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CONCEPTUAL DESIGN OF THE VACUUM SYSTEM FOR THE LSB STORAGE RING*

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Abstract

A detailed design for a new Synchrotron Light Source located in Barcelona (LSB) must be accomplished at the end of 1997. Here we present the storage ring vacuum system for the LSB. The main goal of the vacuum system is to maintain a beam operating on pressure of 1 nTorr or less in order to achieve a 24 hours lifetime approximately. One of the main difficulties that are foreseen in the project comes from the very compact magnetic lattice (TBA) that will impose limitations in the positioning of the vacuum components. Another severe problem is posed by the high gas load induced by the synchrotron radiation. An overview of the general features, requirements and problems associated with the preliminary design of the vacuum system is described.

1. INTRODUCTION

The LSB storage ring is a TBA based lattice formed by 12 cells[1], with 3 combined magnets, 6 quadrupoles and 6 sextupoles each.

The main goal of the vacuum system in the storage ring is to reduce as much as possible the residual gas density in order to ensure a lifetime greater than 24 h.

From the vacuum point of view, we are looking for high conductance apertures, small surface areas with low outgassing rates and the possibility to install pumps with large pumping speed as close as possible to the gas sources. Unfortunately, the machine designers prefer small magnetic gaps to reduce the magnet cost, as well as small slots between the vacuum chamber and the pumping ports in order to minimise the beam induced RF fields, reducing therefore the vacuum conductance. On the other hand, the best places to install the pumps are usually occupied by magnetic elements.

Besides the problems associated with the small apertures and the positioning of the pumps, the high heat load to be removed from the system as well as the gas load due to photon induced desorption, all pose an interesting challenge to the vacuum and engineer teams working on the vacuum design.

The vacuum system for the storage ring is closely related to the machine parameters listed in Table I.

Table I Machine parameters used in vacuum calculations

Beam energy	[GeV]	2.5
Beam current	[mA]	250
Magnet bending radius	[m]	8.251
Bending angle	[mrad]	174.5
Circumference	[m]	251.84
Number of cells		12
Required average pressure	[Torr]	10^{-9}
Photon flux	[ph/s]	$5 \cdot 10^{20}$

2. VACUUM CHAMBER

The aperture requirements for the LSB storage ring have been calculated for an energy of 2.5 GeV [2].

In the horizontal plane the aperture is limited by the Touscheck effect. For a momentum acceptance of $\pm 3\%$, the required horizontal aperture is ± 25 mm.

In the vertical plane, the aperture is only limited by the beam stay clear in this plane, which is ± 11 mm.

Therefore the minimum vacuum chamber could be an elliptical or rectangular pipe of 50 mm x 22 mm with a conductance per meter of 3.8 l/s. This small conductance limits the effective pumping speed that should be reached. To keep a small gap but to increase the conductance, the dimensions will be extended to 80 mm in the horizontal plane and to 40 mm in the vertical one giving a conductance per meter of 20 l/s.

For the calculations that follow the vacuum pipe has been taken as an ellipse of semi-horizontal axis 40 mm and semi-vertical axis 20 mm. This pipe will be used in the straight sections of the LSB storage ring.

In the bending sections, a special vacuum chamber will be designed in order to place photon beam absorbers at the end of the dipoles, where most of the synchrotron radiation would hit the walls. Special vacuum chambers will also be needed for the straight sections with insertion devices.

3. POWER DENSITY

The total power emitted from the bending magnets is given by,

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$$P = 88.5 \frac{E^4 I}{\rho}$$

where E is the beam energy in GeV, I is the circulating intensity in A and ρ is the bending radius in m. The total power from the bending magnets is 105 kW for a 250 mA beam current, i.e. 17 W/mrad θ .

The linear and surface power densities along the chamber wall have been calculated in the space between dipoles. The calculations have been performed for the worst scenario that assumes:

- an elliptical vacuum pipe all along the machine of semi-axes 40 x 20 mm.
- All the photons release their energy when they hit the vacuum chamber.
- 400 mA beam current

The resulting power densities are shown in Figure 1. The maximum linear and surface power at the exit of the dipoles are 3.2 W/mm and 12.7 W/mm² respectively.

