Canadian Light Source / Centre canadien de rayonnement synchrotron

Super-Conducting Wiggler for the BMIT Beam Line

5.8.25.5 Rev. 0

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REVISION HISTORY

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A	02-07-2005	Original Draft	Alex Sitnikov Ingvar Blomqvist
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1.0 INTRODUCTION

1.1 PURPOSE

The Canadian Light Source Inc. (CLSI) requires a wiggler with high critical energy and brightness for the Biomedical Imaging and Therapy beam line (BMIT). This super-conducting wiggler's performance shall meet, at a minimum, the specifications contained in this document while operating under the special conditions that are also outlined in this document. The detailed design of the wiggler is the responsibility of the Vendor.

1.2 SCOPE

The design of the BMIT super-conducting wiggler (the "wiggler") should address the following:

- Magnet arrays and cryostat,
- Power supplies and quench protection system,
- Superconducting magnet's cryogenic cooling system with refilling system (if required)
- Control system,
- Equipment protection system,
- Interlock system,
- Monitoring systems.

1.3 BACKGROUND

The Canadian Light Source Inc., CLSI, is a national research facility on the University of Saskatchewan campus in Saskatoon, Saskatchewan. The facility is a 3rd generation synchrotron light source with an electron beam energy of 2.9 GeV and current up to 500 mA, which will produce high intensity beams of infrared, visible, ultraviolet and x-ray radiation.

1.4 DESIGN PROCESS

The combination of period length, peak field and electron beam aperture requirements are at the limit of the capability of conventional superconducting magnet technology. Therefore, CLSI requires Vendors to first design, build and test a prototype as a proof of concept. If the prototype meets the required specifications, CLSI will authorize the construction of the full size wiggler.

2.0 REQUIREMENTS

2.1 GENERAL

2.1.1 The wiggler for the BMIT beam line shall cover the 5 to 100 keV energy range, which requires a critical energy E_C > 20keV and a wide beam fan K~20 to fulfill its goal of imaging a wide variety of plant, animal, and human specimens using a variety of techniques. The brilliance shall be as high as possible, which means the wiggler period length shall be as small as possible. The combination of high field and period requires a super-conducting wiggler design.

2.1.2 The wiggler may be constructed using flat horizontal race-track coils, or using vertical race-track coils or helical windings around an iron body. Examples of wigglers with horizontal race-track coils are the multipole wigglers installed at MAX-lab [1] and ELETTRA [4]. Examples of wigglers with vertical helical windings are the 14 mm period mini-gap undulator built by ACCEL [2]. The prototype wiggler with NbSn wire under construction at ALS [5] has vertical race-track coils. Each type has advantages and disadvantages [3], and the decision of the geometry to be used is left to the Vendor.

2.1.3 The wiggler shall satisfy the specified values listed in Table1.

Table 1. Specifications at 2.9 GeV

PARAMETER	VALUE
Critical Energy E_C	nominal 20 keV
Magnet Peak Field B_0	≥ 4 T
Period Length λ	nominal 48 mm
Deflection Parameter, K-value	minimum 18
Number of Full Size Poles	25
Total Radiated Power P_{Total}@500mA	nominal 25 kW
Vacuum Chamber Vertical Aperture	≥ 10 mm
Vacuum Chamber Horizontal Aperture	≥ 50 mm
Maximum Overall Length	2000 mm

2.1.4 Preference will be given to designs with a peak field of more than 4 T.

2.1.5 In addition to the 25 full size poles, a number of poles in the entrance and exit may be used for better electron beam orbit maintenance. For the same reason, separate corrector coils may be used outside the wiggler.

2.1.6 The deflection parameter shall be wide enough to guarantee the horizontal beam profile for the experimental program of a minimum of 20cm at 50m from the source point with the ring energy at 2.9GeV. More generally, the K/γ shall be maintained at approximately 3.2 milliradians.

2.1.7 The following Sections refer to a coordinate system with the Z-axis along the stored electron beam, the Y-axis vertical and the X-axis horizontal and pointing outwards from the center of the storage ring.

2.1.8 Limits must be placed on the field integrals and the integrated multipoles of the wiggler to avoid disturbing the stored electron beam. The limits for the horizontal and vertical first and second field integrals on the wiggler centerline shall be (after correction with external steering coils, if applicable):

$$|I_1^x| = |I_1^z| < 50\ 10^{-6}\ \text{T-m} = 5\ \mu\text{rad for a 2.9 GeV beam}$$
$$|I_2^x| = |I_2^z| < 50\ 10^{-6}\ \text{T-m}^2 = 5\ \mu\text{m for a 2.9 GeV beam}$$

The limits on the integrated multipoles are specified in Table 2. The limits are valid in the interval (–10 mm < x < 10 mm). The limits on integrals and integrated multipoles shall be valid for all magnetic field settings.

