A SUPERCONDUCTING 7T MULTIPOLE WIGGLER FOR BESSY II: MAIN CHALLENGES AND FIRST FIELD MEASUREMENTS*

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Abstract
To provide high flux hard X-ray beams with a critical energy of 16.8 keV for material research, a 17 pole superconducting 7T wiggler has been built for the BESSY II ring.
The scope of this paper is to describe the magnetic layout and the main technological challenges of this unique insertion device. Secondly we will report on first tests of the magnet at high fields including the quenching behaviour. Magnetic fields were measured using Hall-probes to determine the on-axis field distribution as well as the lifetime in the persistent current mode and the remanent field strength.
A first evaluation of the measured fields including a comparison with 3D-field calculations indicates that the specified field quality could be met.

1 INTRODUCTION

A 17 pole superconducting wiggler has been built for the BESSY II ring to provide high flux hard X-ray beams. The conceptual design of this magnet and the essential test results of a 7 pole prototype structure have been described earlier [1]. In the meantime the full 17 pole magnet structure has been manufactured and all test measurments, that have to be done before the magnet is finally inclosed in the cryostat, has been performed to check and characterize the magnet. In the present paper the technical layout is described in some detail and the results of these tests are reported.

2 DESIGN ASPECTS AND TEST MEASUREMENTS

The magnet consists of 13 full poles with a field of 7 T and two endpoles on each side with a strength of -¾ and ¼ respectivley to allow the electron beam to wiggle symmetrically around the nominal orbit. For reason of best focussing the beam line the total length of the device is restricted, i. e. the period length of the device is designed to be as low as 148 mm. Figure 1 shows the top view of the lower half of the magnet including the return yoke. Details of the coils and the iron poles are given in figure 2. The coils are of elliptical shape and consists of two windings (851 and 852 turns) which are excited by individual currents (inner windings I_1 =130 A and outer winding I_2=370 A). Because the ¾-side pole is supplied with current I_2 only and the ¼-side pole has I_1 only, it is possible to adjust the first and second integral to zero by just varying the two currents I_1 and I_2. Round wire of NbTi material (NbTi to Cu ratio 1:1.3) with laquer isolation and a diameter of 0.91 mm has been used. Figure 3 shows the wiggler magnet during assembly.

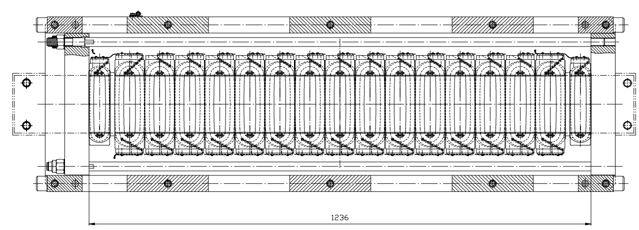

Figure 1: Top view of lower half of the magnet

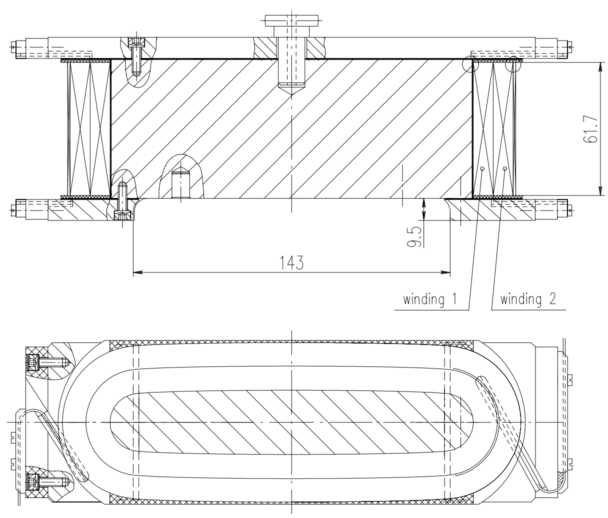

Figure 2: Cut and top view of the poles

Figure 3: Wiggler magnet during assembly

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After assembly of the magnet and proper prestressing of the coils the magnet was cooled down in a bath cryostat to LHe temperature, and a first series of tests were performed to verify the proper operation of the wiggler. Further test measurements after assembling the magnet in its own cryostat will investigate the complete 3D field map using the streched wire technique.

3 QUENCH HISTORY

Earlier prototype tests [1] showed the necessity of a sufficient prestress in the coils preventing the superconducting wire from even small movements, which may quench the magnet. Here the prestress is generated in longitudinal direction with the help of 8 srews (see figs. 1 and 3).

As shown in figure 4 a maximum field slightly above 7.4 T has been reached after only 8 quenches, where 3 quenches could be attributed to technical incidences rather than real quenches. After a first thermal cycle (warm up to LN_2 temperature and cool down to 4.2 K) the first quench occured around 7 T, and 7.4 T could be reached after only 3 quenches. For the operation at a nominal field of 7 T this provides a comfortable safety margin.

