SUPER-ACO STATUS REPORT*

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Abstract

The VUV source Super-ACO is operational since mid 1987. Presently, 4 undulators and 13 beam lines are installed providing photon beams to 23 experiments. Routine conditions in the two main modes of operation are : 400 mA for the initial current and 5 hours for the lifetime with 24 bunches, 200 mA and 2.5 hours with 2 bunches. The possible various ways of operating Super-ACO are discussed in terms of beam gas and Touschek lifetimes, vertical emittance, transverse and longitudinal stability.

New results on beam behaviour with 3 insertions are reported. They include the study of the non linearities excited by the insertions, the injection of an intense single bunch, the FEL operation at 600 MeV.

Main conclusions from a special test with Super-ACO operated with electrons are reported.

Introduction

Since the last 1988 EPAC Conference, Super-ACO has been the subject of large developments and substantial improvements of its performances. Four undulators are now installed on the ring, one of them equipped with a dispersive section, is part of a FEL experiment. Nine bending magnet beam lines are in the operational stage. Altogether, photons are provided to 23 different experiments. The machine is operated on a weekly basis, with 4 x 16 h shifts for the users, another 8 hour shift for FEL and Coherent Harmonic Generation studies and frequently an additionnal 20 hour shift for machine studies and developments. A total of 3 300 hours of beam time has been delivered to the users during the year 1989, the first one where a valid record of operation could be made.

Undulators

n°	Description	K
SU7	2 regular sections : 2 x 10 x 129 mm periods + 1 dispersive section 500 mm.	6
SU6	1 regular section : 14 x 78 mm periods	2.2
SU3	1 regular section : 24 x 129 mm periods	6
SU2	Asym. Hybr. Wiggler : 12 x 263 mm periods, B_M, B_m = 1.05, 0.2 T	11

Table 1

The 4 undulators already installed have the characteristics described in the Table 1, in the installation order on the machine.

The Asymmetric Hybrid Wiggler which uses a hybrid technology with Fe Nd B magnets has been installed during the last shut down in April, this year. All these undulators have the same inner chamber height, 30 mm.

The beam behaviour with 3 insertions is reported in a specific paper [1]. We present here its major conclusions. All fourth order non linear resonances are excited by the undulators. Two of them, not predicted by the standard sinusoidal model, are the most dangerous and lead to sharp beam losses.

Choosing the operating point far from the resonances, we measured the lifetime reduction when closing the undulators. Beam gas lifetime and Touschek lifetime decrease respectively by 35 % and 50 %. The effect of beam gas lifetime reduction will become negligible in the long run with vacuum chamber conditioning. In order to compensate for the observed Touschek lifetime reduction, the beam is set on the coupling resonance.

Modes of Operation

In constrast with many other rings, the two main modes of operation, with 24 and 2 bunches, share equally the production time. In terms of beam current, lifetime and beam emittance, the performances of the machine are given below. The reference terms for the beam emittance are :

$$\varepsilon_x = 4.1\ 10^{-8}\ \text{m.rad},\ \ \varepsilon_z = 1.0\ 10^{-9}\ \text{m.rad}$$

This corresponds to a minimum vertical beam height achieved at the waist in the magnet of $\sigma_z = 71\ \mu$m.

- 24 bunch mode . The initial current is in the range of 450 mA. For an accumulated dose $Q = \int I^+ dt$ of 400 A.h, the product beam current x beam lifetime, a constant except for the static pressure contribution, has now reached the value 2 A.h. This figure is obtained for a vertical beam emittance somewhat larger than the minimum stated above namely :

$$\varepsilon_x = 3.7\ 10^{-8}\ \text{m.rad},\ \ \varepsilon_z = 1.8\ 10^{-8}\ \text{m.rad},\ \ \sigma_z = 300\ \mu\text{m}.$$

The beam is not fully coupled ($\varepsilon_x = \varepsilon_z$), for reasons explained below of optimizing the beam gas lifetime.

- 2 bunch mode. The initial total beam current ranges between 200 and 230 mA. In this case the beam gas lifetime is less important than the Touschek lifetime which is maximized on the coupling resonance. One has :

$$\varepsilon_x = \varepsilon_z = 2.9\ 10^{-8}\ \text{m.rad},\ \ \sigma_z = 380\ \mu\text{m}.$$

The product $I_{tot.}.\tau$ reaches the value 0.5 A.h. The large

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intensity per bunch (> 100 mA) is only achieved with large chromaticities, which in turn bring poorer lifetimes.[2]

Note that the maximum performances for the beam intensity were achieved with 165 mA in a single bunch and 670 mA in 24 bunches. Higher intensities than those mentioned above for routine operation mean lower lifetimes, a situation which does not suit the users. In fact, the request for better lifetimes, even at the cost of a higher vertical emittance, is their final choice. Several long periods of operation with a beam vertical emittance $\varepsilon_z = 7.9\ 10^{-9}$ m.rad, that is less than half the normal value for the 24 bunch operation, have not brought any improvement on the useful photon flux of the users. This may be not uncommon to other V.U.V. facilities.

