HAJIM SCHOOL OF ENGINEERING AND APPLIED SCIENCES
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Department of Chemical Engineering presents

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"Understanding light-matter interaction, melt pool dynamics and spatter formation in laser powder bed fusion processing"

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Abstract: Accurate prediction of the material response associated with any laser materials processing technology begins with precise knowledge of the energy coupling mechanisms active during the laser-matter interaction. In laser powder bed fusion additive manufacturing of metal parts, complex hydrodynamics driven by vapor recoil and Marangoni convection lead to liquid metal interfaces that are steeply curved thereby affecting Fresnel absorptivity (near-keyhole mode absorption). Changes in absorptivity due to melt pool motion can lead to fluctuations in energy coupling which drive excursions in melt pool depth, microstructure and local residual stress. Under certain circumstances, vapor recoil can lead to laser keyhole formation during laser powder bed fusion processing which in turn can lead to part pore defects which adversely affect mechanical properties. Furthermore, ejection of material from the melt pool and entrainment of powder from melt vapor flux can generate spatter particles that become incorporated into subsequent powder layers and can lead to lack-of-fusion defects. To clarify the complex physics involved, a combined experimental and simulation effort is required with sufficient energy, spatial and temporal resolution. In the present work, a laser calorimetric test bed is developed equipped with high speed optical and thermal imaging and used to study changes in energy coupling as a function of laser power above the melting point for bulk metal plates and metal powder layers of several commercially-relevant metal powders. Hydrodynamic finite element modeling of the powder bed is used to simulate the melt pool morphology and dynamics, providing insight to energy coupling, keyholing and spatter generation mechanisms. The measurements and simulations taken together offer powerful new insights into the laser powder bed fusion process which might be exploited to improve efficiency and overall process robustness. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. This work was funded by the Laboratory Directed Research and Development Program at LLNL under project tracking code 15-ERD-037.