HIGH BRIGHTNESS ELECTRON GUN FOR X-RAY SOURCE

S. Ohsawa†, M. Ikeda, T. Sugimura, M. Tawada, High Energy Accelerator Research Organization (KEK), Tsukuba, Japan
Y. Hozumi, The Graduate University for Advanced Studies (GUAS), Tsukuba, Japan
K. Kanno, AET Japan Inc., Kawasaki, Japan

Abstract

A new electron-gun system is under development in order to increase X-ray brightness from a rotating target. In commercial X-ray generators, electron beams usually hit targets at the outer part. Owing to deformation by centrifugal force, there has been a limit on electron beam intensities. In order to overcome this difficulty, we proposed a new system that strongly focuses electrons on a rotating target to strike inside of a ring-shape projection. It has an advantage in that heated-up points have supports back side against centrifugal force. It is expected that this merit makes it possible to raise beam intensity to give stronger X-rays with higher brightness. The experiment with a beam has been performed recently. The first result is reported.

INTRODUCTION

Prof. Noriyoshi Sakabe has proposed a new method that strikes a rotating anode of an X-ray generator from the inside. Since it requires a new electron gun, however, he asked our technical assistance. We studied his beam specifications, which suppose a beam-spot size of 1.0 x 0.1 mm^2 on the anode target for a 60 keV, 300 mA electron beam. We studied and proposed a system that has short and strong focusing, which will be realized by utilizing a fringing field of a 180 degree bending magnet with other focusing magnets such as a magnetic lens and a quadrupole magnet. In order to confirm experimentally the performance of the new injection and focusing system, we have made first beam tests recently, and measured beam sizes on a fixed target by means of an X-ray pinhole camera. Pulsed beams of 1 μs duration were used to avoid problems due to heat generation. We present the first results, which are showing considerable promise as a high brightness X-ray source.

SYSTEM CONFIGURATION

The overall view of the apparatus used in the present experiment is illustrated in Fig.1. Electrons emitted from a 10 mm diameter cathode and accelerated to 60 keV are collimated at a 3 mm diameter hole, and are focused on a target after being bended by 180 degrees. Vertical focusing is more important to get a small size such as 0.1 mm on the target. We adopted a method that uses a fringing field of a bending magnet in order to obtain a strong and short focusing force, which can be adjusted by changing an injection angle by a steering magnet. A Q-magnet is introduced to match with a quadrupole element of the bending magnet, and to makes them a Q-doublet for getting smaller sizes in both directions horizontally and vertically.

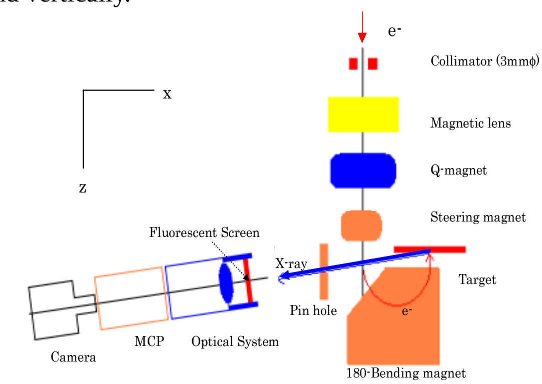

Figure 1: System configuration of main components. An electron beam is focused on a target after being bended by 180 degrees. A pinhole camera measures the beam size on the target.

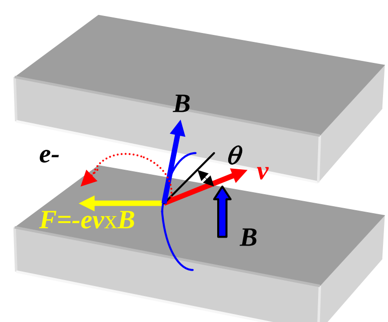

Figure 2: Relation between an injection angle θ and a vertical focusing force produced by a fringing field $\boldsymbol{B}$.

SIMULATION

We simulated beam trajectories for the system shown in Figure 1 with the code GPT. The results are presented in Figures 3a, 3b and 4. For simplicity, we assumed that electrons were emitted from a photo cathode of 3 mm diameter instead of the real configuration in the Figure 1.

The beam is firstly focused weakly by the magnetic lens, then defocused vertically by the Q-magnet, and finally focused strongly by the fringing field of the bending magnet. The steering magnet plays an important role in adjusting the injection angle θ. The simulations predict that the beam sizes on the target meet barely the requirements of 1.0 mm x 0.1 mm if the beam emittances are low enough.

