NEW INSERTION DEVICES FOR BRIGHT BEAMLINES AT THE AUSTRALIAN SYNCHROTRON

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Abstract

In 2016, Australian Synchrotron embarked on the BRIGHT programme to build four new insertion device beamlines: Biological Small Angle X-ray Scattering (BioSAX), High-Performance Macromolecular Crystallography (MX3), Advanced Diffraction and Scattering (ADS), and Nanoprobe beamlines (Nano). To maximise the flux for these very demanding beamlines, cryogenic and short-period devices have been selected. In particular a 1.6 m long 16 mm period superconducting undulator, a 3 m long 18 mm period cryogenic undulator (CPMU), 3 m long 17 mm in-vacuum undulator and a 2 m long 48 mm period superconducting wiggler. This report will discuss some of the design considerations and overall parameters of the new insertion devices.

INTRODUCTION

The BRIGHT programme is the second phase of beamlines to be built at the Australian Synchrotron [1]. Four of the new beamlines require insertion devices (IDs) and the parameters are listed in Table 1.

SCU16

SCU16 was commissioned in 2022 for the BioSAX beamline and has been in user operation since 2023. Details of the SCU and the commissioning experience can be found in Ref. [2]. The photon spectrum has since been measurements with a fluorescence based detector [3] and is shown in Fig. 1. Preliminary analysis indicates an "equivalent" RMS phase error of 10° in line with expectations based on magnetic measurements. Operational experience over the past 12 months has demonstrated it is robust and has quenched five times as a consequence of unscheduled beam dumps/aborts (out of a total of 49 beam dumps during user operation in the same time period). No unprovoked quenches were observed. Current stability in the long term has indicated a possible slow drift of 250 ppm over 80 days when operating at the same field. This corresponds to a change in the photon energy by 0.03 % and for now this drift appears to be acceptable. If necessary a slow feedback will be implemented.

U17

The conventional IVU for the MX3 beamline was designed for single energy (13 keV) operation. For a minimum vacuum gap of 5.5 mm a period of 17.2 mm was selected. The U17 uses Neomax's spring compensation system [4] to improve the mechanical stability for field quality and achieved an RMS phase error of <2.53° (measured with a SAFALI system [5]).

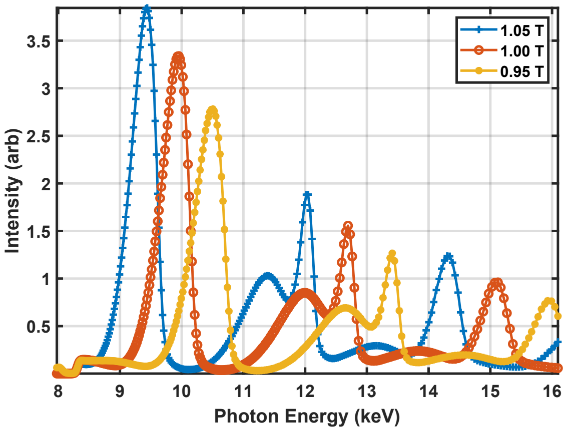

Figure 1: Measurement of the SCU16 photon intensity after white beam slits (14 m from source, 1.6 mm wide by 1 mm high) and a 1 % bandpass DMM. Linear mass absorption of the 0.5 µm Ni foil has been taken into account.

To reduce the risk of multi-bunch instabilities from the coupling of trapped modes in the IVU to the electron beam [6] a combination of flat transition tapers (design from NSRRC's CU15 [7, 8]) and ferrites [6, 9] have been used. Direct measurements using antennas (Fig. 2) installed in an existing U22[2] has previously showed [6] agreement between simulations and measurements of the frequency of the modes and Q factor (as high as 500; τ >330 ns). With the addition of ferrites (Skyworks TT56425) around the upper link rods of the magnet girder of U17, simulations indicate that the Q factor will reduce by one order of magnitude. This has been measured and confirmed for U17 in Fig. 3 showing the measured modes on both the U22 without ferrites and the U17 with ferrites. Commissioning of U17 (Fig. 4 is ongoing and will be completed by the end of 2024.

