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THE NEW BEAM POSITION MEASUREMENT SYSTEM FOR THE DESY SYNCHROTRON

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Summary

In the DESY synchrotron a new beam position measurement system has been installed to provide a fast, reliable and precise determination of the closed orbit. The Q-value (6.2 ... 6.3) of the synchrotron leads to a minimum of 25 stations to satisfy that requirement. Due to lack of available space in the straight sections, very short pick-up electrodes of permalloy-taped ring cores were chosen for the technical solution. The low average beam current in the synchrotron operating in the single bunch mode, requires a very sensitive system. This led to a narrow-band resonant device tuned to the revolution frequency of 947 ± 60 kHz followed by a "slow scan"-processor. For initial operation the output data are transferred to a printer. Later on a link to a computer will be established to provide a fast display of the measured closed orbit, and data for a process computer orbit correction program. First measurements and results with the new system are reported.

Introduction

The synchrotron central building housing the synchrotron central room, provided no space for the controls of DORIS (1974) and PETRA (1978). In order to operate all machines with only one shift crew, a remote control for the synchrotron is now being installed in the DORIS/PETRA control room. These plans in addition to lack of staff and machine time for the regular survey of the synchrotron magnets, motivated the design of a new closed orbit measurement system for DESY replacing the now 13 years old beam position monitors of the synchrotron. Aside from the general objectives for beam position measurement devices like high signal sensitivity, and high accuracy (short and long time), particular problems had to be solved:

- low average/high peak beam current
- mechanical problems in connection with precise positioning of the monitors with respect to the vibrating 50 Hz synchrotron magnets
- insensitivity against electromagnetic interference from an environment with high electromagnetic background over a wide frequency range.

The main beam signal parameters of DESY are the following:

Orbittime/Revolutionfrequency	1.06 µs/947 KHz
RF-/harmonic number	499.666 MHz/528
Q_x, Q_z	≈ 6,23/6,3
Injection Energy linac1(e^-)	55 MeV
linac2/PIA(e^+)	>400 MeV
Ejection Energy	2 ... 7 GeV
Actual currents	
multibunch (50%)	e^-:4mA≙$13.3\cdot10^9$ part.
singlebunch	e^-/e^+:$2\cdot10^9$particles
Injectionrates	50 Hz/n n=1...16
bunchlength	2...3 cm ≙ 200 ps

Technical Concept

For the determinmation of the closed orbit 4 monitors per betatron wavelength are required. According to a Q of about 6.3 this leads to a minimum number of 25 stations equally distributed with respect to betatron phase advance around the synchrotron. With the monitor output signal given by the difference of two faced pick up signals (fig. 2), the displacement of the center of charge with respect to the electromagnetic center of the monitor is determined by

$$V_x = K \cdot i_b \times \Delta_x \quad \text{for the horizontal}$$
and
$$V_z = K \cdot i_b \times \Delta_z \quad \text{for the vertical direction}$$

For analysis of the monitor output signals, we choose a "slow scan" processor in order to keep the cost low. Only one rf-cable per monitor transmits the displacement-signals to the control room. There, an electronically controlled switch (or "multiplexer") sequentially connects these signals to the one-channel processor mentioned above. Since the orbit displacement depends on the energy, only one sample per monitor and acceleration-cycle is available for a given instantaneous energy. Hence for scanning both the horizontal and vertical displacement signals from 25 monitors, (25+25)x20 msec = 1 sec are required. Since the displacement signals $V_{x,z}$ are proportional to both the displacement and the intensity, a reference signal V_r from a current-transformer-type intensity monitor is necessary for normalizing:

$$V_r = K_r \cdot i_b \;;\; i_b = \frac{V_r}{K_r} \qquad \Delta_{x,z} = \frac{V_{x,z}}{K \cdot i_b} = \frac{V_{x,z}}{K \cdot \frac{V_r}{K_r}} = K_\Delta \frac{V_{x,z}}{V_r}$$

For the time being, the central processor unit consists of a microprocessor with a control- and monitor-board (fig. 1) the functions of which later on will be handled by the central control room process computers. The processor executes the above mentioned normalization and provides the individual time delays of the clock pulses necessary to determine the sign of the displacement monitor signals (which is the narrow band monitor step response to the nanosecond pulse signal of the bunch when passing through the monitor). The output data are binary coded and directly available for displays or printers.

