Integrated Stand-Off Optical Sensors for Molten Salt Reactor Monitoring

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ABSTRACT:

New generation of Molten Salt Reactors (MSRs) using fluoride salts as primary or intermediate coolants have gained significant industry attentions because of their attractive heat transfer properties and improved operation safety. These reactors can operate at higher temperatures and at lower operating pressure than traditional Light Water Reactors, which lead to better efficiencies and lower risks. Several American nuclear companies are developing new generation of molten salt reactors. Success of these endeavors will ensure American to have access to clean, safe, and cheap nuclear energy for decades to come.

Molten salts at high temperatures are highly corrosive coolants. To ensure safe and efficient operation of MSRs, robust sensors are needed to monitor both physical and chemical properties of molten salts at high temperatures in harsh radioactive environments. Most of electronic sensors cannot survive in these harsh environments. To address these challenges, this project will develop stand-off optical sensors that does not require physical contacts with liquid coolants to perform measurements. Using a single radiation-harden fused silica rod as the optical port to remotely access reactor cores or flow loops, this project will develop integrated stand-off optical sensors to perform coolant levels, flow rate, and metal impurity characterization in real-time to ensure safe and efficient operation of MSRs. Through optical frequency-domain reflectometry and intracavity self-mixing effects, physical parameters of molten salts can be accurately measured in both reactor vessel and flow loops using low-cost diode lasers from telecom and virtual reality industries. Using advanced dual-pulse laser induced breakdown spectroscopy (LIBS), this project will develop a stand-off laser chemical sensor with detection sensitivity better than 10 ppm to measure dissolved metal such as Ni, Cr, and Mn which are directly connected to molten-salt induced corrosion of pressure vessels.

Optical sensors developed by this project are highly affordable and can function in high-temperature and extreme radiation environments. Working with our industry partner, this project will seek to maturation of the sensor technology to reach TRL-5 and explore potential sensor deployments in large-scale engineering test units of MSRs. Integrated stand-off optical sensors developed by this project will close the sensor technology gap to achieve comprehensive monitoring of MSRs.