SPATIAL RESOLUTION AND CONTRAST OF THE INTENSITY MODULATED ELECTRON BEAM BY THE PHOTOCATHODE RF GUN FOR THE RADIATION THERAPY

T. Kondoh#, J. Yang, Y. Yoshida, H. Kashima, K. Kan, K. Norizawa, A. Ogata, S. Tagawa
The Institute of Scientific and Industrial Research, Osaka University,
Mihogaoka 8-1, Ibaraki, Osaka 567-0047, JAPAN

Abstract

The radiation therapy of cancer is developing to un-uniform beam irradiation as the Intensity Modulated Radiation Therapy (IMRT), for reduce dose to normal tissue. Toward the IMRT, optical modulation of electron beam is studying by a photocathode RF gun. The photocathode RF gun can generate a low emittance electron beam by laser light. Because of the low emittance beam, the modulated electron beam is able to accelerate keeping shape. Electron beam were monitored by CCD cameras measuring the luminescence of the scintillator. Fundamental data such as the spatial resolution, image rotation and the contrast of the modulated electron beam are necessary. The image rotation of the Modulated electron beam in the Photocathode RF Gun was measured. This rotation may be caused by magnetic field of the solenoid with the photocathode RF gun. This rotation of the electron beam is reported here.

INTRODUCTION

At present, many people die by cancer. The Radiation therapy is developing remarkably as one of the cancer therapies in recent years. As for the radiation cancer therapy, when radiation beam is irradiated on cancer tissue, also normal tissue and scarfskin are irradiated, these become problems. When side effects are strong, the Quality of life of patients decreases. The radiation therapy of cancer is developing for reduce dose to normal tissue and concentrate dose to cancer tissue.

The latest X-ray cancer therapy used un-uniform X-ray irradiation such as the Intensity Modulated Radiation Therapy (IMRT). Present IMRT is explained here. Electron beam which was accelerated by a small LINAC is irradiated to a metal target and that is converted into uniform X-ray. The shape and intensity of X-ray are modulated by a multi leaf collimator. The multi leaf collimator is made by many small metal pieces and moving mechanically. And those metal pieces stop and reduce intensity of X-ray. By turning and rotating the accelerator, it can irradiate from multi-direction and it reduces dose to the scarfskin and the normal tissue. It becomes a safe irradiation method to the normal tissue. The X-ray therapy equipment which used an electron beam LINAC can become popular since it is small and cheap comparatively.

The photocathode RF gun was able to generate a low emittance electron beam pulse using a laser light pulse. We thought that the photo cathode RF gun can generate intensity modulated electron beam by optical modulation at the incident optics system. Because of a low emittance, the modulated electron beam pulse was able to accelerate keeping shape.

Electron beam were monitored by CCD cameras measuring the luminescence of the scintillator. Fundamental data such as the spatial resolution, image rotation and the contrast of the modulated electron beam are necessary. The image rotation of the Modulated electron beam in the Photocathode RF gun was measured.

Electron beam image which shaped by photo-masks were rotated in the monitored image between laser image on virtual cathode screen and electron image at the exit of electron gun, shown in Figure1. This rotation of the electron beam was measured and was reported here.

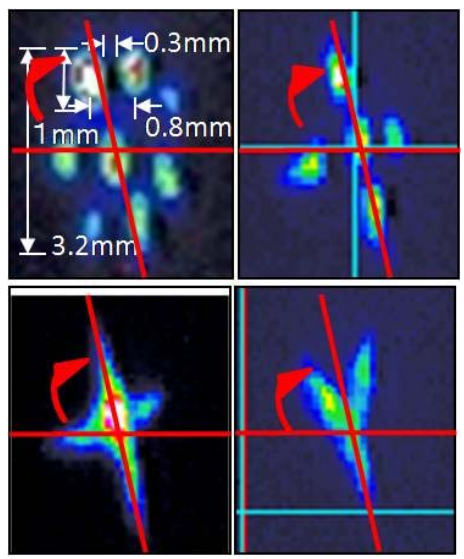

Figure 1: The image rotation was observed in the spacial modulated electron beam at the exit of the electron gun

