Emittance Measurements of FEL Linac at Nihon University

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Abstract

Transverse emittance of the electron beam from the FEL linac at Nihon University [1,2] has been estimated by measuring the dependence of the beam size on the strength of quadrupole magnet. The beam size has been measured using both the wire scanner and fluorescent profile monitor independently. The vertical normalized emittance deduced from the result obtained with the wire scanner, at the electron energy of 93MeV and the beam current of 100mA, was 48.5πmm·mrad, while 76.5πmm·mrad has been obtained from the analysis of the images of the fluorescent profile monitor. The deduced horizontal emittance has been three times larger than that of the vertical one, which is due to the fact that the horizontal distribution of the beam was dispersed or split.

1 Introduction

The fluorescent beam monitor is widely used for monitoring of beam position and profile because of simple operation and setup. However, the visible beam size and the density distribution are not necessarily correct because of the saturation of fluorescence or monitoring TV image. In order to measure the transverse emittance of the electron beam from the 125MeV linac at Nihon University a wire scanner system, which was in use at KEK [3], has been installed in the beam line downstream the exit of the linac. The beam size and density distribution can be measured by moving the wire across the beam. The current on the wire, due to the secondary electron emission caused by the bombardment of electron beam, is proportional to the beam current that hits the wire in a large dynamic range. The information on two-dimensional distribution of the beam density is reduced to one-dimensional distribution along the scanning direction of wires. The beam size along that direction is evaluated from the distribution, then the emittance is deduced from the dependence of the beam size on the strength of a quadrupole magnet.

2 Preliminary Experiment

In order to confirm that the secondary emission current on the wire (0.1mmϕ W) is observable, a preliminary experiment was performed in a very simple way as follows. The test wire was placed in the vacuum chamber downstream the linac, then bombarded with the electron beam of the current of 80mA (Fig.1). The electrical signal waveform from the wire was displayed on the oscilloscope in the control room. The signal is terminated with 50Ω terminator at the input of the oscilloscope. A typical waveform is shown in Fig.2. Consequently, it was found that the electrical signal from the fine wire could be observed with sufficient amplitude. The current is consistent with the calculated value, which is obtained by assuming that the quantum efficiency of the secondary electron emission is 2%[4].

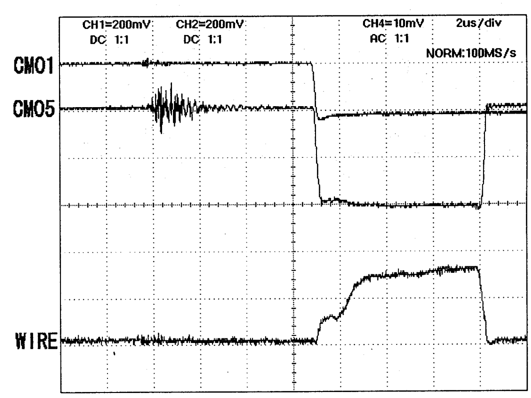

Fig.2. The waveforms of currents measured on the oscilloscope.
CM01 : the emission current from the gun, 400mA/div
CM05 : the beam current at end of the linac, 50mA/div、
WIRE : the wire current, 0.2mA/div

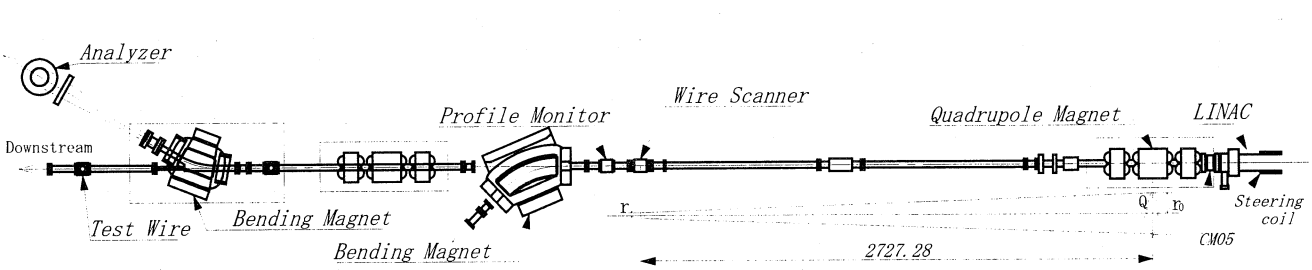

Fig.1. Setup for emittance measurement.

