PROJECT OF THE SHORT PULSE FACILITY AT KAERI*

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Abstract

A low-energy electron accelerator with subpicosecond electron bunches is under construction at the Korea Atomic Energy Research Institute (KAERI). It will serve as a user facility for high-energy ultrafast electron diffraction and synchronized high-power terahertz pulse and short x-ray pulse generation. The accelerator consists of an RF gun with a photocathode and 20-MeV linac. The bunching of an accelerated beam is achieved in a ninety-degree achromatic bend. After that, a fast kicker deflects some of the bunches to the target for x-ray generation, and other bunches come to the terahertz radiator (undulator or multifoil). Bunches from the RF gun are also planned for use in ultrafast electron diffraction. Some details of the design, current status of the project, and future plans are described.

INTRODUCTION

The availability of subpicosecond electron bunches makes possible a variety of new experimental techniques, including the generation of ultra short radiation pulses, time-resolved pump-probe experiments, and ultrafast electron diffraction. The main aim of the project of the short-pulse facility in KAERI is to provide tools for experiments with subpicosecond time resolution and high-power terahertz pulses.

LOW ENERGY PART

The standard way of preparing short electron bunches is the use of a radiofrequency (RF) gun with a photocathode, illuminated by picosecond laser pulses. The best example of such a gun is used in an x-ray free electron laser LCLS (USA) [1]. The RF gun in our project differs from it in two features.

1. It has a coaxial input coupler, which provides the axial symmetry of the accelerating field.
2. The input power is 5 MW, which is 50% that of LCLS. Correspondingly, the accelerating field is 30% less. Therefore, more relaxed tolerances for the inner copper surface treatment are expected.

To obtain short bunches with high enough electric charge, it is necessary to compress the bunches at high

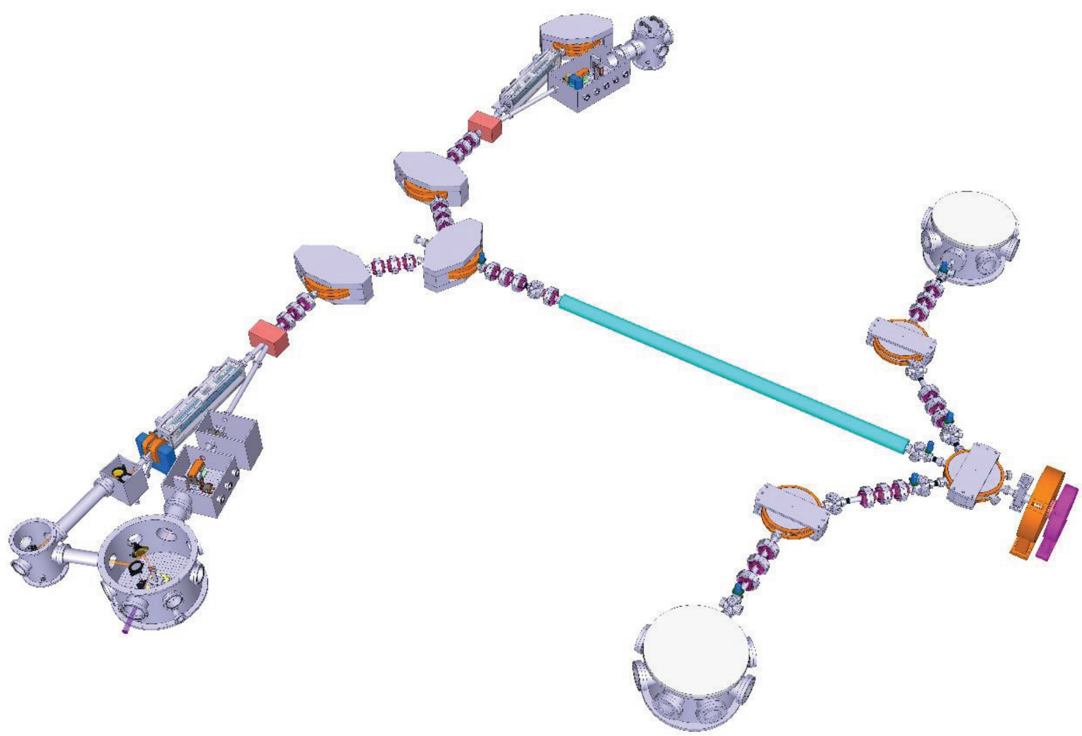

Figure 1: Scheme of a short-bunch accelerator and beamlines.

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enough energy. Therefore, bunches from the RF gun are accelerated further in the 3-meter long SLAC-type accelerating section. At an input power of 4 MW, it gives an energy gain of about 20 MeV. At such energy, the space-charge forces are reduced significantly, and effective bunching is possible.

The scheme of the installation is shown in Fig. 1.

The RF gun and accelerating section have the same axis. Therefore, normal-incidence laser illumination of the cathode along this axis is possible.

The bending magnet, installed after the RF gun, is capable to deflect the beam by 45 degrees right or left to the low-energy beamlines. These beamlines are to be used for experiments with ultrafast electron diffraction.

