DESIGN OF A COLD VACUUM CHAMBER FOR DIAGNOSTICS[*]

S. Casalbuoni[†], T. Baumbach, A. Grau, M. Hagelstein, R. Rossmanith,
Forschungszentrum Karlsruhe, Karlsruhe, Germany
V. Baglin, B. Jenninger,
CERN, Geneva, Switzerland
R. Cimino,
INFN, Frascati, Italy
M. Cox,
DIAMOND,UK
E. Mashkina,
University of Erlangen, Erlangen, Germany
E. Wallén,
MAXLAB, Lund, Sweden
R. Weigel
Max-Planck Institute for Metal Research, Stuttgart, Germany

Abstract

Preliminary studies performed with the cold bore superconducting undulator installed in the ANKA storage ring suggest that the beam heat load is mainly due to the electron wall bombardment. Low energy electrons (few eV) are accelerated by the electric field of the beam to the wall of the vacuum chamber, induce non-thermal outgassing from the cryogenic surface and heat the undulator. In this contribution we report on the design of a cold vacuum chamber for diagnostics to be installed in the ANKA storage ring and possibly in third generation light sources. The diagnostics implemented are: i) retarding field analyzers to measure the electron energy and flux, ii) temperature sensors to measure the total heat load, iii) pressure gauges, iv) and a mass spectrometer to measure the gas content. The aim of this device is to gain a deeper understanding on the heat load mechanisms to a cold vacuum chamber in a storage ring and find effective remedies. The outcome of the study is of relevance for the design and operation of cold bore superconducting insertion devices in synchrotron light sources.

INTRODUCTION

Superconductive 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. This technological solution is very interesting for synchrotron light sources since it permits to increase the flux and/or the photon energy at relatively low costs. One of the key issues for the development of superconducting IDs is the understanding of the beam heat load to the cold vacuum chamber.

EXPERIMENT VRS. THEORY

Possible beam heat load sources are: 1) synchrotron radiation, 2) resistive wall heating, 3) electron and/or ion bombardment, 4) RF effects.

Synchrotron radiation and resistive wall heating losses can be computed as shown in Refs. [1, 2]. In Table 1 are reported the values of the measured beam heat load onto the cold vacuum chambers of superconducting insertion devices installed at different synchrotron light sources: the ANKA undulator, and the DIAMOND and MAXII wigglers. The values of the beam heat load due to synchrotron radiation and resistive wall heating have been calculated for the different cold vacuum chambers and are compared in Table 1 with the measured values. The difference between beam heat load measured and calculated is not understood.

Table 1: Comparison of the beam heat load measured at different synchrotrons with the expected value due to the sum of synchrotron radiation and resistive wall heating losses. I is the stored average beam current and σ_t is the bunch length.

	P_m **(W)**	P_{th} **(W)**	$P_m - P_{th}$ **(W)**
ANKA [2] I=100 mA σ_t=10mm	0.4-1	< 0.085	0.3-0.9
DIAMOND [3] I=125 mA σ_t=5mm	3	~ 0.5	2.5
MAXII [1] I=200 mA σ_t=24mm	1.6	~ 0.9	0.7

Preliminary studies performed with the cold bore super-

---

[*] The authors are thankful to U. Herberger for the technical drawing.

[†] sara.casalbuoni@iss.fzk.de

conducting undulator installed in the ANKA storage ring suggest that the beam heat load is also due to the electron wall bombardment [2]. Low energy electrons (few eV) are repelled by the electric field of the beam to the wall of the vacuum chamber, induce non-thermal outgassing from the cryogenic surface and heat the undulator. If the bombarding electrons acquire enough energy, they produce secondary electrons when they hit the chamber wall, which in turn are accelerated by the electric field normal to the surface. These electrons may bombard again another surface and emit secondary electrons. If the appropriate combination of surface properties and electric fields are fulfilled, this bouncing back and forth between surfaces develops an electron multiplication, or multipacting effect. In the field free regions of accelerators, the electric field producing the multipacting is provided by the beam, so that the two components influencing the electron accumulation are the beam and the chamber surface characteristics [4].

