ELETTRA Vacuum System

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Abstract

Elettra is a third-generation synchrotron light source which is being built especially for the use of high brilliance radiation from insertion devices and bending magnets. The UHV conditions in a storage ring lead to a longer beam lifetime - one of the most important criterion. The Elettra vacuum system presents some pecularities which cannot be found in any already existing machine. The final version of bending magnet vacuum chamber is presented. After chemical and thermal conditioning the specific outgassing rate of about 1.5e-12 Torr. l sec^{-1} cm^{-2} was obtained. A microprocessor-controlled system has been developed to perform bake-out at the uniform temperature. The etched-foil type heaters are glued to the chamber and Microtherm insulation is used. UHV pumps based on standard triode sputter-ion pump were modified with ST 707 NEG (Non Evaporable Getter) modules. A special installation enables the resistive activation of getters and significantly increases pumping speed for hydrogen and other residual gases (except methane and argon). All these technological innovations improve vacuum conditions in Elettra storage ring and consequently also the other parameters of our light source.

I. INTRODUCTION

Third generation light sources are dedicated machines to be built especially for the use of radiation from insertion devices rather than from bending magnets. High brilliance exceeds that of the previous generation by at least an order of magnitude, but high beam currents require a sophisticated ultra high vacuum system.

Elettra light source, which is being built on Carso hills near Trieste, Italy, consists of three main parts:

1. The 1.5 GeV full-injection linac already installed and tested in situ (in future can be upgraded to 2.0 GeV).
2. The transfer line (TL) from linac to storage ring. TL is 93 m long pumped by thirteen 60 l/s sputter-ion pumps which can obtain and maintain the average pressure 2.e-8 mbar.
3. The 260 m long storage ring which is divided into six sectors. The ring contains 24 bending magnets and 12 straight sections, one is for beam injection, 11 are for insertion device radiation beam lines.

In the storage ring the UHV conditions are necessary to drastically reduce the elastic Coulomb gas scattering and bremsstrahlung which strongly affect the beam lifetime. Stored beam lifetime due to gas density must be more than 10 hours and must be achieved soon after start up (short conditioning time).

Machine parameters characterizing the Elettra vacuum system are as follows:

Beam energy, E	1.5 (2.0)	[GeV]
Beam current, I	400	[mA]
Bending radius, ρ	5.5	[m]
Circumference	260	[m]
Required pressure with beam	2.e-9	[Torr]

II. VACUUM COMPONENTS AND MATERIALS

For Elettra storage ring it has been decided to adopt the ante-chamber solution, which is very attractive from the vacuum point of view because of the efficient removal of desorbed gas far away from the electron trajectories where the small dimensions of the beam chamber limit the conductances and then the pumping effectiveness.

The electron beam chamber has a rhomboidal cross-section - 80x56 mm^2 internal dimensions and 2 mm thickness - in order to fit all of the magnetic elements, its specific conductance is 30 l/s. The rhomboidal shape is obtained by cold-rolling a round pipe of suitable diameter.

The bending magnet vacuum chamber is made by coupling the rhomboidal chamber to the ante-chamber obtained by machining a 6.5 cm thick stainless steel sheet. The rhomboidal chamber is bent to the appropriate bending radius, 5.5 m on axis, and connected to the ante chamber via a 1 cm high slot, which is machined on the outer part of the chamber in order to let the synchrotron radiation photons go to experimental beam lines.

A non-standard sealing technique has been applied in a number of vacuum chamber's connections. It is based on VATSeal-type gaskets made of silvered copper with a small edge on both sides. These gaskets have been extensively tested in laboratory up to 300 °C without leaking problems. They required about 8 Nm of sealing torque and due to their geometry, there is no clearance between the coupled flanges and therefore the beam impedance contribution is minimum.

Another important device to be installed in the vacuum system is the photon absorber (or crotch absorber). It should be installed in each bending magnet vacuum chamber in order to absorb about 70% of the synchrotron radiation. Our design of the absorber is based on an OFHC copper block on which an OFHC copper pipe is brazed for cooling water. A second brazing to a stainless steel flange with feedthroughs for water assures the vacuum tightness and facilitates the assembly.

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A 4.8 m long vacuum chamber has been designed for IDs installation. It has an elliptical cross-section with a cylindrical ante-chamber. All system will be pumped by four 60 l/s SIPs, if it will be necessary, NEG modules can be inserted inside.

An austenitic stainless steel ESR AISI 316 LN has been chosen, for its very low magnetic permeability, its high yield stress and well known welding and cleaning procedure.

