VACUUM ASPECTS OF THE EUTERPE STORAGE RING

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Abstract

The electron storage ring Euterpe under construction at the Eindhoven University is a low budget project with a 400 MeV/200 mA electron beam. The bending magnets have a gap of 25 mm. A vacuum of $\leq 10^{-9}$ mbar in the beam chamber is necessary to obtain sufficient beam lifetime of ≈8 hrs. The photon stimulated desorption caused by synchrotron radiation in the dipole chambers is estimated to amount at least 4.10^{-7} mbar.l/s of gas per dipole. Consequently a minimum average pumping speed of >400 l/s is required. Such a value can hardly be obtained by means of external pumps as it is limited by the molecular conductance of these vessels. This problem is solved by a design in which the synchrotron radiation escapes from the dipole into a large pumping chamber. This will be equipped with integrated titanium sublimation pumps, giving rise to a high pumping speed. An external getter ion pump of 60 l/s provides for the pumping of methane. The dipoles magnets will be mounted on a very accurate slide system which locks the dipole position. This allows in-situ bake-out of the ring.

1 INTRODUCTION

Euterpe is intended to be a relatively small electron storage ring with a maximum energy of 400 MeV and a projected current of 200 mA [1]. The dipole magnet gap will be only 25 mm and the Q-poles and sextupoles will have 50 mm free opening. The machine has a four-fold symmetry with twelve dipole magnets. This choice of parameters gives rise to cost reduction, as relatively light magnet power supplies can be applied and the total amount of copper and iron in the magnets will be restricted. On the other hand this design may lead to a higher cost for the dipole chamber construction.

2 THE VACUUM IN EUTERPE DIPOLE CHAMBER

The lifetime of the beam will be limited by scattering of the beam electrons mainly at the nuclei of the residual gas molecules. In order to reach a reasonable beam lifetime of ≈ 8 hours the pressure in a storage ring has to be ≈ 10^{-9} mbar, in which the partial pressure of hydrogen may be neglected due to its small nuclear charge. This vacuum has to be maintained in a large narrow structure with a relatively high gas-load due to photon stimulated desorption (PSD) by the synchrotron radiation. In machines of moderate energy (< 1 GeV) and beam currents near 200 mA the problem is solved by application of integrated getter ion pumps in the dipole chamber, where most of the synchrotron radiation has to be absorbed and where the magnetic fields of the dipole can be used for these pumps [2].

This solution is not suitable for Euterpe. The height of the dipole magnet gap as well as the available area of the poles are too small to build in getter ion pumps of the required capacity, which is estimated in section 3 to be 400 l/s per dipole. We note that this narrow pole gap makes it more difficult to obtain the same effective pumping speed by means of external pumps. This gap also leads to a high cross-section for the residual gas scattering. A detailed study on the gas scattering lifetime in Euterpe has been given by Xi [3].

An alternative approach for the dipole chamber was chosen in which the greater part of the synchrotron radiation is coupled out from the beam line into a large vessel. In there, the gas originating from PSD can be pumped with high efficiency (fig. 1). In this construction the width of the vacuum chamber increases in the “downstream” direction of the electron beam in order to prevent any synchrotron radiation hitting the walls. The maximum width is ~23 cm in our case. This design has two consequences: a) In order to prevent microwave power loss from the beam [4] the dipole chamber must contain a curved slit, which simulates the continuation of a constant cross-section beam pipe and at the same time provides for unhindered passage of the radiation to the pumping room. b) The dipole chamber has to be provided with several vertical columns to withstand the atmospheric pressure, see fig. 1.

This concept resembles that of modern high power rings in which the dipole chambers are provided with antechambers and absorbing crotches to remove most of the synchrotron radiation from the electron beam line [5]. In these machines the beam line pressure is reduced further by a differential pumping system. However, in Euterpe the beam line pressure cannot be lowered in this way. For the dipole chamber is too narrow to realise a pumping speed large in comparison with that of the radiation escape slit. The upstream cross-section of the dipole chamber is only ~40 x 20 mm. Consequently the effect of the pump in the adjacent straight section of the ring has been neglected.

