Potential-well distortion correction in a dual-harmonic RF system*

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Introduction

In a synchrotron the sum of all impedances over n (see equation (1)) is responsible for the losses leading to phase shift and bunch form deformation by potential-well distortion (PWD) both in single- and dual-harmonic RF systems [1]. These can be described by the Haissinski equation for Gaussian longitudinal ion distributions. The phase shift of an ion beam distribution excited by a single harmonic RF system with the frequency $f_1 = h_1 f_{rev}$ (f_{rev}: revolution frequency) can be corrected by giving the RF voltage a synchronous phase Φ_{S1} (see equation (2)) as during acceleration. The beam distribution deformation cannot be corrected. It increases because of the accelerating bucket form [2]. For correcting the ion beam distribution deformation a second higher harmonic of the RF voltage with the frequency $f_2 = h_2 f_{rev}$ is necessary. This second harmonic defines the modified bucket- and therefore the bunch form. By varying the relationship $\alpha = \frac{V_2}{V_1}$ (see equation (2)) of the voltage amplitudes given for the second- (V_2) and main harmonic (V_1) and by varying the phase difference between the second- and main harmonic $\Delta\Phi$ the bunch form deformations can be corrected over all quality factors Q [3] leading to an increasing loss of bucket height with intensity. As the relationship for the frequencies of the dual-harmonic RF system $\frac{h_2}{h_1} = 2$ has been used for these numerical investigations.

$$
\begin{aligned}
Z_{Sh,n||} &= \frac{R_{Sh,n}}{1 + iQ_n(\frac{\omega}{\omega_{RF,n}} - \frac{\omega_{RF,n}}{\omega})} \\
Z_{Sum||} &= \sum_n (Z_{Sh,n||} - iX_{SC,n})
\end{aligned}
\tag{1}
$$

Here n is the harmonic number of the shunt impedance $Z_{Sh||}$ and the space charge impedance X_{SC}. ω_{RF} is its resonance frequency.

$$
\begin{aligned}
V_{RF} =& V_1(sin\Phi - sin\Phi_{S1} - \alpha(sin(\Phi_{S2} + \\
& \frac{h_2}{h_1}(\Phi - \Phi_{S1}) + \Delta\Phi) - sin\Phi_{S2})) \\
& \Delta\Phi = \Phi_2 - \Phi_{S2} - \frac{h_2}{h_1}(\Phi - \Phi_S)
\end{aligned}
\tag{2}
$$

Simulation Results

With increasing intensity of U^{28+} the bunch form deformation and the phase shift caused by PWD is increasing too as can be seen in Figure (1). This leads to increasing requirements for its correction.

It has been found that with constant $\alpha = 0.5$ the necessary phase difference $\Delta\Phi$ to correct for PWD is higher than for addional variation of α between 0.5 and 1.0. For high quality factors Q (smallband impedances) the correcting α increases from 0.5 for low intensities up to 1.0 for high intensities. Only for broadband impedances with $Q \leq 0.1$ α stays constant, as can be seen in Figure (2), at the usually for dual-harmonic RF systems used value of $\alpha = 0.5$.

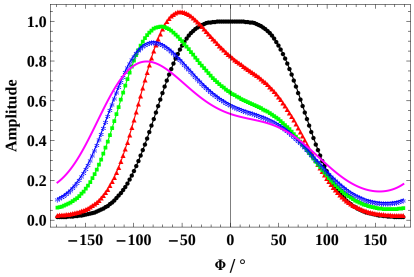

Figure 1: U^{28+} bunched beam distribution deformation and phase shift by PWD. The quality factor Q = 0.1. Black points: no PWD, red triangles: $N_b = 4 \cdot 10^{10}$, green squares: $N_b = 9 \cdot 10^{10}$, blue stars: $N_b = 13 \cdot 10^{10}$ and pink line: $N_b = 20 \cdot 10^{10}$ in SIS-100.

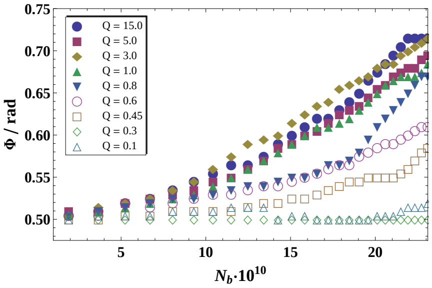

Figure 2: Development of $\alpha = \frac{V_2}{V_1}$ over the U^{28+} intensity with $X_{SC} \neq 0$.

References

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