RECONFIGURATION OPTIONS FOR REUSING A PERMANENT MAGNET UNDULATOR AS A LOW-FIELD WIGGLER SOURCE*

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Abstract

The Canadian Light Source (CLS) currently operates a 1.9 T super conducting wiggler (SCW) that has been in service since 2005. As the risk of failure and maintenance requirements for this aging device increase, and funding for a permanent replacement remains pending, an interim solution is needed to ensure continued beamline operation. Reconfiguring a decommissioned permanent magnet undulator offers a cost-effective alternative that could minimize downtime. Several approaches to modifying the magnetic layout to enhance wiggler performance are under consideration, with the goal of reusing existing mechanical supports, permanent magnets, and vacuum chambers. Proposed modifications include reducing the gap and halving the magnetic period to achieve the desired field characteristics.

BACKGROUND

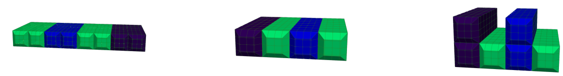
The CLS has operated a 1.9 T SCW as a photon source on the HXMA (Hard X-ray Micro-Analysis) beam line since January 2005. Maintenance needs are increasing for this aging device. High numbers of past quenches [1] also raise concerns regarding the risk of failure. Funding for a new wiggler has not yet been successful driving a need for a low cost option with minimal effort which could be implemented and restore beamline operations quickly if needed.

UNDULATOR RECONFIGURATION

This work explores the feasibility of reconfiguring a decommissioned permanent magnet undulator, U185 [2], as a low-field wiggler. This approach leverages additional decommissioned equipment made available from the previous beamline upgrades to minimize cost and design effort. U185 has a 185 mm magnetic period (λ), a peak field of 0.72 T and could generate photons as low as 5.5 eV with the first harmonic on the 2.9 GeV storage ring at the CLS.

U185 - Design

The U185 device has an eight block per period design, see Fig. 1a, that offers some additional design options for building a replacement wiggler with better field characteristics. The U185 magnet block shape is a square cross-section with sides 23.1 mm, ~ $\lambda/8$. A pair of magnets with aligned magnetization was installed so that the polarization changed by 90° every $\lambda/4$. This cost saving design only required a single block type for full sized magnets. Additionally the device only operated with a minimum gap of 25 mm but



(a) U185 (b) U93A (c) U93B

Figure 1: Magnet blocks in a single period.

the vacuum chamber had an outer thickness of 10 mm. Decreasing the magnetic gap would further increase the peak magnetic fields and improve the performance of the device as a wiggler source.

Reconfiguration Approaches

Several strategies for modifying the U185 were considered to achieve the required wiggler field and photon energy range with minimal cost and design effort. The main approaches include:

- Reducing the magnetic gap to increase the peak field.
- Halving the magnetic period to increase field strength and number of periods.
- Reusing existing mechanical supports, vacuum chambers, and permanent magnets to minimize engineering changes.

Magnetic modeling and field calculations were performed for each configuration to assess feasibility and performance trade-offs.

Table 1: Summary of Key Parameters for U185 Reconfiguration

Config.	Period mm	Gap mm	Poles #	Length m
SCW	35.3	13.5	61	1.06
U185 (orig)	185	25	17	1.635
U93 A	92.5	11-25	33	1.612
U93 B	92.5	11-25	21	1.057

The two reconfigurations U93A and U93B use four and six blocks per period as seen in Fig. 1. While U93B generates higher fields needed for a higher critical energy (ϵ_c), the additional blocks per period reduces the total length of the device that is possible while reusing existing magnet blocks. This tradeoff of ϵ_c versus total length changes with different minimum gaps and will be constrained by the maximum magnetic forces possible with the existing support structure.

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Magnetic Field Calculations

Key parameters for the original U185 and proposed configurations are summarized and compared with the current SCW in Table 1, including period, gap, and length of device. Magnetic field calculations for the original and proposed reconfigurations were performed using Radia [3] for multiple gaps above 11 mm and shown in Fig. 2. Full length fields for the three configurations are shown at a 25 mm gap in Fig. 3. Peak fields increase faster with smaller gaps for the two shorter period reconfigurations. However, the achievable minimum gap will still be limited by increased magnetic forces. The magnetic force between upper and lower girders are shown in Fig. 4. Further mechanical studies are required to determine if the support structure may operate beyond the maximum forces of 13.6 kN in the original magnet design report [4]. If higher magnetic forces are possible, then the alternate designs can achieve even higher peak fields, see Fig. 5. The longer period of the original design has flat top field with an increasing dip for small gaps, which limits the peak fields at smaller gaps.