The two-way 45-degree bending magnet (see Fig. 2) is round. This feature simplifies its focusing properties and

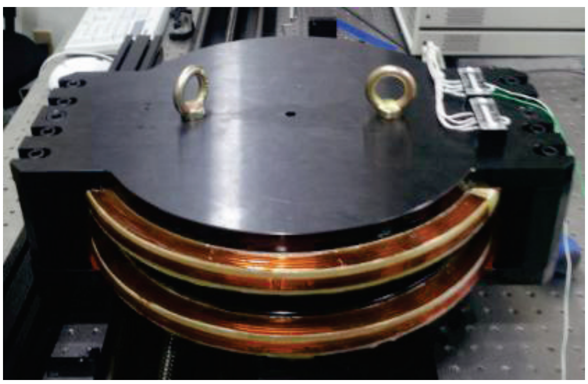

Figure 2: Photo of the low-energy 45-degree bending magnet.

geodesic alignment (input and output directions cross in the geometric centre of the magnet). To conserve the low transverse projection emittance, each low-energy beamline contains a second 45-degree bending magnet, similar to the first one, and three quadrupole lenses (see Fig. 3) between the magnets.

The yoke of this quadrupole consists of four equal

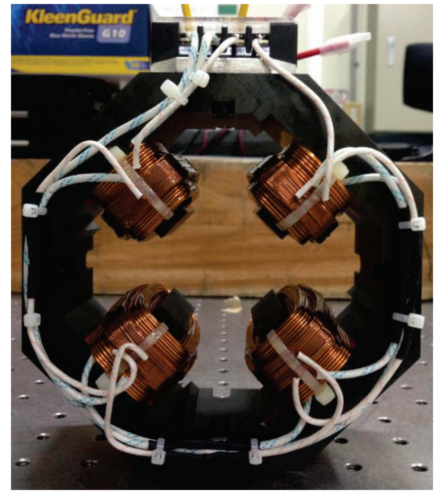

Figure 3: Photo of the quadrupole lens.

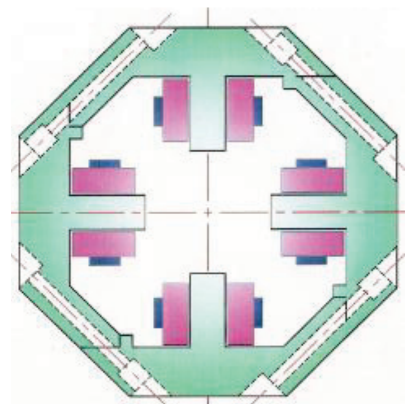

Figure 4: The scheme of the quadrupole yoke.

parts, connected by precisely machined rabbet joints with screws at a 45° angle (Fig. 4). This simplifies the lens manufacturing and assembly.

Two bending magnets and three quadrupole lenses comprise an achromatic bend. The beta functions and

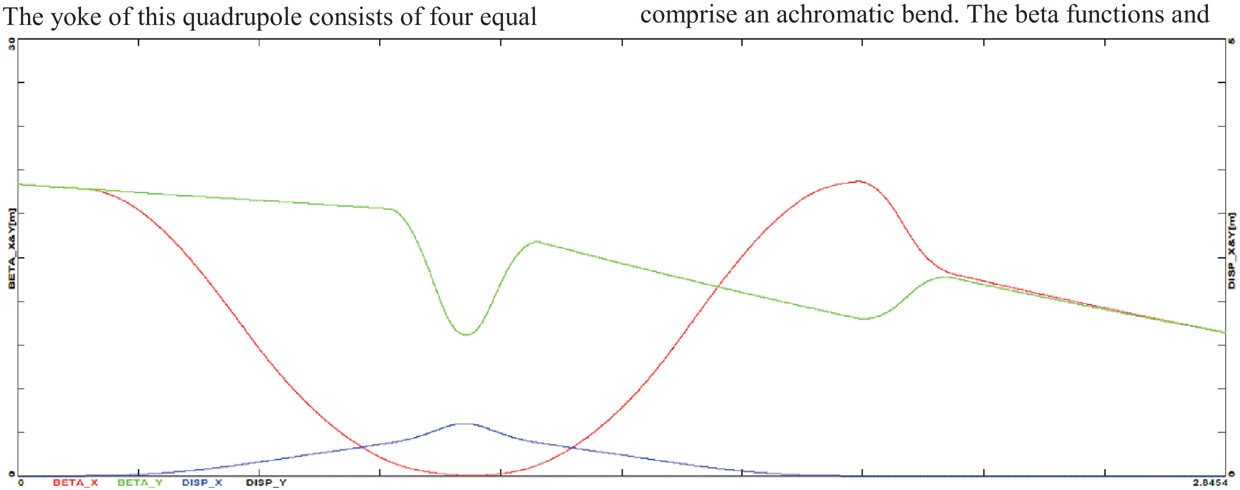

Figure 5: Calculated beta functions (red – horizontal, and green – vertical) and horizontal dispersion (blue) in the low-energy beamlines. Bending magnet and quadrupole lens positions along the trajectory are shown by blue and red segments respectively.

