM LEADER:
**L. Dean Chapman**
dean.chapman@usask.ca
306-966-4111

BEAMLINE ASSOCIATE:
**George Belev**
George.Belev@lightsource.ca
306-657-3814

SOFTWARE DEVELOPER:
**Denise Miller**
Denise.Miller@lightsource.ca
306-657-3815



# BioMedical Imaging and Therapy (BMIT) Facility: Beamlines 05ID-2 and 05B1-1

T. W. Wysokinski
Canadian Light Source Inc.

## Beamline 05ID-2 Overview

| | |
|---|---|
| Status | Construction |
| Source | SC Insertion Device |
| Monochromator | CT Mono - Double Crystal Bent Laue : ~0.1%b.w.<br>KES Mono – Single Crystal Bent Laue : ~0.01%b.w.<br>DEI Mono – Double Crystal Bragg : 0.001%b.w. |
| Spectral range | 20 – 100 keV |
| Flux | $10^{15}$ ph/s/0.1%bw into 0.2mrad vertical x 4mrad horizontal @ 500 mA |
| Brilliance | $4\times10^{14}$ ph/s/mA/mrad$^2$/mm$^2$/0.1%b.w. |
| Resolving power | $10^{-5}$(DEI); $10^{-3}$ -$10^{-2}$ (CT,KES) |
| Beam size | 106 mm (V) x 5 mm (H) @ 26.5 m<br>220 mm (H) x 11 mm (V) @ 55 m |

## Beamline 05B1-1 Overview

| | |
|---|---|
| Status | Accepting letters of intent |
| Source | Bending Magnet |
| Monochromator | Double Crystal Bragg |
| Spectral range | 8 – 40 keV |
| Brightness | $1.5\times10^{11}$ ph/s/mr$^2$/0.1%bw/mA @ 10 keV |
| Resolving power | $10^{-4}$ |
| Beam size | 240 mm (H) x 7 mm (V) @ 25 m |

## Introduction

The suite of BMIT beamlines [1,2] provides a world-class facility with unique synchrotron-specific imaging and therapy capabilities. They will be used to study diverse problems in both human and veterinary medicine, agriculture and other biomedical areas.

## Science

Beamline 05ID-2 is designed for imaging and therapy research primarily in biomedical systems from mice to humans to horses, as well as tissue specimens including plants. Core research programs include human and animal reproduction, cancer imaging and therapy, spinal cord injury and repair, cardiovascular imaging and disease, bone growth and development, mammography, developmental biology, gene expression research, development of new imaging methods as well as extending present imaging capabilities.

The bending magnet beamline will ultimately mirror some of the ID capabilities with computed tomography (CT), diffraction enhanced imaging (DEI) and phase contrast imaging in both CT and planar modes. Additionally, 05B1-1 will host new imaging methods, such as imaging based on structural aspects of tissues by diffraction, absorption spectroscopy imaging, and fluorescence imaging, among others.

## Bending Magnet Beamline 05B1-1

The bending magnet (BM) beamline is intended to be the location for Diffraction Enhanced Imaging (DEI) and Phase Contrast experiments as well as where new ideas in imaging and therapy are tested and validated for eventual translation to BMIT's insertion device beamline 05ID-2. It will also accommodate some of the imaging research from the ID beamline.

### Front End (FE) & Optics Hutch (POE-1)

The front end of 05B1-1 is typical of many CLS beamlines except for the wide horizontal beam required for the wide field of view imaging programs. In 2009 a final alignment procedure was performed which opened the access to the full width of the beam.

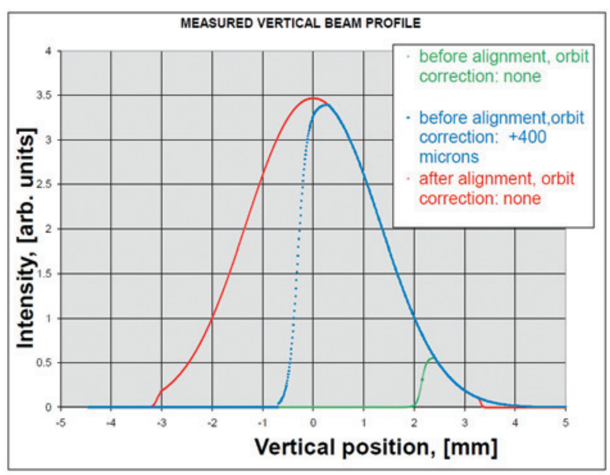


*Figure 1:* 2008 and 2009 beam profile at 19 m.

