APPLE-II Undulator Magnetic Fields Characterised From Undulator Radiation

(TUPF19)

K.P. Wootton[1], M.J. Boland[1,2], B.C.C. Cowie[2], R.P. Rassool[1]

[1] School of Physics, The University of Melbourne, Parkville, VIC 3010, Australia

[2] Australian Synchrotron, 800 Blackburn Rd, Clayton, VIC 3168, Australia

Abstract

The spatial profile of APPLE-II undulator radiation has been measured at high undulator deflection parameter, high harmonic and very small emittance. Undulators are typically designed to operate with small deflection parameter to push the fundamental mode to high photon energies. This unusual choice of parameters is desirable for measurement of vertical emittance with a vertical undulator.

We present 1-D and 2-D measured profiles of undulator radiation and show that this is reproduced in numerical models using the measured magnetic field of the insertion device. Importantly these measurements confirm that for these parameters, the spatial intensity distribution departs significantly from usual Gaussian approximations, instead resembling a double-slit diffraction pattern. This could be an important consideration for photon beamlines of ultimate storage ring light sources.

Undulator magnetic model

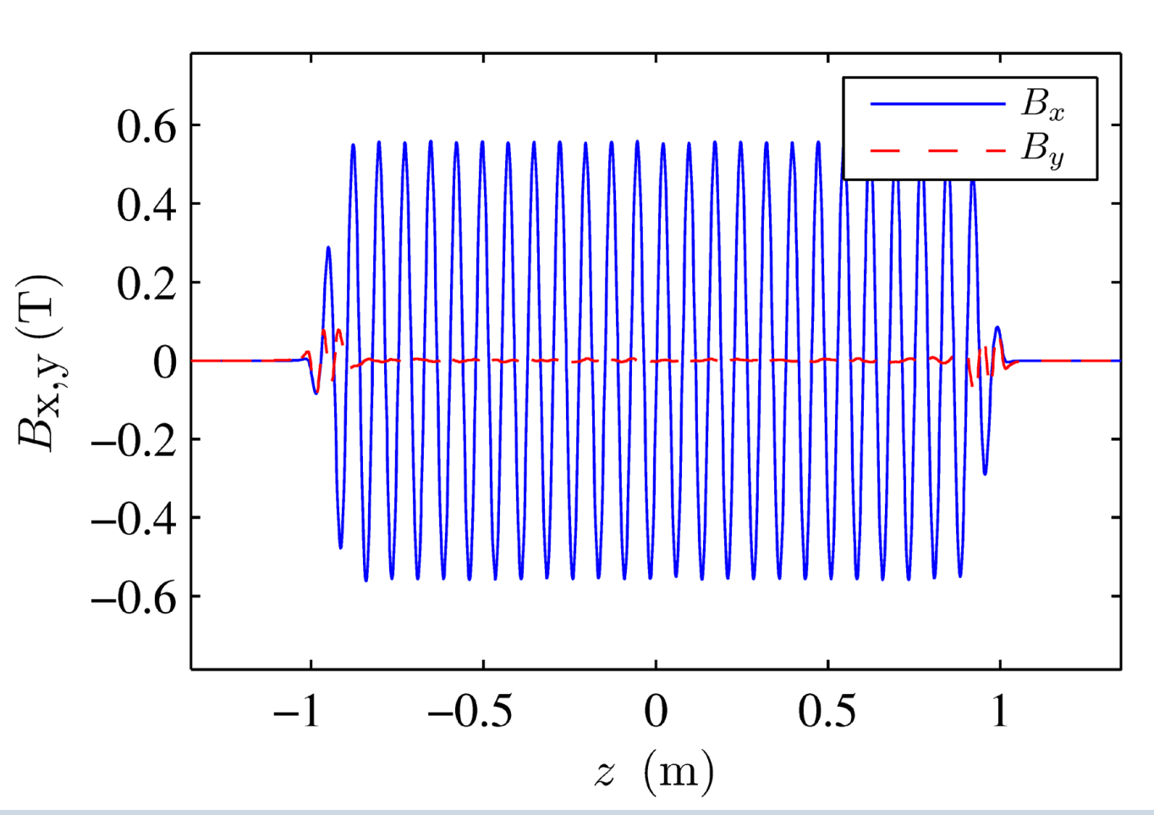
Crucial to the vertical undulator emittance measurement technique is the availability of a high deflection parameter vertical undulator [1, 2]. At the Australian Synchrotron, we use an APPLE-II EPU in a magnet phase configuration for vertically polarised light [3, 4].

