COMPARISON OF ASTRA SIMULATIONS WITH BEAM PARAMETER MEASUREMENTS AT THE KAERI ULTRASHORT PULSE FACILITY

H. W. Kim[#,1,2], K. H. Jang[1,2], Y. U. Jeong[1,2], Y. Kim[1,2], K. Lee[1,2], S. H. Park[1,2], N. Vinokurov[1,2,3], S. V. Miginsky[1,2,3], I. Baek[1], M. Chae[1], B. Gudkov[1], B. Han[1], S. Park[1], S. Setiniyaz[1]
[1]KAERI, Daejon, Republic of Korea
[2]UST Acceleartor and Nuclear fusion physics engineering, Daejon, Republic of Korea
[3]Budker INP SB RAS, Novosibirsk, Russia

Abstract

An RF-photogun-based Linear accelerator for ultra-short electron beam generation is under construction at Korea Atomic Energy Research Institute (KAERI) [1]. This facility are mainly composed of an 1.5 cell S-band (2.856 GHz) RF gun, a travelling wave type linac 3m long and 90-degree achromatic bends.

We have performed computer simulation using ASTRA code to investigate the electron beam dynamics in the system with the input data of bead tested gun electric field distribution and the magnetic fields of the magnets [2]. We will present the simulated and experimental electron beam parameters.

INTRODUCTION

Ultrafast electron diffraction (UED) [3-7] are powerful tools for the study of the time-resolved molecular structure and material science. The UED can reveal inter-nuclear coordinates with high temporal and spatial resolution, therefore observing a change of structure on ultrafast time scale with milliangstrom accuracy.

Figure 1 shows the schematics of experimental setup for relativistic UED at KAERI. The UED beamline is designed to provide electron beams with low emittance and ultrashort pulses. The emitted electron beams are accelerated in high RF field to ~ 3 MeV. The electron beams can be deflected by a first bending magnet installed right after the RF gun. Each beamline has second bending magnet similar to the first one and three quadrupole magnets between the bending magnets. Two bending and three quadrupole magnets compose the 90-degree achromatic bend. The deflected electron beams will be used for UED experiments.

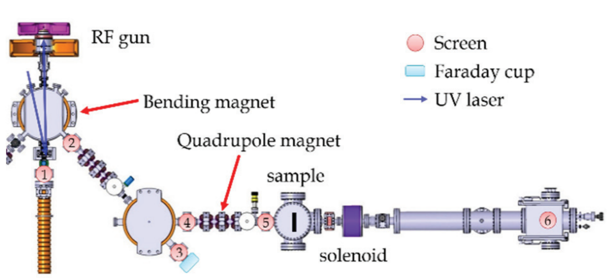

Figure 1: Schematic diagram of UED beamline at the KAERI and experimental setup.

#khw8412@kaeri.re.kr

We measured field distributions of all components and we simulated beam dynamics using measured field distributions.

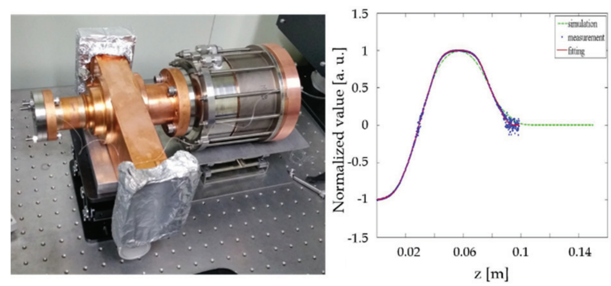

Figure 2: Photo of experimental setup for bead test and measured field distribution.

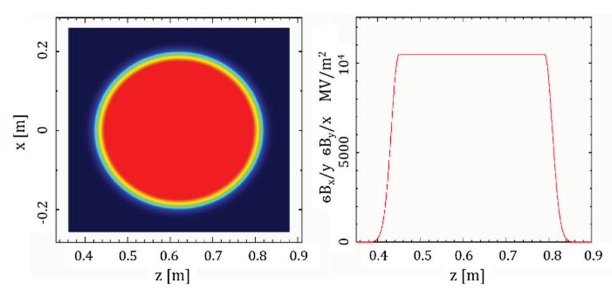

Figure 3: Magnetic field distribution of the 45-degree bending magnet.

Figure 2 shows experimental setup for bead test (left) and measurement data. The RF photogun has a coaxial coupler, which provide axisymmetric accelerating field.

Figure 3 shows magnetic field distribution of a 45-degree bending magnet. The shape of bending magnet is round which has horizontal focusing properties and simplifies alignment because of input and output directions cross in the centroid of the magnet. To achromaticity and isochronism UED beamline contains a second 45-degree bending magnet and three quadrupole lenses. The quadrupole lenses have square yoke (see Fig. 4). The manufacturing and assembly have been simplified.

