Chromaticity measurements at SIS-18 using the head-tail modes*

R. Singh[1,2], *O. Boine-Frankenheim*[1,2], *P. Forck*[1], *P. Kowina*[1], *and T. Weiland*[2]
[1]GSI, Darmstadt, Germany; [2]TEMF, TU Darmstadt, Germany

Introduction

Chromaticity measurements in a synchrotron are routinely performed for understanding and optimization of the machine model. The typical measurement method involves a systematic beam momentum offset, and measurement of the corresponding tune for each offset. However, this requires several machine cycles and is a dedicated experiment in itself. Here we present a fast method based on temporal excitation of the transverse center of mass of head-tail modes [1] using frequency sweep. Chromaticity is extracted by fitting transverse offset of the resulting modes with an analytical expression.

Experiments and Results

The head-tail eigenmodes for an airbag bunch distribution in a barrier potential [1] with the eigenfunctions

$$\bar{x}_k(\phi) = \cos(k\pi\phi/\phi_b)\exp(-i\chi\phi/\phi_b) \tag{1}$$

where $\bar{x}_k$ is the local transverse bunch offset, $\chi = \xi\phi_b/\eta_0$ is the chromatic phase, ϕ_b is the full bunch length and η_0 is slip factor.

Experiments were conducted on the injection plateau of 11.4 MeV/u with a bunched N^{7+} ion beam with $5.0 \cdot 10^9$ particles. The frequency sweep excitation is used to excite each mode individually which allows to resolve the different head-tail modes both spectrally and temporally. The measured bunch offset of each excited mode is fitted to the analytical expression for the head-tail eigenfunction given in Eq. 1, with the chromaticity ξ as the fit parameter.

The fitting method is shown in Eq. 2; the head-tail eigenfunction from Eq. 1 is multiplied with the beam charge profile $\hat{Q}(t)$ and corrected for the beam offset (orbit distortion) Δx at the BPM where the signal is measured.

$$\begin{aligned} F(\phi,\xi,A) &= \Delta x \cdot \hat{Q}(t)\cdot(1 + A\cdot\bar{x}(\phi)) \\ E(\xi,A) &= (M(\phi) - F(\phi,\xi))^2 \end{aligned} \tag{2}$$

The fit error $E(\xi, A)$ is minimized as a function of independent variables, chromaticity ξ and head-tail mode amplitude A. Typical measured curves and the fitted eigenfunctions are shown in Fig. 1 for $k = 0, 1$ and 2. The measured chromaticity is independent of the order of head-tail eigenfunction. The fit error is used to determine the error bars on measured chromaticity. Figure 2 shows the measured vertical chromaticity for various set values of chromaticity using sextupolar settings. The measured tune values have a dependence on the value of chromaticity. It is important to note that this method works only with sweep excitation and requires high signal-to-noise ratio in time domain, which amounts to higher beam current or high excitation power. More details of the experimental set-up can be found in [2].

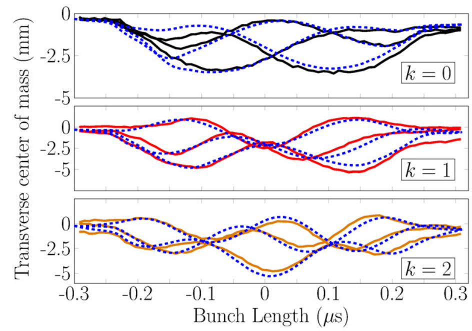

Figure 1: Analytical curves from Eq. 1 (dotted) are fitted to the local transverse offset for the $k = 0, 1$ and 2 modes with the chromaticity as the fit parameter.

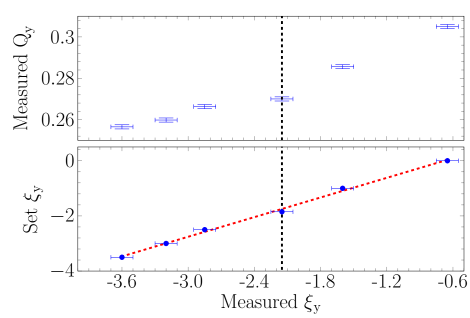

Figure 2: Vertical chromaticity measurement using the mentioned method. The black dashed line marks the measured natural vertical chromaticity of SIS-18.

References

[1] M. Blaskiewicz, Phys. Rev. ST Accel. Beams **1**, 044201 (1998)

[2] R. Singh et al., "Interpretation of transverse tune spectra in a heavy-ion synchrotron at high intensities", Accepted for publication in Phys. Rev. ST Accel. Beams, Feb. 2012.

* This work is supported by DITANET (novel DIagnostic Techniques for future particle Accelerators: A Marie Curie Initial Training NETwork),Project Number ITN-2008-215080