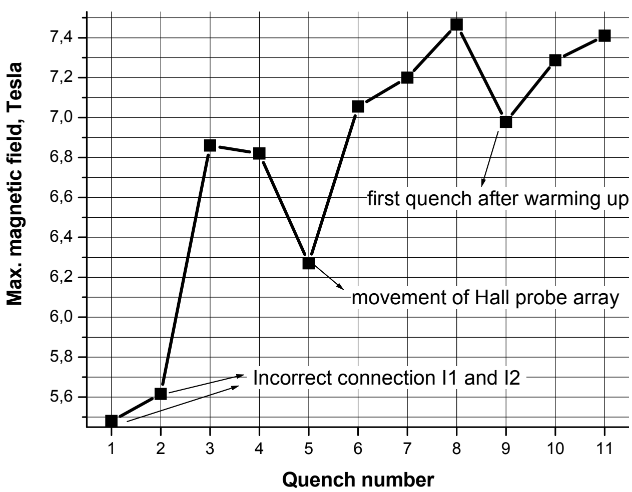

Figure 4: Quench history

4 REMANENT FIELD

After a quench the superconducting wires become normal conducting and all currents, including persistent currents in the wire, disappear. Only the remanent field of the iron, is preserved. As indicated in figure 5 the remanent field has a typical value around 3 mT. Only in the region of the endpoles higher magnetic fields are observed.

The magnetic field caused by the persistent currents in the superconductor, that might disturb the stored electron beam, can be measured after slowly reducing the currents I_1 and I_2 to zero without any quench. Figure 6 shows that the residual magnetic field strength exceeds the remanent field. But the first integral of this residual field is small enough to be corrected by the steerers outside of the wiggler.

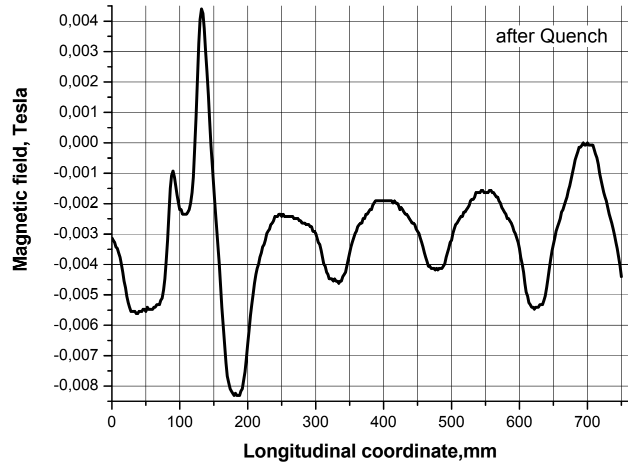

Figure 5: Remanent field in one half of the wiggler after a quench (middle of the wiggler at 700 mm)

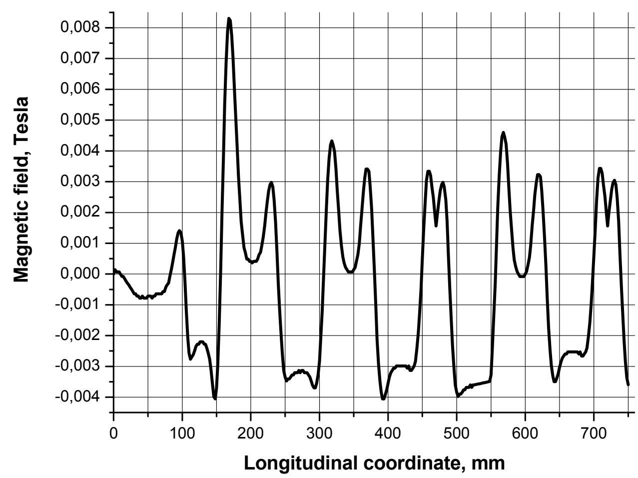

Figure 6: Field distribution in one half of the wiggler after slowly decreasing currents to zero

5 FIELD DISTRIBUTION

To measure the distribution of the wiggler field along the nominal magnet axis a hall probe sitting on a small carriage has been moved through the gap of the magnet while the magnet is hanging in the bath cryostat. Figure 7 shows the measured field and a 3D field calculation with the program MERMAID, written by BINP. Here the calculated field has been normalized at the central pole to the measured field. A more detailed analysis has shown that the two field distributions agree well if the period length of the calculation is reduced to 147.5 mm (from the design value of 148 mm). The deviation might be caused by the high pressure of the prestressing system. This deviation is of no importance for the normal operation of the wiggler.

The horizontal orbit has been determined using the measured and calculated fields, see figure 8, assuming an „on axis“ beam at the entrance of the wiggler. As a result, the orbit error at the exit of the wiggler is Δx=5μm, Δx'=50μrad for the measured field which can be neglected.

Further test measurements will be performed after installation of the magnet in the final cryostat. 3D-field mapping and stretched wire measurements are planned to characterize the field in more detail and evaluate integral multipole errors also.