Table 2. Limits on the Integrated Multipole Components

Integrated Multipole	Horizontal	Vertical
Quadrupole	$< 5\ 10^{-3}$ T	$< 5\ 10^{-3}$ T
Sextupole	< 0.6 T/m	< 0.6 T/m
Octupole	< 100 T/m^2	< 100 T/m^2

Rationale: Generally speaking, turning the wiggler power supply ON or OFF shall not affect the electron beam orbit stability more than 1µm. This can be accomplished with external corrector coils.

2.2 SUPER-CONDUCTING MAGNET ASSEMBLIES

2.2.1 The Vendor shall be responsible for the choice of geometry for the wiggler magnetic assemblies.

2.2.2 ACCEL type geometry for the magnet assemblies has a larger transverse roll off compared to the flat race track coils of the MAX-lab type. To judge the effect of the transverse roll off on the stored electron beam, the Vendor shall include a table with the first and third Fourier components of the spatial distribution of the magnetic field for one period for 0 mm < x < 25 mm, 0 mm < y < 4 mm, step length 1 mm in both x and y. **This table shall be provided independent of the geometry chosen**.

2.2.3 The Vendor shall be responsible for the design of the quench detection system and the magnet protection system [5] of the superconducting magnets. The response time of the protection system shall be sufficient to prevent damage and guarantee electrical isolation of the magnets from the power supplies.

2.2.4 The Vendor shall describe the maximum possible voltage spike during a quench and the insulation characteristics between the coils and the yoke. Maximum temperature after the quench shall be estimated during the design of the wiggler and confirmed during the installation and test of the wiggler.

2.2.5 Ramping time from zero up to maximum field shall not exceed 10 minutes, and the ramp rate shall not exceed 25% of maximum field per minute.

2.3 PROTOTYPE MAGNET

2.3.1 A 5 full size pole prototype magnet shall be constructed and tested in a bath cryostat or approved alternative. The prototype shall meet the requirements specified in Sections 2.1 and 2.2 with the exception of Critical Energy (E_c), number of full size poles and Total Radiated Power (P_{Total}) @ 500mA . The Vendor shall make a Prototype Magnet Test Plan to be reviewed and accepted by CLSI..

2.3.2 The conceptual design and all construction techniques used for the prototype magnet shall be the same as for the full size wiggler magnet.

2.3.3 The prototype shall contain the entrance and exit end sections of the full size wiggler in addition to the 5 full size poles.

2.3.4 The prototype magnet shall be tested to determine the quench current.

2.3.5 The magnetic measurements (see Section 2.2.2) made during the testing of the prototype magnet shall be done with a Hall probe calibrated at liquid helium temperature. The Vendor shall provide the test procedure, the Hall probe calibration procedure and the Hall probe calibration data to CLSI for review/approval.

2.3.6 CLSI reserves the right to witness the test of the prototype magnet and shall be notified at least one month before that test.

2.3.7 When the peak field of the prototype magnet satisfies the specification, the field configuration in the magnetic mid plane shall be measured with the calibrated Hall probe. The measurements shall be taken along lines parallel to the Z-axis for X = -15mm, -10mm, -5mm, 0mm, 5mm, 10mm, and 15mm. The distance between data points in the Z-axis shall be a maximum of 2mm.

2.3.8 The measurements defined in Section 2.3.7 shall be integrated once to obtain the first field integral, and then integrated again to obtain the second field integral. This information will be used to dimension the wiggler correction magnets.

2.3.9 The decision to authorize the construction of the full size wiggler will be based primarily on the data obtained from the prototype magnet testing including the quench protection system.

