ANALYSIS OF BEAM STABILITY IN THE KAERI ULTRASHORT PULSE ACCELERATOR

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Abstract

An RF-photogun-based linear accelerator for the Korea Atomic Energy Research Institute (KAERI) ultra-short pulse facility is under construction [1]. It has a symmetry structure with four different beamlines. The UED beamlines will generate ultra-short electron pulses with over 10^6 electrons per pulse for the single-shot measurements on femtosecond dynamics of atomic or molecular structures. Electron bunches with an energy of ~3 MeV from the RF photogun can be compressed up to less than 50 fs by achromatic and isochronous bends. The intrinsic r.m.s. timing jitter of the pulses through the bends is estimated to be less than 30 fs with the r.m.s. energy fluctuation of 0.1%. In the THz pump and X-ray probe beamline, two successive laser pulses with a time interval of ~10 ns are used to generate two electron bunches having more than 100 pC bunch charges. Two electron bunches are accelerated by a linac up to ~25 MeV and separated into individual beamlines by a fast kicker.

INTRODUCTION

The KAERI ultra-short pulse accelerator consists of a 1.5-cell S-band (2856 MHz) RF photogun and a 3-m-long travelling-wave-type linac. The scheme of the facility is shown in Fig. 1.

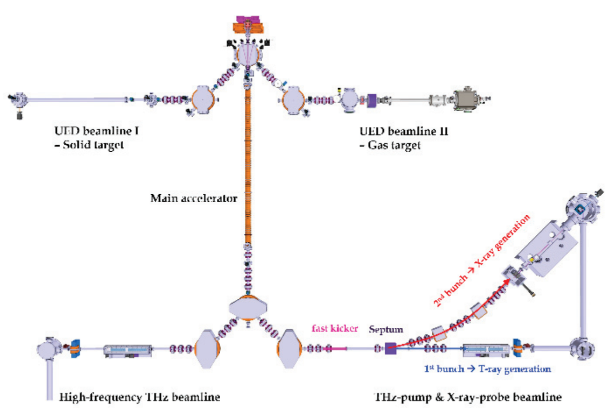

Figure 1: Scheme of the facility.

This facility can be operated in high repetition rate (maximum 500 Hz) and it will provide the ultrafast electron diffraction (UED) and pump-probe experiments to various users. The beam dynamics in the KAERI ultra-short pulse accelerator have been calculated with code ASTRA [2] and ELEGANT [3].

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UED BEAMLINE

A third harmonic of a Ti:sapphire femtosecond laser, with a 200-fs-pulse full width at half maximum (FWHM) and the RF photogun are used to generate femtosecond electron bunches. The simulated beam parameters are listed in Table 1.

Table 1: Simulated UED Beam Parameters

Bunch charge	1 pC
Beam energy	2.6 MeV
Bunch length (FWHM)	< 50 fs
Norm. Emittance	0.3 mm mrad
Energy spread (r.m.s.)	0.3%

The power supply usually have overall stability about 10~100 ppm. It is causative of magnet errors. Two bending magnets and six quadrupole magnets comprise the UED beamline. The effects of the magnet errors estimated with an accuracy of the power supply of 0.1% (r.m.s.), are shown in Fig. 2 and Fig 3.

The time resolution of UED depends on the bunch length and timing jitter. The timing jitter depends mostly on the time of flight of the electron bunches from the RF photogun to the sample. MeV UEDs [4-7] are built in all over the world. All they have straight beamline. By comparison, KAERI facility is longer than the other facility but it is expected to have low timing jitter because of the 90-degree achromatic and isochronous bend. We estimate the timing jitter, which is caused by the energy fluctuation at the sample when the electron beam has 0.1% of the energy fluctuation, are shown in Fig. 4. The calculated r.m.s. timing jitter with the isochronous bend (red) is 16 fs, and that with the straight beamline (green) is 54 fs.

BEAM SEPARATION

Two bunches of electron generated at about 10 ns intervals by the RF photogun are accelerated to 25 MeV in the same linac. After that, two bunches are separated into individual beamlines by a fast kicker.

