

Introduction to SPECTRA

- a synchrotron radiation calculation code

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Introduction

What is SPECTRA?

- Quantitative evaluation of SR is necessary for designing the optical elements in the beamline, analyzing the experimental data, etc.
- However, this requires not only expertise on SR but also numerical implementation to take into account the electron beam dynamics.
- SPECTRA is an application software to help the SR users to accurately evaluate the optical characteristics of SR from various light sources.

Functions Supported

- Spectrum of photon flux (density)
- Spatial profile of photon flux and radiation power
- K-value dependence of photon flux and radiation power
- Degree of polarization (Stokes parameters)
- Brilliance curve
- Filtering
- Coherent and SASE radiation
- Fully graphical pre- and post-processor
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Platforms Supported

- Microsoft Windows (2k,XP,..)
 - Compilation is done on Win2k
 - Most stable
- Mac OS X
 - Compilation is done on MacOSX ???
- LINUX
 - Compilation is done on Fedora Core 5
 - Several bugs reported (related to GUI library) on other distributions
- Other types of unix
 - May be available on demand

Version-up History(1)

Ver.	Release	Remarks (new functions)
~3	??	<ul style="list-style-type: none">• Japanese application on MS-DOS• Based on far-field approximation
4	Sep. 1995	<ul style="list-style-type: none">• English application running on MS-Windows 3.1
5	Oct. 1998	<ul style="list-style-type: none">• Applicable to Mac and Linux• Modification of GUI
6.0	Oct. 2000	<ul style="list-style-type: none">• Significant improvement in the numerical algorithm• Near-field calculation available• Published in Journal of SR
6.1	Jun. 2001	<ul style="list-style-type: none">• Arbitrary-field calculation available

Version-up History(2)

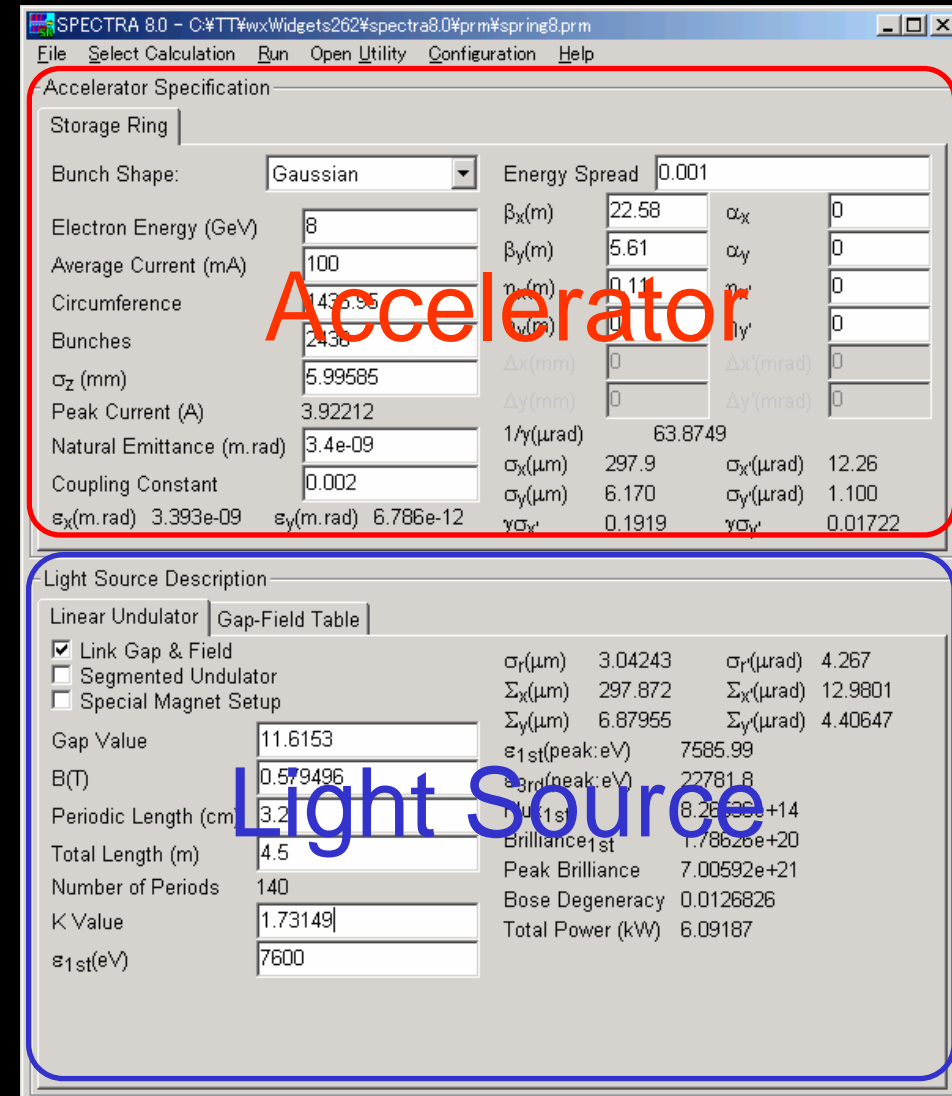
Ver.	Release	Remarks (new functions)
7.0	Mar. 2003	<ul style="list-style-type: none">• Applicable to MacOSX• Modification of GUI
7.1	Nov. 2003	<ul style="list-style-type: none">• Brilliance of wiggler modified
7.2	Mar. 2005	<ul style="list-style-type: none">• Source characterization in the 4D phase space
8.0	Sep. 2006	<ul style="list-style-type: none">• Further improvement of numerical algorithms• Coherent and SASE radiation available• Presented in SRI2006

