FIRST EXPERIMENTS WITH A 100 PERIOD SUPERCONDUCTIVE UNDULATOR WITH A PERIOD LENGTH OF 3.8 MM

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Abstract

A prototype of a novel superconductive undulator with a period length of 3.8 mm is described. The undulator is 100 periods long. In the first tests described in this paper the undulator was cooled in a helium bath and it was shown that it can be operated as expected with a maximum current of 1400 A. Afterwards the undulator field was measured with a miniature Hall probe with an active area of 100x100 µm². Calculated and measured field distributions are in good agreement. A cryostat for a beam test at Mainz microtron MAMI was built in which liquid helium cools indirectly the in-vacuum undulator. At the moment the cryostat is tested and optimized.

1 INTRODUCTION

The principal layout of the superconductive undulator is shown in fig. 1.

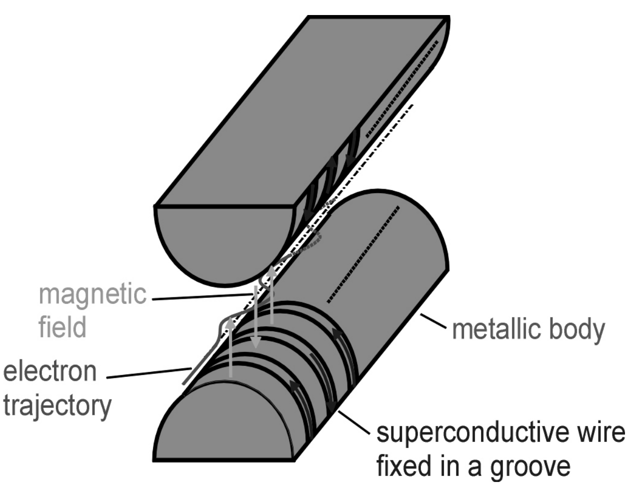

Fig. 1: Principal layout of the superconductive undulator.

The magnetic field is produced by superconductive wires (NbTi wires with a rectangular shape of 1.25x0.8 mm^2). The wires are guided in grooves cut into a metallic block. The current direction alters from winding to winding and, therefore, produces an alternating magnetic field.
The current through the wire is limited by the generated magnetic field. The practical layout is shown in fig. 2.

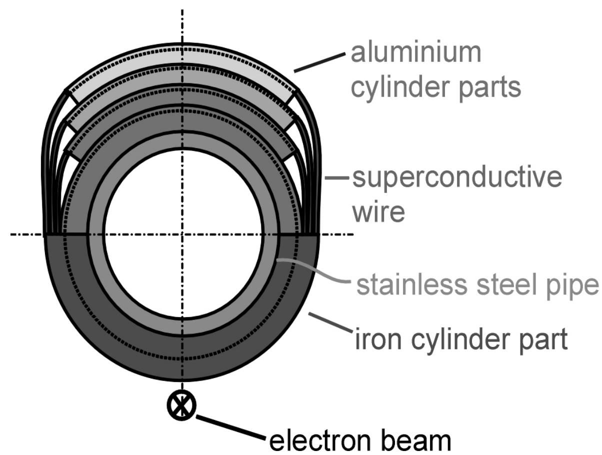

Fig. 2: The practical layout of the undulator.

The undulator consists out of 4 layers of superconductive wires. The layers are wound one after the other around the half cylinders schematically shown in fig. 2. The half cylinder next to the beam is made of soft iron and contains grooves perpendicular to the electron beam. The grooves in the aluminium half cylinders have slopes like a screw.
The winding procedure starts by fixing a loop in the middle of the wire in a special groove. Afterwards the superconductor is wound in the bifilar way shown in fig. 3.

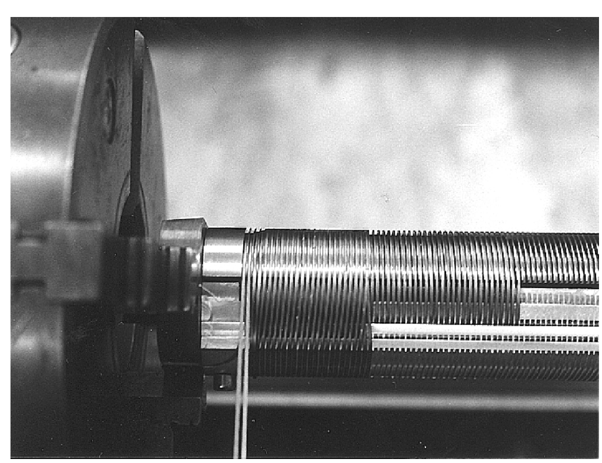

Fig. 3: Bifilar winding procedure of the undulator on a turn table.

In fig. 4 the completely wound undulator together with the attached Hall probe and the guiding rails is shown.

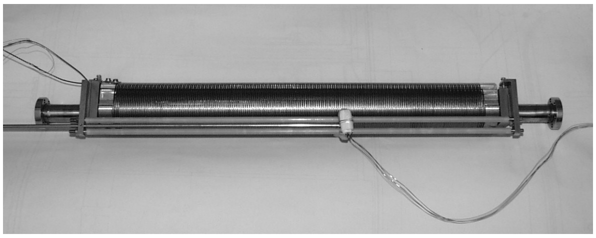

Fig. 4: One undulator half with the miniature Hall probe.

