BEAM DIAGNOSTIC FOR COSY – JÜLICH

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Abstract

The beam diagnostic system for the cooler synchrotron COSY–Jülich is discussed. The major components to determine the beam position, the beam intensity and the beam profil are described. The set–up of the phase measurement between the injector RF and the circulating bunches is shown. The description of the viewers for the run–in phase is given. The basic principles of the data processing by the distributed control system processors for automatic trajectory correction, stability checks, updating of beam position are discussed. The status of the diagnostic hardware and software is given together with the future plans.

Introduction

The COSY–Jülich is a rapid cycling synchrotron with electron and stochastic cooling to diminish the phase space. The momentum ranges between 300 MeV/c and 3.3 GeV/c. The magnets are arranged in a racetrack. The two straights have a length of 40 m each. The arcs have a 6 fold symmetry. The maximal tunes are of the order of 5, the betatron amplitudes ranges between 1 and 50 m. The dispersion is lower than 25 m. The acceptances are 150 π mm mrad in the horizontal and 35 π mm mrad in the vertical plane. The minimum emittances are of the order of 1 π mm mrad. The momentum distribution is 10^{-3}, with cooling 10^{-4}. The accelerating frequency ranges between 0.4 MHz and 1.6 MHz in the single bunch mode, the higher harmonic system have an harmonic number of 60 or 120. The actual status of the COSY project is given in ref. [1].

The beam diagnostic is necessary to guarantee a good beam quality in the COSY ring. The beam instrumentation consists of system with measures the orbit deviations, phase relationship between the RF phase and the beam phase. The intensity monitor gives the current, the beam position monitors and the stripline unit for low beam intensity investigates in connection with the fast kicker the Q–values. To display the beam size florescent screens are used. The emittance is controlled by scrapers.

Non destructive beam monitoring

DC current transformer

The intensity of the charge particle beam over a wide frequency range including DC is measured with a parametric current transformer. The transformer has the following characteristic: Current range +/– 100 mA and +/– 10 mA, resolution 0.0005 mA, frequency range DC/100 kHz. The operating principle is that of an active current transformer and a magnetic parametric amplifier in a common feedback loop (ref. [2]).

The DC average current

$I = Ne\beta c/2\pi R$ with N number of circulating protons,
e = elementary charge,
β = v/c,
c = velocity of light, and
$2\pi R$ = circumference of COSY (184 m)

is expected to be 4.6 μA with one turn injection at the 40 MeV level with the following assumptions:

N = 7.4 10^5 H_2^+ ions per bunch every 35.7 ns, the conversion efficiency $H_2^+ \rightarrow 2$ protons of 1.4, and one turn in COSY corresponds to 60 cyclotron bunches.

Wall current monitor

As a wideband device a wall gap monitor is used. The gap monitor can be viewed either as a single 1:1 transformer, with the beam acting as the primary and the vacuum chamber as the secondary winding or alternatively as a device forcing the wall current (approximately the negative image of the beam current) to an external monitoring resistor. For frequencies between R/L and 1/RC the impedance of the pick–up is approximately R and the phase shift is approximately linear. From the low noise high bandwidth 50 Ω amplifier the signal from the wall current monitor is feed to vector voltmeter resulting the phase relationship between the RF phase and the beam phase.

Beam position monitors

Due to misalignment the closed orbit will deviate from the ideal orbit. This deviation is measured with the position monitors. The deviation causes the beam to oscillate around this new closed orbit. Thus the beam will include more signal on one electrode than on the other.

Due to the linear relationship the position error is determined from the regio of the voltage difference to the voltage sum of the potential induced on the pick–up electrodes. The phase relationship between the signals give the direction of the displacement. The number of monitors is given by about five times the maximum Q–value. The equally spacing of the pick–ups in the machine is interrupted and dictated by other installation (septa, cooling tanks, internal target places etc.). The total mount of pairs of horizontal and vertical pick–ups is 28.

The electronic readout system has two principle modes of operation.