Installation

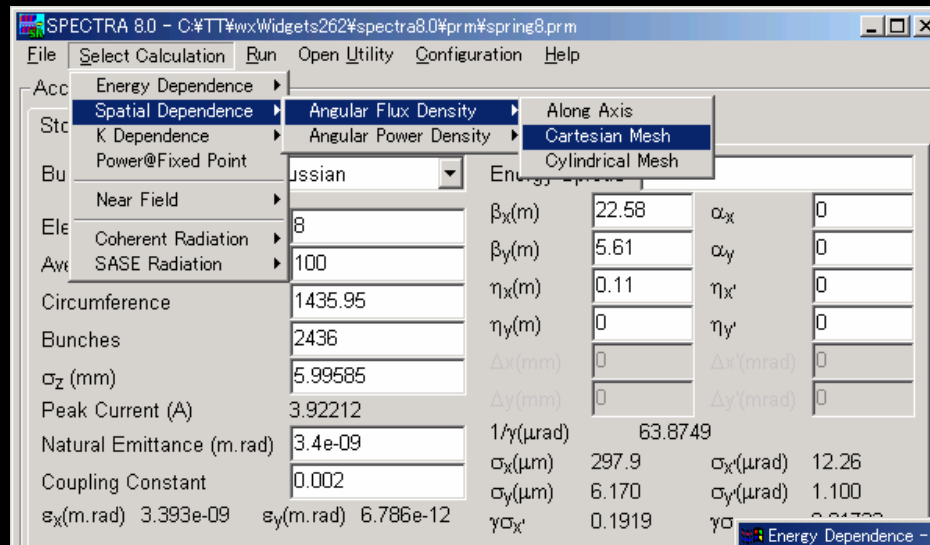
- SPECTRA is available from:
<http://radiant.harima.riken.go.jp/spectra/index.html>
- Before downloading, input a few information about you, please.
- Windows:
 - Just run “spectra_win.exe”.
- Mac OS X:
 - Uncompress “spectra_macosx.sit”
 - Install Stuff It Expander if necessary
- LINUX:
 - “tar xzvf spectra_linux.tar.gz”

General Instruction (1)

1. After starting the program, open a parameter file or run [File]-[Create New].
2. GUI panels pop up to show the parameters defining the accelerator and light source.
3. Edit the parameters related to the accelerator and light source.
4. Save the parameter file if necessary.

