U.S. Particle Accelerator School
Education in Beam Physics and Accelerator Technology

Simulations of Beam and Plasma Systems

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Example Warp Simulations – part 1

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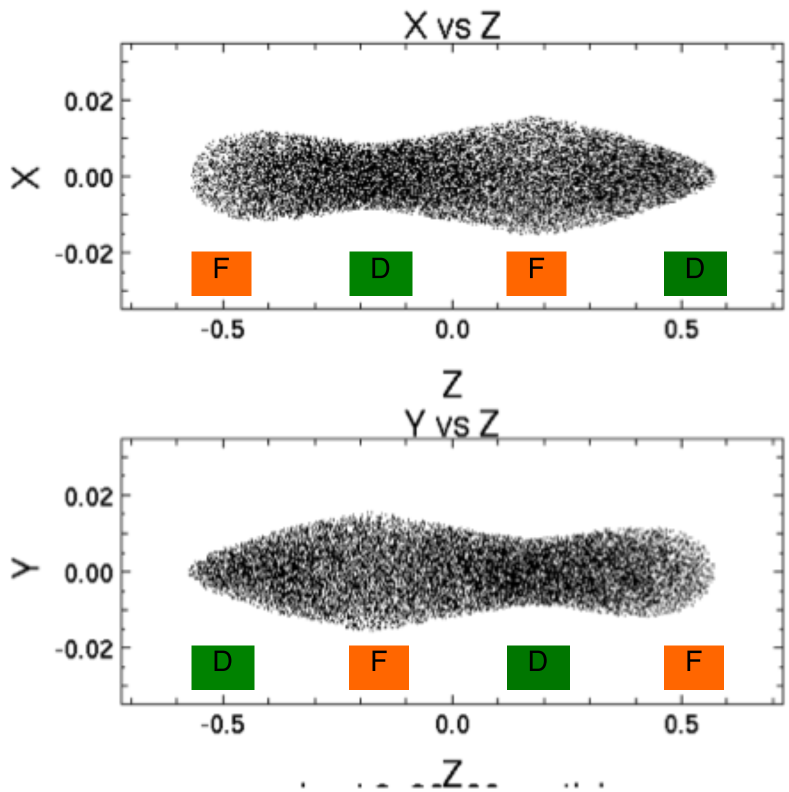
Outline

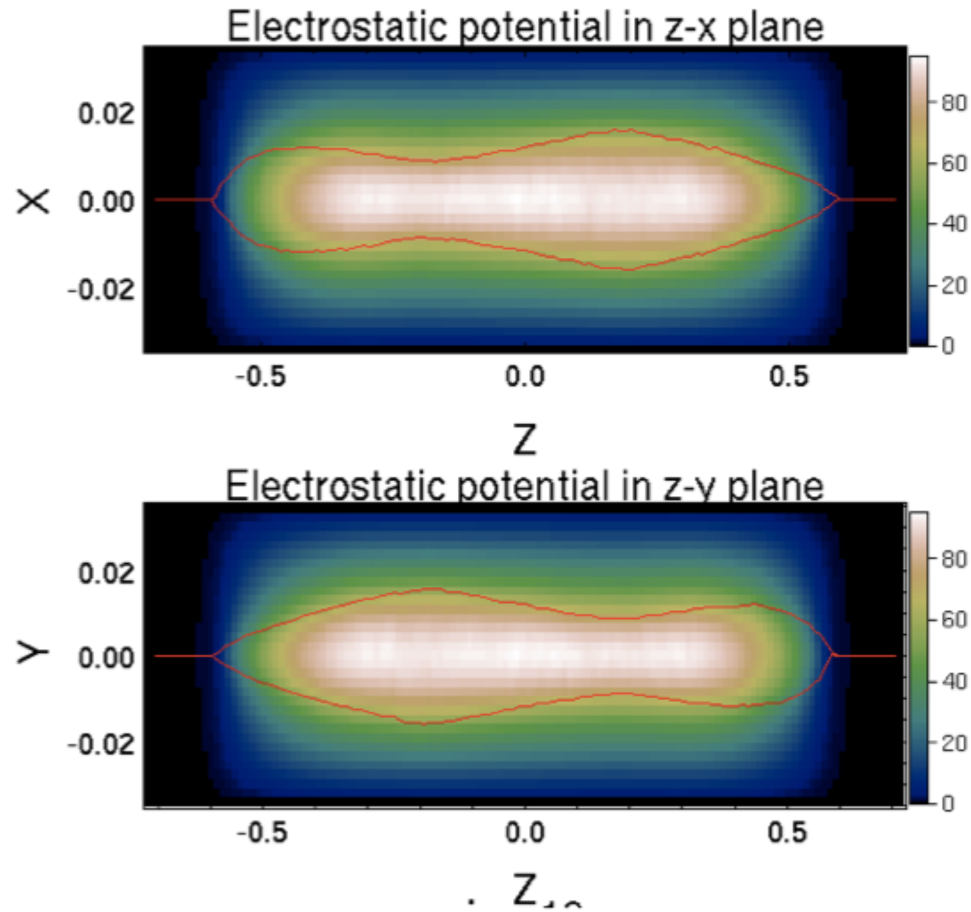
- Quadrupole transport 3D
- Quadrupole transport 2D-XY
- Plasma acceleration

