

Conversion of radiation fields from genesis2, genesis4, and SRW to electric fields in SI units

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1 Genesis Field to Electric Field

The description of FEL radiation field format in the GENESIS manual is scarce. The DFL / RAD.H5 file stores a complex array of `ncar` \times `ncar` points for each simulation slice, over a transverse domain size `[-dgrid, -dgrid]` m in both the horizontal and vertical dimensions.

Let us denote the radiation field value taken from DFL file for n -th slice at i, j transverse location as $F_{n,i,j}$. The manual hints that integrated value of $|F_{n,i,j}|^2$ over the spatial domain yields the total FEL power of n -th slice. Indeed, the value of

$$P_n = \sum_{i,j} |F_{n,i,j}|^2, \quad (1)$$

matches the value of integrated power, in units of Watt, reported in the output file for n -th slice. The values of $F_{n,i,j}$ returned by GENESIS are therefore in the units of $\sqrt{\text{W}}$. One can use this fact to devise the conversion factor for DFL / RAD.H5 to V/m. We first recall that time-averaged energy density is given by (Jackson, Eq. 7.14):

$$u = \frac{\epsilon_0}{2} |E|^2, \quad (2)$$

where ϵ_0 is vacuum permittivity. The local radiation intensity (energy per unit area per unit time) is related to the electric field as:

$$I = cu = c \frac{\epsilon_0}{2} |E|^2 = \frac{E^2}{2Z_0}, \quad (3)$$

where $Z_0 = \sqrt{\mu_0/\epsilon_0} = 1/(\epsilon_0 c)$ is the impedance of free space. In SI units, $Z_0 = \pi \cdot 119.9169832 \text{ V}^2/\text{W}$ exactly. The total power (energy per unit time) over an area A can be approximated by

$$\begin{aligned} P &= \int I dA \\ &\approx \sum_{i,j} \frac{E_{i,j}^2}{2Z_0} \Delta^2 \end{aligned}$$

where $E_{i,j}$ is the electric field value on an equally spaced grid with grid spacing Δ .

According to the GENESIS manual, $\Delta = 2*\text{dgrid}/(\text{ncar}-1)$ m, and therefore we can express the electric field for n -th slice for a i, j -th point on the grid in V/m as:

$$E_{n,i,j} = F_{n,i,j} \sqrt{2Z_0}/\Delta \quad (4)$$

2 SRW Wavefront to Electric Field

SRW's radiation wavefront class `SRWWFr` allows several unit systems. The only documentation is in the code of `srwlib.py`:

```
unitElFld = 1 #electric field units:
0- arbitrary, 1- sqrt(Phot/s/0.1%bw/mm^2)
2- sqrt(J/eV/mm^2) or sqrt(W/mm^2), depending on representation (freq. or time)
```

Assuming the time representation, the conversion from an SRW field F_{SRW} (in units of $\sqrt{\text{W}}/\text{mm}$) to electric field E is therefore:

$$E = F_{\text{SRW}} * \sqrt{2Z_0} * \frac{1000\text{mm}}{\text{m}} \quad (5)$$

J.D. Jackson, *Classical Electrodynamics, Third Edition* (1999)