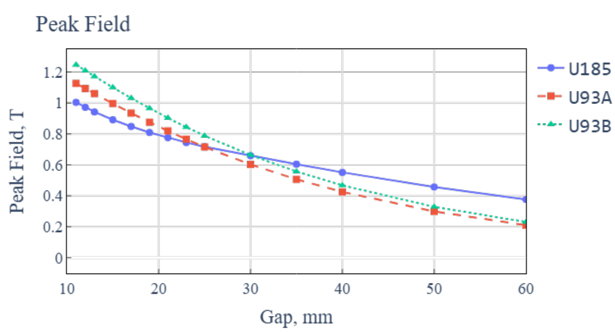

Figure 2: Peak magnetic fields versus gap for three options.

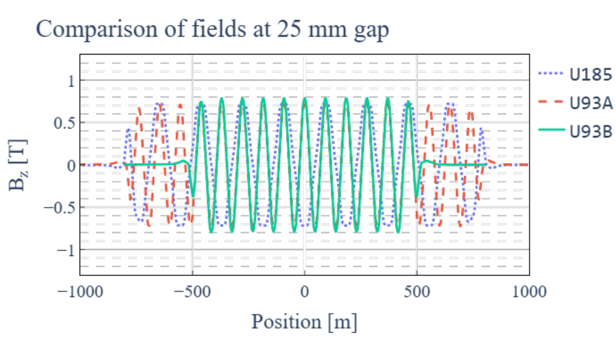

Figure 3: Simulated magnetic fields with peaks of 0.72 T, 0.72 T, and 0.79 T for each of the three options U185, U93A, and U93B at a 25 mm gap.

Wiggler Performance

Magnetic fields calculated using Radia models were used with SRW [5] to simulate the total flux at the primary slit for three configurations of the U185 undulator. The HXMA SCW flux was calculated using a 1.97 T measured field from the factory acceptance tests, which slightly exceeds the current operating point of 1.9 T. A third gap for each of the U93 options was considered where magnetic forces equal the

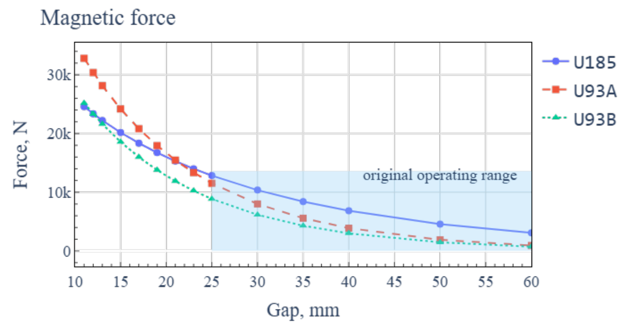

Figure 4: Magnetic force versus gap for three options. Shaded box shows operating range below 13.6 kN force and above the original 25 mm minimum gap.

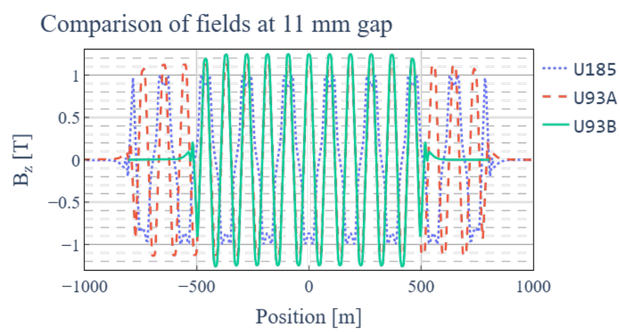

Figure 5: Simulated magnetic fields with peaks of 1.0 T, 1.13 T, and 1.25 T for each of the three options U185, U93A, and U93B at a 11 mm gap.

original 13.6 kN maximum force. These gaps were 23 mm and 19 mm for the U93A and U93B options respectively.

Low energy photon flux is dominated by the number of poles in the wiggler, as seen in Fig. 6. None of the U185 configurations match the performance of the SCW. Below 10 keV these options may provide 30 % to 50 % of the flux currently available from the SCW. The modified U93 configurations are better than the original U185 design. Above 10 keV the lower peak field and corresponding ϵ_c provide significantly less flux, perhaps less than 5 % for photon energies at 25 keV.

If the support structure can't operate with higher magnetic forces U93A and U93B offer two options that may require compromising between higher flux at the low or high energy photon ranges. If higher magnetic forces are possible the U93A configuration may provide the highest overall flux. The achievable gap will likely be determined by the magnetic force and any modifications to strengthen the mechanical structure.

