Installation of a Fibre-Optic Probe LIBS instrument at the Irradiated Materials Examination Facility, KAERI, South Korea.

The Irradiated Material Examinations Facility (IMEF) was constructed to perform post-irradiation examinations of the capsules for newly developed nuclear fuels and the reactor core structural materials irradiated at the High-Flux Advanced Neutron Application Reactor (HANARO). IMEF is equipped with a range of instruments and facilities to perform inspection and testing of irradiated materials – NDT, mechanical testing, metallographic inspection, micro analysis, etc. The IMEF has three stories and one basement with a sectional area of 28.0 m × 51.0 m and approx. 4,000 m^2 of floor space. The hot cell facility consists of 26 work units originally of length 60 m but later extended to 71 m to provide 31 work units after construction of new hot cells in the ground floor area to develop the advanced fuel cycle process techniques. In addition, a pool with a depth of 10 m is located in the service area to transfer the transportation casks into hot cells. The maximum wall thickness of the hot cells is 1.2 m to shield the radiation from the source with the maximum radioactive level of 37 PBq. The client required a LIBS system that could be used for general R&D work on applying LIBS to the elemental characterisation of irradiated materials.

Location:	IMEF at KAERI's facility in Daejeon, South Korea
Inspection task:	General R&D / elemental characterisation of irradiated materials
Environment:	Hot Cell (up to a few Sv / hr)
Location of material:	Within argon compartment of hot cell
Access:	Multiple fibre-optic cables from control unit on cold side of hot cell to probe located inside the argon compartment of the hot cell.

A multi-channel Fibre-Optic LIBS (FO-LIBS) probe developed by APL was used for this application. The pulsed laser radiation is transmitted to the central port of the probe via a fibre-optic cable. The central port of the probe contains two condensing lenses used to collimate and then focus the laser beam on to the sample, as illustrated in the CAD diagrams below. Six collection optic ports are located around the central port, each one containing two condensing lenses used to collect plasma light and couple it to a fibre-optic cable. The collection ports are colour-coded to signify the wavelength range for which their collection efficiency is optimised (Purple = deep UV, Blue = UV-VIS, Red = VIS-NIR). The green tubing shown in the illustration on the right is for feeding gas (e.g. argon) to the probe.