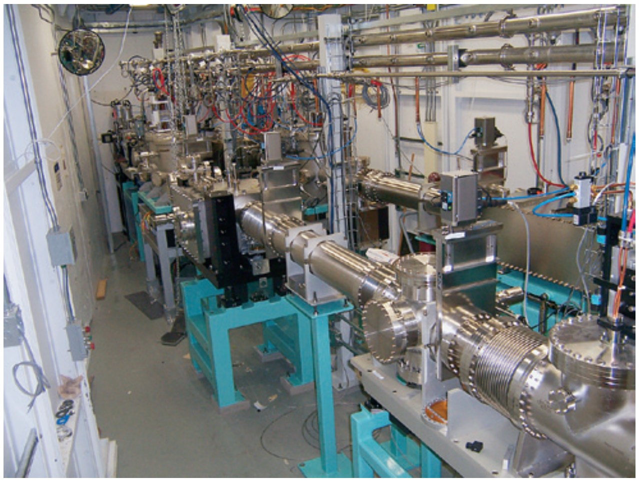

***Figure 2:*** BM and ID components inside POE-1 hutch.

### Experimental hutch (POE-2)

The experimental hutch has a very flexible system which allows imaging (CT and planar imaging) as well as irradiation application with both filtered white and monochromatic X-ray beams. The monochromatic spectral range will span 8–40 keV. In 2010 the upgraded stand for DEI experiments will be installed and an improved detector stage will be developed and commissioned, completing this beamline.

In 2009 several experiments [3-8] were performed on the BM beamline as part of commissioning activities. These included the first live animal imaging on BMIT [8].

***Figure 3:*** First live animal experiments on BMIT - bone imaging.

Components required for synchrotron based therapy were evaluated, including the Microbeam Radiation Therapy (MRT) collimator.

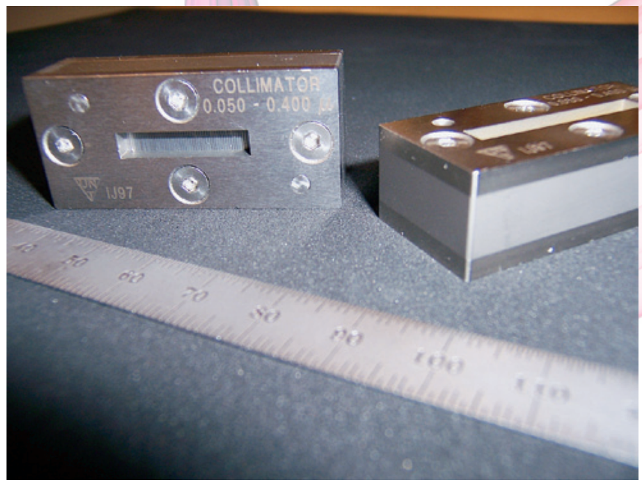


***Figure 4:*** MRT collimator that can chop the beam into 50 μm wide stripes with 400 μm spacing between.

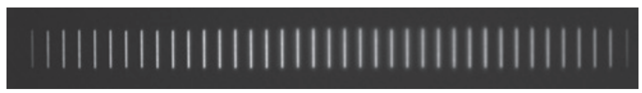

***Figure 5:*** White beam filtered through the MRT collimator, recorded with the detector.

The beamline is now accepting proposals for experiments that require radiography, diffraction enhanced imaging (DEI), phase contrast imaging (PCI), K-edge subtraction (KES) and computed tomography (CT) techniques.

### Insertion Device Beamline 05ID-2

The BMIT insertion device (ID) beamline will provide monochromatic beams with $\Delta E/E \sim 10^{-5}$ for DEI and $\Delta E/E \sim 10^{-3}$ for KES and CT with a wide tunable energy range. This energy range and beam width up to 220 mm will allow imaging and treatment of a wide variety of subject sizes - from mice to horses - with spatial resolution as small as ~10 μm. The ID beamline will host a number of imaging capabilities, including KES, DEI, multiple image radiography (MIR), PCI as well as normal absorption imaging in both projection and CT modes of operation.

Additionally, the beamline will have a filtered white beam capability for microbeam radiation therapy (MRT). Therapy is also foreseen with monochromatic beams, including Synchrotron Stereotactic Radiation Therapy (SSRT). Monochromatic X-ray flux of up to $10^{13}$ ph/s/cm$^2$ will be available. Filtered white beam for MRT will deliver up to 3000 Gy/s.

(Continued on next page)

### ID Source & Front End

The superconducting wiggler source has a maximum normal operating field strength of 4.3 T, a 4.8 cm period length, 25 full and 2 half poles. The high field gives a critical energy over 20 keV, the short period allowing most of the radiation to be accepted by the beamline.