Examples are in simbeamplasma18/warp_scripts from github repository :

- git clone https://github.com/uspas/simbeamplasma18.git.

Quadrupole transport – 3D





File FODO3D.py - basic 3D simulation of an ion beam in a periodic FODO lattice:

- Sets up a periodic FODO lattice and creates a beam that is matched to the lattice.
- The beam is propagated one lattice period.

FODO3D: tasks

① Into FODO3D, open FODO3D.py

② Execute file: “python –i FODO3D.py”

③ Open cgm file and explore:

  a) “gist FODO3D.000.cgm &”

④ Compare the slices emittance diagnostics to the whole emittance diagnostic. Can you explain the differences (i.e. one is constant, the other oscillates)?

⑤ Read input script and try to understand every command

⑥ Change ‘w3d.distrbtn = "semigaus”’ to ‘w3d.distrbtn = ”KV"’ ; rerun & observe

⑦ Change ‘w3d.distr_l = "gaussian”’ to ‘w3d.distr_l = ”neuffer”’ ; rerun & observe

⑧ Insert “beam.x0 = beam.a0/2” on the line following “beam.a0 = …”; rerun & observe

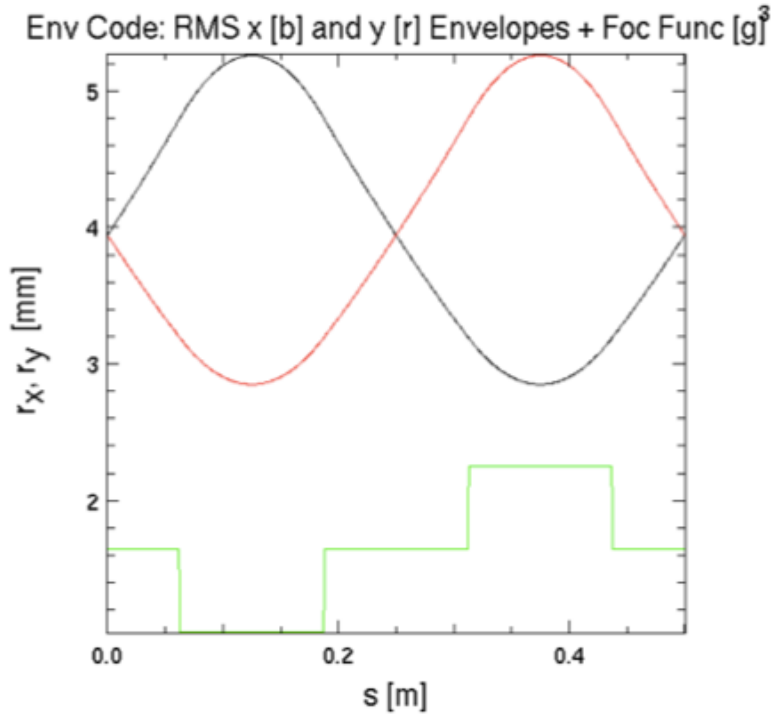
⑨ Check that you have the “ffmpeg” software installed: “which ffmpeg”