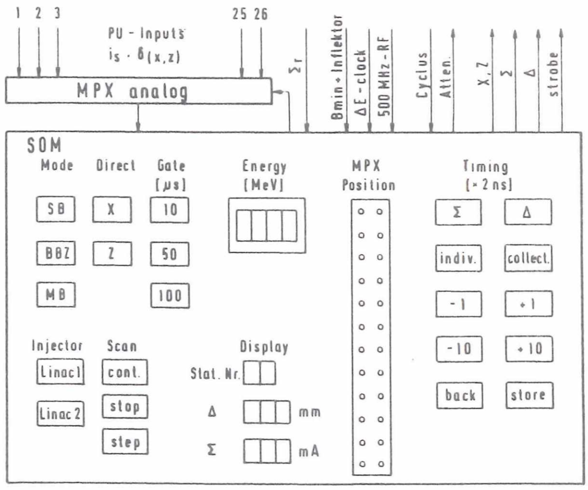

Fig.1 Control- and processorboard (schematic)

Choice of pickupsensors

In principle the broad frequency spectrum of single-bunch fields in DESY would allow the application of different kinds of monitors (2). The use of the high frequency end of the spectrum is excluded because of field distortions caused by discontinuities of the DESY metal- and ceramic vacuum chambers. The extreme low frequency end of the spectrum, on the other side, is infavorable because of electromagnet interference with the "noise" from pulsed power supplies and the 50 Hz spectrum of the magnets. Furthermore, the monitor had to be small because of the limited space in the azimutal direction adjacent to the synchrotron magnets. As a compromise, we chose a pick up system tuned to the revolutionfrequency of 947 KHz and a bandwidth of ±60KHz. With this small bandwidth, we gain in sensitivity, but we loose dynamic range (2). A taped permalloy ringcore carrying partial coils of 27 turns each is used as sensor (fig. 2). With this design, we have the following advantages.

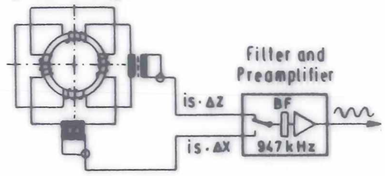

Fig.2 Inputconfiguration of the pickup

1. For materials with $\mu_r \gg 1$ we gain a factor 2 in sensitivity because the expression for beam displacements is defined (1) as

$$V_{\Delta x,z} = \pi \cdot \frac{\mu_r}{\mu_r + 1} \cdot i_b \cdot f(x,z)$$

2. Permalloy material is not only cheaper than ferrite but it has a circular magnetic structure (4) so that saturation effects from external strayfields are comparatively low.
3. Field pattern distortions in the transverse monitor plane can be minimized if the coils are distributed over the whole quadrants (fig. 3)

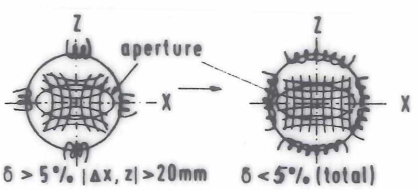

Fig. 3: Linearization of field pattern distortions

4. The ringcore can be placed outside the vacuum chamber and we only need to insert ceramic gap which can be penetrated by the bunch field.
5. While the system is tuned to the rather low revolutionfrequency of 947 KHz the beam displacement can be displayed on a standard scope so one can observe dynamic changes during the whole acceleration cycle particularly in the low energy range (fig.'s 8+9).
6. Standard broadband preamplifiers can be used. A bandpassfilter in the input protects the first transitorstage against high transients and spikes while another filter in the output suppresses the amplifier noise.

