BUNCH SYNCHRONOUS MONITORING OF BEAM POSITION AT SIS

M. Fradj, M. Hartung, P. Moritz, A. Peters, P. Strehl, H. Vilhjalmsson
GSI, Gesellschaft für Schwerionenforschung mbH
Postfach 11 05 52, D-6100 Darmstadt, FRG

The advantages of bunch synchronous monitoring will be demonstrated by examples of Q-measurements, closed orbit determination and measurement of chromaticity at SIS. Using a phase locked timing generator which controls the position measurements and triggering of Q-kickers, bunch related kicker timing is possible even at the highest energies of SIS. By synchronous observation of the betatron phaseshifts at two position pick-ups the integer Q-value can be determined, too.

Introduction

When designing a beam position monitoring system the following main aspects have to be considered:

- Type of signal extraction from the beam which can be of the inductive, capacitive or resistive type.
- Determination of the geometrical shape of the electrodes including the selection of appropriate materials.
- Decision on low or high impedance input signal amplification.
- Optimization of the dynamic range by taking into account the machine parameters as well as the various ion species which have to be accelerated.
- Establishing of measuring sequences which have to be performed.
- Integration of the position measuring electronics into the control system.

The choices taken for the Beam Position Monitoring (BPM) system of SIS at GSI will be shortly discriped and some examples of measurements will be given in the following.

System description

The shape of the capacitive pick up system for the SIS and the main electrical specifications have already been given in [1]. The SIS BPM-system as well as the ESR BPM-system are based on high impedance input signal processing for the following reasons:

- For the high impedance system the signal extracted from the beam can be larger up to a factor 5-15 in comparison to the low impedance system. This depends of course very much on the ratio of plate impedance to the amplifier input impedance.
- For SIS the dynamics of the input signal during acceleration and due to bunch compression is about a factor of 3 smaller compared to a low impedance system. Fig. 1 gives the expected signal strengths and shows the dynamic ranges chosen for the BPM-system. Fig. 2 shows the analogue part of the electronics.
- Due to the low cut off frequency (≅ 3 kHz) of the high impedance system the bunches are shown in their original shape which makes integration much easier.

Theoretically the sensitivity of a rectangular pick up system is given by $S = dx/Ks$, where dx is the beam displacement and Ks is half of the aperture. For the horizontal system of SIS with an aperture of 200 mm Ks has been determined by test measurements to be 174 mm. This could be improved by introducing a narrow grounded strip between the measuring plates reducing their coupling. Based on the experience with the SIS BPM-system the ESR BPM-system has been modified in this way which leads to Ks = 174 for an aperture of 300 mm.

In a very early stage of design it was decided to use single bunches for the evaluation of beam positions, measurement of Q-value, closed orbit determination. In order to allow bunch synchronous measurements the timing generator which is the heart of the BPM-system [2] has been integrated into the digital electronics [3] and the control system as shown in Fig. 3. The programmable hardware of the timing generator creates 160 steps for one revolution of the beam. Therefore the programming and distribution of gate or trigger pulses can be done with a resolution of 2.25 degrees around the ring. Since the pulses are delayed taking into account the programmed geometric position as well as the change of velocity of the praticles during one cycle within ± 5 ns (± 10 ns at injection energy) this corresponds to a transformation of geometric locations around the ring into a time scale with the period of 1 cycle.

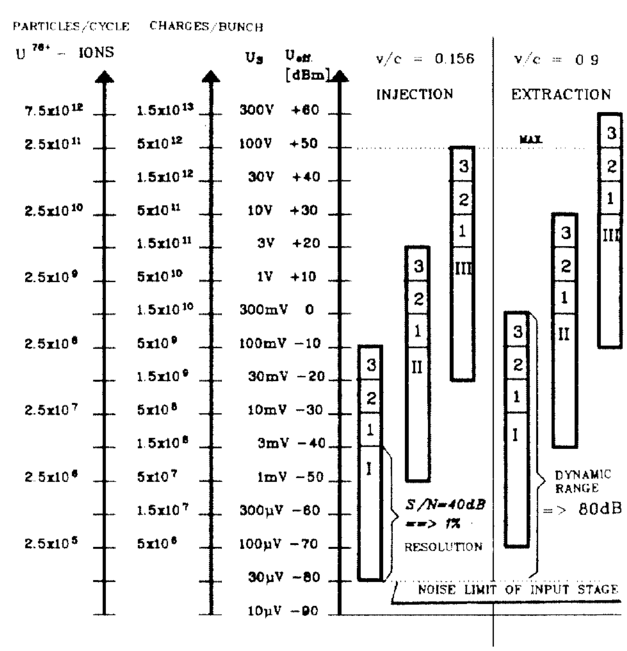

Fig. 1: Calculated signal strengths and dynamic ranges for the SIS BPM-system.
The expected signals are given for injection energy which is the worse case.

