13-1 Toward Advanced Safeguards of Future Nuclear Fuel Cycle Facilities

— Development of Safeguards Verification Technologies for Large Pu-Throughput Facilities with Treating Low-Decontaminated, MA-Bearing Nuclear Material —

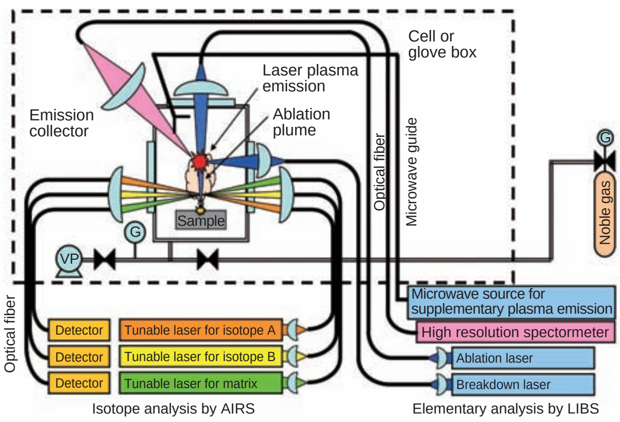

Fig.13-2 Concept of MOX sample verification system for FNFC using LIBS/AIRS

The concentration of an element (Pu) can be measured by detection of breakdown emissions from a plasma produced by interrogation with a breakdown laser onto an ablation plume generated by an ablation laser. It is also possible to analyze the isotopic composition of the element by measuring tuned laser absorption in the ablation plume for each isotope.

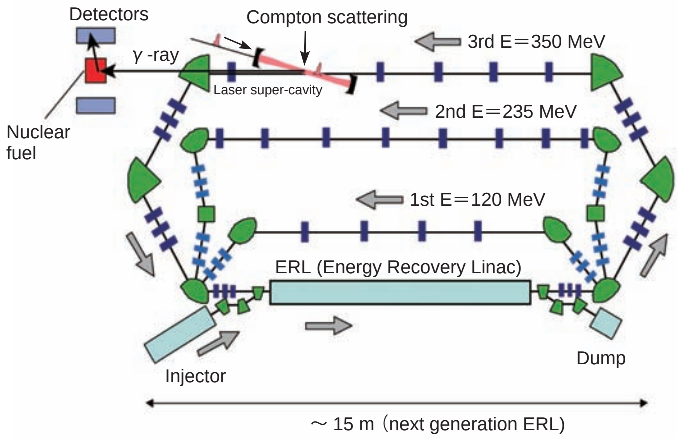

Fig.13-3 Concept of Pu NDA system for spent fuel using NRF with interrogation of LCS γ-rays

Interrogation with 2.143 MeV γ-rays, which are generated from laser Compton scattering of 350 MeV electrons with laser photons, on a spent fuel assembly causes a ^{239}Pu NRF reaction emitting the same energy (2.143 MeV) γ-rays. By counting the γ-rays emitted from ^{239}Pu, we can measure amount of Pu in the spent fuel assembly.

Some future nuclear fuel cycle (FNFC) facilities have the following characteristic features: (1) a very large Pu throughput, (2) treatment of low decontamination nuclear material (containing fission products (FPs)), and (3) recycling of minor actinides bearing material. Here we show examples of advanced safeguards technologies that are proposed or under development based on needs arising from the above features.

Feature (1) means that the accumulated amount of uncertainty in plutonium measurement errors grows very large within a short time period, which requires very frequent safeguards inspections, and thus very fast measurement/analysis technologies are necessary for material accountancy and verification.

Characteristic feature (2) means that nuclear material treated in the FNFC has strong background γ-rays originating from contained FPs. This makes the present γ-ray spectroscopy for determining the isotopic composition of Pu difficult or impossible. In addition, because of feature (3), nuclear material treated in the FNFC contains ^{244}Cm with a very high intensity of spontaneous fission neutrons (10^4 times higher than ^{240}Pu), which means that the present neutron coincidence counting method is difficult to apply to FNFC materials. Given these features, it is necessary to develop new Pu NDA technologies for FNFC materials.

Corresponding to the situations derived from the characteristic features (2) and (3), we are developing a combined method of LIBS (Laser Induced Breakdown Spectroscopy) and AIRS (Ablation Initiated Resonance Spectroscopy) for analyzing the Pu concentration and isotopic composition of Pu in (FNFC) MOX samples (Fig.13-2).

Furthermore, for some time SRD (shipper-receiver difference) has been an issue with reprocessing facilities. Accumulation in the SRD amount tends to increase with increment of reprocessed material. For FNFC reprocessing facilities treating large amounts of plutonium, the SRD issue must be addressed properly.

In addition, there are many spent fuel assemblies in storage pools of reactors with less radiation self-protection because of their very long cooling time. Diversion of fuel rods from assemblies has become a large global concern. Based on this background, development of Pu NDA technologies for spent fuel assemblies, which had been thought to be very difficult, has started.

As one of these technologies, we are proposing a NDA system with a laser Compton scattering (LCS) γ-ray source that uses nuclear resonance fluorescence (NRF) reactions by interrogation of monochromatic γ-rays tuned to the specific resonance energy (within a range of 1~3 MeV) of a target isotope such as ^{239}Pu (Fig.13-3). This system is capable of identifying individual isotopes.

Moreover, FNFC facilities need a variety of advanced safeguards technologies.

Reference

Hayakawa, T., Seya, M. et al., Nondestructive Assay of Plutonium and Minor Actinide in Spent Fuel Using Nuclear Resonance Fluorescence with Laser Compton Scattering γ-rays, Nuclear Instruments and Methods in Physics Research A, vol.621, issues 1-3, 2010, p.695-700.