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EE 367 Project Proposal

Laser powder bed fusion (LPBF) additive manufacturing (i.e., metal 3D printing), is important to industries such as aerospace, biomedicine, and defense for creating parts of near arbitrary geometry with improved performance and efficiency, in ways that are impossible with conventional manufacturing. In this process, a high-power laser selectively melts and fuses metal powders together layer-by-layer into a single part of the desired geometry, side-stepping tooling constraints of conventional manufacturing. However, this process is limited by defect physics including pore formation, cracking, and elemental inhomogeneities introduced in this highly dynamic system [1] – [7].

Operando x-ray imaging has proven to be an invaluable technique for probing the defect physics and mechanisms of this highly dynamic system. However, to date, the only x-ray imaging technique that has been employed to study this field is radiography in the hard x-ray regime at synchrotrons [2] – [7]. Radiography is limited in spatial and temporal resolution by the point spread function (PSF) of the scintillators used in imaging and the detector integration time / source fluence, respectively. My group recently advanced the state of the art in this field by overcoming these limitations using transmission x-ray microscopy (TXM) in which a lens is used to magnify the x-ray image in the x-ray regime, before the scintillator. This allows for higher spatial resolution and by-passes the resolution limits of the scintillator PSF. Employing TXM additionally required moving from synchrotrons to much brighter, more monochromatic, and more advanced x-ray sources known as x-ray free-electron lasers (XFELs), which allowed us to additionally improve the temporal resolution by orders of magnitude [8,9].

While not an issue in this particular work, TXM has a finite depth of field like any other imaging system and is furthermore highly chromatic [10]. I propose to develop a forward model for chromatic aberration, accounting for the finite depth of field of the microscope, to predict blurring introduced by imaging thick samples with finite bandwidth. This serves two purposes: (a) determining the limits of our TXM microscope with regard to acceptable bandwidth and sample geometries, and (b) allowing us to begin exploring the feasibility of more advanced microscope techniques which can exploit finite depth of field to recover 3D sample information.

While some work exists in computationally intensive multi-slice wave-propagation based algorithms for calculating the predicted image [11], I aim to modify known ray optic calculations of x-ray lens performance and defocusing blur to more efficiently approximate the blur behavior of chromatic aberration. I will begin by simulating images in monochromatic beams that account for the finite depth of field using a differential approximation of the sample, then I will integrate this over the probe beam's bandwidth. The end goal of this project is to have a relatively fast and physically grounded computation of TXM images resulting from 3D samples of meaningful thickness in chromatic beams.

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