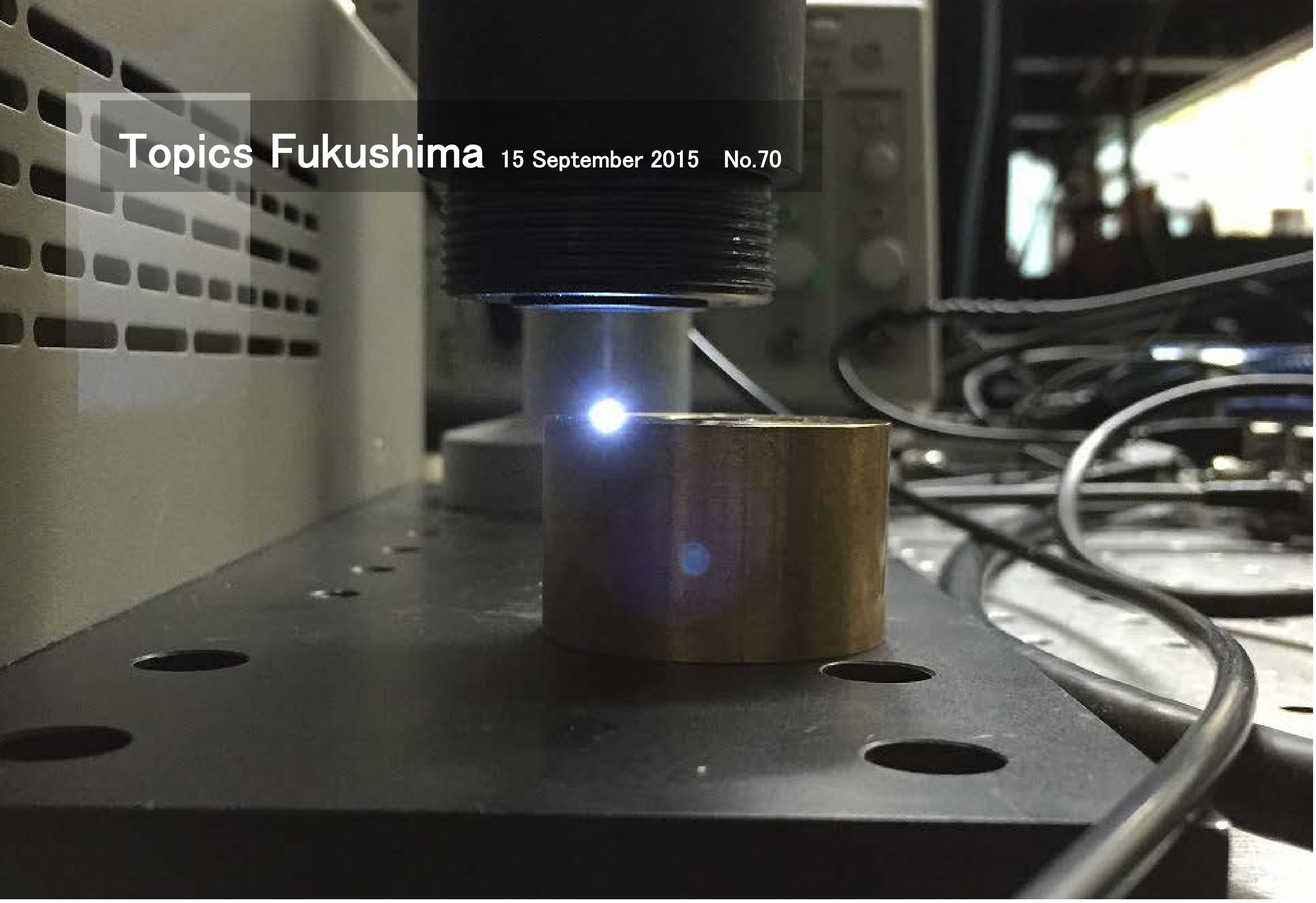


Examination of reactor cores using laser

Analysis of elemental composition in fuel debris became possible

How is the present situation of the reactor cores inside the Fukushima Daiichi Nuclear Power Station (1F), Tokyo Electric Power Company (TEPCO)? Even today, the situation is unknown, because it is difficult to examine it due to the intense radiation. In order to examine reactor cores, the Japan Atomic Energy Agency (JAEA) is developing the technology of the laser monitoring method. The advantages of this method are (1) the instrument can be used under high radiation dose rates, and (2) elemental analysis of the fuel debris inside the core is possible. Thus, the method is expected to be used in the actual decommissioning sites.

