A BEAM POSITION MONITOR FOR AmPS

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Abstract

AmPS (Amsterdam Pulse Stretcher) is a 900 MeV electron storage and stretcher ring. Its construction started early 1991. A fast response, high resolution stripline type beam position monitor has been developed for the ring. The monitor has a quasi elliptic cross section. Its sensing strips have a length of $\lambda/4$; the operating frequency is 2856 MHz. The mechanical construction, the matching of the output ports and the on-line calibration system are described. The results of bench measurements as well as measurements with a 500 MeV beam are also presented.

Introduction

To obtain a duty factor of nearly 90%, the present accelerator facility will be extended with a stretcher ring [1],[2]. The horizontal tune of the ring is 8.30. For central orbit corrections 4 monitors per betatronwavelength are required adding up to 32 monitors in total. For measurement of tune, dynamic aperture and instabilities a fast response is required. Since the revolution time of the ring is 0.7 μs we decided the bandwidth of the monitors to be at least 15 MHz. The accuracy of position measurement must be 0.1 mm for beam currents down to 1 mA. Although for central orbit correction a fast response is not required, for reasons of uniformity we decided upon the fast response type for all monitors. The RF frequency of the ring has been chosen equal to the RF frequency of the accelerator (2856 MHz) [3]. Consequently we looked for monitors based upon this frequency. Stripline type position monitors have been chosen instead of buttons since the output power of a stripline electrode is roughly 20 db more than the output power of a button.

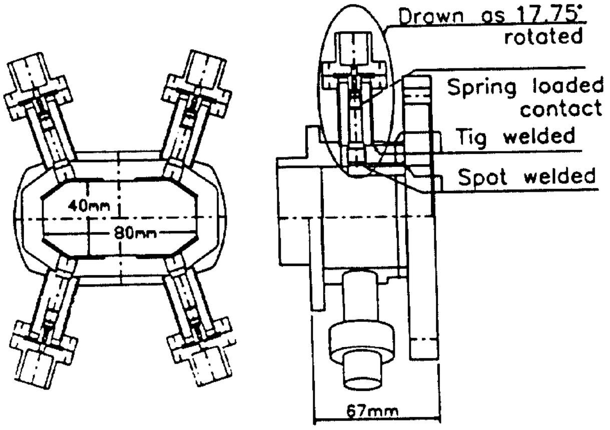

Fig.1. Electrode pick-up assembly.

Mechanical design

The fabrication of the various parts and the final assembly were ruled by the main condition that the electrical axis should not deviate more than 0.1mm from the mechanical axis. To reduce the costs we have chosen for TIG (Tungsten Inert Gas) welding instead of brazing, figure 1. The stripline electrodes are machined separately. At the short circuited side they are connected by spot welding to the stripline housing, see fig. 1. At the other side the inner conductor of the coaxial output port is connected to the electrode also by spot welding. Electrical contact with the output connector is provided by spring brushes. This avoids excessive stress in the ceramic of the vacuum tight output connector. Also the output connector can easily be replaced in case of vacuum leakage. To meet the 0.1 mm accuracy for the electrical axis all welding was caried out with special care using moulds if necessary.

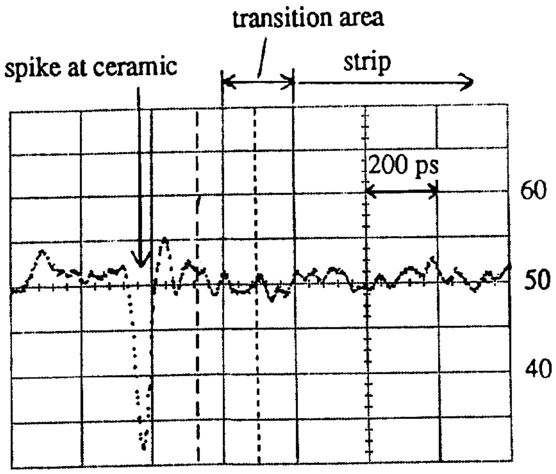

Fig.2. TDR plot of electrode impedance.

