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前置条件

您的系统上需要安装好 node （会自带npm）。

使用 make 或者使用 npm 命令去构建

使用 make 命令的方式构建：

若您可使用 make 命令，简单执行如下命令进行初始化：

```
make init
```

执行如下命令运行服务端：

```
make run
```

使用 npm 命令的方式构建：

若您不能使用 make 命令，或想直接使用 npm 命令，执行如下命令进行初始化：

安装项目依赖：

```
npm install
```

执行如下命令运行服务端：

```
npm run serve
```

访问

直接访问 http://localhost:4000 即可查看本书内容。

Introduction

What SRW Can Do

SRW is a set of tools dedicated to the computation of a number of features of Synchrotron Radiation (SR). The present version of the SRW enables the following types of computation.

Near Field computation of Synchrotron Radiation. The radiation is generated by a filament relativistic electron beam as it travels through an arbitrary magnetic field. It is observed in a plane located at a fixed distance from the source as a function of the photon energy and polarization. The broadening of the intensity profile induced by the non zero transverse emittances is computed on request assuming that one can neglect the variations of the magnetic field of the source as a function of the transverse coordinates.

Propagation of the Near Field SR Wavefronts. This is a more elaborated version of the near field computation. It computes a whole wavefront of radiation and propagates it through any combination of simple optical components such as thin lens, focusing mirrors, drift spaces, diffracting apertures... It makes use of CPU efficient methods of Fourier optics. There is a number of practical limitations to this approach. Therefore anyone interested in performing such computations must read the section entitled "Wavefront Propagation" before starting.

Fast computation of Undulator Radiation Spectra through a Slit for Finite-Emittance Electron Beam. Fast computation of Undulator Radiation Spectra through a Slit for Finite-Emittance Electron Beam. The radiation is generated by an electron beam with non-zero transverse emittance and energy spread travelling in a periodic magnetic field of an undulator. It is collected at a long distance from the undulator within a rectangular slit (or a number of cells) of arbitrary size. Spectra vs photon energy and transverse slit position can be computed. Ellipsoidal undulators are supported.

Computation of Spectral Angular Distributions of Wiggler Radiation. Computation of Spectral Angular Distributions of Wiggler Radiation. The radiation is generated by an electron beam with non-zero transverse emittance travelling in magnetic field of arbitrary configuration, with the emission conditions corresponding to a wiggler case. Spectra vs photon energy and flux per unit surface as a function of transverse position in an observation plane can be computed.

Computation of Power Density of Synchrotron Radiation. Computation of Power Density of Synchrotron Radiation. The radiation is generated by an electron beam with non-zero transverse emittance travelling in arbitrary magnetic field. Power density distributions vs transverse coordinates integrated over all photon energies can be computed.

Estimation of Brilliance of undulator, wiggler and bending magnet sources.

Simulation of Gaussion Beam Wavefronts. One may use this type of calculation to simulate a wavefront of a laser beam (at a desired polarization and mode order). After the wavefront is created, it can be further propagated numerically using the methods of Fourier optics implemented in the SRWP.

CSR Computation taking into account 6D phase space distribution of emitting relativistic electrons.

SASE Computation. This type of computation allows to simulate Self-Amplified Spontaneous Emission (SASE) in Free-Electron Lasers (FEL). In the current version, the implementation is mainly based on the GENESIS 3D code developed at DESY by S.Reiche et. al. For better interoperation with other parts of SRW, this FORTRAN code was converted (with minor modifications) to C and re-compiled as a shared library. The SASE computation in SRW is currently limited by numerical solution of the steady state paraxial FEL equations at the approximation of slowly varying amplitude of the radiation field. If electron beam and FEL undulator parameters, together with the wavelength of observed radiation, are tuned properly, one can simulate the radiation wavefront amplification in the undulator due to interaction with the electron beam. The wavefront (i.e. complex electric field) obtained after this simulation, can be used for further manipulations / propagation through optical elements using the methods of Fourier optics implemented in the SRWP.

System Requirements

The current version of the SRW requires:

- PowerMac under MacOS 8.0 or later or a PC under Windows 95/NT 4.0 or later.
- At least 32 MB of RAM (propagation-related computation may require 64 MB or more).
- Igor Pro 3.1 or later from WaveMetrics ("http://www.wavemetrics.com").
- Patience.

The core part of the SRW is written in C++; the interface-related part is implemented in Igor Pro macro language.

Organization

SRW deals with a number of different structures which encapsulate the information related to a particular object entering into the computation. For example, the electron beam characteristics (energy, current, position, emittance...) are stored in an Electron Beam structure. All the structures are numerical or text waves in the Igor language. The structures are created by some macro commands that the user can invoke either by calling them from the menu "SRW..." or by typing their text equivalents in the Command window. The following are few of the main SRW structures:

- Electron Beam
- Magnetic Field

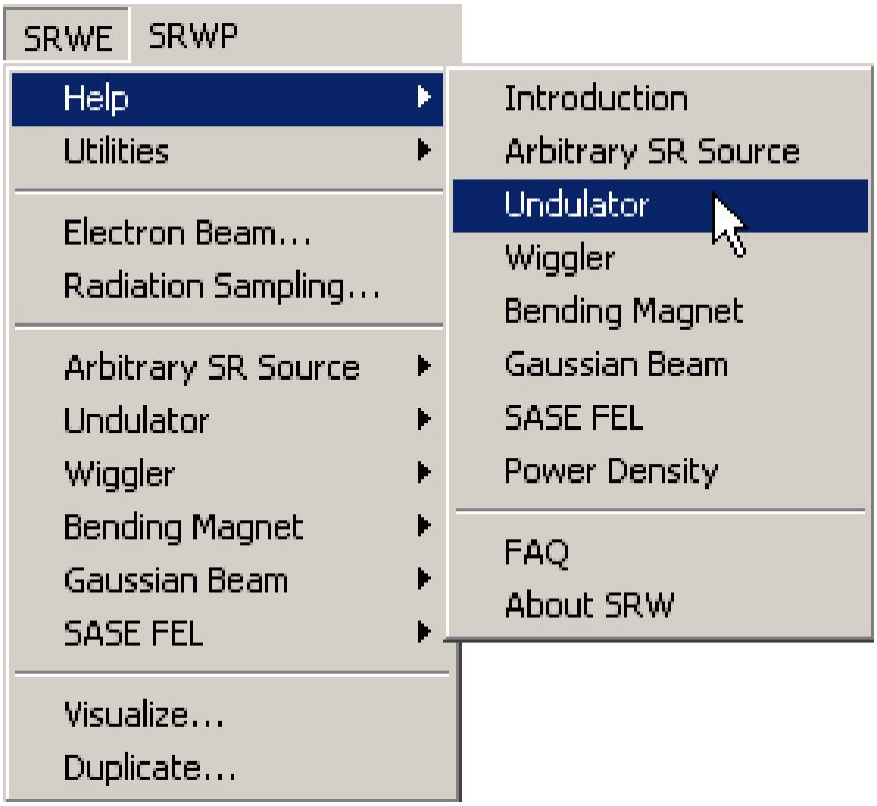
- Radiation Sampling
- Optical Component
- Wavefront

The SRW menu consists of two parts. In the part "SRWE" ("E" stands for "emission"), spontaneous SR emission can be computed with no further propagation through any optical components. In the part "SRWP" ("P" stands for "propagation") the SR can be computed in a mode suitable for further propagation in terms of wave optics, and the SR propagation through various beamline components and drift spaces can be performed.

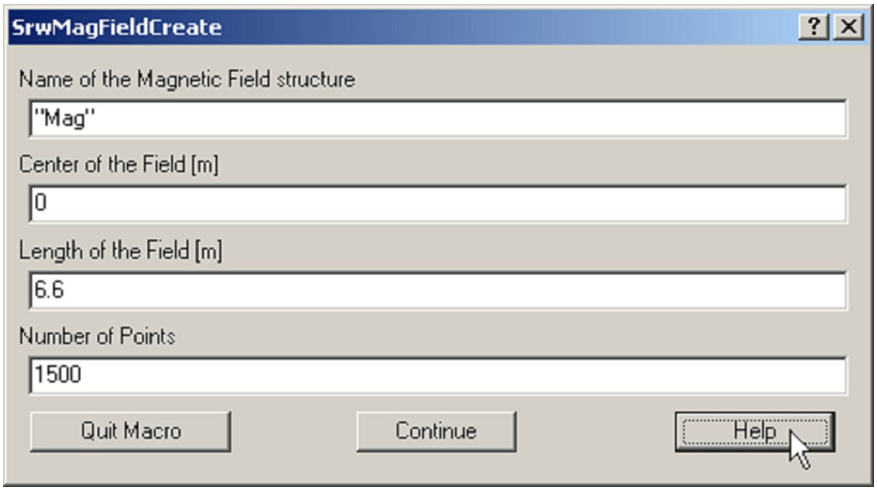
The SRW provides a set of examples illustrating any available mode of computation. Note that even though one can run various examples from the "SRW" menu without any specific knowledge of Igor, we strongly advise the user to get acquainted with the Igor before doing any large-scale computation. Igor Pro comes with many tutorials which greatly help in this respect.

How to Get Help

All the Help information for this version of SRW is concentrated in the "SRW Help.ifn" file. The information is sorted by topics. Some topics can be accessed from the Help sub-menu of the main SRW menu, for example:



Others are accessed by pressing the help button in any of the SRW dialog boxes, as in:



Near Field Computation

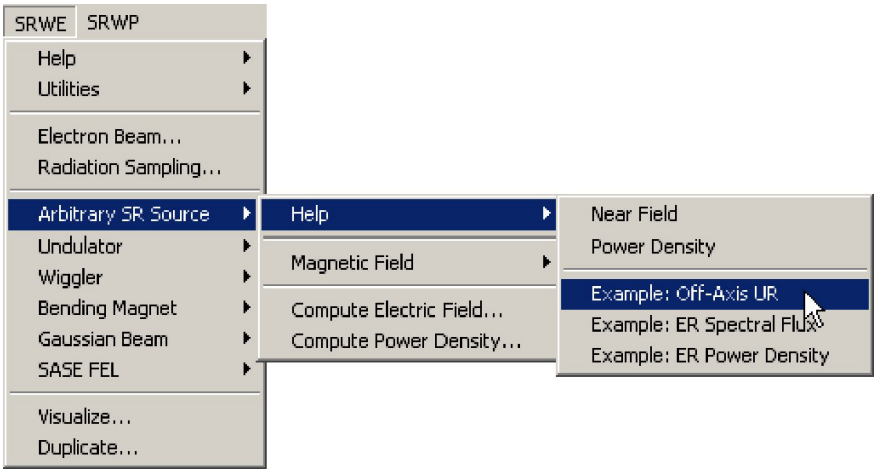
Introduction

Most of currently available synchrotron radiation codes perform the computation in so-called Far Field approximation. This approximation is suitable for the large majority of cases. However, it is known that at long wavelengths, there can be important deviations between the Far Field approximation and the more exact Near Field computation. The macro commands related to this part of the SRW make the computation in the Near Field approximation (see the section "Assumptions" below). We have applied some efforts to implement a CPU-efficient near-field computation algorithm. As a result, there is no significant slow down in the near-field computation as compared to the far-field. Note that the Far Field approximation of the radiation can always be derived from the Near Field computation by moving the observation plane at a very large distance from the source. One then needs to re-scale the range of observation to the distance between the source and the observation plane.