Technical layout

The pickupelectrode and the vacuumchamber are mechanically uncoupled. A short bellowsection near the F-magnet gap was modified to create the gap. Some convolutions of these bellows were removed and substituted with an Al_2O_3-ceramic ring. A precisely milled aluminium box (dimens. 210x210x35 mm) takes up the ringcore (which must be carefully centered on its baseplate so that the electrical center (zero) coincides with the mechanical center within ±0.2 mm) (fig. 4).

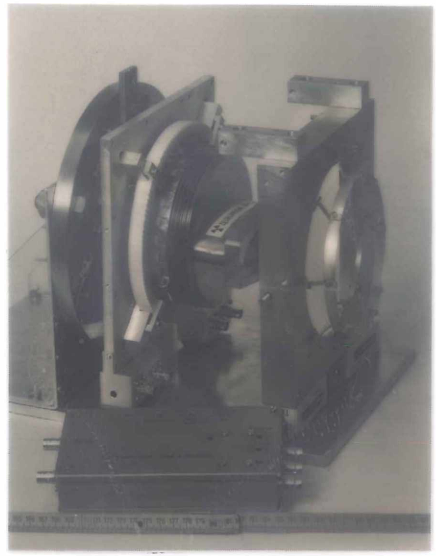

Fig. 4: Pickup-sensor with vacuum-section and preamplifier (housing removed)

Finally this unit is fastened to the next F-magnet. By means of horizontal and vertical slidebearings the station can be quickly positioned and locked in any desired position within ±6mm without interfering with the vacuum chamber. The accuracy is ±0.5mm.

Calibration procedures

Instead of the long wire methode (1) the beam is simulated by a precise groundplane-stub device (fig.5).

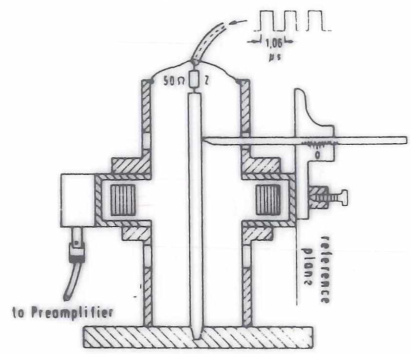

Fig.5 **Setup for alignment and calibration**

Alignment of the sensors

First of all the electrical zero and mechanical center have to be brought into coincidence by moving the ringcore within its box while the station is kept in zeroposition.

Field geometry distortions

With the same setup the aperture was measured step by step in a 1 cm-grid. Local and systematic distorsions did not exceed ±5% anywhere in the usable aperture.

Amplifiercalibration

Finally the station is kept in a definite position for adjustment of the gain of all preamplifiers to the same level: 10mA x 10mm ≙ 600mV.

Crosschecks

The question is how one can get sure that the calibration work done in the lab has something to do with the real beamposition ?. Several tests were carried out to confirm lab calibrations and measurements.

Slit method

A prototype station was installed near a horizontal slit, both carefully positioned. Comparing the measured positions with the collimate values we found an encouraging agreement within 0.5 mm.

FM-method

Another relative check was to change the radial position of the beam by a sudden RF-frequency shift. The agreement with the laboratory measurements was within ±5%.

Mechanical shiftmethod

Some electrodes were moved in millimeters steps away from their original position. The results are in good accordance with the results of the FM-method.

Kick method

A coherent betatronoszillation was excited with a pulsed kicker located at an appropriate place of the ring. If the system works linearly, we can expect that the measured difference amplitudes of all stations must fit into the betatron sine wave. Results are shown in Fig.'s 6,7). The discontinuity indicates the position of the kicker.