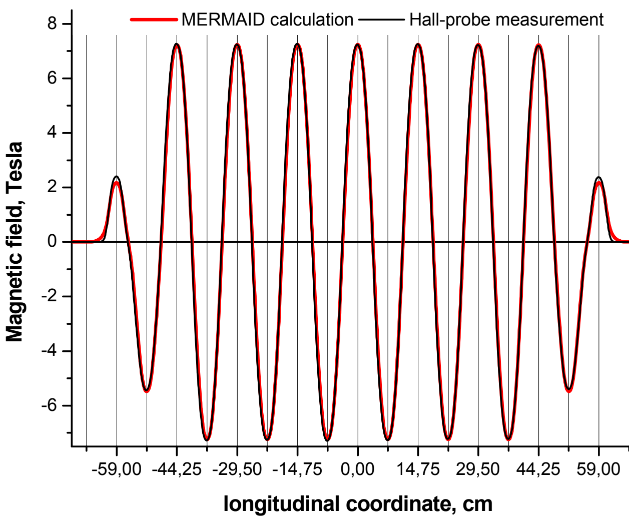

Figure 7: Longitudinal field distribution measured with a hall probe and calculated with MERMAID

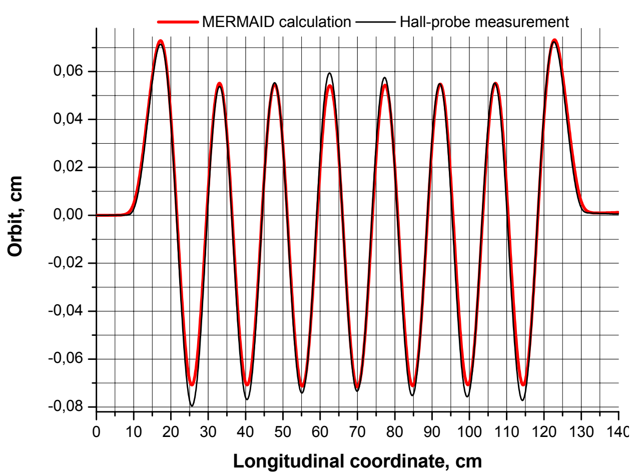

Figure 8: Horizontal electron orbit calculated from the measured and calculated fields

6 LIFE TIME

In the persistent current mode, after de-connecting the power supplies, the currents I_1 and I_2 are decreased only by the ohmic resistance of the connections between the superconducting wires of each winding. The magnetic field is measured to decay at a rate of $\Delta B/B \approx -5*10^{-5}$ per hour, corresponding to a lifetime of the magnetic field of about 2 years. This gives evidence that all superconducting connections were done properly with an ohmic resistance of about 10^{-11} ohm. To reach this rather low resistance a new connection technique has been developed using high pressure clamping combined with inert gas welding. Figure 9 shows one of these connections, where the cap is made from Nb.

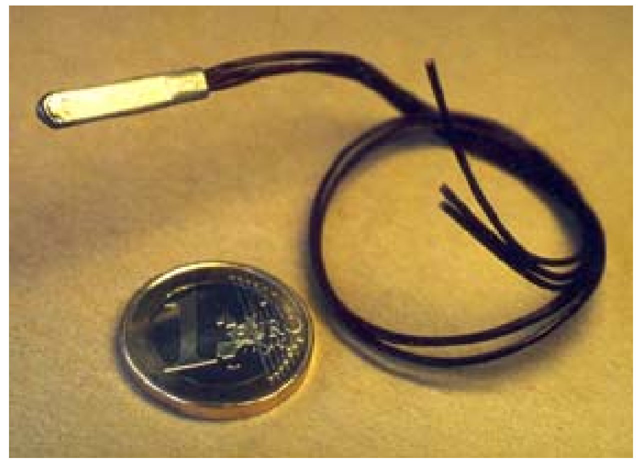

Figure 9: Connection of superconducting wires with ohmic resistance below 10^{-11} ohm

Future stretched wire measurements will examine the different decay rates of the currents I_1 and I_2 and their influence on the first integral as well as on the electron beam.

7 CONCLUSION

The magnet of a new superconducting high field wiggler with 17 poles has been manufactured and all test measurements, that have to be done before the magnet is finally inclosed in its own cryostat, were succesfully completed.

A peak field of 7.4 T has been reached after a few quenches demonstrating the feasibility of the wiggler concept and the correctness of the mechanical design. First field distribution measurements indicate that the magnetic field has the expected properties. Additional measurements are planned after installation of the magnet in the cryostat to determine integral multipole errors.

8 REFERENCES

[1] D. Berger, M. Fedurin, N. Mezentsev, S. Mhaskar, F. Schaefers, M. Scheer, V. Shkaruba, E. Weihreter, "A superconducting 7T multipole wiggler for the BESSY II Ring", PAC'01, Chicago, 2001