Recent progress in simulation and theory towards using nonlinear plasma wakefields to drive a compact X-FEL

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X-ray free electron lasers (X-FELs) driven by kilometer-long radio-frequency based accelerators have already proven to be transformative tools for modern science. Using plasma wakefields accelerators to drive compact X-FELs can much reduce the cost and shrink the size, making it possible to place one at universities. However there are many challenges needed to be overcome before plasma wakefields can generate electron beams with the required beam quality (brightnesses and low energy spreads) inside the plasma and before these beams can be transported from the plasma to the undulator without beam quality degradation. In this talk, we will present our recent progress from PIC simulations and theory on this topic, including concepts for producing beams with unprecedented normalized brightnesses using density down ramp injection in the nonlinear blowout regime, matching the beam out of the plasma using longitudinally tailored plasma profiles, and start-to-end simulations of such plasma wakefied accelerators driven X-FELs.