The magnetic field profile of this APPLE-II ID was measured at the design magnetic gap of 16.0 mm [4]. These experiments are conducted with a gap of 17.1 mm. To compensate for this in our model, the magnitude of the measured magnetic field components at a gap of 16.0 mm have been scaled down until the simulated on-axis peaks of the undulator harmonics were at the same photon energies as the measured spectrum.

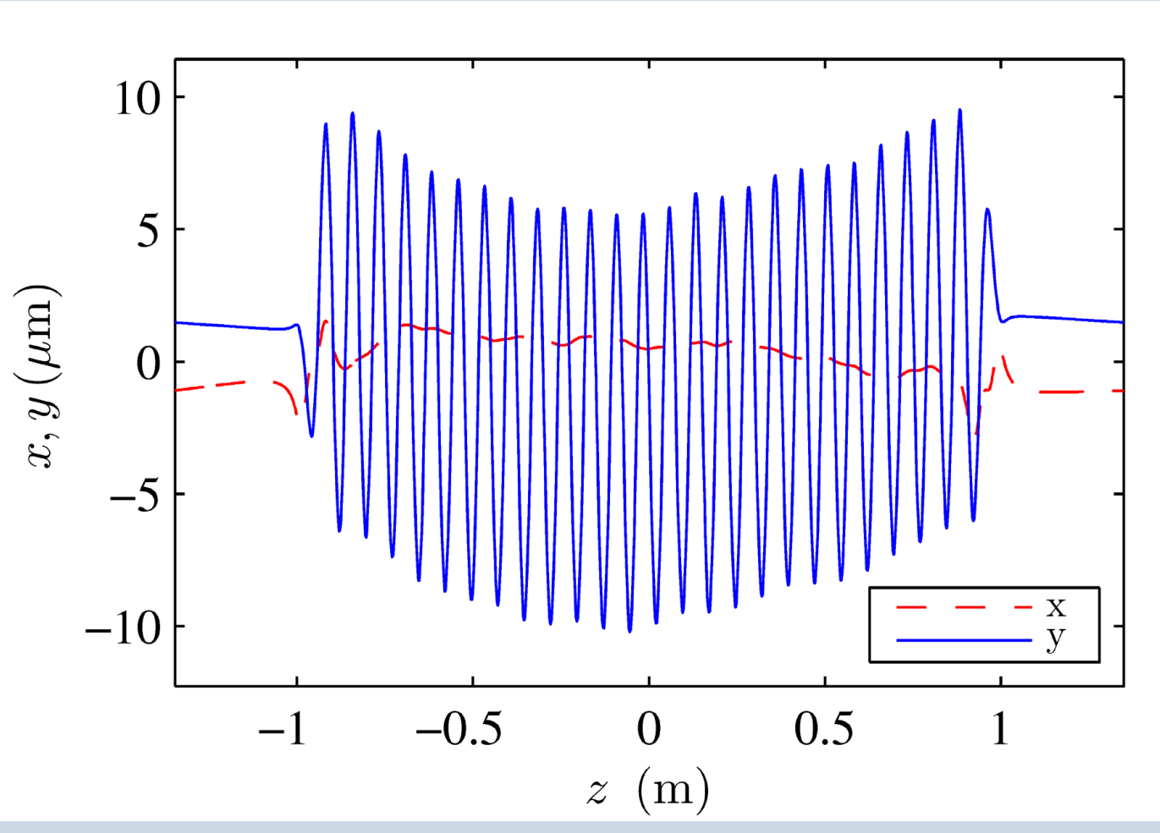
Table 1: Undulator and electron beam parameters for experiment and simulation.

