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APPLICATION OF THE CORIS360 GAMMA RAY IMAGER AT A LIGHT SOURCE

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Abstract

The CORIS360® is a gamma-ray imager developed at Australian Nuclear Science and Technology (ANSTO) for identifying and localising sources of radiation typically from gamma emitting radionuclides. The low EMI and low noise power supply features of the imaging technology have enabled it to have a low energy detection threshold and to detect photons as low as 20 keV. This report shall present the initial measurements performed at the Australian Synchrotron, in the storage ring and beamlines, where the imager is able to detect radiation from all sources of synchrotron radiation (dipole, wiggler and undulator). The radiation imaging results from the injection system and scrapers (to dump the stored beam) will be discussed. Future developments for imaging in pulsed radiation environments and time varying environments will also be discussed.

INTRODUCTION

Synchrotron light sources are a source of radiation with photon energies ranging from milli-eV up to 200 keV. Knowledge of the sources and distribution of ionising radiation is needed to ensure the safety of the people at the facility and also in the protection of equipment susceptible to damage. Simulation of the synchrotron radiation source and its distribution is straight forward however the result of secondary scatter in a complex environment is harder to predict. Therefore we have employed a gamma ray imager to evaluate its effectiveness in diagnosing sources of scattered radiation in the storage ring to detect potential problems and also inform if additional local shielding is required. In this report we present some of the strengths and weaknesses of the CORIS360® gamma ray imager [1] that has been used in this evaluation. In particular the imager is very sensitive and is able to detect sources of hard xray sources from dipole, wiggler and undulator sources. A current drawback of the system is that it requires a constant radiation source intensity. Therefore, the imager will not be suitable for situations with variable source intensities (scraping, transient beam loss) and pulsed sources (injector). The report will conclude with some of the future developments the team at ANSTO are pursuing to address some of these drawbacks.

CORIS360 GAMMA RAY IMAGER

CORIS360® is a novel gamma ray imager developed by ANSTO. Equipped with a 360° × 90° gamma and optical field-of-view (FOV), it can quickly identify and localise gamma-ray and X-ray sources of radiation with energies between 40 keV and >3 MeV. The technology is designed around the theory of compressed sensing and employs two nested cylindrical tungsten masks that independently rotate around a single non-position sensitive detector, which enables a series of quasi-random (incoherent) linear projections of the scene plane to be measured. A compressed sensing approach to gamma-ray imaging had previously been presented in Ref. [2]. The cylindrical mask design provides the 360° × 90° FOV and the compressed sensing approach can localise gamma or X-ray sources of radiation with an order of magnitude fewer samples when compared to traditional imaging techniques, delivering fast results. A modular detector approach means different detectors can ‘plug & play’ into the system. CORIS360® currently uses two different geometry CLLBC detectors that have an energy resolution of ~4 % at 662 keV. A ~44 cm^3 CLLBC detector is used for low to medium dose rate environments and ~ 2 cm^3 detector is used for higher dose rate environments. The CLLBC detector is a dual gamma/neutron scintillator, and for neutron interactions the crystal produces an equivalent gamma energy of 3.1 MeV. During a single image acquisition, these spectroscopic detectors enable any part of the 40 keV to >3 MeV energy range to be imaged over the full system FOV. For this work, the low EMI and low noise power supply features of the imaging technology have enabled the low energy detection threshold to be reduced to 20 keV. A simple to use graphical user interface (GUI) provides the end user with an optical panorama with an overlay of the radiation location, which makes it easy to visualise where the source of radiation is. The GUI also provides the measured spectrum, radionuclide identification and indicates when neutrons have been detected.

MEASUREMENTS

Beamlines

The imager was first used at the beamlines to determine if it were sensitive enough to detect synchrotron radiation from a 1.3 T dipole, 1.9 T wiggler and 22 mm period undulator. In all three cases the imager was placed in the first optical enclosure, where the white beam slits and first optical mirrors were located and was able to detect scattered synchrotron radiation (secondaries that penetrate the vacuum chamber or shielding). Using the observation of the scattered radiation it is possible to identify issues along the optics as was observed on the MX2 beamline. Figure 1 shows how a defunct photon beam position monitor (BPM) appears to still be in the path of the beam. Or it can be used to inform the choice of local shielding that can be used to minimise scattered radiation and improve reliability and longevity of

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any sensitive equipment. For example in Fig. 2 where the first vertical collimating mirror is scattering radiation to the side shield wall then reflecting to the rest of the room, or the wide scattering from the white beam slits as an obvious scattering source. The imager currently does not estimate the potential dose and therefore a direct measurement with a calibrated dosimeter is still required.

