TRANSVERSE INSTABILITY STUDIES AT THE ALBA STORAGE RING

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Abstract

In phase I of the ALBA storage ring operation 3 NEG-coated aluminium chambers, 2 in-vacuum undulators and one wiggler chamber will be installed. Under particular consideration of the multilayer character of these chambers and the injection kickers the thresholds of the transverse mode coupled instability(TMCI) were calculated using MOSES[6]. The thresholds 17.5mA(vert.)/ 40.2mA(hor.) leave a rather large operative margin. The detrimental effect of the NEG-coating on the TMCI is relatively limited and on the resistive wall instability is even negligible. As well the thresholds of the head-tail instability were computed as function of the chromaticity. Also the incoherent tune shifts generated by the quadrupolar resistive wakes due to the flatness of the vacuum chambers were calculated. The computed results have been compared to first measurements of the storage ring commissioning.

INTRODUCTION

ALBA is the Catalan/Spanish synchrotron radiation facility in commissioning phase at Cerdanyola de Vallés near Barcelona. As a third generation light source it will produce high brilliant photon beams on 7 beamlines (extendable up to 33 beamlines) in phase I. It is expected to run in user operation by the beginning of 2012.

THE IMPEDANCE OF THE MULTI-LAYER CHAMBERS OF THE VACUUM SYSTEM

The vacuum system was largely described and its transverse impedance was computed already [1] apart from the resistive wall transverse (henceforth called RW) impedance of vacuum chambers with multi-layer character this article will now report on. We just recall that the standard vacuum chamber is made of stainless steel(SS) and is of octogonal shape with a 2a=28mm vertical and 2b=72 horizontal extension (fig. 1) and is connected at places where it is required with an ante-chamber. The only multi-layer chambers installed right from the beginning are the injection kickers consisting of a ceramic pipe with a vertical extension of 24mm and covered of Ti of only $0.4\mu m$. The low-gap chambers are given in table 1. The wiggler chamber is the only one of these which can be correctly described by the thick wall model[2]. They are gradually installed for the phase I. Different multi-layer RW models for the transverse impedance were studied, the models [3] and [4] were found to be the most adapted ones. According to [4] model the injection kickers are the only elements whose RW-impedance is significantly larger at the excitation frequencies $f = (1 - Q_\beta)f_0$ (Q_β transverse betatron tunes, f_0 revolution frequency) of the RW-instability than the RW-impedance of the thick wall model of Ti (fig. 2). However, the RW-impedance at the RW-instability excitation frequencies of an in-vacuum undulator if it is equipped with a Cu-sheet (covering the ID-magnets) whose thickness is larger than 50μ hardly changes compared to a thick(=several mm) wall of copper. (fig. 2). Furthermore, the influence of the NEG-layer of NEG-coated Al cham-

chamber type	layer [μm]	length L	half gap a[mm]
Ti covered injection kickers	0.4	3.12m	12
NEG-coated Al chamber	1.5	8.1m	4
in-vacuum undulator Cu/Ni	50/50	4m	min. 3
wiggler Cu-chamber	1000	2.5m	4.25

Table 1: low-gap and multi-layer chambers of phase I

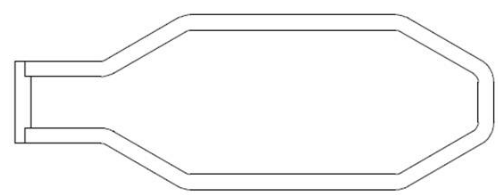

Figure 1: standard vacuum chamber made of stainless steel with its extension for connection with the antechamber

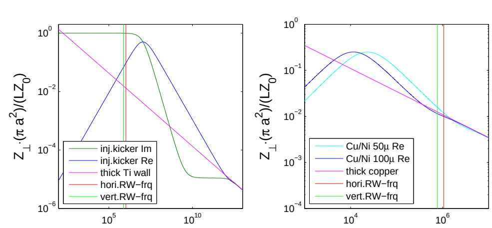

Figure 2: RW impedance of ceramic kicker chamber with 0.4μ Ti-cover(left), and RW impedance' real part of Cu/Ni-sheet for 50μ res. 100μ layer thickness, $Z_0 = 377\Omega$.

bers is only sensible for the impedance at much higher frequencies than at the RW-instability excitation frequencies (fig. 3). So only the injection kickers boosts the