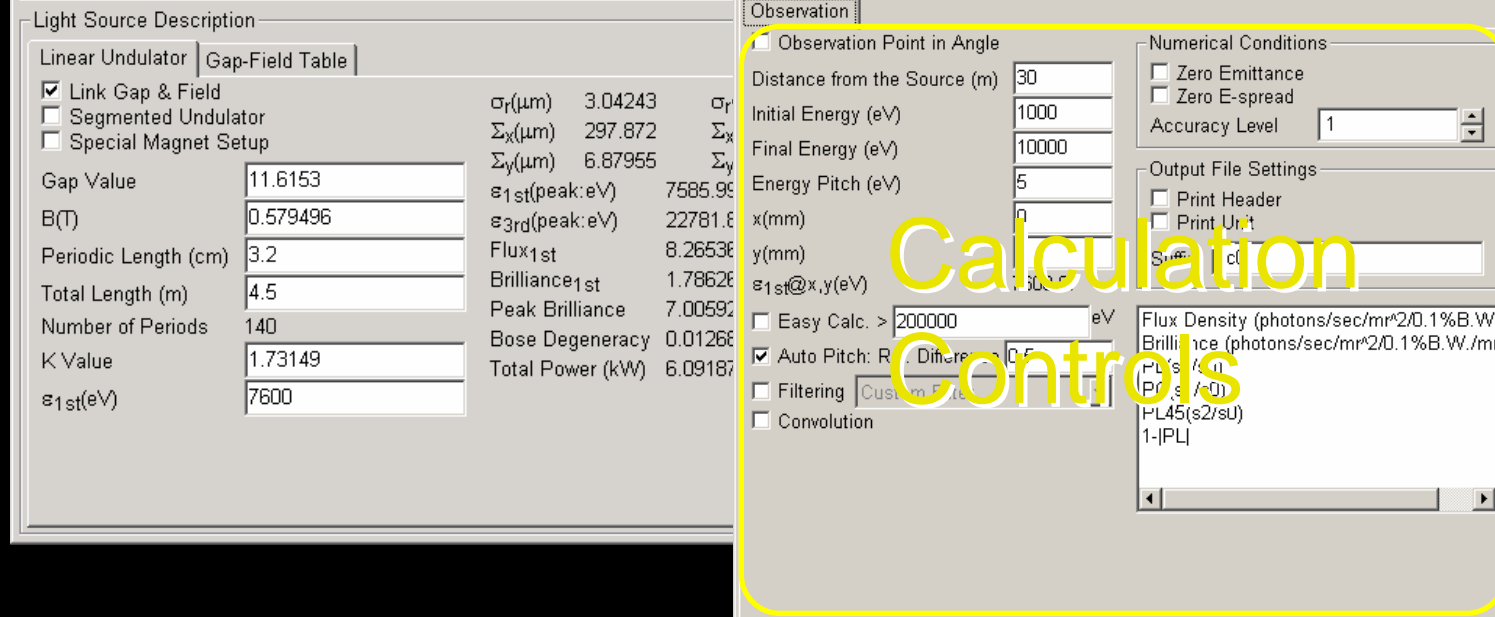


General Instruction (2)