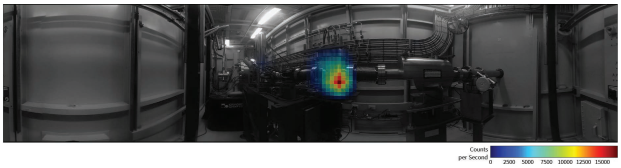

Figure 1: Images taken in the first optical enclosure of the Microfocus Crystallography (MX2) beamline that uses a 22 mm period in-vacuum undulator as its source. A singular source of radiation was identified across the entire spectrum located at an unused beam position monitor, indicating that likely some part of the instrument was intercepting core of the photon beam.

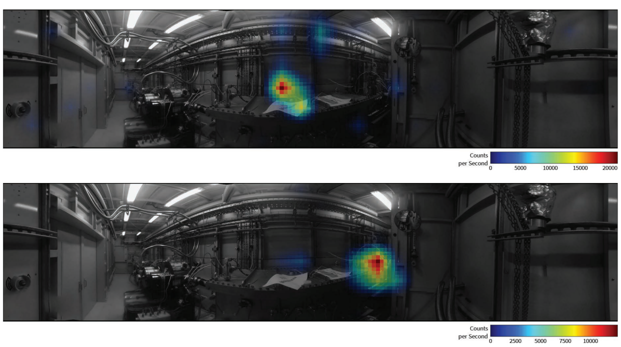

Figure 2: Images taken in the first optical enclosure of the X-ray Absorption Spectroscopy beamline (XAS) that uses a 1.9 T Wiggler as its source. Sources of radiation identified around 40 keV (top) scattered from the hutch wall next to the first vertical collimating mirror and 100 keV (bottom) scattered from the white beam slits. From this beamline the imager could detect photons up to 200 keV.

The spectrum of the scattered radiation measured by the imager from the three different sources is shown in Fig. 3. From the spectrum it is possible to distinguish the broader dipole like spectrum (including wiggler sources) and narrow band undulator spectrum. The imager was also able to capture the transition of the undulator spectrum to a more dipole like spectrum when the K of the in-vacuum undulator (IVU) was greater than 1.5.

Although the photon flux for the undulator beamlines are overwhelmingly at energies below 20 keV which is below the detection of the imager, its sensitivity means that it can still detect minute photons above 30 keV all the way to 300 keV in the case of the XAS wiggler. Therefore the imager can be used as a diagnostic tool for any sources of beam obstruction

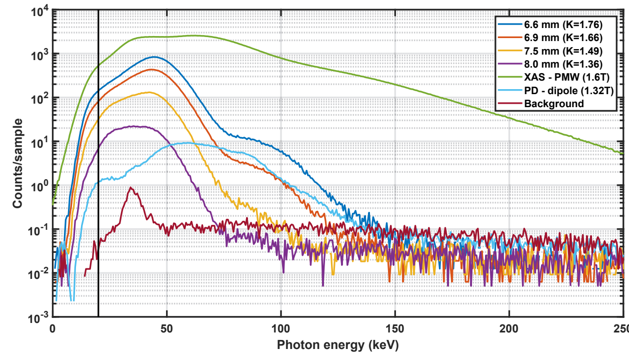

Figure 3: Spectrum measured by the imager in the first optical enclosures of the MX2 beamline (6.6 mm, 6.8 mm, 7.5 mm and 8.0 mm gap of the 22 mm period IVU), XAS beamline (wiggler) and PD beamline (dipole). Both XAS and PD beamline data shows the distinct broadband dipole spectrum while the MX2 beamline shows the undulator spectrum with the enhancement for photons below 70 keV. The spectrum at different IVU gaps clearly show the transition of the undulator to a more dipole like spectrum at higher energies when K is greater than 1.5. Below 40 keV the imager's shielding shows appreciable signal attenuation and exponential roll off below 20 keV (vertical black line).

along the beamline as the higher energy photons will not be generally shielded by the vacuum chamber.

Storage Ring

Further measurements were taken in the storage ring and we used this opportunity to determine the cause of the discoloration of the clear acrylic protective barriers and hardening of wire insulation around two insertion devices. These insertion devices have been installed with narrow gap Aluminium vacuum chambers with a NEG coating on the inner surface. The cause was believed to be the same as observed at Soleil [3] where synchrotron radiation from the upstream dipole illuminating the chamber wall resulted in secondary scattered synchrotron radiation as well as x-ray fluorescence of elements in the NEG coating. The images as shown in Fig. 4 confirm that the radiation is coming from the upstream dipole as the undulator was fully open. The spectra displays the same dipole like spectrum as seen in Fig. 3. Any effects of the fluorescence could not be clearly determined as it is below the detection limit of the imager.

