Karlsruhe Institute of Technology

Utilizing differentiable beam dynamics code for simulated optimization

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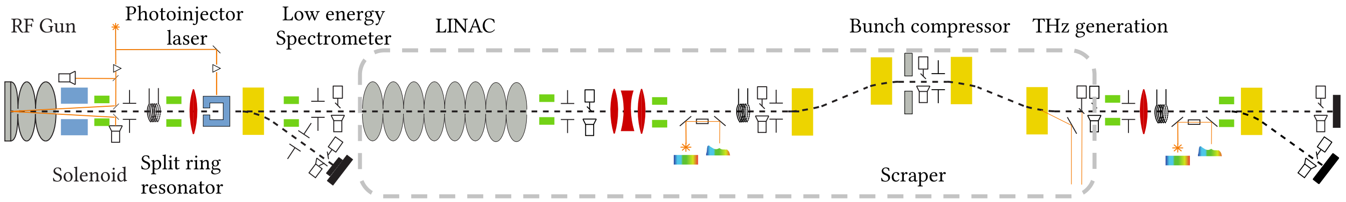
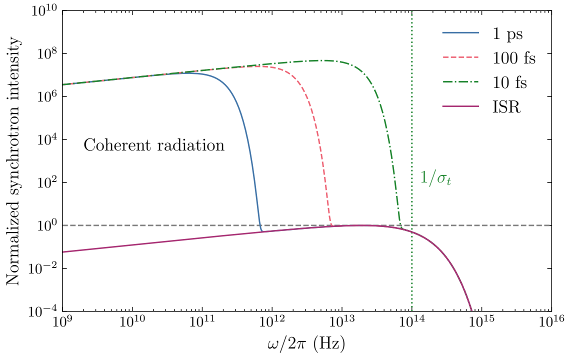
Intensive CSR THz pulse generation at FLUTE





Bunch SR intensity

$$\frac{d^2 I}{d\omega d\Omega} = [N_e + \underbrace{N_e(N_e-1)}_{\text{Coherent part}} F(\omega)] \frac{d^2 I_0}{d\omega d\Omega}$$

Coherent part Form factor

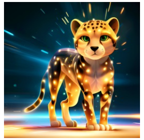
CSR E-field calculation

$$\boldsymbol{E}(t) = N_e \int_{-\infty}^{\infty} \boldsymbol{E}_0(\tau)\varrho(t-\tau)\, d\tau$$

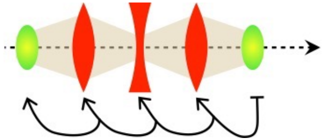
Charge density ρ step-wise linearly interpolated

Differentiable simulation models allows gradient-based optimization

Particle tracking using **Cheetah**, Pytorch-based beam dynamics code.



Auto-differentiation of the output beam with respect to input parameters (accelerator settings)



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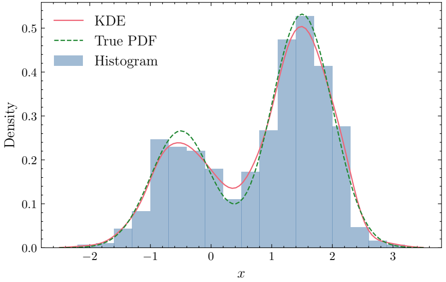
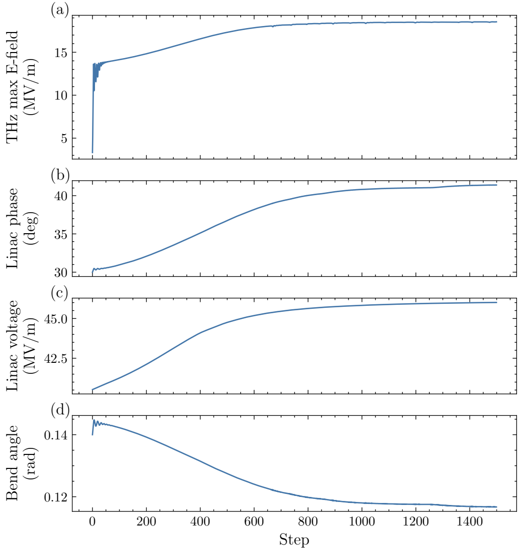
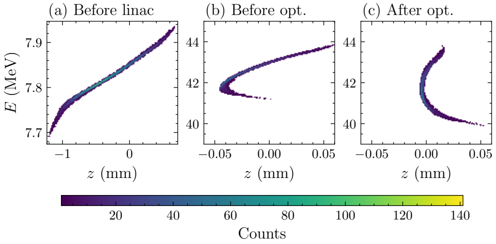
Analytical CSR electric field calculation

Charge density estimation using KDE



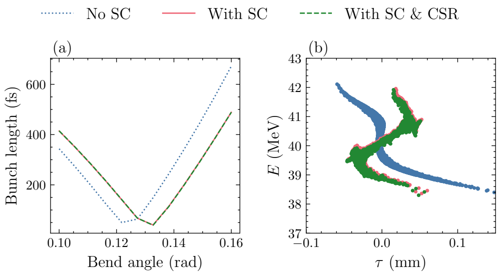


Longitudinal phase spaces

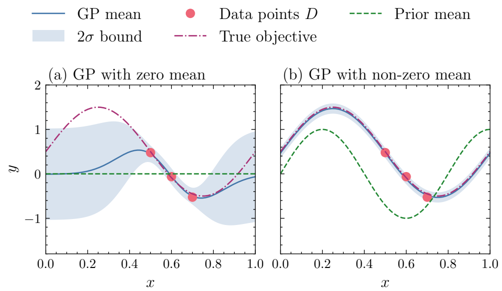


Physics-informed BO for efficient optimization under collective effects

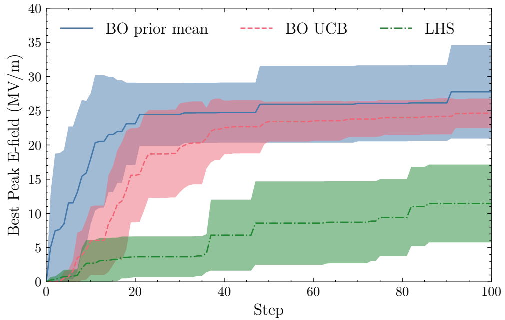
Collective effects like space charge and CSR can deteriorate the LPS



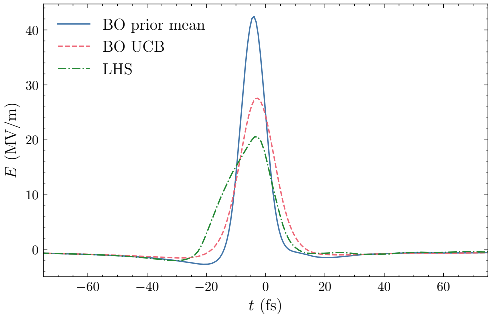
Using simulation as prior mean for more sample-efficient and accurate GP modeling



Optimization progress



Resulted E-field of the THz pulse



Longitudinal phase space