2.3.10 After acceptance of the prototype test results, the prototype can be salvaged for use in the production wiggler.

2.4 ELECTRICAL COMPONENTS

2.4.1 CLSI does not plan to use persistent current operation for the wiggler.

2.4.2 All electrical and electronic equipment shall meet the requirements of:

- CLS Magnet Power Supply Specification 8.4.30.1.
- Canadian Electrical Code C22.1-02, Part 1, 2002 include all external cabling and interconnection wiring size; the wire marking as per Table 19; temperature rating, and flame rating FT4 preferred.
- The Saskatchewan Electrical Inspection Act, E6-3 {1} available at http://www.qp.gov.sk.ca/documents/English/Statutes/Statutes/E6-3.pdf, with special attention to Section 18 "Manufacture, Sale …**use** etc." of electrical equipment. These requirements may be satisfied either by certification to the relevant CSA standard by an authorized inspection agency or by special inspection carried out by an authorized inspection agency which shall then put a certification mark on the equipment. A list of acceptable certification marks can be found at http://www.saskpower.com/services/cecr_sk/bulletins/item14.shtml. Each power supply, other powered auxiliary equipment, and the wiggler shall have their own certification mark.

2.4.3 The current-regulated power supplies shall have a long-term stability of < $1x10^{-5}$ of maximum current. Stability is the sum of drift from line, load, time, temperature and ripples. The wiggler power supplies shall meet this stability requirement over the range from 5 amps up-to full current.

2.4.4 All power supplies shall perform in a stable fashion and exhibit no evidence of oscillation over their entire operating range.

2.4.5 The power supplies shall have a fast disconnection from the wiggler to protect the wiggler during a quench, see Section 2.2.3 above.

2.5 CONTROL REQUIREMENTS

2.5.1 The Vendor shall meet the general control requirements defined in Appendix A-F of the CLSI Control System Technical Specification 7.4.39.1. The design of the control system shall be subject to prior acceptance by CLSI.

2.5.2 The control system shall:

- implement machine protection functionality,
- provide PID current control and motion,
- provide control of all cryogens: temperatures and level of Helium,
- provide PID temperature status of the super-conducting magnet,
- provide PID status inside vessels (vacuum or pressure, what applicable),

2.5.3 The control system shall be based on the Siemens S7/300 or S7/400 PLC (see details in Appendix C of the CLSI Control System Technical Specification 7.4.39.1 Section C.14: PLC Hardware)

2.5.4 It is the intention of CLSI to integrate the Siemens PLC into EPICS. The vendor shall work with CLSI on developing and implementing this interface. Data logging shall be provided through EPICS.

2.5.5 The control system shall be equipped with local touch panel control as well as provisions for remote control using Profibus / DP.

2.5.6 Temperature sensors (especially on cryo-heads) shall be calibrated and have a resolution of better that +/- 0.1 C.

2.5.7 The vendor shall use standardized CLSI process monitoring equipment. Analogue and digital signals shall be monitored by the PLC. RS-232 interfaces shall go to CLS furnished monitoring equipment.

2.5.8 All cabling shall be CSA approved (see Section 2.4.2 above) and contain CLSI issued cable numbers. These numbers shall be shown on wiring diagrams.

2.5.9 CLSI shall supply a template in Auto-CAD for the vendor to develop wiring diagrams for all control cabling.

2.5.10 The vendor shall provide a Process and Instrumentation Drawing (PID) subject to CLSI design review.

2.6 THE ELECTRON BEAM VACUUM CHAMBER

2.6.1 Fabrication of the vacuum chamber shall meet requirements of the CLSI Fabrication Specification 8.8.33.4.

2.6.2 The wiggler vacuum chamber shall be designed to reduce the induced heating from the stored electron beam. The copper inner surface must be smooth and polished in accordance with CLSI Document 8.8.33.4 to reduce heating from the high frequencies induced by the bunch structure of the beam.

2.6.3 The overall length of the wiggler assembly shall not exceed 2000 mm, and fit in the area defined in drawings SR1/ME/0044510 Rev.1, SR1/ME/0044511 Rev.0, SR1/ME/0044512 Rev.0.

2.6.4 Vacuum chamber for connection to the Storage Ring vacuum system shall be equipped with a flexible bellows ending in 6 inch Conflat flanges (150 mm OD).

2.6.5 The bellows shall be RF shielded, and create a smooth transition from the wiggler chamber to the storage ring chamber. The preferable transition ratio is 1:10 (rise:run), however the minimum acceptable transition ratio is 1:5 (rise : run).

2.6.6 All elements of the wiggler chamber will be protected from synchrotron radiation by a water cooled fixed mask with an 8 mm vertical aperture placed in front of the wiggler. The design and fabrication of the mask will be determined in collaboration with CLSI during the initial design review.

2.6.7 Once the detailed design is complete, the Vendor shall transfer all applicable drawings to

CLSI for review and approval.