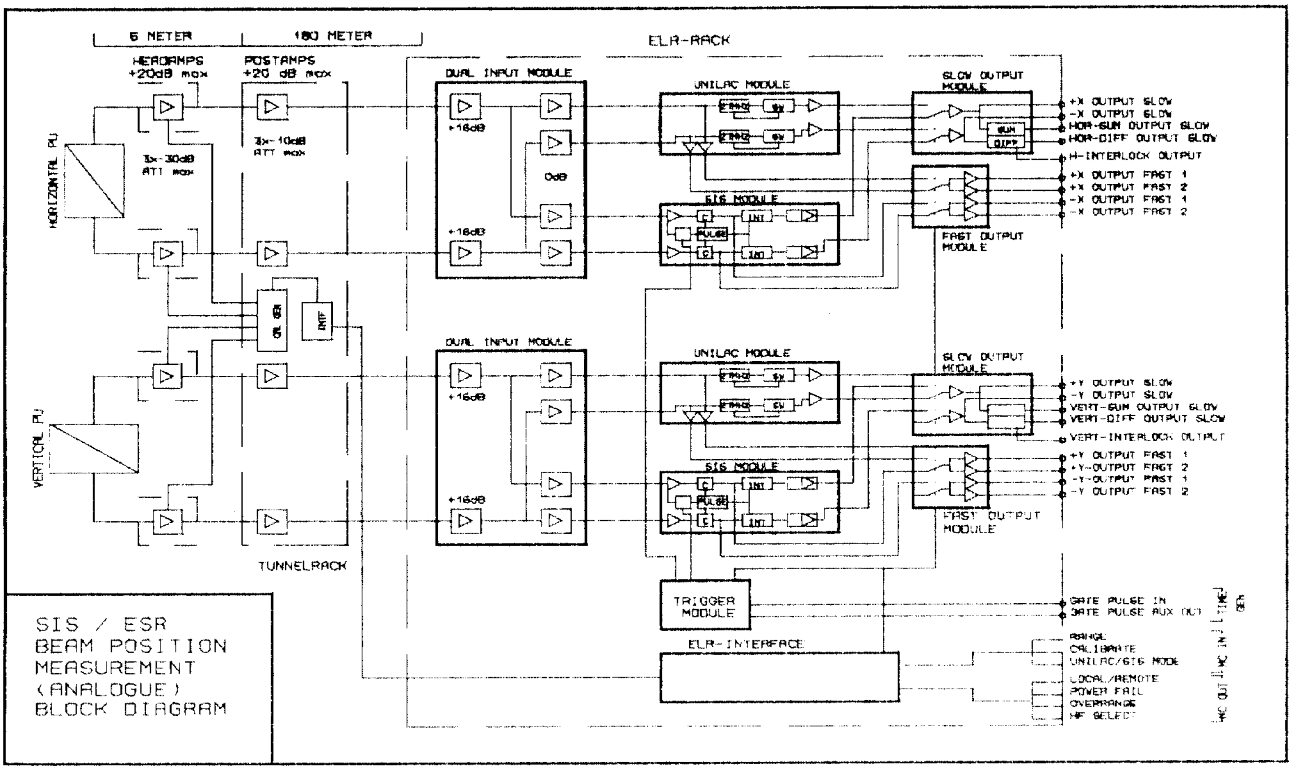

Fig. 2: Block diagram of the analogue electronics.

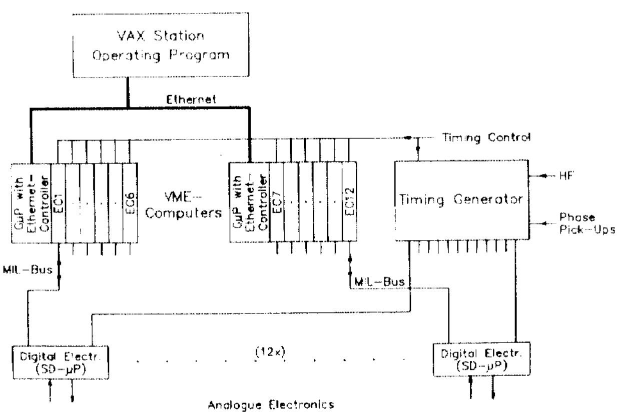

Fig. 3: Digital part of the BPM-system.

