Development of Analysis Program for Beam Transverse Profile and Emittance Measurements

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Abstract

Development of measurement procedure and analysis for studying particle beam properties is very important for the progress of particle accelerator technology. This research studies on measurements and analysis of transverse properties of electron beam from a linear accelerator at the Plasma and Beam Physics Research Facility, Chiang Mai University. The interested transverse electron beam properties are position, beam size, beam shape , beam profile and emittance. An analysis program has been developed based on the Microsoft Visual Studio 2013 tools. This program suit consists of three main parts. The first part uses an image processing to study the transverse size and the profile of electron beam image, which is recorded when the beam hits the fluorescent screen. The second part is the emittance analysis tool using in the quadrupole scan technique. The third part is the ellipse phase space. This program will be a useful and convenient tool for the user to analyze the measured transverse profile and emittance of electron beams.

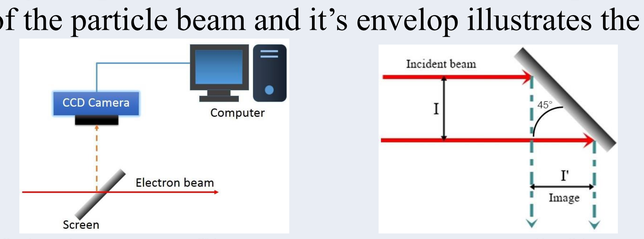
Introduction

Generation of reliable particle beams is a major key in successful operation of any accelerator and future light source. Investigation of the beam properties is one of the main issues in development of accelerator technology. In this research we develop a new software tool for analyzing the measurement data of the transverse properties. This tool is called the “Beam Emittance Analysis Tool (BEAT)”. It can be used to analyze the measurement data of the transverse beam profile and emittance of electron beam at the linear accelerator laboratory of the Plasma and Beam Physics research facility (PBP), Faculty of Science, Chiang Mai University.

Methodology

Beam profile measurement

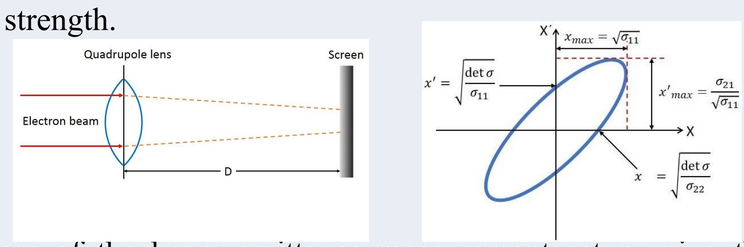
The beam image is measured by using a phosphor screen, CCD camera and a computer equipped with an image capture card. The transverse beam profile displays transverse intensity distribution of the particle beam and it’s envelop illustrates the transverse beam size.



A Schematic layout of the beam profile measurement system (left) and a schematic diagram of an image calibration system (right).

Beam emittance measurement

A quadrupole scan technique is used to measure the transverse emittance of the electron beam. The principle of this method is to measure the electron beam size as a function of the quadrupole field strength.

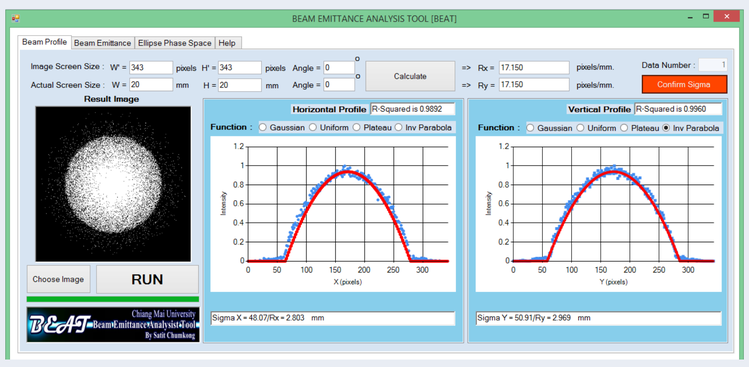


Schematic diagram of the beam emittance measurement setup using the quadrupole-scan technique (left) and a phase ellipse (right).

