# THE SIS-BEAM DIAGNOSTIC SYSTEM

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A survey of the beam diagnostic elements for the new heavy ion synchrotron SIS at GSI is given. The design parameters are discussed with special reference to the electronics, data processing and provided measurement procedures.

## Introduction

For the beam diagnostics the relevant SIS parameters are:

| | |
|---|---|
| Revolution time | : 4.6 µs > $T_u$ > 765 ns |
| $\beta$ = v/c | : 0,156 < $\beta$ < 0,9 |
| Circulating bunches | : 4 |
| Bunchlength (FWHM) | : 420 ns > $\Delta t$ > 30 ns |
| Q-values | : $Q_H$ = 4.2; $Q_V$ = 3.4 |
| Ramping time | : 100 ms < $T_r$ < 400 ms |
| Number of injected turns | : 1 < N < 50 |
| Slow extraction time | : 1 ms < $t_{exs}$ < 100 ms |
| Vacuum | : < $10^{-11}$ Torr |

## First Turn Diagnosis

At the beginning of SIS-operation the beam will be stopped after one turn by a Faraday cup. In front of the cup a profile grid and a capacitive pick-up are provided for the measurement of further beam parameters.
The Faraday cup and the grid have an aperture of 190 x 70 mm and are driven by a compressed air actuator. The cup takes a maximum beam power of 10 kW with a maximum power density of 10 kW/cm$^2$.
The grid has 63 vertically aligned wires with a spacing between 2-4 mm to measure the horizontal beam profile and 31 to measure the vertical one. There are clearing wires in front and behind the grid. The signal processing electronics are described in Ref.1.
The capacitive pick-up has been designed taking the well known parameters of the Unilac beam in the longitudinal phase space into account. Due to the "drift space" of more than 300 m (transfer channel + SIS-ring) the geometrical bunch length will be in the order of 12 - 15 cm.
The pick-up itself consists of 4 plain plates each directly attached to a 50 Ohm vacuum feedthrough. With the pick-up, monitoring of the SIS bunch shape can be performed. Rough beam position measurement is possible in principle.

## Diagnostics for SIS-Operation

There are 12 beam position monitors (BPM) within the SIS-ring. In Fig. 1 one pick-up is shown. The electrodes are copper plated ceramic plates mounted in an aluminium frame. Horizontal and vertical beam position is measured by two separate electrode pairs with the dimensions of 200 x 70 x 120 mm each. Within a rectangular aperture of ± 50 x 20 mm an accuracy of better than 0.5 mm and a resolution of about 0.2 mm is required. Therefore a computer controlled test system for BPMs was developed[2] which has a mechanical accuracy of better than ± 0.05 mm. Taking advantage of the computer control linearity, resolution, reproducibility, scale factor and offset-correction factor of each BPM is measured[3] very precisely before installation into the SIS-ring.
The analog electronics for the SIS BPMs consist of three units:

- four headamplifiers mounted directly on the pick-up,
- signal postamplifiers, a calibration generator and interfacing boards in the SIS-tunnel,
- signal conditioners to give the integral of the horizontal and vertical sum and difference signals.

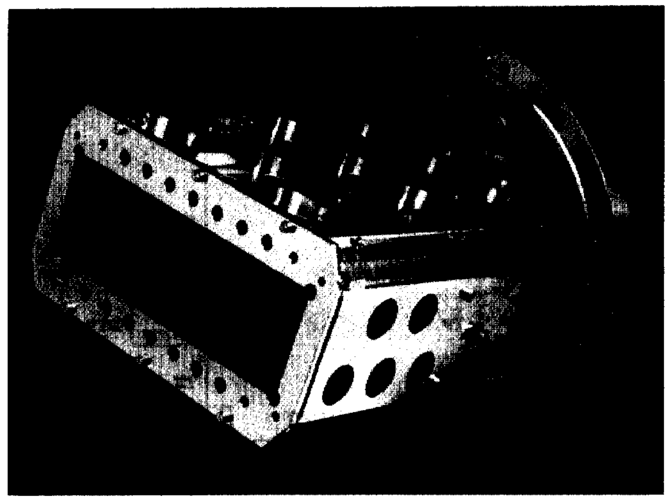

Fig. 1: Beam Position Monitor (BPM) for SIS

The headamplifiers as shown in Fig. 2 are the most critical parts of the signal processing system. They have the following specifications:

| | |
|---|---|
| PU input impedance : | 1 Megohm , 10 pF parallel capacitance constant impedance for all attenuation settings |
| calibration input : | 75 ohm |
| output impedance : | 75 ohm |
| input noise voltage : | 5 nV/Hz$^{1/2}$ (equ. 20 microvolts RMS /20MHz) |
| max. input voltage : | with max gain 400mV$_{pp}$, with max. att. 600 V$_{pp}$ |
| input protection : | +/- 20 mA continuous , 200 mA peak |
| gain: | +20 dB |
| bandwith : | (10 kHz - 50 MHz) +/- 0.5 dB, (-100 MHz) -3dB |
| risetime : | 3.5 nS |
| group delay : | 7 nS |
| attenuations : | -30dB/-60dB, remote-controlled |
| output compression level : | +20dBm / -1dB gain compression |
| dynamic range : | 80 dB / range , 140 dB total range |
| power supply : | +15 V/100mA, -15 V/100mA, +5 V /max. 100mA with internal stabilization |
| connectors : | N-type 50 ohm /in, 75ohm /cal in, out |
| dimensions : | 150×64×34 mm, aluminium case |
| matching : | adjustable to match a pair of amplifiers to within +/- 0.02 dB 10kHz-50 MHz |

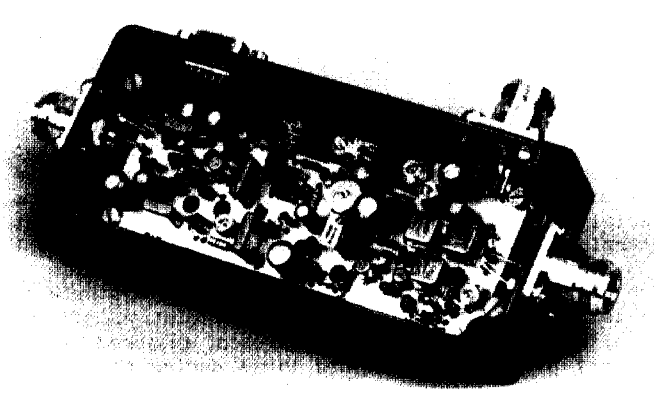

Fig. 2: Headamplifier

Since it has been decided to monitor one or two bunches per turn, gate pulse generation, synchronisation and timing for special measurements like determination of Q-value is performed by a timing generator which will be the heart of the BPM-system as shown in Fig. 3.
The distributed gate pulses have to be delayed taking into account the geometric position of each pick-up electrode in the ring and the change of velocity of the particles during one cycle. Furthermore the length of the gate pulses has to be adapted to the dynamic changing of bunch length, too.

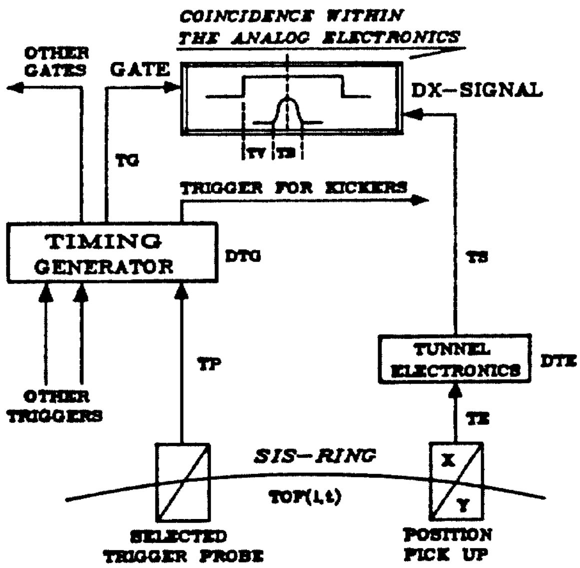


Fig. 3: Arrangement around the Timing Generator

In Fig. 3 the following relationes are considered:

- TOF (i,t) is the time of flight of the particles from the trigger probe to the selected pick-up with number i;
- TE,TS the time for the transmission of the DX-signal through the cables;
- TP the total transmission time of the trigger signal from the pick-up to the timing generator;
- TG is the transmission time for the gate pulse from the timing generator to the point of coincidence;
- DTG,DTE are delay times within the electronics;
- TB (t) is the dynamically changing bunch length;
- TV (t) the advance of the gate pulse, also changing during ramping.

