FACTORY ACCEPTANCE TEST OF COLDDIAG:
A COLD VACUUM CHAMBER FOR DIAGNOSTICS

S. Gerstl*, T. Baumbach, S. Casalbuoni, A. W. Grau, M. Hagelstein, D. Saez de Jauregui,
T. Holubek, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany,
C. Boffo, G. Sikler, BNG, Würzburg, Germany,
V. Baglin, CERN, Geneva, Switzerland,
M. P. Cox, J. C. Schouten, Diamond Light Source, Oxfordshire, England,
R. Cimino, M. Commisso, B. Spataro, INFN/LNF, Frascati, Italy,
A. Mostacci, Rome University La Sapienza, Rome, Italy,
E. J. Wallén, MAX-lab, Lund, Sweden,
R. Weigel, Max-Planck Institute for Metal Research, Stuttgart, Germany,
J. Clarke, D. Scott, STFC/DL/ASTeC, Daresbury, Warrington, Cheshire, England,
T. W. Bradshaw, STFC/RAL, Chilton, Didcot, Oxon, England,
R. M. Jones, I. R. R. Shinton, University Manchester, Manchester, England

Abstract

Superconducting insertion devices (IDs) have higher fields for a given gap and period length compared with the state-of-the-art technology of permanent magnet IDs. One of the still open issues for the development of superconducting insertion devices is the understanding of the heat intake from the electron beam. With the aim of measuring the beam heat load to a cold bore and the hope to gain a deeper understanding in the underlying mechanisms, a cold vacuum chamber for diagnostics was built. It is equipped with the following instrumentation: retarding field analyzers to measure the electron flux, temperature sensors to measure the beam heat load, pressure gauges, and mass spectrometers to measure the gas content. The flexibility of the engineering design will allow the installation of the cryostat in different synchrotron light sources. The installation in the storage ring of the Diamond Light Source is foreseen in November 2011. Here we report about the technical design of this device, the factory acceptance test and the planned measurements with electron beam.

INTRODUCTION

At ANKA we are running a research and development program on superconducting insertion devices (SCIDs). One of the key issues for the development of superconducting IDs is the understanding of the beam heat load to the cold vacuum chamber. Possible beam heat load sources are synchrotron radiation, resistive wall heating, electron and/or ion bombardment and RF effects.

Although the values of the beam heat load due to synchrotron radiation and resistive wall heating have been measured at different light sources the disagreement between measurements and calculations is not understood [1-3]. Studies performed with the cold bore superconducting undulator installed at the synchrotron

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radiation source ANKA suggest that the main contribution to the beam heat load is due to secondary electron bombardment [2].

Figure 1: Picture of COLDDIAG at ANKA

In order to gain a quantitative understanding of the problem and to find effective remedies we have designed a cold vacuum chamber for diagnostics (COLDDIAG) [3] to be installed in different synchrotron light sources. The goal is to measure the heat load, the pressure, the gas content and the flux and spectrum of the low energy electrons bombarding the wall. The vacuum chamber was fabricated and assembled by the company Babcock Noell GmbH, whereas ANKA was responsible for the diagnostic components. In the following we describe COLDDIAG [4], the factory acceptance test and the planned measurements with beam.