The near-field computation of SRW essentially consists in computing the radiation produced by an electron beam travelling through some magnetic field and observed in a plane located at some distance from the source. The longitudinal axis is orthogonal to the observation plane and passes through the origin of the source. The horizontal and vertical axes are orthogonal to the longitudinal axis and to each other. The horizontal and vertical components of the magnetic field are defined as arbitrary waveforms extending over some range of longitudinal coordinate. The computation is made over a range of horizontal and vertical position (in the observation plane) and a range of photon energy. The time needed to perform the computation is almost proportional to the total number of points over the transverse positions and energy. For example, if one wants to compute the radiation for 10 values of the horizontal coordinate, 10 values of the vertical coordinate and 10 values of the photon energy, the CPU-time required will be 1000 that of a single point computation. The result of the computation essentially contains the horizontal and vertical components of the frequency-domain complex electric field for each point and energy of observation, produced by a filament electron beam. It is kept in memory with a few other pieces of information. A one- or two- or three-dimensional cut of the electric field data can be made, converted into intensity of desired polarization and displayed in a window as a graph, contour plot or graphical slicer. This can be done for the filament or "thick" (non-zero emittance) electron beam.

Getting Started

We assume that you have successfully installed the SRW on your computer, strictly following the instructions in the "ReadMe.txt" file supplied with the distribution pack. Run Igor Pro. Menu items "SRW..." should appear in the Igor Pro menu. Select the following sub-menu of SRW:



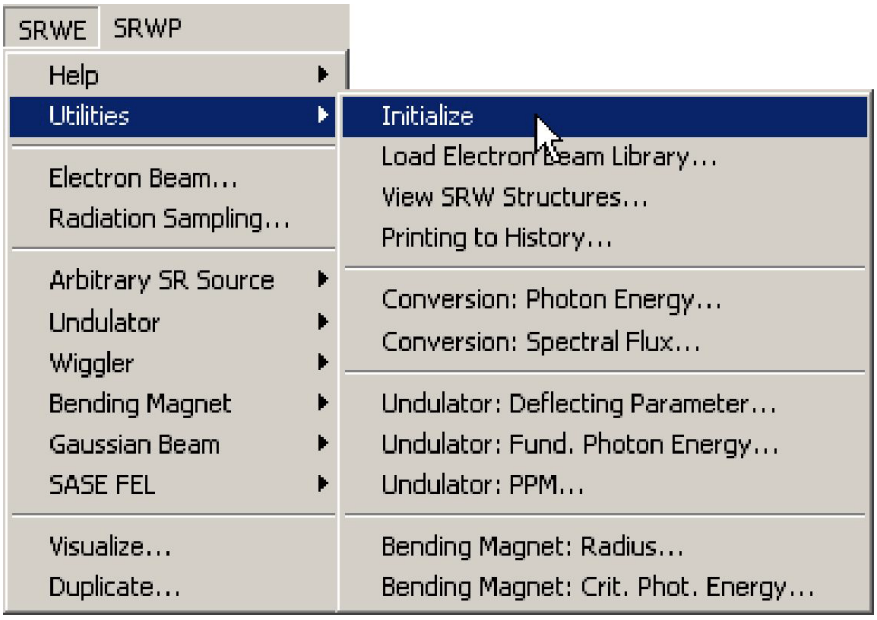
An example of computation will start. During the execution of the example, a window giving some explanations on the content of the computation being made should appear on your screen. Please read the explanations and make sure that everything goes as prescribed (you can also find the text of the explanations in the section "Examples"). If everything goes well, at the end of the computation you should obtain a set of graphs displaying the results, which should fit the explanations.

If you have passed this step successfully, you are ready to perform your own computation.

Near Field Computation Step by Step

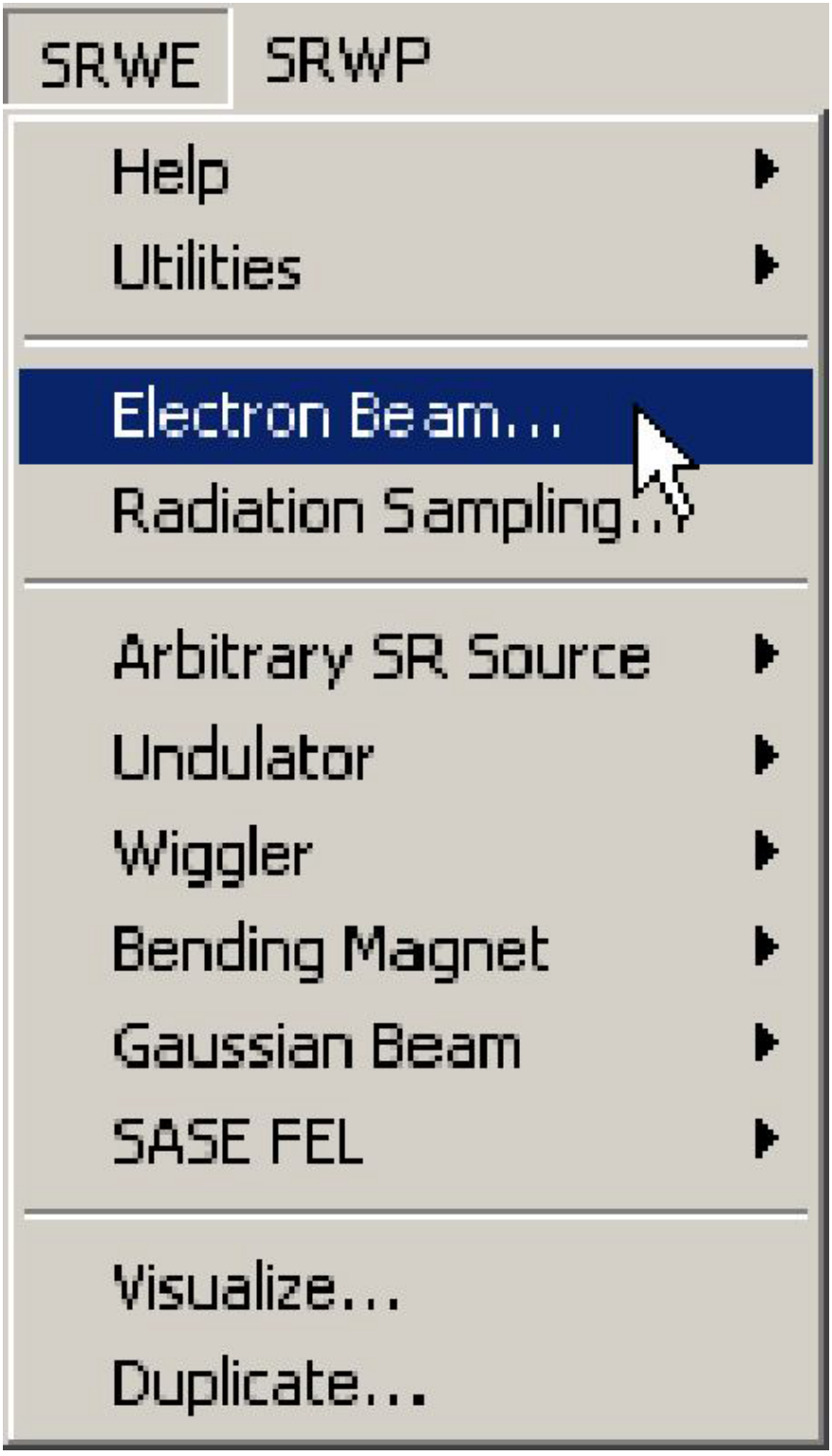
The following are steps one typically needs to make in order to perform the Near Field SR computation with SRW. Depending of particular goal, some of the steps may not be necessary, others may require several iterations.

1) Initialize SRW.



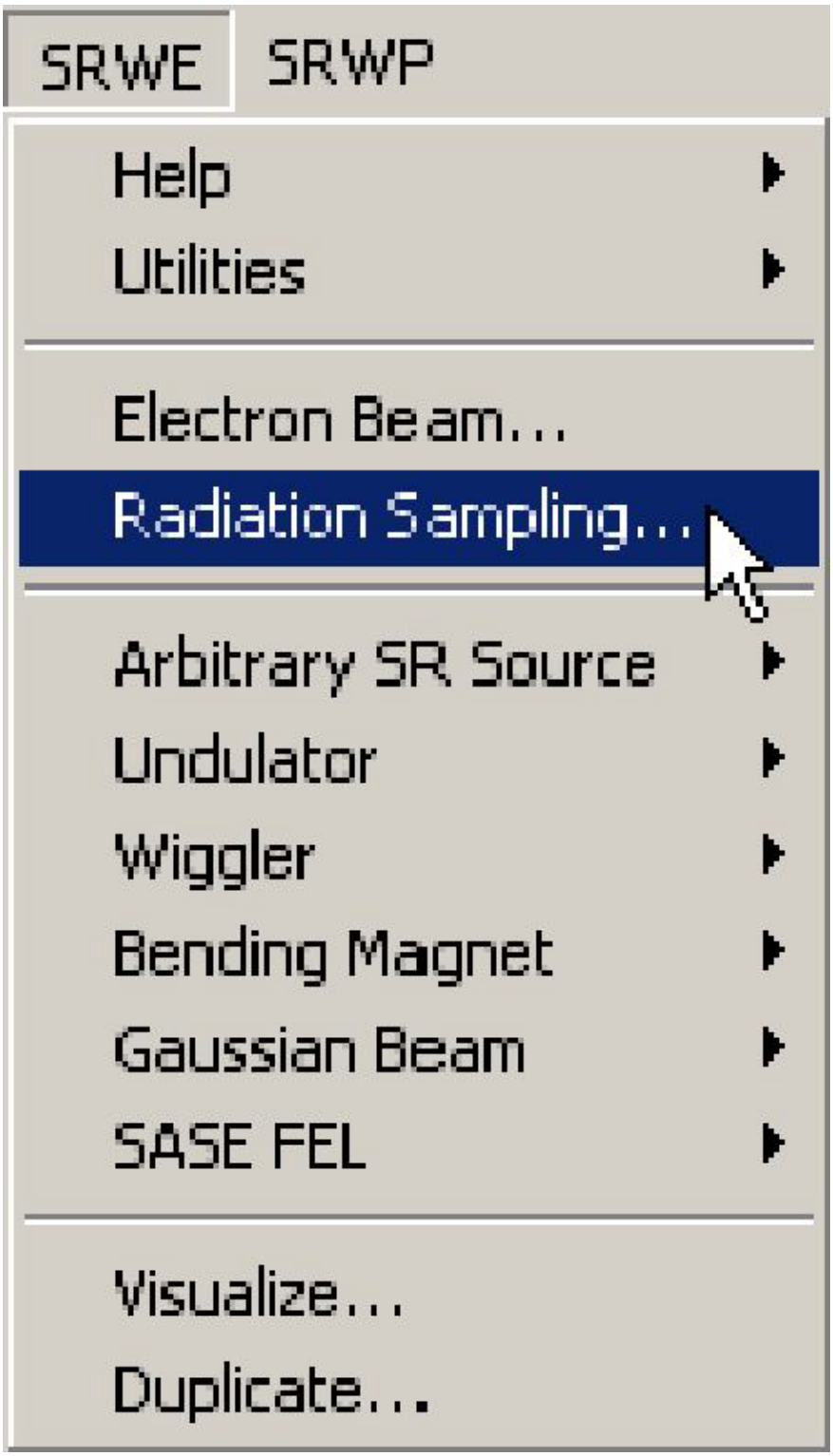
Normally, the initialization is executed automatically when you start Igor with the SRW installed. However, if you may still need to execute it manually when starting a new "experiment", to ensure that all SRW global variables are (re-)initialized to their default values. It is not recommended to make more than one initialization in the same experiment.