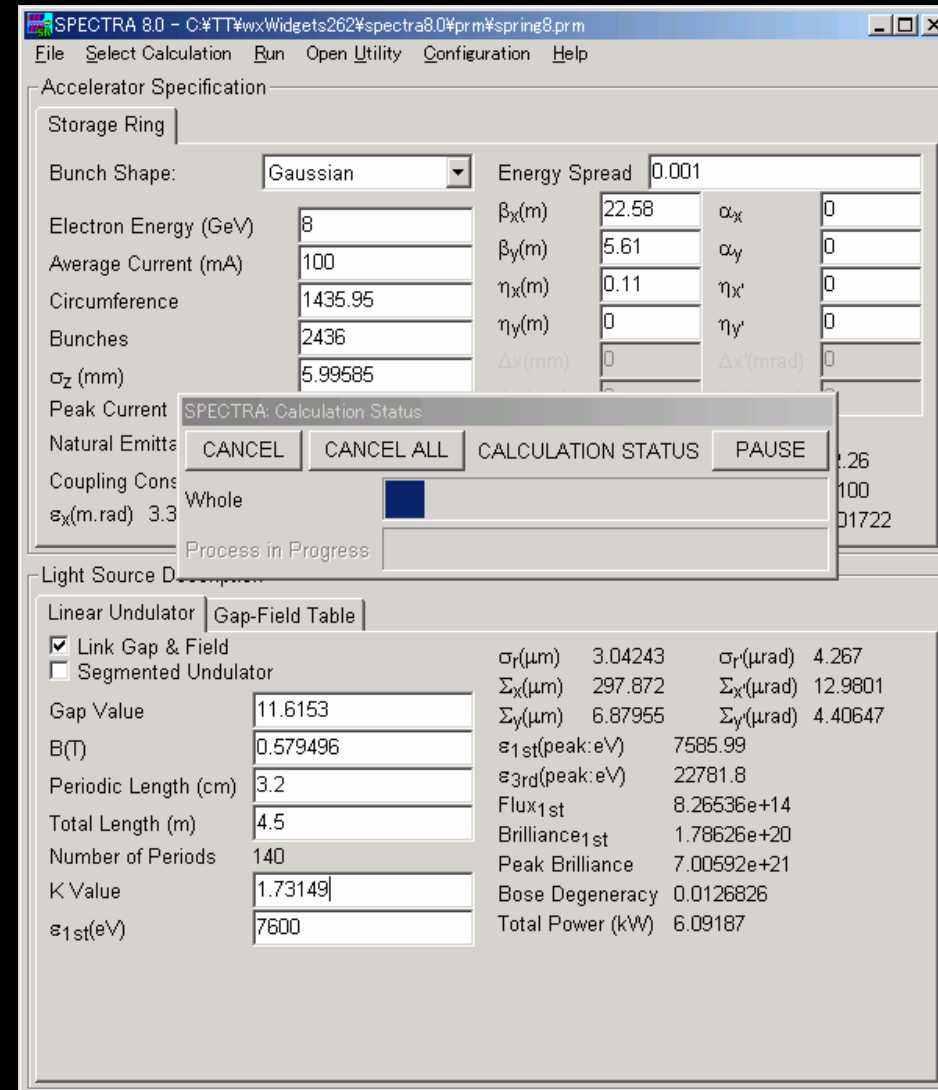
5. Select the type of calculation (dependency and main item) from submenus of [Select Calculation].