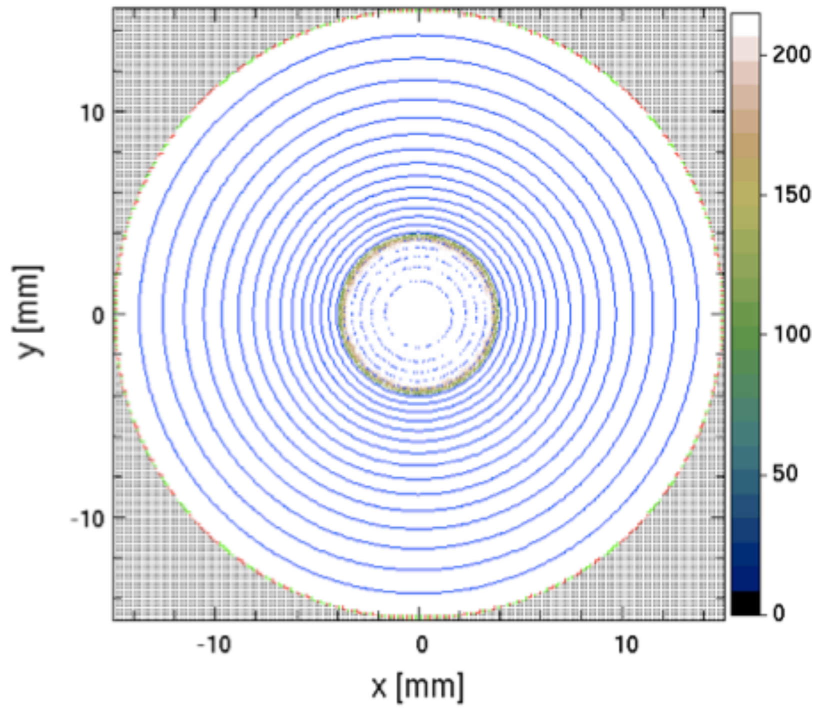
- If not, download and install ffmpeg

⑩ Change “l_movieplot = False” to “l_movieplot = True” & rerun

- If all goes well, after a few minutes, you should have a movie “movie.mp4”

Quadrupole transport – XY





File xy-quad-mag-mg.py:

nonrelativistic Warp xy slice simulation of a K^+ ion beam with intense space-charge focused by a hard-edge magnetic quadrupole doublet focusing lattice.

xy-quad-mag-mg: tasks

① Into XY-quad, open xy-quad-mag-mg.py

② Execute file: “python –i xy-quad-mag-mg.py”

③ Open cgm file and explore: “gist xy-quad-mag-mg.000.cgm &”

④ Read input script and try to understand every command.

⑤ Comment ‘w3d.distrbtn = "SG”’ and uncomment ‘w3d.distrbtn = ”KV”’, rerun and compare to results using the KV vs SG distributions.

⑥ Change the initial emittance “emit = 10.e-6” to “emit = 10.e-7”, rerun and observe effect on matching and emittance preservation.

⑦ Change switch “l_automatch = False” to “l_automatch = True”, rerun and observe difference with previous run.

⑧ Change n_grid=200 to 400, rerun and observe differences. Can you explain?

