WIRE SCANNER FOR MULTIBUNCH BEAM

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Abstract

The tungsten wire scanners are used for a measurement of the very small beam size and the emittance in Accelerator Test Facility (ATF). They are installed in the extraction beam line of ATF damping ring. The extracted beam emittance are $\varepsilon_x=1.3\times10^{-9}$ m.rad, $\varepsilon_y=1.1\times10^{-11}$ m.rad with single bunch 2×10^9 electrons/bunch intensity at 1.3GeV energy [1]. The detail of the system and the performance are described in elsewhere [2]. In the end of year 2000, multibunch operation has started. The fast gamma detector is commissioned for the measurement of each bunch size in the multibunch by the same wire scanners. An avalanche photo-diode (APD) is employed for the fast Cerenkov gamma detector.

1 INTRODUCTION

ATF is a test accelerator to realize a small emittance beam which will be used in an electron positron linear collider. The beam emittance measurement in the ATF extraction line is required for a single bunch and 20 multi-bunched beam which has 2×10^{10} electrons in each bunch with 2.8ns spacing [3]. The required resolution of the beam size monitors is less than 1μm for the beam of 6 - 7μm vertical size. On the other hand, the horizontal beam size is around 50 -150μm, bigger than vertical one. The wire scanner beam size monitor is the most appropriate monitor for the required performance. The five wire scanners together with a gamma detector at downstream are installed at the region of no dispersion in the extraction line between quadrupole magnets. The beam sizes from 4 or 5 scanners are used to fit an emittance assuming the optics between the scanners [4].

Precise measurement of such a small vertical beam size with big horizontal size is discussed in elsewhere [2]. In case of multibunch beam, gamma rays from a beam-wire interaction have also the same time structure as the multibunch beam. A fast rise and fall response within 2.8ns is required for the gamma detector of the multibunch. APD was chosen instead a photo-multiplier tube for the Cerenkov light detector. The performance of the APD and measurement of multibunch beam size are described here together with multibunch emittance measurement.

2 WIRE SCANNERS

The wire mount shown in Fig.1 in the wire scanner vacuum chamber is supported by the two arms from outside of the chamber. A 50μm diameter gold plated tungsten wire is stretched simultaneously to X, Y and U directions which are 45 degree tilted from the X direction. In the other side of the mount, a 10μm diameter gold plated tungsten wire is also stretched to X, Y, U and 10 degree tilted from X direction. Both end of wire are fixed to copper pillars with holding by solder. The moving direction of the wire stage is 45 degree between X and Y axis has an advantage of that the only one moving direction is necessary for 3 axis scans. The error from the design angle is less than 1 degree. The installation into the beamline was done to have 10μm horizontal wire to sit in the precise horizontal direction. Using an alignment telescope, tilt angle of the whole wire scanner chamber was adjusted within 0.2 degree.

The two arm supports of the wire mount inside the vacuum chamber are fixed to the two stages with two bellows at both ends of support arm. This two-arm support reduces the vacuum pressure loading for the stage movement. Furthermore a vibration of the wire mount is also reduced by using this double support stage compared with a single end support. The one end of the wire mover stage is powered by a 5-phase stepping motor stage assembly (Physik Instrumente M-510.10). This stage is driven by a ball bearing spindle of 1mm pitch for one revolution. The stepping motor performs one rotation by 2000 steps. Combining the ball bearing spindle and the precise stepping motor, the resolution of step is 0.5μm and repeatability of the positioning is less than 0.1μm.

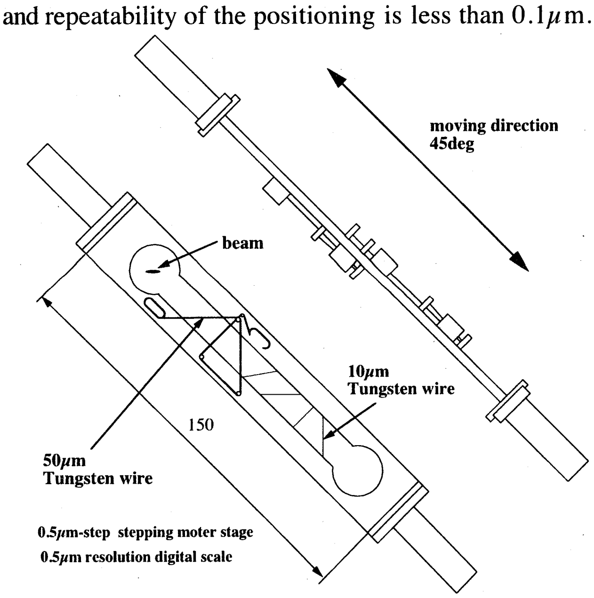

Fig.1: wire mount in the wire scanner chamber

The stepping motor stage assembly has a radiation resistant. Also, the stage position sensor must have a radiation resistant. The Magnescale position sensor is adopted, because it does not have processing electronics near the sensor. It includes a magnetized rod with very fine pitch and a pickup coil. The processing electronics is placed outside of the accelerator tunnel. The resolution of the Magnescale is 0.5μm for 100mm travel, enough small for the beam size measurement of 10μm.