6. Edit the parameters related to calculation controls.



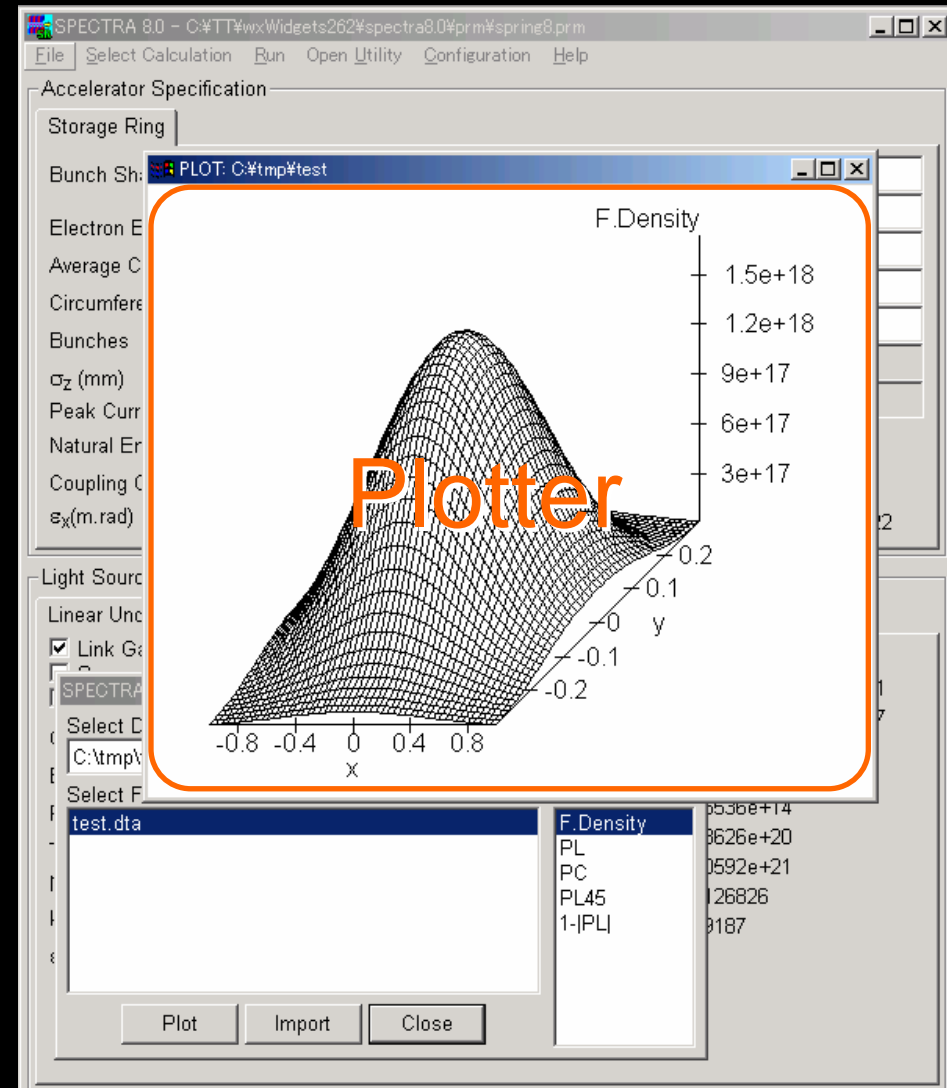
General Instruction (3)

7. After specifying all the parameters and selecting options, run [Run]-[Start Calculation] command to start a calculation.
8. Input a file name to save the calculation results in the dialog box that pops up.
9. A progress bar pops up to indicate the status of the calculation.



General Instruction (4)

10. The calculation results are saved in a file with the name you specified and a suffix specific to the type of calculation in ascii format.
11. To verify the calculation results graphically, select the data name and items to be plotted, then click "Plot".



Type of Calculation

- The type of calculation is specified both by “Dependency” and “Main Item”.
- [Energy Dependence]-[Total Flux] means that the photon flux integrated over the whole solid angle is calculated as a function of the photon energy.
- In addition to the “Main Item”, several optical properties are simultaneously calculated and saved in the output file.

TUTORIAL (with tutorial.prm)

- I. Simple Calculation
- II. Scanning a Parameter
- III. Filtering Option
- IV. Special Magnet Setup
- V. Calculations with External
Magnetic Data
- VI. Coherent Radiation

I-1. Spectrum

1. Select [Energy Dependence]-[Partial Flux]-[Rectangular Slit].
2. Edit the slit dimensions: $\Delta x=2\text{mm}$, $\Delta y=1\text{mm}$.
3. Start calculation; run [Run]-[Start Calculation] command and input a data name, "tutorial1-1".
4. Wait for a while until the calculation completes. The data will be saved in "tutorial1-1.dc0"
5. Check the results; in the "SPECTRA Result Viewer" GUI window, click "Plot" to show the calculation results.

I-2. Flux Spatial Profile

1. Select one [Spatial Dependence]-[Angular Flux Density]-[Along Axis].
2. Create a calculation process; run [Run]-[Create Process] command and input a data name "tutorial1-2a".
3. Change the fixed energy (e.g., 9900eV).
4. Create a process with "tutorial1-2b"
5. Run [Run]-[Start Calculation] to start the two calculation processes.
6. Compare the two calculation results with different energies.

