VACUUM SYSTEM OF ELETTRA, THE SYNCHROTRON LIGHT SOURCE IN TRIESTE

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Abstract

A synchrotron radiation (SR) source, ELETTRA, capable of operating between 1.5 and 2 GeV is being built in Trieste. Its operation should start in 1993. It is constituted of a 1.5 GeV linac injecting the electrons directly in the storage ring. The latter is a 260 meter long ring with 24 bending magnets (BM), allowing a maximum of 12 bending magnet beamlines and up to 11 insertion device (ID) beamlines. A very compact magnet lattice and a very high synchrotron radiation induced gas load pose severe problems from a vacuum point of view. An average pressure in the low nanotorr range should be reached in order to obtain the required electron beam lifetime [1]. A 316 LN stainless steel vacuum chamber, sputter-ion pumps and Non-Evaporable Getters (NEG) combined with careful chemical cleaning, in-situ bakeout and oil-free roughing pumps have been chosen to fulfil the task.

In this paper a status report of the ELETTRA vacuum system development is given.

Vacuum Requirements

The following table lists some of the parameters useful for vacuum calculations in ELETTRA:

Beam energy	[GeV]	2
Beam current	[mA]	400
Magnetic bending radius	[m]	5.5
Circumference	[m]	259.2
Number of periods		24
BM synchrotron radiation critical energy	[KeV]	3.23
BM synchrotron radiation power	[KW]	103
ID synchrotron radiation power	[KW]	40
Required average pressure with beam	[Torr]	$2 \cdot 10^{-9}$
No. of photons/second emitted @ 2 GeV, 400 mA $6.46 \cdot 10^{20}$		

The fraction of SR photons with energy lower than 10 eV is 18 %, therefore the dynamic gas load is [2]

$$Q = 16.46\,\eta\,F \qquad [\text{Torr l/s}] \qquad (1)$$

where η is the desorption yield in molecules/photon and F is a geometrical factor accounting for the dependence of the desorption on the angle of incidence of the SR photons on the vacuum chamber. Several different assumptions can be made on the F factor [3,4]. Fig.1 shows the comparison between some of them. As already anticipated, the magnetic lattice is very compact, i.e. there are many tightly packed quadrupoles and sextupoles to improve the properties of the beam: therefore a uniform rhomboidal cross-section has been chosen in order to best utilize the apertures between the magnetic poles and to leave room for the heating strips and insulation for bake out. The specific conductance is about 30 lm/s (fig.2).

With no ID installed in the machine, over 200 m out of 260 m of the whole chamber length will have this cross-section, the remaining portion being constituted by the BM vacuum chambers and special equipment (bellows, RF-cavities, kicker magnets, transitions, etc.).

The BM vacuum chambers will be divided in two groups: the first one for ID beamlines and the other one for BM beamlines, both with an antechamber welded on the outer side allowing the SR light to the beamlines via a 1 cm high-3 cm wide slot, fig.3.

At the end of the slot in the BM chamber, a specially designed radiation absorber (acting like a crotch) will stop the major part of the radiation allowing only a chosen part to go to the beamlines. About 30 % of the SR emitted in the BM will hit the wall of the following straight section located downstream: this should be the most critical portion of the vacuum chamber due to the high desorption rate that will occur there, and due to the low conductance and limited room for pumping.

In the pessimistic hypothesis of no SR photon scattering, the highest linear power density in this section of the vacuum chamber is about 2.1 KW/m (@ 2 GeV, 400 mA) [5], and therefore a cooling channel brazed on the outer side of the chamber is foreseen.

The expected pressure profiles corresponding to this configuration have been calculated in two different ways, and they give comparable results [6]. A first method is based on the Continuity Principle of Gas Flow (CPoGF), fig.4, the other one on a Monte Carlo (MC) simulation, fig.5.

Both give an average pressure of about $3 \cdot 10^{-9}$ Torr with $\eta = 10^{-6}$ molecules/photon. Note that, in these calculations, a conservative value for the thermal outgassing rate of $5 \cdot 10^{-13}$ Torr l/s/cm^{-2} has been chosen.