2) Define Electron Beam.



Here one defines all the parameters of the electron beam. See the Reference Manual records for the dialog box "Electron Beam" and the macro commands SrwElecFilament and SrwElecThick.

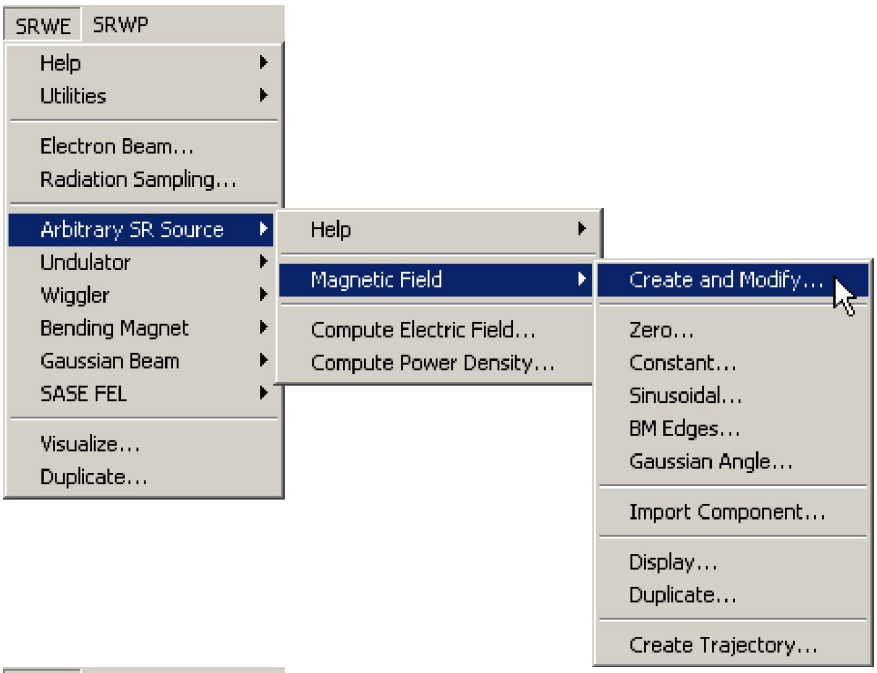
3) Define Radiation Sampling.

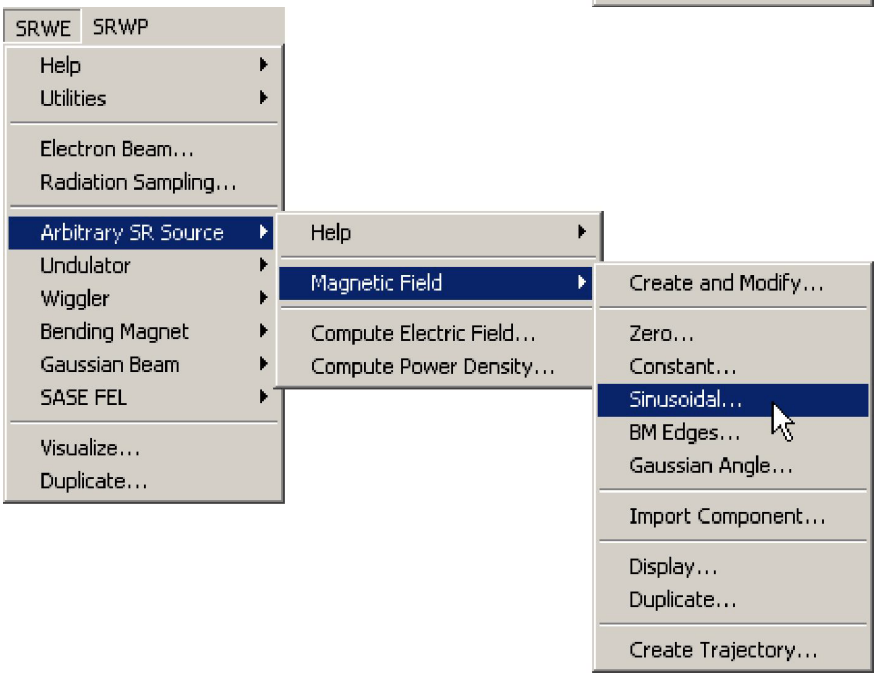


Here one defines the longitudinal position of the observation plane, ranges of transverse positions and photon energy and number of points where the radiation will be computed. For details on the Radiation Sampling definition, see the

Reference Manual topic Radiation Sampling and the records on the macro commands SrwSmpCreate and SrwSmpScanXZE.

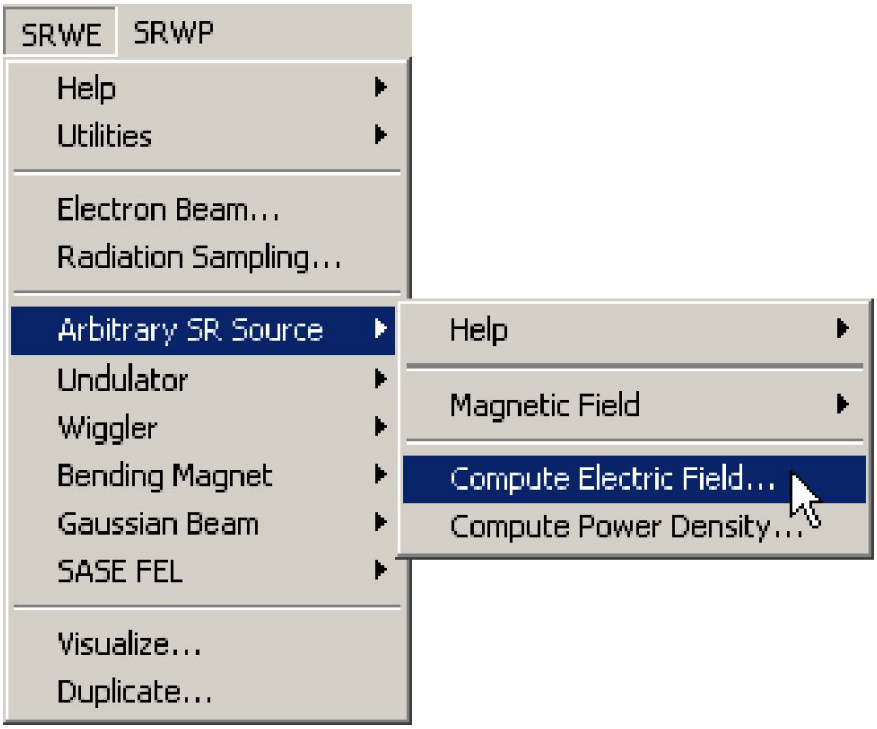
4) Define Magnetic Field.





Here one defines all the parameters of the magnetic field. For details on the magnetic field definition, see the Reference Manual records on the macro commands **SrwMagFieldCreate**, **SrwMagZero**, **SrwMagConst**, **SrwMagSin**, **SrwMagEdge**, **SrwMagGsnAng**, **SrwMagImportCmpn**, **SrwMagDisplayField**, **SrwMagElecTraj**, **SrwMagDupl**.

5) Compute the Near-Field SR Electric Field.



This is where the radiation is computed. It is the only place which may take significant CPU time depending on the number of points defined in the Radiation Sampling structure. For details on the Near Field SR computation, see the section "Near-Field SR Computation Method" in the "Theoretical Notes", and the Reference Manual records for the dialog box "Compute Electric Field" and the macro commands SrwWfrCreate and SrwMagPrec.

6) Visualize the computed SR component of interest.

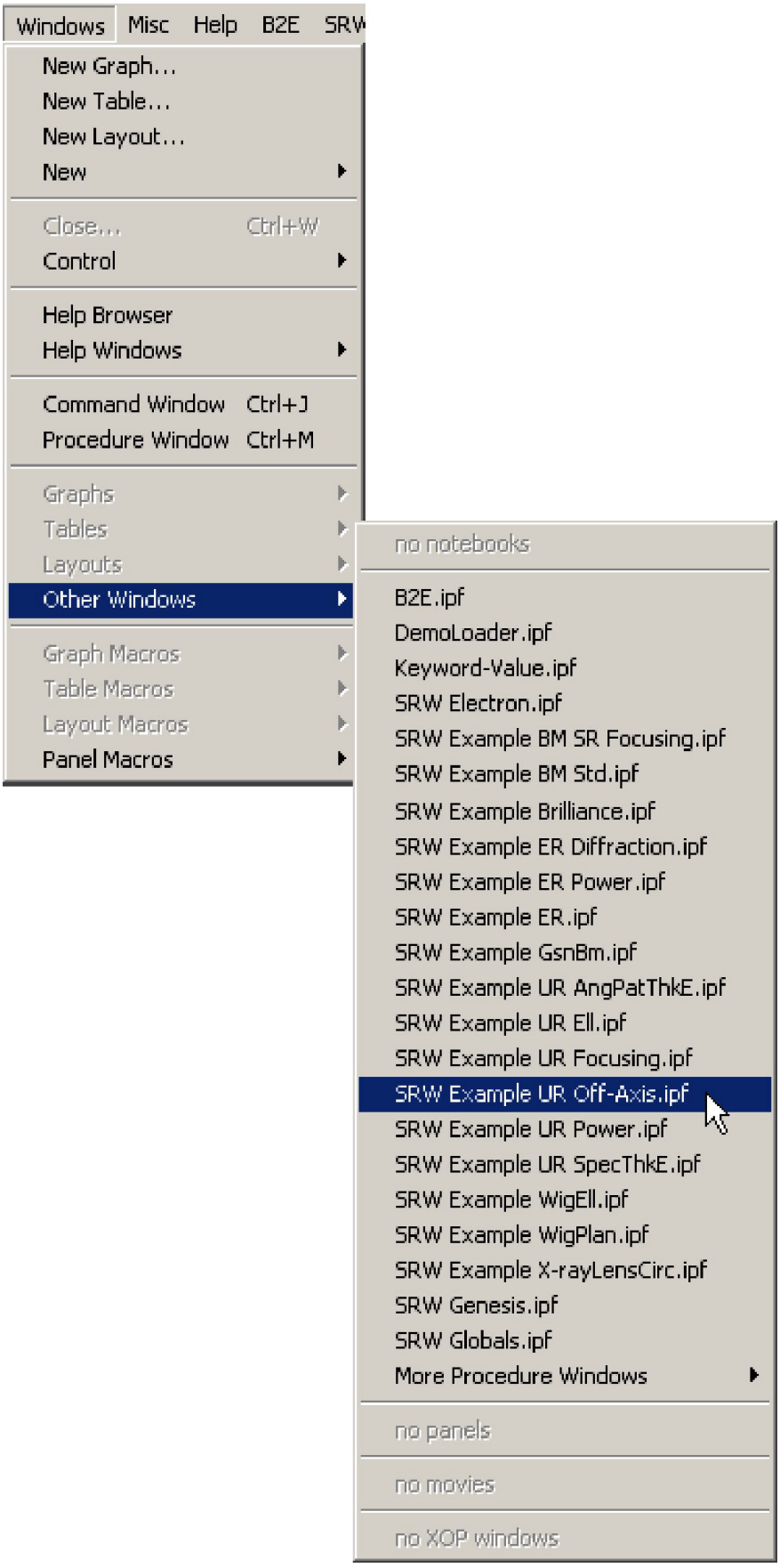
This is where one plots the data associated with a particular polarization. For details on options of visualization of single-electron or multi-electron SR components see the Reference Manual record for the dialog box "Visualize" and the macro command SrwWfr2Int.