The existence of low energy electrons bombarding the wall of the room temperature vacuum chamber in the ANKA storage ring has been proved using as a pick up a clearing electrode installed in the ring. Biasing the electrode with negative bias the electrons are repelled from it, while biasing it with positive bias the low energy electrons filling the beam pipe are collected. The electron flux measured at the clearing electrode with a beam current of 100 mA, beam energy of 2.5 GeV and 10 mm long electron bunches is 1.6×10^{14} el/s m^2 [5]. The electron flux needed to explain the beam heat load due to electron bombardment in the undulator cold bore is four orders of magnitude higher, namely 2.2×10^{18} el/s m^2 [2]. The main difference between the 4.2 K and 300 K regions is the surface of the vacuum chamber. At 300 K the metallic vacuum chamber presents an oxide layer, while at 4.2 K a layer of cryosorbed molecules loosely bound by Van der Waals forces. The surface properties for such a cryosorbed gas layer, as secondary electron yield, photoemission yield, photoemission induced electron energy distribution, are needed in the simulation codes to determine the eventual occurrence and size of an electron-cloud build-up. These surface properties are to the authors knowledge only partly been measured for a cryosorbed gas layer. The beam heat load due to the electron cloud $P_{\rm el}$ is roughly given by:

$$P_{\rm el} = \Delta W \cdot \dot{N}, \qquad (1)$$

where ΔW is the energy increase of one electron due to the kick by a bunch and $\dot{N}$ is the number of electrons hitting the wall per unit time. Thus, it seems to the authors that the best appraoch to understand the problem would be a direct measurement of the total beam heat load P and of the electron cloud flux $\dot{N}$ and energy ΔW to the walls of a vacuum chamber at cryogenic temperatures.

A COLD VACUUM CHAMBER FOR DIAGNOSTICS

With the above considerations in mind and in order to understand the still unexplaind data of beam heat load onto cold vacuum chambers in the different synchrotron machines, it would be useful to have a dedicated experiment to measure the heat load, the pressure, the gas composition, and the electron energy and flux of the electrons bombarding the wall in a cold vacuum chamber. This could be performed at ANKA where there is an ongoing R&D program for superconducting insertion devices. This COLD vacuum chamber for DIAGnostics (COLDDIAG) is planned to be installed in one of the short straight sections of the ANKA storage ring shown in Fig. 1. A sketch of the planned diagnostics is shown in Fig. 2. The cryostat will be:

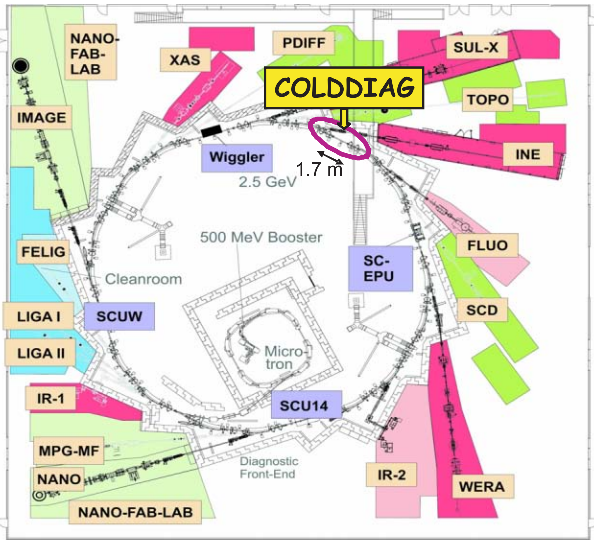

Figure 1: Location of possible installation of COLDDIAG in the ANKA storage ring.

- A cryogen-free system. Operating temperature 4 K, with the possibility to operate at higher temperatures up to 300K.
- The cryostat will have two vacuum systems: a ultra high vacuum (UHV) for the inner vacuum chamber where the electron beam goes through, and an insulation vacuum for the outer shells between the 4 K and 50 K and betwen the 50 K and 300 K shields.
- The inner vacuum chamber will be removable in order to test different geometries and materials. This will allow the installation of the cryostat in other synchrotron light sources.
- For the measuring time at ANKA the gap of the inner vacuum chamber should be fixed to a value compatible with ANKA user operation (25mm).