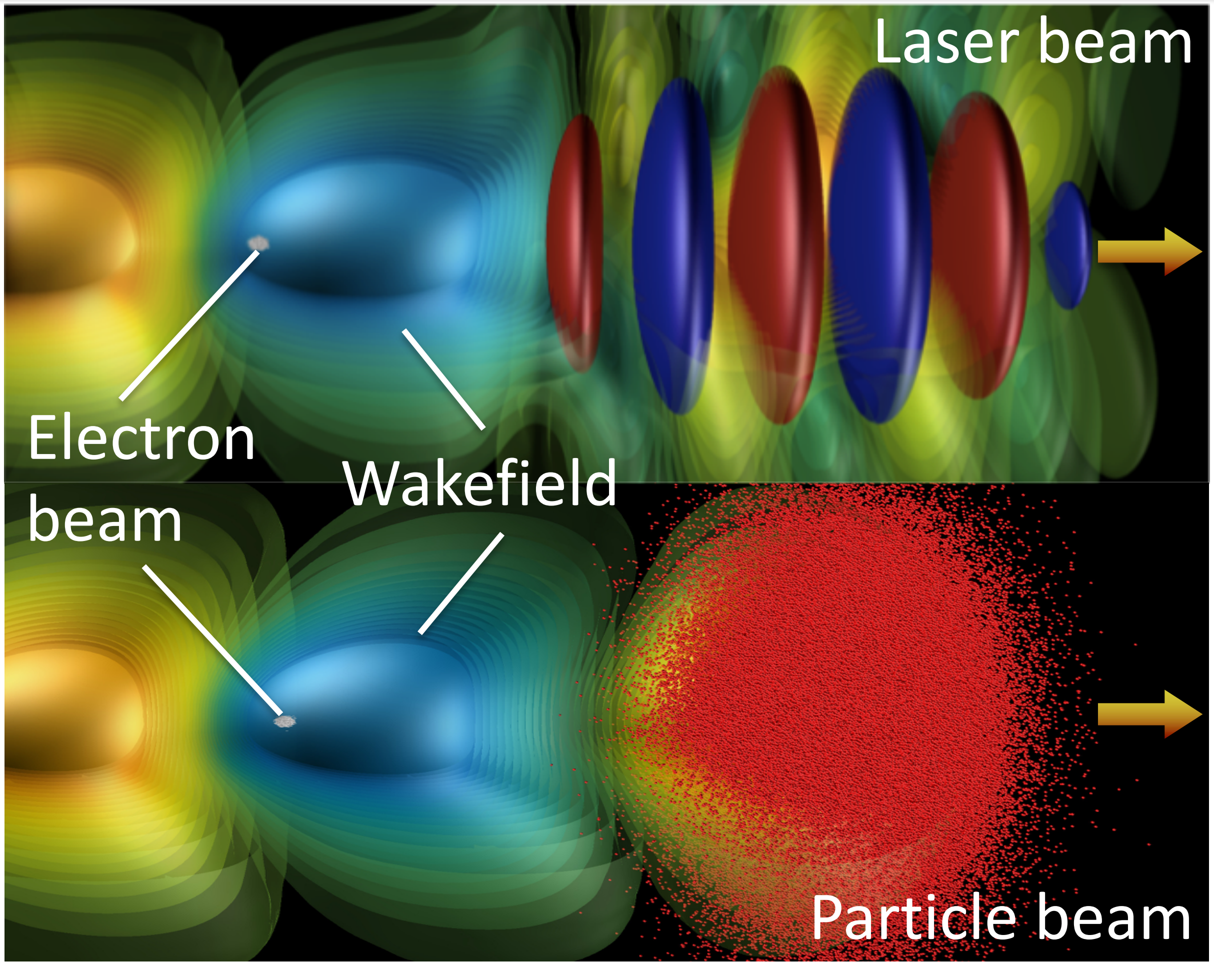
⑨ With the simulation back at the python prompt, type ‘dump()’, then run for another 500 steps: “step(500)”.

⑩ In another terminal, start python and type:

- from warp import *
- restart(‘xy-quad-mag-mg001000.dump’)
- step(500)

Reopen “xy-quad-mag-mg.000.cgm” and compare to “xy-quad-mag-mg.001.cgm”.

Plasma acceleration



Scripts lpa_script.py, lpa_script_2d.py, pwfa_script.py – basic plasma acceleration runs:

- Generate plasma, laser or beam driver, and injected electron beam and follow self-consistent evolution.

Plasma acceleration tasks

① In Plasma_acceleration, open LWFA_3D/lwfa_3d.py and PWFA_3D/pwfa_3d.py

② Execute the files "python –i lwfa_3d.py" and "python –i pwfa_3d.py" separately.

③ It takes some time to run. While it runs, you may open periodically the cgm files ***_script.000.cgm and see the progress. In the meantime, also go through the input scripts and try to understand all the commands.

④ At the end of the run, a plot displays the energy of the accelerated beam versus z.

⑤ Explore data using the OpenPMD notebook viewer by running 'openPMD_notebook' in the run directory. While exploring data, run 2000 additional time steps.

⑥ In plasma_acceleration, open LWFA_2D/lwfa_2d.py and execute.

⑦ Open cgm file and explore:

  a) "gist lpa_basic_2d.000.cgm &"

⑨ Read input script and try to understand every command.

⑩ Run the script ptime displaying the history of the elapsed time and the time per step. Observe the spikes from the diagnostics.