†satoshi.ohsawa@kek.jp

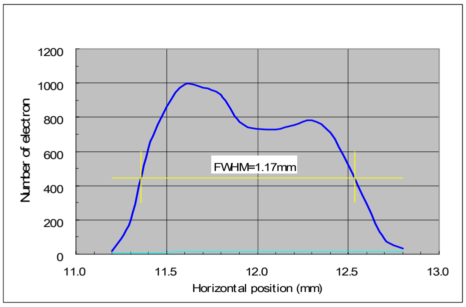

Figure 3a: Horizontally projected beam distribution on the target.

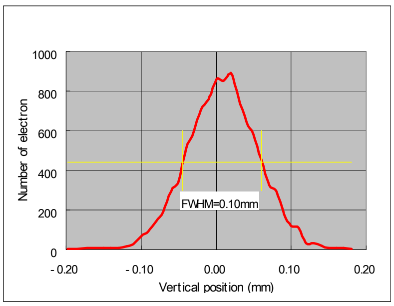

Figure 3b: Vertically projected beam distribution on the target.

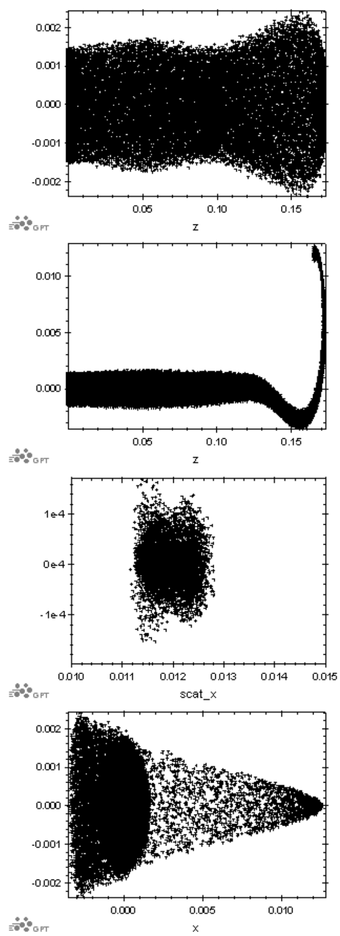

Figure 4: Beam trajectory simulation from an electron gun to the target.

BEAM SIZE MEASUREMENT

Electrons rotate horizontally in the flat chamber (Fig.5a) counter clockwise, and strike a fixed copper target (Fig.5c) that is installed through a mini flange in the right side of the chamber. The target has a function of a beam current monitor. It is a good sensor for roughly adjusting the focusing system.

Figure 5a: Flat chamber for 180-degree bending magnet.

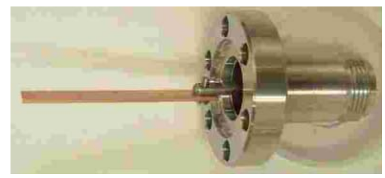

Figure 5b: Be window. Figure 5c: A fixed target.

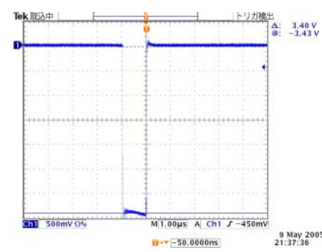

Figure 6: A pulse shape of a 1μs beam operated at 20Hz. The beam current was 68mA as can be reduced from the value on the picture.

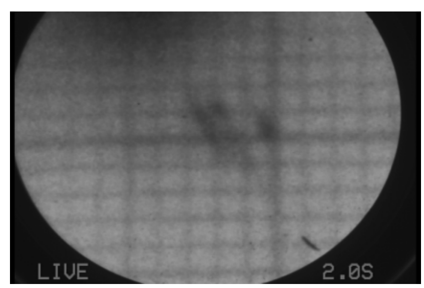

Figure 7a: Picture of a graph paper ruled into 1-millimeter squares observed by a pinhole camera.

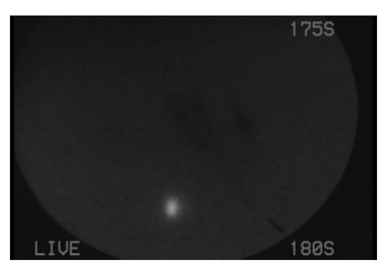

Figure 7b: Typical beam spot observed by a pinhole camera.

0-7803-8859-3/05/$20.00 ©2005 IEEE

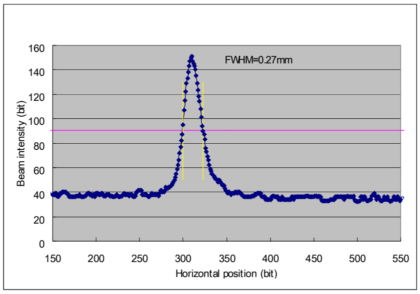

Figure 8a: Horizontal cross section of a beam spot observed by a pinhole camera.