RF design electrode pick-up assembly

The available space in the ring is limited. To reduce required space and to lower the beam coupling impedance the lenght of the stripline has been chosen $\lambda/4$. The geometrical design was optimized to obtain equal sensitivities in x and y direction. The beam pipe has a quasi elliptical cross section with 8 and 4 cm as main dimensions (figure 1). All fundamental TM and TE modes that can disturb monitoring performance are below cut-off. For accurate position measurement and a low contribution to the overall longitudinal beam coupling impedance the strip assembly should be well matched to 50 Ω over a frequency range up to 20 GHz. Fine adjustment of the stripline characteristic impedance

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and matching the transition of the coaxial output port to the stripline has been carried out empirically. For this purpose a model has been constructed with 1.5 λ long, removable strips. In figure 2 a TDR plot of the final result is shown. The frequency ranged from DC to 20 GHz. We see that besides a spike located at the ceramic of the vacuum tight coaxial connector the impedance equals 50 Ω with an accuracy of +/- 2 Ω . For the transition area this could simply be achieved by small increments of the diameter of the central conductor of the output port and partial recess of the stripline length (figure 1).

Bench measurements

Bench measurements can be divided in measuring loss factor and measuring monitor response. In both cases the monitor is mounted between two pipes. Each pipe consists of 25 cm pipe with monitor cross section and a 25cm taper from monitor cross section to a coaxial connector. The coaxial connector is the same as used for the electrode pick-up assembly. For loss factor measurements the central conductor is a rod with the same diameter as the central conductor of the coaxial connector (7 mm). For monitor response measurements also a 0.3 mm wire is used as central conductor. For matching purposes this wire is connected to the inner conductor of the coaxial connector by means of a 190 Ω SMD. The measurements have been performed with a HP8720B network analyser. The bunch in the ring has a σ of 30 to 50 psec. Simulating a bunch width σ= 48 psec with the network analyser resulted in a loss factor of 0.04 V/pC. The monitor response measurements can be divided in calibration and position measurements. For calibration the rod is centered in the monitor with an accuracy of 0.03 mm. The output of the ports is measured with 0.02 dB accuracy. Since 1.2 dB corresponds with 1 mm displacement of the wire, the electrical axis can be calibrated with a total accuracy of 0.06 mm. For position response the wire is laterally displaced. The displacement can be more than 15 mm without exceeding the elasticity. Results of these measurements are combined with results of beam measurements shown in fig. 5.

Signal processing

The output power of each pick-up electrode is transmitted to a 90° hybrid through 2 m semi-rigid cable and an isolator (fig.3). Since the length of the stripline is λ / 4 only odd harmonics are coupled out. However the mixer attenuates the third harmonic already 50 dB with respect to the fundamental. Therefore filters in front of the hybrids are not required. Per diagonally positioned pair of electrodes AM is converted to PM in the hybrid. Behind the hybrid the frequency is converted by mixing to a 75 MHz IF frequency. The isolator is required since the stripline is shorted at the end. Reflections of the hybrid will be completely reflected by the stripline. Without isolator this will cause deterioration of the position measurement. For calibrating purposes the hybrid inputs are provided with 20 dB directional couplers. During the injection cycle (2.2 μs) RF power from the accelerator driveline can be fed into a calibration power line. Through this line RF power is distributed to the directional couplers of all monitors in the ring. In this way a centered beam is simulated enabling to correct for thermal and (radiation) aging drifts of all components excluding those upstream of the couplers. However drifts in these upstream components (pick-up assembly, semi-rigid cable, isolator) are negligible. All components except isolators and oscillator are integrated in one stripline board. To compensate for different phase shifts of the mixers, adjustable phase shifters in the oscillator lines are incorporated on the stripline board. The 75 MHz output signal is transported outside the vault to the electronic unit shown in figure 4. The main specifications of the phase detector in this unit are,

