THE MAX WIGGLER

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Abstract

The demand for high fluxes of x-rays at MAX-lab will be met with a novel insertion device called the MAX-Wiggler. The cold bore superconducting MAX-Wiggler with 47 3.5 T poles and a period length of 61 mm has been built at MAX-lab. This note describes some of the properties of the MAX-Wiggler as well as some of the results of the prototype studies.

1 INTRODUCTION

There is an increasing demand at MAX-lab for high fluxes of x-rays to perform crystallography and material physics. The MAX-II storage ring [1], which is a third generation light source, has somewhat limited beam energy to produce high fluxes of x-rays using conventional insertion devices. The beam energy in MAX-II cannot be increased beyond 1.5 GeV and the stored current is limited to about 200 mA. The desired enhancement of the x-ray flux at MAX-lab must therefore be obtained by further development of the insertion devices installed at the accelerator.

A new type of insertion device, The MAX-Wiggler, which will give a high flux of x-rays, has been built at MAX-lab. The MAX-Wiggler is a cold bore super conducting wiggler with 47 poles and a field strength of 3.5 Tesla. With such a device and the 1.5 GeV electron beam of 200 mA in the MAX-II ring, a flux of approximately 2.3×10^{14} photons/sec/mrad/0.1% can be expected at the critical energy of 5.2 keV. The spectral flux from the MAX-Wiggler is shown in Figure 1. The MAX-Wiggler parameters are tabulated in Table 1.

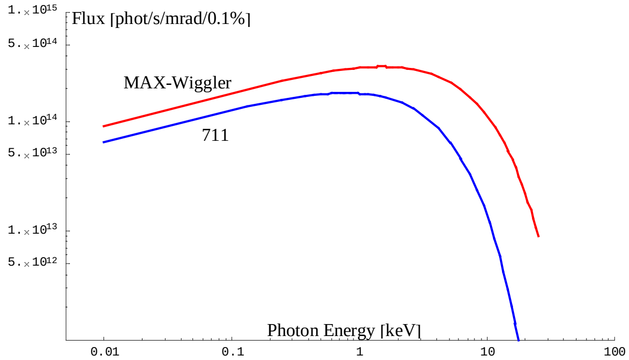

Figure 1: Spectral flux from a 47-pole wiggler with a 3.5 T peak field compared to a 27-pole wiggler with 1.8 T peak field (711). The stored electron beam current is 200 mA at an energy of 1.5 GeV.

Table 1: Parameter list of the MAX-Wiggler.

Wiggler period	61 mm
Vertical Aperture	10.2 mm
Horizontal Aperture	70 mm
Total Length of Magnetic Assemblies	1512 mm
Number of Full Size Poles	47
Total Number of Poles	49
Peak Field	3.54 T
Peak Field for End Poles	2.10 T
K, Deflection Parameter	21.2
Total emitted power, 200 mA current	5.0 kW
Stored magnetic energy	38.4 kJ
1st Field Integral	1.4×10^{-4} Tm
2nd Field Integral	10.2 T^2m
3rd Field Integral	31.7 T^3m

2 MAGNET

2.1 The Coils

The basic building block of the MAX-Wiggler is a pair of superconducting racetrack coils with iron cores and iron return field yokes building up a pole pair. A schematic layout of a pole pair including the racetrack coils, the iron central pole and the return field yokes at the top and bottom is shown in Figure 2.

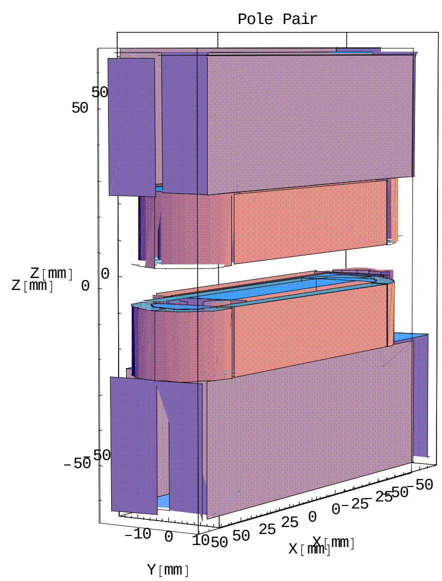

Figure 2: Schematic layout of a pole pair in the MAX-Wiggler, showing the coils, the iron central cores and the return yokes.

The MAX-Wiggler consists of 49 such pole pairs. The first and last pole pairs have smaller coils and a weaker magnetic field than the 47 central pole pairs. A zero field integral in the wiggler is maintained by a correction current that can be subtracted or added to the main current in the end coils.

The superconducting wire is commercially available. It has 54 NbTi filaments with a diameter of 57 µm in a Cu matrix. The coils are wound on the iron cores and then epoxy impregnated.