THE VACUUM CHAMBER

COLDDIAG consists of a cold vacuum chamber located between two warm sections, one upstream and one downstream. The electron beam will go through a
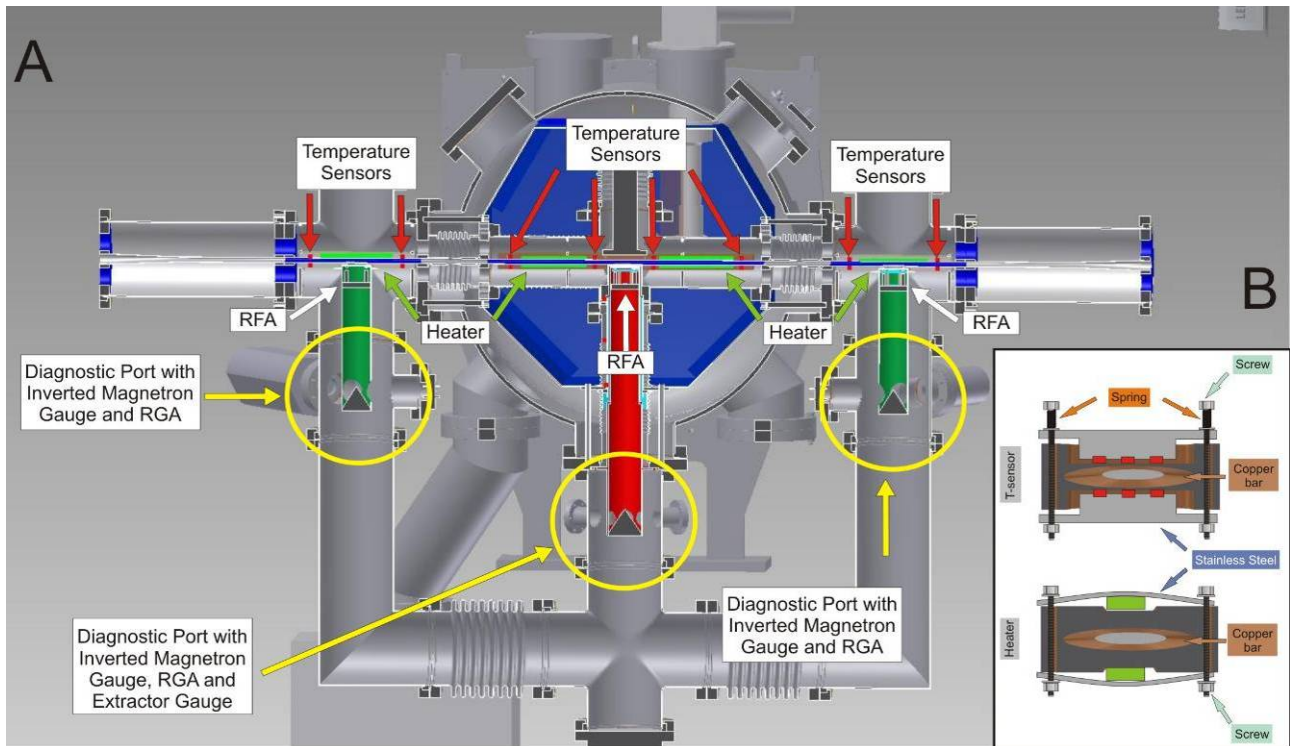
Figure 2a, b: Overview of the cryostat and the diagnostics installed in COLDDIAG

liner designed to be exchangeable. The first liner that will be tested at Diamond is a full copper block with a 60 mm x 10 mm elliptical bore. The inner surface is plated with 50 µm copper to simulate the surface of the SCIDs used at Diamond and ANKA.

The diagnostic devices are connected to the cold liner through a warm tube to avoid gas condensation along the path between liner and diagnostic device. For the diagnostic port in the cold section a design based on the COLDEX device [5] was chosen.

The vacuum system of COLDDIAG consists of two volumes: the insulation vacuum and the beam vacuum (UHV). A DN100 CF stainless steel 6-way cross separates the two vacua (fig. 2a). The beam vacuum includes all the diagnostic devices as well as the liner.

In order to simulate the liner of superconducting insertion devices the liner must be cooled down to reach a base temperature of around 4.2 K in absence of beam. COLDDIAG is cryogen-free and cooled by a Sumitomo RDK-415D cryocooler. The system has three temperature regimes: 300 K, 50 K at the radiation shield, and 4 K at the liner.

To suppress the low energy electrons bombarding the wall, a solenoid on the beam axis producing a maximum field of 100 Gauss is wound around on one of the long arms of the cold UHV cross.

DIAGNOSTICS

In total 40 temperature sensors will allow to monitor the status of the chamber and measure the beam heat load. 8 PT100 sensors in each of the warm sections and 16 Lakeshore Cernox 1050-SD in the cold section are placed

directly on the liner block (fig. 2a, b) by spring loaded screws. To simulate the heating from the beam and to calibrate the temperature sensors to the beam heat load we use 6 ceramic heaters, which will be placed on the copper block (fig. 2a, b).

In each of the connection pipes, between the liner and the diagnostic ports a small half moon shaped retarding field analyzer (RFA) is placed to obtain the electron flux of the electrons impinging the wall. To solve the problem of the secondary electrons produced in the RFA [6] an improved setup using a lock-in technique was successfully tested. To do so we use an AC voltage inductively coupled to the retarding grid and detect the signal on the collector plate. With this setup we can directly acquire the first derivative of the electron current on the collector, which gives us the electron energy distribution.

At each of the three diagnostic ports, an Inverted Magnetron Gauge and a residual gas analyzer are installed, to monitor the total pressure and the gas composition of the beam vacuum. The middle diagnostic port will also be equipped with an extractor gauge, which is more sensitive than the Inverted Magnetron Gauges.