2.7 THE CRYOGENIC SYSTEM

2.7.1 The wiggler shall be a self-contained system cooled with cryo-coolers with or without liquid helium as the cooling medium.

2.7.2 The Vendor shall design the wiggler cryostat, liquid helium filling system, monitoring of the helium level system and control system according to best practices.

2.7.3 The general arrangement of equipment on and within the Storage Ring shall be reviewed and approved by CLSI.

2.7.4 The vessel shall be equipped using standard CLS models of the vacuum components such as cold cathode gauges, thermal capacitance gauges, ION Pumps and roughing port.

2.7.5 The cryo-cooler compressors shall be installed in 19 inch racks to be located on top of the storage ring tunnel. The Vendor shall provide assembled racks and interconnect cables. For planning purposes, cable lengths should not be required to exceed 15 m.

2.7.6 If liquid helium is used as the cooling medium, the period between refills shall be at least 3 months.

2.7.7 The cryogenic system will be designed to handle a 2 watt beam-induced heating load on the vacuum chamber.

2.8 ALIGNMENT MARKS

2.8.1 Fiducial points shall be attached to the wiggler for the installation in the Storage Ring.

2.8.2 Fiducial points shall be accurately referenced to the magnetic axis within ±50μm.

2.8.3 Fiducial point positions shall be determined in collaboration with CLSI. CLSI uses 38.1mm diameter sphere mounted retroreflectors. These devices are mounted via a precision 8mm diameter hole, and machined flat.

2.9 CORRECTOR MAGNETS

2.9.1 Should the Vendor’s design include the requirement for corrector magnets, they must comply with Sections 2.1.8, 2.4.2, 2.5.1 and 2.5.7-2.5.10 inclusive.

3.0 SAFETY AND ENVIRONMENT

3.1 STORAGE RING TUNNEL SPACE

3.1.1 The straight section #5 where the wiggler will be installed is shown in the drawing SR1/ME/0044510 Rev.1 [7a].

3.1.2 The design of the interfaces between the wiggler and the Storage Ring components and CLSI's services (such as water cooling lines, pressurized air lines, electrical and control systems) is the responsibility of CLSI. The interface requirements will be determined during the initial design review.

3.1.3 The ceiling of the Storage Ring tunnel[7c] is solid (drawing SR1/ME/0044512 Rev.0 refers), and the wiggler must be rolled along the inside of the tunnel to the straight section #5 (see drawing SR1/ME/0044511 Rev.0). Drawing SR1/ME/PPG/WTR/0076700 Rev 4 shows the plan view of the technical facility.

3.1.4 The wiggler shall be installed on two bridges over the cooling water lines (see drawing SR1/ME/PPG/WTR/0076705 Rev 3 [7d]). The Vendor shall be responsible for the design of the bridges.

3.1.5 The wiggler shall stand on three or four alignment pads bolted to the bridges. The alignment pads shall have an adjustment range of ± 10 mm along the X, Y and Z-axes.

3.1.6 The Vendor is responsible for designing a suitable transporter that will move the wiggler from the test area to straight #5 and transfer the wiggler onto the bridges. CLSI has developed a transport system for an undulator which is available to the Vendor if desired.

3.1.7 The exact placement of the compressors, liquid helium Dewar and so on will be determined in collaboration with CLSI.

3.1.8 The vacuum chambers shall be capable of operation in an ambient temperature range of +10 to +40 degrees C. The normal ambient temperature of the Storage Ring tunnel is +27 degrees C. The expected temperature stability of the tunnel will be better than +/-1 degree C during normal operation.

3.1.9 The components shall be able to withstand a relative humidity range of 0 % to 95%. The expected relative humidity limits under operation are from 25% during the winter months and to a maximum of 50% during the summer months. The expected relative humidity range for components under storage will be the same.

3.1.10 Cable with Teflon insulation shall not be used in the storage ring tunnel. Teflon insulated cable may be used outside the tunnel but its use shall be minimized.

3.1.11 Unless absolutely essential to the design, electronics shall be located outside of the storage ring tunnel.

3.2 VIBRATION STANDARD

3.2.1 The magnetic components shall have a maximum vibrational movement of less than 0.4 microns RMS at frequencies less than 100 Hz under normal operating conditions.

3.3 WATER / PNEUMATICS

3.3.1 Low conductivity cooling water (LCW) will be supplied by CLSI if active cooling of the any component is needed. The supply water will have a conductivity of less than 6 μS/cm.