I-3. Power Spatial Profile

1. Select one [Spatial Dependence]-[Angular Power Density]-[Cartesian Mesh].
2. Change the observation range (e.g., $\pm 4\text{mm}$ for both the axes).
3. Start calculation with “tutorial1-3”.
4. Check the result in the simple plotter by creating a 3-D surface plot.

I-4. Brilliance Curve

1. Select [K Dependence]-[Easy Calculation]-[Brilliance@Peak Energy].
2. Specify the harmonic range from 1 to 5.
3. Start calculation with “tutorial1-4”.
4. You will find three files “totorial1-4.d01”, “tutorial1-4.d03” and “tutorial1-5.d05”, which correspond to the 1st, 3rd and 5th harmonics, respectively.
5. Select “Brilliance” in the “Select Y Axis” list in the plotter and plot to show the brilliance curve.

I-5. Power@Fixed Point

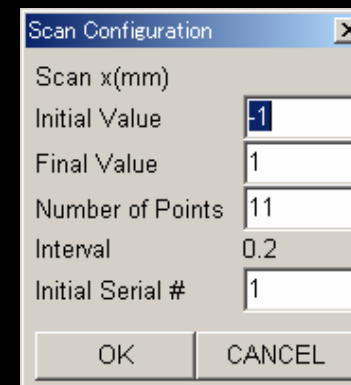
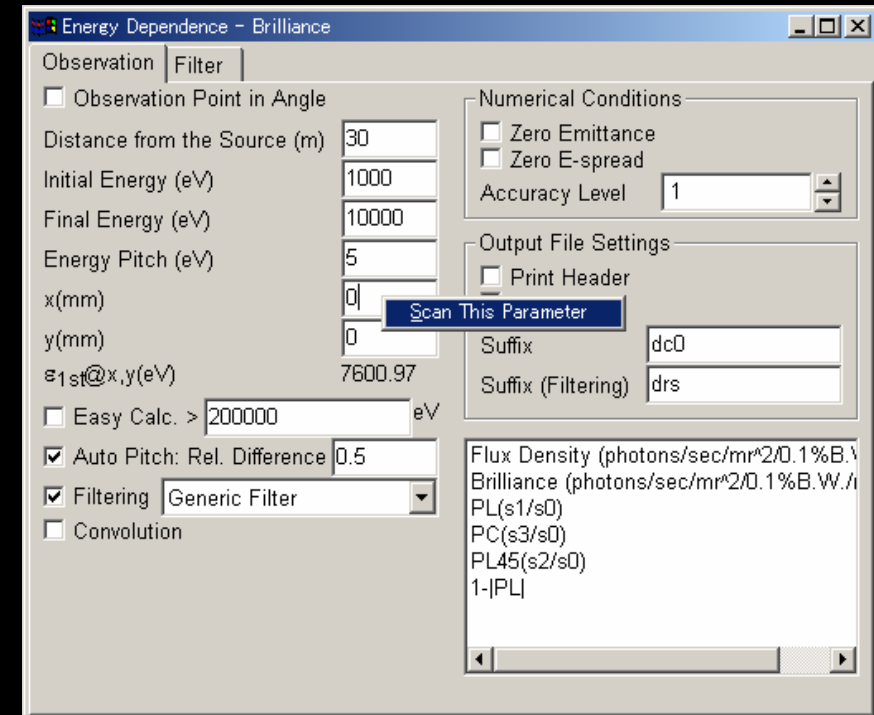
1. Select [Power@Fixed Point].
2. Specify the observation conditions.
3. Select a target item from the “Specify Item” list and click “Calculate” button.
4. You will find the results near the “Calculate” button. (Note: The result is not saved in a file in this type of calculation.)

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Scanning a Parameter (1)

- Most of the parameters can be scanned to check the behavior and look for an optimum value.
1. In order to specify a parameter to scan, select the parameter and right click, then run “Scan This Parameter”.
 2. Edit the parameters in the dialog box that pops up in order to specify the conditions for scanning.