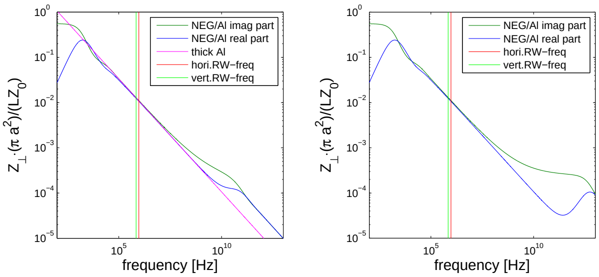

Figure 3: RW-impedance of 1.5μ-NEG-layer on Al chamber, left resistivity $\rho = 2.5\,10^7\Omega m$,right $\rho = 5.5\,10^4\Omega m$

RW-instability above the values expected from the thick wall model, but all mentioned chambers will nevertheless reduce the single bunch thresholds of the transverse mode coupled instability (TMCI) more than it would be for the thick wall model. Finally, the already reported RW instability thresholds[1] were updated considering correctly the multi-layer chambers of table 1 which yield 35.5mA(vert.)/139.7mA(horz.)[1] at zero chromaticity.

COMPUTATION OF THE TRANSVERSE MODE DETUNING

The geometrical as well as the RW-impedance of each element are computed, numerically with GdfidL [5] for the former and analytically for the latter. The calculation assumes the vacuum chamber geometry apart from exceptions like to be like a horizontal parallel plate which gives rise to a quadrupolar wake field component which only depends on the test particle position. That one has to be separated and treated apart from the usual dipolar wake field component (based on[7]). Following this decomposition the impedance values are weighted by the local β-function of the element. The spectra of the geometrical transverse dipolar impedance are determined. Multi-resonator models are fitted to both spectra. The found parameters are entered in MOSES. Moreover, in a extended MOSES version developed by the author which allows the specification of different RW descriptions, as well the RW parameters of the multi-layer and mono-layer chambers were entered. The transverse mode detuning and coupling was calculated at zero chromaticity(fig. 4) whose thresholds of 17.5mA(vertical) and 40.2mA (horizontal) are still rather large. Even if a NEG-coating with more resistivity (fig. 3 right) in the Al-chambers is considered, the effect on the detuning is hardly visible due to their low fraction in the ring (8.1m of 268m total circumference). Probably the surface structure of the coating would have to be included into the model to see larger tune shifts found at other synchrotrons[8]. Finally, the budget of quadrupolar impedance on both planes is processed in order to ob-

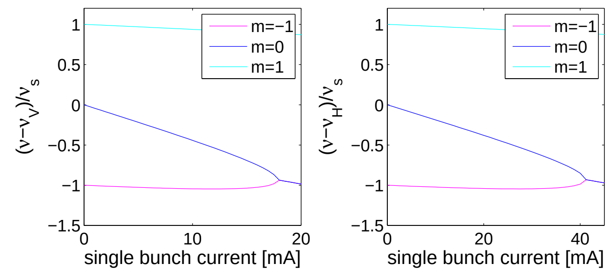

Figure 4: single bunch coherent mode detuning in phase I computed by MOSES, left vertical, right horizontal. The quadrupolar wake field is not taken into account.

tain the incoherent single bunch tune shifts. They were added to the transverse coherent mode detuning already computed. Whereas vertical coherent detuning and incoherent tune shift add up the horizontal coherent detuning is almost compensated by the incoherent horizontal tune shift which is of opposite sign (fig. 5). The thresholds thereby do not change. However, the bunch length dependency of the detuning has still been neglected.

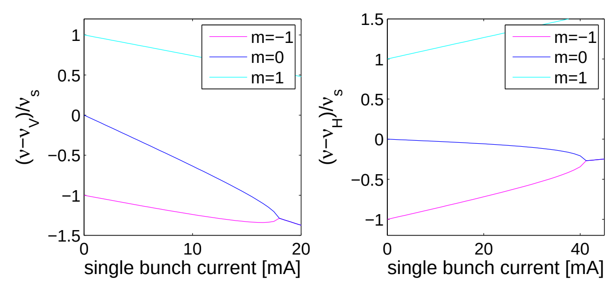

Figure 5: single bunch mode detuning in phase I computed by MOSES, left vertical, right horizontal. The quadrupolar wake field is taken into account.

HEAD-TAIL INSTABILITY

For non-zero chromaticity the growth rates of the modes $m = 0, 1, 2$ of the Head-Tail instability were calculated. The computation was carried out via analytical formulas developed for broadband resonator and resistive wall impedance though for the latter the formal result was expressed in a power series of the head-tail phase. However, in this case multi-layer chambers were considered as mono-layer. The thresholds (fig. 6) reach currents significantly smaller than the TMCI thresholds, but are larger than the bunch current in homogeneous filling.

