TRANSPARENT USER OPERATION OF OPHELIE AT SUPER-ACO*

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Abstract

OPHELIE is a crossed electromagnetic undulator installed on Super-ACO. The magnetic fields and their longitudinal dephasing ϕ will be scanned and fully controlled by the users during the shift. As a consequence, this insertion device must be transparent for other users. Most of the effects of OPHELIE, in terms of closed orbit and focusing, have been measured and compensated during its commissioning phase in the DC mode and the main results (for $\phi = 0$) were presented at PAC99 [1]. The coupling introduced when both undulators are switched on has been measured and found to be small compared to the undulators focusing. The effect of dephasing (between +90° and –90°) on closed orbit is now measured and corrected for all field values using additional coils fitted on undulators poles. Finally, in order to take into account coupling and tune variations in the AC mode, a new working point has been chosen for each mode of operation (2 and 24 bunches) using feedback systems on both position and tunes.

1 INTRODUCTION

Up to now, OPHELIE [2] has been operating in the DC mode [3], at $\phi = 0$, with only one undulator (H or V) switched on. The closed orbit distorsion induced by the dephasing is now fully corrected with additional coils installed on both undulators. This will allow the DC operation at $\phi \neq 0$ until September 2000. Then the AC mode (V-field switching, $\phi \neq 0$) will be used, first slowly (1 cycle per minute) and then at a 0.1 Hz rate in 2001. As this type of operation must be transparent for other users, two new working points will be used, both with large vertical beam size in order to maximize Touschek lifetime. One is obtained with a strong coupling, the other by excitation on tunes. For both, the effects induced by OPHELIE become negligible.

2 COUPLING MEASUREMENTS

When the two undulators are switched on, the positron beam is subject to horizontal and vertical fields, leading to an inclined betatron oscillation plane. As a consequence, a coupling effect, which depends on both undulator fields, is added to the focusing one. Experimental studies have been performed for different configurations of H and V fields at $\phi = 0$. One of the 2 skew quadrupoles of the ring was used to measure the amount of coupling by an exact compensation of the undulators effects. Two characteristic experiments show the contributions of focusing and coupling to the tune variation when undulator fields vary. Figure 1 summarizes the experiment where the inclination of the oscillation plane varies from 0° ($B_x = 0$, $B_z = -B_{max}$) to 90° ($B_x = B_{max}$, $B_z = 0$) and 180° ($B_x = 0$, $B_z = +B_{max}$) with $B_x^2 + B_z^2$ = Constante. Figure 2 summarizes the experiment where the inclination is 45° ($B_x = B_z$) and B_x and B_z vary from 0 to B_{max}.

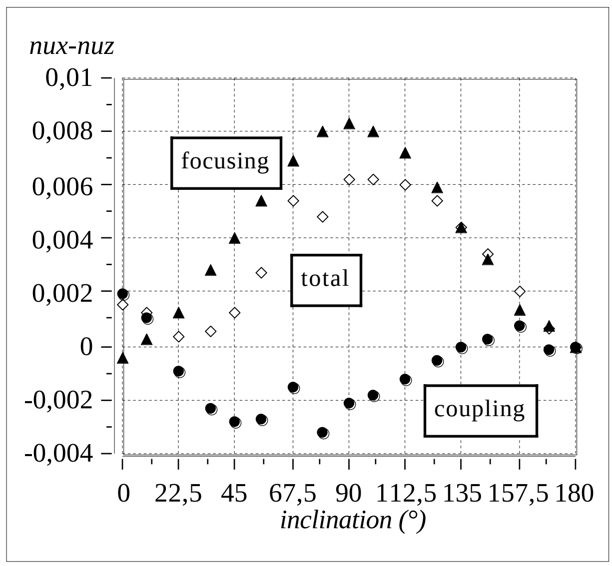

Figure 1 : Tune variation due to inclination variation ($\phi = 0$)

In the first case, focusing effect is dominant, with a maximum coupling effect at about 45°. In the second case, the coupling effect is dominant because the two undulator focusing effects compensate each other. The coupling introduced by the undulators changes the resonance width but not the beam dimensions. As the operating point is on the coupling resonance, a vertical beam size variation will occur only if the focusing effect is dominant. The challenge is then to compensate for the focusing effect in all configurations of undulators fields or to make it negligible (see section 4).