IMPORTANT: It is important to make several cycles of computation with different values of the integration precision parameters (dialog "Compute Electric Field"). The independence, at a given precision level, of the computation results on the

integration parameters is the necessary condition for the validity of the results (however, it is not at all a sufficient condition...).

If you end up doing always the same kind of computation varying a few parameters each time, you may find it cumbersome to select all the time the same menus. There are several alternatives.

- The simplest one consists in re-executing the macros by copying them in the History window and pasting them into the Command window. After pasting and before executing, you may want to edit some parameters.
- You may group all the macro calls into your own macro. You can type your own macro directly into the procedure window, yet this is not a recommended method because you must know the text equivalent of each command and remember its list of arguments (that you can derive from the Reference Manual section, by the way). A better method is to copy the macro command calls one by one from the History window or from another macro. For this, you may want to have a look and print a macro associated with one of examples included in SRW. You can access the files containing the SRW examples from the menu "Windows" of Igor:


Windows
Misc
Help
B2E
SRW
New Graph...
New Table...
New Layout...
New
Close... Ctrl+W
Control
Help Browser
Help Windows
Command Window Ctrl+J
Procedure Window Ctrl+M
Graphs
Tables
Layouts
Other Windows
Graph Macros
Table Macros
Layout Macros
Panel Macros
no notebooks
B2E.ipf
DemoLoader.ipf
Keyword-Value.ipf
SRW Electron.ipf
SRW Example BM SR Focusing.ipf
SRW Example BM Std.ipf
SRW Example Brilliance.ipf
SRW Example ER Diffraction.ipf
SRW Example ER Power.ipf
SRW Example ER.ipf
SRW Example GsnBm.ipf
SRW Example UR AngPatThkE.ipf
SRW Example UR Ell.ipf
SRW Example UR Focusing.ipf
SRW Example UR Off-Axis.ipf
SRW Example UR Power.ipf
SRW Example UR SpecThkE.ipf
SRW Example WigEll.ipf
SRW Example WigPlan.ipf
SRW Example X-rayLensCirc.ipf
SRW Genesis.ipf
SRW Globals.ipf
More Procedure Windows
no panels
no movies
no XOP windows

You may copy the whole macro of the SRW example into the Procedure window and modify it for your convenience, but then do not forget to change its name (to avoid name conflict). Also, it is recommended to replace the "proc" qualifier (at the beginning of the macro) by the "macro" in such a way that you can call it directly from the "Macros" menu of Igor without typing its text definition in the Command window.

Assumptions

I. The following assumptions are made when computing the Near Field SR:

- The electrons are relativistic.
- Radiation from different electrons is incoherent.
- Only transverse SR polarization components are considered.
- Electron trajectory passes at a distance larger than at least several wavelengths from the observation point.
- The angle between the electron velocity and the direction to the observation point is (much) smaller than 1 radian at any point of the electron trajectory.
- SR emission is not affected by conductive walls of a vacuum chamber.
- Diffraction effects on the vacuum chamber are neglected. II. The following assumptions are made at the computation of the intensity distributions due to Non-zero Emittance Electron Beam:
    - The particle distribution in the electron beam is Gaussian over transverse positions and angles.
    - Magnetic field is transversely uniform in the region where the SR is emitted.

Problems and Limitations

The implemented method of the Near Field SR computation has the following problems and limitations.

Observation distance and wavelength.
This version does not treat separately the Electric and Magnetic fields of the radiation. Only transverse components of the Electric field are actually considered. Such a consideration is valid only if the electron trajectory passes at a distance from the observation point considerably larger than the wavelength of the observed radiation. This requirement is easily satisfied in most of the cases of SR extraction in high-energy storage rings, where the electron beam is deflected by a bending magnet before the SR comes to a beamline. However, any treatment of the SR very close to the electron beam should be done with due regard for this limitation.

Consistency of the input data.
To get a correct result of the SR computation, one needs to input Magnetic Field versus longitudinal position and Electron Beam parameters allowing explicit definition of the (average) trajectory, to properly set up the Radiation Sampling and Mode of Integration. These independent parameters should be consistent between each other. For example, if one wants to compute the flux per unit

surface produced at some photon energy into some direction, one must provide the magnetic field defined over a sufficiently large longitudinal range to allow the SR computation for the given direction. If this is not the case, SRW may throw an error message asking to increase the range of definition of the magnetic field.

Theoretical Notes

1. **Near-Field SR Computation Method**
   To compute the Near Field SR in frequency domain, an approach based on retarded potentials is applied. Starting from Fourier transformations of the retarded scalar and vector potentials, one can easily get the following expression for the electric field of the radiation emitted by a relativistic electron (Gaussian System):

$$\mathbf{E} = iek \int_{-\infty}^{+\infty} \left[\boldsymbol{\beta} - \mathbf{n} \left[1 + i(kR)^{-1} \right] \right] R^{-1} \exp\left[ik(c\tau + R) \right] d\tau$$

   where k is a wave number, ? instant relative velocity of electron, ? unit vector directed from instant electron position to an observation point, R distance from the electron to the observation point, c speed of light, e charge of electron. The integration is done over the time in laboratory frame.

The electric field is computed in the code almost directly from the above formula, after a proper phase expansion that preserves variation of R with the electron movement and allows to avoid losses of precision in the phase (see paper: O.V.Chubar, Rew. Sci. Instrum., Vol. 66, No.2, 1995, pp. 1872-1874).

To ensure fast convergence of the above integral, semi-analytical treatment of its outer parts is performed according to the following simplest asymptotic expansion:

```
expression
```

This allows to compute numerically only the integral between some values of the longitudinal position s1 and s2. These values are chosen in such a way that the interval [s1,s2] is as small as possible yet still satisfies the requirement that the second term of the asymptotic expansion is essentially smaller than the first one.

It can be shown analytically, that for a non-zero frequency, the method based or the retarded potentials is equivalent to a more widely used one which treats separately the acceleration and velocity fields (J.D. Jackson, Classical Electrodynamics, 2nd. ed., New York: Wiley, 1975, p. 657). We have also tested this numerically on a number of cases. We believe that for numerical calculations, the method based on the retarded potentials has more advantages.

1. **Thick Electron Beam**
   The previous section treats the single-electron emission. This section describes how a non-zero emittance of electron beam is taken into account in the Near Field computation.

The SR intensity distribution corresponding to electron beam with non-zero transverse emittance is computed in the code by making a 2D convolution over horizontal and vertical coordinates of the single-electron intensity distribution, with a 2D Gaussian. The RMS of this Gaussian are given by the electron beam sizes propagated to the observation plane, using the rules of the second-order moments propagation.

Let ? and ? be horizontal emittance and relative energy spread of the electron beam. Then the second-order central moments of particle distribution in the beam can be readily computed at any longitudinal position from the values of lattice functions (alpha, beta, dispersion function and its derivative) at that position:

```
expression p12_1
```

Let T be a 3 x 3 matrix describing the transformation of the (horizontal) second-order moments from the source point to the observation plane. The RMS of the Gaussian used in the convolution with the single-electron intensity ?? is obtained from the matrix relation:

```
expression p12_2
```

The vertical moments are treated similarly, with the only difference that the vertical dispersion is neglected.
This treatment of non-zero transverse emittance of electron beam is valid within the assumption of a transversely uniform magnetic field in the region where the SR is emitted. This assumption is met in most of the SR sources. However there are cases, such as SR produced in a quadrupole, which cannot be computed in this manner.

Examples

1. **Near-Field Edge Radiation**
   This example illustrates the simplest near-field SR computation. It gives the Spectral Flux per unit surface (intensity) of the Edge Radiation at 0.7 m from downstream bending magnet edge at 12.4 μm wavelength for the parameters of the SOLEIL ring, in assumption of a filament electron beam. The intensity vs horizontal coordinate, the magnetic field and beam trajectory are displayed in graphs.
2. **Off-Axis Undulator Radiation**
   This example computes several spectra produced by a filament electron beam of ESRF (6 GeV, 200 mA) injected through a U35 undulator (46.5 periods of 35 mm, peak field of 0.7 T), and observed at a distance of 30 m from the undulator in the photon energy range between 11 and 14 keV corresponding to the 5-th harmonic. The spectra are computed on the electron beam axis and with a vertical displacement of 1, 1.5 and 2 mm away from the on-axis position. As expected, the photon energy of the harmonic peak is displaced towards lower energies. Another feature appears, namely the shape of the peaks changes and becomes significantly broader as one

observes the radiation away from the axis. This is a typical case when the radiation computed in the near field differs from the far field approximation. The peculiarities of the near-field undulator radiation were described in the paper: R.P.Walker, Nucl. Instr. and Meth., A267 (1988), pp. 537-546.

3. **Polarization of Bending Magnet Synchrotron Radiation**
   This example computes electric field of standard bending magnet synchrotron for the parameters of SOLEIL (E = 2.75 GeV, I = 0.5 A) and shows spectral flux per unit surface at different polarizations.

CSR Computation

Introduction

If the transverse emittance of the emitting electron bunch is smaller than the diffraction limit at a given wavelength, then the frequency-domain electric field of the Free-Space Coherent Synchrotron Radiation (FS CSR) can be easily computed from the Single-Electron SR field, by multiplying it by a longitudnal form-factor of the electron bunch (which is proportional to the Fourier transform of longitudinal distribution of the electron density).

We propose a more general method, which takes into account 6D phase space distribution of electrons in bunches, and covers such cases as "wide and short" (or "rotated" in phase space) electron bunches, when the transverse emittance of the total electron beam can no longer be neglected.