3 System Configuration

3.1 Wire Scanner

The wire scanner and the profile monitor built in the beam line are shown in Fig.3. The former consists of a vacuum chamber and a motor driving system that moves the wire stage. The wire is strained in three directions, x, y and u (45°). Then the wire measures the beam distribution in the three transverse directions. The wire stage moves in the direction with the angle of 45° for the horizontal plane as shown in Fig.4. The stroke of the wire stage is about 70mm. The fluorescent profile monitor is located about 150mm downstream the wire scanner. The fluorescent plate has made no serious effect on the current of the wire.

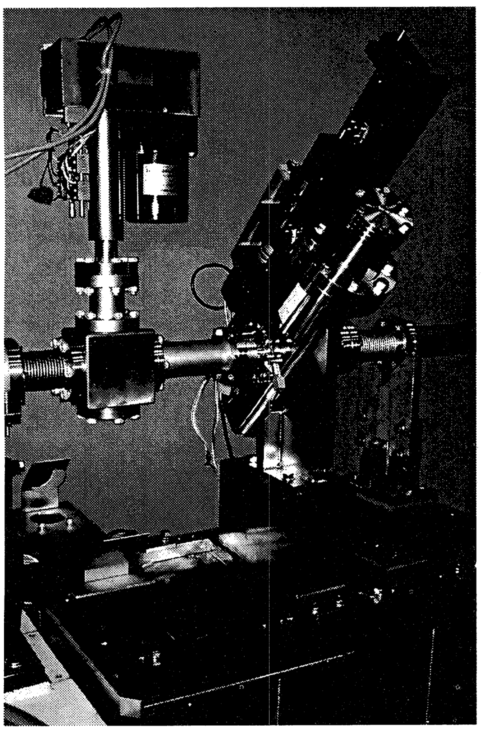

Fig.3. Photograph of the wire scanner (rigth) and the beam profile monitor (left) .

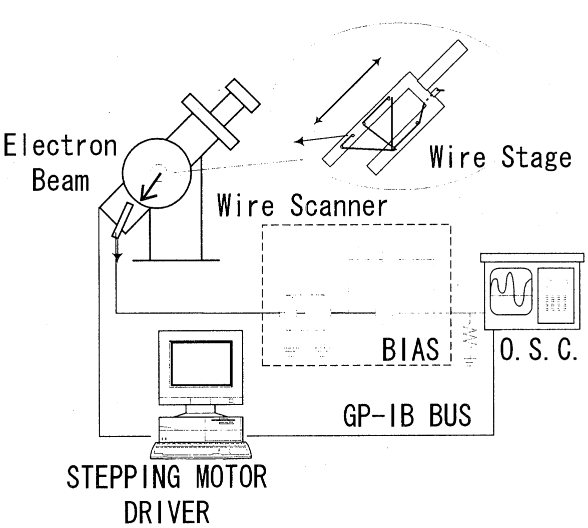

Fig.4. Block diagram of the wire scanner system.

3.2 Block Diagram of Electronics for Wire Scanner

The block diagram of the signal flow is shown in Fig.4. The wire stage is driven with a stepping motor that is controled by a personal computer. The limit swiches are mounted on the wire stage to avoid overrun of the motor beyond upper and lower locations. The wire position is set by the count of pulses fed to the stepping motor. The electrical signal is displayed on the oscilloscope. The waveform digitized by the oscilloscope is transfered to the personal computer and recorded in the disk. The stage stays at each period of measurement.