In order to test the feasibility of the design the expected vacuum was estimated as follows: As for PSD the usual assumption has been made, that it is zero for photon energy smaller than a certain threshold energy ε_0 and has a constant value of η molecules/photon for all energies > ε_0. This assumption results in a total number *N* of desorbed molecules per second given by [6, 7]:

$$N = 8.08 \cdot 10^{20} EI\eta\left[1-\left(\varepsilon_0/\varepsilon_c\right)^{1/3}\right] \qquad (1)$$

in which *E* is the beam energy in GeV, *I* the beam current in A and ε_c the critical photon energy of the machine. For Euterpe *E*= 0.4 GeV, *I*= 0.2 A and ε_c = 149 eV. It is assumed that ε_0 = 10 eV. This results in a gas load of *Q*= 0.13 η mbarl/s for the PSD in one dipole.

As usual, a complete coupling out of the radiation from the dipole chamber can not be realised. Some fraction of the radiation will hit the horizontal walls because of the gaussian vertical distribution [6]. Moreover ~5 % of the photons will be absorbed by the vertical columns and a small part of the photons and PSD molecules will be scattered back from the pumping room absorber. It is estimated that the gas load of the dipole chamber will be 10% of the total dipole PSD.

Another problem is to find a value of the effective pumping speed of the dipole chamber. This will be much higher than the transmission pumping speed of this vessel as the greater part of the gas production will take place in the down stream part of the chamber with large width. An effective pumping speed S_{eff} of 50 l/s is assumed for nitrogen, which corresponds to the transmission of a rectangular box with the height of the vessel, half its length and a width of 10 cm i.e. the value halfway the vessel, see fig.1.

The surface area of the dipole chamber is ~2000 cm^2. Assuming a thermal desorption rate of 10^{-11} mbarl/cm^2s with 80% hydrogen results in extra gas load of 4.10^{-9} mbarl/sec. With a required pressure of 10^{-9} mbar and S_{eff} = 50 l/s this contribution can be neglected and the required value for η will be < 4.10^{-6} molecules/photon. As a target value in the design η = 3.10^{-6} molecules/photon has been taken.

3 THE PUMPING SYSTEM

Assuming η = 3.10^{-6} molecules/photon for all absorbing walls in the ring results to *Q* = 4.10^{-7} mbarl/s for the PSD per dipole. The area of the pumping chamber is ~10.000 cm^2, which results in a negligible extra gas load. Consequently a total pumping speed of > 400 l/s per dipole has to be realised to reach 10^{-9} mbar.

As the greater part of the PSD-gas consists of N_2, CO and CO_2, a rather low cost system can be obtained by the application of titanium sublimation pumps. An additional small getter ion pump has to be added to remove the methane which is 10 - 20% of the total gas load. The advantage of a titanium sublimation pump is its very high pumping speed. The main disadvantage is the need of periodically renewing the active titanium layer, which leads to a short pressure rise in the system. So the capacity of the layer has to be at least sufficient for pumping during the beam lifetime of ~ 8 hours. It is estimated that a Ti layer of > 1000 cm^2 surface area can fulfil this demand. Beside the Ti shields and Ti supply wires the pumping room has to contain an absorber for the synchrotron radiation. For the pumping of the entire ring with a 40 m circumference additional ion getter pumps, 60 l/s per short section will be used.

