STATUS OF THE ELECTROSTATIC AND CRYOGENIC DOUBLE RING DESIREE

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Abstract

DESIREE is a double electrostatic storage ring being built by the Manne Siegbahn Laboratory and the Physics Department of Stockholm University., and a common straight section along which stored ions can interact. The ion optics for both rings will be housed in a single, double walled vacuum chamber built like a cryostat with a radiation screen and several layers of super insulation in between the two chambers. The bottom of the inner chamber, which holds all the optical elements, will be cooled to around 10 K by four cryogenerators. It is constructed in low-alloy aluminium to ensure a good thermal conductivity over the whole structure. This low temperature in combination with the unique double ring structure will result in a powerful machine for studying interactions between cold molecular ions close to zero relative energy.

For the outer vacuum chamber construction steel is used which will provide screening of magnetic fields on the outside. Two injectors will be able to supply both positive and negative ions to both rings.

INTRODUCTION

When DESIREE, the double electrostatic storage rings under construction at the Manne Siegbahn Laboratory in Stockholm, is ready for cooling down next year, it will be the latest contribution to the growing family of storage rings that are using electrostatic instead of the more common magnetic confinement. When high particle energies are not required there are several reasons to choose an electrostatic storage ring. A key feature of electrostatic elements is that the bending power is independent of the ion mass and accordingly electrostatic storage rings have no upper mass limit. Another important fact is that electrostatic storage rings are less expensive than magnetic ones. In DESIREE there are two electrostatic rings which share a common straight section. The rings are placed in a common vacuum vessel which will be cooled to around 10 K. This unique construction will offer the possibility to study interactions between very cold molecular ions, in conditions that are similar to those in interstellar space.

Since the main features of DESIREE have been described earlier, see i.e. in ref [1], this paper will mainly focus on some of the technical challenges of the project.

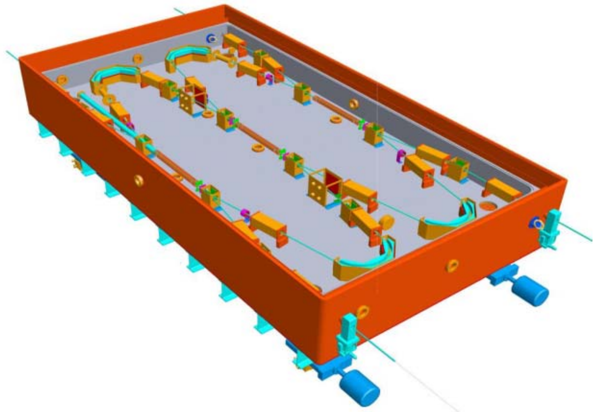

Figure 1: Drawing of DESIREE.

MECHANICAL CONSTRUCTION

The DESIREE vacuum system is designed like a cryostat with an inner aluminium chamber and an outer steel vacuum chamber. Cooling of the inner chamber is achieved by four cryogenerators (Sumitomo RDK-415D) connected to the bottom plate via flexible copper braids.

The choice of material for the inner chamber is critical, since a good thermal conductivity is essential to be able to reach the desired low temperature over the whole chamber. Even though aluminium alloys in general are good thermal conductors, there can be a considerable difference in thermal conductivity between different alloys. This is especially true at temperatures below 100 K where the thermal conductivity is several times higher for the purer alloys compared to the ones used in more conventional constructions. In order to ensure efficient cooling of all parts of the inner chamber it is therefore constructed from an alloy with a high aluminium content (Al 6063, 98.6% Al) which is a good thermal conductor, also at cryogenic temperatures, and, equally important, has good mechanical properties. In Fig. 2 a comparison for two different aluminium alloys of the calculated temperature distribution over one quarter of the chamber with one cryogenerator is shown. As can be seen, the choice of a material with a good thermal conductivity at low temperatures is essential to achieve efficient cooling of the whole inner chamber. Calculations of heat transfer were performed using the finite element simulation package COMSOL Multiphysics [2]

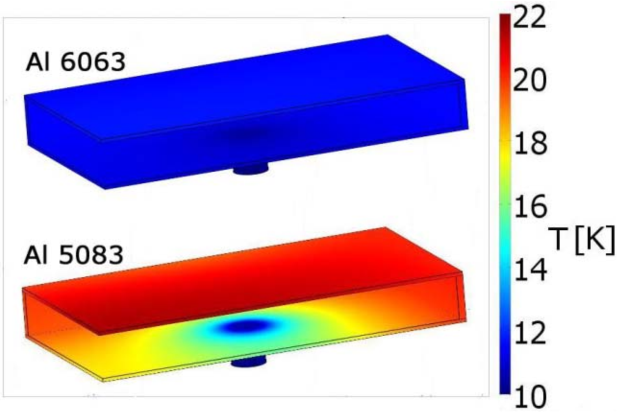

Figure 2: Calculated temperature distribution over one quarter of the aluminium chamber cooled by one cryogenerator for two different Al alloys.