The undulator shown in fig. 4 is 100 periods long and has a period length of 3.8 mm.
The maximum current through the wire is limited by the magnetic field generated by the current. A quench test in a bath cryostat showed that the critical current of the undulator winding is about 1400 A.

2 FIELD MEASUREMENTS

The magnetic probe has to operate under cryogenic conditions. The detector has to be moved from outside (preferably from a room temperature environment) in a precise way to measure the field strength of the undulator. In addition the resolution of the probe must be about 0.1 mm in order to measure the real field of an undulator of 3.8 mm period length.
A first measurement was performed with a miniature Hall probe gliding along the undulator on a guiding rail. The semiconductor Hall probe has an active area of 0.1x0.1 mm^2 and can operate at helium temperatures. The probe was calibrated by using a solenoid of known field strength at liquid helium temperatures. During the measurement which was performed in a liquid helium bath the Hall probe was moved along the undulator in a distance of 0.5 mm and the magnetic field profile shown in fig. 5 was measured. Fig. 6 shows a small part of fig. 5 with a better resolution.

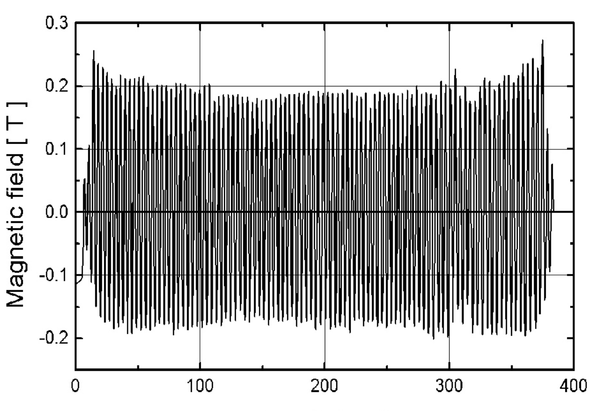

Fig. 5: Measured field of one undulator half.

In fig. 5 the 100 periods are clearly visible showing disturbances of the field especially on the right hand side in the last third of the undulator. This disturbance is caused by a zone of not precisely machined grooves. The extended view in fig. 6 shows the relatively smooth sinusoidal field of the undulator.

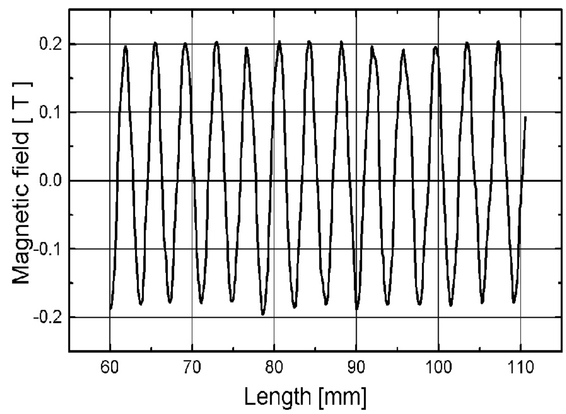

Fig. 6: Extended view of the magnetic field in the middle of the undulator.

It should be mentioned that the measured field is lower than the field calculated with MAFIA [1]. These discrepancies have to be clarified and can be due to the measurement or the model that was used for the calculations. Nevertheless, the shape of the calculated and measured field are almost identical. This is especially true for the end fields in which measurements and calculations agree almost in a perfect way.

3 THE CRYOSTAT FOR AN IN-VACUUM EXPERIMENT

In order to conduct a beam test of the undulator at the 855 MeV microtron MAMI in Mainz a cryostat was constructed which is presently tested. The basic concept of the cryostat is shown in fig. 7. Inside a vacuum chamber a helium shield is installed which houses the undulator parts in its center. In order to maximize cooling liquid helium also flows through the undulators.
The main problem is the heat flow from the top of the system via the current feed-throughs and the bellow (a bellow was used between room temperature and helium tank in order to minimize the heat transfer). In order to keep the heat flow low the feed-throughs are cooled by cold helium gas and the wall thickness of the bellow is very small.
A picture of the cryostat and the undulator is shown in fig. 8.

