Development of Laser-Based Experimental Platforms for the Study of Thermophysical Properties of Nuclear Irradiated Fuels at High Temperature

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Even though the overall phenomenology is relatively well known for both design basis accident and emergency conditions, increasing understanding of some phenomena and extending knowledge to the areas of very high temperatures are still, in some cases, of utmost importance. In this general context, and more specifically in order to extend knowledge related to the behavior of fuel (together with its corresponding thermophysical properties) in accident situations, the CEA Fuel Study Department has carried out, in collaboration with the Fresnel Institute, the development and qualification of laser based experimental platforms. They rely on: high-power fiber lasers, devoted experimental assembly, and specific sample holders. Optical means devoted to generating variable laser beam shapes and intensities, and the associated instrumentation (pyrometers, high-speed and high-resolution infrared cameras, IR spectrometer) have also been implemented. These experimental platforms are systematically coupled with numerical approaches, thanks to multiphysics code modelling, regarding laser/material interactions and heat transfers. Three complementary laser-based platforms have been developed: (1) CHAUCOLASE (French acronym for laser-controlled heating), since 2017, for concepts validation; (2) CHARTREUSE (French acronym for laser-controlled heating on active materials), since 2022, for qualification involving non irradiated nuclear fuel before implementation in hot-lab facilities; and finally (3) MALAGA for application on irradiated nuclear fuels (implementation at the LECA hot-Lab scheduled in 2028).

This paper provides an overview of the three main current R&D directions that have been carried out thanks to these modular platforms. A specific interest will be given to the closed-future applications to irradiated fuels and the associated consequences in terms of methodology:

- **The thermal properties of nuclear fuels**. Two techniques have been developed to evaluate thermal conductivity (by thermal diffusivity measurements) of nuclear fuel and its evolution as a function of temperature (up to 3100 K): (1) the classical laser flash method, which is a non-contact measurement of the thermal response of a studied sample at a mm scale, (2) the more innovative, in the field of nuclear fuels, Infrared microscopy (IRM) technique.
- The **nuclear fuel behavior under thermal loads.** The main goal here is to quantify the impact of thermal transients at extremely high temperatures and/or rates (typically representative of RIA or LOCA) on the fuel thermomechanical response and fission products behavior/release.
- **Laser micro/macro-machining.** The objective here is to develop a technique, using Short-Pulse lasers, to prepare irradiated fuel samples ranging in size from micrometers to millimeters (or more) of excellent quality and without impact (thermal and/or mechanical affected zone) due to the preparation, for further separate-effect tests or property determination .