To avoid deformation due to stresses in the aluminium during cooling the number of welds has been kept at a minimum. Only the corners of the 40 mm thick side-boards are welded while all other components will be screwed onto this frame. All "flanges" needed to connect electrical feedthroughs, pumps, injection ports, laser windows, etc. are machined directly into the aluminium plates of the top lid, bottom plate and sides of the chamber.

The inner chamber will rest on four thin-walled stainless steel tubes supported by the bottom plate of the outer chamber. The tubes can be adjusted in height for the final positioning of the inner chamber.

To make sure that also the optical elements are cooled efficiently they are mounted directly onto the bottom plate of the cooled aluminium chamber. The somewhat closed design of DESIREE, with two large boxes placed within each other, limits the access for alignment of the optical elements. To be able to make the necessary adjustments of the elements outside the vacuum chambers, each element is represented by a foot print that is machined with very high mechanical precision in the bottom plate of the inner chamber. The position of each foot print is given by the ion optic calculations. The optical elements will be mounted on an aluminium plate that fits precisely in the foot prints in the bottom plate. They will be aligned outside the chambers and subsequently positioned in their respective foot print inside DESIREE. Using this procedure, the error in the placement of the elements is estimated to be less than 0.2 mm, which should be small enough to avoid large errors in the closed orbit of the stored ions.

DE-MAGNETIZATION OF THE STEEL CHAMBER

The outer vacuum chamber (4.7x2.5x0.7 m3) is constructed from SS1312 construction steel. This chamber will therefore act as a shield for any magnetic fields that are present outside the chamber, thus minimizing perturbations of the trajectories of the slow ions stored in DESIREE. Since this material itself can become magnetized an effort has been made to reduce any contribution to the magnetic field inside the chamber. The background magnetic field present in the laboratory has been measured to be of the same strength as the earth magnetic field in the Stockholm area: $B^{V}_{earth} \approx 0.4$ Gauss, $B^{H}_{earth} \approx 0.15$ Gauss.

After the manufacturing of the DESIREE chamber it was demagnetized at the station used by the Swedish Navy for demagnetization of marine vessels. Their system has three pairs of Helmholtz coils that compensates for external magnetic fields in all three coordinates and a central coil that generates the alternating field for the degaussing. See Fig. 3 for a schematic drawing of the system. The parameters of the degaussing were: frequency, 0.07 Hz; number of turns, 190 and maximum degaussing current, 250 A. The resulting maximum degaussing magnetic field was 47 500 A-turns/m. For the iron used in DESIREE chamber with a thickness of 45 mm and a permeability of $\mu = 100 - 200$, the degaussing frequency used should be low enough to let the field penetrate the thickness of the material.

Before degaussing the inhomogeneity of the magnetic field inside the chamber was ≈ 0.3 Gauss. After degaussing these inhomogeneities were decreased to ≈ 0.09 Gauss and the average remaining magnetic field inside chamber was ≈ 0.1 Gauss

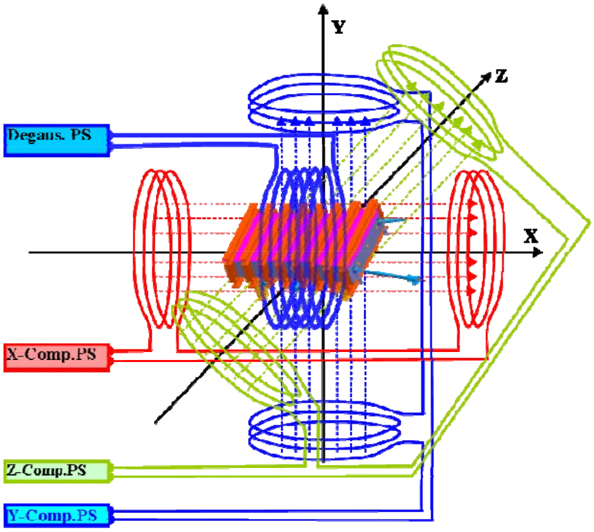

Figure 3: The system used for degaussing of DESIREE.