Vacuum system

Vacuum chamber

As already mentioned, the ELETTRA vacuum chamber will be 259.2 m long. AISI 316 LN stainless steel has been preferred to aluminum for the following reasons:

1) easier weldability;

2) possibility of thermal cycles at high temperatures to lower the outgassing rate;

3) lower initial SR-induced desorption;

4) higher mechanical strength;

The rhomboidal straight chambers will be obtained by cold deformation of a round tube of suitable dimensions, while the BM chambers will be made of various pieces welded together.

Special vacuum chambers to fit the narrow vertical apertures of the IDs are foreseen. They will have an elliptical cross-section and an ante-chamber for distributed NEG pumping [7,8]. Prototypes of these components are being built and tested.

Beam stoppers/absorbers

These devices will be made of dispersion strengthened copper (Cu with a fraction of percent in weight of Al_2O_3) characterized by enhanced mechanical properties compared to copper. They are being designed and their prototypes will soon be ready.

Bellows

About 50 hydroformed-type bellows will be necessary. They have internal sliding contacts both for geometrical and electrical continuity of the electron beam chamber.

Sealing

There are about 100 beam position monitors (BPMs) around the machine used to measure the position of the electron beam in the vacuum chamber [9]. Each of them is obtained by machining a 316 LN stainless steel block and has 4 ceramic feed-throughs for the button electrodes. In order to avoid problems arising from the presence of steps or cavities nearby these electrodes, a special seal will be utilized instead of using the standard ConFlat flanges or

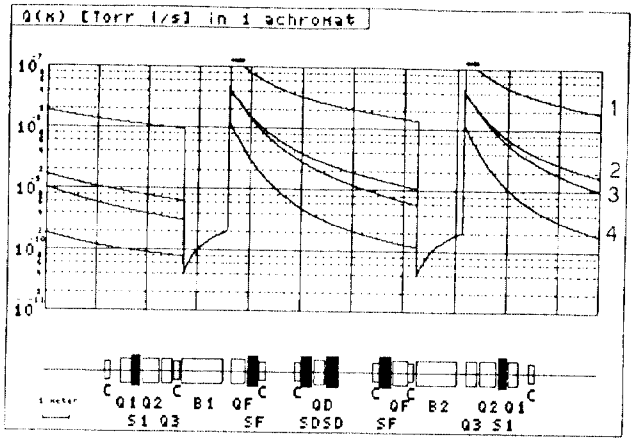

Fig.1 Outgassing profiles Q(x) corresponding to different dependencies on the angle of incidence of the SR photons:

1) $Q(x) \approx 1 / \sin \phi$; 2) $Q(x) \approx 1 / \sqrt{\sin \phi}$;

3) Q(x) ≈ data of ref. [4]; 4) Q(x) independent of ϕ.

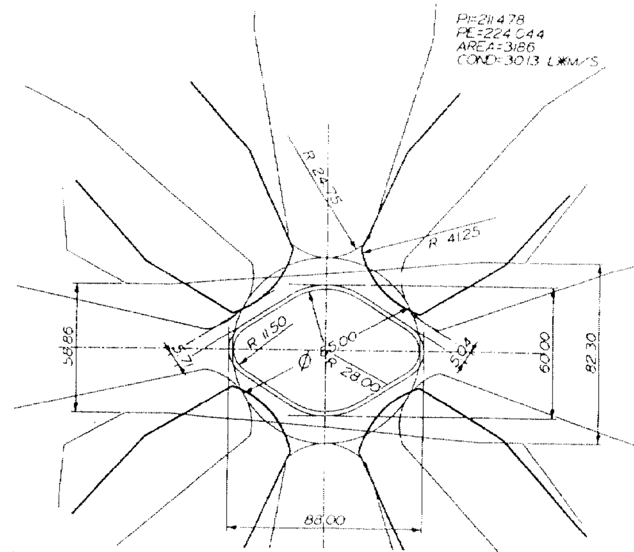

Fig.2 Vacuum chamber cross-section and pole profiles.