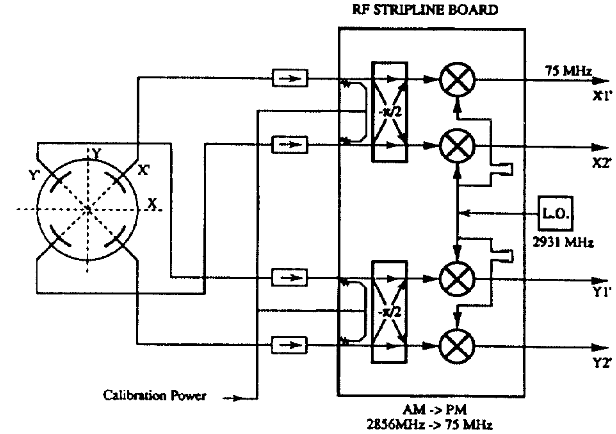

Fig.3. Block diagram of RF signal processing.

bandwidth	15 MHz
phase range	-70 to +70°
phase linearity	0.2° for -40 to +40°
current dependent phase error	1° rms for 1 to 300 mA

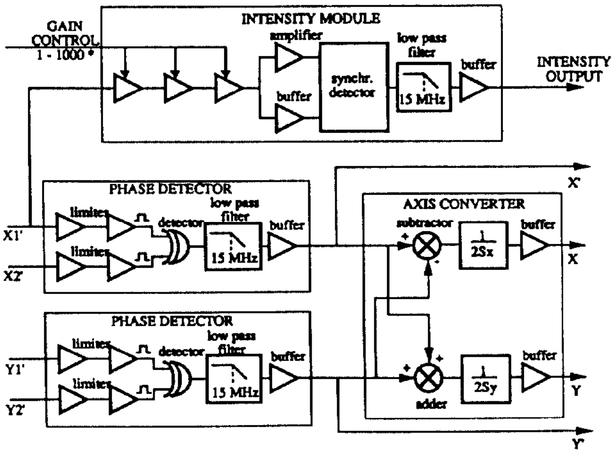

Fig.4. Block diagram of the electronic unit.

To measure amplitudes correlated with larger phase shifts than 70°, phase compression can be achieved by interconnecting the inputs X1',X2' and Y1',Y2' through resistors. The sensitivities Sx and Sy in figure 4 are defined by,

$$Sx = dX'/dx = -dY'/dx \quad \text{and} \quad Sy = dX'/dy = dY'/dy$$

Beam measurements

Tests have been done with a 6 mA peak current 380 MeV beam. The beam has been displaced in vertical and horizontal direction over +/- 3.5 mm. The response was linear. This is shown in figure 5 by the shaded area. The nonlinearity outside the shaded area was extrapolated from bench measurements. The sensitivities were ,

$$Sx = 3.0^\circ/\text{mm} \quad \text{and} \quad Sy = 2.9^\circ/\text{mm}$$

The resolution was 0.2 mA.mm. The measured sensitivities are about 30% below a theoretical estimate. We don't have an explanation yet for this deviation. Further measurements are going on.

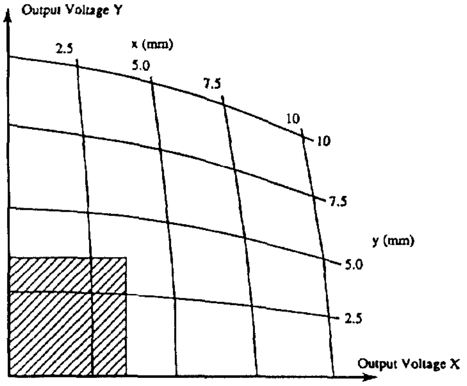

Fig.5. Monitor response, isoposition lines, shaded area shows beam measurements, outside shaded area shows extrapolations from bench measurements.

Acknowledgement

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