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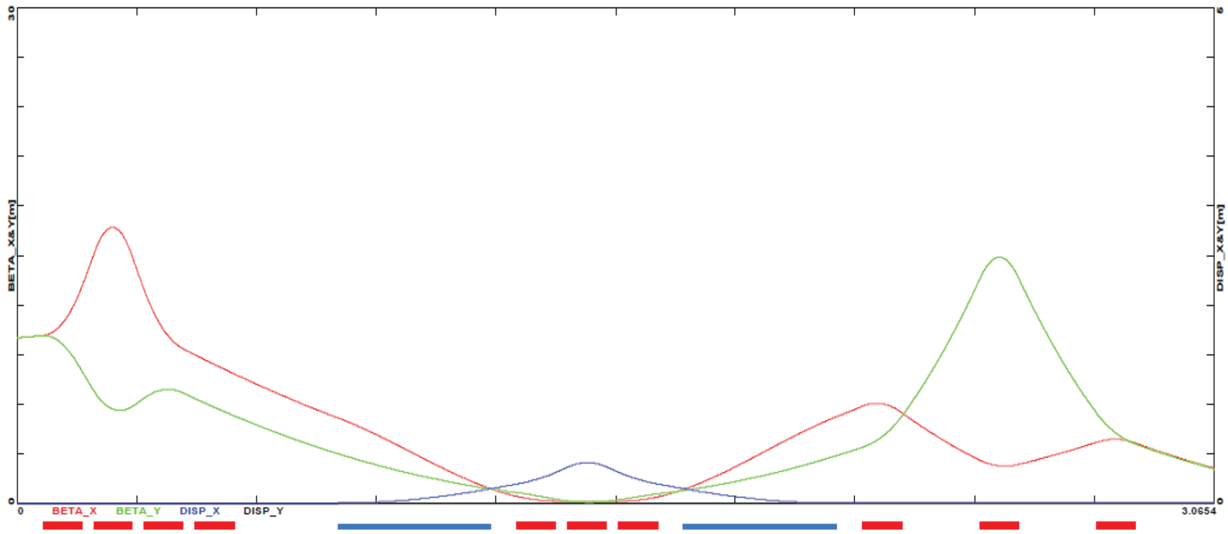

Figure 6: Calculated beta functions (red – horizontal, and green – vertical) and horizontal dispersion (blue) in the high-energy beamlines. Bending magnet and quadrupole lens positions along the trajectory are shown by blue and red segments, respectively.

horizontal dispersion in the low-energy beamlines, calculated with code OptiM [2], are shown in Fig. 5. The low-energy beamlines are almost isochronous.

HIGH ENERGY PART

If the central low-energy bending magnet is switched off, electrons, pass through the accelerating section. Next, having up to 25 MeV energy, they are deflected by the two-way 45-degree bending magnet to one of the high-energy beamlines. These beamlines also contain achromatic bends. The calculated beta functions and horizontal dispersion in the high-energy beamlines are shown in Fig. 6. The sextupole correction in the central quadrupole of the achromatic bend provides the second-order achromaticity. The value of longitudinal dispersion R_{56} is 8 cm. It was chosen to achieve a tight bunching. Moreover, the proper strengths of the quadrupoles provide proper R_{566} for a compensation of the quadratic longitudinal aberrations, caused by the second derivative of the accelerating field over time. This compensation was simulated through a calculation of the trajectories (Fig. 7).

Simulations show that the bunch length can be less than 0.1 ps at a bunch charge of up to 0.5 nc.

The availability of subpicosecond electron bunches makes possible a variety of new experimental techniques.

After the high-energy achromatic bend the short electron bunches pass through the fast kicker. In the two-bunch operation mode, it has to deflect the second bunch by 10 degrees. The deflected bunch will be directed to the target for x-ray generation, while the first undeflected one will generate a terahertz pulse in an undulator or multifoil radiator [3].

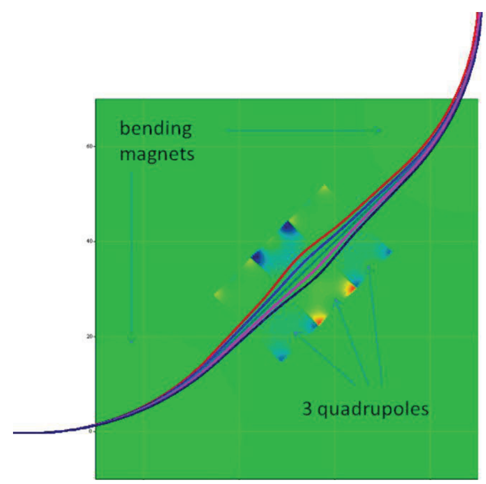

Figure 7: Field (different colours show different values of the vertical magnetic field) and particle trajectories for different energy deviations (-6%, -3%, 0, 3%, and 6%) in the 90-degree second-order achromatic bend.

In this way, two synchronized pulses will be available for pump-probe experiments. The kicker is the single-wind magnet. There is a plan to feed the kicker by a Blumlein pulse generator with a thyratron switch.

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