3.3 Experiment

The schematic drawing of the experimental setup is illustrated in Fig.1. In this experiment, the bias voltage has not been applied to the scanning wire. The quadrupole magnet at the exit of the linac is excited in each 0.05A step, and the wire scanner moves across the electron beam at 0.5mm step from upper to lower limit position at each excitation current. Each run takes about 7 minutes. The electron beam current is 100mA at the end of the linac. The current of the secondary electrons from the wire is measured with the oscilloscope at every wire position. Examples of the current distribution at different excitation currents are shown in Fig.6. Three peaks correspond to distribution of the current along Y(left), 45° (middle) and X(right) directions, respectively. Only the focus in the vertical direction is changed while the horizontal focus field is not applied. The origin of the position of the wire scanner is at the upper limit. Fig.7 shows an example of a beam profile imaged by means of a CCD camera [5]. The left hand side in the Fig.7 is the original image, while the right hand side is the processed image of the left hand side with the solarization method. An approximate beam size is estimated with vertical and horizontal reference lines drawn on the screen (Rb: fluorescent plate) at intervals of 3 mm.

Besides the series of emittance measurement, the effect of the bias voltage applied to the scanning wire has been tested. When the wire was biased at –57.8V the current signal was 1.3 to 1.6 times larger compared with the case without bias. Also the full width at half maxmum was different. The difference of the signals according to the bias voltage is shown in Fig.5.

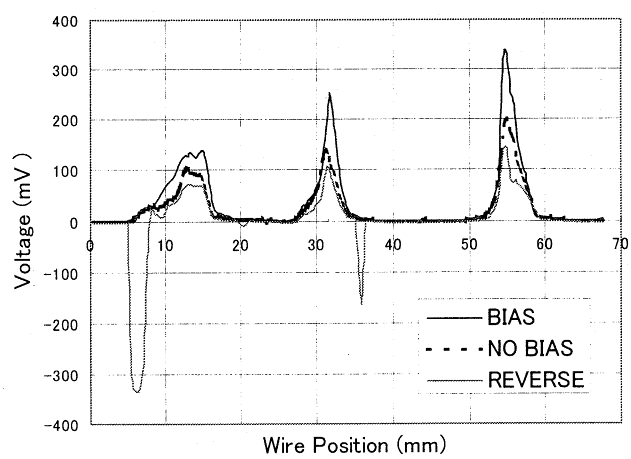

Fig.5. The signals from the wire with the bias voltage.

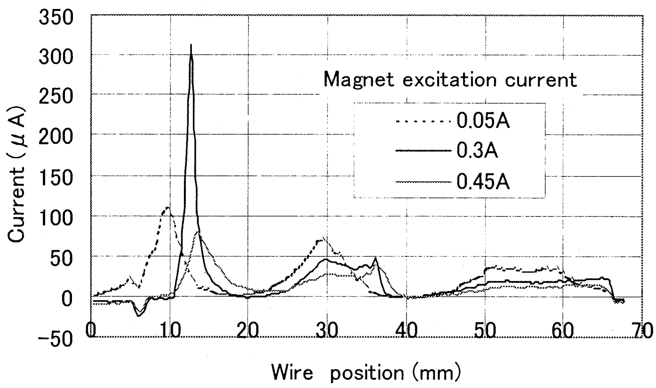

Fig.6. The current of the secondary electrons from the wire at each position.