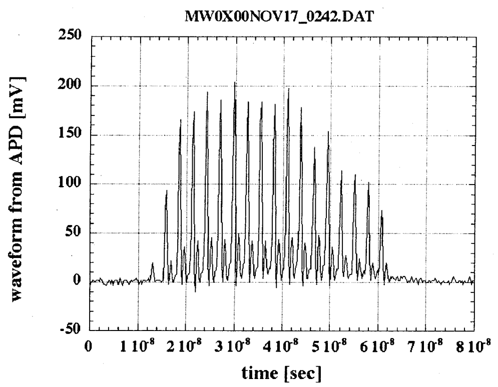

Fig.2: APD waveform of multibunch gamma rays

3 GAMMA DETECTOR USING APD

A breamsstrahlung gamma rays is used for the signal of beam and wire interaction. The gamma detector is placed at the last bending magnet in the end of beam diagnostic section. There are two types of Cerenkov detector which consists of 2mm thick lead plate converter, air light guide and a photo-detector. As for the single bunch detector, a photo-multiplier tube is used with its HV voltage operated from 600V to 950V depending on the beam size and the wire diameter. On the other hand, APD assembly unit (Hamamatsu C5658) with around 200V DC bias voltage, temperature stabilization circuit and pulse amplifier included is used for multibunch signal detection. The multibunch detector is installed behind the single bunch detector. Since the Cerenkov light is emitted like a sharp cone, two mirrors are used for the light transmission and a lens for focusing into APD cell. The multibunch wire signal out from the APD which is amplified following the fast built-in pulse amplifier of gain 100 is a pulse train signal with around 1ns width and 2.8ns spacing. Typical output pulse height is around 150mV. The output signal from the APD assembly is sent out from the damping ring tunnel by 20m Suco-flex (Suhner) cable, and is digitized by TDS694C (Tektronics) oscilloscope of 10Gs/s sampling and 3GHz bandwidth. Fig.2 shows a typical waveform captured by the scope during the multibunch beam hitting on the wire. The processing software finds a peak amplitude of each bunch signal inside of +/-1.4ns window at around given sampling point which is determined in advance. The interference of tail ripple at 2.8ns behind into the next signal peak is less than 9%.

4 BEAM SIZE MEASUREMENTS

The acquisition of the wire signal is done by the oscilloscope reading task which read the APD signal from a GPIB interface in a CAMAC crate. Since this reading cycle is not fast enough compared to BPM reader task, the