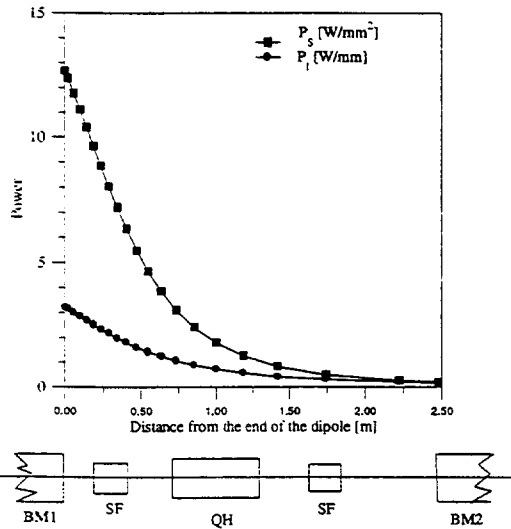


Figure 1 Power density distribution between bending magnets

In order to reduce the power density, the vacuum chamber along the dipole will extend at least 0.5 m from the end of the dipole, so that an absorber can be placed there and the maximum power density hitting the wall of the chambers will go down to 5 W/mm².

4. GAS DESORPTION

Two processes are responsible for the gas load in synchrotron light sources: the thermal desorption and the photon induced desorption.

The thermal outgassing rate is taken constant along the ring and equal to 10⁻¹² Torr l/s cm² after the usual cleaning procedures have been applied. With the ring dimensions, the thermal gas load will be,

$$Q_{th} = 5 \cdot 10^{-7} \text{ Torr l/s}$$

The photon induced desorption is [3],

$$Q_{SR} = 2 \dot{N} (\eta\gamma) k$$

where \dot{N} is the photon flux,

$$\dot{N} = 8.08 \cdot 10^{17} E[\text{GeV}] I[\text{mA}]$$

($\eta\gamma$) is the desorption efficiency or number of molecules generated per photon impinging onto the chamber and k is a conversion factor, $k = 3.1 \cdot 10^{-20}$ Torr l/molecule.

Assuming a beam dose of 100 Ah, the desorption efficiency is 2.7 10⁻⁷ molecule/photon [4], then the gas load due to photon induced desorption is,

$$Q_{SR} = 1.2 \cdot 10^{-5} \text{ Torr l/s}$$

The total gas load in the system is $Q_T = 1.25 \cdot 10^{-5}$ Torr l/s. The pumping speed is calculated using,

$$S[\text{l/s}] = \frac{Q_T}{P}$$

If a final pressure of 10⁻⁹ Torr is required then the pumping speed should be 12500 l/s or 1041 l/s per cell.

