COMMISSIONING OF SUPER-ACO

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Abstract

The first beam was stored on March the 18th 1987. Since then many results were obtained in the "low emittance" configuration and with the 100 MHz RF system. They are generally in good agreement with the design values, both from the standpoint of optics and collective effects. Machine performances are presented, and next developments with special emphasis on undulators are described.

Summary

Super ACO is a dedicated 800 MeV V.U.V. Synchrotron Radiation source which was built during the 1983-1986 period. It consists of four achromatic arcs and can accommodate up to six insertions. It is filled with positrons delivered by the 2.3 GeV Orsay linac.

The machine and several optics have already been described [1]. The results presented below refer to the so-called "low emittance" optics.

The amplitude and dispersion functions are shown on Fig.1.

Tests of the optics

We compare the values predicted by the model to the experimental results. The differences reflect the imperfections of the model. These discrepancies are generally small enough, so that the model can be used for further simulations. (See table 1).

	Predicted values	Experimental values
Betatron Tunes	$\nu_x = 4.818$ $\nu_z = 1.758$	$\nu_x = 4.761$ $\nu_z = 1.708$
Synchrotron tunes	$\nu_s = 3.2\times10^{-3}$	$\nu_s = 3.4\times10^{-3}$
Chromaticities	$\xi_x = -11.7$ $\xi_z = -6.2$	$\xi_x = -11.0$ $\xi_z = -5.5$
Dispersion function	$\eta_0 = 0$ $\eta^* = 1.2$ m	$\eta_0 = 0 \pm 0.02$ m $\eta^* = 1.5 \pm 0.05$ m

Table 1

With the initial quadrupole settings, η was found to be 0.10 m and 1.40 m at the BPM locations, respectively in the odd and even numbered straight sections. With the proper adjustments these values were brought to those indicated on the table.

Amplitude functions

They are measured by changing the strength of a quadrupole family and calculated using the formula

$$\langle\beta_y\rangle_q = \frac{\pi}{2\ell_q}\ \frac{1}{K_i}\ \frac{\Delta\nu_y}{\Delta K_i/K_i}$$

$y = x$ or z, ℓ_q = quadrupole length.

Table 2 shows the predicted and experimental values of $K_i \dfrac{\delta\nu_{x,z}}{\Delta K_i}$

Quad Family \ $K\frac{\Delta\nu}{\Delta K}$		Predicted	Experimental	Difference	Accuracy
Q_1	X	2.70	2.55	$-6\ 10^{-2}$	$6\ 10^{-2}$
	Z	4.25	3.90	$-8\ 10^{-2}$	$4\ 10^{-2}$
Q_2	X	9.08	7.98	$-12\ 10^{-2}$	$1.3\ 10^{-2}$
	Z	2.94	2.67	$-9\ 10^{-2}$	$4\ 10^{-2}$
Q_3	X	9.68	8.27	$-15\ 10^{-2}$	$1\ 10^{-2}$
	Z	3.09	2.43	$-21\ 10^{-2}$	$4\ 10^{-2}$
Q_4	X	3.00	2.90	$-3\ 10^{-2}$	$5\ 10^{-2}$
	Z	4.50	3.91	$-13\ 10^{-2}$	$4\ 10^{-2}$

Table 2

There is so far no relevant explanation for the differences being systematically negative.

Closed orbit

After correcting for stray magnetic fields from the current feeds and for the asymmetry of the bending magnets, the natural closed orbit excursions are within $\pm$ 6 mm horizontally and $\pm$ 3 mm vertically.

Using one vertical and two horizontal steerings the optimized closed orbit characteristics are :

$$\bar{X} = 0.2\text{ mm} \quad \hat{X} = 2\text{ mm} \quad X_{rms} = 1.3\text{ mm}$$

$$\bar{Z} = 0.3\text{ mm} \quad \hat{Z} = 1.5\text{ mm} \quad Z_{rms} = 0.8\text{ mm}$$

Orbit steering

The horizontal steerings are located in the bending magnets and the focusing quadrupoles, the vertical steerings in the defocusing quadrupoles.