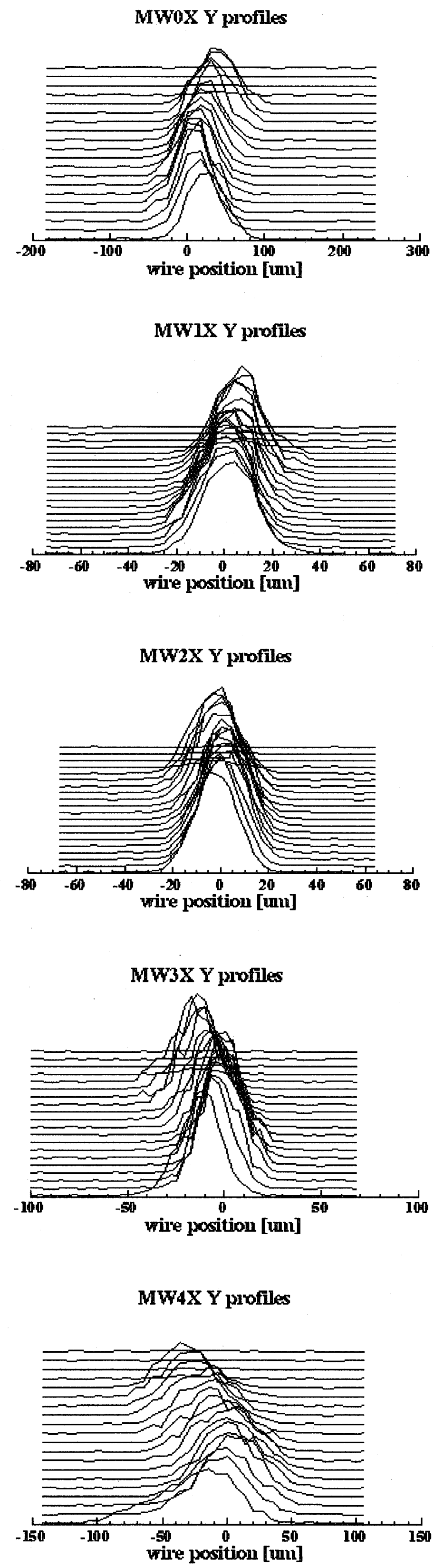

Fig.3: Y profiles of multibunch in 5 wire scanners

wire signal, the beam intensities and the beam positions are not fully synchronized each other for the same beam pass. However, in case of 0.78Hz beam repetition, almost all data are synchronized. On the other hands, single bunch wire scan does synchronization in any repetition. A fluctuation of the wire signal caused by the beam intensity is corrected by normalizing the wire signal by the extraction beam intensity.

The scanning speed is around 30sec for one profile. The slow scan is coming from both the 0.78Hz beam repetition, the slow stage movement and slow acquisition from the oscilloscope. The scan is made as follows; by setting the wire stage to the initial position at first, then wait the beam passing, get the wire signal of each bunch together with the beam intensity, go to the next stage position, then repeat again until the end position coming. So far, the multibunch injection into DR is not stable pulse-to-pulse, accumulating the gamma signal and averaging them are used for a clear beam profiles of each bunch. Measured typical beam sizes of y-direction are from 9μm to 26μm, x-direction from 50μm to 200μm. Fig.3 shows y profiles of each bunch in the 5 wire scanners. The beam size of each bunch is not change, however, profile centroids are shifted from head bunch to tail. It seems to be an x-y coupling between two extraction kickers, however it will be studied in the next machine time.

5 EMITTANCE MEASUREMENTS

In damping ring multibunch operation, vertical emittance blow-up in the tail was observed at the initial stage. After making horizontal bump orbit tuning especially at the end of south straight section, the vertical emittance blow-up was disappeared. Even after careful tuning of damping ring, vertical emittance is still two times higher than the one in single bunch at the same beam intensity. As for the wire scanner measurement, a careful tuning of the extraction diagnostic region is made by usual way using single bunch condition, such as orbit correction and dispersion correction. Then multibunch beam emittance is measured by using APD detector based wire scanners after switching to multibunch condition. In case of the PMT based detector for use of single bunch, the projected average of the beam profile can be measured. When the beam of damping ring is well tuned for the multibunch, their detectors give the similar value of the emittance. Fig.4 shows the vertical emittance of each bunch at around 3×10^{-11} with bunch intensity around 3×10^{9} electrons/bunch, which is twice much as the one in the single bunch. The reasons of this bigger emittance compared with single bunch emittance 1.4×10^{-11} of the same intensity might be come from residual gas-scattering, some resonant mode acting evenly to every bunch and so on, because the vertical emittance of each bunch are kept constant from head bunch to tail bunch, and the vacuum pressure is twice much higher in multibunch operation. On the other hand, it can not be minimized by the tune, RF voltage, and bump orbit. Further study is needed to reduce the vertical emittance in multibunch.

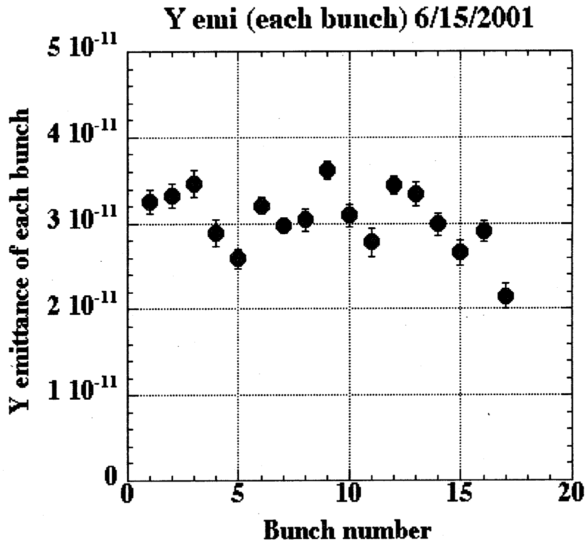

Fig.4: measured Y emittance of each bunch

6 SUMMARIES

The five wire scanners in the ATF extraction line are used to measure the multibunch beam size of 50 - 200μm in horizontal and 9 - 26μm in vertical using APD based gamma detector. The measured emittance is near the ATF target even in case of multibunch operation. The twice much emittance growth in the vertical direction compared with single bunch is still not understandable.

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