AN OVER-MODED STRIPLINE BEAM POSITION MONITOR

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Abstract

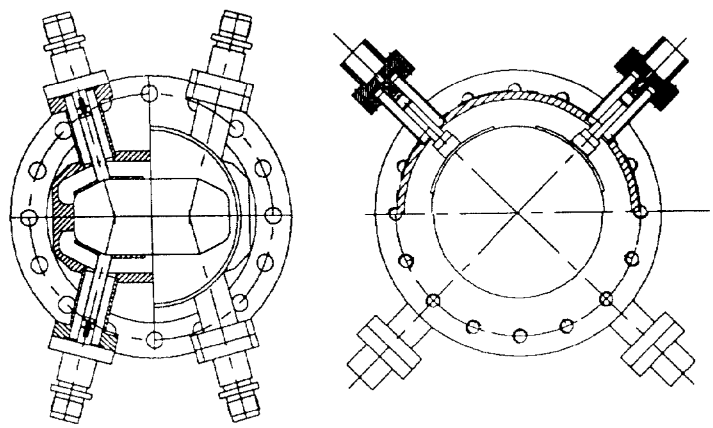
The operating RF frequency of the AmPS stretcher ring is 2856 MHz. The beam pipe cross section is above cut-off for some modes of this frequency. This inhibits proper functioning of the stripline beam position monitors. The problem has been solved by applying particularly shaped high vacuum quality RF dampers.

Introduction

The 900 MeV AmPS stretcher ring has become operational in the middle of 1992 [1]. Two types of experiments will be enabled by this new facility. Physics with a high duty cycle (90%) extracted beam (stretcher mode) and internal target physics (storage mode).
The inner size of the beam pipe is determined by making the machine suitable for both types of experiments. For proper extraction the beam pipe should have a relative large width in the extraction area. From the optical design [2] it follows that also elsewhere in the ring the beam width will be large. The inner beam pipe height is determined by the requirement to store the beam at least one hour.
Therefore in the curves the inner beam pipe width is 8.0 cm and the height is 4 cm. In the straights the round beam pipe has an inner diameter of 9.2 cm.
In stretcher mode the frequency of the RF power source in the ring is the same as the RF frequency of the 900 MeV injecting accelerator: 2856 MHz [3]. This is necessary to trap all injected bunches in the RF bucket, otherwise an intolerable loss of beam would occur.
The revolution time of the beam is 0.7 μsec. For proper measurement of successive turns we decided that the bandwidth of a position monitor should be at least 15 MHz. For this purpose the 2856 MHz frequency component of the beam must be used and stripline position monitors based on this frequency have been developed [4]. The stripline monitors have the same cross section as the beam pipe, thus allowing the same beam clearance. As a consequence, the combination of this high RF frequency and large inner beam pipe size results in a over-moded beam position monitor. For instance the TE01 mode is above cut-off in the curves and the TE11 mode is above cut-off in the straights. Without any precautions the monitors wouldn't work due to disturbing wakefields.

Wakefields

The ring consists of four 90° bends connected by straights. According to the two different beam pipe cross sections there are two types of stripline monitors fig.1.



Curve-type Straight-type

Fig.1. Stripline Position Monitors

One with the cross section of the curve and one with the cross section of the straight. In each curve and each straight four monitors have been installed.
We expect wakefields mainly to be generated at strong alterations of inner beam pipe size. Propagation of these wakefields through the beam pipe is then possible by mode conversion into a mode above cut-off. Since the propagation of such a mode is not synchronous with the beam, the energy content of the propagating mode can not be further enhanced by the beam. Initially we thought it to be sufficient to put only RF damping material in the straights. The positions we had in mind were the transitions straight-curve and close to disturbing objects as kickers and septa. Beam measurements however showed that a proper response of the monitor could only be obtained if the monitor itself was sandwiched between RF damping material.

RF dampers

The RF dampers consist of pieces ceramic pipe coated with a resistive paint. The paint obtains its resistive property after a special bake out treatment. After this treatment the vacuum properties of the paint are excellent. The outgassing is comparable with a stainless steel surface [5]. We have investigated what resistive value gives the best result. For this purpose a stripline monitor in a beam line has been provided with dampers with resistive values between 10 and

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1000 ohm per square (see beam tests). Also the attenuation of the dampers has been measured on a bench using the beam pipe as a waveguide. A resistive value of 140 ohm per square proved to be the best choice. It performed the best beam response as well as maximum attenuation.
The bench measurements were done by putting the damper in 1 m beam pipe terminated at the ends by tapering to S-band waveguide WR-284. For the selected 140 ohm dampers the attenuation was 6 dB for a complete (upper and lower part) 38 mm long curve type damper and 10 dB for a complete 75 mm long straigth type damper. Over the important frequency range 2 to 4 GHz the attenuation showed to be quite constant.

RF damper assembly

In the straights the dampers are put directly in the pipe (fig.2) thus affecting the beam stay clear in vertical direction.