Two bunches are vertically deflected by the steering coil. The first bunch is deflected downward about 10 mm after traveling 0.92 m of drift space. It goes straight for generating intense terahertz pulse.

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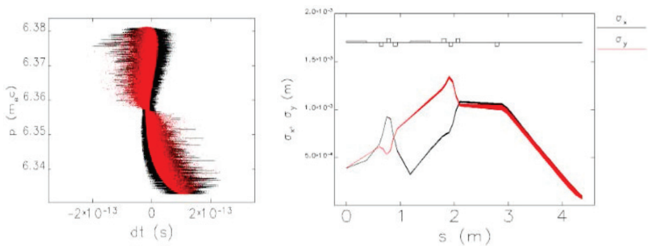

Figure 2: Longitudinal phase space (left) and beam size (right) change due to magnet errors.

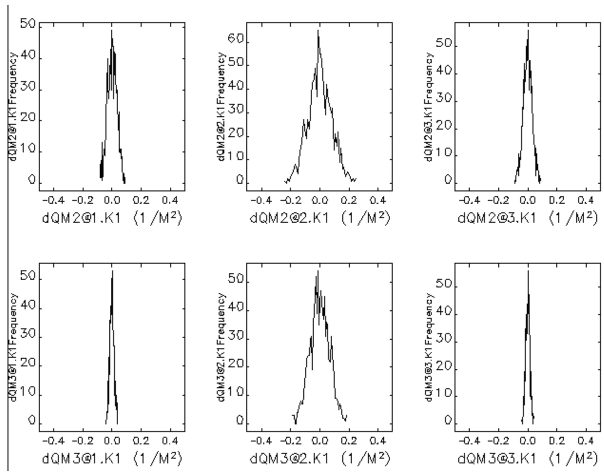

Figure 3: Variation of quadrupole strengths by power supplies with a fluctuation of 0.1%.

After 10 ns the second bunch is kicked upward by the fast kicker. The length of kicker is 0.5 m and the bending angle is 1.7°. The two bunches have a 20 mm vertical distance in front of a septum and the second bunch is deflected to horizontal direction by the septum magnet. The septum has a 0.2 m length and 15° bending angle. The achromatic bend of the two-bunch beamline consists of the septum, a rectangular dipole, and a triplet. The second bunch is focused to the metal target for generating an x-ray pulse by a triplet after the achromatic bend.

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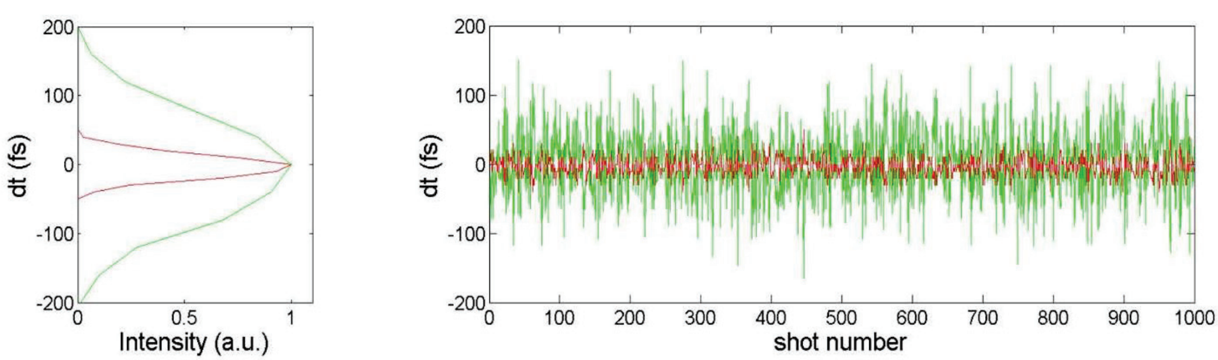

Figure 4: Calculated timiing jitter (red – in a 90-degree achromatic and isochronous bend, green – straigth beamline) at the target when the beam has 0.1% of an energy fluctuation. (without space charge effect).

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