REAL AND VIRTUAL FREE-ELECTRON LASER EXPERIMENTS: FROM VISA TO THE FEMTOSECOND FRONTIER

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Abstract

The VISA experiment has been recognized for its role not only in exploring the physics of high-gain SASE free-electron lasers, but in its methodology as well. In VISA, a high degree of correspondence between intricate beam and FEL diagnostics, and detailed start-to-end simulations was developed. These tools worked together to uniquely reveal the underlying microscopic mechanisms that produce complex FEL behavior. We review examples of new and novel physics arising from VISA, and show how they challenged our conceptual and analytical picture of the FEL. We then look next-generation FELs, in which "virtual experiments" must reveal critical physical issues without direct experimental verification. As a relevant context, we take our proposal of using very low-charge beams to produce sub-fs, single-spike FEL pulses. With orders of magnitude lower charge, pulse length, and FEL wavelength beyond current practice, we must face a myriad of challenges enabling this exciting new path for FEL science. We show how simulations identify qualitatively new behavior in the beam/FEL system. The approach to benchmarking these phenomena with new experiments and extended simulation tools are discussed.

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