Injection Speed

With an incoming beam of 8 10^8 positrons per pulse at a repetition rate of 25 Hz, the injection speed is 5 $A.h^{-1}$ with all the undulators open. These performances have been achieved by chosing the tunes and the sextupole strengths so as to minimize the influence of the $\nu_x + 2\,\nu_z = 8$ resonance. When closing the first 3 undulators of the above table, the injection speed is still 2.5 $A.h^{-1}$. For sake of simplicity all beam fillings are performed with the undulators closed, except for SU2 at the moment.

Vacuum

Due to the compacity of Super-ACO, a large number of problems on the vacuum chamber system were encountered mainly from electrons, photo electrons and stray photons. These had severe drawbacks on the pressure measurements with B.A. gauges and the ion pump current readings (DIP's and the diode pump). A RF pick-up from the beam had also a very detrimental effect on each gas mass analyser. In the last two years, these problems have been identified one after the other and solutions were devised which are progressively applied at the occasion of vacuum chamber openings [3].

Of special importance for the machine performances was a non linear pressure rise $p > 10^{-8}$ Torr, at currents higher than 250 mA. It has been understood as arising from a RF excitation by the beam of the non shielded gate valve enclosure. Conditioning, with time at large currents, was fortunately experienced and pushed the non linearity threshold above 400 mA. Finally, large bunch currents resulted in an overheating of the kickers, partially overcome by extra air cooling. This probably arises from a too thin Ti coating of the ceramics (0.1 μm) and an increase to 1 or 2 μm is considered.[4]

Beam Gas Lifetime and Machine Tunes

Beam gas lifetime was found to vary with the machine tune in a region close to the coupling resonance $\nu_x - \nu_z = 3$. In order to establish clearly the experimental facts, a series of measurements were taken using the so called Argon method described elsewhere [5]. Ion pumps are switched off and due to the Argon release, the pressure is let to increase in the 10^{-8} Torr range.

At low current, 15 mA, Touschek lifetime and photon stimulated desorption can be neglected. A beam gas lifetime of order of 5 to 10 minutes is observed, which can be measured with a 2 % accuracy in a short time. Fig. 1 shows typical plots of the product $\overline{P}.\tau$ of the average pressure $\overline{P}$ by the beam lifetime τ as a function of the vertical tune, for 3 different values of the horizontal tune. A dip of average amplitude 0.65 occurs at a distance $\delta\nu_z = 7.0\ 10^{-3}$ from the coupling resonance.

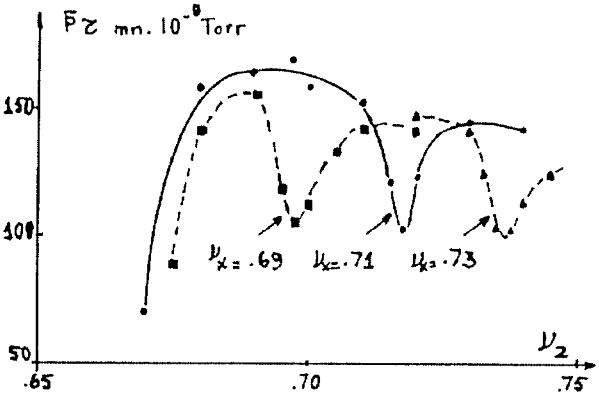

Fig. 1 : Product $\overline{P}.\tau$ versus ν_z.

Fig. 2 which shows a plot of the dip tune versus ν_x, suggests that the damped beam is above the coupling resonance whereas, due to octupolar terms, the large amplitude particle resonance corresponds to $\nu_x - \nu_z = 3$. Assuming this, one can proceed to calculate the dip effect. Away from the resonance, the total cross section for the beam particle interaction with Ar atoms leading to losses has two contributions : the cross section for events with energy change which is computed to be $\sigma_{inel.} = 19.8\ 10^{-24}\ cm^2$ and the cross section for elastic scattering on Ar nuclei which is,

$$\sigma_{scatt.} = \frac{2\pi\, r_0^2\, Z^2}{\gamma^2\, h^2}\, \beta_z^c\, \overline{\beta_z}$$

