RECENT OPERATION CHANGES AT THE ESRF

U. Weinrich, J.C. Biasci, J.M. Filhol, J. Jacob, L. Hardy, E. Plouviez, ESRF, Grenoble, France

Abstract

At the ESRF, developments are continuously being made to the machine in order to better satisfy the beamline users' requirements. A new temperature control was implemented on the storage ring cavities, which allows a better tuning to get rid of parasitic HOMs. This enabled the main filling pattern to be changed from 2/3-filling to 2 times 1/3-filling to provide a time structure required by some experiments. Additionally the RF voltage was reduced from 12 MV to 9 MV to gain in Touschek lifetime. Recently beam was also delivered in uniform filling to the users for one week. Progress on the coupling correction enabled the reduction of the coupling to 0.25 %. A significant reduction of the horizontal emittance was also achieved when the beam was delivered at 4 GeV (instead of 6 GeV) for a few days. A global vertical feedback as well as a local horizontal feedback system was made operational to further stabilise the fast beam motion in the frequency range of up to 110 Hz. A new type of absorber was developed to enable the front-ends to handle higher X-ray beam power densities. The main changes and their impact on beam parameters and on beamline operation will be presented.

1 RECENT DEVELOPMENT

1.1 New cavity water temperature regulation

Partial filling was one of the standard methods applied at the ESRF to avoid HOM driven Longitudinal Coupled Bunch Instabilities. The mechanism of Landau damping, which results from a spread in synchrotron frequencies when only a portion of the storage ring is filled, has been extensively investigated and quantified.

Within this study [1] it was demonstrated that a careful choice of the temperatures of the cavities could permit the tuning of dangerous Higher Order Modes (HOM) of synchrotron beam resonances, thereby substantially increasing the current thresholds for Longitudinal Coupled Bunch Instabilities (LCBI). An improved temperature regulation system that allows the adjustment of the individual cavity temperatures within a range from 22°C to 60°C with an accuracy and stability of ±0.05°C was put into operation in January 1999. A view of the cooling circuit is shown in Fig. 1. For each cavity, the system consists of a three way valve that mixes the warm return water and fresh water, a buffer bottle and a pump. It was used in the course of 1999 to develop new operation modes for the ESRF storage ring.

1.2 New filling modes (2x1/3rd and uniform)

The search for an improved Touschek lifetime led us to reduce the RF voltage from 12 to 9 MV, slightly above the minimum voltage required to maintain the ring energy acceptance (+/- 3%). This reduction resulted in an effective increase of the bunch length and allowed the reduction of the over-compensation of the chromaticities used to cure transverse instabilities.

The combination of this RF voltage decrease and a symmetric filling pattern that does not provide any Landau damping reduces the current thresholds for HOM driven LCBI. Stable operation was obtained by means of a careful temperature tuning of the cavities. As a result, the symmetric 2x1/3rd filling pattern at 9MV was implemented as the standard setting for 200 mA operation, in replacement of the 2/3rd filling mode. This new mode consists of two trains of 330 bunches spaced by a gap of 1/6th of the ring. It has all the advantages of the 2/3rd filling, i.e., an intensity of 200 mA and a lifetime up to 65 hours, whilst having the time structure needed for some experiments. This filling pattern doubles the photon count rate for some nuclear resonance scattering experiments whilst the change is transparent to other users.

Uniform filling of the storage ring at 200 mA with similar tuning has also been tested successfully and was delivered to the users early in the year 2000. Since it provides the highest Touschek lifetime, this uniform filling will become the standard filling pattern for all user beam time without time structure requirements.

Figure 1: The new cavity temperature regulation system

1.3 New beam energy: 4 GeV

During six User shifts, the beam was delivered at 4 GeV for the first time in order to evaluate the benefit gained from the smaller horizontal emittance compared to that of the standard 6 GeV operation.

The natural synchrotron damping being much lower at reduced electron beam energy, the thresholds for HOM driven LCBI are about 5 to 20 mA at 4 GeV, depending on the RF voltage and the level of Landau damping that results from the partial filling of the ring. Thanks to the improved cavity temperature control, a stable working point with 4.5 MV RF voltage was established allowing the delivery of 100 mA in 2/3rd filling with a lifetime of 10h.