MULTIBUNCH INCOHERENT TUNE SHIFT

Apart from the single bunch detuning, the resistive quadrupolar wake can add up along the whole bunch train since all the contributions from the particles only vary in

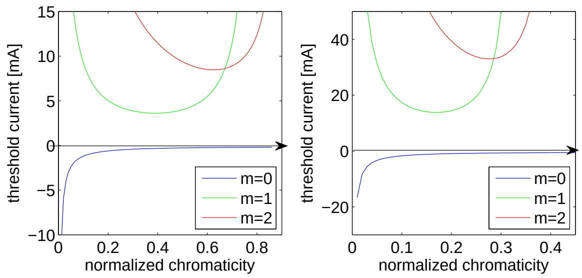

Figure 6: Head-Tail instability vertical (left) and horizontal (right)

strength, but maintain all the quadrupolar form along the chamber symmetry axis. In the calculation of the resulting tune shifts (fig. 7) the decay of the wake upon penetration into the chamber wall of finite thickness was taken into account according to [9].

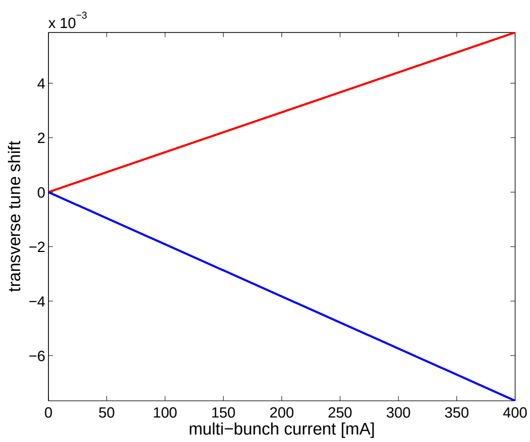

Figure 7: horizontal(red) and vertical(blue) multi-bunch incoherent tune shifts for the phase I

COMMISSIONING

The schedule did not allow many instability related measurements. Thresholds of beam cross section blow-up have been observed increasing up to lately $\sim$ 20mA(vert.)/50mA(horz.) in the corresponding plane which was cured by chromaticity increase. This behaviour is still not well understood since the vertical RW-instability is expected to behave rather insensitive to chromaticity and the onset of the horizontal one at much higher current [1]. As the observed excitation pattern (fig. 8) suggests, the blow-up was considered as mainly caused by ions. The RW instability thresholds were computed for homogeneous filling, so those only give an approximate prediction of the thresholds as a function of chromaticity in partial filling, in particular with the fillings used during commissioning.

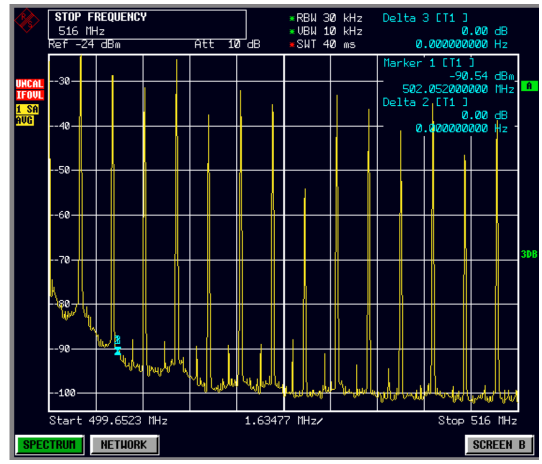

Figure 8: beam spectrum at 120mA shows a bump at higher revolution harmonics what is interpreted as a sign for the presence of ions

CONCLUSIONS

The ALBA storage ring has been characterised by all important impedance related collective effects as RW-instability, TMC-instability and Head-Tail instability. In phase I the occupation with low-gap chambers is still rather limited, so their effect is rather small as only middle long straight sections with rather low β-function values are occupied. ALBA will certainly benefit from this situation even with more low-gap chambers as long as the low-gap chambers for the 3 long straight sections will be chosen with care. The design of some elements can be still improved, in particular the injection and the feedback kickers which are in fact no low-gap. The effect of ions must be more thoroughly studied and understood. Also the validity of the parallel plate approximation of the vacuum chamber geometry on the single bunch detuning will be rechecked.

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