NEUP Nuclear Energy University Programs

U.S. Department of Energy

Gyrotron for Rapid Extreme Thermal Processing of Materials for Nuclear Energy

PI: S.K. Sundaram, Alfred University

Collaborators: N/A

Program: General Scientific Infrastructure

ABSTRACT:

We propose to establish a unique extreme thermal processing capability at Kazuo Inamori School of Engineering, Alfred University. The proposed system consists of a 94 GHz, 10 kW CW gyrotron with a liquid cryogen-free superconducting magnet along with appropriate power source and auxiliary systems. The system will also be coupled to millimeter wave radiometry (MMW) operating at 137 GHz for in situ temperature measurements. The MMW radiometer is already established at the AU. With appropriate setting up and calibration, a processing temperature as high as 5000-10000°C can potentially be achieved in the laboratory. This facility can be used for processing many different materials for a variety of applications relevant to nuclear energy and environment. This also opens up access to new processing paradigm for material manufacture. Novel materials can be processed at higher temperatures in a short time scales. In addition, the gyrotron can be used for welding, ablation, and nanoparticle manufacturing, spurring growth in advanced manufacturing in the USA.

Our main objective is to establish a gyrotron-based extreme thermal processing capability that will directly support the missions of the Department of Energy (DOE)'s Nuclear Energy (NE) as well as Nuclear Energy University Program (NEUP). Major advantages of proposed gyrotron system are: 1) It increases the number of modes and thus improves heating homogeneity. For instance, increasing the frequency from 2.45 GHz to 94 GHz as proposed here would increase the number of modes by a factor of 57,000. This is critical for reproducible microstructure and homogeneity of ceramic and glass waste forms as well as non-oxide ceramic materials for structural applications in a reactor. 2) The energy absorption is higher at 94 GHz due to the increase in dielectric loss with frequency, thus efficient heating of these materials. 3) In an alternative direct heating scheme where the MMW radiation is directly focused on the target a shorter wavelength is beneficial because it can be focused into a tight spot whose transverse dimensions are of the order of a wavelength. This enables localized heating and repairing of thermal systems in a reactor in service. In addition, it is possible to completely eliminate the need for a mode stirrer or sample rotation at 94 GHz due to the increased homogeneity of the heating in the equipment.

The proposed new capability will initially support existing two NEUP projects. For example, rapid sintering of ceramic waste forms to as a high temperature as possible but below the melting temperature using a gyrotron system ensures high-density waste form with minimal volatilization of critical constituents, including radionuclides. In addition, this capability can be used for processing many different materials for a variety of applications relevant to nuclear energy and environment. This capability will be a user-facility that will be open current and future NEUP PIs, other scholars, engineers, and other clients, including commercial nuclear power plants.