To measure wideband signals in the time domain there is a broadband mode. A typical application for this mode is the Q–value analysis from a kicker induced ringing signal. There the tune is measured via FTT analysis using a special fast kicker to excite the betatron oscillations. In table 1 the performance data of the fast kicker (ref. [3]) is summarized.

Precise measurement will be done with a narrowband mode in the frequency domain. In this mode the electronic acts like a network analyser. The system is tracked by the harmonic of the master oscillator. The data aquisitation is be done with a twofold oversampling ADC. This allows a more releaxed design of the low pass filter in the preamplifier stage of the electronic. A constant group delay of the whole operation band of the COSY acceleration–system offers the possibility for dedicated monitors to feed and correct the RF–phase. The block diagram is shown in fig. 1.
While the data is always caputered digitally and in parallel for all monitors more advanced data reduction methods can be used.

The monitor has a linear cut configuration. The pick–up dimensions are 150 x 60 x 100 mm³ in the arc sections and ϕ 150 x 100 mm³ in the straights. The mechanical design is given in fig. 2. The sensitivity is 1 μV/mm for N = 10^8 protons per pulse.

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Destructive beam monitoring

Florescent screens

For beam observation in the run–in phase six screens are placed inside of the COSY ring. The viewers have a sensitivity of about $2 \cdot 10^6$ protons/mm^2 and with digital processing the position and the profiles of the beam is measured. The digital processing system consists of an ELTEC VMEbus microcomputer with a 68020 CPU, 3M byte RAM and an image processing boards, each with four analog input channels for cameras. The layout of the viewer station with image processing is given in fig. 3. It converts intensities to 256 grey levels in a picture with 512 x 512 pixels.

Some viewers will be removed after the commissioning to give a additional place for stochastic cooling equipments. The holder of the stripping target will be coated with cromium activated $Al_2 0_3$ to work as an additional viewer.

Scrapers

With four scrapers in the cooler telescope section the transverse emittances are controlled. The energy loss is around 1% at 2.5 GeV in the copper jaw. The protons are loosed in the dispersive arcs.

The positions of the destructive elements are given in fig. 4.

Data processing

For every pair of beam position monitors there is a seperate computing unit. The local corrections is calculated in this unit. The higher level data reduction and thinks like FFT will be done in a seperated computing unit based on a digital signal processor, DSP 56001.

The reduced data is sent to the diagnostic cell controller to provide information to the operator and the high level control system services. In the destructive diagnostic device region also a distributed computing approach will be used. Field controller handle the equipment via a Multidrop Fieldbus.

The process I/0 interface is integrated in the power electronic part and via the PDV–bus or the Bitbus (Trademark of Intel) connected to the field controller.
The field controller exchanges his information via a Ethernet with the diagnostic workcell. An overview draft is shown in fig. 5.

The different layers of functionally are marked man–machine interface for the console computer, workcell for the UN*X based mini computer and field controller for the discless VME–systems.

Summary

In the year 1989 testing is done with the DC current transformer, with the prototyp of the beam position monitor together with electronic readout to determine the long turn stability. Further measuring is necessary to improve the phase probe for operation at lower beam intensities.
It is planned to design transvers and longitudinal pick–up stations for the Schottky noise analysis of the unbunched beam.

Acknowledgement

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References

[1] R. Maier, S. Martin, U. Pfister for the COSY–team, the COSY–Jülich project – Feb. 1989 status.

[2] K. Unser, A toroidal DC beam current transformer with high resolution, IEEE Transactions on Nuclear Science, Vol. NS–28, No.3, June 1981.

[3] K.D. Metzmacher and L. Sermeus, Final Design Proposal for a Diagnostic Kicker for the KFA Jülich COSY Project.

