

R&D Projects based on the SC RF Electron Accelerator at KAERI

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1. Introduction

Since 1992, KAERI has developed several electron accelerators for free electron lasers, from a mm-wave to an infra-red wavelength. The first is an electrostatic accelerator used for the generation of the mm-wave FEL, which was dismantled after its demonstration. The second one is a magnetron-driven microtron, dedicated to a compact FIR FEL with a wavelength range of 100 - 300 μm . The FIR FEL is now routinely operating with an average power of 10 Watt for a macropulse of 3-4 μsec , a spectral width of 0.5 %, and a high stability of less than 1% jitter. Beam diagnostic system for the users of THz applications is under development. The last is a superconducting (SC) Radio-frequency (RF) linear accelerator (Linac), being developed for a multi-purpose system: high power MIR FELs, a compact quasi-monochromatic X-ray source via Compton scattering, a 10 MeV electron beam irradiator, and so on. The 10 MeV electron beam irradiator is currently commissioning for R&D on electron beam irradiation applications, capable of operating up to 100 kW. Developments for other high-brightness beam sources, such as, ERL-based FELs and X-rays, are underway. We discuss the present projects as well as future plans based on the KAERI SC RF Linac.

2. The KAERI SC RF Linac System

The KAERI SC RF linac system is comprised of the 2 MeV injector, main linac, and beam transport lines. The injector includes a DC electron gun, a buncher, and two RF accelerating cavities. The electron gun generates electron bunches of 350 kV and 1 nC per pulse. It can generate the average current up to maximum of 50 mA by increasing the repetition rate up to 22 MHz. The buncher can compress each electron bunch with the pulse duration less than 1 nsec. Two NC (Normal Conduction) RF cavities are operated at 176 MHz and accelerate electron beams to 2 MeV. However, the maximum average current is limited by the power of RF generator, as 10 mA at the energy of 2 MeV.

Parameter	Value
Energy	10 – 20 MeV
Ave. current	Up to 10 mA
Emittance	40 $\pi\text{mm}\cdot\text{mrad}$
Radio Frequency	352 MHz
Repetition rate	Up to 22 MHz

Table. Parameter of electrons in the SC RF Linac

Main accelerator consists of one SC RF cryomodule, of which is comprised of two 352 MHz 4-cell SC cavities, transferred from CERN in Europe. The typical gradient of cryomodule is 6–8 MV/m. The electron beam parameters are listed in Table.

2.1 10 MeV Electron Beam Irradiator

A electron beam is accelerated to 10 MeV at the 352 MHz SC RF linac, bent 90° through the transport beam line, and exposed to irradiation cell or samples through the 80 μm thick tantalum window of the scanning cone. The irradiation cell is shielded with lead and polyethylene wall and the samples for irradiation are carried by transfer caters through the conveyor chain. The ozone removal system is installed to remove toxic gases produced by the interaction between electrons and molecules in the air. The commissioning of the 10 MeV electron beam irradiation system is underway, followed by the development of radiation dosimetry as well as the irradiation services to users.

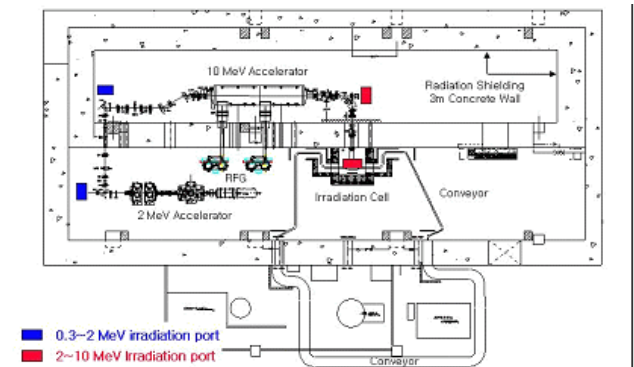


Fig. 1. Layout of the KAERI SC RF Linac and 10 MeV electron beam irradiation system

For a 2 MeV electron irradiation, a tantalum window is installed at the downstream of straight beamline from the injector. In this port, a defocused electron beam with the energy below 2 MeV is extracted, while a sample is scanned in the x-y plane, using translation stages.