The imager was also used at the location of a set of vertical beam collimators used to shift losses due to vertical beam scatter and reduce any demagnetisation effects on the IVUs used in the storage ring. The purpose was to see if the imager could be used to identify radiation sources initiated by Bremsstrahlung radiation. This was accomplished by reducing the vertical collimators until the electron beam lifetime was less than 10 hours to instigate a higher than normal rate of Bremsstrahlung radiation in this particular location. The spectrum in Fig. 5 shows the presence of the Bremsstrahlung radiation in the area however it was not

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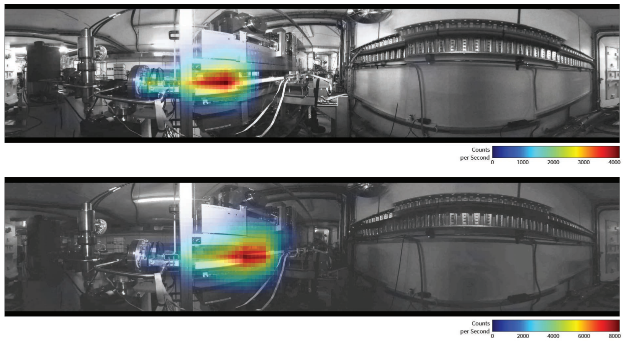

Figure 4: Image of the radiation at 60 keV with the insertion device "open". Scattered radiation from the upstream dipole penetrating the Aluminium chamber with the beam on axis (top). With a vertical bumped (bottom) the source of the radiation shifts further upstream of the vacuum chamber.

able to define any unique source. Even in this situation the radiation levels are still dominated by scattered dipole radiation making it harder to identify any other sources. The results from the imager indicates that the Bremstrahlung radiation was a broad scatted field and does agree with what one would expect from 3 GeV Bremsstrahlung creating a veritable sea of secondary particles with energies of a few keV up to many MeV.

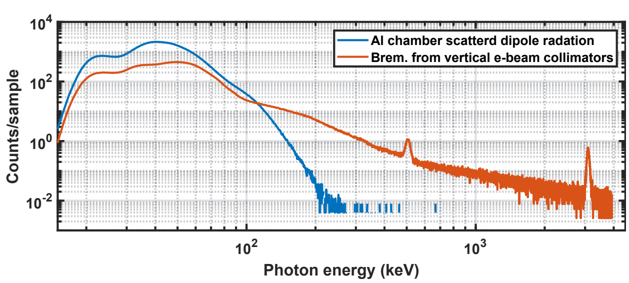

Figure 5: The radiation spectra measured at the vertical collimators (top) indicate the radiation below 100 keV is coming from scattered dipole radiation from a second set of Aluminium chambers that is also captured in this measurement. The source of radiation above 100 keV is from Bremsstrahlung and shows the 511 keV positron-electron annihilation peak as well as a neutron detection peak at 3.1 MeV.

Variable and Pulsed Radiation Sources

To determine the effectiveness across other sources of radiation at the facility the imager was also used to image radiation losses from our injector and from the use of the vertical collimator to remove the stored electron beams. In the first case the imager was not able to identify a source as the imager requires a constant intensity long enough to generate an image. In the second case the dose rate was too high with a very low duty factor where all the is generated radiation in less than 0.2 µs every second (injection rate). There was some evidence that during each pulse the detector was saturating, and future work will investigate if the system could be adapted to pulsed sources. Given the original design parameters of the imager was for the detection of radionuclides with a constant radiation output, it was not surprising that under the two conditions imager could not resolve an image. Despite such a limitation the imager can still be used to identify and characterise the nature of the radiation.

CONCLUSIONS AND FUTURE PLANS

The measurements that has been obtained has shown that the CORIS360® gamma ray imager's sensitivity is able to resolve and uniquely identify the different types of radiation created at a light source. It was interesting to observe the transition of the undulator spectrum to a dipole like spectrum. The imager will be used in beamlines and storage ring to discover local hot spots and to be used as a diagnostic tool to identify potential obstructions to the synchrotron radiation. The findings from the Aluminium chambers has resulted in a review of the way we design the absorbers that shield the dipole radiation in the straight sections.

We will continue to work with the team that developed the imager to see if it can be modified and optimised for light sources (energies below 1 MeV). This could be achieved by using different detectors and adjusting the thickness of the mask and casing. To address the variable nature of some of the sources of radiation, it may be possible to integrate an external normalisation signal, either in real-time or in post-analysis. Due to the modular design it may be possible to find a combination of detector and MCA that is more suitable for pulsed radiation sources. This is currently under investigation.

Following the measurements in this report, plans are in place to continue to survey the rest of the storage ring to look for anomalies and to determine the scatter pattern from the photon shutter in the front-end of our 4.2 T superconducting wiggler. The data will help inform if additional local shielding is required to help minimise long term damage from radiation.

REFERENCES

[1] Coris360, `https://www.ansto.gov.au/products-services/detection-imaging/coris360/`.

[2] D. Boardman, A. Sarbutt, A. Flynn, and M. Guenette, "Single pixel compressive gamma-ray imaging with randomly encoded masks," *Journal of Instrumentation*, vol. 15, no. 04, p. P04014, 2020.

[3] N. Hubert *et al.*, "Radiation Damages and Characterization in the SOLEIL Storage Ring", in *Proc. 2nd Int. Beam Instrumentation Conf. (IBIC'13)*, Oxford, UK, Sep. 2013, paper WECL2, pp. 644–647.