Parameter	Value
Electron beam energy	3.033 GeV
Beam energy spread	0.0011
Horizontal emittance	10 nm rad
Vertical emittance (nominal)	100 pm rad
Undulator K	3.85
Undulator period length	75 mm
Number of full periods	25
First harmonic photon energy	134.7 eV

Undulator and electron beam parameters.



Magnetic field map of insertion device, scaled from measured field [4].

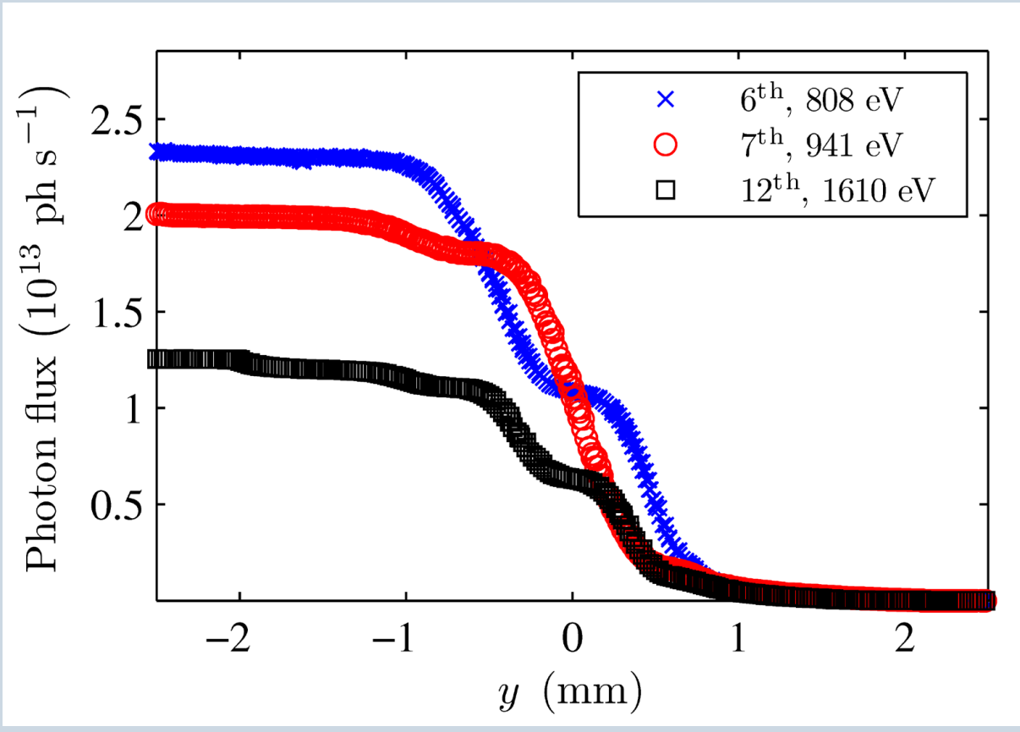


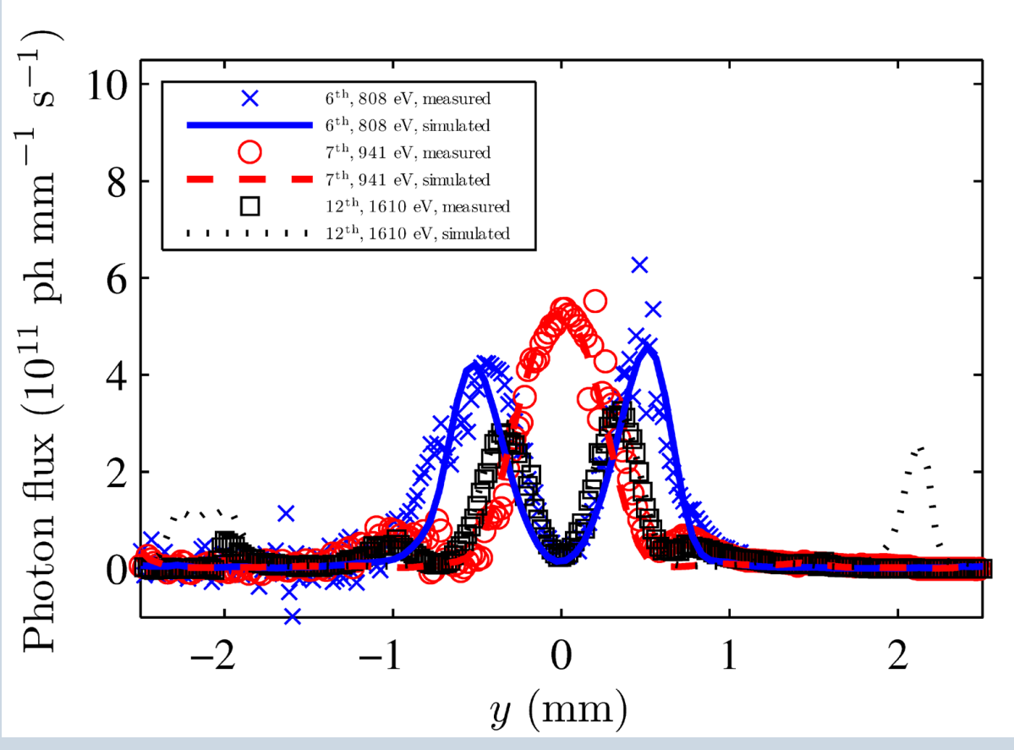