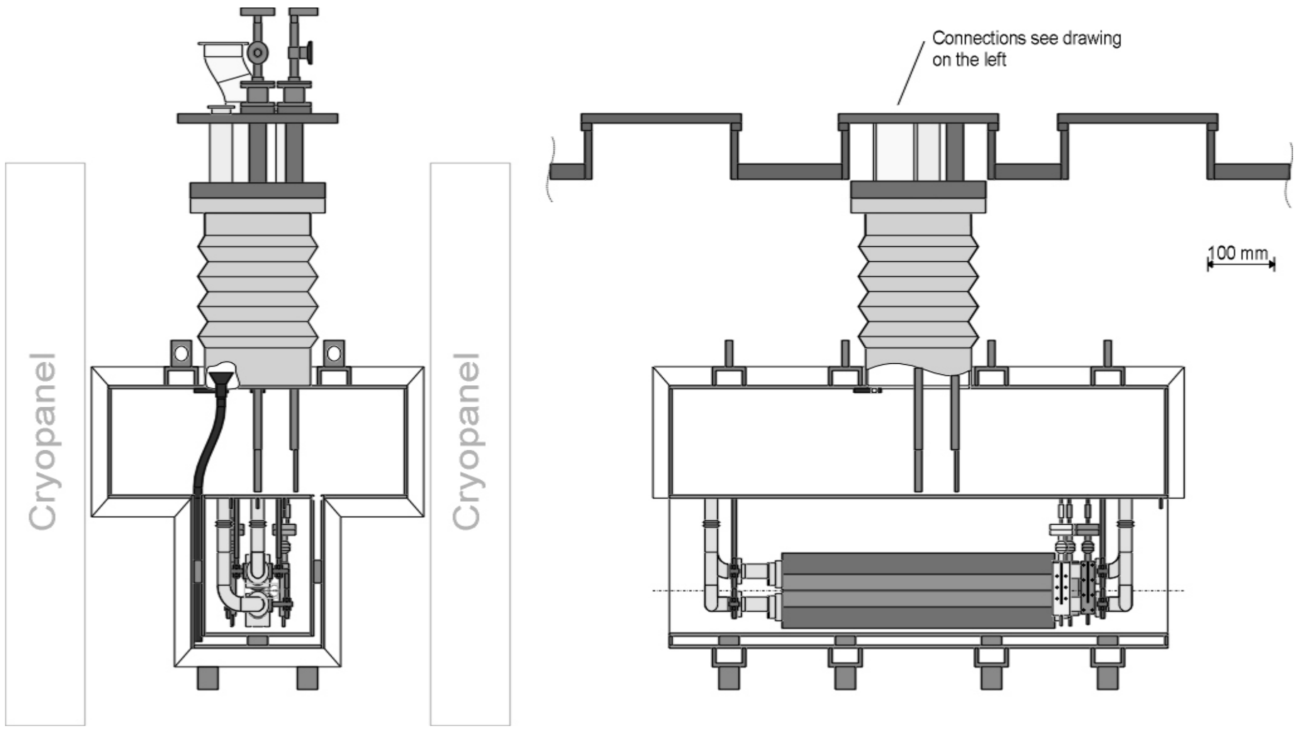

Fig. 7: Principal layout of the cryostat for an in-vacuum experiment.

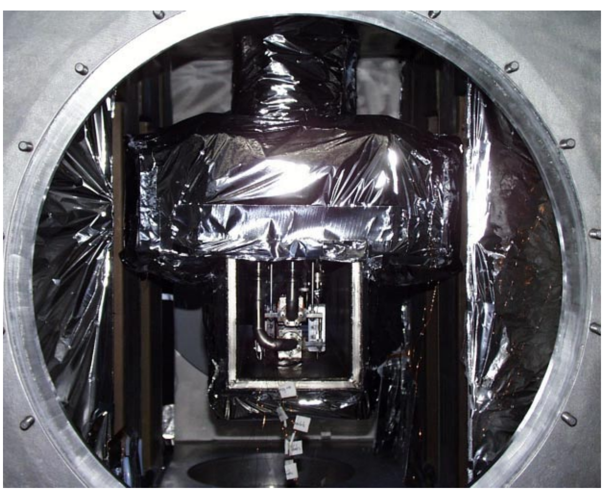

Fig. 8: Picture of the test set-up for the in-vacuum experiment.

The pictures can be explained by comparing figs. 7 and 8. In the upper picture the He-tank (with super-insulation) and the He shield can be seen. In the lower picture the current feed-throughs and the two undulators are clearly visible

Extensive tests were performed to study the feasibility of such a cryostat. The results so far are: it was possible to cool down the undulator to a temperature between 4 and 5 K which is low enough so that the undulator becomes superconductive. The cooling of the superconductive wires between the helium bath and the undulator causes presently still problems. At the moment the cooling in this part of the undulator is improved in order to be able to send an electric current of about 1000 A through the undulator.

4 PREPARATIONS OF BEAM TESTS

The superconductive undulator presented in this paper can only work in an accelerator when the energy deposited from the electron beam in the 1 mm gap can be carried away by the indirect cooling with liquid helium. Therefore, tests were performed at MAMI where the beam profiles and the deposited energy were measured. The profile was measured with a wire scanner. The energy deposition in a 1 mm gap was measured with a metal block with a vertical slit of 1 mm height. The vertical beam size was 25 µm (one sigma), the horizontal 40 µm (one sigma). The deposited heat load was estimated to be less than 0.03 W at 1 µA and 3.1 W at 100 µA beam current. These measurements were performed without any up-stream shielding of the beam halo.

5 SUMMARY

It was shown that a superconductive in-vacuum undulator is a viable concept. Beam tests will be performed this summer. Afterwards it should be decided if such a system can be used in a high current synchrotron light source.

6 REFERENCES

[1] MAFIA, CST, Darmstadt, Germany, 1996