Examples

- **Coherent Synchrotron Radiation from Rotated Electron Bunches**

Consider an electron bunch with small (30 micron) longitudinal size (or bunch length) and large (2 mm) vertical size. Such "rotated" bunches can be created in a storage ring using a transverse RF-kick technique (this technique was proposed for the generation of femtosecond X-ray pulses by A.Zholents et. al., 1998). The current example calculates the infrared free-space CSR generated by such bunches travelling through a bending magnet of a 2.75 GeV storage ring, and compares this calculation with that of the incoherent SR. The electron density distribution in the bunches is assumed to be Gaussian with respect to 6 phase-space variables.

Fast Computation of Undulator Radiation Spectra through a Slit

Introduction

This part of SRW treats undulator radiation emitted by an electron beam with non-zero emittance and energy spread in a periodic magnetic field and observed through some kind of rectangular aperture. The typical computation is a spectrum integrated through a slit or an image of the radiation pattern observed at a single energy at some distance from the source. The computation is performed in far-field approximation. This type of computation is probably less accurate than the near-field computation. Its main advantage is speed.

Getting Started

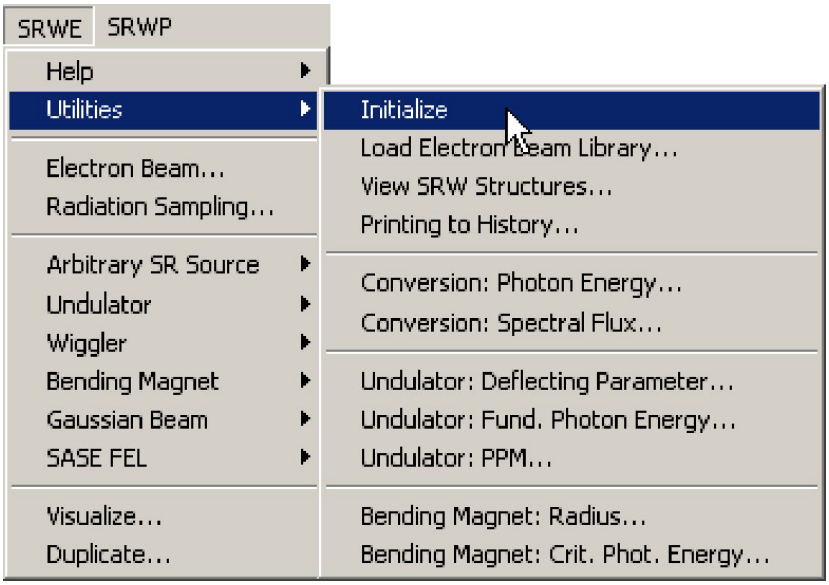
We assume that you have successfully installed the SRW on your computer, following the instructions in the "ReadMe.txt" file supplied with the distribution pack. Run Igor Pro. Menu items "SRW..." should appear in the Igor Pro menu. Select the sub-menu SRWE: "Undulator Examples" and choose a computation example of your interest. During the execution of the example, a window giving some explanations on the content of the computation being made should appear on your screen. Please read the explanations and make sure that everything goes as prescribed (you can also find the text of the explanations in section "Examples"). If everything goes well, at the end of the computation you should obtain a (set of) graph(s) displaying the results, which should fit the explanations.

If you have passed this step successfully, you are ready to perform your own computation.

Computation of Undulator Radiation Spectra through a Slit Step by Step

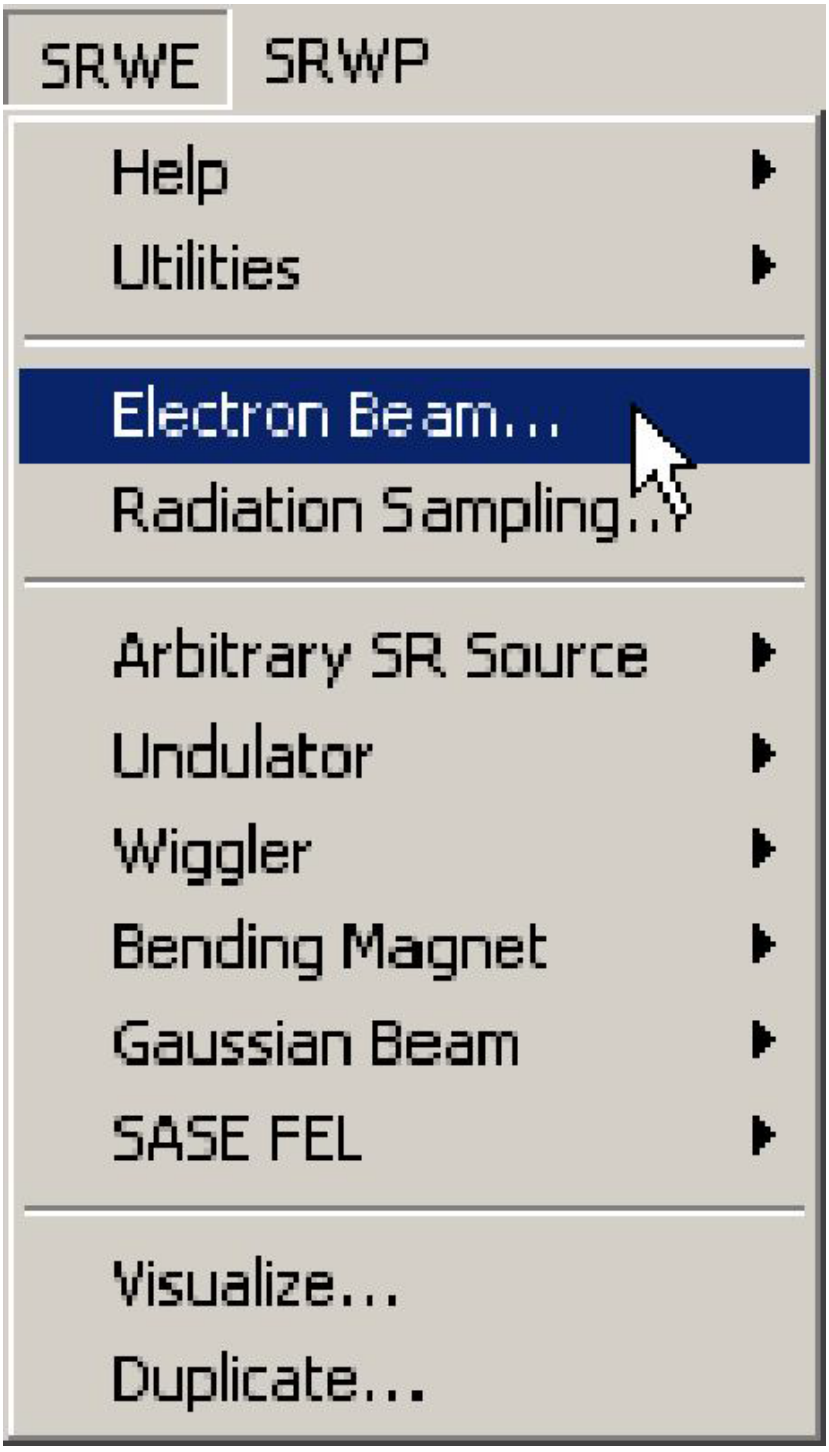
The following are the steps one needs to make in order to perform the computation of the undulator radiation.

1. Initialize SRW.



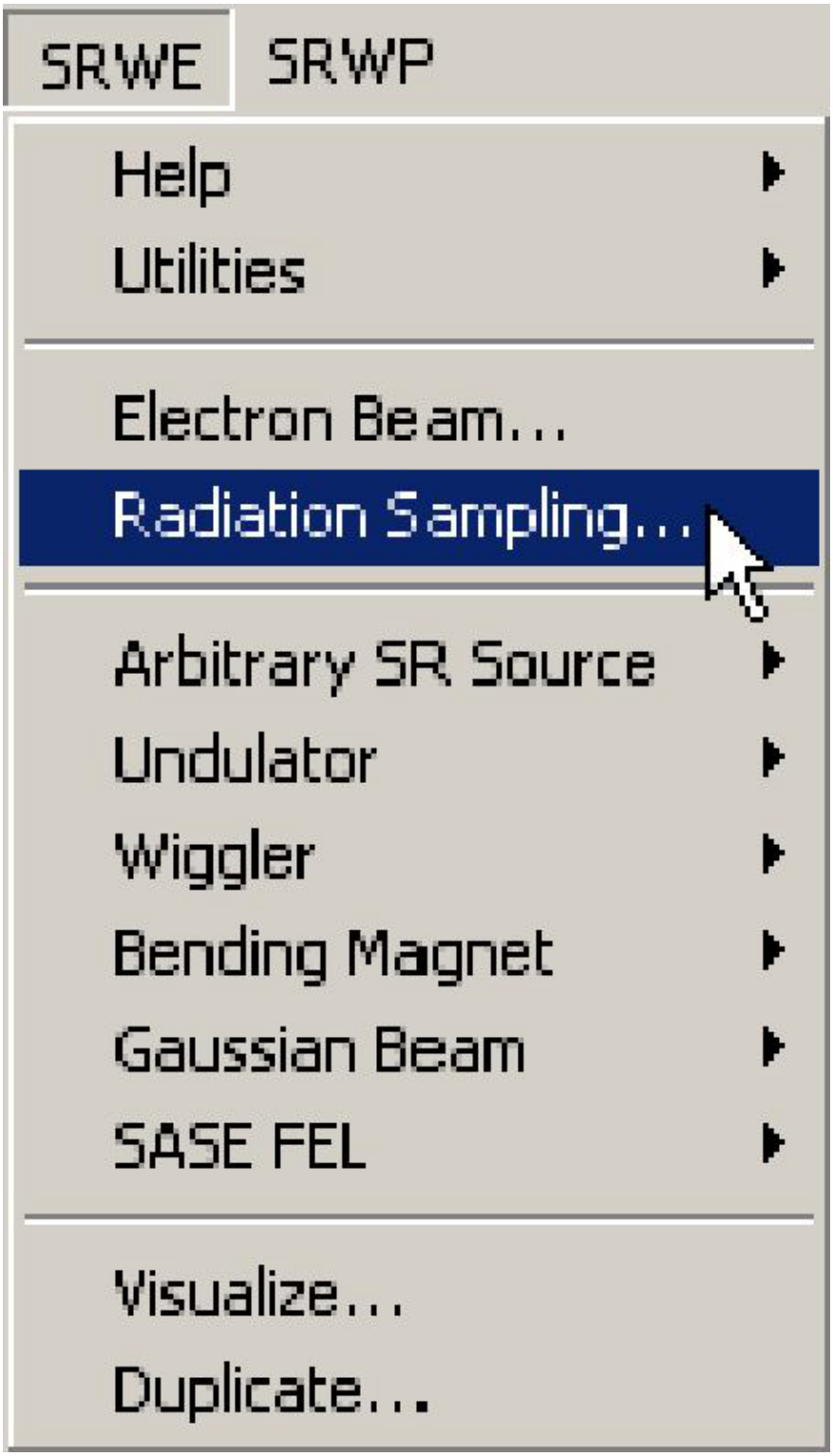
In any Igor experiment, the initialization should be done only once, before you start to work with the SRW. It is not recommended to make more than one initialization in the same experiment.It is not recommended to make more than one initialization in the same experiment.

