Dielectric Wakefield Calculator and Solver

# Main menu

Mesh an existing beam so fields can be calculated. This is unlikely to be used but will be extended in future to be applicable when concerting a beam from another simulation software format

Calculating the fields in a planar or circular DLW. Requires a beam file which has been meshed.

Making a beam including meshing in a format ready to use with the field solver. **Usually the first step in a simulation.**

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Plotting single/multiple beams and printing beam properties

Plot fields from DiWaCAT field calculator files. Able to label and plot multiple field files and output data for external plotting

Simulate a beam through a DLW. Needs a field file and beam file (these can be the same). Able to save single beams from output or the beam at each step. Simple beam properties (size, charge transport) at each step plotted whilst simulation ongoing

Some simple generic beam functions. Beam optics (drift, quads, collimation), beam slicing, and screen simulator

# Simulation Steps

In general, a DiWaCAT simulation follows a linear order with each step separated.

## A screenshot of a computer Description automatically generatedMaking a beam

The head of the bunch is on the left

These variables relate to the scope and density of the mesh:

* Cells per sigma: mesh density
* Maximum cell: +/- position relating to the maximum grid position.

Variables worth noting

* RMS beam size:
  + This is the size at the waist – not at the position the beam is outputted at
* Waist position
  + This is relative to the bunch – can be either positive (the waist is downstream so beam converging) or negative (waist is upstream so beam diverging at output)
* Longitudinal RMS Bunch Length:
  + Whether this is sigmaz or sigmat depends on which option is given by Bunch Length Scale
* Correlated energy spread – relates to beam chirp
  + A positive number = high energy at the tail
  + Negative number = high energy at the head
* Uncorrelated energy spread
  + Does not relate to beam chirp and can be used in conjunction with an energy chirp
* Emittance is in units of m rad
  + Setting a scale of micro is therefore mm mrad

Several beam profile shapes can be set:

* Gaussian – variables as in the screenshot
* Uniform – no new/different variables
  + RMS longitudinal bunch length is ¼ of the total bunch length
* Skew-Gaussian:
  + Skew factor (alpha)
    - Alpha from the standard definition of skewness with the PDF given by
      * + is the standard Gaussian PDF
        + where erf is the error function
    - Positive alpha = current towards the bunch head
    - Negative alpha = current towards the tail
* Plateau
  + As with uniform – the total length is 4x RMS longitudinal bunch length
  + Plateau rise time / sigmaz
    - The time to reach peak current normalised to the set bunch length
    - Gaussian added to the head/tail
    - Does not change the total bunch length
    - If set to between 2 and 3 the overall profile is approximately Gaussian since the rise/fall time accounts for the whole bunch length
* DoubleGauss
  + The second Gaussian is always towards the tail
  + Both delay time and second Gaussian RMS length are in units of ‘Bunch Length Scale’ – matching the scale of the first RMS bunch length
  + Amplitude is relative to the first
    - Ratio of peak current values
  + Delay time is peak to peak distance – doesn’t stop there being overlap

## Calculate the fields in the DLW

A screenshot of a computer

Description automatically generatedA green screen with black text

Description automatically generatedTwo options: Planar and circular DLW

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Description automatically generatedA green circle with a grey circle with a grey circle with a grey circle with a grey circle with a grey circle with a grey circle with a grey circle with a grey circle with a grey circle

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* In both cases the beam position is given in cartesian coordinates, matching the cartesian beam position/mesh positions in the beam file
* Save file dialog opens when calculation finishes
* Console window gives estimated remaining time for simulation
* Non-trivial input parameters:
  + L = length of dielectric
    - This is not relevant for beam tracking but the number is saved in the output HDF5 file – can be set to zero
  + ε,μ = relative permittivity/permeability of dielectric
  + Simulation parameters:
    - Using the default parameters will be sufficient in (almost) all cases
    - nX, nY = minimum number of X/Y modes used
    - nRadial, nTheta = same as above for circular DLW
    - Ticking convergence ensures the number of modes required are calculated before the field is calculated
    - Root precision = accuracy of the wavenumber of each mode
    - Mode accuracy = convergence of the last 5 modes (planar) or last mode (circular)
      * Used if convergence is ticked
    - No. steps = number of steps
      * Either 0 or 1
        + If 1 then the beam phase space will be kicked by the field calculated multiplied by the length of the dielectric
        + Recommend set to zero and allow tracking to be dealt with separately
    - Max longitudinal position
      * If a number greater than the tail of the bunch is given, mesh points will be added upto that point
      * Allows for calculation of 3D fields behind the bunch
      * Scientific notation can be used (e.g. 1e-6, 1E-6)
      * Set to zero if not required (if this value is within the bunch nothing will be done)
* N.B. the option 1D Green’s Function is not relevant for DiWaCAT simulations
  + Calculates the wake potential (3D) as a function of longitudinal position in a planar DLW
  + 1D since given at a single x,y position
* N.B. if a circular DLW is used, it is recommended to use a larger mesh density (typically 3 or 4 cells per sigma)

