SR source related calculations with SRW

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SR source related calculations with SRW

Outline:

- What do we want from source related calculations?
- Which elements constitute the source in SRW?
- How is it done?
- Live demo using OASYS

What do we want from source related calculations?

Spectral properties:

- “on axis” or “through slit” photon flux (and tuning curves for undulators);
- spectral brightness;
- coherent flux and fraction;
- spectral & cumulated power (“total” or “through slit”)…

Spatial properties:

- beam profile or angular distribution (intensity and phase);
- coherent mode decomposition, cross spectral density, mutual intensity…
- power density…

Spectral distribution of spatial properties and spatial distribution of spectral properties (3D data sets)…

Which elements constitute the source in SRW?

Electron beam (`SRWLPartBeam`):

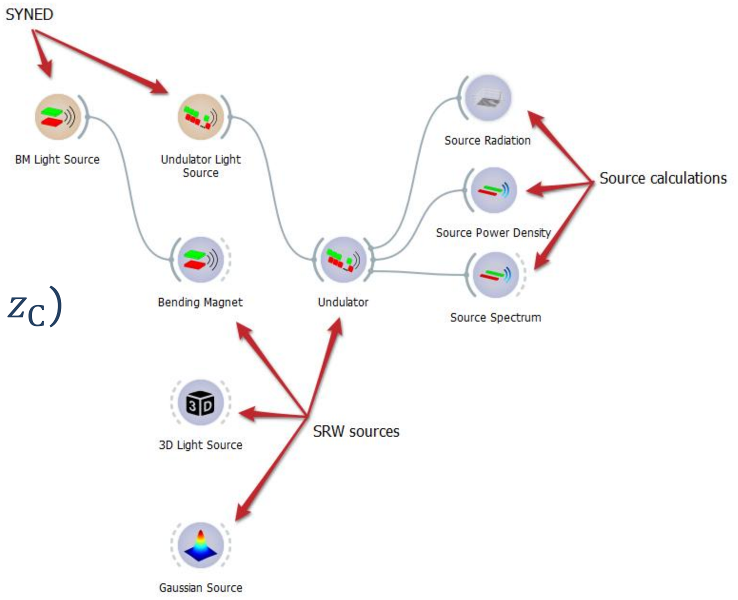
- storage ring current and energy $\mathcal{E}$
- single electron initial condition ($x_0, y_0, z_0, x_0', y_0'$ and $\mathcal{E}_0$ – first order statistical moments).
- electron beam second order moments (Twiss parameters or RMS values).

Magnetic field container (`SRWLMagFldC`):

- magnetic field structure:
  - arbitrary 3D field (`SRWLMagFld3D`)
  - dipole magnet (`SRWLMagFldM`)
  - undulator (`SRWLMagFldU`)
- center positions of magnetic field elements (x_C, y_C, z_C)

Stokes container (`SRWLStokes` or `SRWLWfr`):

- allocates arrays for electric field calculations.



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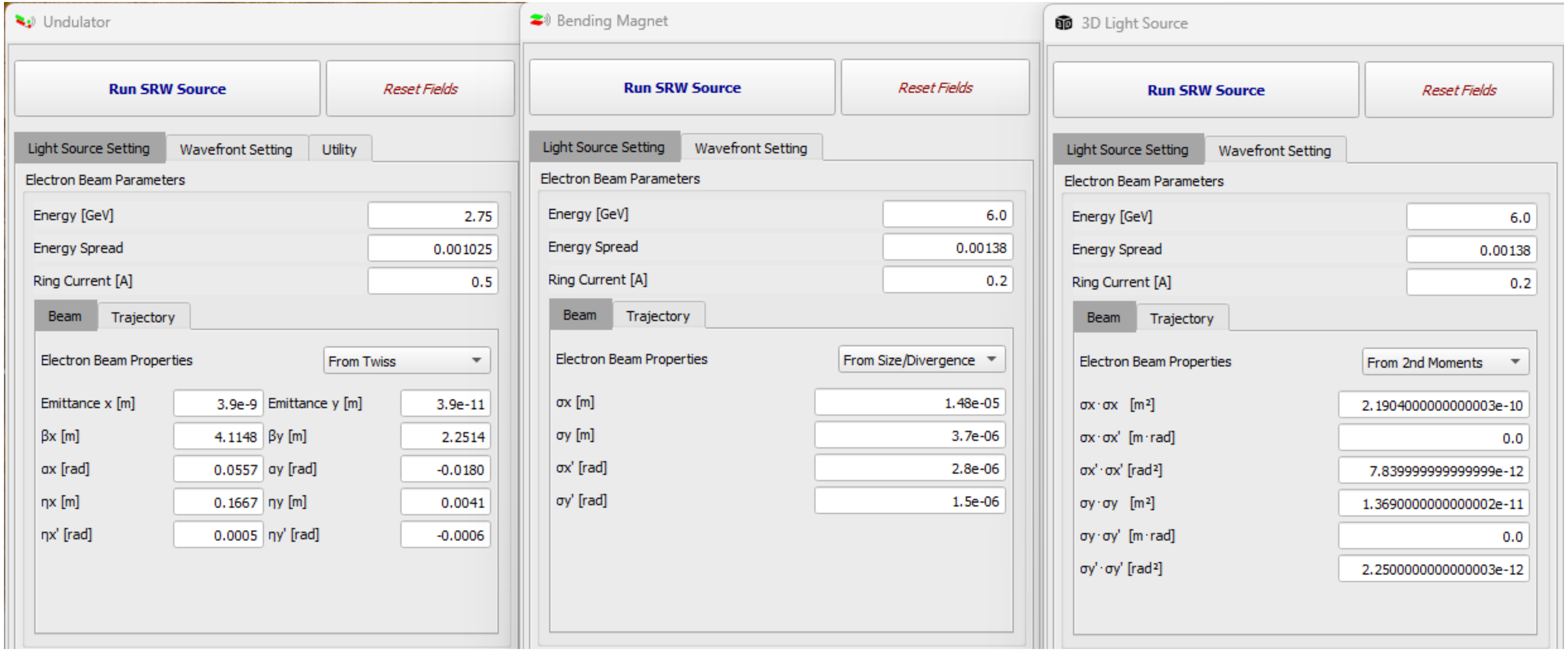