Magnet	Gap height	96	mm
	Gap width	140	mm
	effective length	>800	mm
Max. deflection angle (horz.)		1	mrad
Max. ∫ Bdl		12	mTm
∫Bdl	rise time	<600	ns
	fall time (5–95%)	<200	ns
	flat–top	0.22–1.4	μs
timing filter		<50	ns
pulse repetition rate		>0.2	Hz

Table 1: Performance data of the fast kicker

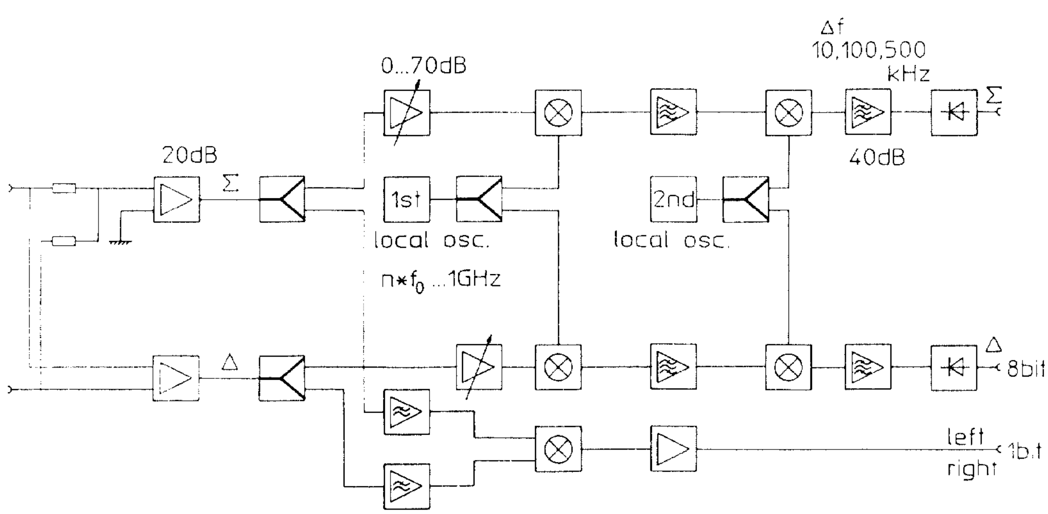

Figure 1: Electronic readout of beam position monitor

