FR8100118

11. International conference on high energy accelerator.
Geneve, Suisse, July 7 - 11, 1980.
CEA - CONF 5491

THE SATURNE BEAM MEASUREMENT SYSTEM FOR ORBIT CORRECTIONS AND HIGH AND LOW INTENSITY BEAM ACCELERATION

L. Degueurce, A. Nakach, J. Solé,
Laboratoire National Saturne, CEN-Saclay (France)

ABSTRACT

This paper summarizes the dipolar and multipolar correction system and the main beam diagnostics of Saturne II : wide-band RF electrostatic pick-up electrode for observation of bunches, beam position and tune measurement systems, special electrodes for observation of emittance blow-up when particules cross a resonance line. For low intensity beams, special electrodes and electronics have been developped. All this instrumentation is computer controlled.

1. INTRODUCTION

Saturne II has been designed for nuclear physics with a wide variety of particles and intensities [1], ranging from strong proton beams ($1\text{-}2.10^{12}$) to low intensity heavy ion beams (10^7). The characteristics of the cell with strong focusing quadrupoles determine the principles of diagnostics and corrections.

We have two different sets of diagnostics : one for strong beams (5.10^{10} up to 2.10^{12} elementary charges/cycle) and the other for weak beams ($< 5.10^{10}$). They provide signals for monitoring the acceleration system and measure the main beam characteristics for correction of magnetic field errors and machine aligment.

It must be pointed out that the large value of $\frac{\beta_{max}}{\beta_{min}}$ (fluctuation of the enveloppe : almost 10) gives strong decoupling of horizontal and vertical motions ; the sensitivity of measurements is accordingly increased, the localisation of defects with correction codes is more accurate and it is possible to use quadrupolar pick-up electrodes to detect the emittance blow-up when the beam crosses resonances.

2. BEAM DIAGNOSTICS AND CORRECTIONS FOR STRONG BEAMS

2.1 Wide-band RF electrostatic pick-up electrodes for observation of bunches and phase monitoring of the acceleration system (Figure 1)

Two similar devices are in use ; one provides the RF signal for the adjustement of the phase of the accelerating frequency, the other is reserved for the observation of bunches and beam instabilities and for the measurement of beam intensity. The stainless steel electrodes have a cylindrical cross-section and their electrical ground (as well other electrodes) is separated from the ground of the machine. The electronic circuits must allow detailed observation of bunches of which the revolution frequency ranges from . 25 MHz up to 2.75 MHz ; for this purpose the bandwidth is 125 MHz. It has been decided not to put electronic elements near the ring ; the electrodes are directly connected to the coaxial cables and the differentiated signals must be restored at the cable ends. The