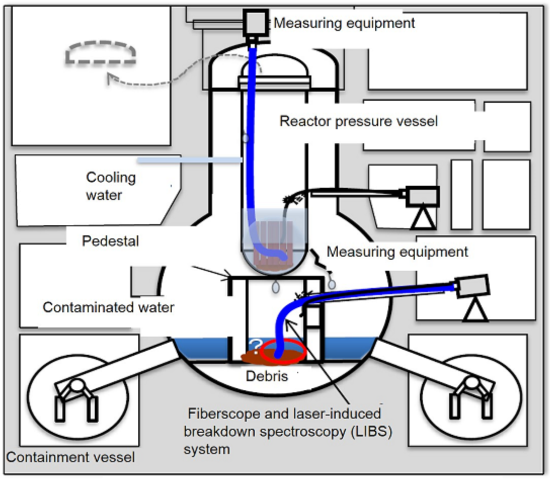
Dr. Ikuo Wakaida, Group Leader Fuel Debris Handling and Analysis Division, Cooperative Laboratories for Advanced Decommissioning Sciences (CLADS), JAEA

The followings are the reports on the interview with Dr. Ikuo Wakaida (Cooperative Laboratories for

Advanced Decommissioning Sciences, CLADS) about the current status of the technological development.

- In order to promote the real decommissioning of 1F, it is necessary to examine the inside condition of the nuclear reactor. How much is known at present?

Several specialized robots, which have been developed by TEPCO and the International Research Institute for Nuclear Decommissioning (IRID) for examining inside reactors cores, have been used in 1F. We hereby have been able to know the temperature, radiation dose rates, and take photographs of the outer section of the containment vessel pedestal, which is located above the debris. However, we haven't been able to observe the debris itself.



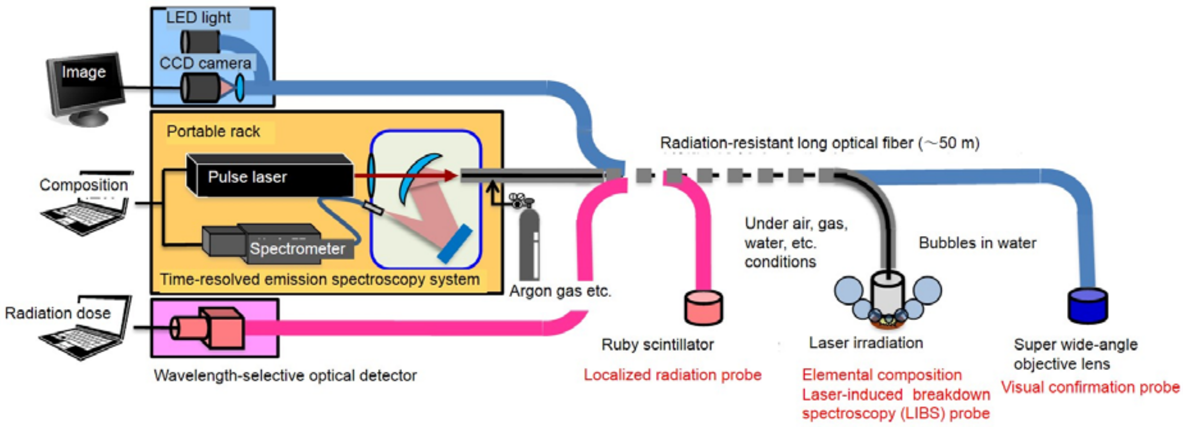
Schematic diagram of inside monitoring system for reactor