t-kondo@sanken.osaka-u.ac.jp

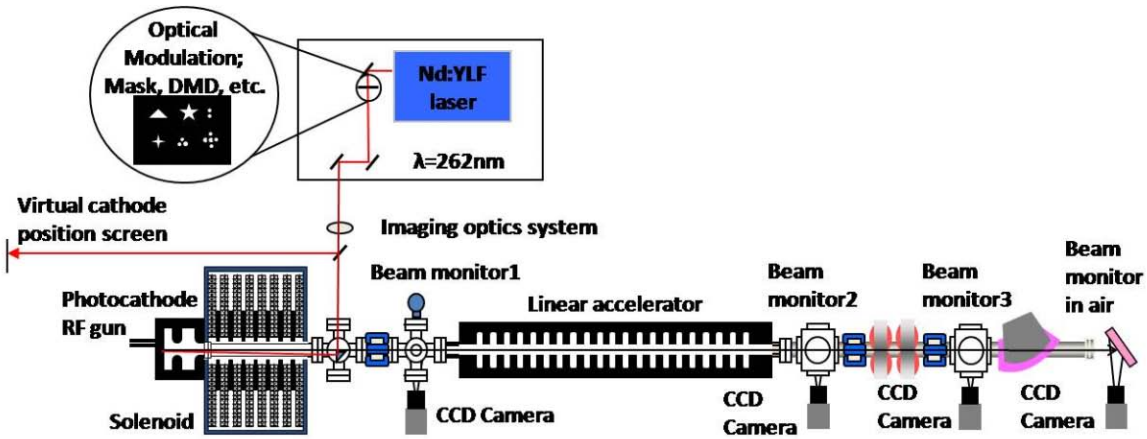

Figure 2: The Laser photocathode RF Gun Linac with optical modulation system in the ISIR, Osaka University.

EXPERIMENTAL

Electron beam were generated by the laser photo-cathode RF gun S-band LINAC at the Institute of Scientific and Industrial Research, Osaka University.

Experimental equipments are shown in Figure 2. This photo-cathode was made of Oxygen-Free Copper. Fourth harmonic generation (FHG: 262nm) of Nd: YLF laser (Timebandwidth) with 5ps pulse duration was injected into a photo-cathode perpendicular toward a cathode surface. Photo-masks were used for the shaping of an incident laser light as the most basic optical processing. Some images on photo-masks were transported to the cathode surface by optical relay imaging. Electron was generated by photo- electric effect on the copper surface. Maximum acceleration electric field which was operated by 2856MHz RF reached 100 MV/m at the cathode surface. Electron beam which generated at the cathode surface was accelerated immediately to 4MeV in a 1.6 cell RF cavity. Therefore, the expanse of the electron bunch by coulomb repulsion force among electrons was small in comparison with a thermionic electron gun.

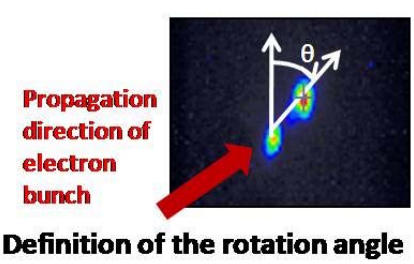

Figure 3: Definition of the rotation angle of electron beam image on the scintillator.

A coaxial solenoid was arranged to compensate emittance growth of the electron beam at downstream of the electron gun. This solenoid was very important for imaging of the electron beam. Electron beam was accelerated up to 32MeV by an accelerating tube in the downstream of solenoid. The Normalized transverse emittance was 3mm-mrad at 1nC.

The electron beam was monitored by measuring the luminescence of the scintillator (Demarquest AF995R) with an ordinary CCD camera. Captured images processed by computer, low intensity area become blue and high intensity region expressed by red.

The rotation angle (θ) of electron beam image on the scintillator was defined as a Figure 3. In the Electron beam image looked from upper stream, the angle between a plumb direction and the direction that links two spot. The detail of the Photo-cathode RF gun LINAC in the ISIR was already reported in ref [1].

RESULTS AND DISCUSSIONS

The 4th harmonic generation of the Nd:YLF picosecond laser which was processed by the various photo masks were injected into the photocathode shown in Figure1. Various photo masks were used, such as two holes, triangle, cross type, multi holes, etc. In Figure 1 left side, eight spots electron beam and cross shape electron beam was observed at exit of the electron gun.

Since original laser intensity distribution was the Gaussian distribution, it thinks that the centre of the shaped electron beam became strong. Total size of processed electron beam was about 3.2mm. Spatially separation of a spot to a spot at the exit of the gun is about 0.3mm. One spot size was about 1mm.