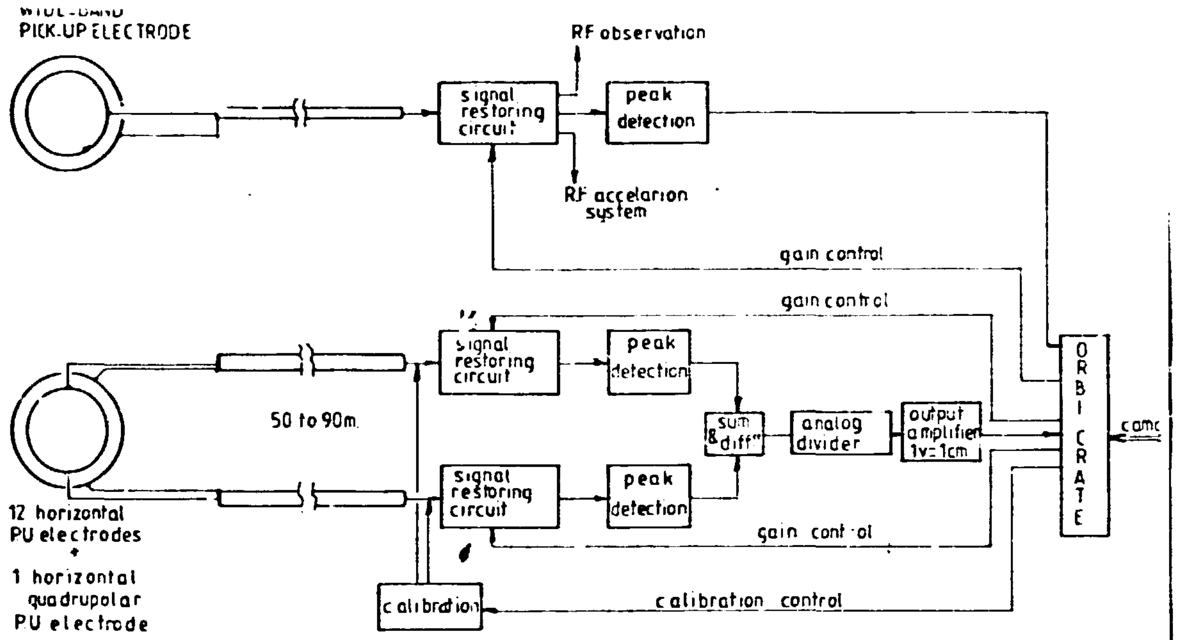

Figure 1 - Beam horizontal position measuring system with wide band P.U. electrode and quadrupolar horizontal electrode. A similar system is in use for the vertical motion.

voltage is processed, digitally converted at four selected times during the cycle and transmitted to the computer which calculates the beam intensity.

2.2. Wave number measurement, beam position measuring system and bipolar correction system

2.2.1 Wave number measurement [2] (Figure 2)

We don't systematically perform a υ measurement. Earlier we had calibrated υ_x and υ_z as function of the main quadrupole current. A computer code which uses the calibration allows us to move the operating point during the acceleration cycle [3]. The wave number measurement is therefore only used ɔ check the calibration. Two devices (for υ_x and υ_z independantly) give a short "kick" to the beam, once per cycle and we perform a fast measurement of the lower frequency of the spectrum of the induced signal on a positi⌃n electrode.

The kicker [4] is made of a glass-tube surrounded by two pairs of loops energized by a current of 1000 A during 350 nsec. Each pair of loops can deflect the beam a few millimeters. The inside of the glass-tube has been metallized to form electrostatic plates which can be used to correct beam instabilities. We use low intensity beam detection electrodes which will be described later on. The signals pass through a set of filters, of which the low frequency cut-off is constant and high frequency cut-off increases from 260 kHz to 1086 kHz. This frequency variation is obtained by switching active filters. The output frequency is measured in 10µs by a fast counter ; the computer calculates the ratio

