Cockcroft 07-41

DEVELOPMENT OF A FULL SCALE SUPERCONDUCTING UNDULATOR MODULE FOR THE ILC POSITRON SOURCE*

Y. Ivanyushenkov#, E. Baynham, T. Bradshaw, A. Brummitt, S. Carr, A. Lintern, J. Rochford
STFC Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX, UK
J.A. Clarke+, O.B. Malyshev+, D.J. Scott+, B.J.A. Shepherd+
STFC ASTeC Daresbury Laboratory, Daresbury, Warrington, Cheshire WA4 4AD, UK
I.R. Bailey+, P. Cooke, J.B. Dainton+, L. Malysheva+
Department of Physics, University of Liverpool, Oxford St., Liverpool, L69 7ZE, UK
D.P. Barber+
DESY-Hamburg, Notkestraße 85, 22607 Hamburg, Germany
G.A. Moortgat-Pick+
Institute of Particle Physics Phenomenology, University of Durham, Durham DH1 3LE, UK

Proceedings of PAC07, Albuquerque, New Mexico, USA

DEVELOPMENT OF A FULL SCALE SUPERCONDUCTING UNDULATOR MODULE FOR THE ILC POSITRON SOURCE*

Y. Ivanyushenkov#, E. Baynham, T. Bradshaw, A. Brummitt, S. Carr, A. Lintern, J. Rochford
STFC Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX, UK

J.A. Clarke+, O.B. Malyshev+, D.J. Scott+, B.J.A. Shepherd+
STFC ASTeC Daresbury Laboratory, Daresbury, Warrington, Cheshire WA4 4AD, UK

I.R. Bailey+, P. Cooke, J.B. Dainton+, L. Malysheva+
Department of Physics, University of Liverpool, Oxford St., Liverpool, L69 7ZE, UK

D.P. Barber+
DESY-Hamburg, Notkestraße 85, 22607 Hamburg, Germany

G.A. Moortgat-Pick+
Institute of Particle Physics Phenomenology, University of Durham, Durham DH1 3LE, UK

Abstract

An undulator based positron source is the baseline for the International Linear Collider (ILC). The HeLiCal collaboration in the UK is working on the development of a full scale 4-m long undulator module. Several prototypes have been built and tested in the R&D phase of the programme that culminated in the development of manufacturing techniques suitable for construction of the first full scale undulator sections. This paper details the design and the construction status of 4-m long undulator module.

INTRODUCTION

The work of the HeLiCal collaboration has 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 in the first stage).

An extensive technological research and development programme on short-period superconducting helical undulators has been completed, culminating in the manufacture and test of several undulator prototypes. The programme has built up the technological expertise necessary to manufacture 2-m long sections of undulator magnet. This has enabled the design of a full scale 4-m long undulator module as required for the ILC positron source.

The design and construction status of the undulator module is presented in this paper.

* Work supported by the Commission of the European Communities under the 6th Framework Programme "Structuring the European Research Area", contract number RIDS-011899.
# Y.Ivanyushenkov@rl.ac.uk
+ Cockcroft Institute, Daresbury Laboratory, Warrington, Cheshire WA4 4AD, UK

ILC UNDULATOR PARAMETERS

The requirements for the ILC positron source undulator are presented in the ILC Reference Design Report [1]. They are summarized in the following Table 1.

Table 1: ILC Undulator Parameters

Electron Drive Beam Energy	150 GeV
Photon Energy (1st harmonic cutoff)	10.06 MeV
Photon Beam Power	131 kW
Undulator Type	helical
Undulator Period	11.5 mm
Undulator Strength	0.92
Field on Axis	0.86 T
Beam Aperture	5.85 mm
Undulator Length	147 m

SUPERCONDUCTING UNDULATOR R&D

Several years ago the HeLiCal collaboration launched an extensive R&D programme with the goal of developing construction techniques applicable for manufacture up to 2 m-long superconducting helical undulator sections which could be used to build a full-scale undulator module for the ILC positron source. This phase of the project included magnetic modelling (see [2] for more details) as well as a technological R&D. The programme addressed the issues of machining undulator formers with a precision of 50 μm or better, development of winding technique and vacuum impregnation, as well as building a test facility. During this phase of the project several short prototypes have been manufactured and tested verifying and developing the manufacturing techniques. More information on the results of the R&D programme can be found in [3]. Successful completion of this stage has now lead to the design of a full scale 4-m long undulator module.