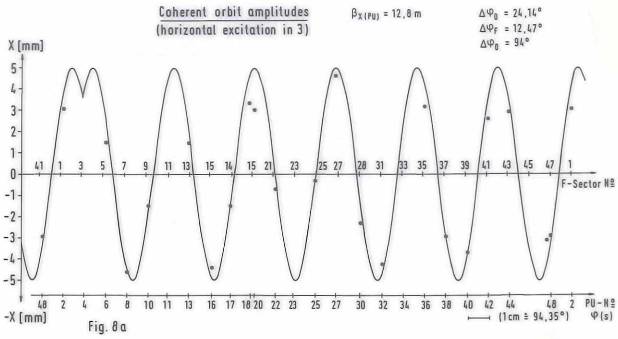

Fig. 8a

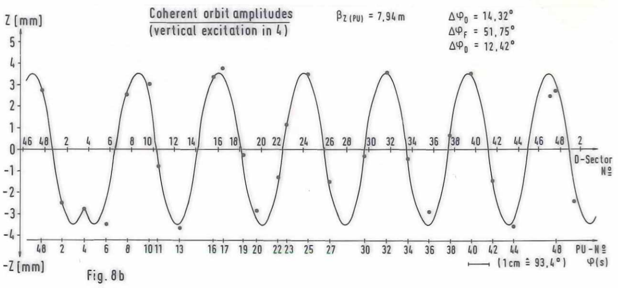

Fig. 8b

Comparison of measurements in multi- and singlebunch

Originally the layout was based on multibunch operation because of the higher average currents (fig. 8). But experience showed that even the displacement of single bunches with intensities (fig. 9) of $\geq 1.5 \cdot 10^9$ can be measured, even though the noise level is somewhat higher.

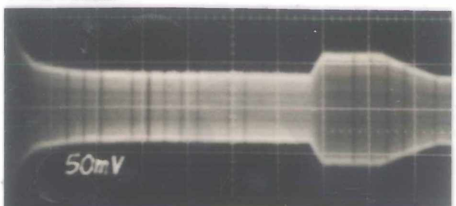

Fig. 8

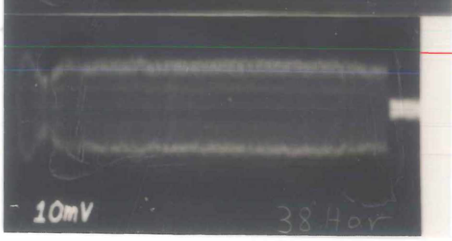

Fig. 9

Applications

Although the processor unit is not quite complete yet, we already have had some useful applications such as:

1. steering the beam to the center of the usable chamberaperture after injection by setting up the local dipolcorrections.
2. plotting the actual orbit amplitudes as an indication of magnet misalignments (fig. 10).

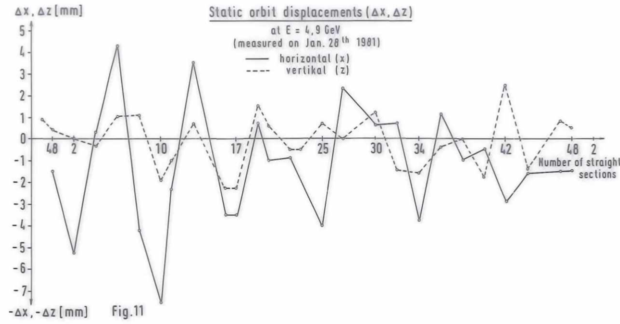

Fig.11

3. Optimization of the 50 Hz compensation in the magnet resonant circuit
4. Looking for dynamic orbit distorsions caused e.g. by harmonics in the main ac-magnet current (fig.s 8,9).

Pickup-data

Dimensions:		
Aperture		155 mm diameter
Length	mechanical	40 mm/electrical 13 mm
Material (ringcore)		Trafoperm N2 δ=0.05 mm
Linearity		±5%
Sensitivity:		
multibunch (mb):		$\frac{6mV}{mm \cdot mA}$ (50 %)
singlebunch (sb):		$\frac{\lesssim 1,6}{mm \cdot 10^9}$ (particles)
Noise:		$<2mV_{pp}$
Center frequency		947 KHz
Bandwidth		± 60 KHz

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