CPMU18

CPMUs have been in development and used for many years at many light sources [10–14]. This CPMU will be the first commercial offering by Proterial/Neomax and is based on recent developments at NSRRC with the CU15 [8] and CU18 [15]. CPMUs typically utilise either PrFeB or NdFeB magnets. Although PrFeB has a 2 % advantage over NdFeB magnets, PrFeB needs to operate at a temperature of 70 K

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[2] 2 m long, 22 mm period undulator

Table 1: Parameters of New Insertion Devices

Insertion Device[1]	**SCU16**	**U17**	**CPMU18**	**SCW48**
Beamline	BioSAX	MX3	Nano	ADS
Energy Range	8 - 15 keV	13 keV	5 - 25 keV	50 - 150 keV
Magnet / Current	862 A	NMX-S41EH	NMX-U52SH	495 A
Magnet Period	16 mm	17.2 mm	18 mm	48 mm
Magnet length	1.6 m	3.0 m	3.0 m	2.0 m
Maximum Field	1.084 T	0.86 T	1.23 T	4.5 T
K	1.62	1.38	2.07	20.2
Magnet Gap	8.0 mm	5.8 mm	5.2 mm	8.0 mm
Vert. Vacuum Gap	5.6 mm	5.6 mm	5.0 mm	6.0 mm
Max power	2 kW	2.5 kW	5.2 kW	45 kW
Operating Temp.	4 K	297 K	170 K	4 K
Cooling Method	Conduction	-	Conduction	Conduction
Vendor	Bilfinger Noell	Proterial	Proterial	Bilfinger Noell
Status	User	Commissioning	Build	Build

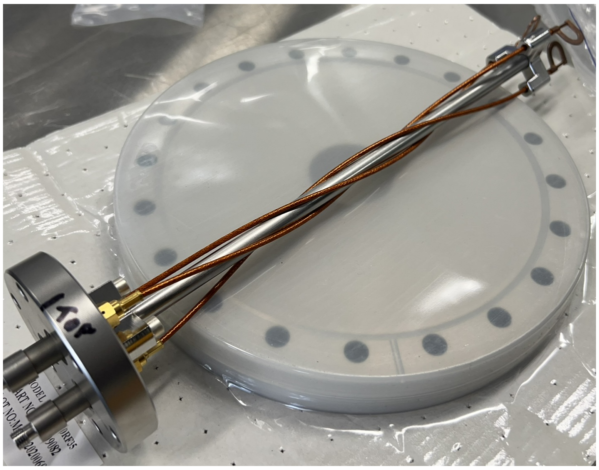

Figure 2: Antenna installed near the transition tapers to measure the beam induced trapped modes in U17.

compared to NdFeB which peaks at 150 K. The higher and broad peak of NdFeB magnets make the cooling easier to accomplish as well as being less sensitive to temperature fluctuations. The gradients around the peak are expected to be < 50 ppm/K. The CPMU is conduction cooled with two Leybold cold heads (COOLPOWER250MDi) with a total cooling capacity of 500 W at an operating temp of 110 K, well over the expected total heat load of 300 W. Temperature control will be achieved through six heater elements, four short (400mm) at the up/down stream ends and two long (2200 mm) in the middle section of the girders. Splitting the heating elements was designed to compensate for the 2 K temperature gradient along the length of the undulator partially driven by passive and beam induced heating [8]. Two optical gap sensors will be used to measure the "true" gap through sapphire ports in the vacuum chamber.

As with the U17, ferrites (TDK IB-017 tiles machined locally) have been installed to minimise the risk of trapped mode driven beam instabilities. Both U17 and CPMU18 use

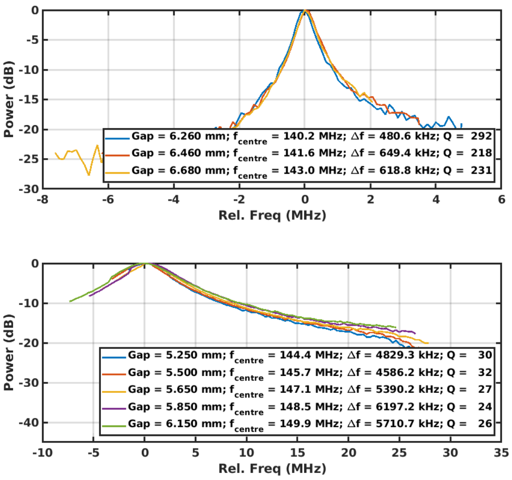

Figure 3: 140 MHz trapped mode for both an existing 2 m 22 mm period undulator with no ferrites installed and bowed tapers (top) compared to U17 with ferrites (bottom).