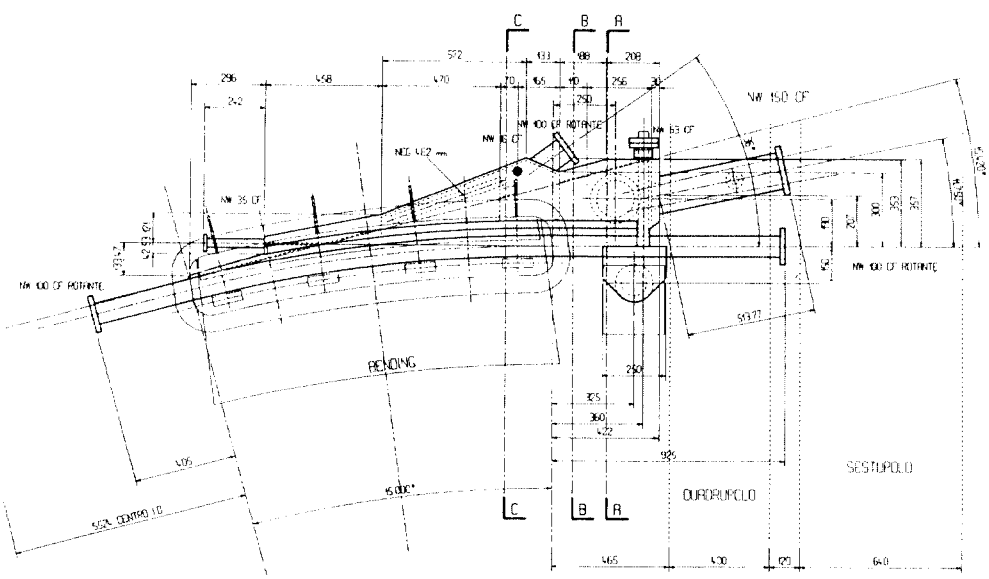

Fig.3 CAD drawing of the bending magnet vacuum chamber (BM beamline).

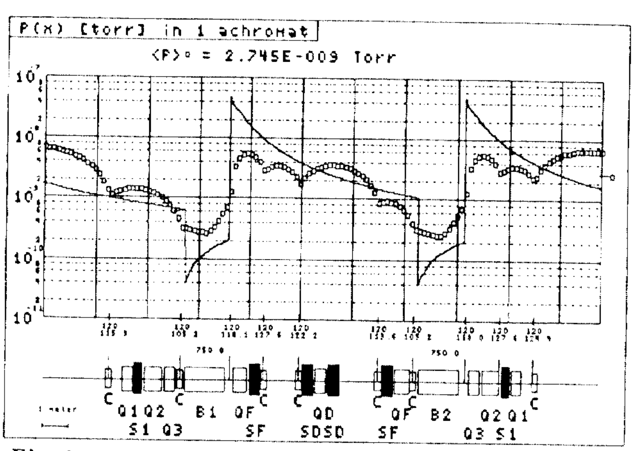

Fig.4 Pressure profile obtained by means of the CPoGF; E = 2 GeV, I = 400 mA, $\eta = 10^{-6}$ molecules/photon.

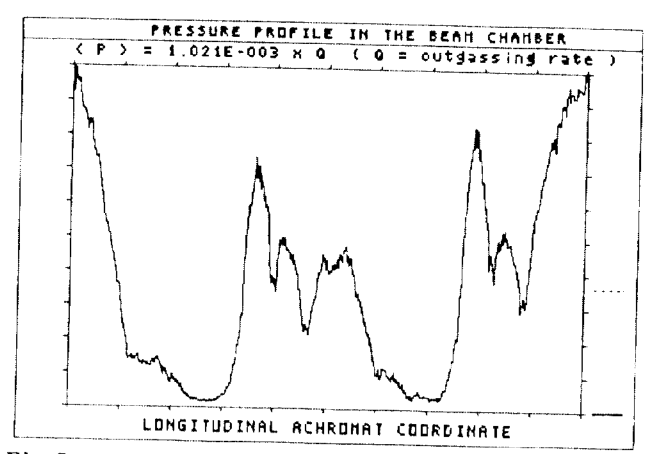

Fig.5 Pressure profile obtained by means of a MC simulation of the molecular flow; same parameters as fig.4.

welding the BPMs directly to the vacuum chamber. A silver-plated copper gasket with the rhomboidal chamber shape will be used. Once this gasket is squeezed between flat flanges, electrical and geometrical continuity of the vacuum chamber is guaranteed.