3.3.2 Any Vendor-designed water-cooling systems shall follow the requirements specified in Section 4.14 of the CLSI Design Specification 8.4.33.1

3.3.3 Supply temperature of the LCW will be nominally between +25 to +30 degrees Celsius.

3.3.4 Clean, dry instrument quality air may be used with review and acceptance by CLSI. Air is supplied at 758 kPa (110 PSI) and room temperature.

4.0 QUALITY ASSURANCE

The Vendor shall maintain and apply a quality assurance program consistent with ISO-9001 for the design, manufacture and testing of the wiggler system. CLSI reserves the right to inspect all quality assurance documents at the vendor's facilities during the life of the contract.

5.0 ACCEPTANCE TESTS

5.1 FACTORY ACCEPTANCE TEST

The Vendor shall make a Factory Acceptance Test Plan to be reviewed and accepted by CLSI. At a minimum, the test plan shall include but not be limited to:

- cooling down and warming up of wiggler;
- ramping up and down of magnetic field;
- test of quench protection system;
- measurement of remnant field after a quench;
- measurement of the magnetic field as a function of X in the interval -15 mm < X < 15 mm in 5 mm step for maximum field;
- measurement of the magnetic field at X = 0 for various field settings below the maximum field;
- measurement of the vertical and horizontal first and second field integrals for different field settings; and
- test of pressure relief valves and other machine protection functionality.

5.2 ACCEPTANCE TEST AT THE CLSI SITE

5.2.1 The Vendor shall make a CLSI site test plan to be reviewed and accepted by CLSI. At a minimum, the Acceptance Test shall include but not be limited to the items covered in the Factory Acceptance Test.

5.2.2 The Vendor is responsible for the stable operation of the wiggler power supplies at all field settings and during ramping up and down of the wiggler field.

5.2.3 The Vendor and CLSI shall jointly develop feed forward tables for the wiggler correction coils and the wiggler power supplies to safeguard the stable operation of the electron beam with minimum impact on the beam positions around the ring for all modes of wiggler operation.

6.0 RELIABILITY AND MAINTAINABILITY

6.1.1 Long term reliability and ease of use are critical to the application and operation of this magnet. Specifically, the cryostat must be able to operate continuously for up to a year. The system should be robust enough to last several decades of experimental use. It is essential that the operation be easy enough for reliable low temperature operation without continuous operator intervention.

6.1.2 The system shall require no more than 24 hours of scheduled maintenance per year not including refilling the helium system. Each helium refill shall not require more than 6 hours.

6.1.3 The system shall only be warmed up at most once per calendar year.

6.1.4 The cool down or warm up period should not exceed 48 hours.

6.1.5 All instrumentation shall be labeled following the CLSI naming convention.

6.1.6 All cables shall be labeled with CLSI cable numbers.

7.0 OTHER REQUIREMENTS AND CONSTRAINTS

7.1 DOCUMENTATION AND LABELLING

7.1.1 All documentation shall comply with CLSI Vendor Documentation Specification 0.4.1.1 and Section 6 of the CLSI Design Specification 8.4.33.1.

7.1.2 The Vendor shall supply complete documentation of all components and subsystems. In addition to Section 2.11 of the CLSI Vendor Documentation Specification 0.4.1.1 this documentation shall include but not be limited to the following:

- Control system interface commands/protocols,
- Hook-up instructions (both operational and preventative),
- Normal adjustments and calibration setup procedures,

Electrical diagrams shall comply with CLSI Document 0.4.1.1 Vendor Documentation Specification.

7.1.3 The Vendor shall provide the CLSI with electronic copies of all custom developed source code, PLC programming and embedded logic in source and binary format on CD-ROM.

7.1.4 All test measurement results shall be incorporated into the final report that shall be provided to CLSI in hardcopy, on CD-ROM, and also archived at the Vendor's location.

7.1.5 The labeling shall be in accordance with Section 8 of the CLSI Design Specification 8.4.33.1. The nameplate information shall be in 14 point size fonts.

7.2 INSTALLATION

7.2.1 The Vendor is responsible for transporting the wiggler to CLSI and installing the wiggler in the storage ring.

7.2.2 The wiggler shall be packed and handled in accordance with Section 9 and Section 10 of the CLSI Fabrication Specification 8.8.33.4 and be capable of being lifted by a 10 tonne crane such that the assembly can be transported over the Storage Ring tunnel and the Booster Ring tunnel to an area between the Storage Ring and the Booster Ring. The free height under the crane hook is 3 meters. The CLSI acceptance test will be carried out in this area.

