AN UHV VACUUM SYSTEM FOR DAΦNE

V. Chimenti, A. Clozza, C. Vaccarezza, INFN-LNF, Frascati, Italy

Abstract

A 510 MeV high luminosity Φ-Factory is under construction in Frascati. The main goal of the vacuum system is to maintain a mean pressure of $1 \cdot 10^{-9}$ Torr, after conditioning, with a stored current of 5.3 A per beam. The vacuum chamber is almost entirely made of aluminum. The inner surface of the chamber has a roughness of about 0.1 - 0.2 μ R_a. The vacuum system is completely oil free and all the vacuum components are all metal type. Special RF shielded bellows were designed avoiding any sliding contact. The synchrotron radiation produced by bending magnets and wigglers is intercepted by water cooled copper synchrotron light absorbers. The design of the pumping system is optimised in order to install the required pumping speed, about $1.2 \cdot 10^5$ l/s, on a 100 m long ring. A combination of titanium sublimator pumps, sputter ion pumps and non evaporable getter pumps as been chosen.

1 INTRODUCTION

The DAΦNE Φ- Factory [1] is a twin ring 510 MeV e^+e^- collider facility under construction at INFN-LNF in Frascati. A mean pressure of $1 \cdot 10^{-9}$ Torr with a stored beam of 5.3 A is required in each ring. A 10-meter long vessel constitutes the vacuum chamber of the eight bending sections. One of the bending sections of the positron ring is shown in Fig. 1. The selected material is Al 5083-H321 and the vacuum chamber is milling machined in two halves and welded along the perimeter. Special care has been taken in order to lower as much as possible the desorption yield from the vacuum chamber walls.

The procedure for the aluminum surface treatment is reported in section 2. Special RF shielded bellows were designed in order to follow the longitudinal expansions and the offsets of the vacuum chamber (section 3). Water cooled absorbers are employed to cope with the Synchrotron Radiation (SR) produced in the wigglers and dipoles, as reported in section 4. The total gas load in each of the electron/positron ring is $Q \approx 1.2 \cdot 10^{-4}$ Torr l/s for CO, with a photodesorption rate of $\eta \approx 1 \cdot 10^{-6}$ molec/ph [2], after ≈ 40 Ahr of conditioning. The required pumping speed for each ring is $\approx 1.2 \cdot 10^5$ l/s, and is achieved using Titanium Sublimation Pumps (TSP), Sputter Ion Pumps (SIP), and Non Evaporable Getter Pumps (NEG), (see section 5).

2 VACUUM CHAMBER

2.1 Vacuum chamber design

Both the two rings of the DAΦNE collider can be mainly divided into three parts: bending sections, straight sections, with injection and RF cavities, and interaction regions. In the bending sections, arcs, the main concern is the high and concentrated photodesorbed gas load due to the synchrotron radiation emitted in the two dipoles and the wiggler. The arc vacuum chamber is designed in such a way that the most of the synchrotron radiation is stopped by water cooled copper absorbers. A 10÷ 20 mm slot divides the beam channel from an antechamber where the absorbers and the pumping stations are located. In Fig. 2 two arc cross sections, with beam chamber and antechamber and pump ports, are shown, referring to the dipole and wiggler vacuum chambers respectively.

