STATUS OF THE ESRF VACUUM SYSTEM

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Abstract

An overview is given of the present status of, and research and development (R&D) program for, the vacuum system of the 6 GeV ESRF storage ring (SR).

1 STORAGE RING PARAMETERS

Table 1 lists the relevant parameters of the ESRF SR's vacuum system. ID stands for insertion device.

Table 1: Storage ring parameters

Beam Energy	6 GeV
Circumference	844 m
Nominal Current	200 mA
Bending Radius	23.366 m
Critical Energy	20.5 KeV
No. of Straight Sections/Length	32 / 6 m
Number of Cells / Superperiods	32 / 16
Filling Patterns:	Multi-bunch
	32-bunch
	16-bunch
	Single-Bunch
	Hybrid
Synchrotron Radiation Power (BM only, 200 mA)	6.7 KW/m
Synchrotron Radiation Flux (BM only, 200 mA)	5.6E+18 ph/s/m
No. of ID Installed	55

2 VACUUM PERFORMANCE

After several years of conditioning, the average pressure around the ring is low enough not to constitute a limitation to the operation of the machine. Table 2 lists some of the relevant parameters of the vacuum system of the SR of the ESRF.

2.1 Multibunch Filling Mode

The most commonly used filling pattern is the so called 2/3-mode. In this mode two thirds of all RF buckets are filled and the maximum current is limited to 200 mA. The limiting factor is the temperature increase of some un-cooled parts of the vacuum chamber, caused by the radiation scattered by the absorbers immediately following the crotches, the called "bellow flat absorbers". In fact, all crotch absorbers in the ring had been replaced for similar reasons after about one year of operation with new ones made out of GlidCop. It is planned to replace these bellow flat absorbers with a new design in order to allow injection to higher currents.

The ESRF SR is equipped with three sets of RF cavities, each of them constituted by two 5-cell cavities (LEP-type).

The 2/3-mode does not create any vacuum problem to the RF cavities.

Table 2: Vacuum system parameters

Pumping System (Regular Cell)	
Sputter-Ion Pumps, No. / Size	5 / 45-60 l/s
	4 / 120 l/s
	2 / 400 l/s
NEG Cartridges (GP200)	11
Instrumentation (Reg. Cell):	
Penning Gauges	6
Pirani	1
Residual-Gas Analyzer	1
No. of Sliding Joints (Reg. Cell)	6
Vacuum Chamber Material:	
Stainless Steel	316LN
GlidCop	Crotch-Absorbers
OFC Copper	Absorbers
5m-Long ID Chambers with NO Pumps	(See Table 3)
Beam Lifetime:	
Multibunch (2/3-Filling)	50 hours / 200 mA
16-Bunch	17 hours / 90 mA
Single-Bunch	12 hours / 15 mA

2.2 16-Bunch Filling Mode

This mode of operation is requested by some experiments where the temporal structure of the photon beam is important, namely nuclear spectroscopy. The maximum current presently injected is limited to 90 mA. The limiting factor is constituted by the third set of RF cavities, SRRF3, which was installed in the SR in the summer of 1998. If the current is increased above such a limit, it is likely that pressure bursts will be generated and the cavities tripped.

Conditioning of these cavities in 16-bunch mode has been a slow process, and a modification of the pumping system originally installed on the two cavities has been necessary. The modification consisted in replacing two GP200 non-evaporable getter (NEG) modules installed on

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400 l/s sputter-ion pumps (SIPs) with two titanium-sublimation pumps (TiSPs). The TiSPs are routinely regenerated prior to each 16-bunch filling or as soon as it is realized that the pressure in the SRRF3 cavities is going up. Occasional beam trips due to pressure bursts are still observed from time to time. The conditioning of SRRF3 is shown in fig. 1. The sudden decrease of the pressure following the sublimation of the titanium is evident.