On the other hand, TEPCO and the High Energy Accelerator Research Organization (KEK) have set an instrument measuring muons in cosmic rays near a building adjacent to 1F, and have analyzed the obtained data. Consequently, it was observed that high-density materials like debris do not exist at the reactor core in the pressure vessel. Although it is an indirect evaluation, the results are important as a fact, considering that the situations of the reactor cores had not been clear at all. Nevertheless, it is difficult to speculate the nature of debris only by this method, and we can only estimate the location and shape of debris indirectly.

- How is the laser monitoring method developed by your group?

The system that we have developed for examining the inside of reactors is like a large "endoscope". The tip of the long optical fiber, which is inserted into the reactor, is equipped with a lens for irradiating laser light onto the debris, a camera lens, and a scintillator for emitting light by radiation. These are connected to a laser oscillator, a photodetector, and a TV camera, which are located in low-radiation place where we operate them. The light observation signals, which are obtained at the tip of the optical fiber, are sent to the devices in front of us via the optical fiber. Thus we can observe the situation without being affected by the radiation.

The advantages of this device are as follows: (1) it can be used under high radiation condition, (2) elemental analysis is possible even in water, and (3) it enables observing images and radiation levels in the reactor.



Laser monitoring system and observation probe for inside of reactor (under development)

In addition, because the fuel debris at 1F is located inside of the pressure and containment vessels, it is difficult to bring the monitoring system near the debris. In this regard, because the optical fiber bundle is only a few millimeters in diameter and flexible, we expect it can relatively easily deliver the system close to the debris.

- Please tell us more details about how it works.

Let's again compare the instrument to an endoscope. The camera section at the tip of an endoscope is called "probe". The probe of our system is composed of three components. The first is the fiberscope. In this component, a CCD camera images the objects that are illuminated by LED. The second, which is the key component of our system, is the elemental composition analysis probe using laser. When the pulse laser collimated by the lens is irradiated on an object such as the debris, the object partially evaporates generating plasma. The atomic emission from plasma is collected and sent as light to the spectrometer. The elemental composition of the object is analyzed by observing the wavelength of the light. The third is the radiation probe. This component enables us to measure the radiation doses of the object by measuring the intensity of light emission from scintillator with photodetector.

All of the observed data are transmitted as light signals through the optical fiber of dozens of meters in length. This optical fiber was developed for monitoring the inside of the fast reactor "JOYO" at the Oarai Research and Development Center, JAEA. Hydroxyl group (OH) is mixed in this fiber so as to become resistant to intense radiation.

- So, the key features of this system are the thinness of the optical fiber and the elemental composition analysis probe at the tip of the optical fiber. Is it right?

Yes. The optical fiber is very thin and flexible. Also a long fiber can be manufactured. Therefore, this makes it easy to send it inside the reactor core and close to the debris. To send the fiber to the target, it is necessary to develop it in combination with robot technology. While the

CCD camera gives only images, the analysis probe using laser gives information about the elemental composition of the object. For example, we can determine that the main component of some debris is iron or uranium. These results will be useful for deciding how to treat the debris after it is extracted. (The photo on the right shows a prototype system for analyzing objects in water)

Prototype of portable Laser-Induced Breakdown Spectroscopy (LIBS) instrument with fiber transmission that can be used in water

- What kind of results can be expected to be found?

We will be able to find out where the debris is located and also what it is made of. In order to confirm this, we fabricated a mock-up of the debris by mixing and sintering uranium oxide and zirconium oxide in various composition ratios. We then placed it in water and examined with our method. As a result, we were able to analyze the composition ratio of uranium and zirconium in the simulated debris. In addition, we found that isotopic ratio in the object can be also determined by this method when the ablation resonance spectroscopy is simultaneously used.