Extensive laboratory tests have shown that this gaskets can withstand many bakeout cycles at 300 °C.

Pumping ports

Slotted pumping ports are envisaged to avoid beam impedance contributions. Tests to find the best slot dimensions and shapes are in progress.

Valves

Twenty four all-metal angle valves will be used to connect/disconnect the roughing pumping stations to the chamber. The machine will be divided in 6 vacuum sectors by means of 6 gate valves with internal contacts.

Pumping system

Roughing pumps

A good forevacuum will be obtained by means of 4 mobile turbomolecular stations mounted on carts which can be connected/disconnected to the vacuum chamber by means of the mentioned angle valves located in the BM regions.

Each 520 l/s oil-free turbo pump has magnetic bearings to avoid hydrocarbon backstreaming and is backed by a 180 l/s molecular drag-diaphragm pump. These stations will operate on one vacuum sector at a time (2 achromats) while it is baked out and then they will be moved to another sector.

Ultra-high vacuum (UHV) pumps

Sputter-ion pumps with internally installed NEG modules have been chosen because of their very high pumping speed for all the gases which are usually found in an all-metal UHV system (mainly H_2, CO, CO_2 and CH_4).

The NEG module inside the pump's body will be activated by means of Joule effect via an electrical feed-through taking a suitable current. The NEG module roughly doubles the pumping speed for active gases.

The SIPs installed in the straight sections will be of 120 l/s nominal pumping speed, while the ones placed just below the radiation absorbers will be 400 l/s each. Additional NEG modules will be installed in the BM antechamber, in front of the radiation absorbers, in order to manage part of the desorbed gases escaping the 400 l/s SIPs.

We are also looking for the possibility of powering in parallel 3 or 4 SIPs in order to reduce the cost of the power supplies. Nevertheless the possibility of reading the current absorbed by each pump in a group is foreseen.

Each achromat will have ten 120 l/s and two 400 l/s SIPs with NEG modules plus two NEG modules for distributed pumping in the BM antechamber.

Vacuum measurements

Low vacuum

Capacitive gauges will be used in the 760 - 10^{-3} Torr range.

High vacuum

Inverted-magnetron cold-cathode gauges will be used down to $5 \cdot 10^{-11}$ Torr. Some Bayard-Alpert hot-cathode gauges for lower pressure measurements are also foreseen.

Residual gas analyzers (RGA)

Each sector will have at least one RGA of the quadrupole type to monitor the gas composition and check for leaks.

Bakeout system

Due to the mentioned limited gap between the chamber and the magnetic poles, the heating strips and insulation for in-situ bakeout must be accomodated within 5 mm. Therefore very thin heating elements are mandatory: they are of the etched foil type, 0.2 mm-thick polyimide films capable of delivering the 0.08 W/cm^2 needed to reach the envisaged 150 °C bakeout temperature. The heating strips are glued to the vacuum chamber. The insulation jacket is made by two 1.5 mm-thick aramid cloth layers lined with aluminum foils on the internal side.

This configuration allows us to have less than 70 °C on the outer side of the insulation jacket when the vacuum chamber temperature is 150 °C. The bakeout system will be locally microprocessor-controlled in order to guarantee a uniform heating of the chamber thus minimizing the stresses and the probability of cracking of the weldings.

The SIPs will have their own heating elements.

Vacuum control system

Pressure and pumping data will be locally processed in order to take proper actions (for instance valve's closures when necessary). Topical informations will then be sent to the machine control system.

Vacuum treatments

Standard chemical cleaning procedures plus a thermal outgassing of at least 30 hours at a temperature of about 400 °C in a vacuum oven at a pressure of 10^{-6} Torr is planned for all vacuum chamber portions. At the end, the NEG modules and the heating strips will be installed in the BM chambers and these will be stored under a dry nitrogen atmosphere until final installation in the ring.

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