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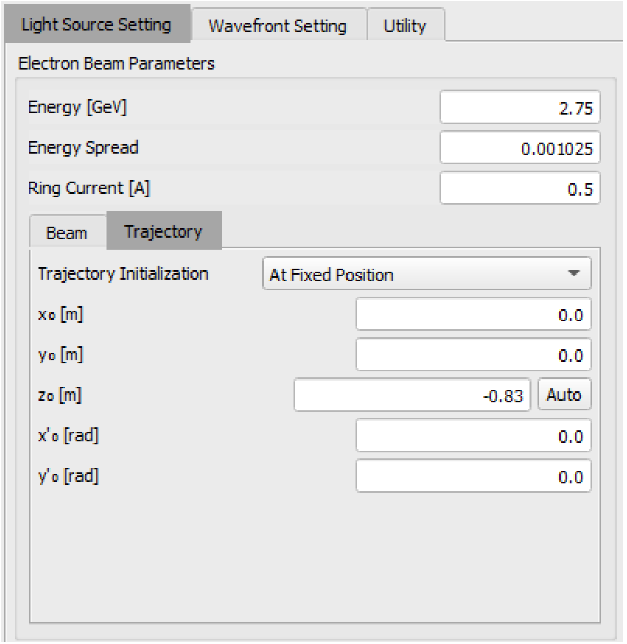

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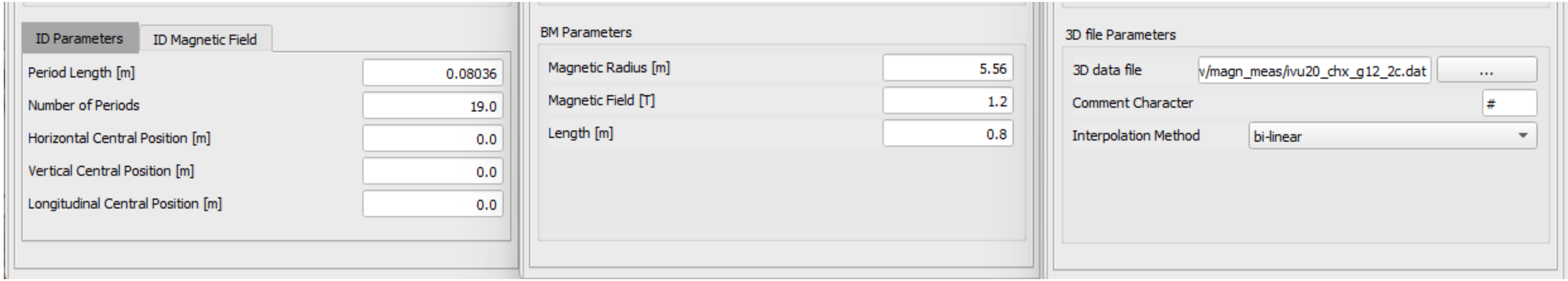