Scanning a Parameter (2)

3. Input a data name (e.g. “scan”) in the dialog box as in the normal case.
4. A GUI window pops up to indicate the specified calculation process.
5. Repeat the above, then start calculation.
6. The output files are saved in the directory with the same data name.
7. The results of scanning can be visualized with a built-in postprocessor.

II-1. Scanning the K Value

1. Select [Energy Dependence]-[Brilliance]
2. Right-click the “K Value” entry and run “Scan This Parameter”
3. Edit scanning conditions (Initial Value=0.5, Final Value=2.5, Number of Points=21) and click OK.
4. Input “tutorial2-1” for the data name and start calculation.
5. Check that all the output files are saved in the directory “tutorial2-1” with a serial number attached “tutorial2-1/tutorial2-1-1.dc0”, and so on.

II-2. Scanning the Photon Energy

1. Select [Spatial Dependence]-[Angular Flux Density]-[Cartesian Mesh].
2. Change the observation range ($\pm 0.5\text{mm}$ for both the axes). Tick “Zero Emittance” and “Zero E-spread”.
3. Right-click “Fixed Energy” and run “Scan This ...”.
4. Edit scanning conditions (Initial Value=9500, Final Value=10100, Number of Points=61) and click OK.
5. Input “tutorial2-2” for the data name and start calculation.

II-3. Visualization of Scanning Results

1. Run [Open Utility]-[Visualization of Scan Results].
2. Click “Import” and select “tutorial2-1.hdr”
3. Click “Single Plot”. A GUI window pops up to show the results of calculation.
4. Click “Start Animation” to view the results as an animation.
5. Repeat the above procedure for “tutorial2-2.hdr” to see the results for the photon energy scan.
6. “Multiplot” is to show several items of the calculation result simultaneously.

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Type of Filter

- **Generic Filter**
 - Any kind of components in the SR beamline to absorb or attenuate the SR beam.
 - Thickness and composition of elements should be specified.
- **Bandpath Filter**
 - Specified by the maximum transmission rate and bandwidth
 - Gaussian, Boxcar, and Lorentzian
- **Custom Filter**
 - Defined by the user
 - External data should be imported

III-1. Filtered Power: BPF

1. Select [Spatial Dependence]-[Angular Power Density]-[Along Axis].
2. Tick “Filtering” option and select “Bandpath Filter”. Untick “Zero-***” options.
3. Click “Filter” tab and edit BPF configurations (e.g., center energy 9900 eV, width 100 eV)
4. Change the observation range (e.g., +-2mm for x, +-1mm for y).
5. Start calculation with “tutorial3-1”.
6. The filtered power is saved in the same file in the 3rd column. Plot the results to compare the power.

III-2. Generic Filter Configuration

1. Click “Observation” tab and select “Generic Filter”, then click “Filter” tab again.
2. Click “Edit” button in the “Filter Specification” pane and input a new filter name (e.g., “Be Window”)
3. Select “Be” in the “Material Name” list.
4. Input 0.5 mm in “Thickness”.
5. Click “PLOT” at the bottom to verify the transmission rate of the specified filter.
6. Start calculation with “tutorial3-2”.

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Special Magnet Setup

- Natural Focusing
 - Due to edge focusing, the electron beam is focused in the ID field.
 - Time-consuming due to integration over the 4D e-beam phase space.
- Tapering
 - Magnetic field strength is varied linearly along the longitudinal position to intentionally broaden the bandwidth of UR.
- Offset
 - Estimates the effect due to ambient field.
- Multipole Data
 - Multipole components are added.

IV-1. Tapering

1. Select [Near Field]-[Energy Dependence]-[Spatial Flux Density] and untick “Filtering” option.
2. Edit the energy range (e.g., 9000~11000eV)
3. Create a process with “tutorial4-1a”.
4. Tick “Special Magnet Setup” and click the tab.
5. Input “0.01” in “By Tapering(/m)” entry. This leads to a field variation of 1%/m.
6. Create a process with “tutorial4-1b” and start calculation.
7. Check the effects due to tapering.