Internal surfaces and welds exposed to the vacuum must be free of microinclusions and cracks. Surface roughness must be less than 1 μm and free of oxides or impurities.

All vacuum components were carefully cleaned and finished to obtain the required vacuum level (<1.e-10 mbar without the beam). A complete surface treatment included the following phases:

i) Organic solvent degreasing - all principal contaminations were eliminated by means of organic solvents as the acetone or the benzol; for components contaminated by oil an additional cleaning with perchlorethylene at 120 °C was necessary.

ii) Ultrasonic washing - a bath in phosphateless alcaline solution at about 60 °C for minimum 4 hours.

iii) Two phases rinsing - the first with normal water which eliminated detergent residues, the second in demineralized water, which removed the impurities from the normal water.

iv) Drying - a hot air flow dries the walls and prevents dust deposition on them.

Cleaned vacuum components were than pre-baked and degassed in the high vacuum oven. This treatment is believed by a number of authors to give a lower desorption yield. The vacuum oven is 6 m long and 0.9 m of diameter cylindrical vessel made of stainless steel. It can be pumped by three oil-free turbo pumps, fore-vacuum is obtained by means of a 500 l/s piston pump.

Pre-baking was performed at 350 °C for 24 hours, while the pressure in the oven decreased down to e-7 mbar range. Cooling procedure took of about 36 hours and on the end the pressure was better than 1.e-9 mbar. Before opening, the oven was saturated with dry nitrogen. The components were then taken out from the oven and immediately covered with flanges. One of the flanges had a small pipe to flush inside dry nitrogen. All flanges were closed, the pipe was cutting off and as fast as possible cleaned and pre-baked vacuum components were stored in anti-dust bags under overpressure atmosphere of dry nitrogen.

III. PUMPING AND MEASURING SYSTEM

Eight moveable roughing pumps are used to obtain fore-vacuum up to 1.e-7 mbar in the storage ring. We have also developed a new kind of UHV pumps based on standard triode sputter-ion pumps (SIPs) combined with Non Evaporable Getter modules (NEG) St 707 (SAES Getter, Milano). Pumping speeds of such modified SIPs were measured for gases H_2, N_2 and CO in our laboratory [1].

The installation of additional 12 lumped NEG pumps (LNPs) was inevitable in a straight section between two magnets where a SIP of comparable pumping speed cannot be fitted. This pump is based on NEG module inserted in a rectangular vacuum chamber, UHV feed-through is used to connect the NEG module with an external power unit for activation of the getter. Pumping speeds of LNPs, also developed in our laboratory, were measured at different experimental conditions, as well [2].

Totally 108 of 120 l/s and 24 of 400 l/s Varian StarCell pumps modified with St 707 NEG modules are used.

The total pressure in our vacuum chamber is measured by cold cathode (Penning) gauges TPG 300.

The analysis of residual gas mixtures and partial pressure measurements are performed by 6 quadrupole mass analyzers Balzers 421 (one for each sector). Linearity, sensitivity and stability tests of this instrument were done in our laboratory [3]. Spectrometers can be used for leak checking, bake-out monitoring and local surface outgassing, when radiation hits a surface.

IV. BAKE OUT PROCEDURE IN SITU

A microprocessor-controlled bake out system has been developed. The heaters are of the resistive deposit over a Kapton foil, which are glued to the chamber. The Microtherm insulation 3 mm of thickness guarantees the uniform temperature of 180 °C in all parts of vacuum chamber. The outside temperature does not exceed 95 °C (measurements were performed without magnets around the chamber).

Two control systems for both the sputter-ion pumps and the bake out heaters have been developed. The first enables to power four SIPs with only one power unit. There is a possibility of individual reading of the absorbed current and automatic current to pressure conversion. The second allows us to obtain a very uniform bake-out temperature by ramping of 23°C per hour.

V. RESULTS OF TESTS

All tests were measured on the prototype of bending magnet vacuum chamber. Bake-out procedure were performed at two different temperature: 150 and 180 °C. As it is illustrated in fig. 1 - the lowest ultimate pressure was reached after bake-out at 180 °C.

Our prototype was pumped by two 120 l/s and one 400 l/s SIPs and one LNP. All getter modules were activated at 450 °C for 45 min. The quadrupole mass analyzer has detected peaks 2 (H_2^+), 16 (CH_4^+), 28 (CO^+) and 44 (CO_2^+) as usual for a baked UHV system. Water peak 18 could be observed only after a bake-out procedure at 150 °C.

The outgassing rate measurements have been performed connecting the bending magnet vacuum chamber light port to a standard test-dome for measuring pumping speeds - fig. 2.

