5–5 Toward Nondestructive Assay of Fissile Materials

— Generation of 500 keV Electron Beam from DC Photoemission Gun —

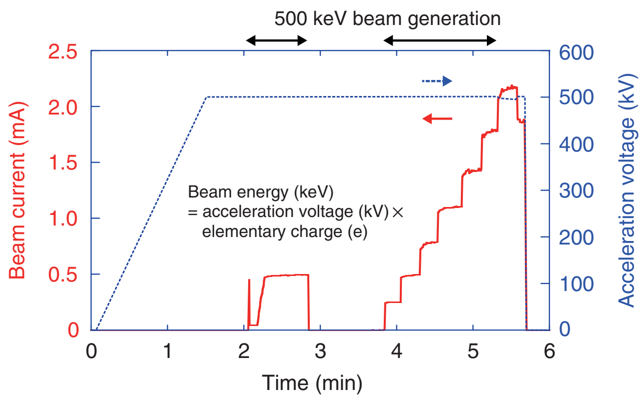

Fig.5-12 Generation of a 500 keV electron beam
A DC photoemission gun generates an electron beam upon laser irradiation. The black arrows represent the periods where a 500 keV electron beam was generated. The blue dashed line represents acceleration voltage; and the red solid line, the beam current.

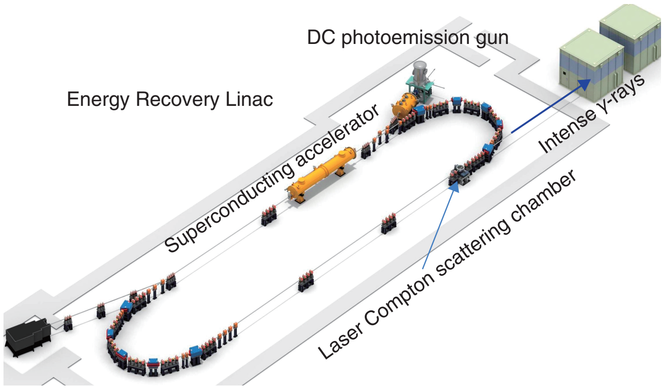

Fig.5-13 γ-ray source based on energy recovery linac
An energy recovery linac is under development at KEK. The accelerated electron beam is delivered to the Compton scattering chamber for γ-ray generation. A proof–of-principle experiment for the proposed nondestructive isotope identification will be conducted next year.

The quantification of fissile materials such as uranium-235 (^{235}U), plutonium-239 (^{239}Pu), and minor actinides in spent fuel assemblies requires isotope-specific identification. We propose the use of nuclear resonance fluorescence (NRF) to identify the isotopic composition of sample materials nondestructively. A mono-energetic γ-ray beam tuned to the resonance state of the target nuclear isotope is injected into the spent fuels, and NRF γ-rays generated spherically from the fuels are detected with a γ-ray detector.

The proposed nondestructive isotope identification system requires a high-intensity mono-energetic γ-ray beam. Although a mono-energetic γ-ray beam can be generated using a conventional laser Compton scattering technique, the generation of a high-intensity γ-ray beam requires an electron beam of unprecedentedly high brightness, which can be generated with an advanced accelerator system known as the energy recovery linac (ERL). A technological challenge of the ERL system, which we have addressed, is the development of a high-brightness, high-current electron gun.

The generation of high-brightness beam requires a gun exit energy of ≧ 500 keV to avoid the beam degradation that occurs due to nonlinear space charge effect. The gun operational voltage has, however, been limited to 350 keV because of a discharge problem. We have successfully solved this problem by employing a segmented insulator and optimizing the gun configuration.

Fig.5-12 shows the result of a beam generation test. The electron beam is generated upon laser irradiation. The beam current is proportional to the laser power. As shown in the figure, we successfully generated a 500 keV electron beam with a current of up to 2 mA.

The gun was recently moved to the compact ERL (cERL) facility at KEK, where it is connected to an adjoining superconducting accelerator, as shown in Fig.5-13. Mono-energetic γ-ray generation using Compton scattering will be commenced next year.

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Reference

Nishimori, N. et al., Generation of a 500–keV Electron Beam from a High Voltage Photoemission Gun, Applied Physics Letters, vol.102, issue 23, 2013, p.234103-1–234103-4.