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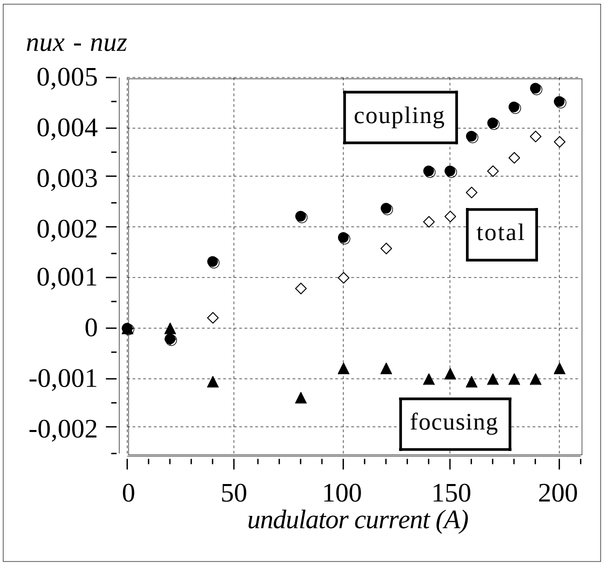

Figure 2 : Tune variation due to field variation ($B_x = B_z$, $\phi = 0$)

3 CLOSED ORBIT CORRECTION AT $\phi \neq 0$

First measurements on dephasing effects [1] have shown that two compensation coils at both entrance and exit of each of the two undulators are sufficient to correct for orbit distorsion in both horizontal and vertical planes. Because of the large number of compensation currents to be defined (for all undulators fields and dephasing from –90° to 90°), a fast method has been chosen : the beam position feedback system, using the undulators compensation currents and the machine BPMs. For the control of the device, a polynomial fit (depending on undulators fields and dephasing), deduced from these measurements, is used.

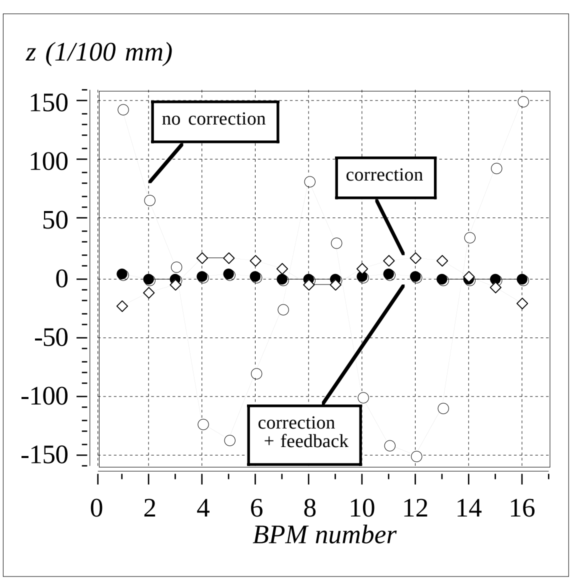

Figure 3 : Correction of the vertical closed orbit due to the horizontal undulator at ϕ = - 90° and $B_x = B_{max}$.

This correction leads to a residual closed orbit smaller than 0.25 mm in both planes, which is cancelled by using the beam position feedback.

In order to improve the feedback correction efficiency during OPHELIE's operation, the usual matrix has been modified to include the machine dipolar correctors close to the insertion device. As an example, Figure 3 shows the correction of the vertical closed orbit generated by the horizontal undulator, for ϕ = - 90° and $B_x = B_{max}$.

4 THE 2 NEW OPERATING POINTS

The usual operating point of Super-ACO is on coupling resonance and the focusing effect of OPHELIE changes the vertical beam size (see section 2). A feedback system on betatron tunes has been developed [1] in order to compensate for this effect. Nevertheless, when the horizontal undulator field varies, the tunes become closer and cross each other, and the betatron tune feedback is no more effective. It was then necessary to find another operating point where OPHELIE's effects become negligible and where the Touschek lifetime remains satisfactory, i.e. the vertical beam size is large.

4.1 Strong Coupling Operating Point

Starting from a point where the tunes are as far as possible from the coupling resonance, the coupling was increased from its minimum value to the one that gives the vertical beam size used in routine (σ_z = 400 µm). The minimum coupling value was obtained with two skew quadrupoles by minimizing the coupling resonance width. The large coupling was obtained by increasing the strength of one skew quadrupole (QT4) and with some tune adjustments. Table 1 compares the new point performance and the routine point one. The lifetimes, measured for the maximum stored current (400 mA in 24 bunches), are equal. At this point, the tunes are on the coupling resonance and its width is so large ($2\ 10^{-2}$) that tune variations of several 10^{-3} introduced by OPHELIE (coupling or focusing) are negligible and do not induce any effects.

