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DEVELOPMENT OF A SUPERCONDUCTING HELICAL UNDULATOR FOR THE ILC POSITRON SOURCE*

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Abstract

An undulator positron source has been recently selected by the International Liner Collider (ILC) community as a baseline. For the ILC a helical undulator capable of producing 10 MeV photons and with a period as close as possible to 10 mm is required. The HeLiCal collaboration in the UK is looking at the merits of both permanent magnet and superconducting technologies for the design of a helical undulator. For the superconducting option, several prototypes have been built and tested. This paper details the design, construction and test results of the first superconducting prototypes.

INTRODUCTION

The work of the HeLiCal collaboration is focused on R&D aimed at the construction of an undulator which meets the specifications for operation in the ILC (500 GeV e^+e^- interactions).

Options for undulator insertion devices in electron accelerators include permanent magnet and superconducting magnet technologies. The collaboration built and tested short undulator prototypes based on both technologies and eventually decided in 2005 to select superconducting technology for the ILC undulator.

This paper details the design, construction and test

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results of the first superconducting prototypes.

ILC UNDULATOR PARAMETERS

The requirements for the ILC undulator were discussed at the Second ILC Accelerator Workshop at Snowmass [1] and agreed by the Global Design Effort Meeting in Frascati [2]. They are listed in the following table.

Table 1: ILC Undulator Parameters

Electron energy	150 GeV
Photon energy	10 MeV
Period	10 mm (desirable)
Beam stay clear	4 mm
Total length	100 m

SUPERCONDUCTING UNDULATOR R&D

Aim of R&D phase

The HeLiCal collaboration has launched an extensive R&D programme with the goal of developing construction techniques applicable for building up to 2 m-long superconducting helical undulator sections which can be used to build a full-scale undulator module for the ILC positron source. This phase of the project will lead to the design and manufacture of the first 4-m long undulator module followed by measuring its performance in an electron beam.

Magnetic modelling

Intensive magnetic modelling as a part of R&D programme, is being carried out in order to choose the

winding geometry of the undulator. Software packages OPERA 2d and 3d from Vector Fields Ltd [3] are used for the modelling studies.

The results of magnetic modelling indicate that:

- A winding with a flat shape (with the minimal radial height to width ratio) creates maximal field on axis for a given current density. However, taking into consideration the peak field in the conductor, a square shape was found to be optimal.
- The peak field in the conductor is about twice the field on the undulator axis. According to the modelling, the highest field in the conductor is usually in the internal layers of the winding.
- The inclusion of magnetic material outside the winding increases the field on axis. The largest field enhancement is achieved when, in addition to the outer yoke, the former poles are also made of magnetic material.

More results of the magnetic modelling can be found in our paper [4].

Fabrication R&D

An extensive programme of fabrication R&D has been launched to develop fabrication techniques applicable to up to 2-m long sections of short-period helical undulators. The issues of machining undulator formers with precision of 50 μm or better, incorporating a beam pipe into the former, developing winding and vacuum impregnation techniques are being addressed.

SHORT UNDULATOR PROTOTYPES

In order to test the techniques developed during the manufacture R&D, a number of short undulator prototypes with a length of about 300 mm have been built. Parameters of first two short prototypes built and tested, are listed in Table 2.

Table 2: Parameters of Short Prototypes.

Parameter	Prototype 1	Prototype 2
Design field on axis	0.8 T	≥ 0.8 T
Former material	Al	Al
Winding period	14 mm	14 mm
Winding bore	6 mm	6 mm
Magnet bore	4 mm	4 mm
Winding	8-wire ribbon, 8 layers	9-wire ribbon, 8 layers
Prototype goal	Check winding technique	Check effect of mechanical tolerances

We are building at least three more short prototypes. Prototypes 3 and 4 will differ only in the former material (Al in one and soft iron in the another) and will be used to compare the results of magnetic modelling with measurements. And prototype 5 will check the final

geometry of winding before manufacturing longer undulator sections of the first full-scale undulator module.

Prototype 1

The very first 300 mm-long superconducting helical undulator prototype was built and successfully tested. Its description and the results of preliminary tests can be found in [5]. The final view of this prototype before installation into the cold test rig is shown in Fig.1.

The field measurement facility for short undulator prototypes has been recently improved. It now allows a precise control over the movement of Hall probe in the undulator bore. This new facility was used to re-measure the performance of prototype 1 and will be employed to test all the following prototypes.