These steerings are generally used in combination in order to control the beam position and angle in both planes independently in each insertion.

Transverse dimensions

The beam transverse dimensions are mesaured with a CCD camera. The source point is at 7° downstream of the A2 bending magnet entrance. The measured horizontal dimension σ_x is 280 µm, as compared to the expected value σ_x = 255 µm.

The minimum vertical dimension measured after optimization of the skew quadrupole strength is σ_z = 70 µm.

This corresponds to a coupling factor $\kappa^2 = 2.3 \times 10^{-2}$. The experimental values of the emittances are

$$\varepsilon_x = 4 \times 10^{-8} \text{ m.rad} \qquad \varepsilon_z = 9 \times 10^{-10} \text{ m.rad.}$$

It was observed that the value $\kappa^2 = 1$ could not be reached.

Bunch length

Fig.2 shows the variation of the bunch length with the bunch intensity. The turbulent threshold is about 7 mA and the best fit using the BBI code [2] yields a broadband resonator frequency of 2.5 GHz and a vacuum chamber impedance $\left|\frac{Z}{n}\right|_0 = 2.8\ \Omega$.

Machine performances

Injection

The length of the linac pulse is presently 30 ns and therefore three to four 100 MHz buckets are filled simultaneously. With 6×10^8 e^+ per pulse at 25 Hz repetition frequency, the injection rate is about 3 A/h. This efficiency is optimized by minimization of the $\nu_x + 2\nu_z = 8$ resonance strength using the non-chromatic sextupole families.

Current limitations

The maximum intensity stored in a single bunch is 31 mA. This limit is related to the transverse mode-coupling instability [3], where modes 0 and 1 merge.

The maximum stored current in 24 bunches is 260 mA. Presently, longitudinal stability is achieved only with a single bunch or two equidistant bunches.

Lifetime

The detailed study of the lifetime versus current [3] shows that in the multibunch mode the beam-gas lifetime is dominant. In the single bunch mode, the lifetime is ultimately limited by single intrabeam scattering. This can be deduced from direct measurements and also from the variation of the lifetime with the vacuum chamber aperture. One obtains a value of 7 ± 0.5 hours for a bunch intensity of 20 mA. This figure is 20 % below the computed value.

Recent developments

An optical klystron was installed last december in straight n°7. It has the following characteristics.

$$\lambda_0 = 12.9 \text{ cm},\ N = 2 \times 10 \text{ periods},\ K = 5.8$$

$$\int B^2 d\ell = 0.4\ T^2\ m$$

The minimum gap is 38 mm, and the vacuum chamber aperture 30 mm.

The maximum vertical tune-shift $\Delta\nu_z = 3.10^{-2}$ is close to the expected value. The machine is globally retuned by trimming the Q_1 and Q_2 quadrupole families [4].

With these corrections, the beam lifetime has recovered and injection can be performed at a rate of 2 A/h, the undulator being closed at minimum gap.

The beam lifetime is now very sensitive to the fourth order resonances $4\nu_z = 7$, $2\nu_x + 2\nu_z = 13$ and $3\nu_x + \nu_z = 16$. The first two ones are expected from the undulator field non linearities, but the origin of third one is still not understood.

Tracking of the large amplitude particles at injection with the BETA code [5] shows evidence for the effect of the $4\nu_z = 7$ resonance (Fig.3).

Energy ramping

The FEL experiments require the Super-ACO operation at lower energies (down to 400 MeV). The machine is ramped down at constant tune, matched dispersion and zero chromaticity. The energy 550 MeV is reached with a stable bunch of 20 mA. At 400 MeV, a bunch of 11 mA is unstable.

The problems encountered are : vertical excitation and longitudinal instabilility.

Future developments

- Installation of new beam lines on bending magnets A_2, A_3, A_6.

- Installation in straight n°6 of the undulator formerly used on ACO.