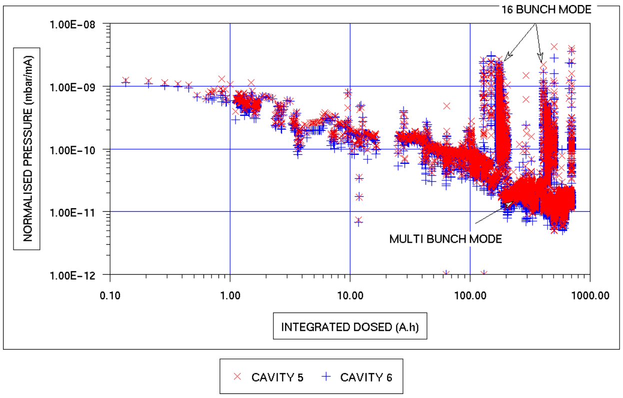

Fig.1: Conditioning of SRRF3.

Another problem related to the 16-bunch mode operation is the interaction of the very intense image currents and high-order mode losses travelling with the bunches, and the RF-contact fingers of the many sliding joints installed around the ring, see subsection 2.5.

2.3 Single-Bunch Filling Mode

Single-bunch operation is limited to 15 mA by considerations of beam lifetime related to intra-beam scattering, and does not constitute a problem for vacuum.

2.4 Hybrid Filling Modes

The hybrid modes are those where one third or two thirds of the RF buckets are filled with electron bunches, and one or a ew high-intensity bunches are filled in the position diametrically opposite to the centre bucket of the multibunch train. These modes also do not generally constitute a problem for vacuum.

2.5 Insertion Device Chambers

The ESRF has approximately 55 IDs installed around the ring. Each straight section can accommodate up to three ID segments, the maximum length of which is fixed. Like other third-generation synchrotron radiation sources, the ESRF's mission is to deliver high-intensity, high-brilliance photon beams. The trend is to reduce the gap of the IDs, and this leads to smaller and smaller vacuum chambers being necessary. The limitation of the size of the chambers usually arises in the vertical direction, and this has led the ESRF to develop ID chambers which are void of pumping distributed along the length, with lumped sputter-ion pumps installed at either end [1,2]. The distribution of the size of the chambers in the vertical direction is shown in table 3.

Table 3: ID Chambers

Vertical Aperture (mm):	Number:
10	4
13	1
15	15
19	3
Other: minigap, superconducting wiggler	3

Two additional 15-mm ID chambers which had been installed in the past have been replaced by 10-mm chambers.

There is only one straight section available for the installation of 5m-long ID chambers. The total number of sections not available due to the presence of either RF cavities, injection, or diagnostics is five.

This solution has proven to be successful from the point of view of the pressure in spite of the commonly used parabolic pressure profile model which would predict a pressure bump too high for operating safely the beamline downstream of such a chamber. It is recalled here that such chambers have cross-sections giving a specific conductance as low as less than one litre per second per metre. Without going into detail, it can be said that the "activation" of the inner surface of the chamber due to a prolonged high-temperature bake-out has been held responsible for a "wall pumping" effect which would reduce the pressure bump in the centre of the chamber. This heuristic model has been confirmed by the fact that the radiation levels in the beamline hutches are not compatible with the pressure bump model predictions. Our experience shows that when an in-situ bake-out is not carried out, such ID chambers generate a high level of bremsstrahlung radiation in the experimental hutches. In the past, the in-situ bake-out has been performed at high temperatures, up to 400 degrees Centigrade. This has generated very low static pressures and quick conditioning of the chambers and associated beamline equipment (monochromators, mirrors, etc…), but is also believed to have been responsible for the damage to the RF-contact fingers installed inside the sliding joints mounted immediately upstream and downstream of the ID chamber. We have tried to simulate the damage to the RF-contact fingers by setting up a mock-up of a 5m-long ID chamber and upstream-downstream assembly. It has been found that the distribution of heating power previously employed during bake-out was responsible for the uneven elongation of the ID chamber, leading to a radial displacement of more than one centimetre at the location of the contact fingers. This, combined with the longitudinal elongation of several centimetres, may cause the breaking of one or more fingers. This damage goes unnoticed in 2/3-filling mode operation, but may lead to further damage due to very intense heating generated by the 16-bunch operation. Melting of the fingers and retaining springs (Nimonic) has been observed. In at least one case, injection of the beam has been prevented by a finger protruding inside the beam stay-clear area.