2.2 The Prototype Wiggler

In order to test the coil design before starting production, a test cryostat was built and a prototype wiggler, with 3 full size poles and two smaller poles, was constructed. All of the dimensions of the prototype wiggler were the same as will be used in the full size ones except for the length. A comparison of the measured and calculated fields for the prototype wiggler can be seen in Figure 3. Figure 4 is a schematic drawing of the prototype wiggler.

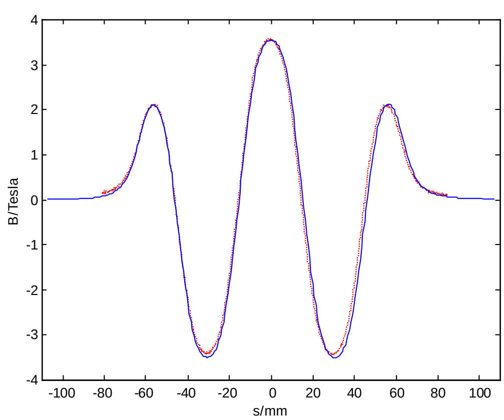

Figure 3: Comparison of the measured (dashed) and calculated (solid) magnetic fields for the prototype wiggler.

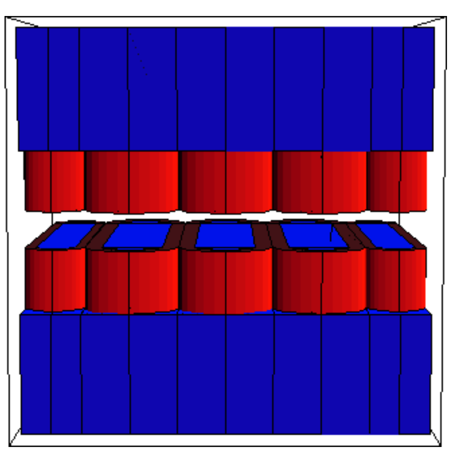

Figure 4: Schematic drawing of prototype wiggler.

The calculations were made with a Mathematica™ add on package called Radia [2]. The measurements were made with a transverse Hall-probe sensor mounted on rod that could be moved along what would be the beam path. The applied current was 280 A.

3 CRYOGENIC SYSTEM

The MAX-Wiggler cryostat is cooled by a liquid He bath at 4.2 K and the superconducting coils are completely immersed in the liquid He. The enthalpy of the cold boiled off He gas is used for cooling the rest of the cryostat, i.e. the cold He gas passes the accelerator vacuum tube, the thermal shields, supports, and current leads on its way out of the cryostat. The buffer volume in the He vessel is about 350 litres, which is sufficient for one week of operation. The expected He consumption of 2 litres per hour is determined by the 1.4 W heat leak to the 4.2 K temperature level.

Figure 5 shows a schematic layout of the cryogenic system for the MAX-Wiggler cryostat with a He buffer tank. The system is assumed to have five temperature levels and heat loads, denoted T1-T5 and Q1-Q5 in Figure 5. The expected temperatures and heat loads are given in Table 2.

Temp. Level	[K]	Heat Load	[W]	Description
T1	4.2	Q1	1.4	He tank
T2	9.2	Q2	1.8	First Cooling Point on accelerator vacuum tube
T3	26.7	Q3	6.3	Second Cooling Point on accelerator vacuum tube
T4	50.0	Q4	8.4	Thermal Shield
T5	69.0	Q5	3.4	Warm end of the HTSC current leads.

Table 2: Temperature levels (T1-T5) and heat loads (Q1-Q5) in the MAX-Wiggler.

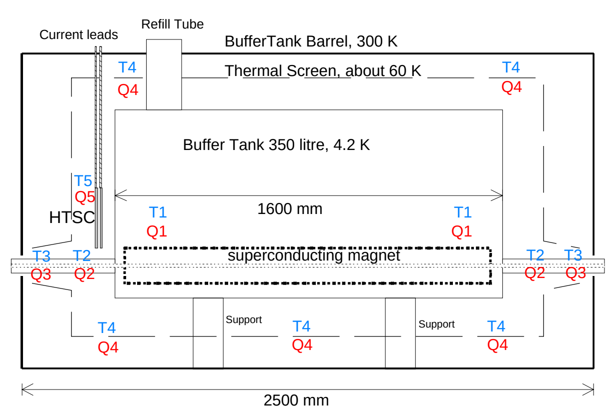

Figure 5: Schematic layout of the cryogenic system of the MAX-Wiggler cryostat.