We have performed computer simulation using ASTRA code to investigate the electron beam dynamics in the system with the measured field data.

ISBN 978-3-95450-134-2

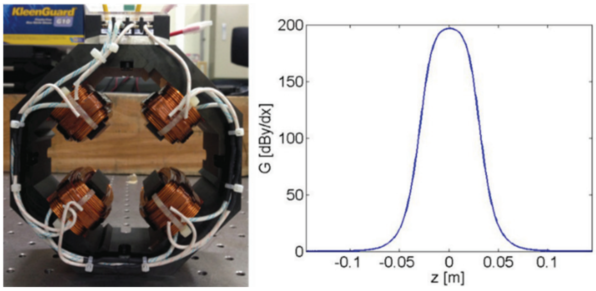

Figure 4: Photo and focusing field distribution of quadrupole lens.

COMPARISON OF SIMULATIONS WITH MEASUREMENTS

The electron beam is emitted from the copper cathode by a third harmonic of a Ti:Sapphire femtosecond laser (267 nm). The transverse and longitudinal profile of the laser both are Gaussian. A main solenoid with bucking coil is installed around the RF gun for suppress beam blow up due to space charge force.

The first electron beam has been generated on March and further optimization is in progress. Figure 5 shows a dark current image at the screen1 (see Fig. 1.).

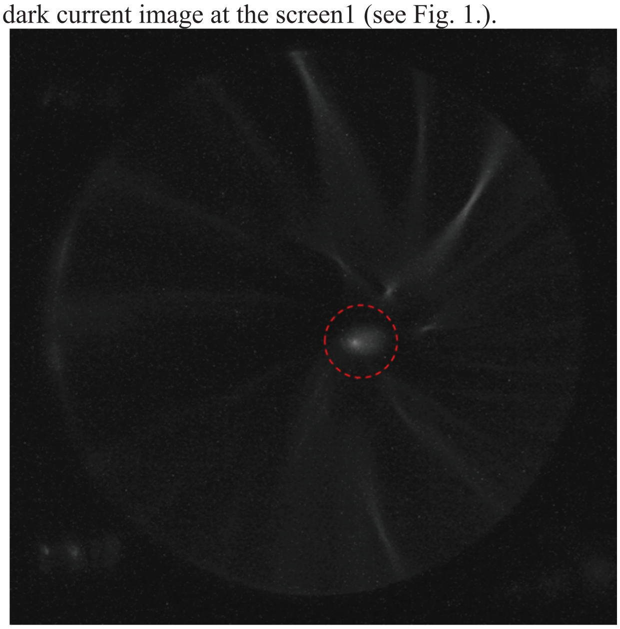

Figure 5: An electron beam image (red dot circle) with a dark current at the screen1.

The beam energy measured using the first 45-degree bending magnet. The momentum p is given by

$$p = 0.2998\mathrm{B}\rho,$$

where B is a magnetic field of bending magnet and ρ is a bending radius. The charge was measured at the screen3 (see Fig. 1.) by using a Faraday cup. We measured beam parameters varying a laser injection phase when a maximum energy gain is 0-degree. The measurement results as function of the laser injection phase are shown in Fig. 6. The blue dot line indicates a measured total energy and red line indicates a simulated total energy. The green line indicates the charge with 1 μJ laser and purple line indicates the charge with 0.4 μJ laser. The dark current is almost removed after the first bending magnet because of the energy of dark current is lower (2~2.5 MeV) than main beam. The ratio of dark current to main beam is 1.5% and the quantum efficiency of cathode is 1.2×10^{-5}.

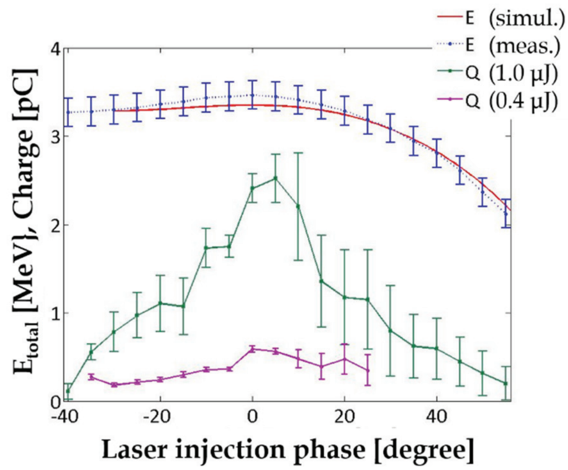

Figure 6: The measurement results of total energy and charge as function of a laser injection phase.