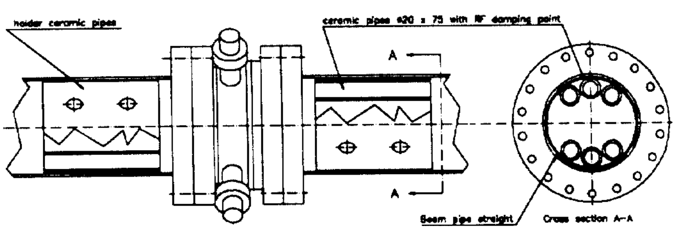

Fig.2. RF damper assembly, straight-type monitor.

This is allowed since the large beam pipe size is required in stretcher mode where the beam excursion is large in the horizontal direction only. One holder comprises six 20 mm diameter, 75 mm long ceramic pipes. Three at the upper side and three at the lower side of the beam pipe.
In the curves it was not allowed to decrease the beam clearance. The only possibility to fit dampers around the stripline monitors in the curves was to use the bellows of each monitor. In fig.3 is shown how this has been realised.

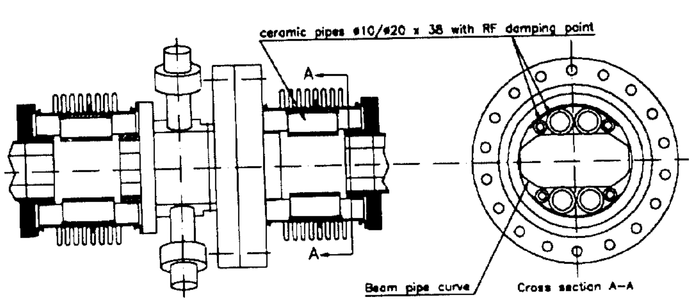

Fig.3. RF damper assembly curve-type monitor.

The original smoothing RF sleeves have been removed. Then the corrugated surface of the bellows has been covered with a metal foil. Hereafter the holders with the damping pipes have been positioned, one in the upper and one in the lower part of the bellows. Each holder comprises two 20 mm diameter ceramic pipes in the middle and two 10 mm diameter ceramic pipes at the sides. The length of the pipes is 38 mm giving the bellows 5 mm length clearance which is sufficient for alignment purposes.
It appeared to be difficult to reproduce the resistive value. Therefore the dampers are provided with ceramic pipes in such a way that the average values of upper and lower part of a damper were equal and close to 140 ohm.

Coupled beam impedance

We assume that the dampers only contribute to the broadband impedance. That means only the single bunch current threshold is affected by the RF dampers [6]. Applying the coaxial wire method [7] for beam impedance measurements, the sum of all dampers will contribute 2.8 ohm to the longitudinal broadband impedance Z/n in the frequency range 2 to 4 GHz. This value also includes RF dampers elsewhere in the ring, for instance at the straight-curve transitions. However this increase of the broadband impedance will not disable the original aimed maximum beam current in the ring (200 mA).

Beam tests

Prototypes have been tested in a 6 m long part of the beam line. The test sections comprised one or two stripline monitors and 6 m beam pipe with the same cross section as the monitor. As mentioned before a variety of resistive values for the RF dampers has been used. The best response was obtained with 140 ohm per square. Other resistive values performed lower sensitivities and distorted responses. The response on beam position with 140 ohm dampers is shown by the isoposition lines in fig.4. The X and Y output voltages are obtained after signal processing [4]. The average sensitivity constants (defined in [8]) were,

curve type $K_x = 24$ mm $K_y = 25$ mm
straight type $K_x = 50$ mm $K_y = 50$ mm

After installation in the ring the centre position of the monitors has been calibrated by centring the beam in the quadrupoles (by wobbling) in between the monitor has been positioned. Also the sensitivities have been measured. The average centre offsets appeared to be $dx = -0.8$ mm and $dy = 0.7$ mm with standard deviations of $\sigma x = 2.0$ mm and $\sigma y = 5.4$ mm. The average sensitivities were equal to those measured in the test section however with standard deviations of 33 % for x and 28 % for y.
This result is not as good as could be expected from the prototype tests. An explanation and possible cure requires more research but probably two effects can be blamed for it:

the generation of much stronger wakefields in the ring compared with the test section and the non-uniformity of the dampers with respect to the resistance and also slightly the geometry. Summarised the response of the stripline monitors is not ideal but they are suitable for position measurement if properly corrected for the individual deviations.

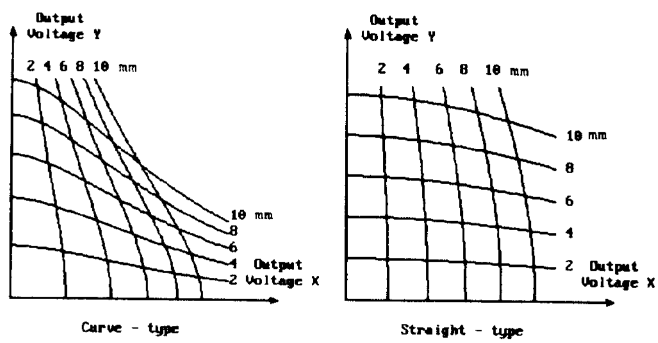

Fig.4. Beam position response, isoposition lines.

Acknowledgement

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