7.2.3 After the CLSI Acceptance Test, the wiggler must be transported from the test area to the straight section #5. The Vendor is responsible for the design of the transporter (see also Section 3.1.5).

7.2.4 The wiggler is then transferred from the transporter to the bridges and installed in the storage ring.

8.0 APPLICABLE CODES, STANDARDS AND PROCEDURES

The Vendor's design shall consider standards from the following organisations:

- American National Standards Institute (ANSI);
- International Standards Organization (ISO); and
- American Society for Testing and Material (ASTM).

The design and workmanship shall adhere to the following codes, standards and procedures. The revision status of any of the following documents shall be the effective revision as of the date of request for tender. Any conflicts between this specification and the referenced documents shall be brought to the attention of the CLSI in writing for resolution before any related action is to be taken by the Vendor:

- American Society of Mechanical Engineers, Boiler and Pressure Vessel Code

(ASME-BPVC);

- CAN/CSA B51-97 Boiler, Pressure Vessel, and Pressure Piping Code;
- CSA B52-99 Mechanical Refrigeration Code;
- CSA Canadian Electrical Code 1998 Safety Standards for Electrical;
- CLSI Vendor Documentation Specification 0.4.1.1 Rev.3;
- CLSI Control System Technical Specification 7.4.39.1 Rev.2;
- CLS Magnet Power Supply Specification 8.4.30.1 Rev.1;
- CLSI Vacuum Design Specification 8.4.33.1 Rev.3;
- CLSI Vacuum Component Cleaning Technical Procedure 8.7.33.1 Rev.1;
- CLSI Vacuum Component Leak Test Technical Procedure 8.7.33.2 Rev.1;
- CLSI Vacuum Component Fabrication Technical Specification 8.8.33.4 Rev.0;
- Canadian Electrical Code C22.1-02, Part 1, 2002; and
- The Saskatchewan Electrical Inspection Act, E6-3 {1}, with special attention to Section 18 “Manufacture, Sale, etc.”.

9.0 REFERENCES

[1] G. LeBlanc, E. Wallen, “Evaluation of the MAX Wiggler”, Contributed paper, EPAC’02, Paris, 2002.

[2] R.Rossmaninth et al, “Superconductive 14 mm Period Undulators for Single Pass Accelerators (FELs) and Storage Rings”, Contributed paper, EPAC’02, Paris, 2002.

[3] I Blomqvist, Canadian Light Source, Saskatoon, SK. CLS Conceptual Design Report 6.2.25.5 Rev 0, “Magnetic Design of a Superconducting Wiggler for CLS”.

[4] A. Batrakov et al, ”A Superconducting 3.5 T Multipole Wiggler for the ELETTRA Storage Ring”, Contributed paper, EPAC’02, Paris, 2002.

[5] E. Wallen, “Quench Analysis of a Superconducting Magnet with 98 Coils Connected in Series”, To be Published in IEEE Transactions on Applied Superconductivity, 2003.

[6] CLSS Prestemon et al, “Design and Evaluation of a Short Period Nb3Sn Superconducting Undulator Prototype”, Contributed paper, PAC’03, Portland, 2003.

[7] Drawings:

a. SR1/ME/0044510 Rev.1;

b. SR1/ME/0044511 Rev.0;

c. SR1/ME/0044512 Rev.0;

d. SR1/ME/PPG/WTR/0076705 Rev 3 (see Detail #5);

e. SR1/ME/PPG/WTR/0076700 Rev 4.

10.0 SUMMARY TABLE

Table 3. BMIT Wiggler Specifications at 2.9 GeV

Parameter	**Value**	**Notes**
Critical Energy E_C	nominal 20 keV	
Magnet Peak Field B_0	≥ 4 T	
Period Length λ	nominal 48 mm	
Power Supply Stability	< $1x10^{-5}$	ΔI/I
Cool down or Warm up Time	≤ 48 hours	
Deflection Parameter, K-value	minimum 18	K/γ ~ 3.2milliradians.
Number of Full Size Poles	25	
Total Radiated Power P_{Total} @ *500mA*	nominal 25 kW	
Vacuum Chamber Vertical Aperture	≥ 10 mm	
Vacuum Chamber Horizontal Aperture	≥ 50 mm	
Maximum Overall Length	2000 mm	
Operating Time Between Service	1 year	
Time between LHe fill up	minimum 3 months	If LHe used.
Time for a LHe fill up	Maximum 6 hours	If LHe used.