1. Define Electron Beam.



Here one defines all the parameters of the electron beam. See the Reference Manual records for the dialog box "Electron Beam" and the macro commands **SrwElecFilament** and **SrwElecThick**for details. It is important to properly set up both "filament" and "thick" beam parameters for this mode of computation.

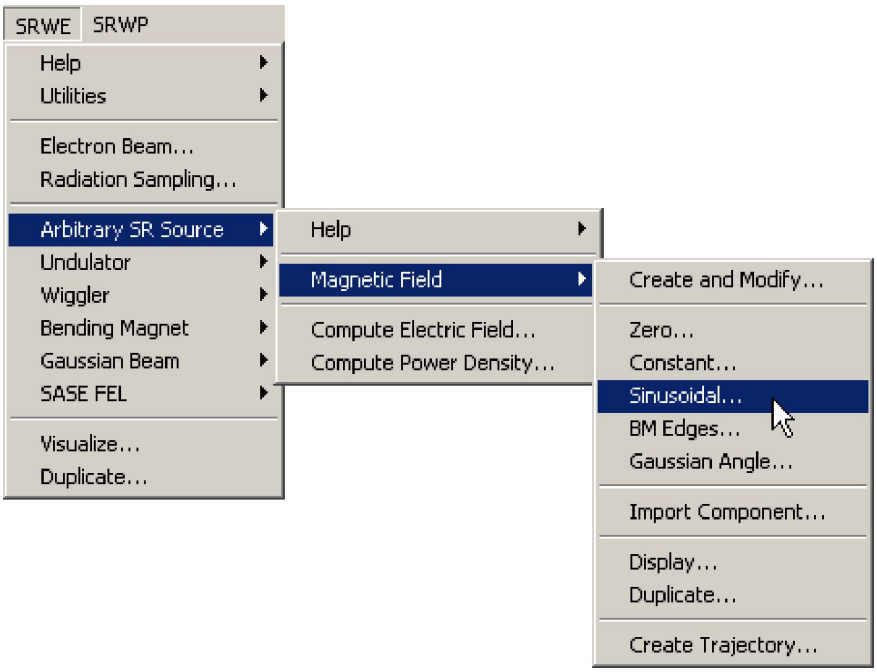
1. Define Radiation Sampling.



Here one defines the longitudinal position of the observation plane, ranges of transverse positions and photon energy and number of points where the radiation will be computed. For details on the Radiation Sampling definition, see the Reference Manual topic **Radiation** Sampling and the records on the macro commands **SrwSmpCreate** and **SrwSmpScanXZE**. Please note that for this method of computation, the Radiation Sampling parameters have slightly different meaning compared to the other methods implemented in SRW, since this mode of computation produces Spectral Flux integrated within a slit, while most of the

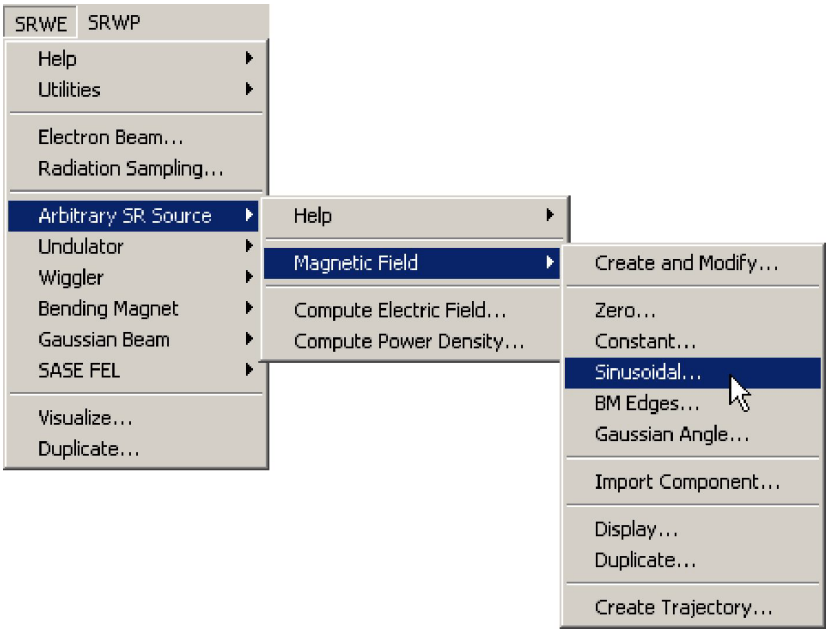
other methods in SRW produce Spectral Flux per Unit Surface (or the electric field from which the Spectral Flux per Unit Surface can be deduced). The details of these differences can be found in the Reference Manual record for the macro command **SrwPerStoCreate** (menu call "SRWE -> Undulator -> Compute Stokes...").

1. Define Periodic Magnetic Field.



Here one sets up all parameters of the periodic magnetic field. For details on the magnetic field definition, see the Reference Manual records for the dialog box "Periodic Magnetic Field" and macro commands **SrwMagPerCreate2D**, **SrwMagPerAddHarm**, **SrwMagPerPPMUndField**.

1. **Compute** UR spectrum through a slit.



This is where the radiation is computed. For details on the computation, see the sections "Assumptions", "Problems and Limitations", "Theoretical Notes" below and the Reference Manual record on the macro command **SrwPerStoCreate**.

1. **Visualize** the UR component of interest.

This is where one plots the data associated with a particular polarization. For details on options of visualization of the UR spectra and intensity distributions see the Reference Manual record for the dialog box "Visualize" and the macro command SrwSto2Int.

IMPORTANT: It is important to make several cycles of computation with different values of precision parameters (macro SrwPerStoCreate). The independence, at a given precision level, of the computation results on the precision parameters is the necessary validity condition for the results (however, it is not at all a sufficient condition...).

If you end up doing always the same kind of computation varying a few parameters each time, you may find it cumbersome to select all the time the same menus. There are several alternatives.

- The simplest one consists in re-executing the macros by copying them in the History window and pasting them into the Command window. After pasting and before executing, you may want to edit some parameters.
- You may group all the macro calls into your own macro. You can type your own macro directly into the procedure window, yet this is not a recommended method because you must know the text equivalent of each command and remember its list of arguments (that you can derive from the Reference Manual section, by the way). A better method is to copy the macro command calls one by one from the History window or from another macro. For this, you may want to have a look and print a macro associated with one of examples included in SRW. You can access the files containing the SRW examples from the menu "Windows" of Igor. You may copy the whole macro of an SRW example into the Procedure window and modify it for your convenience, but then do not forget to change its name (to avoid name conflict). Also, it is recommended to replace the "proc" qualifier (at the beginning of the macro) by the "macro" in such a way that you can call it directly from the "Macros" menu of Igor without typing its text definition in the Command window.

Assumptions

The following **assumptions** are made when computing the **UR Spectra through a Slit**:

- Electrons are relativistic.
- Radiation from different electrons is incoherent: the flux is proportional to the number of electrons.
- Only transverse SR polarization components are considered.

- Distance from undulator to observation plane is considerably larger than the length of the undulator.
- Number of periods in the undulator is significantly larger than 1.
- The effect of terminating poles of the undulator is neglected.
- Angle between electron velocity and direction to the observation point is comparable with the angular size of central cone of the undulator radiation.
- SR emission is not affected by conductive walls of a vacuum chamber.
- Diffraction effects on the vacuum chamber are neglected.

Problems and Limitations

The implemented computation method of **UR Spectra through a Slit** has the following **problems and limitations**. Number of Periods. The computation method implemented is valid at 1 << Nper <= Infinity, where Nper is the number of periods. The smaller is Nper, the less precise is the computation. Observation Angles and Distance from Undulator. Basically, the implemented method is the Far-Field SR computation method. Therefore it can not give a high precision at small distances or large observation angles, especially at small electron beam emittance values. Peculiarities of the Near-Field undulator radiation were discussed in the paper: R.P.Walker, Nucl. Instr. and Meth., A267 (1988), pp. 537-546.

Theoretical Notes

- **Computation of UR Spectra through a Slit for a Finite-Emittance Electron Beam**

Consider a non-zero emittance ("thick") electron beam travelling in a finite-length undulator and emitting the radiation which is collected within a rectangular slit (aperture) at a large distance from the undulator.

For a photon energy range around the resonant energy value of a given harmonic for a given observation direction, the radiation from a finite-length undulator and a "thick" e-beam can be represented with a reasonable precision as a convolution of a spectrum resulting from an infinitely long undulator with a resonant (sin(x))^2/x^2 function describing the shape of harmonic for the case of finite-length undulator and zero-emittance electron beam.

So the computation is done in two steps in SRW. First, the spectrum for the infinite-length undulator and finite transverse emittance (but zero energy spread) of electron beam is computed. After that, a convolution is performed in order to take into account the finite number of periods of the undulator and finite energy spread of the electron beam.

Examples

- **UR Spectrum through a Slit**

This example computes Spectral Flux through a slit vs photon energy for the finite-emittance electron beam of ESRF (energy 6 GeV, current 200 mA, horizontal and vertical emittances 3.9 nm and 0.039 nm, beta functions 35.6 m and 2.5 m, rms energy spread 0.1%), injected through an undulator (total length 3.2 m, period 35 mm, deflection parameter 2.2). The 0.5 mm x 0.5 mm rectangular slit is located at 30 m distance from the undulator, with its center on the undulator axis. Due to finite beam emittance and slit size, the on-axis spectrum possesses both even and odd harmonics. The shapes of the harmonics strongly differ from the single-electron shape.

- **UR Angular Pattern**

This example computes undulator radiation Spectral Flux per Unit Surface produced by finiteemittance electron beam of ESRF (energy 6 GeV, current 200 mA, horizontal and vertical emittances 3.9 nm and 0.039 nm, beta functions 35.6 m and 2.5 m, rms energy spread 0.1%), injected through an undulator (total length 3.2 m, period 35 mm, deflection parameter 2.2), and by a filament electron beam. The radiation is observed in transverse plane at 30 m distance from the undulator. The photon energy is 13.5 keV, which is between resonant values of harmonics 4 and 5 of the on-axis spectrum. In the image plots, the contributions from harmonics 5 and 6 are well seen. The harmonics with lower numbers (1 - 4) make no contributions to the observed intensity distributions. Since horizontal emittance of the real electron beam is considerably larger than the vertical emittance, the "undulator rings" are stronger smoothed-off horizontally than vertically.

To reduce the CPU time, the computation in this example is performed in the mode of "infinite" undulator, with the intensity normalized to that of the real 3.2 m length undulator. One can make the same computation in the mode of "conventional" undulator (see Reference Manual record for the macro **SrwPerStoCreate**). This will significantly enlarge the computation time, yet will bring-in almost no changes to the plots. Stronger differences in the cases of "infinite" and a finitelength undulator may appear for the values of photon energy in a small region slightly higher than on-axis resonant value of an odd harmonic.