FULL SCALE UNDULATOR MODULE

Specification

The goal of a full scale module is to demonstrate the technology required for construction of the ILC positron source undulator. Parameters used to define this undulator module are listed in Table 2.

Table 2. Undulator Module Specification

Module cryostat length	4 m
Number of magnet section per module	2 (powered separately)
Magnet section effective length	1.74 m
Vacuum bore	5.23 mm
Undulator period	11.5 mm
Field on axis	0.86 T
Nominal current	216 A

The module consists of two undulator sections immersed in liquid helium inside a LHe vessel, this assembly forms the cold mass of the undulator module. The cold mass is supported by four tie rods inside the cryostat and is enclosed by a radiation shield held at the temperature of 50 K. The cryostat turret incorporates two pairs of HTS current leads allowing independent powering of the magnet sections as well as a liquid helium condensing chamber, cooled down by a two-stage cryocooler.

Magnet sections

Each of two magnet sections is a scaled up version of the 0.5-m – long undulator prototype built and tested during the R&D phase. It is wound onto the former which is assembled out two soft iron pre-machined springs and a copper tube. The magnet design concept is illustrated in Fig.1.

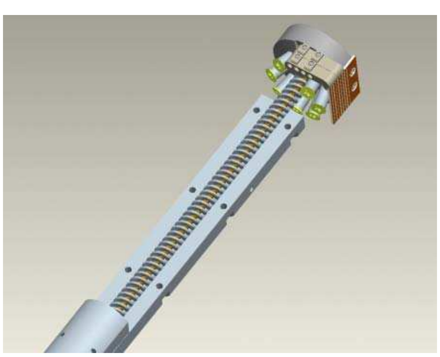

Figure 1: Conceptual design of the helical undulator section.

The undulator is covered by the soft iron yoke which provides a mechanical support for the former and also increases the field by about 7 % . The multi-layer winding of the undulator is performed with a ribbon glued of 7 superconducting wires as shown in Fig. 2. The wires of the ribbon are interconnected on a printed circuit board at one end of the undulator section. More information on the undulator manufacture can be found in [4].

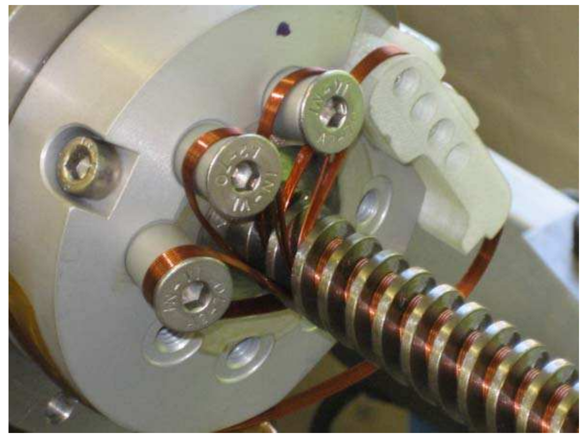

Figure 2: Details of the undulator winding.

The sections are wound on a specially built winding machine which is shown in Fig. 3, and then vacuum impregnated.

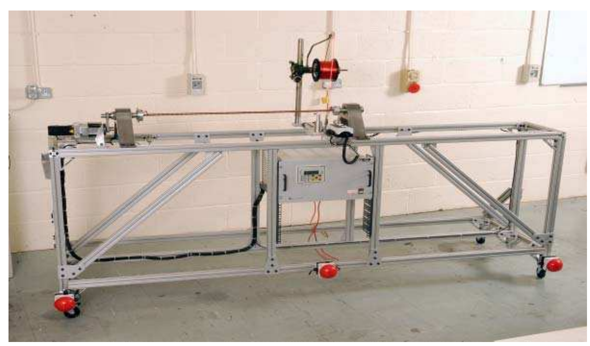

Figure 3: A test winding of 1-m long undulator prototype on a custom built winding g machine.

Each magnet section will be tested in a dedicated test facility where the field profile on the undulator axis and the quench current measurements will be performed. After testing the sections are assembled in a stiff U beam and installed into the liquid helium vessel.

Cryostat

The cold mass is mounted inside the vacuum vessel as shown in Fig. 4. It is covered by a thermal radiation shield cooled by conduction from the cryosooler first stage and kept at temperature of 50 K. The LHe vessel is pre-cooled by passing liquid nitrogen through the cooling pipe on the outside of the vessel, it is then cooled further using liquid helium from a dewar. In operation the liquid level inside the LHe vessel will be maintained by condensing the boiled off He gas in a condenser cooled by the second stage of the cryocooler. The level of liquid helium inside the LHe vessel will be monitored by a level sensor.