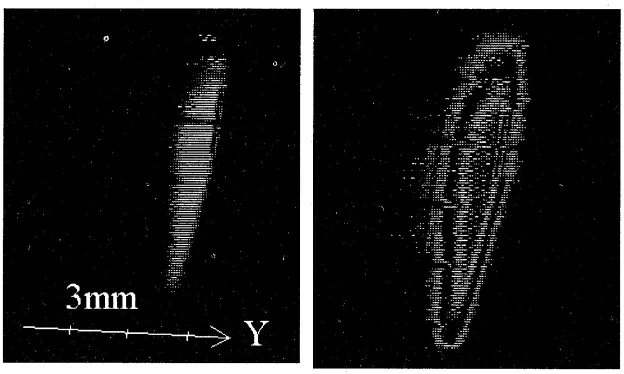

Fig.7. Beam profile images, the original image (Left) and the processed image (right)

4 Result and Discussion

In the analysis of the emittance the beam size is assumed to be the full width at half maximum of the distribution curves obtained as in Fig.6. The beam size can be estimated also from the beam profile image by the assumption that the brightness of the image is proportional to the beam intensity. The square of the beam size vs the quadrupole strength is plotted in Fig.8, where the curves are the approximate quadratic functions for the experimental values. In the fitting procedure on the data obtained from the beam profile, the data points at the maximum and minimum quadrupole strength are not included because the beam spread at these points is beyond the screen.

Fig.8 shows a discrepancy in the beam size dependence on the quadrupole strength between different methods of beam size measurement. Since the method of the wire scanner measures the values proportional to the primary electron beam current across the wire, the result is more reliable compared with the result obtained by means of the beam profile monitor.

In the case of the measurement of the horizontal beam emittance, the beam distribution showed a strange split peak. Therefore, the data for the horizontal beam size was not available for a proper estimation of the emittance.

The measurement has been performed at the electron energy of 93MeV. According to the beam transfer matrix theory, the dependence of the beam radius on the quadrupole strength has to be hyperbolic. We can estimate the normarized emittance from the electron energy and the variation of the beam size depending on the quadrupole strength [6]. This process is equivalent to the fitting procedure mentioned above. In the case of the wire scanner method, the deduced normalized emittance in vertical direction is 48.44±4.74πmm·mrad, however the result from the analysis of the beam profile gives 76.48±28.5πmm·mrad.

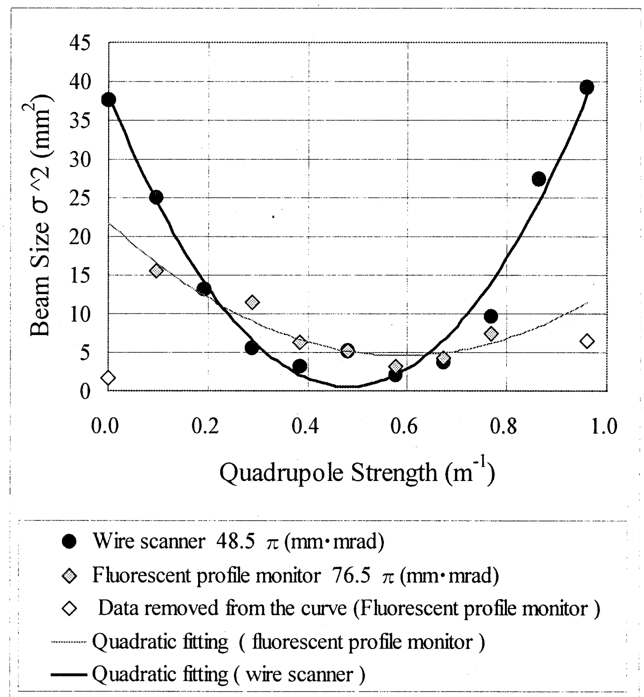

Fig.8. The square of the beam size to the quadrupole strength.

5 Conclusion

The transverse beam emittance for the 125MeV FEL linac has been estimated by different two methods. Although the results are not consistent, we can conclude that the result obtained by means of the wire scanner is more reliable than that by the fluorescent profile monitor. The normalized emittance in vertical direction was deduced as 48.5πmm·mrad. This value is reasonable as an emittance of the beam from the linac. However, it is not necessarily enough for application to FEL in the region of the visible light. For more accurate measurement of the emittance, the wire should be biased and a finer wire will be required.

References

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