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Synergy Between Experiments and Simulations in Laser and Beam-Driven Plasma Acceleration and Light Sources[1]

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Computer simulations have been an integral part of plasma physics research since the early 1960s. Initially, they provided the ability to confirm and test linear and nonlinear theories in one-dimension. As simulation capabilities and computational power improved, then simulations were also used to test new ideas and applications of plasmas in multi-dimensions. As progress continued, simulations were also used to model experiments. Today computer simulations of plasmas are ubiquitously used to test new theories, understand complicated nonlinear phenomenon, model the full temporal and spatial scale of experiments, simulate parameters beyond the reach of current experiments, and test the performance of new devices before large capital expenditures are made to build them. In this talk I review the progress in simulations in a particular area of plasma physics: plasma based acceleration (PBA). In PBA a short laser pulse or particle beam propagates through long regions of plasma creating plasma wave wakefields on which electrons or positrons surf to high energies. In some cases the wakefields are highly nonlinear, involve three-dimensional effects, and the trajectories of plasma particles cross making it essential that fully kinetic and three-dimensional models are used. I will show how particle-in-cell (PIC) simulations were initially used to propose the basic idea of PBA in one dimension. I will review some of the dramatic progress in the experimental demonstration of PBA and show how this progress was dramatically helped by a synergy between experiments and full-scale multi-dimensional PIC simulations. This will include a review of how the capability of PIC simulation tools has improved. I will also touch on some recent progress on improvements to PIC simulations of PBA and discuss how these improvements may push the synergy further towards real time steering of experiments and start to end modeling of key components of a future linear collider or XFEL based on PBA.

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