The energy spread estimated by using equation as follows,

$$\sigma_{S2} = \sqrt{\sigma_{S1} + \left(\eta \frac{\Delta E}{E}\right)^2},$$

where σ_{S1} is a rms beam size at the screen1, σ_{S1} is a rms beam size at the screen2 (just after the first 45-degree bending magnet) η is dispersion and $\Delta E/E$ is the energy spread. The estimated energy spread was 0.3%.

The emittance was measured at the screen5 (see Fig. 1.) by using the quadrupole scan technique [8]. The dispersion is compensated by three quadrupole lenses between two bending magnets. The dispersion compensation was checked to focus beam horizontally, as shown in Fig. 7.

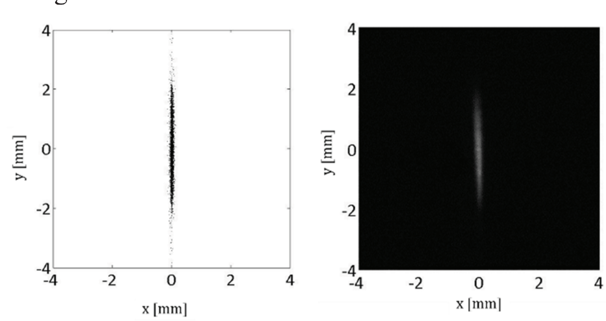

Figure 7: The simulated (left) and experimental (right) beam image at the screen5.

The experiment conditions were used initial value for simulation. It is summarized in Table 1.

ISBN 978-3-95450-134-2

Table 1: Experimental Condition and Initial Parameters for Simulation.

Experimental condition	
Laser pulse power	~ 0.5 μJ
Laser spot size	0.5 mm
Laser pulse length	130 fs
Quantum efficiency	10^{-5}
E_{z_peak}	61 MV/m
Solenoid current	0.205 T

The measured horizontal and vertical normalized emittance were 0.33 mm-mrad and 0.5 mm-mrad, respectively. The simulated horizontal and vertical normalized emittance were 0.31 mm-mrad and 0.28 mm-mrad, respectively. We assume that a difference of vertical emittance is un-uniformity of cathode surface, as shown in Fig. 8.

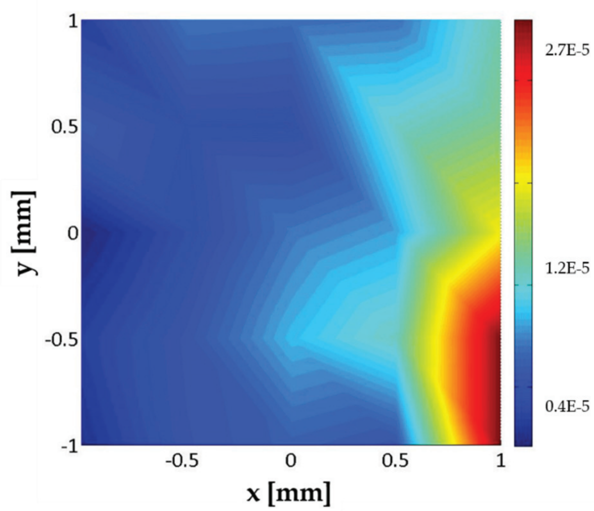

Figure 8: Quantum efficiency map of cathode at the UED beamline.

CONCLUSION

The first beam generation has succeeded in March this year. Baking and aging of the RF photogun and solenoid are in the march. We measured a beam energy, energy spread, charge and emittance. The experimental data and simulation data has showed a little different results. The differences between simulation and experiment might be misalignment of RF photogun, solenoid and the un-uniformity of cathode surface. We will align all components precisely and will try to get UED pattern.

REFERENCES

[1] N. Vinokurov, et al., in: Proceedings of the Free Electron Laser Conference 2013, New York, 2013, pp. 287.
[2] K. Floettmann, A Space Charge Tracking Algorithm ASTRA, http://www.desy.de/~mpyflo/
[3] X.J. Wang, et al., J. Korean Phys. Soc. 48 (2006) 390.
[4] J.B. Hastings, et al., Appl. Phys. Lett. 89 (2006) 184109.
[5] P. Musumeci, J.T. Moody, C.M. Scoby, Ultramicroscopy 108 (2008) 1450.
[6] R.K. Li, et al., Chin. Phys. C 33, Suppl. II. To appear.
[7] J. Yang, et al., Nucl. Instr. and Meth. A 637 (2011) S24.
[8] S. Setiniyaz et al., in: Proceedings of the Free Electron Laser Conference 2015, Daejeon, 2015, MOP063.

ISBN 978-3-95450-134-2