with h being the vacuum chamber height at the critical point where the vertical betatron function value is β_z^c . $\overline{\beta_z}$ is its average over the ring circumference. On the coupling resonance, the scattering cross section takes the more general form :

$$\sigma'_{scatt.} = \frac{2\pi\, r_0^2\, Z^2}{\gamma^2\, h^2}\, \beta_z^c \left(\overline{\beta_z} + \overline{\beta_x}\right)$$

with $\beta_z^c = 13$ m, $\overline{\beta_z} = 9$ m and $\overline{\beta_x} = 7.2$ m, one has :
$\sigma_{scatt.} = 33.9\ 10^{-24}\ cm^2$, $\sigma_{tot.} = 53.7\ 10^{-24}\ cm^2$
and $\sigma'_{scatt.} = 61\ 10^{-24}\ cm^2$, $\sigma'_{tot.} = 80.8\ 10^{-24}\ cm^2$

The value $\sigma_{tot.}/\sigma'_{tot.} = 0.664$ is very close to the amplitude of the dip reported above.

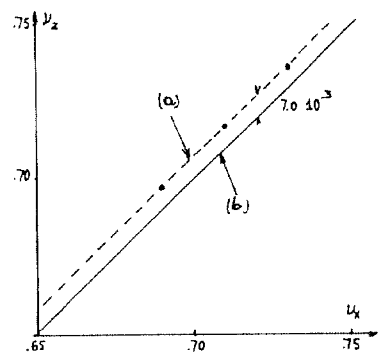

Fig. 2 : Coupling Resonance
(a) For a damped beam
(b) For particles with 15 mm oscillation amplitude.

Electron filling

Super-ACO was designed for positron filling and from the very beginning, operated in this configuration. In particular no provision was made for clearing electrodes. Only recently, the decision was taken to run Super-ACO for a while with electrons. The results of a 3 day test can be summarized as follows.

For large currents, 400 mA, the beam lifetime as compared to the one with positrons is reduced by 30 %. At lower current and independently of the number of bunches, the lifetime reduction becomes more and more severe. In consequence, the 24 bunch operation would require more frequent refills, but the 2 bunch operation could not even be considered.

Attention was given to the problem of microlosses of beam current observed with electrons, but not with positrons. These are understood as the result of photoionised dust particles, with diameters in the range of 10 µm, being raised by the electron beam. When crossing it, they lead to particle losses through multiple scattering. The process has been looked in detail [6] and can produce a growth of beam emittance in the case of large energy and low emittance rings at moderate current. For low energy rings and moderate currents, dust particles can stay oscillating around the beam, leading to short lifetimes in competition with positive ion trapping effects.

Longitudinal Feedback

The longitudinal feedback system, based on the well known CERN booster scheme, has been already described [7].

The signal from a pick-up electrode is fed to an excitation electrode through a signal processor centered on the 91st harmonic of the revolution frequency. The electrode has been matched by an external circuit in order to resonate at the frequency (378.8 MHz) chosen as the highest possible, compatible with the filter components.

New improvements, and extensive measurements at 800 MeV with 4 and 3 bunches have been performed. The system is able to damp respectively the dipole modes 1 and 3 for 4 bunches, 1 and 2 for 3 bunches, thus reducing the peak to peak oscillation amplitude from 1.5 ns to less than 100 ps.

In the 4 bunch case, some random instability on mode 2 remains but 3 bunches are stable up to 240 mA total current.

Two bunches at 180° are stable at 800 MeV without feedback, but start to oscillate during the ramping to the energy 600 MeV required for FEL experiments. The feedback is therefore also used in this case, the filter being centered on the 90th harmonic. However quadrupolar and sextupolar modes, harmful for this experiment, are not stabilized by the system. They always occur in the same range of current : the sextupolar modes above 100 mA total current, the quadrupolar modes between 100 and 50 mA while the dipole mode is observed below 50 mA.

Transverse Instability Close to the Coupling Resonance

A transverse instability similar to the one seen on DCI [8] is observed on Super-ACO in the vicinity of the coupling resonance. With the help of a skew quadrupole and after a suitable vertical closed orbit distorsion in the sextupoles, the horizontal-vertical coupling can be reduced to the point where $\delta\nu = \nu_x - \nu_z$ is as small as $2\ 10^{-4}$.

Starting from these conditions, a 18 mA bunch is stable when $\delta\nu$ is varied over a wide range ($> \pm\ 10^{-2}$) by changing the machine tune. However a transverse instability develops on both sides of the minimum, when the coupling is increased by means of the skew quadrupole or by vertical orbit distorsions in the sextupoles. This is observed in a narrow range of $\delta\nu$ and for bunch currents well below the above quoted value.

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