Beam diagnostics for the Amsterdam pulse stretcher AmPS.

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Abstract

AmPS is an electron storage and pulse stretcher ring operating between 300 and 900 MeV with stored beam currents up to 200 mA. For beam diagnostics the AmPS ring has been provided with 32 stripline beam position monitors, 17 low beam impedance designed screens, a DCCT and 4 synchrotron light ports. In addition 3 scanning wires for injection control, 32 air filled ionisation chambers for beam loss control, a kicker for tune measurements and a harmonic shaker have been implemented. Purpose, design and performance of these devices will be described. The data acquisition for closed orbit correction and tune measurement will be presented as well.

Introduction

The AmPS ring has been constructed for two types of experiments. Physics with a high duty cycle (90%) extracted beam (stretcher mode) and internal target physics (storage mode)[1]. Commissioning started in the middle of 1992 [2]. Meanwhile extracted currents of 10 uA at three turn injection, duty cycles up to 94 % and stored currents of 150 mA have been performed. To obtain these results precise adjustment of the ring parameters is necessary especially in stretcher mode. For this purpose the ring has been provided with adequate diagnostics.

Stripline type beam position monitors

For proper measurement of sucessive turns a bandwidth of 15 MHz has been chosen since the revolution time of the beam is 0.7 us. For closed orbit correction 32 of these position monitors have been installed (4 per betatron wavelength) Although for closed orbit correction a fast response is not necessary it has been decided for reasons of uniformity to make them all of the fast response type. The data of the 32 monitors are read by a sample (3 us) and hold system and digitized by a 12 bits ADC, 32 channel VME 566 unit. For calculation and execution of an orbit correction a selection of monitors and orbit correctors can be made. This enables the exclusion of badly calibrated or malfunctioning monitors. Due to the high RF frequency in stretcher mode (2856 MHz) [4] the monitors have an over-moded size which should inhibit proper functioning. This has been cured by sandwiching them between RF dampers [5]. However they stil suffer from some defects. They have large centre offsets dependent on the inner beam pipe geometry close to the monitor and more nonlinearity than corresponds with the monitor geometry itself. The centre offsets are calibrated by centring the beam in a preceding quadrupole (by wobbling) one monitor at a time. To make the calibration more straightforward a software tool is under development to center the beam at the same time in al the calibration quadrupoles. This is done by wobbling the quadrupoles individually and calculating the beam ofset in the quadrupole from the deviation in a position monitor. Centring the beam in the quadrupoles is then obtained by using the same orbit correction algorithem as exist for the position monitors. In addition this enables us to adjust the closed orbit if to few reliable and calibrated stripline monitors are available.

Beam viewers

A low cost, low impedance beam viewer has been developed. The housing consists off a piece of straight section pipe

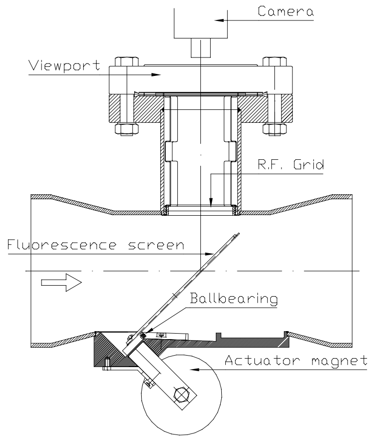

Fig. 1. Beam viewer

which has been squeezed vertically to obtain a quasi elliptical cross section. The actual screen plate is a 6 by 4 cm chromium doped aluminum oxide plate which pivots upon small ball-bearings. If the screen is not used it lies on the bottom of the housing due to its own weight. In this position the disturbance of the beam pipe cross section is minimum an so is the beam impedance. The screen is activated by a magnetic field of a coil outside the vacuum. In this way the dynamical mechanics inside the vacuum are restricted to only the screen plate ball-bearings. A window has been positioned at the upper side. To reduce the beam impedance the entrance of the window pipe has been shielded with a 90 % open s.s. mesh. For global adjustment of the beam position in the ring 16 beam viewers have been installed equally shared along the ring 2 per straight and 2 per curve. One additional beam viewer has been installed in the injection area.