The glovebox was repaired for laser spectroscopy experiment by newly installing windows for laser and terminals for optical fibers.

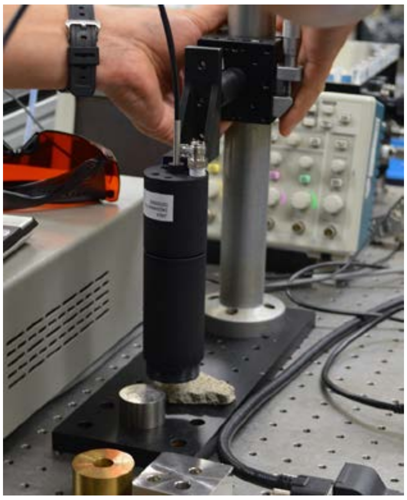
By using this technique, firstly we can in situ evaluate the status of debris, e.g. whether it is composed of structure materials or it contains a lot of nuclear fuels. This gives us vital information for planning specific measures for debris extraction programs. In addition, if we know the elemental composition of the debris to be extracted, the countermeasures and separate collection for debris become possible at the extraction stage from the reactor. Furthermore, even after the debris has been extracted, we can also utilize the system for verifying residues. This technology will be used in a variety of situations from the initial stage to the final phase of decommissioning.

- What are the key issues?

The first issue is a development of robot technology. A robot is required in order to carry the optical fiber to its destination at the reactor core. The second issue is the analyzing depth of our method. The analyzing depth of the method using laser is limited to only the surface of the object. On this point, the Fukushima Research Infrastructural Creation Center is developing a technology to cut debris using a remote controlling system and laser. By combining these technologies, the optical fiber can access the objects and the analysis of the cut sections will become possible. So it is expected that we can know the composition of inside of debris. I think that these new technologies will overcome the issue.

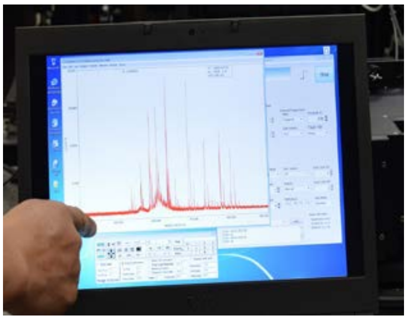
- Was this technology developed for 1F?

No. The basic parts of this technology have been developed from FY2005 under the project “Innovative Nuclear Research and Development Program” entrusted by Ministry of Education, Culture, Sports, Science and Technology. The project was started for the purpose of developing a method for direct, non-contact, remote and rapid inspection and analysis of next-generation high-level nuclear fuels containing long-life radionuclides such as fission products and minor actinide elements. These next-generation fuels are not only required in new nuclear fuel cycles for fast breeder reactors, but they are also being used in developing nuclear transmutation technologies for converting long-life nuclear waste to short-lived nuclides by burning in a fast reactor or an accelerator-driven transmutation reactors.



Analytical head of prototype instrument

This technology was cultivated by combining radiation-resistant optical fiber technology for examining the internal status of JOYO reactor with ultra-high radiation, and laser instrument technology using optical fiber developed at the Quantum Beam Science Center, JAEA, in order to respond to the 1F accident after the earthquake. This kind of fundamental technology, which can be applied to a variety of situations, requires a considerable time to develop. As for the long-term outlook, we consider that it is important for us to continue to develop these technologies.



Example of emission spectrum for analysis of element composition

The activities at the Cooperative Laboratories for Advanced Decommissioning Sciences (CLADS) have opened a collaboration channel in research and development with the Nuclear Damage Compensation Facilitation Corporation (NDF), IRID and TEPCO's Decommissioning Company. As a result, we were rapidly able to make good relation with the persons who are concerned with the decommissioning of 1F. Our technology has attracted much attention. For example, it was proposed that this technology will be used not only inside of nuclear reactors but also outside of reactors. We are now preparing to use these instruments on-site as early as possible.

TOPICS Fukushima No. 70

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