Electron beam trajectory through scaled magnetic field.

1-D blade scans

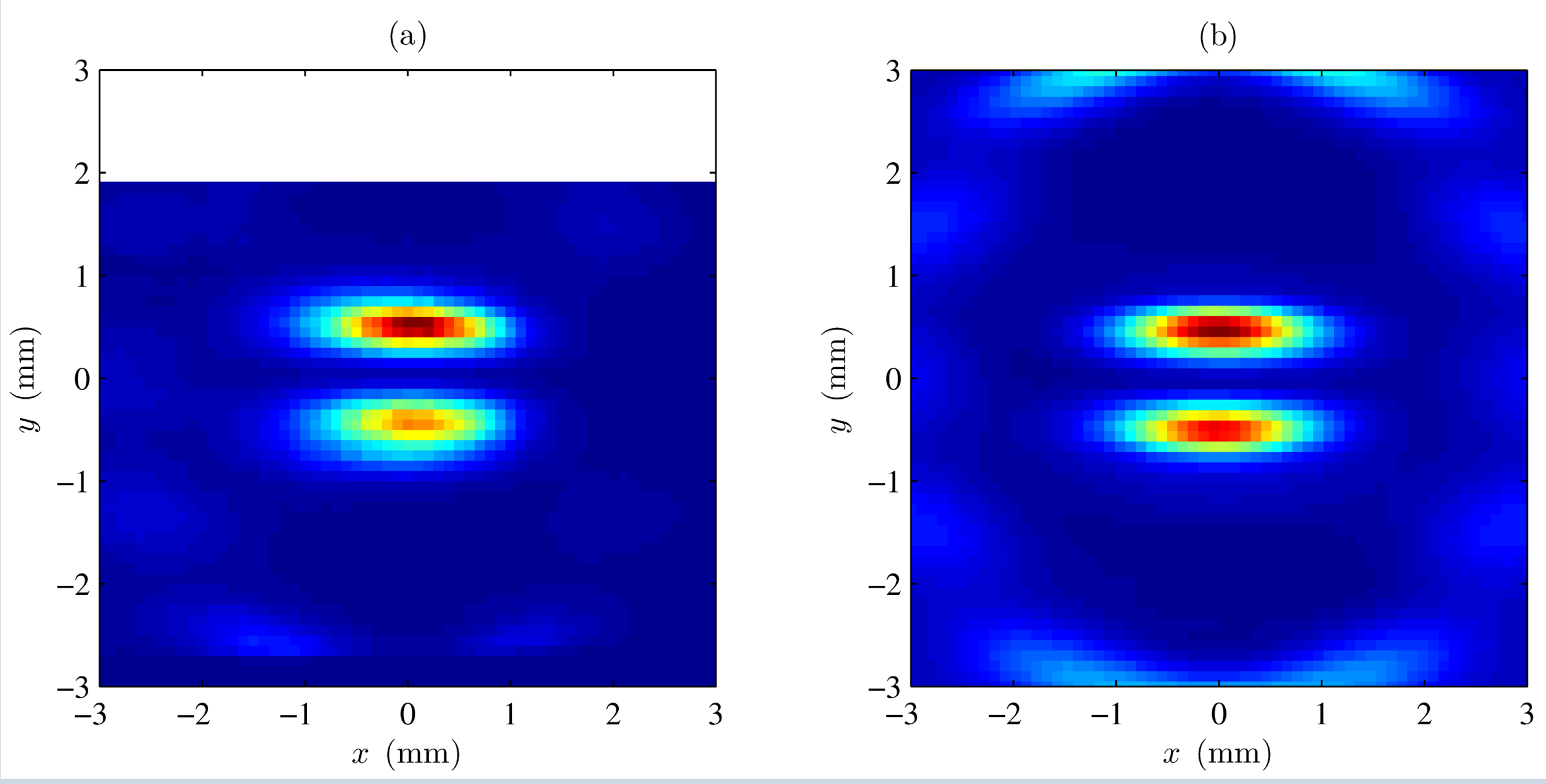
The spatial profile of the radiation was characterised in the vertical direction alone using blade scans. With a horizontal aperture of 0.5 mm, the lower blade of the white beam slits was stepped vertically upwards through the radiation distribution. The change in measured photon flux through the aperture with blade position is plotted at right.