Synchrotron light ports

Four synchrotron light ports are available. Three at positions with negligible dispersion in the beginning of a curve and one at maximum dispersion in the middle of a curve. They consist simply of a light pipe ending in a window at 83 cm from the light source point. Inside the vacuum in front of the window a 2 mm thick freely expandable quartz plate acts as soft x-ray absorber. Damage of the window by heating up is now prevented. Behind the window outside the vacuum the light beam is deflected by a adjustable mirror to a camera. A lens system on the camera images a light source area of 30 mm horizontal and 24 mm vertical on the light sensitive front-end of the vidicon tube inside the camera. Between mirror and camera is a remotely controlled set of light attenuation filters. The set contains four filters in line with attenuation numbers 3,10,100 and 1000. Any combination of the filters can be put in the light beam. So light attenuation from zero to 65 db can be obtained with 5 db steps. There is no additional light port for alignment. Alignment is done with reference to the magnet pole. Camera and mirror are aligned as one system in a dummy magnet and then replaced to the actual magnet. A computer generated reference frame is superimposed on the light spot image. Due to the absorber the light spot is distorted. This disables high accuracy beam size measurements. Therefore high quality synchrotron ports with a cooled metal mirror inside the vacuum are under development now. Moreover the light of these ports will be transported outside the vault.

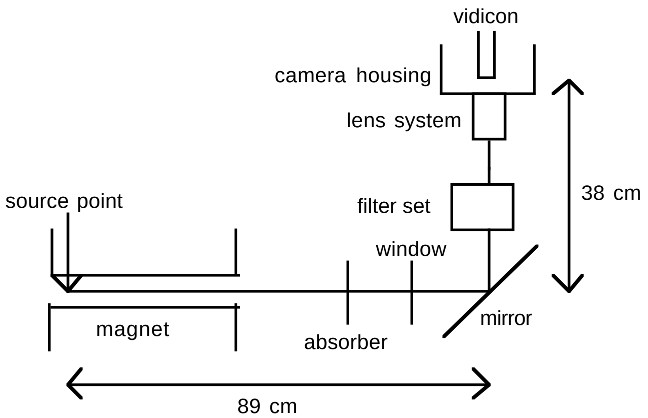

Fig.2 synchrotron light port, schematc lay-out

Scanning wires

For high precision measurement of the injected beam position, wire scanners have been installed. Three in a drift space at the end of the accelerator and three in the injection area. Those at the end of the accelerator are also meant for phase space measurement. Each scanner consists of a horizontal and vertical 50 um tungsten wire driven across the beam by a stepper motor. One step of the stepper motor is 12.7 um. A horizontal and vertical beam profile in one scan is performed by a 45 degrees tilted mechanical stroke. So one step is horizontally and vertically 9 um. The absolute position reference is a high precision Baume switch. The accuracy of the switch itself is 2 um. To preserve this high accuracy as position reference the switch is hooked up in a sliding holder kept at center position by a screw spring. The switch is activated when the wires pass

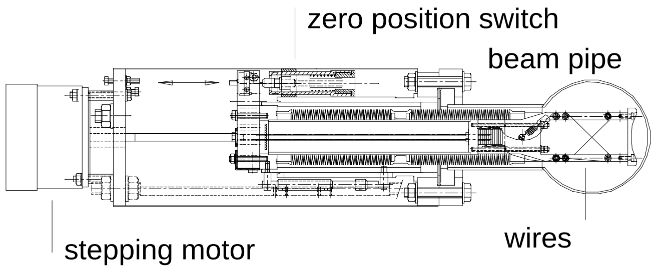

Fig.3 wire scanner

the centre. So at one half scan the switch holder is in center position and the other half scan the holder is taken along with the wire movement. In this way a position accuracy of 0.01 mm is obtained. However due to pulse to pulse beam instabilities the beam position and size accuracy is not better than 0.1 mm. The beam profile measurement is based on secundary emission signal sampling. Each sample covers a complete beam pulse. The sample resolution of the preamplifier located in the vault close to the monitor is 2 fC. However due to interference noise the total resolution is 30 fC. The samples are digitized by a 8 bits ADC and stored in memory. From these data the position of the beam mass center and the beam diameter containing 95 % of the current are calculated. From the three sequential diameters at the end of the accelerator the emittance is calculated. The shape of the beam is shown on a graphic display.