- **Ellipsoidal Undulator**

This example computes Spectral Flux through a slit vs photon energy for the finite-emittance electron beam of ESRF (energy 6 GeV, current 200 mA, horizontal and vertical emittances 3.9 nm and 0.039 nm, beta functions 35.6 m and 2.5 m, rms energy spread 0.1%), injected through an Ellipsoidal Undulator (total length 3.2 m, period 42 mm, deflection parameters: Kz = 2, Kx = 1). The 0.5 mm x 0.5 mm rectangular slit is located at 30 m distance from the undulator, with its center on the undulator axis. The radiation is generally circularly polarized. Note the presence of circularly polarized on-axis emission at higher harmonics. The image plot of the Power Density distribution illustrates small heat load in the on-axis direction.

- **Brilliance at ESRF**

This example estimates the brilliance of undulator radiation source at ESRF (U42 undulator, electron beam energy 6 GeV, current 200 mA, horizontal and vertical emittances 3.9 nm and 0.039 nm, beta functions 35.6 m and 2.5 m, rms energy spread 0.1%). The computation is only done on the odd harmonics of the spectrum. The brilliance at any photon energy is computed for particular deflection parameter value which makes the energy of the selected harmonics to coincide with the photon energy of interest. This corresponds to a continuous gap change (current change in coils) for a permanent magnet (electro-magnet) undulator.

Computation of Wiggler Radiation

Introduction

This part of SRW computes spectral flux per unit surface of radiation emitted by an electron beam with non-zero emittance in a wiggler. Typical computation is a spectral flux per unit surface at fixed photon energy in a transverse plane at some distance from the wiggler, or a spectrum vs photon energy at fixed direction (observation point).

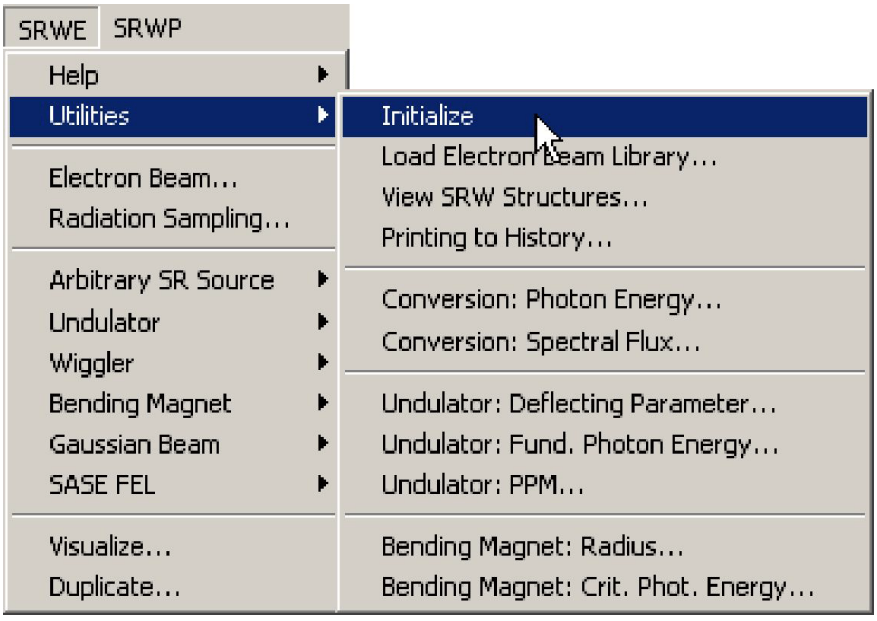
Getting Started

We assume that you have successfully installed the SRW on your computer, following the instructions in the "ReadMe.txt" file supplied with the distribution pack. Run Igor Pro. Menu item(s) "SRW..." should appear in the Igor Pro menu. Select the sub-menu "Wiggler-> Examples" and choose a computation example of your interest. During the execution of the example, a window giving some explanations on the content of the computation being made should appear on your screen. Please read the explanations and make sure that everything goes as prescribed (you can also find the text of the explanations in section "Examples"). If everything goes well, at the end of the computation you should obtain a (set of) graph(s) displaying the results, which should fit the explanations.

If you have passed this step successfully, you are ready to perform your own computation.

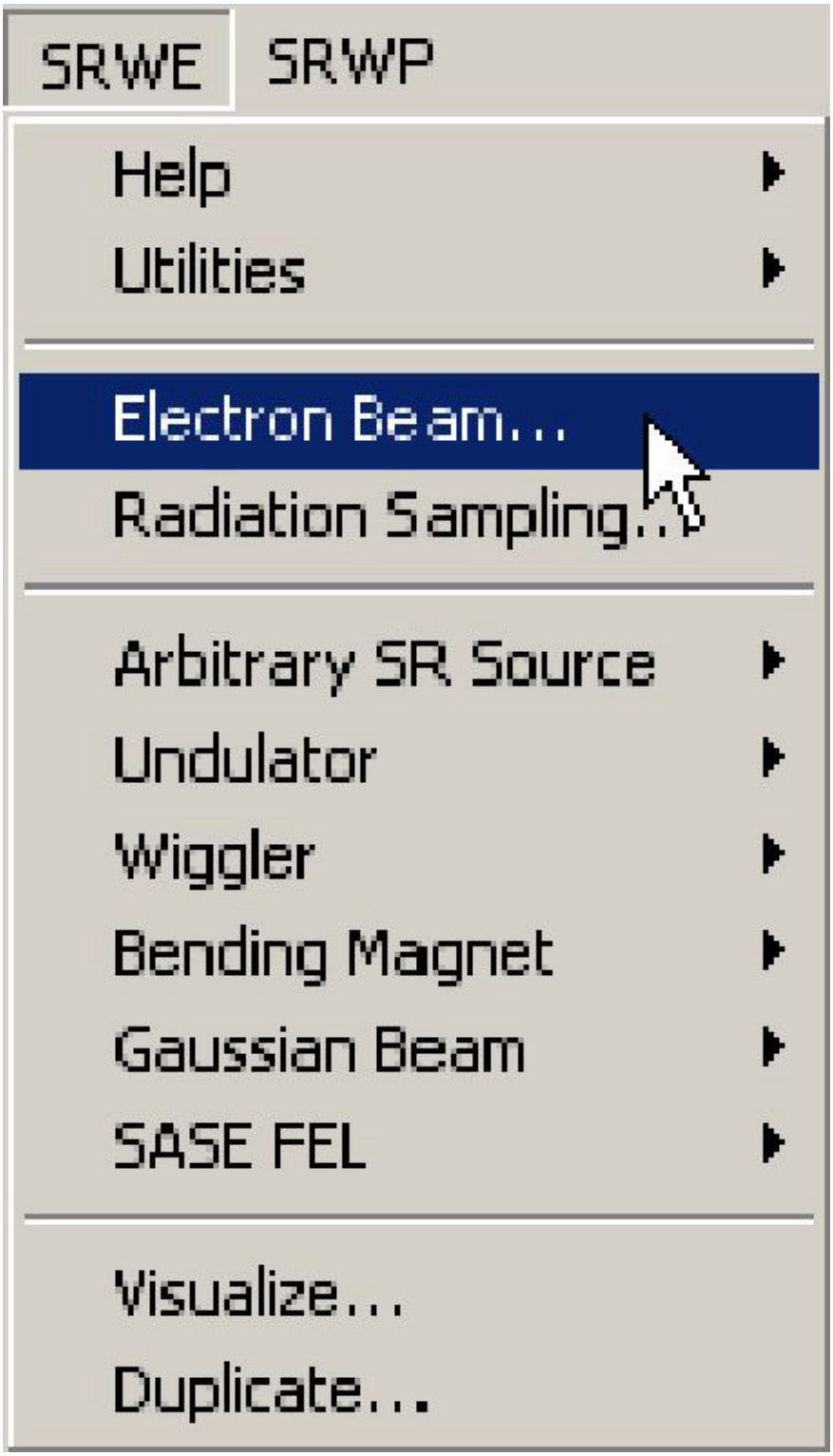
Computation of Wiggler Radiation Step by Step

The following are the steps one needs to make in order to perform the computation of spectral angular distributions of wiggler radiation. 1) **Initialize** SRW.



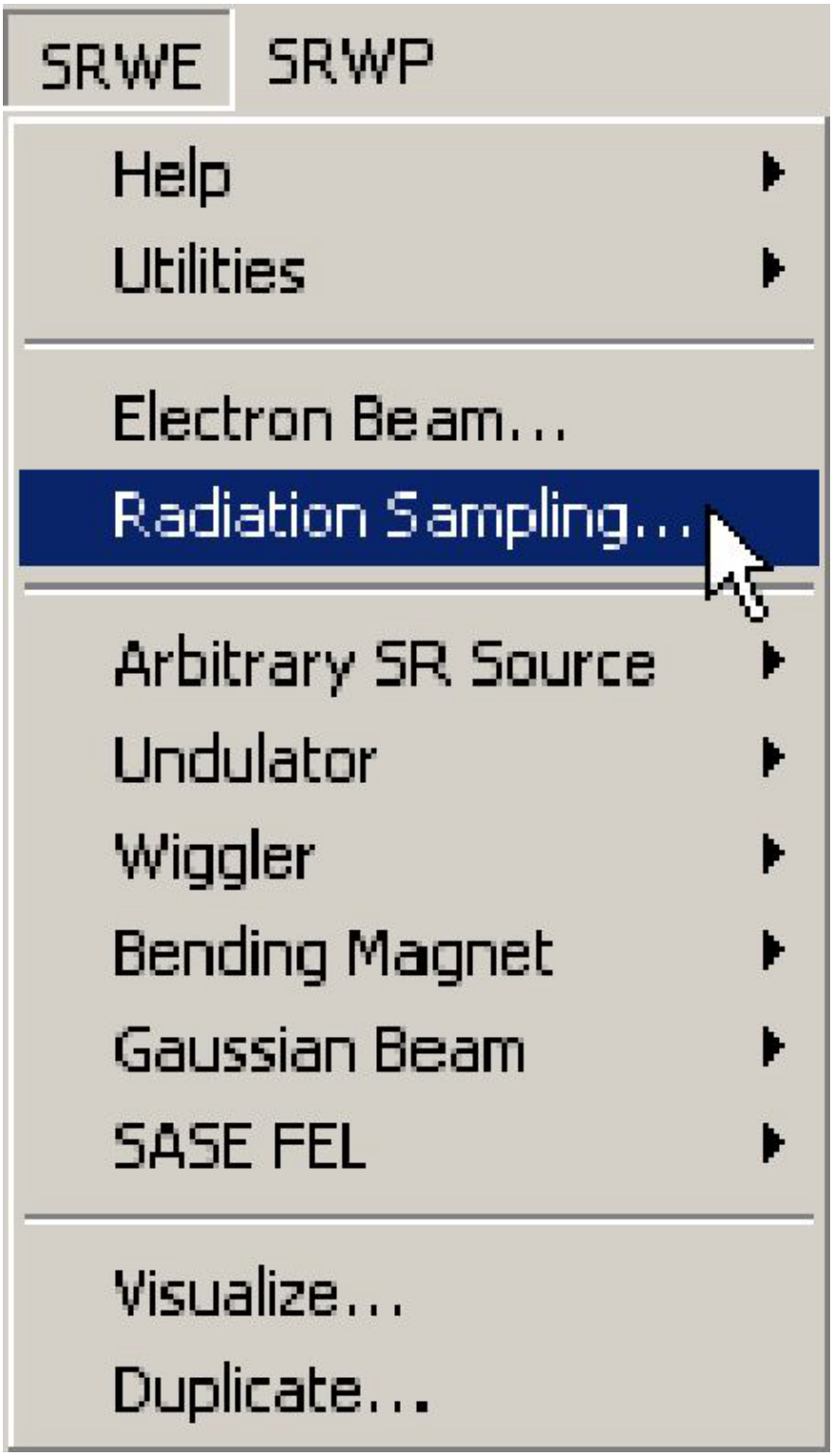
In any Igor experiment, the initialization should be done only once, before you start to work with the SRW. It is not recommended to make more than one initialization in the same experiment.

