Short pulse laser irradiation has the ability to bring material into a state of strong electronic, thermal, phase, and mechanical non-equilibrium and trigger a sequence of structural transformations leading to the generation of complex multi-scale surface morphologies, unusual metastable phases and microstructure that cannot be produced by any other means. A combination of experimental and computational probing of laser-materials interactions can provide unique insights into the core materials science questions, such as the generation of crystal defects (vacancies, dislocations, growth twins, grain boundaries) in the course of the rapid resolidification, the kinetics of homogeneous nucleation and growth under conditions of rapid temperature variations, atomic mixing and generation of highly supersaturated solid solutions, etc. In this talk, I will briefly discuss the impact the field of laser-materials interactions is making on the fundamentals of materials science, and highlight the role of large-scale atomistic simulations in theoretical interpretation of the results of time-resolved experimental probing (particularly UED) of laser-induced processes.

**Figure:** Illustration of some of the results of large-scale atomistic modeling of short-pulse laser induced structural and phase transformations.