This energy led to a record in emittance values: εx = 1.7 nm.rad and εz = 12 pm.rad. Several beamlines took advantage of the beam to perform experiments up to 30 KeV (using very high undulator harmonics). As an outcome it was decided to do a similar test at 5 GeV for which a higher intensity, lifetime and photon energy can be expected.

1.4 Smaller vertical emittance

Studies have been carried out to further decrease the vertical emittance to the diffraction limit [3]. With the developed correction method consisting of a response matrix modelling and minimisation of measured vertical beam sizes, a record vertical emittance of 12 pm.rad was achieved as measured on 2 different X-ray pinholes at the end of 1998.

Following this achievement, activities in the year 1999 started with the pursuit of the limit of correction by investigating various surrounding effects such as the influence of vertical beam motions. It was seen that the global orbit feedback that corrects the vertical beam oscillations up to 100 Hz could bring the measured vertical emittance a few picometres below the level without feedback. The effects of fast beam oscillations arising from resistive wall instabilities were also investigated.

To evaluate the impact on the beamlines the beam was delivered to users with a vertical emittance of 10 pm.rad instead of the typical 30 pm.rad for one full week.

Figure 2 shows the emittance values during beam delivery as recorded permanently by a pinhole camera. The vertical emittance (in red, magnified by 100) was shrunk from 25 to 10 pm.rad, whilst the horizontal emittance (in blue) was kept at 3.8 nm.rad. The lifetime (in green) was reduced accordingly from 65 hours to 50 hours.

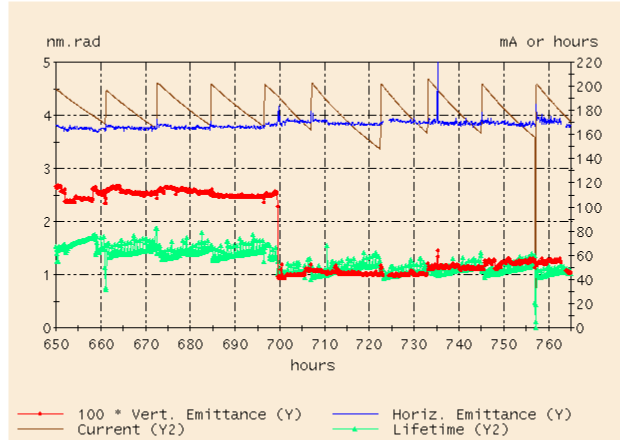

Figure 2: Beam delivery with very low coupling.

1.5 Local fast position feedback systems

Several ESRF beamlines have increased their performance to a point where they suffer from fast horizontal beam oscillations in the µm range. To cope with this, local horizontal feedback systems were put into operation. Such systems use two electron fast BPMs to measure the horizontal electron beam position at both ends of the straight section and four fast steerer dipole magnets to produce a local correction bump (a closed bump which does not change the beam position in the rest of the machine). An overview of the principle is given in Fig. 3.

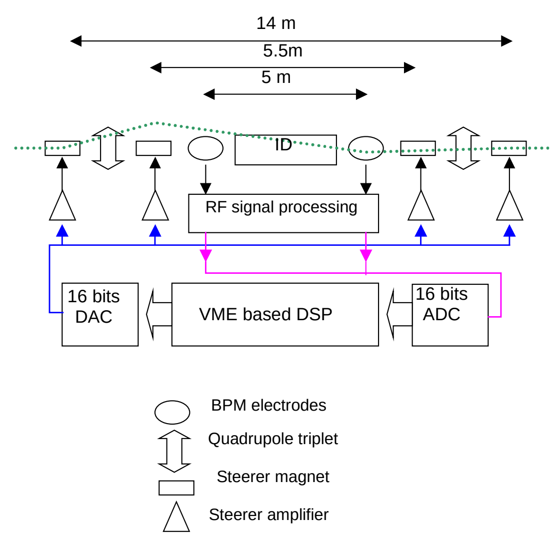

Figure 3: The local feedback principle

The system reduced the typical horizontal beam oscillation amplitude from 7 µm to 1 µm in the corresponding straight section, to be compared to the 400 µm rms horizontal beam size. Three of these systems are now under permanent operation, in addition to the global vertical fast position feedback, which reduces the amplitude of the fast vertical beam motions all around the machine.

