

SR source related calculations with SRW

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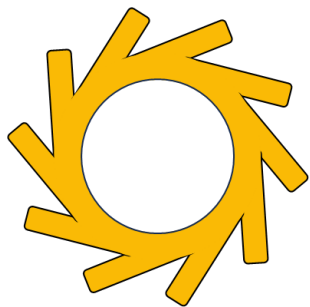


SR source related calculations with SRW

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):

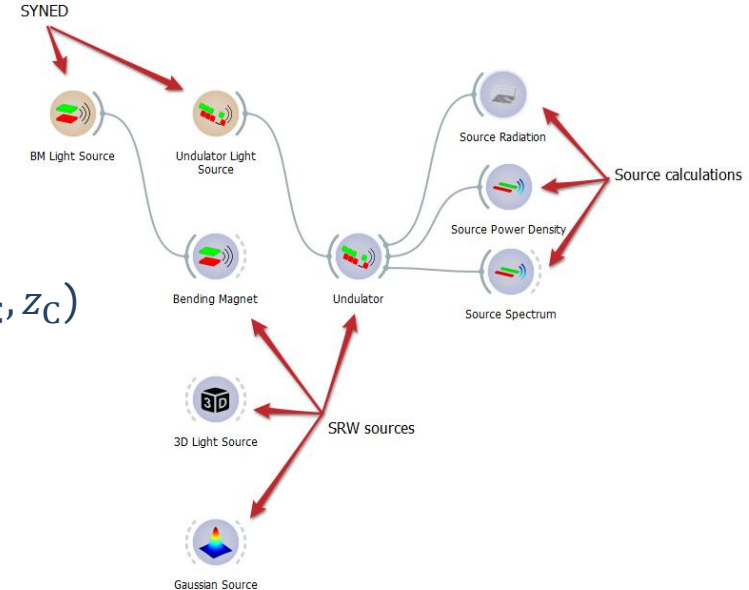
- storage ring current and energy \mathcal{E}
- single electron initial condition ($x_0, y_0, z_0, x'_0, y'_0$ and \mathcal{E}_0 – first order statistical moments).
- electron beam second order moments (Twiss parameters or RMS values).

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.



How is it done?

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

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

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

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

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

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

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

$$\begin{aligned} \int_{-\infty}^{\infty} F \exp(i\Phi) ds &= \int_{-\infty}^{s_2} F \exp(i\Phi) ds + \int_{-\infty}^{s_1} F \exp(i\Phi) ds + \int_{s_2}^{+\infty} F \exp(i\Phi) ds \\ &\quad \int_{-\infty}^{s_1} F \exp(i\Phi) ds + \int_{s_2}^{+\infty} F \exp(i\Phi) ds \approx \left[\left(\frac{F}{i\Phi'} + \frac{F'\phi' - F\Phi''}{\Phi'^3} + \dots \right) \exp(i\Phi) \right]_{s_1}^{s_2} \end{aligned}$$

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How is it done?

Spontaneous emission by whole relativistic electron beam in free :

$$\frac{dN_{ph}}{dt dS(d\omega/\omega)} = \frac{c^2 \alpha I}{4\pi^2 e^3} (I_{ISR} + I_{CSR})$$

The incoherent synchrotron radiation is given by:

$$I_{ISR} = N_e \int |\vec{E}_\omega(\Omega)|^2 \cdot f(\Omega) d\Omega$$

And the coherent synchrotron radiation is given by:

$$I_{CSR} = N_e(N_e - 1) \left| \int \vec{E}_\omega(\Omega) \cdot f(\Omega) d\Omega \right|^2$$

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

$$\int f(\Omega) d\Omega = \int f(x, y, z, x', y', \delta\gamma) dx dy dz dx' dy' d\delta\gamma = 1$$

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Chubar, *Infrared Physics & Technology* 49(1–2), 96–103 (2006)

Examples

Live demo using OASYS...

Thank you!