To study the influence of the cryosorbed gas layer to the beam heat load, we have foreseen the possibility to inject different gases through the middle diagnostic port. To this end, a heated high precision all metal leak valve, which allows controlling the gas flow to the chamber down to 10^{-10} mbar l/s was chosen.

FACTORY ACCEPTANCE TEST

During the factory acceptance test the overall leak rate of COLDDIAG and the base temperature was checked. The leak rate of the UHV was found to be less than $4.3*10^{-10}$ mbar l/s whereas the leak rate of the insulation
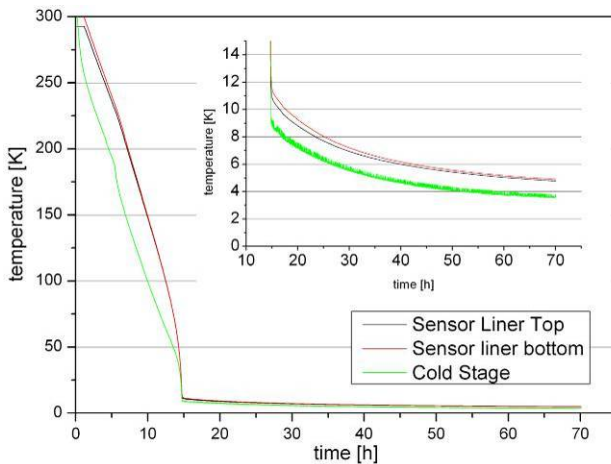

Figure 3: Temperature during cooldown

vacuum was lower than $8.1*10^{-9}$ mbar l/s. During a first cooldown an average temperature of 9.6 K on the liner was reached after 21h. However the surrounding 6-way cross was still at 200 K, because of a bad cooling connection between solenoid and cryocooler.

For the second cooldown, the cooling connection to the solenoid was changed and after 87 h the average over the sensor readings gave a base temperature of 4.8 K on the liner, which is only slightly higher then expected. At this time the temperature on the 2nd stage of the cryocooler was at 3.3 K, which means on one hand that there is a low
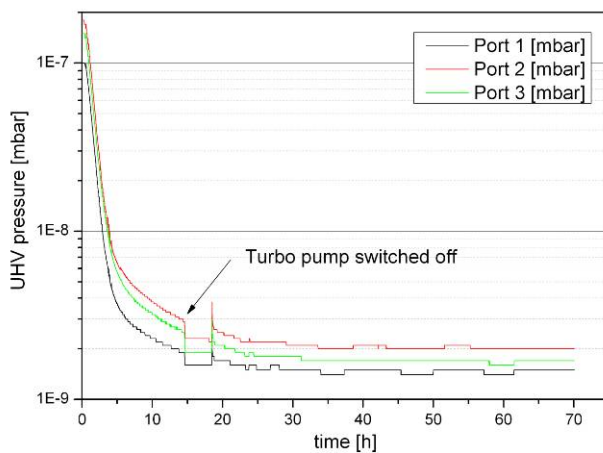

Figure 4: Pressure during cooldown

heat intake to the cryocooler and on the other hand that the cooling connection to the liner gives a gradient of about 1.3 K. The 1st stage of the cooler, which is connected to the shields shows a base temperature of 35 K. After the cooldown all temperature sensors and heaters have been tested again.

After delivery and reassembly at ANKA the UHV parts outside the cryostat were baked at 100 °C for 48 h. The pressure after baking was lower than $2*10^{-7}$ mbar. During the following cooldown we reached a liner temperature of 10 K after about 17 h and a base temperature of almost 4.8 K after 75 h (fig. 3). Due to the cryopumping cold surfaces inside the UHV the pressure dropped below $3*10^{-9}$ mbar during cooldown (fig. 4).

PLANNED MEASUREMENTS

During normal user operation the temperature, electron flux, pressure and gas composition will be monitored to collect statistics. During machine day physics at Diamond we plan to change:
1) the average beam current to compare the beam heat load data with synchrotron radiation and resistive wall heating predictions,
2) the bunch length to compare with resistive wall heating predictions,
3) the filling pattern in particular the bunch spacing to test the relevance of the electron cloud as heating mechanisms,
4) beam position to test the relevance of synchrotron radiation and the gap dependence of the beam heat load,
5) inject different gases naturally present in the beam vacuum (H_2, CO, CO_2, CH_4) to understand the influence of the cryosorbed gas layer on the beam heat load and eventually identify the gases to be reduced in the beam vacuum.

SUMMARY

In this paper we have reported about the design of COLDDIAG as well as the factory acceptance test and the planned measurements. First tests of the experimental setup are ongoing at ANKA. A first installation of COLDDIAG in the Diamond Light Source is planned for November 2011.

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