Multi-field Mixed *hp*-FE Framework for Modeling Laser Pulse Heating Processes in Irreversible Thermodynamics

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In this presentation, new multi-field variational formulations are introduced for solving the following thermodynamic models [1]: (i) the ballistic-conductive system, (ii) the Guyer–Krumhansl heat conduction model, and (iii) the Maxwell–Cattaneo–Vernotte model, which are representative models of extended irreversible thermodynamics. In these formulations, the temperature, heat flux, and the current density of heat flux are treated as independent field variables [2]. Based on this variational framework, a family of mixed *hp*-version finite element methods (FEM) is developed, which is capable of reliably and efficiently modeling temperature responses [1].

The performance of the proposed *hp*-FE framework is demonstrated through two benchmark heat pulse experiments: (1) a sinusoidal laser pulse heating process and (2) a rectangular (step-like) laser pulse train. Numerical results confirm that uniformly stable (robust) and oscillation-free temperature response functions can be obtained not only for the ballistic-conductive system and the Maxwell–Cattaneo–Vernotte model, but also for both under-diffusive and over-diffusive parameter regimes of the Guyer–Krumhansl model.

It is shown that the *hp*-FE solutions successfully reproduce the expected characteristics in all cases, in contrast to COMSOL Multiphysics simulations (see [3]). This is particularly significant, as low-order, mesh-refinement-based FE approaches do not perform satisfactorily in all scenarios.

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