Table 1 : Operating point characteristics.

	"Routine"	"Strong Coupling"
QT4 (A)	1.28	4.0
ν_x	4.7105	4.72
ν_z	1.7060	1.70
σ_x (µm)	182	185
σ_z (µm)	380	408
I (mA)	394	381
τ (h)	8.6	8.3

4.2 Operating Point with Transverse Excitation

In the 2 bunch mode of operation, it is possible to increase the vertical and horizontal beam sizes by using excitation on both vertical and horizontal tune.

The excitation is transmitted by four 45° strip line electrodes. The carrier frequency (2.975 MHz) is the central frequency between the fractional parts of ν_x and ν_z. A modulation, made by a 5 kHz ramping signal, leads to a spectral range of $3.8\ 10^{-2}$, which covers tune variations during a shift, with a resolution of $1.2\ 10^{-3}$ on both tunes.

In this case, the tunes are far away from the coupling resonance and the global coupling is minimum (a few %). For the same vertical beam size as in the routine point (about 400 μm) and a slightly increased horizontal one, the lifetime at high current (2x100 mA) is 2 times better than the routine one (10 h compared to 5 h). In fact, on Super-ACO, the lifetime measured at the routine point, with full coupling, is limited by the vertical physical aperture in undulator sections (± 15 mm). Figure 4 compares experimental variation of beam lifetime with coupling (with chamber effect) and expected lifetime variation with vertical beam size (no chamber effect).

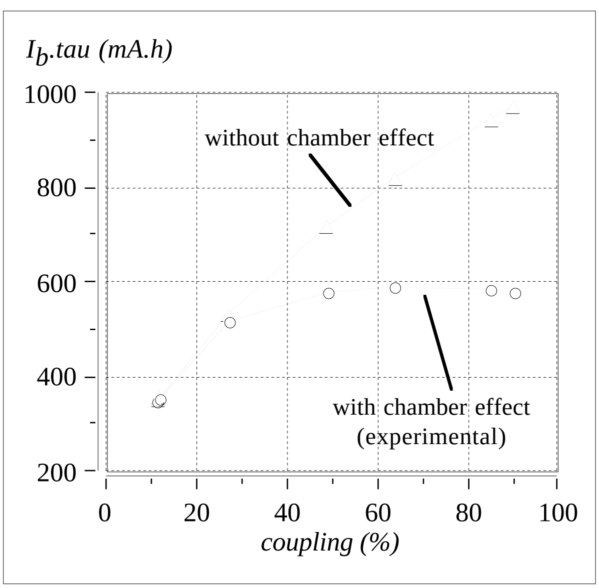

Figure 4 : Beam lifetime variation with coupling.

The vertical aperture becomes a limitation above a 30% coupling value. The "excitation mode" cancels this limitation and gives a longer lifetime because the large vertical beam size is obtained at very small coupling where there is no chamber effect.

5 TRANSPARENT USER OPERATION

Undulator field and dephasing variations have been performed using the two new operation points. The vertical beam size and the lifetime remain constant during variations, and in the 2 bunch mode of operation, transverse excitation is not seen by the users. However, some beam losses (several mA) have been observed during field variations. These are due to some vertical excitation of the beam and can be suppressed by increasing the vertical chromaticity. Tests have shown that power supplies and field control speed are not the origin.

Obviously, the transparent operation of OPHELIE is required in the two modes of operation of Super-ACO. The best situation would be to operate with the "excitation mode" in all cases. At the moment, the vertical excitation of the beam is not possible when 24 bunches are stored but developments are in progress. A solution could be to excite the 24 bunches on several turns instead of 1 turn. Then, the analog feedback system on tunes could have two functions : compensation of tune variations and excitation of the beam.

An other important point is to improve the speed required for switching the vertical undulator field from B_{max} to $-B_{max}$ in the AC mode. Presently, speed limitation is due to undulator power supplies (5 s for one switch) and to the control system (20 s).

6 CONCLUSION

The effects of OPHELIE on closed orbit, due to residual field integrals are now corrected with undulators coils for all fields and dephasing values. The beam position feedback cancels residual defaults. The small variations of tune and coupling, which were intolerable at the routine point, become negligible when using two new operation points. These two points lead to the same lifetime, or a better one, and allow the transparent operation of OPHELIE in the DC mode and the "slow" AC mode. Future developments concern the use of the "excitation mode" in the 24 bunch mode of operation, and the increase of the switching speed in the AC mode.

ACKNOWLEDGEMENTS

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