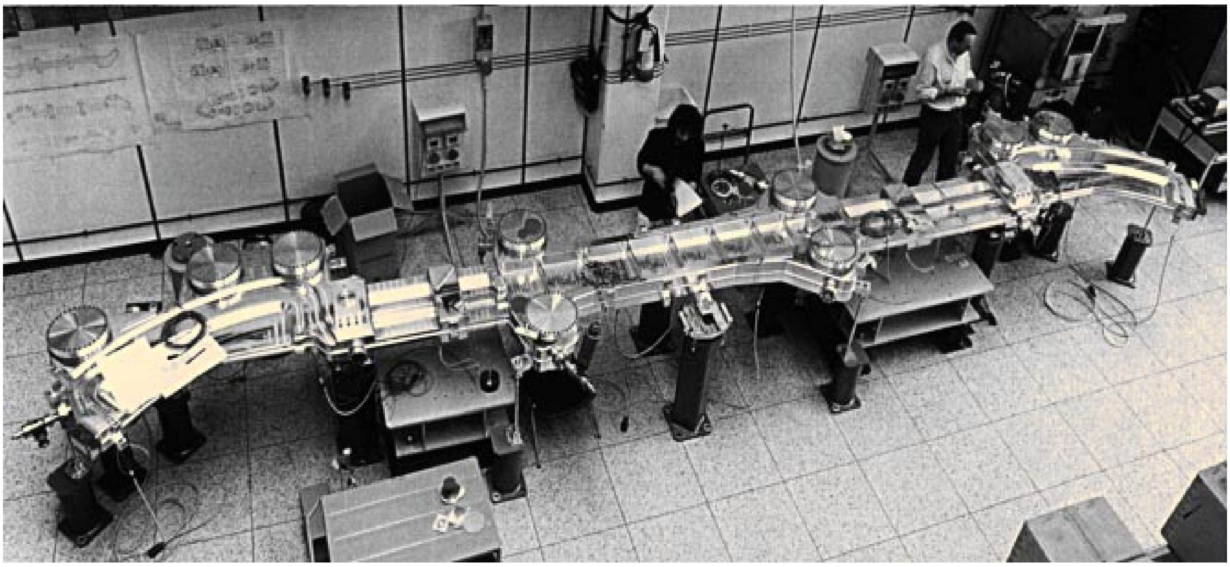

Figure 1: One of the arcs of the DAΦNE positron ring, under testing at the LNF vacuum laboratory.

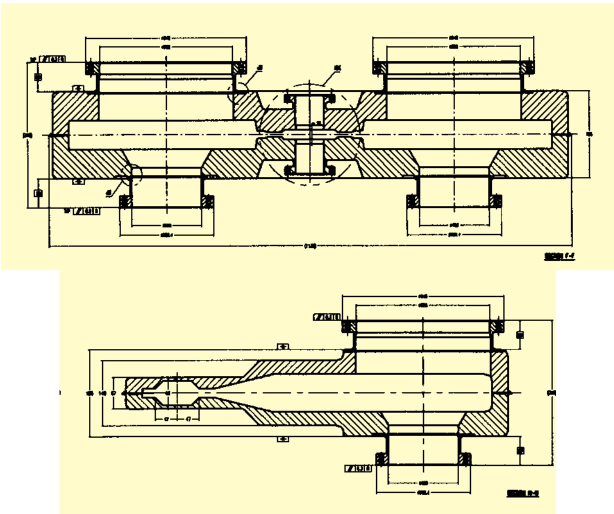

Figure 2: Two cross sections of the arc vacuum chamber, are shown. The first on top corresponds to the wiggler, the second below to the dipoles.

For the straight sections, (injection and RF cavities), a circular Al 6082 vacuum pipe is provided, tapered to match the vacuum chamber cross section of each lattice element, in order to reduce the impact of the vacuum chamber impedance on the beam dynamics. The two interaction regions of the DAΦNE Φ-Factory, consist of a stainless steel AISI 304L (with copper coating) tapered pipe up to the interaction point where two thin Be vacuum chambers (500 μ thick), are provided according to the experiment requirements.

2.2 Machining and cleaning

Each of the arcs is a 10-meter long aluminum vessel milling machined in two halves from a 120 mm thick Al 5083-H321 plate, (1.6 m width, 10 m length), thoroughly ultrasonic tested. In order to lower as much as possible the surface desorption yield the roughness of the surface has been limited to an average value $R_a \leq 0.2$ μ. The measured value in the most critical points, i.e. the beam closest zones, is $R_a \approx 0.15$ μ.

Considerable care has been taken of the Al surface contamination during the machining. The CIMSTAR MB-602 has been employed as cutting liquid, avoiding any contamination with sulphur or silicone compounds. For the Aluminum surface cleaning a detergent solution with Almeco 18 (HENKEL) at 50 ˚C has been used [3], followed by rinse with distilled water; reducing in this way the aluminum three-hydroxide formation on the surface.