Therefore, at the point of coincidence for analog signal and gate pulse, the relation holds:

$$TVZ(i,t) = TOF(i,t)+TE+DTE+TS-TP-TG-DTG-TB(t)/2-TV(t)+TU(t),$$

where TVZ(i,t) is the required delay time.
The gate pulse generation is realized using a fast RAM-table, whereby addressing is performed by an rf-related clock frequency. A more detailed description of the timing generator is given in Ref.4.
Sum and difference signals of each BPM-station are digitized using a fast ADC with a sampling rate of 2.5 MHz. Digitized data are stored into a 4 kRAM under hardware control, which means 1 kRAM for sum and difference signals of each plate system. In principle two different measurement modi are possible, the function mode and the normal mode. The function mode performs special algorithms like Q-measurement, closed orbit determination, trouble shooting etc. In this mode the 1 kRAM can be divided into N blocks with 1024/N data in each block. Since the data acquisition is always related and synchronized to the revolution of one bunch, the stored data blocks represent measured values for very precisely determined times during the cycle.

In the normal mode one measurement per revolution is performed during the whole SIS-cycle and the RAM will be filled several times. An eventual alarm signal stops the system in such a way that a "post mortem diagnosis" will be possible. Fig. 4 shows the systems interconnections.

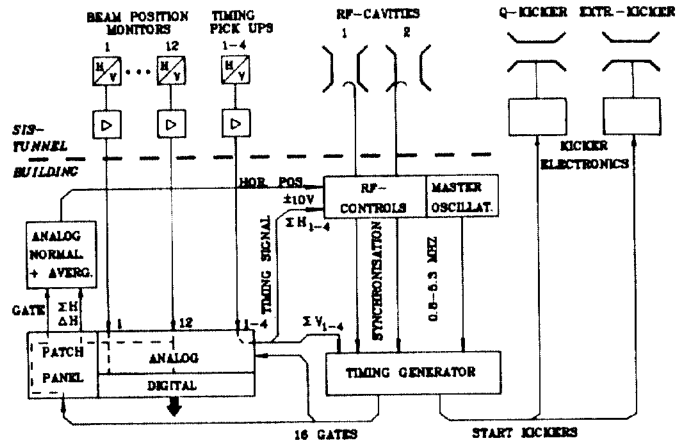


Fig. 4: Beam Position Monitoring and Systems Interconnections

A passive pulse current transformer DT-S is provided to measure the injection efficiency and to observe the current steps during multiturn injection. The main specifications of the DT-S are:

| | |
|---|---|
| Aperture | : 200 mm |
| Insulation gap | : $Al_2O_3$, metalized with high impedance |
| Vacuum chamber | : length : 600 mm<br>maximum diameter : 400 mm |
| Shielding | : double electromagnetic shield |
| Baking Temperature | : 300° C |
| Cooling | : thermal screen, water cooled |
| Ranges | : 8, 100 µA ... 300 mA, 1-3-10 scaling |
| Rise time | : ~ 0,5 µs, all ranges |
| Upper frequency limit | : ~ 750 kHz, all ranges |
| Pulse droop 15 µs | : < 1/0.3/0.1 % depending on range |
| Lower frequency limit | : 500/150/50 Hz, depending on range |
| Resolution (S/N=1) | : ~ 5 $\mu A_{pp}$ for 100 µA-range<br>> 30 $\mu A_{pp}$ for other ranges |
| Gain accuracy | : < 1 % |
| Digitizing | : 11 Bits, 1.25 MHz sampling rate, fixed |
| Storage | : 2 kWords |
| Analog output | : 10 V FSR differential, video output. |

Fig. 5 shows a block diagram of the analog electronics.

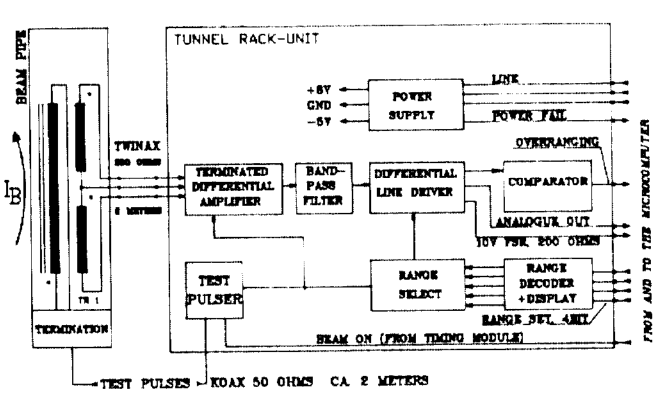


Fig. 5: Passsive Beam Current Transformer, Simplified Electronic Circuit Diagram

A second transformer system for monitoring during acceleration and on flat top is installed in the same housing. To cover the whole range of response from DC up to about 20 kHz, a 2-core magnetic modulator is combined with a L/R-integrator type of transformer to obtain DC-stable operation. Fig. 6 shows a simplified electronic circuit diagram of the combined system. The main electrical specifications are:

| | |
|---|---|
| Ranges | : 8, 300 µA ... 1 A, 1-3-10 scaling |
| Rise time | : 15-20 µs, all ranges |
| Upper frequency limit | : ~ 20 kHz, all ranges |
| Lower frequency limit | : DC |
| Resolution (S/N=1) | : ~ 0.5 $\mu_{pp}$, BW = 1 Hz, 300 µA-range<br>~ 2-3 $\mu A_{pp}$, full BW<br>< 1 % for all other ranges |
| Zero drift vs time | : ~ 1 µA/10 min after 72 h warm up |
| Zero drift vs temperature | : < 10 µA/°C, estimated |
| Absolute gain error | : < 0.1 % zero error at DC |
| Linearity error | : < 0.1 % zero error, estimated |
| Modulator ripple | : < 30 µA rms, without ripple suppressor loop, reduction expected |

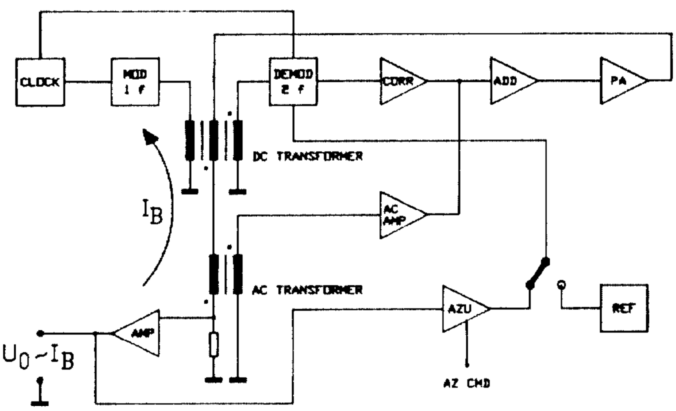


Fig. 6: Active Beam Current Transformer, Simplified Electronic Circuit Diagram

Four capacitive pick-ups are provided for rf-phase control in a closed loop system. The same electrode system as used for the BPMs will be installed for this purpose. The main electrical specifications are:

| | |
|---|---|
| Accuracy | : ± 2° from 0.8 - 6 MHz |
| Bandwidth | : 0.5 - 10 MHz |
| Analog output | : 2 $V_{pp}$ rf-signal |

In section 3 of the SIS-ring a scraper system with the following features will be installed:

| | |
|---|---|
| Drive | : stepping motor, feedthrough |
| Stroke | : 80 mm |
| Material of jaws | : Cu |
| Dimensions of jaws | : 65 x 220 mm (V)<br>65 x 100 mm (H) |
| Thickness | : 265 mm |
| Maximum power loss | : 10 kW, watercooled |

Six beam loss monitors (BLM) detecting neutrons can be placed around the ring. Liquid scintillators of the type NE 224 have been selected. Fig. 7 shows a simplified circuit diagram of the BLMs.

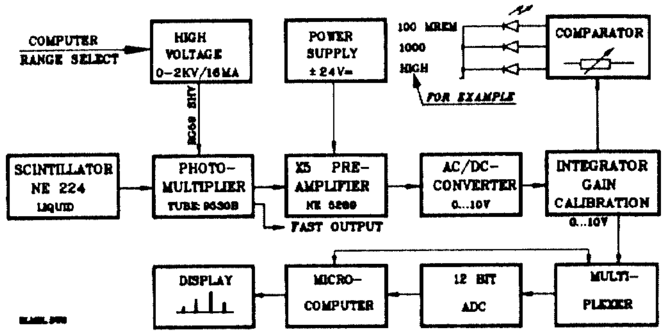


Fig. 7: Beam Loss Monitor (BLM), Block Diagram

Beside a signal evaluation by the microcomputer, a set of comparators will give the operator a rough information about the radiation level and therefore about the location of beam loss.

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