The existing SCW has a small deflection parameter (K), see Fig. 7, which results in a small amount of undulator structure in the flux spectrum at low energies. Mitigation efforts included adding shims to pseudo-randomly modify the periodicity of the device and reduce this effect [6]. These oscillations can be seen in the SCW spectra in Fig. 6 even with the period shimming. One small benefit of all the U185 options is a larger K value which almost entirely eliminates these small intensity oscillations. Only U93A shows some

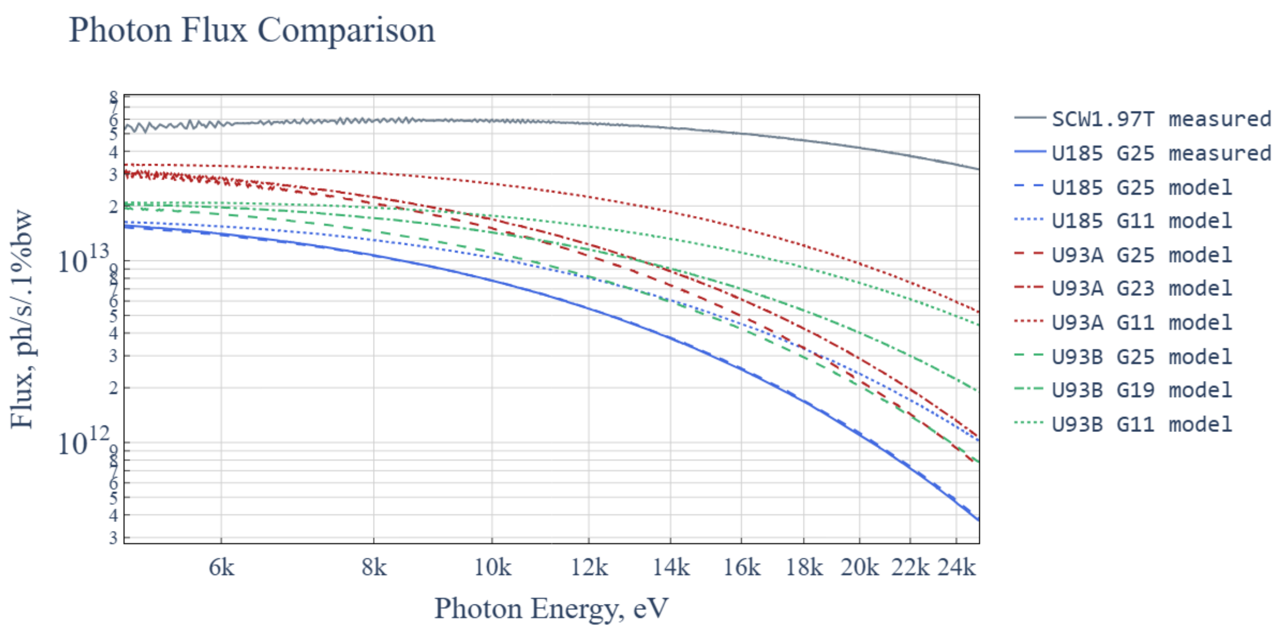

Figure 6: Comparing total flux in a 1 mm × 6 mm aperture at the primary slit for the existing SCW and three configurations of the U185 device.

small oscillations with an ideal field and it is expected that field errors or a small taper would entirely eliminate this effect.

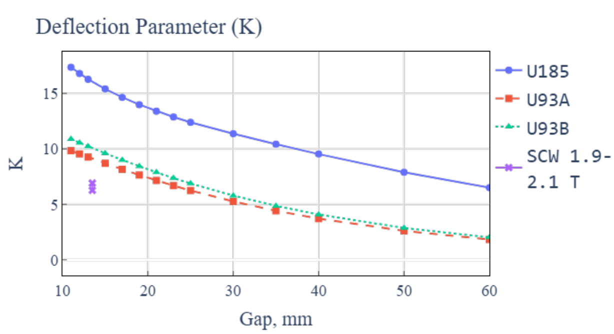

Figure 7: Deflection parameter, K, for SCW and three options.

CONCLUSION

The analysis demonstrates that a decommissioned undulator can be effectively reconfigured as a low-field wiggler, providing an interim solution for continued beamline operation at CLS if the current SCW were to fail. The proposed modifications allow reuse of existing hardware, reducing cost and installation time. Further optimization of the magnetic layout may improve performance and could be pursued as needed. This approach is driven by significant resource constraints, but offers a practical path to maintain some beamline capabilities while awaiting a permanent replacement. Ideally preliminary work needed to determine the maximum forces would be done in advance of any need to install the ID. This would allow an informed decision to be made on whether to modify the magnetic layout and determine which option from U93A or U93B would offer the best overall performance for the beamline.

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