Taking the derivative of this distribution with respect to the vertical position of the blade, the intensity distribution of undulator radiation is recovered. SPECTRA [5] simulations of the spatial profile of undulator radiation are compared.



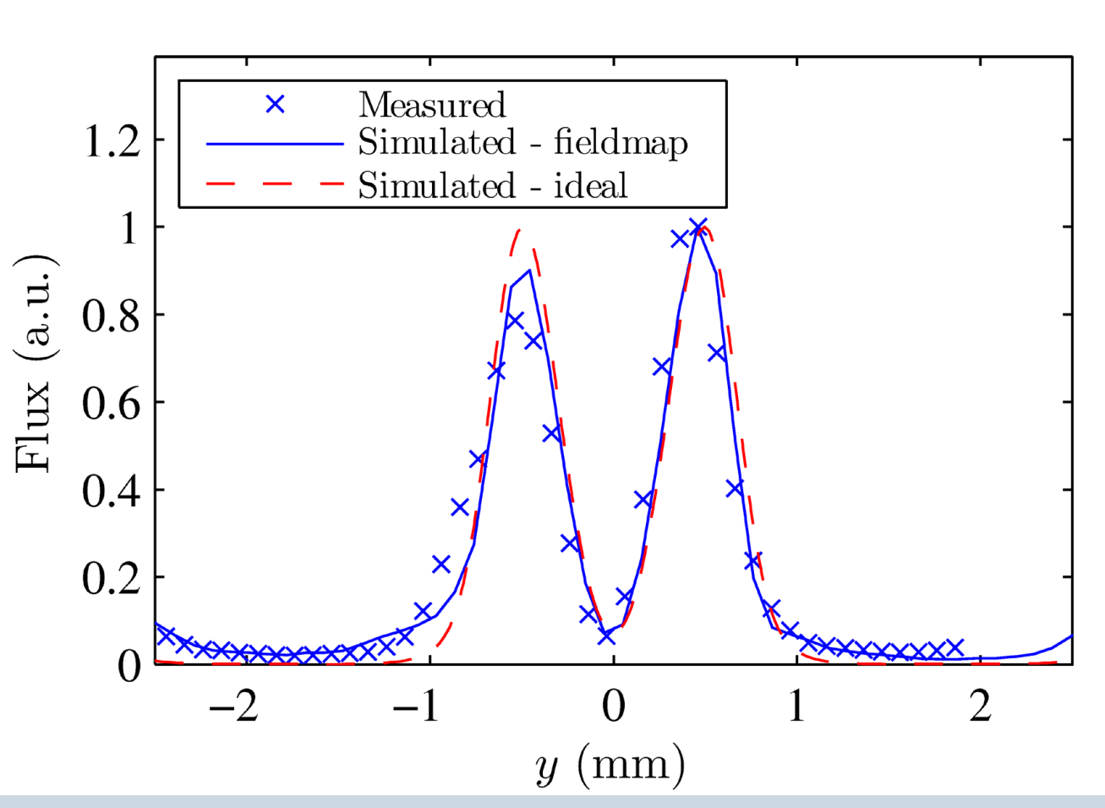


2-D profile



Spatial profile of undulator radiation from a vertical undulator, 15 m from ID.
(a) Measured spatial profile of 6th undulator harmonic, at 808 eV.
(b) SPECTRA [5] simulation of spatial profile of 6th undulator harmonic, at 808 eV.

These measurements confirm assumptions regarding the spatial distribution of undulator radiation, which is sensitive to vertical emittance. The angular distribution of undulator radiation departs from usual Gaussian approximations, and at such low emittances resembles a narrow interference diffraction pattern. This is observed because the vertical emittance is so small relative to the transverse deflection of the undulator.



Vertical profile of figure above.

USR implications

Low emittance light sources are beginning to produce undulator radiation of interesting spatial distributions [6]. As electron beam light sources approach diffraction limits, the spatial distribution of radiation may become a topic of interest. Diffraction-limited ultimate storage rings are currently proposed with horizontal emittance of order 100 pm rad [7-9]. Such proposals should be aware of the diffraction-limited spatial distribution of undulator radiation, and its departure from usual Gaussian-approximated, emittance dominated photon beams.