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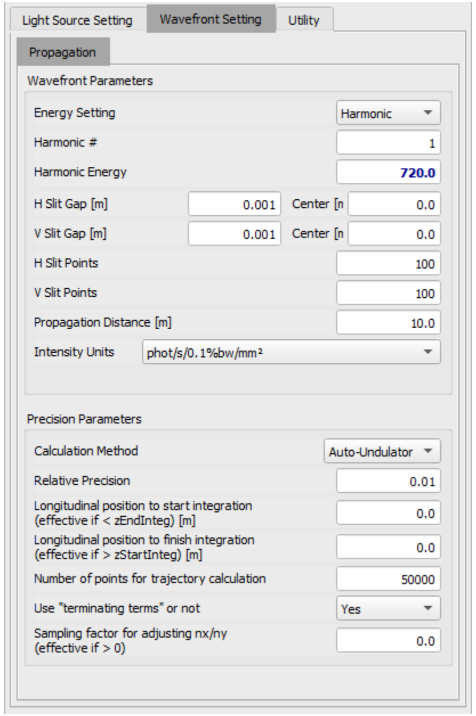

How is it done?

Spontaneous emission by whole relativistic electron beam in free :

$$\frac{\mathrm{d}N_{ph}}{\mathrm{d}t\mathrm{d}S(d\omega/\omega)} = \frac{c^2\alpha I}{4\pi^2 e^3}(\mathrm{I}_{\mathrm{ISR}} + \mathrm{I}_{\mathrm{CSR}})$$

The incoherent synchrotron radiation is given by:

$$\mathrm{I}_{\mathrm{ISR}} = N_e \int \left|\vec{E}_\omega(\Omega)\right|^2 \cdot f(\Omega)\,\mathrm{d}\Omega$$

And the coherent synchrotron radiation is given by:

$$\mathrm{I}_{\mathrm{CSR}} = N_e(N_e - 1)\left|\int \vec{E}_\omega(\Omega) \cdot f(\Omega)\,\mathrm{d}\Omega\right|$$

The particle density distribution in the 6D phase space is described by the function $f(\Omega)$ and normalised to 1:

$$\int f(\Omega)\,\mathrm{d}\Omega = f(x, y, z, x', y', \delta\gamma)\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}x'\,\mathrm{d}y'\,\mathrm{d}\delta\gamma = 1$$

Chubar, *Review of Scientific Instruments* 66(2), 1872–1874 (1995)
Chubar, *Infrared Physics & Technology* 49(1–2), 96–103 (2006)

How is it done?

Spontaneous emission by a relativistic electron in free space (retarded potentials approach in Gaussian CGS):

$$\vec{E}_\omega = \frac{ie\omega}{c}\int_{-\infty}^{\infty}\frac{1}{R}\left[\vec{\beta}-\vec{n}\left(1+\frac{ic}{\omega R}\right)\right]\exp\left[i\omega\left(\tau+\frac{R}{c}\right)\right]\mathrm{d}\tau$$

where $\vec{r}(\tau)$ is a particular electron trajectory, $\vec{\beta} = c^{-1}\mathrm{d}\vec{r}\mathrm{d}\tau$ is the relative velocity of the electron; $\vec{n} = \vec{R}/R$, $\vec{R} = r^* - \vec{r}$, $R = \left|\vec{R}\right|$; r^* denotes the observation point.

The phase in the exponent can be expanded assuming small observation angles while still preserving the variation of R with the electron position (near field calculation):

$$\omega\left(\tau+\frac{R}{c}\right) \approx \frac{2\pi}{\lambda}z^* + \frac{\pi}{\lambda}\left[\frac{s}{\gamma^2}\int_0^s\left|\vec{\beta}_\perp\right|^2\mathrm{d}\tilde{s} + \frac{(x^*-x)^2+(y^*-y)^2}{z^*-s}\right]$$

with $s = \tau\left|\vec{\beta}\right|c$ as integration variable.

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Asymptotic expansion of the radiation integral (to accelerate computation):

$$\int_{-\infty}^{\infty} F\, \exp(i\Phi)\, \mathrm{d}s = \int_{s_1}^{s_2} F\, \exp(i\Phi)\, \mathrm{d}s + \int_{-\infty}^{s_1} F\, \exp(i\Phi)\, \mathrm{d}s + \int_{s_2}^{+\infty} F\, \exp(i\Phi)\, \mathrm{d}s$$

$$\int_{-\infty}^{s_1} F\, \exp(i\Phi)\, \mathrm{d}s + \int_{s_2}^{+\infty} F\, \exp(i\Phi)\, \mathrm{d}s \approx \left[\left(\frac{F}{i\Phi'} + \frac{F'\phi' - F\Phi''}{\Phi'^3} + \cdots\right) \exp(i\Phi)\right]_{s_1}^{s_2}$$

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Examples

Live demo using OASYS…

Thank you!