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

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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-
dergree achromatic bend. The deflected electron beams 
will be used for UED experiments.

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

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-
dergree bending magnet.

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

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

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

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

$$p = 0.2998B\rho,$$

where $B$ is a magnetic field of bending magnet and $\rho$ 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 $\mu$ laser and purple line indicates the charge with 0.4 $\mu$ 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 $1.2\times10^{-5}$.

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

where $\sigma_{S1}$ is a rms beam size at the screen1, $\sigma_{S1}$ is a rms beam size at the screen2 (just after the first 45-degree bending magnet) $\eta$ 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.

The experiment conditions were used initial value for simulation. It is summarized in Table 1.
Table 1: Experimental Condition and Initial Parameters for Simulation.

<table>
<thead>
<tr>
<th>Experimental condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser pulse power</td>
<td>~ 0.5 µJ</td>
</tr>
<tr>
<td>Laser spot size</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Laser pulse length</td>
<td>130 fs</td>
</tr>
<tr>
<td>Quantum efficiency</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>$E_z$ peak</td>
<td>61 MV/m</td>
</tr>
<tr>
<td>Solenoid current</td>
<td>0.205 T</td>
</tr>
</tbody>
</table>

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