### POE-1 & POE-2

The first primary optical enclosure (POE-1) accepts beam from both 05B1-1 and 05ID-2. The ID beam is filtered, collimated by slits, optionally monochromatized with a double crystal bent Laue monochromator and shuttered in POE-1. A movable Bremsstrahlung stop allows either the filtered white beam or monochromatic beam (20-100keV) to enter the secondary optical enclosure, POE-2.

POE-2 is a white beam hutch which accepts the bend magnet and ID beam. The bend magnet beamline 05B1-1 terminates in this hutch. The ID beam will optionally terminate in POE-2 or be safely transported downstream to POE-3 and SOE-1 by a shielded pipe. When the ID beam is terminated in POE-2, the filtered white beam or monochromatic beam can be used for imaging or therapy research using a large positioning system situated in a 2.6 m deep pit. The positioning system will be capable of a 0.7 m vertical excursion range with subjects as large as humans.

### POE-3 & SOE-1

Carried by the shielded pipe, the ID beam is transported to POE-3 which contains elements to filter, aperture and monochromatize the beam for the experimental program in the secondary optical enclosure (SOE-1). POE-3 has three monochromators for normal absorption imaging, DEI, MIR, and KES. Additionally, an analyzer system is sited in SOE-1 to complete the DEI/MIR system.

***Figure 6:*** back-wall moveable shielding in POE-3.

An optics table in POE-3 allows a flexible system of beam monitoring, characterization and filtration to be implemented for the wide variety of imaging and therapy programs that will be carried out in SOE-1.

SOE-1 has a basement structure 4 m below the experimental floor level to accommodate a positioning system capable of positioning and manipulating animals as large as a horse.

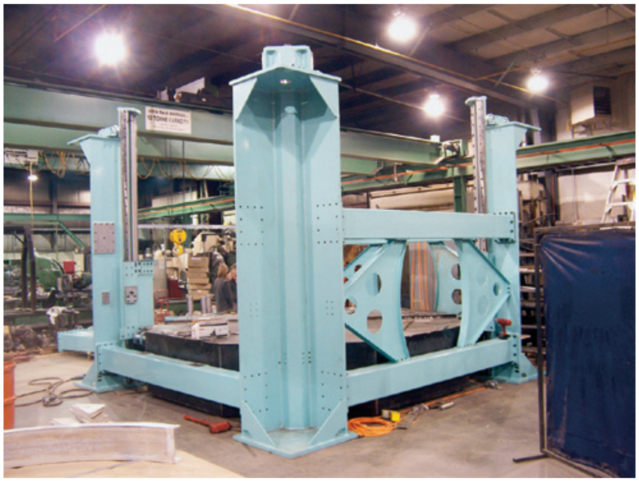

***Figure 7:*** Frame of the Large Positioning System before installation at CLS.

Additionally, this system will have a mode in which the positioning system from POE-2 can be transferred and rigidly mounted within it. SOE-1 (excluding the basement) is 6 m wide, 5 m tall and 10 m long with a removable back wall to accommodate installation of the large positioning system. Several different detectors will be available with resolution ranging from 20 μm to 150 μm.

## References


1. Wysokinski, T. W., Chapman, D., Adams, G., Renier, M., Suortti, P. and Thomlinson, W. 2007. NIMA 582 (1) 73-76.
2. Beamlines of the biomedical imaging and therapy facility at the Canadian light source--Part 2
3. T. W. Wysokinski, D. Chapman, G. Adams, M. Renier, P. Suortti, and W. Thomlinson, Nuclear Instruments and Methods in Physics Research Section A. In Press, (2010).
4. Cooper, D.M.L.,et al. This Report, pp 52 - 53.
5. Wiebe, S. et al. This Report, pp. 56 - 57.
6. Zhu N., et al. This Report, pp. 174 - 175.
7. Johns, P.C., et al. This Report, pp. 176 - 177.
8. Olkowski, A.A., et al. This Report, pp. 54 - 55.


## Acknowledgements


The BMIT beamline team gratefully acknowledges the following agencies for their support:

Canada Foundation for Innovation, Province of Saskatchewan, Canadian Light Source Inc., Western Economic Diversification Canada, Alberta Cancer Board, The Breast Cancer Society of Canada, The Canadian Cancer Society (Saskatchewan Division), Heart & Stroke Foundation of Saskatchewan, Regina Qu'Appelle Health Region, Royal University Hospital Foundation, Saskatchewan Cancer Agency, Saskatoon Health Region, Saskatchewan Health Research Foundation, and the University of Saskatchewan (Department of Psychology, Colleges of Dentistry, Kinesiology, Medicine, Nursing and the Western College of Veterinary Medicine).