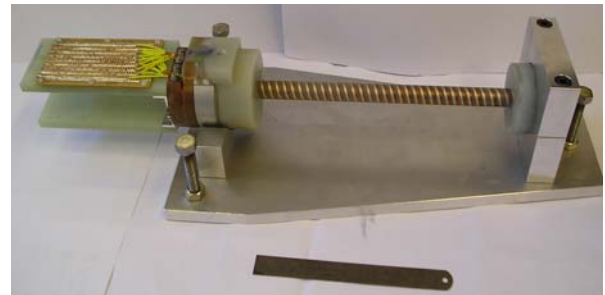


Figure 2: Undulator prototype 1 completed.

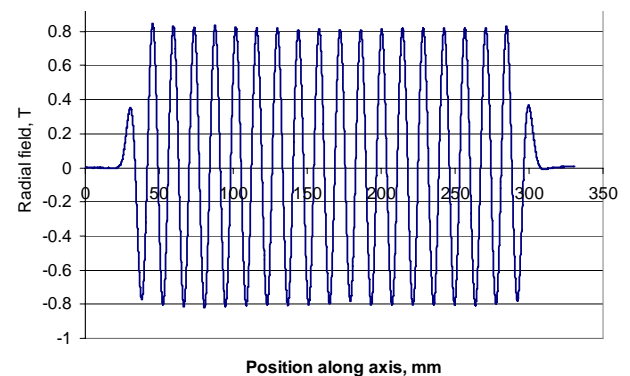


Figure 1: Profile of the axial component of the magnetic field on the undulator axis for prototype 1.

The prototype 1 field profile profile measured at the current of 220 A, is shown in Fig.2. The radial field reaches its nominal value of 0.8 T on the undulator axis.

Prototype 2

The goal for this prototype was to machine a former with a helical groove capable to accommodate winding with a 9-wire ribbon and to check the effect of mechanical tolerances on the field quality. The former for this prototype was milled on a 4-axis machine unlike the prototype 1 former which was turned on a lathe. After the measurements of the field profile have been completed, the winding was sectioned in order to measure the actual

geometry of the winding. It is found that the winding bore (inner winding diameter) of this undulator is about 100 μm smaller in the middle part as compared to the nominal winding bore of 6 mm while the end parts have a larger winding bore. This leads to the increase of the radial field on axis in the middle part of the undulator by about 0.017 T or by about 2%.

Variation of the average radial field on axis with the inner winding diameter measured for prototype 2 is shown in Fig.3. while Fig. 4 shows a section of the prototype 2 winding.

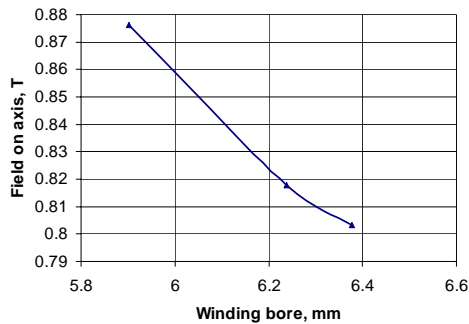


Figure 3 Dependence of average radial field on axis versus average winding bore as measured for prototype 2.

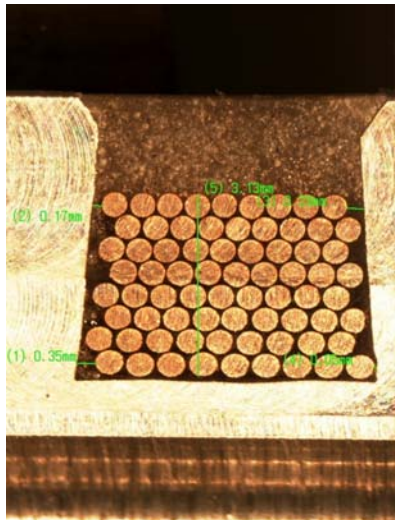


Figure 4: Undulator prototype 2 winding cut.

CONCLUSION

The HeLiCal group is running an R&D programme aiming to develop first full-scale undulator module which meets specifications for the operation in the ILC positron source.

This programme includes both the magnetic modelling and the technological R&D aiming at manufacture of 2-m long sections of a superconducting helical undulator.

Several short prototypes are being built, two of them have been tested. Both prototypes reached the design field on axis of 0.8 T.

At least three more short prototypes will be built to study the effect of iron poles in the former on the field value and to compare the results of magnetic modelling with measurements.

Successful completion of the R&D phase will enable techniques to develop first full-scale undulator module.

ACKNOWLEDGMENT

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