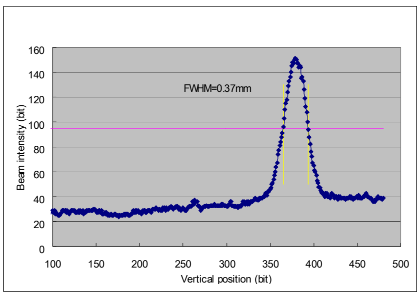

Figure 8b: Vertical cross section of a beam spot observed by a pinhole camera.

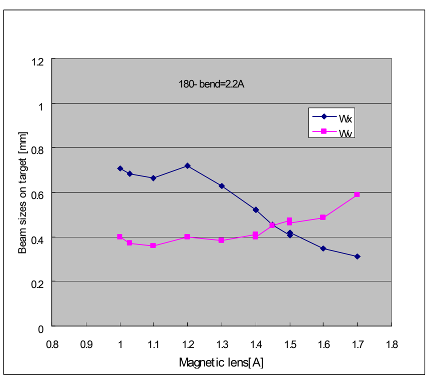

Figure 9a: Beam sizes versus magnetic-field strength.

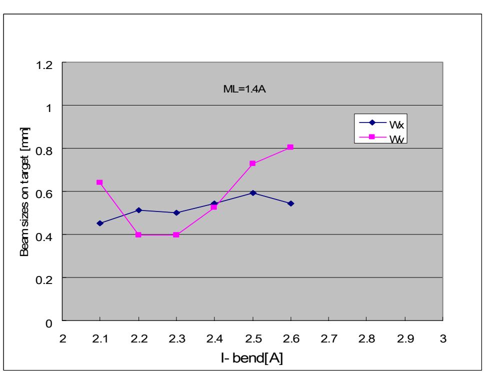

Figure 9b: Beam sizes versus bending magnet magnetic-field strength.

At a mini flange in the left side, there is a beryllium widow, on which a pinhole collimator of 100 μm diameter is set. X-rays passed through the hole hit a fluorescent screen and make a beam image, which is observed by a dark field camera after being intensified by MCP. On the backside of the fluorescent screen, there is a graph paper ruled into 1-millimeter squares (Fig. 7a). It is useful to focus the optical system and also to calibrate the observed sizes.

Beam size behaviours are shown in figures 9a and 9b versus field strengths of the magnetic lens and the bending magnet, respectively. Information on focus or defocus near the target is presented in figures 9c and 9d for different cases. Each data can be interpreted consistently that the injection angle is inadequate.

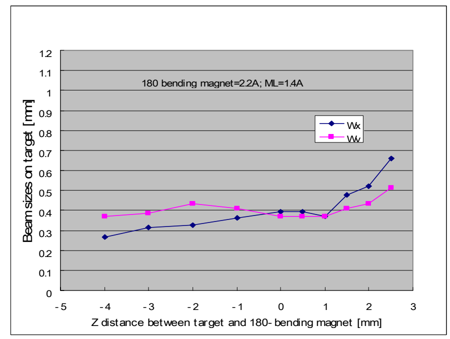

Figure 9c: Beam-sizes measured in the region near the target. Vertical focusing is week. (θ~0)

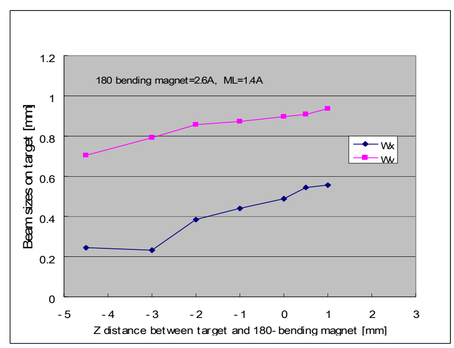

Figure 9d: Beam-sizes measured in the region near the target. The beam is vertically defocused. ($\theta < 0$)

SUMMARY

Measured data are showing that in many cases, electron beams are injected into the fringing field of the 180 degree bending magnet at an injection angle θ<0, in which case beams are defocused in the vertical direction.

It seems to be obvious that beams will be properly focused vertically if we deflect beams stronger in rightward before injecting into the fringing field so that the injection angle θ becomes positive. Then the beam spot sizes will be expected to become as small as 1.0 mm x 0.1 mm, which is our goal for a beam of 300 mA.

ACKNOWLEDGEMENTS

We would like to thank Prof. Noriyoshi Sakabe for advising X-ray measurement and supplying a device.