IV-2. Ambient Field

1. Set “Bx Tapering” to 0. Select [Near Field]-[Spatial Dependence]-[Spatial Flux Density] –[Along Axis].
2. Change the observation range ($\pm 0.5\text{mm}$ for both the axes) and increase the mesh number (e.g., 101). Tick “Zero Emittance” and “Zero E-spread”.
3. Create a process “tutorial4-2a”.
4. Set “Bx Offset (T)” to “ $3\text{e-}5$ ” (comparable to the earth field) and create a process “tutorial4-2b”. This induces a uniform deflection in the y axis.
5. Start calculation and check the effects especially along the y axis (.dty files)

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Calculations with Arbitrary Field Profile

- Due to magnetic errors, the field in ID is not necessarily sinusoidal.
- In order to accurately evaluate the optical properties, calculations should be made with the field-error effects taken into account.
- The field profile data is usually measured by field mapping with a magnetic sensor such as Hall probes.
- To perform a calculation with an external magnetic field, select [User Defined] as a light source.

V-1. Undulator Data (1)

1. Select [Configuration]-[Light Source]-[Source Type]-[User Defined]
2. Untick “Special Magnet Setup”
3. Click “Edit” and run “Import Field Data” and specify “undulator_std_error.dat”.
4. Select correct units (Gauss&cm).
5. Run [Configuration]-[Accelerator]-[Adjust Initial Conditions]-[Average Over Device Length]. This calculates the optimum e-beam conditions ($\Delta x, \Delta x'$, etc) and show the electron trajectory.

V-1. Undulator Data (2)

7. Try other conditions to check the behavior of the electron trajectory.
8. Select [Near Field]-[Energy Dependence]-[Spatial Flux Density].
9. Change the energy range (1000~20000eV) and start calculation with “tutorial5-1”. Leave “Zero Emittance” and “Zero e-spread” ticked.
10. Check the effects due to the error field.

V-2: Edge Radiation (1)

1. Click “Edit” and run “Import Field Data” and specify “bm_fringe_field.dat”.
2. Select correct units (Tesla&mm) for the field data.
3. Run [Configuration]-[Accelerator]-[Adjust Initial Conditions]-[At the Center]. Check the difference from the former example.
4. Select [Near Field]-[Spatial Dependence]-[Spatial Flux Density]-[Cartesian Mesh]. Leave “Zero Emittance” and “Zero e-spread” ticked.

V-2: Edge Radiation (2)

5. Change observation conditions (± 10 mm for both axes) and Set “Fixed Energy” to 5 eV.
6. Create process with “tutorial5-2a”.
7. Change energy to 10 eV and create process with “tutorial5-2b”.
8. Start calculation.
9. Compare the pattern at two different energies to check the interference between the two BM magnetic fields.

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Coherent Radiation

- Coherent SR (CSR) is emitted by an electron bunch with a bunch length shorter than a specific wavelength.
- The intensity of CSR is proportional to N^2 , while that of the incoherent (normal) SR is to N , where N is the number of electrons in the bunch.
- Recent progress of the accelerator technology has made it possible to generate an extremely short-bunch electron beam, and intense CSR in the THz region, useful in imaging experiments.

VI. Example of CSR

1. Select [Configuration]-[Beamline]-[SCS CSR] in which “Linac” is selected as the accelerator type and “Bending Magnet” as the light source.
2. Select calculation [Near Field]-[Energy Dependence]-[Spatial Flux Density] and create a process with “tutorial6-a”.
3. Select calculation [Near Field]-[Coherent Radiation]-[Energy Dependence]-[Spatial Flux Density] and create a process with “tutorial6-b”.
4. Start calculation and compare the results for the CSR and incoherent SR.

Outlook

- Improvements to be made in the future
 - Supporting macro commands to make it easy to specify multiple calculations with different conditions of calculation.
 - Calculations with reflectivity of generic mirrors.
 - Numerical algorithms for SASE calculations.
 - SR from an electron beam with non-Gaussian profiles.

Feedback Welcome!