2.6 Corrosion of Brazed Joints

The design study of the ESRF's vacuum chamber started about ten years ago, following a conventional scheme, employing stainless steel (SS) as the material of choice for the chamber and OFC copper for the distributed absorbers in the straight, quadrupole chambers. About 60 percent of the length of the chamber is made up of such materials. Figure 2 shows the typical cross-section of such a chamber. Corrosion has developed along the SS-to-copper braze. Since three leaks have developed in the last 6 months, we are currently ordering new spare vessels.

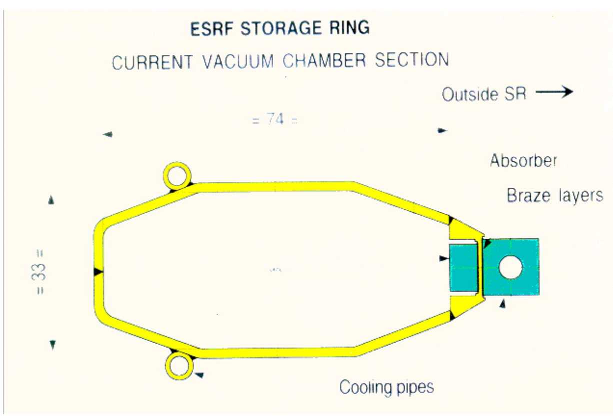

Fig. 2: Cross-section of a quadrupole chamber.

3 NEW DEVELOPMENTS

The main fields of action of our R&D program are highlighted.

3.1 Insertion Device Chambers

A number of new developments are foreseen for the near future. Among them the most important is the solution to the problem of damage to the RF-contact fingers, especially in the 5m-long ID sections. A new bake-out procedure, implementing an optimized distribution of the heating power, has been found. This reduces the radial displacement of the contact fingers to a few millimetres.

3.2 Cold-Cathode Gauge Controllers

Another source of trouble for the operation of the accelerator has been the triggering of interlocks by some cold-cathode gauge controllers. Those originally installed in the SR have been found to be sensitive to electromagnetic interference. When an interlock signal is generated, the beam is dumped and it is necessary to wait several minutes before being able to re-inject the beam. After several attempts at fixing the problem ended in a non-satisfactory way, we have decided to buy and install a new type of controller. The installation of approximately 200 of them is scheduled to happen before the end of this year.

3.3 Automatic Monitoring of Partial Pressures

Most of the ESRF's beamlines are physically separated from the SR vacuum by means of one or more beryllium windows. Six of them, though, are windowless, ultra-high vacuum (UHV) beamlines, and special care has to be taken in order to guarantee the integrity of the UHV environment of the SR. We are in the process of testing and installing a residual gas analysis (RGA) system which automatically checks the height of some relevant peaks in the RGA spectrum and sends a signal to the operator in case one or more peaks are above a given limit.

3.4 In-Vacuum Undulator

In quest of a higher photon flux and brilliance from the IDs, an in-vacuum undulator has been designed. It accommodates a standard length ID segment, and is capable of closing the gap down to two millimetres. All parts inside the vacuum vessel (permanent magnets, iron poles, supports, shims, etc…), have been carefully designed in order to avoid trapping air and a quick pump down. The chamber, without the ID elements, has been manufactured and has passed the acceptance test. It is now being tested in the final configuration, with the SIPs and TiSPs installed. Installation in the SR of the complete assembly is scheduled by the end of 1998.

3.5 Photo-Desorption Beamline

We have set up a beamline dedicated to photo-desorption experiments. Our short term goal is to validate the "wall pumping" effect following a bake-out of the 5m-long ID chambers.

4 CONCLUSIONS

The ESRF vacuum system has proven to be, over the years, adequate to handle the copious amounts of synchrotron radiation generated by the 64 bending magnets and 55 ID segments installed around the ring.

An intense program of R&D is pursued in order to follow the overall improvement of the performance of the machine.

REFERENCES

[1] N. Rouviere, "Undulator Vessels Devoid of Distributed Pumps", EPAC'96, Sitges, June 1996.
[2] N. Rouviere, "New Development in Undulator Vessels", this Conference.