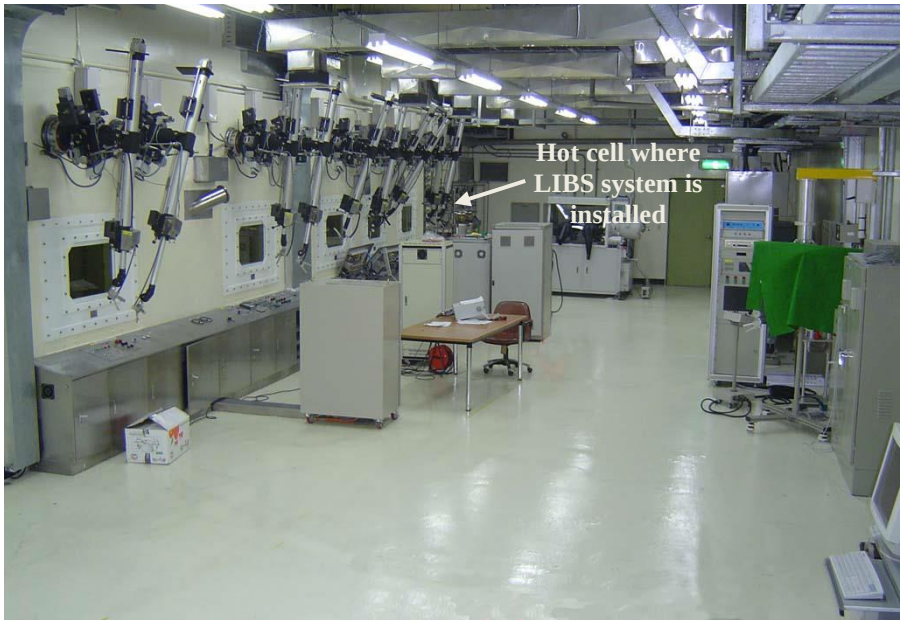

Image of IMEF hot cell facility highlighting the location of the LIBS system

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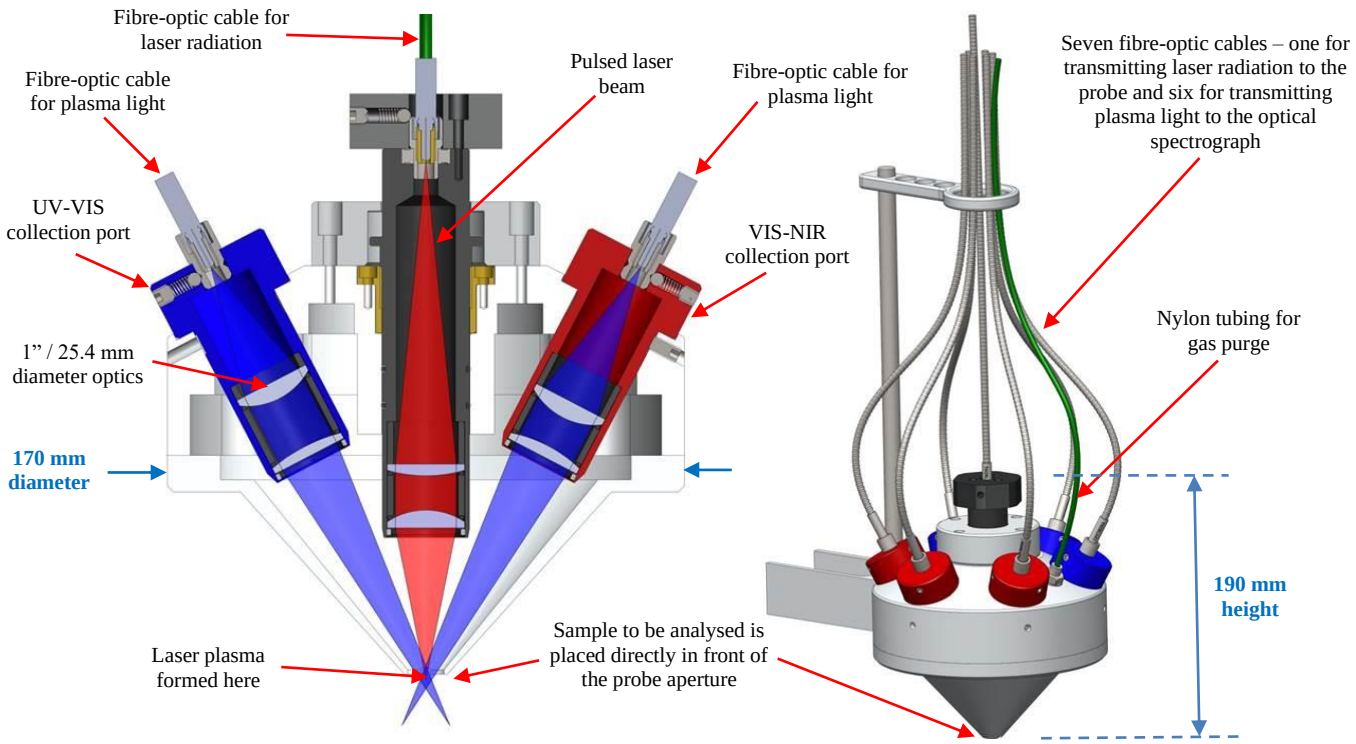

CAD images illustrating the design of the multi-channel Fibre-Optic LIBS probe

The design of the probe includes the following features:

- Adjustable focus laser beam optics (MSM friendly)
- Quick-connect fibre-optic cables (MSM friendly)
- Gas purge
- MSM friendly handle attached to probe body
- Nozzle aperture to facilitate correct positioning of the sample to be analysed
- Radiation-hard components

A high-resolution optical spectrograph (Catalina Scientific EMU-120/65) fitted with an EMCC camera (Raptor Photonics Falcon Blue) was used to record LIBS spectra. A 100 mJ, 1064 nm, 20 Hz laser was coupled with the fibre-optic cable connected to the LIBS probe, with the pulse energy limited to approx. 50 mJ to avoid damaging the all-silica fibre. These components together with a delay generator and system computer were housed inside a mobile rack unit, as shown in the following images.

AI Whitehouse at the IMEF during installation of the FO-LIBS instrument (Sept. 2014)

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Images of the LIBS instrument rack unit housing the laser, the optical spectrograph, fibre launch optics and system computer

References

"Applications of remote LIBS deployment for safeguards of nuclear materials within a hot cell environment", International Conference on Laser Applications in Nuclear Engineering 2013 (LANE 13), Bo-Young Han, Y.S. Kim, H.S. Shin, H.D. Kim (KAERI), Y. Lee (Mokpo National University), Andrew I. Whitehouse (Applied Photonics Ltd, UK)

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