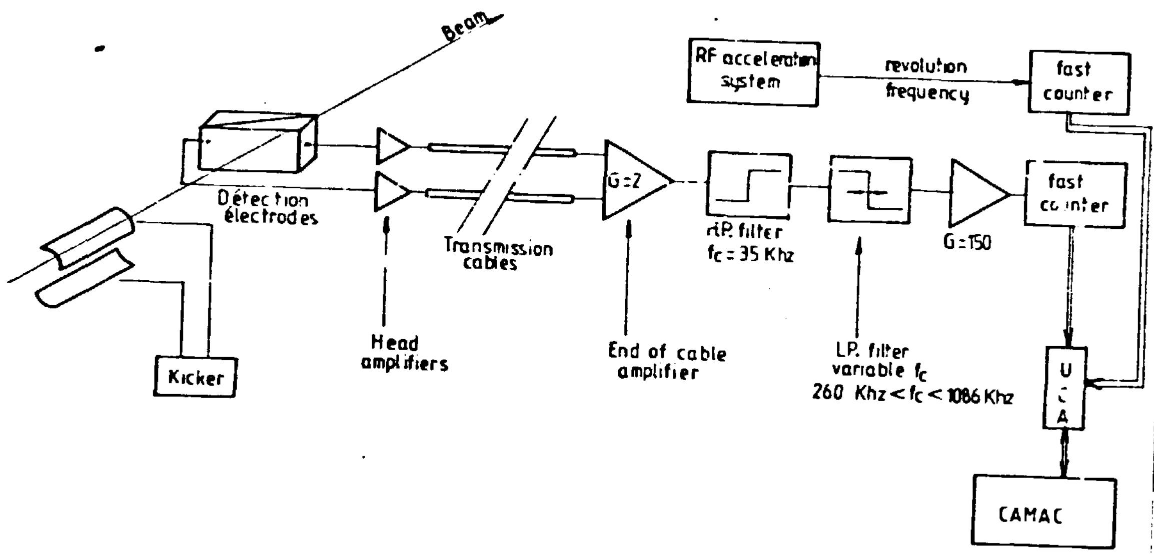

Figure 2 - υ measurement system.

between the betatron frequency and the revolution frequency to give the wave number ; with repeated measurements an accuracy of 10^{-3} is obtained.

2.2.2 Beam position measuring system (Figure 1)

A dipolar electrode has been installed for this purpose at the end of each quadrupole[5]; we have consequently 12 horizontal electrodes and 12 vertical ones (3 points per wavelength) ; they are made of metallized alumina with a pattern on the internal face so that they are sensitive to the beam position. Each of the two RF signals induced by the circulating beam is electronically treated in the same way as in 2.1. The processed sum and difference signals are divided in an analog fashion and the resulting voltage is representative of the beam position. The 12 values are digitized and transfered to the computer which delivers the orbit display to a graphic terminal. The computer also controls the gain of the system and performs the calibration. The accuracy is ±1.5 mm on a single measurement and better than ±1 mm with repeated measurements.

2.2.3 Dipolar corrections [6-7]

The goal was to get a residual orbit of ±4 mm after correction. At first, the focusing quadrupoles are remotely moved while the accelerator is running (the defocusing quadrupoles are manually moved, the machine being stopped) ; this correction is valid all along the cycle. At low energy certain other defects are present which disappear at higher energy ; these are suppressed by weak (10 Amp) d.c. currents in dipolar windings. These windings are made of a thick layer of copper in form of double face printed circuit (Cu : 0.5 mm) ; they are located inside the quadrupoles and their thickness does not exceed 1.5 mm. From the beam measurements, a code calculates the displacements and currents to be applied. The power supplies are controlled by the computer. The remaining closed orbit is within ± 2.5 mm in both planes.

For special nuclear physics experiments, low intensity proton beams are needed, so that about 10^9 protons/cycle are accelerated : to maintain the strong beam injection settings and facilitate extraction, we inject 10^{12} protons and large $\frac{\Delta P}{P}$ and we lose 99,9 % of the beam at the beginning of the acceleration ; this is done by means of vertical correction currents which act during a few milliseconds before the regulation of the acceleration system is switched on. Thus, the intensity is easily limited without disturbance in the horizontal motion ($\frac{\Delta P}{P}$ is not affected).

2.3 Observation of emittance blow-up and multipolar correction system

The crossing of a resonance line can yield a loss of particules or an emittance blow-up ; only the loss can be detected on the R.F. electrode which gives the beam intensity. To reveal an emittance blow-up, two quadrupolar detectors [8] have been studied and mounted in β_{max} and β_{min} points. The electrodes are similar to the dipolar electrodes but the inside pattern is different : the internal area is divided in four sectors connected in pairs ; the same electronic treatment is also used ; we can observe a L.F. signal either on a CRT screen or sampled, restored by the computer and displayed on a terminal.