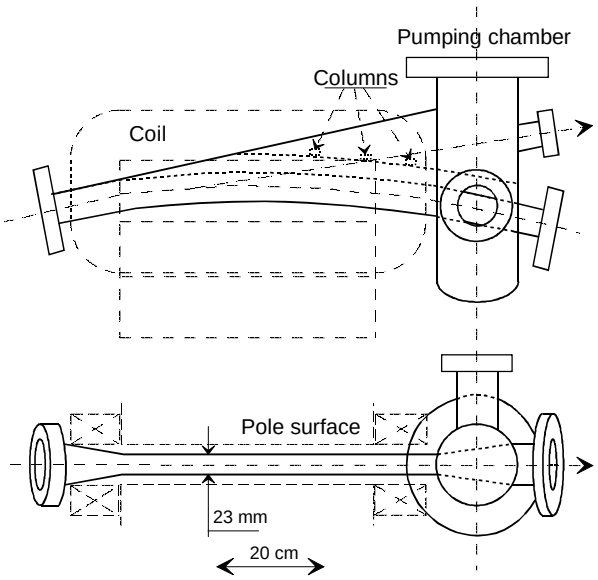

Fig. 1. Design of dipole chamber Euterpe.

It will be necessary to bake out the ring in-situ at 150-200 °C to remove water vapour. Due to the small dipole magnet gap there is no space left for permanently mounted heat sheets and insulating layers between the vacuum chamber and poles. Thanks to the low magnet weight of ~600 kg these can be wheeled away during bake-out of the system and re-positioned with the required accuracy. The design for accurate re-alignment of the dipole is under construction.

4 PHOTON STIMULATED DESORPTION

In test tubes as well as in storage rings a decrease in η is observed of the form $\eta \approx D^{-\alpha}$ with increasing total photon dose D, generally α ~½. As a rule of

thumb a dose of 10^{22}-10^{23} photons/m tube length will be sufficient for this cleaning process. Consequently the low photon density in the dipole chamber is a disadvantage of the Euterpe design. The total density of desorbing photons is $\approx 4.10^{19}$/s and it is assumed that 10% will be absorbed in the dipole chamber, roughly corresponding to 4.10^{17} photons/sm. Consequently the application of a good pre-cleaning process is of paramount importance. Many data can be found concerning the effect of gas-discharge cleaning. The first experiments were based on the equivalence of PSD and desorption by electron bombardment (ESD) [8]. It was reported that a total ESD of $2.5.10^{-7}$ molecules/electron could be reached for stainless steel and copper by glow-discharge in argon oxygen mixture [9], which would correspond to a PSD of roughly $0.5.10^{-7}$ molecules/photon [10]. This value was stable after exposure to air. In PSD experiments the observed effect is far less favourable e.g. Foerster et al [11] found a decrease of η_{CO} for stainless steel tubes from 3.10^{-4} to 1.10^{-4} after such glow-discharge treatment and a change from 2.10^{-5}-1.10^{-5} after subsequent synchrotron radiation exposure.

In view of these contradictory result we started some measurements of ESD from small stainless steel samples. In our set-up the influence of electron- or ion-bombardment, gas discharge, heating and gas adsorption can be studied. The application of small samples instead of part of a vacuum tube will have some advantages, e.g. the measurements are not perturbed by interfering pumping action of a large area cleaned surface [12]. Nevertheless the contribution of such effects can be checked by measurement of the pumping speed for various gases at the position of the rest gas analyser before and after each ESD experiment.

From preliminary results it can be concluded an ESD value of 2.10^{-5} molecules/electron for CO from stainless steel can be obtained after small doses of electron- or argon ion-bombardment. However, this value is not stable even during storage in UHV. This behaviour might be ascribed to a clean metallic layer. Presumably a clean and closed oxide layer is more favourable to obtain a low and stable η-value as it is inactive for adsorption and forms a barrier for bulk diffusion [13]. We note that also the thermal gas desorption from stainless steel depends critically on the method of surface cleaning [14].

5 CONCLUSION

Vacuum aspects of the Euterpe electron storage ring have been presented. The machine has dipoles with a gap of 25 mm and suitable dipole vacuum chambers have been designed, in which the synchrotron radiation is coupled out into a large pumping chamber. Titanium sublimation pumps are applied. The total required pumping speed has been calculated. Bake out as well as sophisticated pre-cleaning procedures will be required. For the bake out procedure a removable dipole system has been designed.

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