Transverse beam diagnostics at GSI SIS-18 Synchrotron*

R. Singh[1,2†]
GSI, Planckstrasse 1, Darmstadt, Germany ‡

Introduction

Betatron tune spectrum measurement is an integral part of the beam diagnosis for all circular accelerators and storage rings. Advanced efforts in pushing the beam intensity thresholds or beam cooling require high precision tune measurements as well as complete understanding of tune spectra in all operational intensities and energy regimes. GSI SIS-18 synchrotron is undergoing a major intensity upgrade to facilitate the upcoming FAIR facility, thus the topic of precise tune spectra measurements has gained major attention and is the focus of this doctoral work.

Principle of tune measurement

Passive tune measurements require high sensitivity(Schottky) pick-ups, low noise electronics and long averaging time to achieve reasonable signal-to-noise ratio. For fast tune measurements using standard pick-ups, external excitation is often applied for measurement of transverse beam signals as done at GSI SIS-18. Two parallel tune measurement systems were installed at SIS-18 i.e. Tune, Orbit and Position measurement system (TOPOS) and Baseband Q measurement system (BBQ). The TOPOS system is primarily a digital position measurement system which calculates tune from the calculated position [1]. Whereas, the BBQ system performs tune measurement based on the concept of diode based bunch envelope detection concieved at CERN [2], and provides higher measurement sensitivity. Several excitation types were tested in the procedure of commisioning the tune measurement system to minimize beam disturbance for normal operations.

A. TOPOS

The signals from each of the 12 shoebox type BPMs at SIS-18 pass through a high dynamic range and broadband amplifier chain(90 dB,100 Mhz) from the tunnel to the electronics room, where the signals are digitized using fast 14-bit ADCs at 125 MSa/s. Bunch-by-bunch position is calculated from these signals using FPGAs in real time, and displayed in the control room. Tune is measured by calculating FFT of the position data. Bunch-by-bunch position resolution is ≈1 mm. Hence, TOPOS is a versatile system which provides accurate bunch-by-bunch position, tune, chromaticity, longitudinal beam profile as well as beam intensity information.

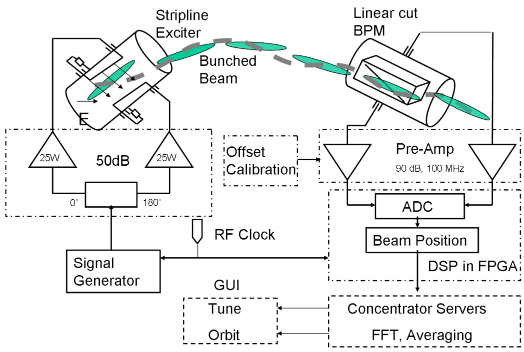

FIG. 1: TOPOS: Tune, Position and Orbit measurement system

B. BBQ

The BBQ front end system is divided into two distinct parts; a diode based envelope detectors and an analog signal processing chain consisting of input differential amplifier and

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†Electronic address: `r.singh@gsi.de`
‡Also at Technische Universität Darmstadt, Schlossgartenstr.8, 64289 Darmstadt, Germany

a variable gain signal chain of 1 MHz bandwidth. The simple schematic of BBQ system configuration at SIS-18 is shown in Fig. 2 and the detailed principle of operation can be found in ref. [2].

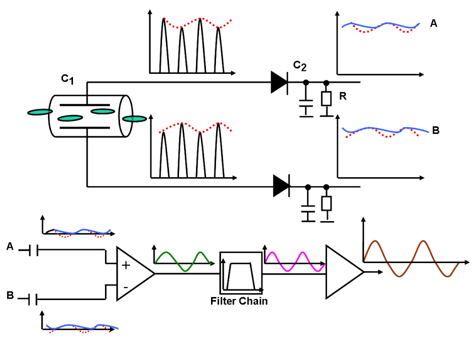

FIG. 2: BBQ: Baseband Q measurement system. Diode detectors (top) and signal chain (bottom).

C. Comparison of TOPOS and BBQ

The sensitivity of BBQ is observed to be ≈10-15 dB higher than TOPOS under present configuration. The main reason for the difference is the relative bandwidth of the two systems and their tune detection principles. In BBQ, the bunch envelope signal is detected immediately after the BPM plates using diodes, while in TOPOS position calculation is done after passing the whole bunch signal through a wide bandwidth amplifier chain. Even though the bunches are integrated to calculate position in TOPOS which serve as a low pass filter, the net signal-to-noise ratio is still below BBQ.

D. Beam Excitation Methods

The electronics used for beam excitation consist of a signal generator connected to two 25 W amplifiers which feed power to 50Ω terminated stripline exciters as shown in Fig.1. Excitation types such as band limited noise and frequency sweep are utilized at various power levels to induce coherent beam oscillations.

1. Band limited noise:

Band limited noise is a traditionally used beam excitation system for slow extraction at GSI SIS-18. There are two main advantages; first it is an easily tunable excitation source available during the whole acceleration ramp. The band limited nature of the noise results in an efficient excitation of the beam in comparision to white noise. The main drawback is the difficulty in correlation of the resultant tune spectrum with the excitation signal.

2. Frequency sweep:

Frequency sweep (chirp) using a network analyzer for BTF measurements is an established method primarily for beam stability analysis [3]. However, it is not suitable for tune measurements during the acceleration due to change in tune frequency. This method offer advantages compared to the previous method for careful interpretation of tune spectrum in storage mode, e.g., injection plateau or extraction flat top.

High Intensity Effects

Several experiments were performed to study the high intensity effects on tune spectra using the afore-mentioned systems and are presented in another contribution in this symposium [4]. The measurements allowed direct measurement of coherent and incoherent tune shifts based on frequency shift of head tail modes for the first time [5].

Acknowledgments

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