The first four positron arcs have been tested. After few cycles of 150 ˚C bake-out for 48 hours each, the measured specific outgassing rate is: $q_d \leq 1 \bullet 10^{-14}$ Torr l s^{-1} cm^{-2}, obtained both dynamically and with the rising pressure method.

The ultimate pressure (with one pump of S = 200 l/s) turned out to be $P \approx 4 \bullet 10^{-11}$Torr, close to X-Ray limit of $2 \bullet 10^{-11}$ Torr of the ionisation gauge.

2.3 Gaskets and bolts

For the mixed joints aluminum-stainless steel of the DAΦNE ring vacuum chamber, the Helicoflex gaskets will be used; Al diamond type gaskets will be used for the aluminum-aluminum joints. (The Al diamond gaskets result to be reliable also for the mixed joints with a lower bake-out temperature, e.g. T ≈ 120 ˚C). In order to avoid the use of any lubricant, many self-lubricant alloys have been tested for the bolts production. The Cu-Al bronze turned out to have the best mechanical properties, but it is slightly magnetic and it results to affect the nominal value of the magnetic field of the main ring dipoles, if close to the flanges. The Cu-Sn bronze will be adopted. Prolonged bake-out tests showed that these bronze bolts maintain their reliability at least up to 200 ˚C.

3 RF SHIELDED BELLOWS

Between the DAΦNE arcs and the straight section vacuum chambers, special RF shielded bellows will be mounted [4]. They must allow 35 mm longitudinal expansion and 10 mm horizontal offset, mainly during the bake-out. Any sliding contact will be avoided to prevent the burning out due to the high current flowing on the bellows screen, and the creation of dust particles between the sliding surfaces. The bellows screen consists of thin CuBe-C17000 waved strips, (150 μ thick, 5 mm wide) vertically oriented and separated by small gaps. The strips will be hot formed and connected to the stainless steel AISI 316L bellows by brazing or mechanical clamp.

4 SYNCHROTRON RADIATION ABSORBERS

The DAΦNE synchrotron radiation absorbers are realised in one monolithic object (including the flange), from a bar of OFHC Copper.

In order to avoid any water-vacuum joint, the cooling channel is entirely machined as one path from the outside water inlet/outlet. Detailed calculations, together with laboratory tests, of the absorber deformation under the radiation load, show that any distorsion remains in the tolerances of the project.

5 PUMPING SYSTEM

The arc pumping system is designed to guarantee a mean operating pressure of $1 \bullet 10^{-9}$ Torr with a circulating current of 5.3 A.

The total photon flux per arc is :

$$N_{tot} = 8.8 \bullet 10^{20} \text{ ph/s}. \tag{1}$$

The resulting gas load is:

$$Q = \frac{N_{tot} \cdot \eta}{3.4 \times 10^{19}} = 2.6 \times 10^{-5} \text{ Torr l s}^{-1} \text{ (20 ˚C)}, \tag{2}$$

where η (molec/ph) is the phodesorption rate of the Al vacuum chamber after conditioning [2].

The synchrotron radiation (SR) is almost entirely intercepted by the copper absorbers located in the antechamber, leading to a high and concentrated photodesorbed gas load. Close to the copper absorbers nine pumping stations per arc are located, each one consisting of a Titanium Sublimator Pump (TSP) on top, and a Sputter Ion Pump (SIP) below, see Fig. 3.

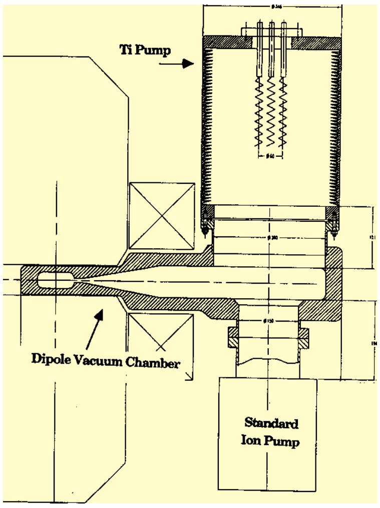

Figure 3: Final full scale prototype of DAΦNE TSP-SIP pumping station and Dipole vacuum chamber.