Conclusion

The spatial distribution of radiation from a vertical insertion device has been characterised at very low vertical emittance. Both 2-D and 1-D spatial distributions of radiation have been measured, using a combination of blade scans. Simulations of the insertion device radiation are given, using a magnetic field distribution scaled from the measured field. It is shown that these simulations accurately reproduce the measured photon beam distribution. This close agreement between simulation and experiment is important both for the vertical emittance undulator technique, and potentially also for insertion devices at proposed ultimate storage ring light sources.

References

1. K.P. Wootton, et al., Phys. Rev. Lett. **109** (19), 194801 (2012).
2. K.P. Wootton, et al., Proceedings of IBIC 2012, Tsukuba, Japan, MOCB04 (2012).
3. S. Sasaki, Nucl. Instrum. Methods A **347**, 83 (1994).
4. C. Ostenfeld, et al., Proceedings of PAC 2007, Albuquerque, USA, TUPMN006 (2007).
5. T. Tanaka and H. Kitamura, J. Synch. Rad., **8**, 1221 (2001).
6. J. Bahrdt, et al., Phys. Rev. Lett., **111**, 034801 (2013).
7. M. Bei, et al., Nucl. Instrum. Methods A **622**, 518 (2010).
8. Y. Shimosaki, et al., Proceedings of IPAC 2012, New Orleans, USA, TUPPC014 (2012).
9. L. Farvacque, et al., Proceedings of IPAC 2013, Shanghai, China, MOPEA008 (2013).

Australian Synchrotron

ACAS Australian Collaboration for Accelerator Science

THE UNIVERSITY OF MELBOURNE

Presented at the International Beams Instrumentation Conference 2013, Oxford, United Kingdom, 16 – 19 September, 2013.