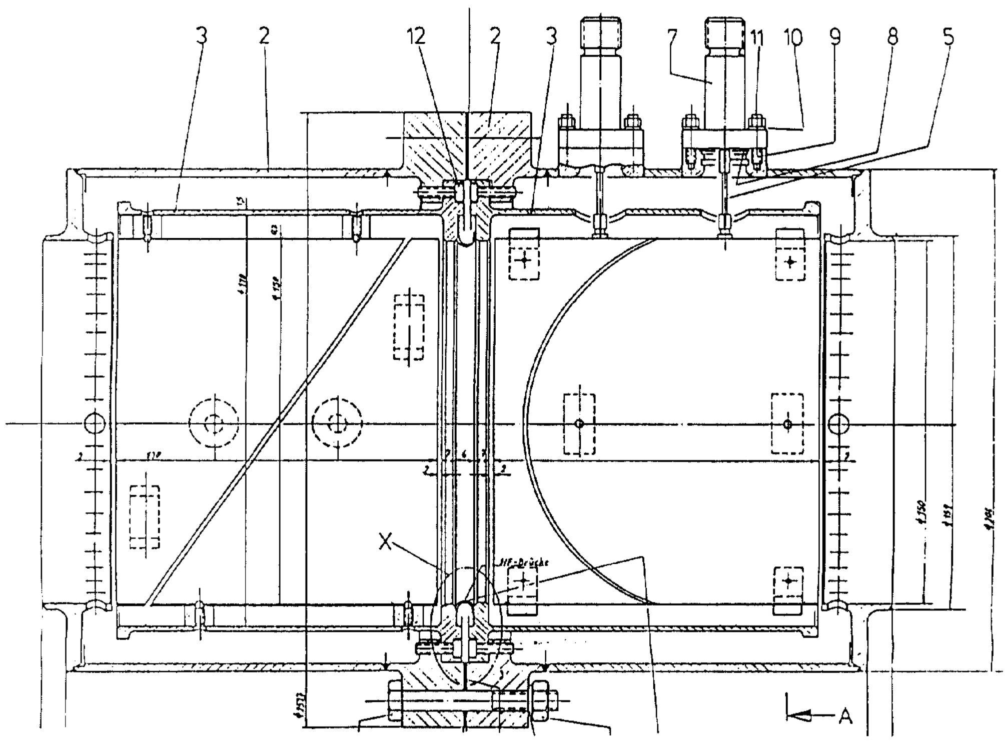

Figure 2: Mechanical layout of beam position monitor

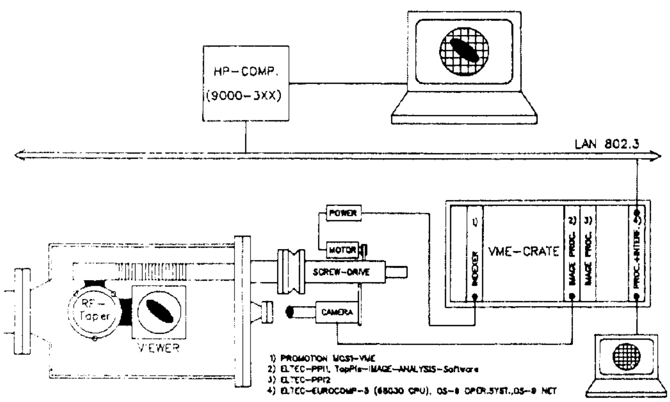

Figure 3: Viewer Station with digital processing

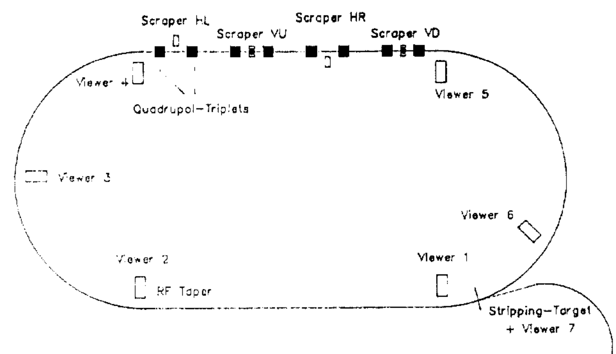

Figure 4: Disturbing monitoring equipment

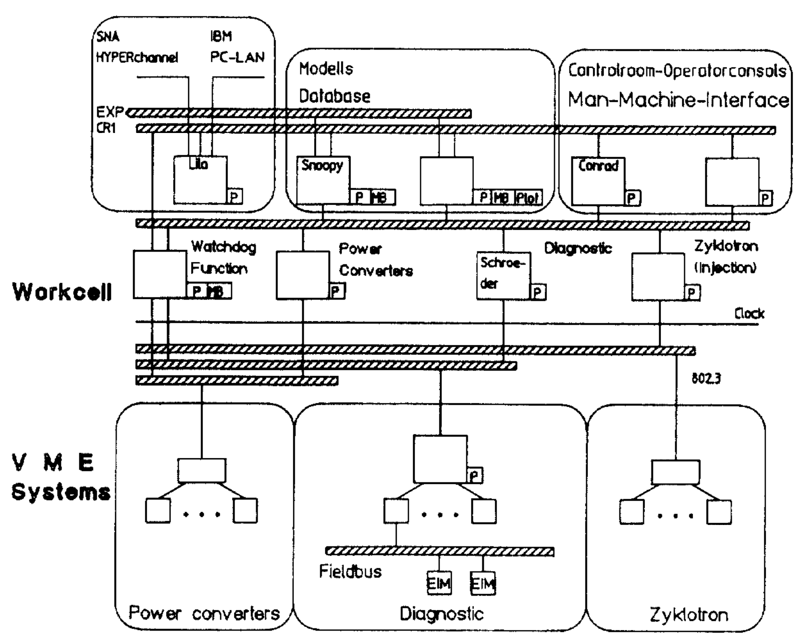

Figure 5: Distributed processors network