1.6 More and more insertion devices

More than 60 segments of insertion devices are now in operation around the ring. In addition to new conventional segments, some more exotic devices have recently been successfully put into operation: A second quasi-periodic undulator segment, a fast switching planar/helical electromagnet undulator and a first prototype in-vacuum undulator. This in-vacuum undulator is now operating in USM with a minimum gap of 6 mm without any perturbation to the beam lifetime in both 16 bunch and 2 x 1/3 filling modes of operation. The in-vacuum undulator technology is more expensive and less flexible than conventional technology with magnet blocks in air. However, an in-vacuum undulator produces a spectrum shifted by 1.57 (1.3) towards higher energies compared to that of a 16 mm (11 mm) gap undulator with magnet blocks in air. This makes this technology attractive for beamlines operating at high X-ray energies [4].

1.7 New high power front end absorber

Until very recently the movable absorbers in the front-end were not able to sustain the power and power density produced at 200 mA by 5 m of undulators closed to a minimum gap of 11 mm. The limitation was for a maximum of 2 undulator segments (3.2 m long) at a minimum gap of 16 mm. A new high power front-end absorber was therefore designed and tested with a total power of 10 kW and a power density of 280 kW/mrad^2. This device should be able to withstand a power density of up to 400 kW/mrad^2. Note that the transmission of such a high power density requires the replacement of the Beryllium window/carbon filters assembly with a diamond window.

A first movable absorber is now in operation on a beamline and other front-ends will be equipped soon. A view of the absorber is given in Fig. 4.

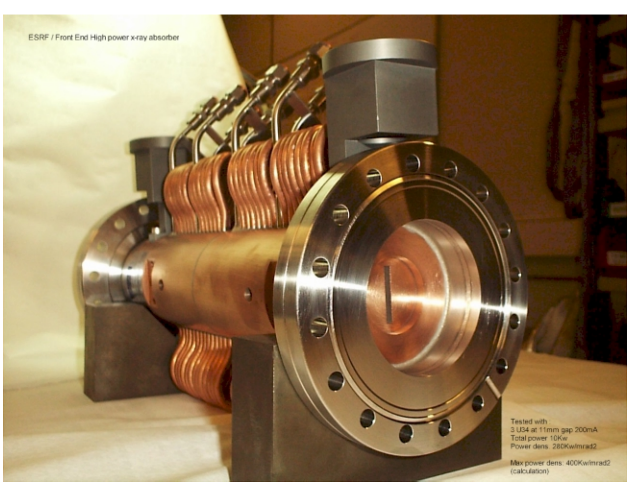

Figure 4: The new high power front-end absorber

2 OUTCOME

The figure of merit for synchrotron light sources is the brilliance. A lot of machine development at the ESRF is therefore permanently directed to increasing it. An overview of the presently available brilliance at the ESRF is given in Fig. 5.

The maximum brilliance at 10 keV is now higher than $4 \cdot 10^{20}$ photons/s/0.1% bw/mm^2/mrad^2. This is a factor 200 above the initial ESRF target specifications.

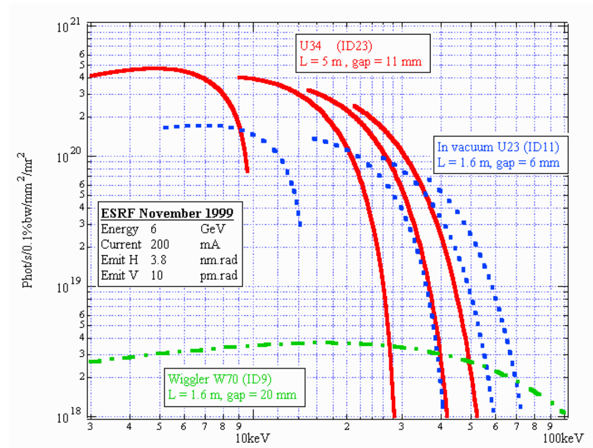

Figure 5: Brilliance at the ESRF

This last increase results from both the reduction of the vertical emittance to 10 pm.rad and from the possibility to operate 3 undulator segments (giving a 5m total ID length) closed at an 11 mm gap.

With the use of an in-vacuum undulator, a brilliance of higher than 10^{19} photons/s/0.1% bw/mm^2/mrad^2 can be obtained up to a 50 keV X-ray energy.

3 CONCLUSION

Following several operation changes the maximum brilliance at the ESRF has again been increased. In parallel the beam position stability has been improved in order to let the beamlines fully benefit from these achievements.

REFERENCES

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