If we find the early stage cancer less than 1 mm, it is possible to be cured. The best resolution of the current commercial CT is about 0.5mm. The spacial resolution of

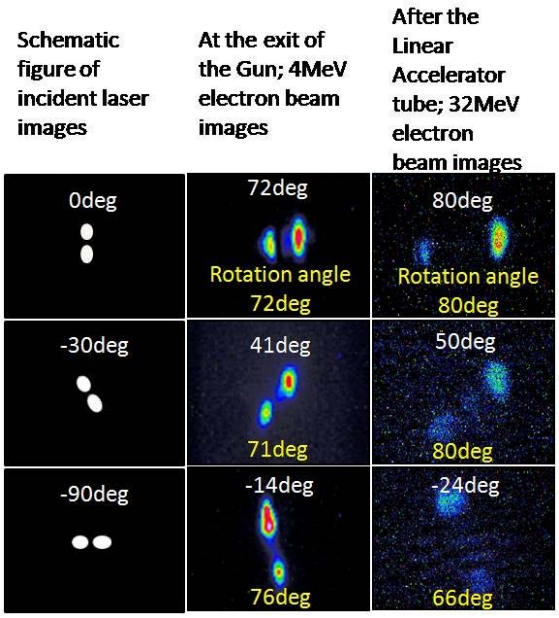

Figure 4: Measurement of the rotation angle of electron beam image at the exit of electron gun and after the linac tube.

the intensity modulated electron beam is approximately equal with this. Shaped electron beam had fine spatially resolution enough to use radiation therapy.

The electron beam image of figure 1 was slanted only the same angle. It seems to turn when it was compared with the image of the incident laser at the cathode equivalent position. The rotation angle of the shaped electron beam image of two spots was measured.

We defined a rotation angle as Figure 3.The angle between the straight line to link two spots of the electron beam image and the plumb direction was measured in the view point of electron gun side. A rotation angle was estimated from the difference of the angle of the electron beam and the angle of the incident laser. As a result, the rotation angle was about 70 degrees at the exit of the electron gun. It did not turn from the exit of the electron gun to the exit of the linear acceleration tube. It is thought that this rotation was caused by magnetic field of the co-axial solenoid downstream of the photocathode RF gun.

Schematic figure is shown in Figure 5. An electron propagation direction is blue, and a solenoid magnetic field is green, and Lorentz force is shown with orange. The radius vector direction ingredient of the solenoid magnetic field is regarded as the cause of the turn of the electron beam image

SUMMARY

For the Optical IMRT (Intensity Modulated Radiation Therapy), we are developing a new system of optical modulation of electron beam by the photocathode RF gun. Electron beam image which shaped by photo-masks were rotated in the monitored image between laser image on virtual cathode screen and electron image at the exit of electron gun. The two spots electron beam was used for measurement of rotation angle. This rotation angle was about 70 degree. This rotation would be caused by magnetic field of solenoid in the electron gun.

REFERENCES

[1] J. Yang, T. Kondoh, K. Kan, T. Kozawa, Y. Yoshida, S. Tagawa, Nuclear Instruments and Methods in Physics Research A 556(2006)52-56

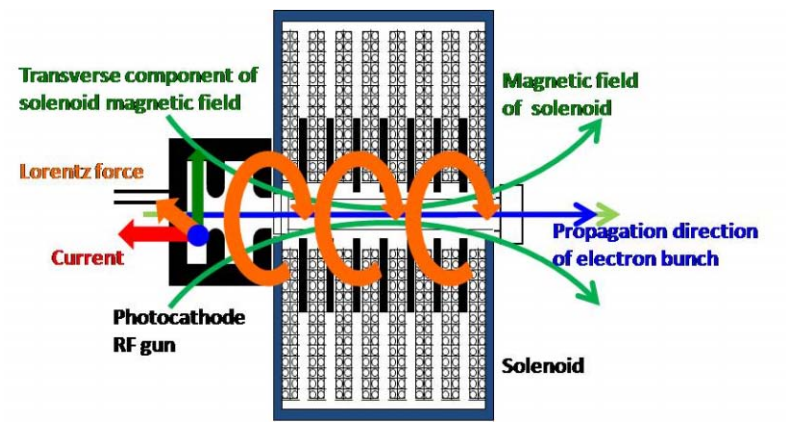

Figure 5: Magnetic field of solenoid and the Lorentz force around the photocathode electron gun.