Parametric current transformer

The current in the ring is measured with a commercially available parametric current transformer (PCT)[6]. The PCT is positioned around the beampipe outside the vacuum close to an aluminumoxide isolation gap in the beam pipe. A copper electrical shield and a u-metal magnetic shield cover the PCT and isolation gap.

Loss monitors

A loss monitor consist of a piece of air filled cable acting as an ionization chamber. These monitors have been positioned all around the ring combined in 32 groups. Each group is read out individually and showed on a graphical bar display.

Tune kicker

The tune is determined from the betatron oscillations induced by injection or by kicking the stored beam with the tune kicker. The betatron oscillations are measured with a stripline position monitor and sampled by a Lecroy 9450 oscilloscope. The oscilloscope has a Built in FFT function which calculates the frequency spectrum and thus the tune frequency. The kicker consists of four copper rods 1 cm diameter and 50 cm long placed parellel to the beam. In cross section the rods lye on the angular points of a square with horizontal and vertical edges of 6 cm. At one end the rods have been connected through. Each pair of diagonally positioned rods forms a loop. Forcing a current pulse through one of the loops performs a magnetic field with equal horizontal and vertical components. This enables measurement of the horizontal and vertical tune simultaneously. Only a horizontal or vertical magnetic flux is obtained by powering both loops simultaneously.

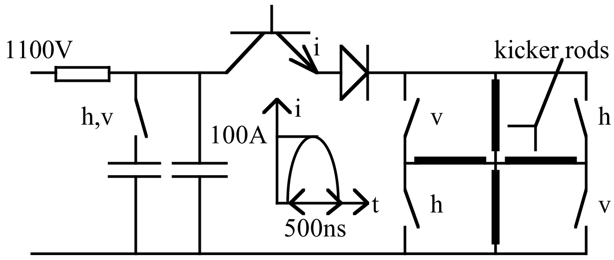

Fig.3. Tune kicker power system, schematic lay-out

Selection between horizontal or vertical flux is obtained by reversing the current in one loop with respect to the other. This is done by activating the swiches h or v in fig. 3. A sine shaped current pulse is obtained by discharching a capacitor by a high voltage transistor. The capacitor and high voltage transistor have been positioned in the vault as close to the kicker loops as possible to minimize additional inductance. The capacitor value has been adjusted to make the base lenght of the current pulse 0.5 us which is sufficiently short to fit into the revolution time of 0.7 us. At a capacitor voltage of 1100 V is the current amplitude 200 A if both loops are powered. The bending angle at 500MeV is then 0.4 mrad. This corresponds with a betatron oscillation of 2 mm in the curves.

Harmonic shaker

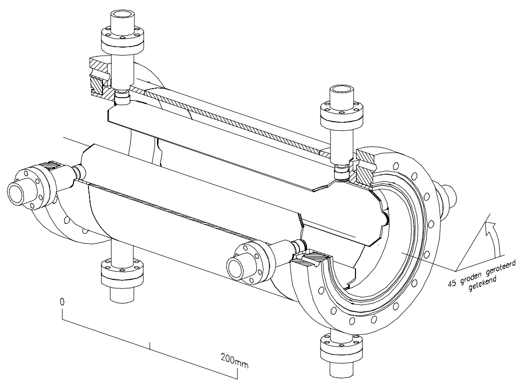

Fig.4 Harmonic shaker

For investigation of stored beam properties also a harmonic shaker has been installed. Since this device will be driven over a wide frequency range the electrodes and connectors have to be well matched to a 50 ohm system. Therefore we modified the straight type stripline monitor design. The harmonic shaker is actually a straight type stripline monitor with 20 cm long electrodes not short circuited at one end but with connectors at both sides. The position of the exitation electrodes with respect to the beam is similar to the tune kicker. At one end each pair of diagonally positioned electrodes have been connected through creating again two loops. The other ends of the electrodes are transported outside the vault. There one or two loops in series terminated with 50 ohm can be connected onto a transmitter. Similar to the tune kicker horizontal and/or vertical RF fields can be obtained by proper combination of the loops.

Image dissector tube

For bunch length measurements a dissector tube has been ordered [7]. The theoretical bunchlength of AmPS is of the order of 90 ps in storage mode.The resolution of the dissector tube is about 10 ps which makes it suitable for our purpose.

Acknowledgement

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