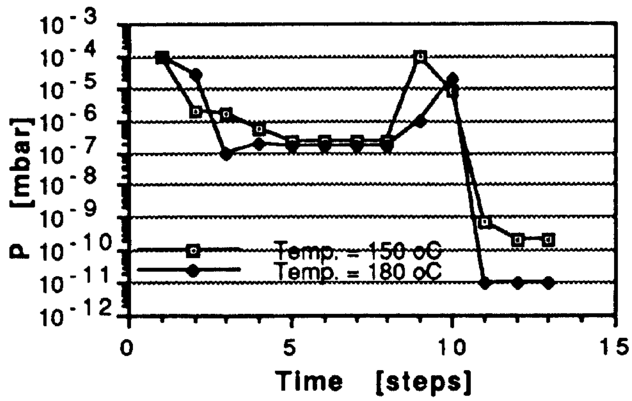

Figure 1. Pressure decrease after bake-out at 150 and 180 °C.

situated between the magnetic elements so a reliable installation is very difficult if standard CF flanges are to be used. Therefore we have developed and tested rhomboidal-shaped flanges with flat surfaces where a special gasket ensures vacuum tightness even after prolonged baket-out procedures at higher temperatures.

VI. CONCLUSIONS

All presented technological innovations and measurements led to improve conditions in the Elettra vacuum system. We are confident that our light source and, particulary our UHV system will meet all the specifications before machine's start up in septamber 1993.

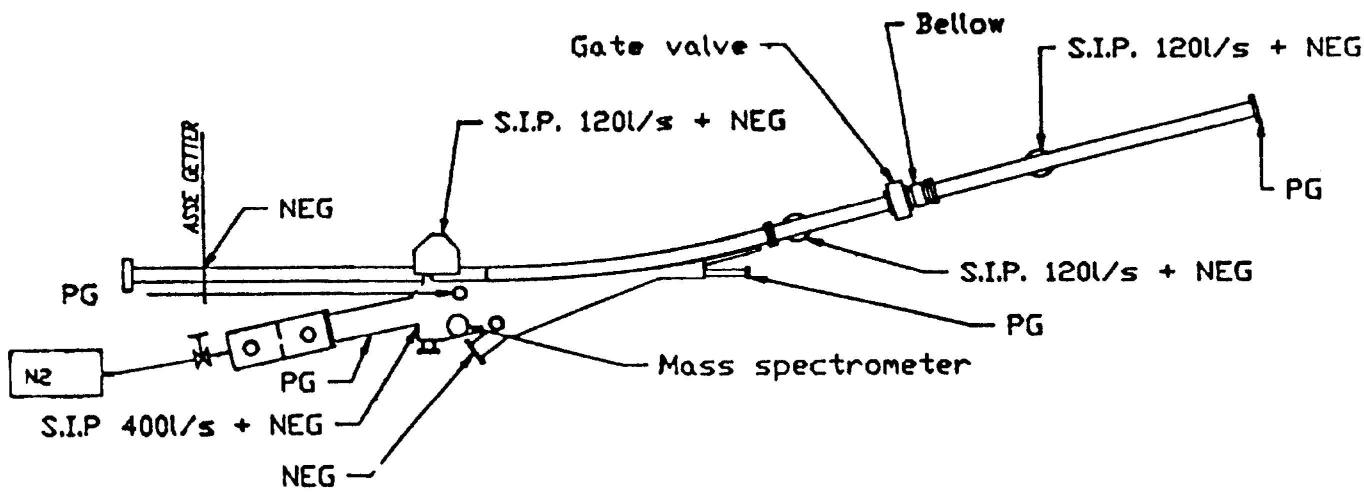

Figure 2. Bending magnet vacuum chamber outgassing rate measurements.

The prototype was pumped only by 520 l/s turbo pump. Outgassing rate was evaluated by the throughput method, pressures P_1 and P_2 in the upper and lower part of the test-dome were measured with Bayard-Alpert gauges. The specific outgassing rate was determined after both bake-out procedures, corresponding values are 1.5e-12 Torr.l.sec^{-1}.cm^{-2} and 5.e-13 Torr.l.sec^{-1}.cm^{-2} at 150 and 180 °C, respectively.

Special bellows with internal RF sliding contacts have been succesfully leak-tested subjecting them to many thousands mechanical cycles at temperatures higher than that foreseen for the bake-out in situ [4].

A non standard flanging technique has been used for connecting the beam position monitors (BPM) to the vacuum chamber. In fact, there are more than 100 BPMs distributed arround the machine's circumference. Many of them are

VII. REFERENCES

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