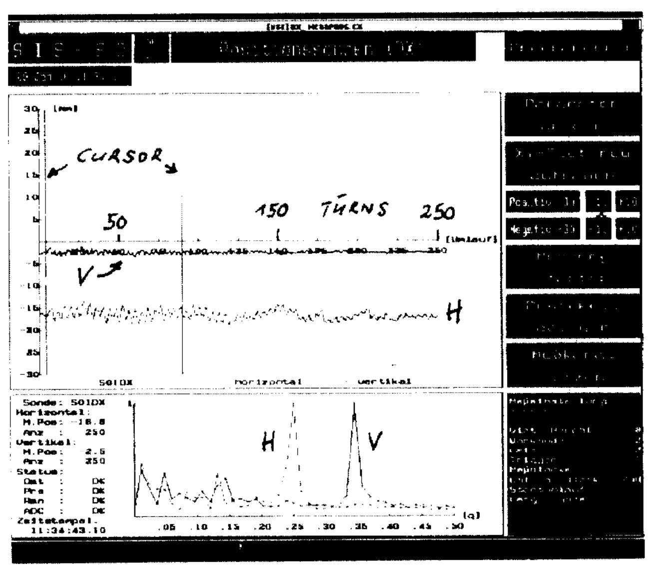

Fig. 4: Computer plot of a Q-measurement.

Measurement examples

Fig. 4 shows a computer plot of a Q-measurement using only one position pick up. Although the displayed data correspond to 250 turns the two vertical lines show that only about 90 turns can be used for the determination of q (= non integer part of Q) by a fast fourier transformation. This depends on the strength of the Q-kick and the damping of the oscillation. The values for q are given on the q-scale below the position data. Taking only data from one pick up the accuracy of q is about 1/(4N), with N = Number of turns used for the calculation.

Fig. 5 shows a series of Q-measurements on the ramp taking advantage of the function mode implemented in the microprocessor of the digital electronics as described in [1-3]. In this mode N-block data with 1024/N data in each block can be taken at any time during one cycle.

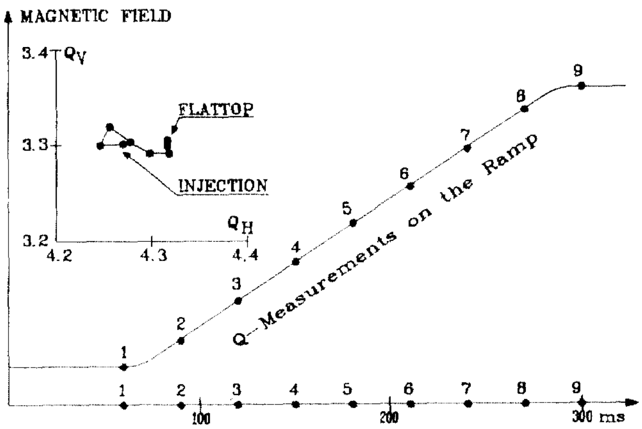

Fig. 5: Q-measurement during acceleration.

A closed orbit measurement for an Ar^{40}-beam with 200 MeV/u is shown in fig. 6. Two different methods have been used for the determination of the chromaticity: Fig. 7 gives Q-values measured with the BPM-system in comparison to Schottky scan data displayed against the offset from the mean radial position of the beam. The calculation of the chromaticity from this data is given in [4].

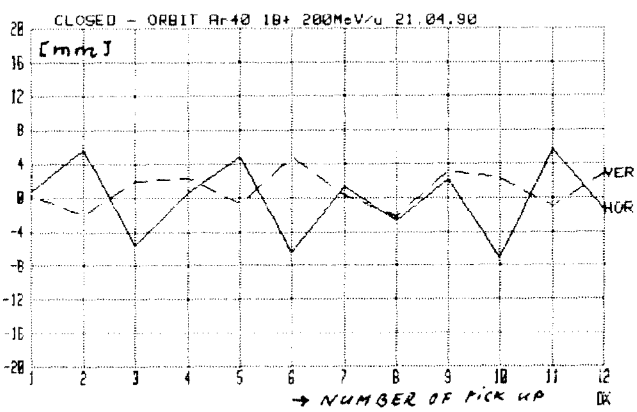

Fig. 6: Closed orbit determination for an Ar^{40}-beam with 200 MeV/u.