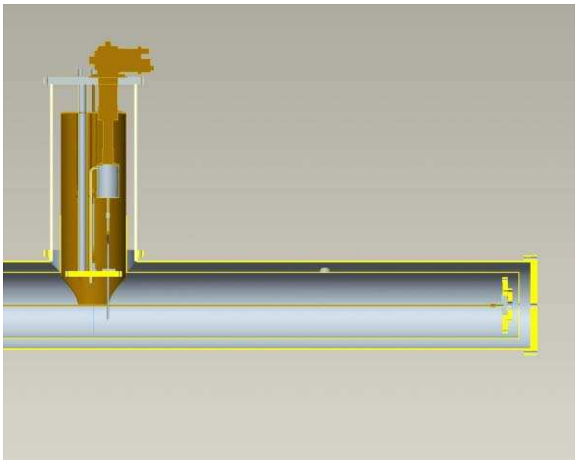

Figure 4: Undulator module cryostat assembly.

The cold mass inside the vacuum vessel is supported by four rods. The support system constrains the cold mass movement but still permits its thermal contraction of about 6 mm along the axis at each end.

Turret

The cryostat turret incorporates a two-stage cryocooler as shown in Fig. 5.

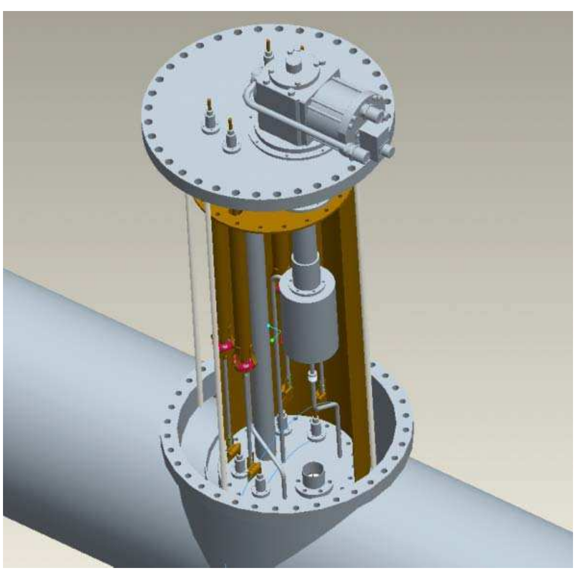

Figure 5: Cryostat turret layout.

The first stage of the cryocooler is used to cool the radiation shield as well as two pairs of HTS current leads. The cryocooler second stage cools a liquefaction plate in the helium condenser where the cold helium gas is re-condensed. Preliminary thermal calculations suggest that a closed-cycle cooling scheme could be achieved in principle, although the beam heat load on the cold mass is an important parameter that need to be verified by testing the module in the beam.

Instrumentation

The undulator module is instrumented with a number of thermal sensors to measure the temperature of the cryocooler stages as well as the temperature of current leads. Level sensors are employed to monitor the level of liquid helium inside the condensing chamber and in the LHe vessel. The current leads are equipped with the voltage taps to monitor magnet quenches.

Project status

The group is currently finishing the detailed design of the undulator module, while the manufacture of the undulator sections has already been started. The formers for two magnet sections are completed and the test winding of the first section is on the way. The test facility is under preparation. The group's goal is to test the first undulator section in summer 2007 and to complete the undulator module by end 2007.

CONCLUSION

A full-scale 4-m long superconducting helical undulator module is being built at the Rutherford Appleton Laboratory by HeLiCal group. It will achieve the parameters required for the ILC positron source undulator. The group's aim is to complete the module by end 2007.

ACKNOWLEDGMENT

The authors thank the members of the Magnets and Electrical Systems Group of CERN Accelerator Technology Department for their help in the manufacture of the superconducting wire ribbon.

REFERENCES

[1] International Linear Collider Reference Design Report, ILC-Report-2007-01, April, 2007.

[2] J. Rochford et al., "Magnetic Modelling of a Short Period Superconducting Helical Undulator for the ILC Positron Source", Proceedings of EPAC 2006, Edinburgh, p.840.

[3] Y. Ivanyushenkov et al., "Status of R&D on a Superconducting Helical Undulator for the ILC Positron Source", these proc.

[4] Y. Ivanyushenkov et al., "Development of a Superconducting Helical Undulator for a Polarised Positron Source", Proceedings of PAC05, Knoxville, May 2005, p. 2295.