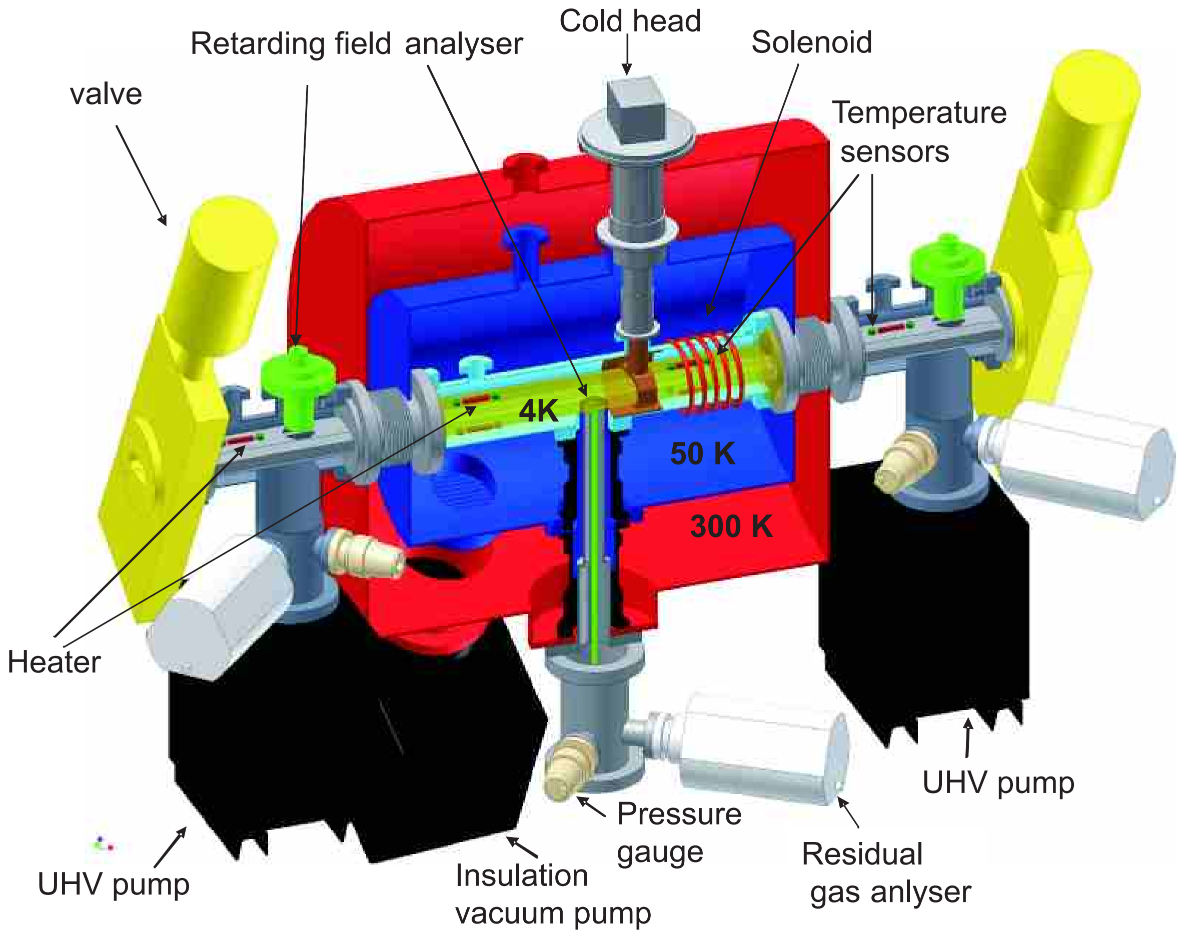

Figure 2: Scheme of COLDDIAG with the two room temperature sections provided with the same diagnostics: retarding field analyser, residual gas analyser, pressure gauge, temepratures sensors and heating wires for calibration.

- A solenoid to be wound around the 4 K vacuum chamber with circular cross section is foreseen in order to suppress the electron cloud [6].
- RF bridges will be implemented in the transition region of the electron beam vacuum chamber between 300 K and 4 K.

The diagnostics should include:

- Heat load measurement with temperature sensors calibrated with heating wire.
- Electron energy distribution measurement with calibrated retarding field analyser. The retarding field analyser can be calibrated at INFN, Frascati.
- Possibility to inject gases and control the surface coverage with temperature.
- Possibility to warm up the system (heating wire) and estimate the amount of desorbed gas.
- Pressure measurements with calibrated total pressure gauges and calibrated residual gas analyser. The pressure gauges and residual gas analyser can be calibrated at CERN.

As shown in Fig. 2 two room temperature sections provided with the same diagnostics as the cold section are foreseen: one upstream and one downstream. This will allow to observe the influence of synchrotron radiation onto the beam heat load and to make a direct comparison of the cryogenic and room temperature regions.

REFERENCES

[1] E. Wallén, G. LeBlanc, *Cryogenics* **44**, 879 (2004).

[2] S. Casalbuoni et al., *Phys. Rev. ST Accel. Beams* **10**, 093202 (2007).

[3] M. Cox, http://ankaweb.fzk.de/conferences/ Mini%20workshop/ Diamond%20SCW%20ANKA- -%20mini%20workshop%20final%20corrected.pdf

[4] Proceedings ECLOUD'02, ECLOUD'04 Workshops .

[5] S. Casalbuoni et al., Proceedings of EPAC 2008, Genova, Italy 2008.

[6] Y. Cai, M. Pivi and M.A. Furman, *Phys. Rev. ST Accel. Beams* **7**, 024402 (2004).