
Femtosecond Laser Ablation Machining & Examination - Center for Active Materials Processing (*FLAME-CAMP*)

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ABSTRACT:

Post-irradiation examination (PIE) of fuel and cladding materials are the bottle neck in obtaining reliable and meaningful data from irradiated materials, especially fuel rods. Specimen preparation, material property evaluation (including thermal properties), isotope distribution, swelling, mechanical properties, and microstructural changes to assess performance in service is a difficult, time consuming, and costly task. Furthermore, the amount of data generated is limited due to the lack of available diagnostics tools applicable in hot cell environment and the extraordinary costs in operating within hot cells. Recent irradiation campaigns feature miniature fuel rod (“rodlets”) to enable fast and systematic understanding of fuel rod performance in test reactors. However, large amounts of samples irradiated in reactors today are awaiting a thorough PIE.

It is the aim of this proposal to develop and demonstrate femtosecond laser ablation-based diagnostic and processing of materials in a rapid throughput and low-cost fashion, while developing new materials sampling capabilities not deployed in the nuclear materials research field presently. This approach will enable fast and effective PIE fuel rodlet examination, thereby reducing costs and accelerating research. Furthermore, this work will pave the way to a completely new set of tools deployable for any radioactive sample of interest.

The core of this proposal is centered around the significant advantages that femtosecond laser ablation inherently possesses for both machining and spectroscopy applications, and the ability to integrate all of these into a single system. Laser-based processing allows for non-contact materials processing even through glass windows preventing contamination of the surrounding areas and tools. This, by itself, is a tremendous advancement when deployed for highly irradiated material. Laser and optical-based methods to evaluate component geometries (swelling) is a common technique and can be combined with the pre-existing optics. Additionally, the plasma generated by short laser pulses can be used for materials diagnostics such as Laser Induced Breakdown spectroscopy (LIBS) providing elemental composition information. The debris produced by the laser ablation is further used to analyze the isotopic content through Laser Ablation Mass Spectroscopy (LA-MS) techniques. Finally, laser-based pump probe experiments provide information about thermal properties. Combining all these techniques with high resolution machining in a transparent (glass) chamber provides spatially resolved elemental, isotopic, and thermal properties on a fuel rod, while also manufacturing small specimens for microstructural and mechanical property evaluations. This proposal will enable us to develop a one of a kind multi-function tool suitable for hot cell deployment to work on active materials.