Results and Discussion

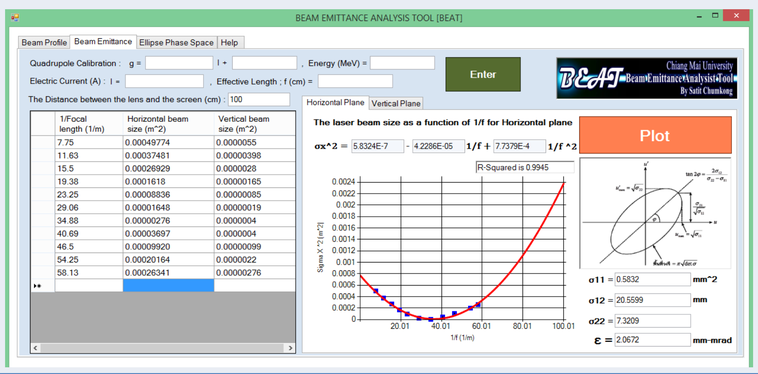
Beam profile analysis

The electron beam image on the phosphor screen is captured with the CCD camera. The recorded beam image is then be analyzed by the beam profile analysis application tool in BEAT. An example of the beam profile analysis result for the electron beam with the Gaussian distribution is shown in the figure. The actual beam profile distributions are plotted together with the fitted curves on the BEAT panel. This analysis procedure results in the horizontal and vertical beam sizes of 2.803 mm and 2.969 mm, respectively. The R-squared value of this fitting is 0.9892 and 0.9960.



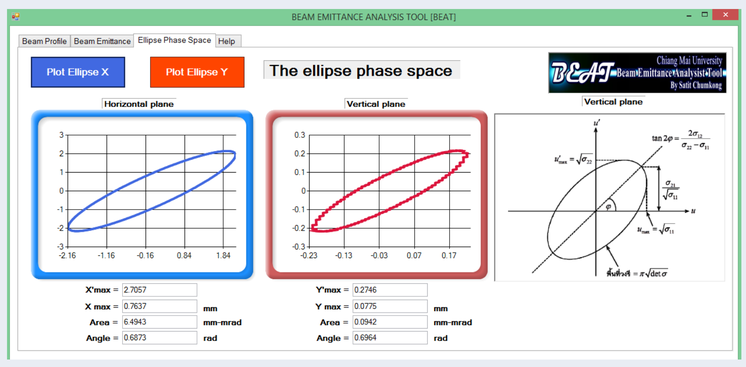
Beam emittance analysis

In the emittance measurement by using the quadrupole scan technique, several beam images are captured for a given focal lengths. The program calculates beam sizes for all quadrupole focal lengths and plots these data on the emittance measurement chart. The beam emittance value and the beam matrix elements are then extracted from the emittance measurement chart by performing the 2nd order polynomial fitting. An example of the analysis of the emittance measurement. In show in the following figure. The BEAT program estimates the geometrical emittance value from this measurement to be 2.0672 mm-mrad.



Ellipse phase space

From Liouvill’s theorem provides a powerful tool to describe a beam in phase space for any transport line. It says that we can determine the location and distribution of the beam without knowing information of every individual. It is easy and customary to describe the collection of electrons in the beam by an ellipse in phase space called phase ellipse . In show in the following figure. From the beam matrix elements and the beam emittance value. We can calculate and fitting ellipse phase space chart by using The BEAT program. And we get important values such as angle of Horizontal plane and Vertical plane is 0.6873 and 0.6964.



Conclusion

The Beam Emittance Analysis Tool (BEAT) has been developed to obtain the transverse beam profile and to calculate the beam size and beam emittance as well as to construct the ellipse phase space. Six algorithms can be used for analysis of the beam profile distribution including the most used Gaussian distribution. This tool can be used in the measurement of the beam emittance via the quadrupole scan technique. By modifying the transfer matrix, the tool can also be applied in the emittance measurement with the solenoid scan method. The BEAT tool simplifies and speeds up the measurements of the electron beam profile, beam size and beam emittance. This will contribute to the great progress in the development of the diagnostic system of the electron linear accelerator laboratory at Chiang Mai University. Nevertheless, it can also be used in other particle accelerator facilities.

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