2.2 High brightness Compton X-rays

Quasi-monochromatic X-rays can be generated via Compton scattering. Due to high quality of electron beam from the SC RF linac, the brightness of X-rays is also high enough. There are several schemes to generate Compton X-rays. For the first demonstration,

we will use external lasers for scattering with electron beam from accelerator. As shown in Fig. 2, Compton scattering beamline will be installed in the straight line of downstream. Fig. 3 illustrate the expected X-ray parameters depending on the emittance and the beta function. We expect to generate 10^7 ph/sec at the energy range of 1–2.6 keV.

Next, we plan to complete the recirculating beamline for energy recovery (ER). The scheme of ER is good for reducing the radiation hazard and increasing the flux of X-rays.

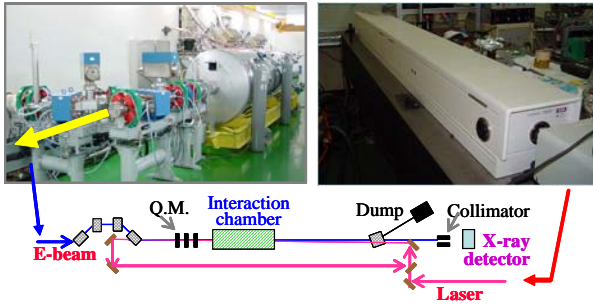


Fig. 2 Layout for 1 keV Compton X-ray generation

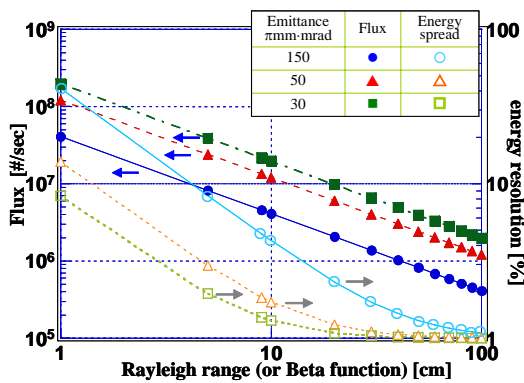


Fig. 3. The expected Compton X-rays depending on the emittance and the beta function of electron beam

Thirdly, we propose to generate atto-second high harmonic X-rays via coherent nonlinear Compton scattering. High harmonics via non-linear Compton scattering of an intense fs Ti:Sapphire laser light with a micro-bunched electron beam, with a scale of less than

300 nm, will be coherently added up to produce an atto-second X-ray pulse. The micro-bunching of electron beam can be obtained through the energy modulation in an undulator and the density modulation in a half-period strong magnet. By selecting the proper seed laser, the micro-bunching with required scale can be produced.

For fs X-rays, the photocathode gun as well as the chicane for compression of electron bunches are required for our system.

2.3 High power Free Electron Lasers

A free electron laser is a coherent light source using electrons and insertion device as a gain medium. The fundamental wavelength of 10 - 70 μm can be generated at the KAERI SC linac system. Since the tuning range depends on the energy of electrons and the period and magnetic strength of undulator, we have to carefully design the undulator and optical resonator to satisfy the lasing condition of selected wavelengths at a given accelerator. Main issues to design are how to increase the FEL gain and how to minimize the optical loss at the same time. The undulator will be the hybrid type as like one used in FIR FEL. The period is 35 mm and the magnetic strength is adjustable from 1.5 to 3.3 kG using an electrical magnet. The optical resonator should be designed to avoid thermal degradation due to high power load on the cavity mirrors. We expect to produce the FEL power up to 1 kW in average.

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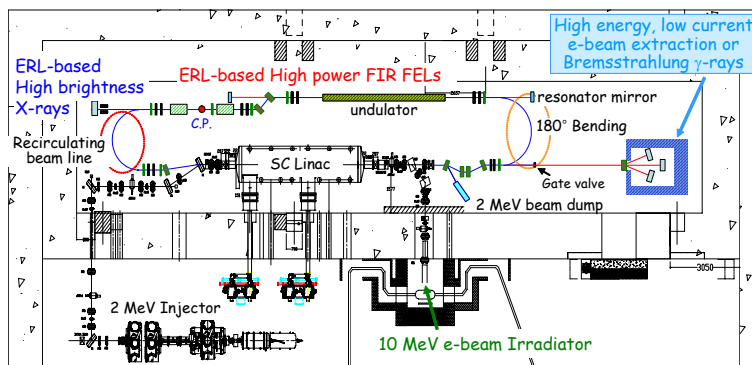


Fig.4 Layout of Multi-purpose Quantum beam generation system