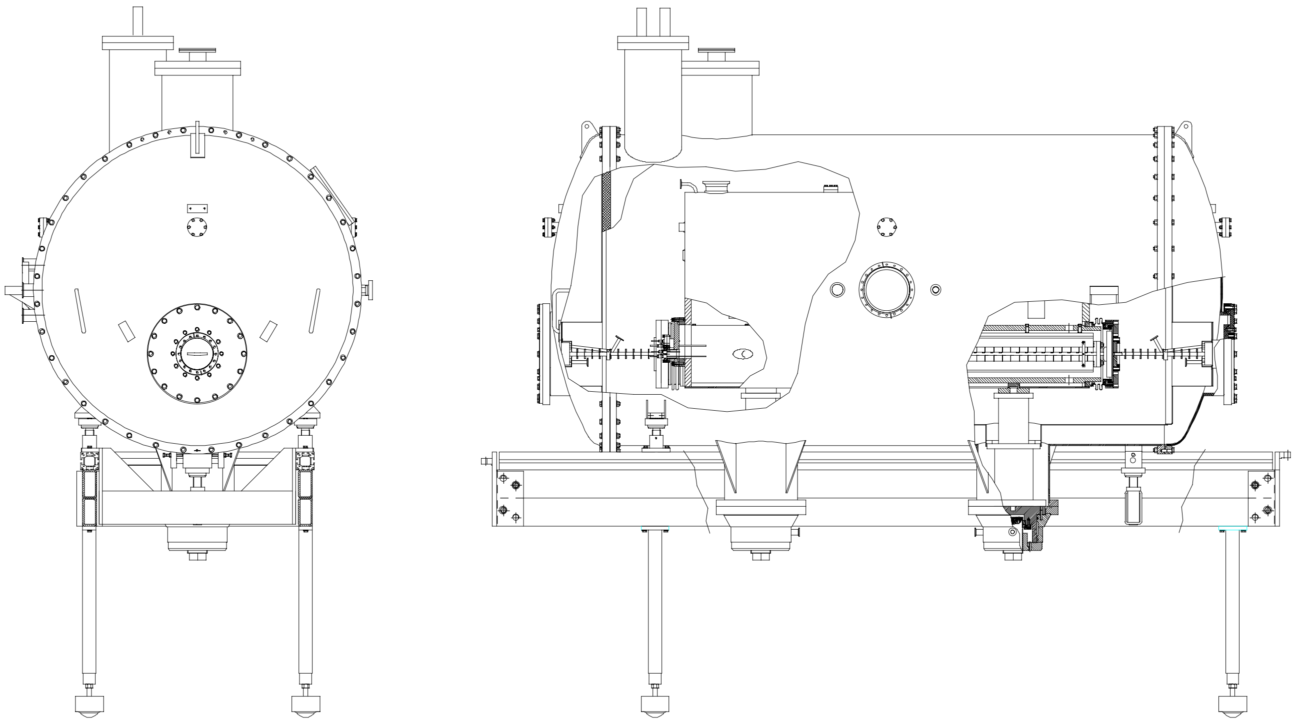

Figure 6: The MAX-Wiggler Cryostat

Figure 6 shows a drawing of the actual cryostat with girder as it will look when installed in the ring. From flange to flange it is approximately 2.5 m and the diameter of the outer tank is 1.1 m.

The thermal loads to the cryogenic system stems from a number of different sources, a few of which are thermal conductance through the supports and accelerator vacuum tube, thermal radiation, synchrotron radiation, image currents, and resistance in current leads. In 1999, a test cryostat with an identical vacuum tube to the MAX-Wiggler was mounted in the MAX-II storage ring in order to verify that it is possible to use the cold bore concept. The runs with the test cryostat and stored electron beam in MAX-II have shown that the cold bore concept does not give rise to an uncontrollable input of heat to the cryogenic system.

The current leads are of hybrid type. The first stage is a brass pipe leading the current from the outer wall at 300 K to the junction at 69 K (T5 in Fig. 5). The second stage is a high temperature super-conductor (HTSC) leading the current from the junction at 69 to 4.2 K. The normal conducting part leading the current from 300 K to 69 K needs cooling from the boiled-off He gas. The use of the boiled off gas for cooling the current leads puts a restriction on a minimum boil-off of liquid He of about 1 l/h, or a 0.7 W heat load at 4.2 K. The system is self-regulating in that a lower He boil off will result in a higher heat load which increases the He boil off.

5 CONCLUSIONS

In order to meet the demands for high fluxes of x-rays at MAX-Lab and other, similar lower energy third-generation light sources, the only alternative is to further develop the insertion devices. As stated previously, increasing the beam energy of MAX-II is not an option, neither is increasing the current.

At present, all of the magnet coils in the first wiggler have been tested to over 300 A current. The cryostat is in the final stages of testing. The second cryostat is being manufactured and the coils for it are being tested. The first wiggler is scheduled for installation during the summer 2001 shutdown and the second one at the end of 2001.

7 REFERENCES

[1] Å. Andersson et. al., ‘The MAX II Synchrotron Radiation Storage Ring’, Nucl. Instr. and Meth. A 343 (1994) 644-649.

[2] Shareware program developed at ESRF, Grenoble, France, for more information look at the web-site http://www.esrf.fr/machine/support/ids/Public.