## Simulate the beam through a DLWA screenshot of a computer Description automatically generated

* Inputs:
  + Beam file
  + Field file
  + These can be the same (the field file outputted included the beam positions)
* Variables:
  + DLW length – total length of the DLW
  + Number of steps – steps within the DLW
    - Allows for tracking within the DLW
  + Post DLW drift – if non-zero an extra beam is added
* In the tracked beam list, single beams can be selected and saved
  + Save file dialog opens and file name can be given
* If save all beams is pressed, a folder is selected in which all beams are saved with name matching the list of beams
* Beams can be meshed or not (for example if the output of one simulation is used as input to calculate fields again)
* Beam properties can be selected and tracked
  + During tracking field distribution (Fx(x,y,z) etc.) is assumed to be constant
    - This holds so long as the beam size and length does not considerably change
    - Beam property plots allow for any significant changes to be seen
    - If static field condition does not hold, the beam at that position can be saved and used to recalculate the field

## Output plotting/visualization

### A screenshot of a computer Description automatically generatedFields

* Single or multiple fields can be plotted
* X Axis can be normalised to the RMS beam size/length
* The Central X/Y/Z positions relate to the variable not being plotted
  + E.g. in the example above Ez(z) is plotted at x = 0, y = 0
* Data can be extracted with right-click -> Export

### A screenshot of a computer Description automatically generatedBeams

* Plot or print beam properties
* The number of histogram bins relate to the histograms at the top and left of the scatter plot
* Drift distance = drift applied before beams plotted or properties outputted
* N.B. if an axis is ‘t’ – the head of the bunch is positive values of time. If ‘z’ the head is negative values
* Outputting data works for each plot individually but not as a set of 3

# Beam Manipulation Functions

## Beam Slicing

* Beam slicing can be performed before or after a simulation.
  + N.B. since the field is sampled at macroparticle positions, tracking can be performed on a sliced beam without issue.
  + A screenshot of a computer

    Description automatically generatedLongitudinal positions do not change during tracking. It makes no difference using longitudinal slices before or after a simulation.
* Equal width slices between the minimum and maximum values
* N.B. for longitudinal slices
  + Positive values of t = head
  + Positive values of z = tail
* When saving slices a folder dialog box opens
  + Beams saved in this folder with names Slice1, Slice2, etc.
  + Slice 1 is minimum slice (e.g. in the screenshot above Slice1 would be 0 – 12.5 um)

## A screenshot of a computer Description automatically generatedBeam Transportation

* Perform a series of beam transport functions. Single beams can be selected and saved or beam transport reset to a selected point or to the input beam (file at the top of the page)
* If all beams are saved, a folder dialog box opens. File names match those in the list, giving the beam number and function applied
* Individual functions:
  + i. Thin Quad
    - A screenshot of a computer

      Description automatically generatedThe thin quad brings all macroparticles to a waist at the same point. This should be avoiding in most cases where wakefields have been applied or there is momentum spread.
  + ii. Thick Quad
    - A more suitable quadrupole function than thin-lens
    - Positive quad strength relates to horizontal focusing/vertical defocusing.
    - Negative quad strength relates to vertical focusing/horizontal defocusing.
  + iii. Dipole
    - Function has not yet been written.
    - If pressed this will perform a drift of 0 m – no effect on the beam.
  + iv. Drift
    - Drift in free space for a given distance.
  + A screenshot of a computer

    Description automatically generatedv. Collimate
    - Works like the beam slicing function – gives a single slice between the minimum and maximum values given.
    - A collimated beam can be tracked in the same way as a sliced beam.