Combined with a SIP (200 l/s), each TSP has to provide:

$$S = \frac{2.8\times10^{-6}}{2\times10^{-9}} \approx 1.4\times10^{3} \ \ \text{l/s} \ , \qquad (3)$$

where the value $2\cdot10^{-9}$ Torr is the maximum pressure allowable in the arc to maintain a mean pressure of $1\cdot10^{-9}$ Torr in the ring. In Fig. 4 the performance of one Ti filament is reported.

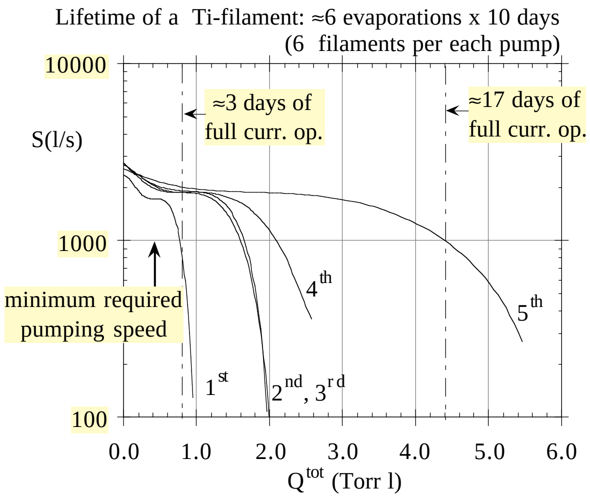

Figure 4: The pumping speed S (l/s) of the DAΦNE TSP with one Ti filament is reported vs. the total pumped gas load Q^{tot}(Torr l). Each filament allows 6 sublimation covering ≈ 60 days of full current operation (after conditioning). Each TSP cartridge provides 6 filaments.

In each TSP a cartridge of 6 filaments will be mounted, which is supposed to cover 6x60 days of full current operation, after conditioning. In the straight sections conventional Sputter Ion Pumps (Starcell, 200 l/s) are employed. For the interaction region Non Evaporable Getter (NEG) pumps have been chosen. In the experiment detectors design no room is available for lumped pumps set-up, therefore the NEG elements are arranged around the beam pipe, separated from the beam by a proper RF shield. A new high capacity composition of the getter Capacitorr™ has been tested at the Frascati Labs for the first time.

In Fig. 5 the performance of the new getter in its final configuration has been reported. The gas load of this section is $Q \approx 1\bullet10^{-7}$ Torr l/s, the required pumping speed is $S \approx 1000$ l/s, the test results indicate for this pump a duration time of tenth of years before re-activation (500 ˚C).

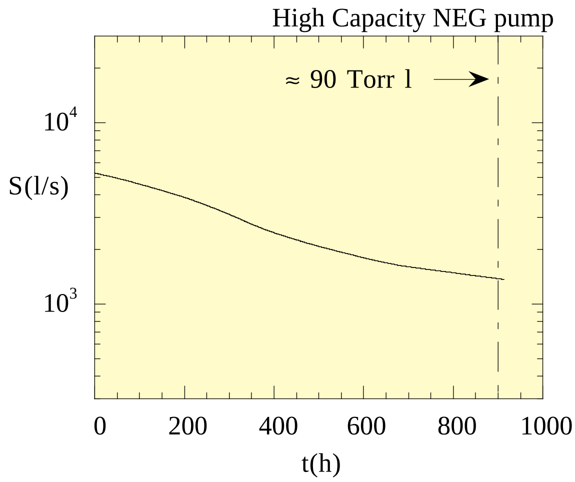

Figure 5: The result of the test on the final configuration of the DAΦNE High Capacity NEG is reported. The pumping speed S (l/s) vs. time is shown. The testing conditions relate 900 hr to ≈ 90 Torr l of pumped gas.

CONCLUSIONS

A UHV vacuum System for DAΦNE has been designed. The first arc vacuum chambers have been tested matching the specified project requirements. The different pumping system elements in their final configuration have been tested together with the performance of the Synchrotron Radiation absorbers, giving satisfactory results.

REFERENCES

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