INTENSIFIED BEAM VIEWER FOR THE INJECTION LINE

To measure the transverse properties of the beams in the beamlines an image-intensified beam viewer of the type that originally was developed for the low-intensity radioactive beams at REX-ISOLDE at CERN will be used [3,4]. To investigate the properties of this type of beam viewer, a prototype was built. In Fig. 4 a drawing of the viewer is shown. The ions impinge on a metal that emits secondary electrons when hit by the ion beam. These electrons are accelerated through a thin grid and impinge on two stacked micro channel plates (MCPs). As has been shown in [3], the transverse energies of the electrons are small compared to the longitudinal energy they get from the acceleration. Thus, the geometrical information of where the ions have hit the plate is mapped onto the face of the first MCP. The MCPs multiply the electrons up to 10^6 times, depending on the voltage applied to the MCPs, and are finally detected with the help of a fluorescent screen where the light emitted is registered by a video camera.

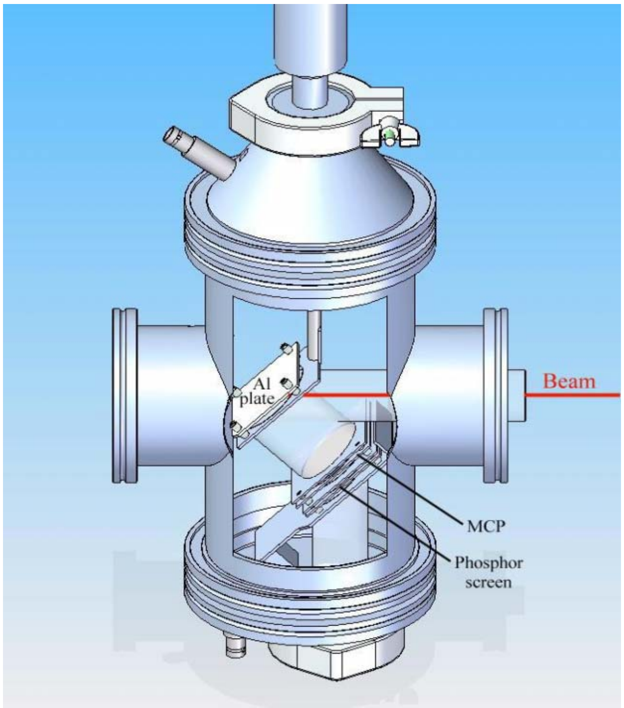

Figure 4: Drawing of the image-intensified beam viewer. For ease of construction, the whole unit is installed in a standard vacuum cross with CF100 flanges.

The main reason for our choice of an image intensified viewer is the extreme sensitivity that can be obtained. The wide dynamic range of the system is also an advantage. By adjusting the voltage applied to the MCPs, the sensitivity of the system can easily be adjusted to a wide range of beam currents. An advantage is also the ruggedness of the system. Furthermore, since the ions impinge on a metal plate, the viewer should not suffer from the loss of sensitivity that is known to occur on fluorescent screens after some time, see e.g. the results of Sieber et al. in [5].

During the first tests of the viewer some extra light was seen coming from areas that did not correspond to where the beam hit the plate. Furthermore, the sensitivity was higher when the beam was moved closer to the edge of the screen. After covering the screen with a thin metal mesh to prevent any charging up of the surface of the phosphor, this effect disappeared. Due to the improved contrast even the light from single particles could be detected. In Fig. 5 a photo of the screen showing spots from a few particles is shown. The brighter and smaller spot to the left is an artefact. This picture was taken with a beam of 1 keV protons after the beam current had been lowered until the flickering of single particles could be seen on the screen. The voltage of the MCPs was near the maximum allowed. A video clip showing the detection of the individual particles of this weak beam can be found on http://www.msl.se/MSL_files/REXvideo.avi.

Figure: 5. Image of a few 1 keV protons.

As expected, the dynamical properties were excellent. By varying the voltage on the MCPs, the intensity of the emitted light could easily be adapted to a suitable level for the video camera for beam currents from several μA down to single particles. The viewer has been tested with singly charged argon ions and protons at total energies ranging from 40 keV to 1 keV. While there were no difficulties to detect the beams of the lowest energies, no systematic investigation of the sensitivity of the viewer for different ions or energies has been performed.

ACKNOWLEDGEMENTS

This work has been supported by The Knut and Alice Wallenberg Foundation and the Swedish Research Council.

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