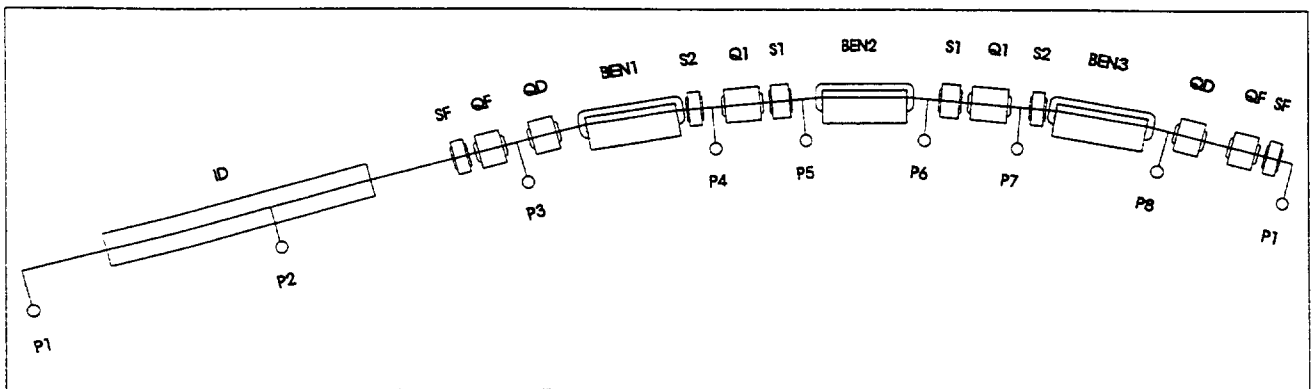


Figure 2 Pump distribution along a cell for the LSB storage ring

5. PRESSURE DISTRIBUTION

In order to locate the pumps in the most effective way, a computer program [5] has been used to calculate, in a first approximation, the pressure profiles along a cell of the ring. This program divides the cell in segments and allows the inclusion of pumps at the beginning of each segment. The thermal desorption is uniformly distributed along the segments, while the photon induced desorption is distributed in a discrete form. The pumps have been situated following the next criteria:

- Place the pumps with high pumping speeds as close as possible to the end of the bending magnets
- Maintain a pressure profile below 10^{-9} Torr in the long straight section

A pressure profile giving an average pressure of 10^{-9} Torr along the cell has been obtained when 8 pumps have been placed in the cell. Three of them with a nominal pumping speed of 400 l/s are located in the bending region and the other 5 pumps are distributed along the cell with nominal speed of 125 l/s. Figure 2 shows the pump distribution along the cell.

The static pressure distribution, when no beam is in the storage ring, is shown in Figure 3. The average pressure is $1.2 \cdot 10^{-10}$ Torr.

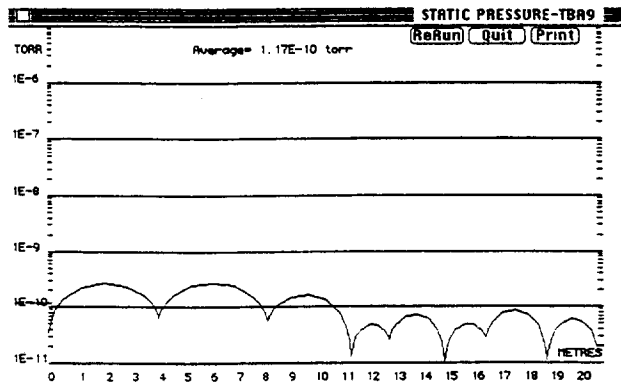


Figure 3 Static pressure profile

The dynamic pressure profile, with beam on, is shown in Figure 4. The profile was calculated assuming that the gas load due to synchrotron radiation is localised at the end of the bending magnet vacuum vessel with a value of $2.4 \cdot 10^{-7}$ Torr l/s and distributed in the remaining segments. The average pressure in this case is $6.7 \cdot 10^{-10}$ Torr but we can observe values near $3 \cdot 10^{-9}$ Torr in the bending magnets. These values could be further reduced by introducing distributed pumps in the bending magnet vacuum chamber.

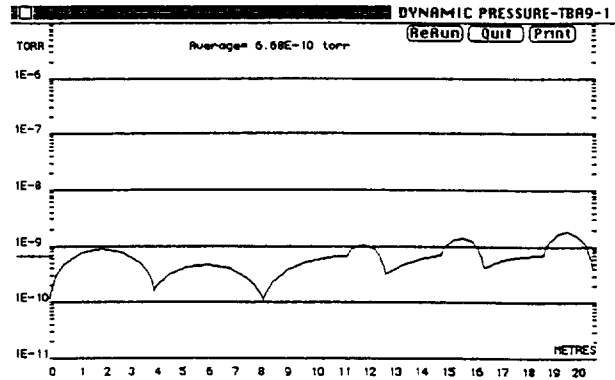


Figure 4 Dynamic pressure profile

6. CONCLUSIONS

The pump distribution chosen for the LSB storage ring requires 1 pump of 400 l/s in each of the bending magnet vacuum vessel and 5 pumps of 125 l/s distributed along the cell to achieve an average pressure of 10^{-9} Torr, which is necessary in order to have a lifetime around 24 hours.

ACKNOWLEDGMENTS

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