- Test of new optics : quasi isochronous machine , lower β_z for high K insertions.

Longer range activities include the following devices : a pseudo-wiggler λ_0 = 12.9 cm N = 22 periods, K = 5.8, an asymmetric hybrid wiggler (1T, λ_0 = 25 cm, 12 periods) for the production of circularly polarized radiation, a triode gun for single bunch injection with shorter linac pulses (≤ 7 ns), a 500 MHz RF system.

References

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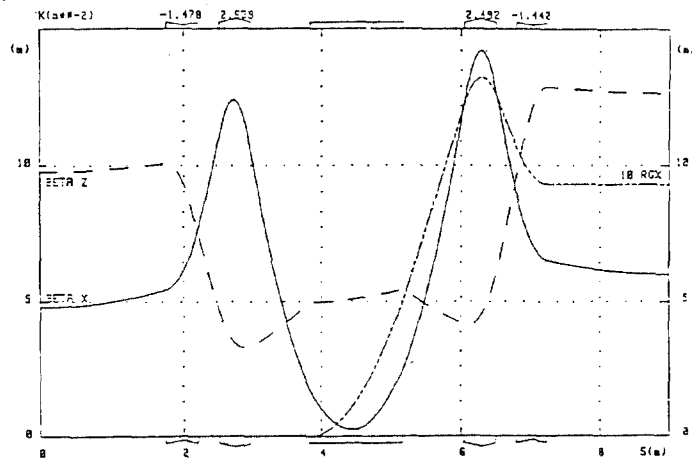

Fig.1. LOW EMITTANCE LATTICE FOR A HALF PERIOD (ν_x = 4.781, ν_z = 1.758)

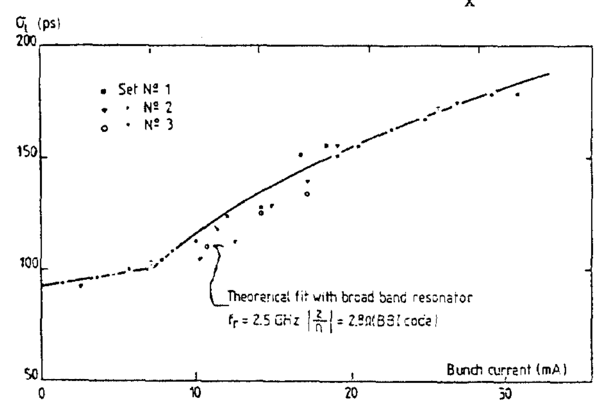

Fig.2. BUNCH LENGTH VARIATION WITH CURRENT

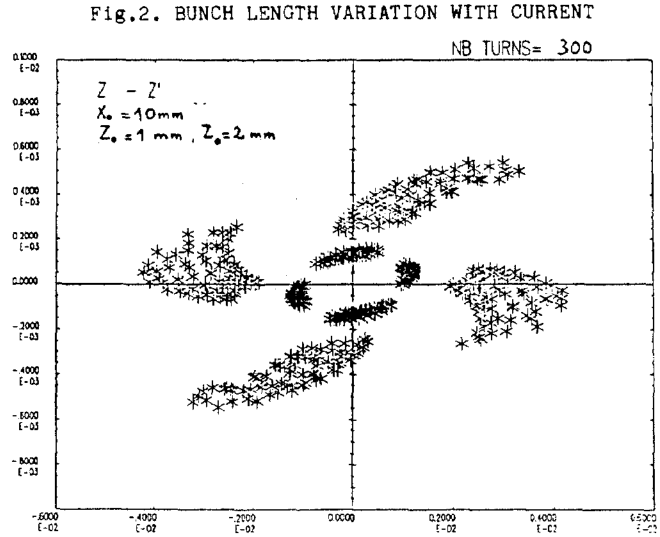

Fig.3. VERTICAL PHASE SPACE FOR LARGE AMPLITUDE PARTICLES : ν_z = 1.750 WITH SD7 UNDULATOR