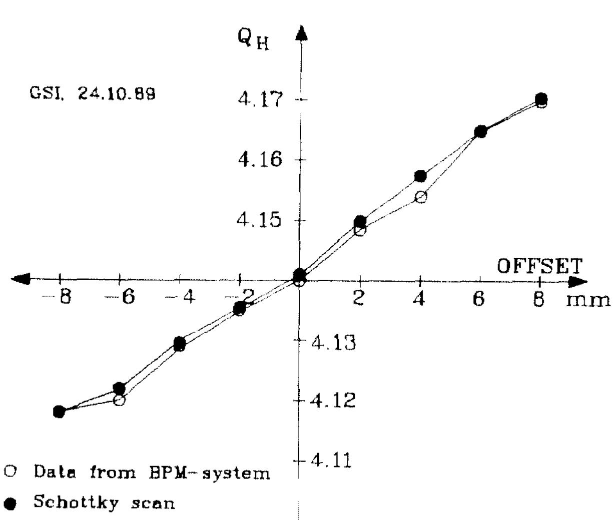

Fig. 7: Measurement of chromaticity.

Since betatron oscillations can be monitored synchronously at all the position pick ups the integer of Q-value can be determined by measuring the phaseshift between two or more pick ups. For the phaseshift of the slow oscillation at one pick up the relation:

$$\Delta\phi_1 = k_1 \cdot \Delta P \cdot 2\pi R$$

holds, where $k_1 = 2\pi/\lambda_p$ is the wave number of the slow oscillation with $\lambda_p = P \cdot 2\pi R$ as the wavelength. Here P is the number of turns for one period and R is the radius of the SIS.

On the other hand the betatron phaseshift between two pick ups within a distance of Δs is given by:

$$\Delta\phi_2 = 2\pi - k_2 \cdot \Delta s = 2\pi - Q/R \cdot \Delta s$$

where $k_2 = 2\pi/\lambda_\beta$, is the wave number of the fast betatron oscillation which has a wavelength of $\lambda_\beta = 2\pi R/Q$. Combining the two equations and taking $\Delta s = 2\pi R/6$ which corresponds to the sequence of odd numbered pick ups yields:

$$Q = 6(1 - \Delta P/P).$$

The results of a measurement are shown in fig. 8. From the values given in the figure Q turns out to be 3 for the integer part in agreement with the calculated tune of the machine.

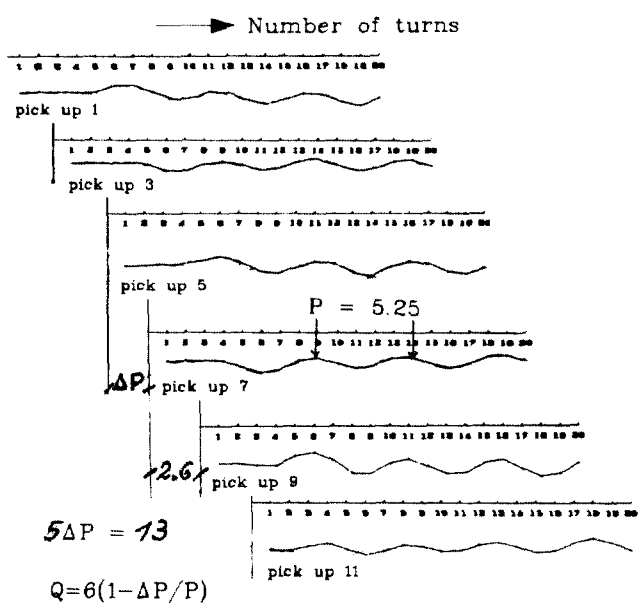

Fig. 8: Determination of the integer Q-value.

References:

[1] Strehl, P., Vilhjalmsson, H., "The SIS-Beam Diagnostic system", EPAC, Rome, June 1988, pp. 1413-1415.

[2] Fradj, M., Moritz, P., Strehl, P., Vilhjalmsson, H., "Timing of the SIS-Position Measuring System", GSI-Report 88-1 (1987), p. 375.

[3] Fradj, M., Hartung, M., Losert, W., Strehl, P., "Digital Signal Processing for the SIS-Position Measuring System", GSI-report 89-1 (1989), p. 389.

[4] Franczak, B., for the SIS-Project-Group, "Report on the First Year of SIS operation", presented at EPAC, Nice, France, June 12-16.