To correct resonances, eight multipolar correcting lenses [9...10] (four in each plane) are located around the ring either at 90° or 180° angles for an even or odd harmonic to be created ; every one of them contains three windings : quadrular, hexapolar and octupolar ; they are of the same construction type as the dipolar circuits. The pulsed correcting currents do not exceed 10 Amp and are controlled by the computer. Figure 3 shows for example, the correction of one among the strongest lines : $3\nu_z = 11$; with a first adjustement the loss of particules has disappeared ; the remaining emittance blow-up is then suppressed by the last settings [11].

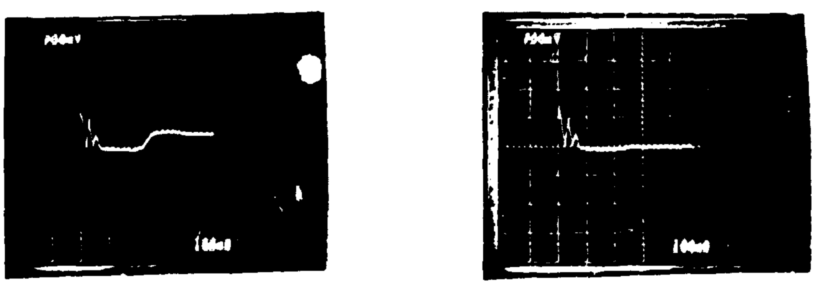

Figure 3 - correction of the resonance line $3\nu_z = 11$, with help of quadrupolar electrodes

3. LOW INTENSITY BEAM DIAGNOSTICS[12]

They are 1 m long, are all located in a straight section and include three electrodes : the first one allows the observation of bunches, the phase control of the accelerating system and intensity measurement. The two others give horizontal and vertical position. Closed orbit measurement is not possible. The electrodes are made of stainless steel and carrefully shielded. In order to decrease low frequency noise, preamplifiers have been used and the signal restoring devices suppressed ; the weak induced signals can be amplified at the end of the transmission lines by switched amplifiers with gain of 10 ; rigid coaxial cables are used to reduce noise pick-ups. These special electrodes and electronics are now very often used ; they perform the regulation of the acceleration system down to 10^8 charges/cycle but measurements can be carried out down to 5.10^7 charges/cycle.

4. CONCLUSION

These devices have been successively operated and optimised since July 1978 ; some improvements are still needed (for example easier measurement of the ν value). We chose to make extensive use of the computer and this helped us to achieve good machine control. At the present time we can easily correct resonances and get a residual closed orbit of ± 2.5 mm in the complete range of accelerated beams, from 10^8 up to 2.10^{12} charges/cycle.

The named authors would like to thank J. BOURBONNEUX, C. COMPAGNON, J. GERNO, R. NOEL, P. STARZYNSKI, G. VALLADE, of the Corrections and Diagnostics Group.

REFERENCES

1) J.P. Aknin et al, Status report in rejuvenating Saturne and future aspects, San Francisco (1979),

2) L. Degueurce, Measurements of the ν value in Saturne, Germa 76-56/CD-30,

3) A. Ropert, Utilization of the GENVEN Code, LNS 025,

4) A. Nakach, Electrical and mechanical characteristics of the Saturne II "Kicker" Germa 75-40/CD-18,

5) L. Degueurce, A. Nakach, Sensitivity improvement of the Saturne electrodes, Germa 75-27/CD-13,

6) A. Nakach, Closed orbit correction system, Germa 74-131/CD-04,

7) A. Nakach, Alignment and survey of an accelerator with help of beam observation, SOC-Germa RS 74-84/CD-02

8) L. Degueurce, A. Nakach, Emittance blow-up measurements with quadrupolar electrodes, Germa 75-35/CD-14,

9) A. Nakach, Coreless quadrupolar lenses, Germa 74-111/CD-03,

10) A. Nakach, Coreless hexapolar lenses, Germa 74-134/CD-05,

11) A. Nakach, Correction of the resonance line $3\nu_z = 11$, LNS/SM 79/65 - DIA 08

12) L. Degueurce, A. Nakach, Detection electrodes and electronics for low intensity beam, LNS/SM 79/14 - DIA 04.