

# SR source related calculations with SRW

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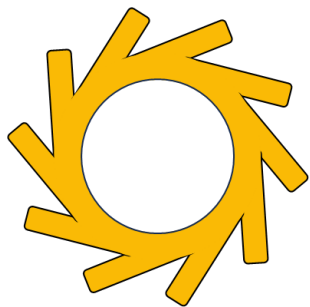


# SR source related calculations with SRW

## 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):

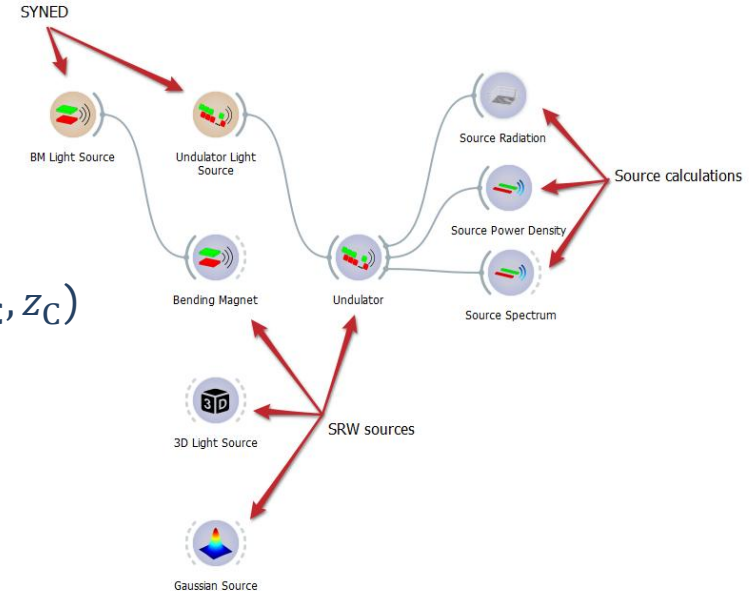
- storage ring current and energy  $\mathcal{E}$
- single electron initial condition ( $x_0, y_0, z_0, x'_0, y'_0$  and  $\mathcal{E}_0$  – first order statistical moments).
- electron beam second order moments (Twiss parameters or RMS values).

## 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.



# Which elements constitute the source in SRW?

## Electron beam (SRWPartBeam):

Undulator

Run SRW SourceReset Fields

Light Source SettingWavefront SettingUtility

Electron Beam Parameters

Energy [GeV]2.75

Energy Spread0.001025

Ring Current [A]0.5

BeamTrajectory

Electron Beam PropertiesFrom Twiss

Emittance x [m]3.9e-9

Emittance y [m]3.9e-11

$\beta_x$  [m]4.1148

$\beta_y$  [m]2.2514

$\alpha_x$  [rad]0.0557

$\alpha_y$  [rad]-0.0180

$\eta_x$  [m]0.1667

$\eta_y$  [m]0.0041

$\eta_x'$  [rad]0.0005

$\eta_y'$  [rad]-0.0006

Bending Magnet

Run SRW SourceReset Fields

Light Source SettingWavefront Setting

Electron Beam Parameters

Energy [GeV]6.0

Energy Spread0.00138

Ring Current [A]0.2

BeamTrajectory

Electron Beam PropertiesFrom Size/Divergence

$\sigma_x$  [m]1.48e-05

$\sigma_y$  [m]3.7e-06

$\sigma_x'$  [rad]2.8e-06

$\sigma_y'$  [rad]1.5e-06

3D Light Source

Run SRW SourceReset Fields

Light Source SettingWavefront Setting

Electron Beam Parameters

Energy [GeV]6.0

Energy Spread0.00138

Ring Current [A]0.2

BeamTrajectory

Electron Beam PropertiesFrom 2nd Moments

$\sigma_x \cdot \sigma_x$  [m<sup>2</sup>]2.1904000000000003e-10

$\sigma_x \cdot \sigma_x'$  [m·rad]0.0

$\sigma_x' \cdot \sigma_x'$  [rad<sup>2</sup>]7.839999999999999e-12

$\sigma_y \cdot \sigma_y$  [m<sup>2</sup>]1.3690000000000002e-11

$\sigma_y \cdot \sigma_y'$  [m·rad]0.0

$\sigma_y' \cdot \sigma_y'$  [rad<sup>2</sup>]2.2500000000000003e-12

# Which elements constitute the source in SRW?

Electron beam (SRWLPartBeam):

The screenshot displays the 'Light Source Setting' tab of the SRW software interface. The 'Electron Beam Parameters' section is active, showing the following settings:

- Energy [GeV]: 2.75
- Energy Spread: 0.001025
- Ring Current [A]: 0.5

Below these, the 'Trajectory' sub-tab is selected. It shows the 'Trajectory Initialization' dropdown set to 'At Fixed Position'. The initial coordinates and angles are defined as follows:

Parameter	Value
$x_0$ [m]	0.0
$y_0$ [m]	0.0
$z_0$ [m]	-0.83 (with an 'Auto' button)
$x'_0$ [rad]	0.0
$y'_0$ [rad]	0.0

# Which elements constitute the source in SRW?

**Magnetic field container** (SRWLMagFldC):

The screenshot displays the configuration interface for the SRWLMagFldC element, organized into three main panels: ID Parameters, BM Parameters, and 3D file Parameters.

**ID Parameters / ID Magnetic Field:**

- Period Length [m]: 0.08036
- Number of Periods: 19.0
- Horizontal Central Position [m]: 0.0
- Vertical Central Position [m]: 0.0
- Longitudinal Central Position [m]: 0.0

**BM Parameters:**

- Magnetic Radius [m]: 5.56
- Magnetic Field [T]: 1.2
- Length [m]: 0.8

**3D file Parameters:**

- 3D data file: v/magn\_meas/ivu20\_chx\_g12\_2c.dat
- Comment Character: #
- Interpolation Method: bi-linear

# Which elements constitute the source in SRW?

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

The screenshot displays the 'Wavefront Setting' tab of the SRW software interface. It is divided into two main sections: 'Wavefront Parameters' and 'Precision Parameters'.

**Wavefront Parameters:**

- Energy Setting: Harmonic (dropdown)
- Harmonic #: 1 (input field)
- Harmonic Energy: 720.0 (input field)
- H Slit Gap [m]: 0.001 (input field)
- Center [m]: 0.0 (input field)
- V Slit Gap [m]: 0.001 (input field)
- Center [m]: 0.0 (input field)
- H Slit Points: 100 (input field)
- V Slit Points: 100 (input field)
- Propagation Distance [m]: 10.0 (input field)
- Intensity Units: phot/s/0.1%bw/mm<sup>2</sup> (dropdown)

**Precision Parameters:**

- Calculation Method: Auto-Undulator (dropdown)
- Relative Precision: 0.01 (input field)
- Longitudinal position to start integration (effective if < zEndInteg) [m]: 0.0 (input field)
- Longitudinal position to finish integration (effective if > zStartInteg) [m]: 0.0 (input field)
- Number of points for trajectory calculation: 50000 (input field)
- Use "terminating terms" or not: Yes (dropdown)
- Sampling factor for adjusting nx/ny (effective if > 0): 0.0 (input field)



# 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:

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

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):

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

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.

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

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

Chubar, *Review of Scientific Instruments* 66(2), 1872–1874 (1995)

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

# Examples

Live demo using OASYS...

**Thank you!**