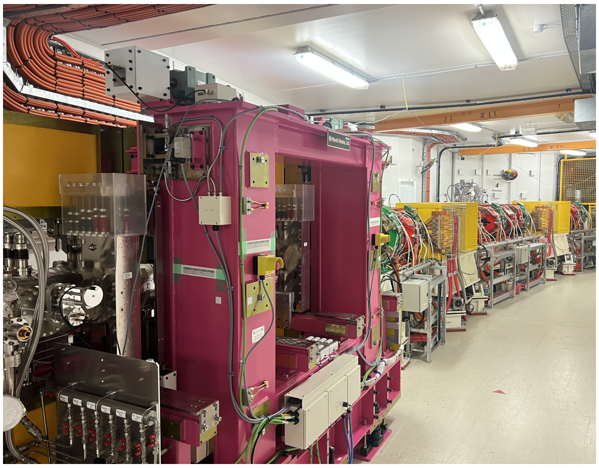

Figure 4: U17 as installed in the storage ring.

similar ferrite blocks as shown in Fig. 5. Although ferrites will be a heat source as it acts as a lossy element in the system, the total heat load is expected to be under 5 W and is within the cooling budget. CPMU18 will be installed in late 2024.

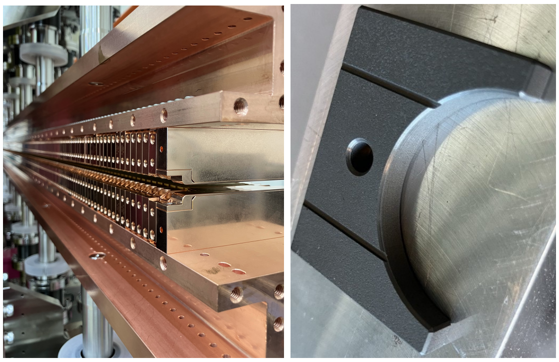

Figure 5: CPMU18 magnet array attached to a OF copper beam and ferrite that will be mounted around the vertical link rods.

SCW48

SCW48 will be the second superconducting wiggler installed in the storage ring and the minimum period was chosen to keep the total power under 45 kW while maintaining a vacuum gap >6 mm. The design of the SCW48 will follow that of the SCU16 and HEX SCW at Diamond [16]. Unlike the previous superconducting devices from Bilfinger Noell there will be room temperature horizontal/vertical dipole correctors external to the cryostat. The magnet will be conduction cooled by four Sumitomo cold heads (RDK-415D2 and RDK-408S) with a total cooling capacity of 3 W at 4 K (double the expected load of 1.8 W).

Some design challenges that will be implemented here are improved winding techniques to ensure horizontal roll-off is close to design. If the design roll-off is maintained the dynamic integrals should only result in an equivalent maximum tuneshift of 2.5×10^{-3} at the edge of the acceptance of the storage ring as seen in Fig. 6. More detailed modelling is in progress.

Another challenge will be minimise the number of unintended quenches due to a beam dump as the quench recovery time expected to be around 45 minutes. The current method to dump the stored beam is to turn off the RF drive and allow the beam to coast and scatter, which does instigate a quench of our first SCW. To ensure that beam dump induced quenches are eliminated a method for a controlled beam dump will be implemented. This method will be done by transmitting the abort signal to our timing system to trigger two of the four injection kickers and sending the stored beam into inner horizontal scrapers. Preliminary tests have proven that this method to does significantly reduce the incidence of induced quenches of our first SCW. SCW48 is expected to be installed in the middle of 2025.

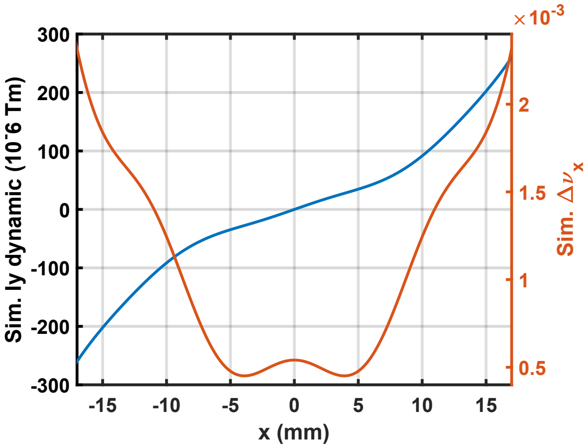

Figure 6: Dynamic integral and tuneshift as a result of expected ideal roll-off.

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