2) Define **Electron Beam**.



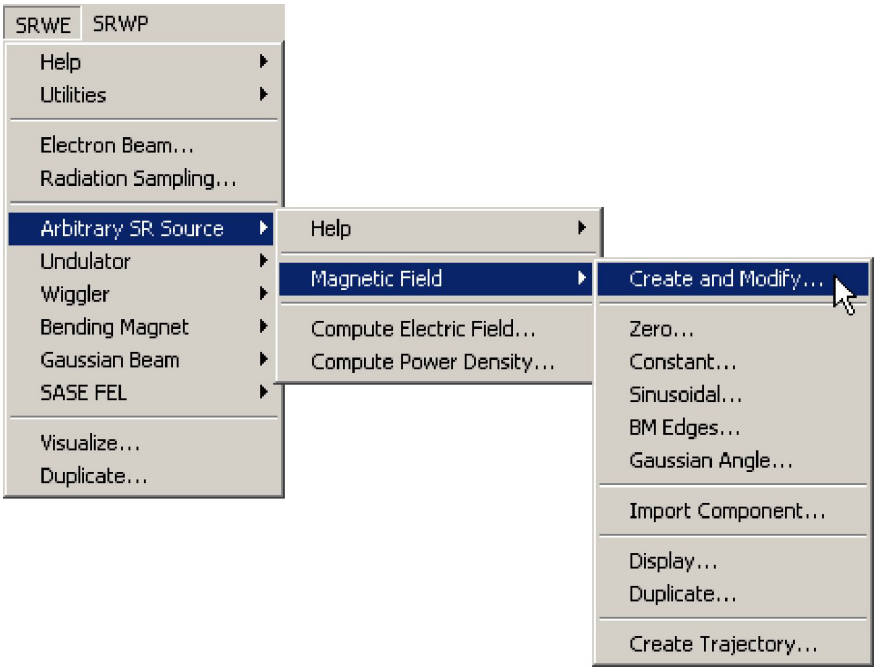
Here one defines all the parameters of the electron beam. See the Reference Manual records for the dialog box "Electron Beam" and the macro commands **SrwElecFilament** and **SrwElecThick** for details. It is important to properly set up both "filament" and "thick" beam parameters for this mode of computation.

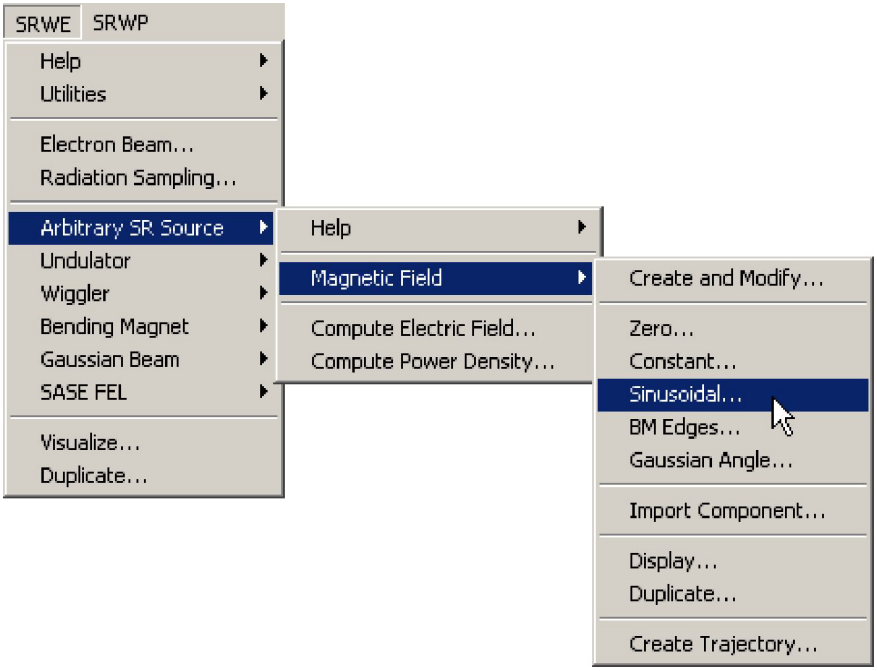
3) Define **Radiation Sampling**.



Here one defines the longitudinal position of the observation plane, ranges of transverse positions and number of points where the radiation will be computed. For details on the Radiation Sampling definition, see the Reference Manual topic **Radiation Sampling** and the records on the macro commands **SrwSmpCreate** and **SrwSmpScanXZE**.

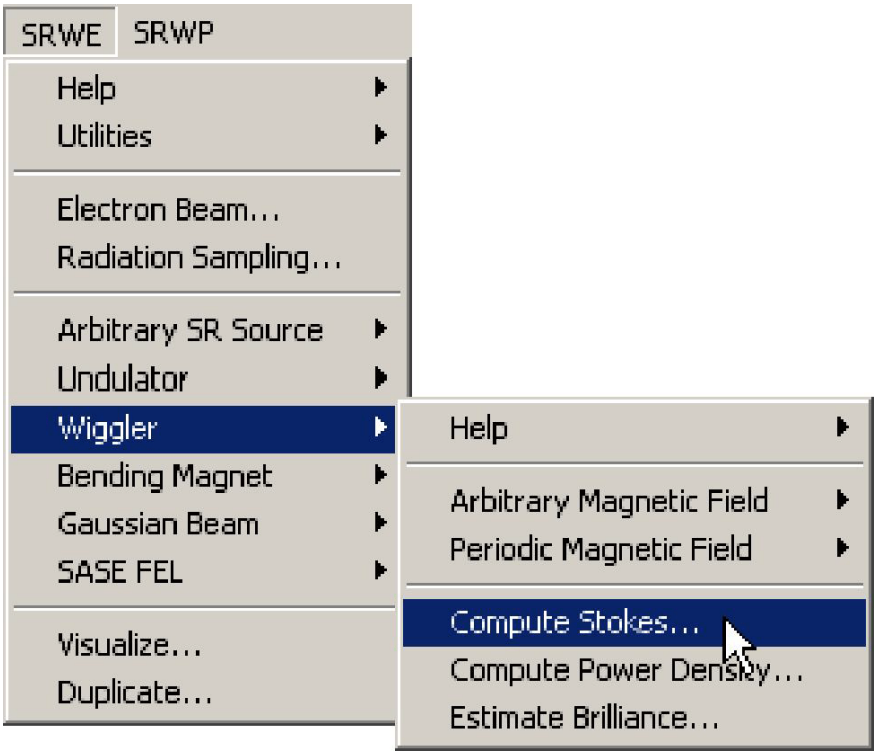
4) Define Arbitrary or Periodic **Magnetic Field**.





Here one sets up all parameters of the arbitrary or periodic magnetic field. For details on the magnetic field definition, see the Reference Manual records on macro commands **SrwMagFieldCreate**, **SrwMagZero**, **SrwMagConst**, **SrwMagSin**, **SrwMagEdge**, **SrwMagGsnAng**, **SrwMagImportCmpn**, **SrwMagPerCreate2D**, **SrwMagPerAddHarm**.

5) **Compute** Stokes components of Spectral Flux per Unit Surface of wiggler radiation.



This is where the radiation is computed. For details on the computation, see the section "Assumptions" and the Reference Manual records on the macro command **SrwStoWigCreate**.

6) **Visualize** the SR component of interest.

This is where one plots the data associated with a particular polarization. For details on options of visualization of the wiggler radiation spectra and intensity distributions see the Reference Manual record for the dialog box "Visualize" and the macro command **SrwSto2Int**.

IMPORTANT: It is important to make several cycles of computation with different values of precision parameter (macro **SrwStoWigCreate**). The independence, at a given precision level, of the computation results on the precision parameter is

the necessary validity condition for the results (however, it is not at all a sufficient condition...).

Assumptions

The following **assumptions** are made when computing spectral angular distributions of **Wiggler Radiation**:

- Electrons are relativistic.
- Radiation from different electrons is incoherent: the flux is proportional to the number of electrons.
- Only transverse SR polarization components are considered.
- **Emission conditions correspond to a wiggler case**, i.e. radiation is generally emitted from distinct separate parts of electron trajectory, and phase shifts of the radiation between these trajectory parts is much larger than Pi.

Examples

- **Planar Wiggler**

This example computes spectral flux per unit surface of synchrotron radiation emitted by a nonzero emittance electron beam in a planar wiggler (Bmax = 1.8 T, 3 periods of 150 mm length). The effect of the wiggler terminations is taken into account. The electron beam parameters are those of ESRF (energy 6 GeV, current 200 mA, horizontal and vertical emittances 3.9 nm and 0.039 nm, beta functions 35.6 m and 2.5 m).

- **Ellipsoidal Wiggler**

This example computes spectral flux per unit surface of synchrotron radiation emitted by a nonzero emittance electron beam in an ellipsoidal wiggler (Kz=20, Kx=1.2, 3 periods of 150 mm length). The effect of the wiggler terminations is NOT taken into account. The electron beam parameters are those of ESRF (energy 6 GeV, current 200 mA, horizontal and vertical emittances 3.9 nm and 0.039 nm, beta functions 35.6 m and 2.5 m).

Computation of Bending Magnet Radiation

Introduction

This part of SRW computes spectral flux per unit surface of radiation emitted by an electron beam with non-zero emittance in a bending magnet. Typical computation is a spectral flux per unit surface at fixed photon energy in a transverse plane at some distance from the bending magnet, or a spectrum vs photon energy at fixed direction (observation point).

Assumptions

The following **assumptions** are made when computing spectral angular distributions of **Bending Magnet Radiation**:

- Electrons are relativistic.
- Radiation from different electrons is incoherent: the flux is proportional to the number of electrons.
- Only transverse SR polarization components are considered.
- Spectral-angular distribution of the bending magnet radiation is computed in far-field approximation.

Examples

- **Standard Bending Magnet Radiation**

This example computes spectral flux per unit surface and power per unit surface of synchrotron radiation emitted by a non-zero emittance electron beam in a bending magnet. The bending magnet and electron beam parameters are those of ESRF (B = 0.85 T, energy 6 GeV, current 200 mA).

Computation of SR Power Density

Introduction

This part of SRW computes power density integrated over all photon energies for synchrotron radiation emitted by an electron beam with non-zero emittance in arbitrary magnetic field. Typical computation is power density distribution (heat load) in a transverse plane located at some distance from the SR emission region.

Getting Started

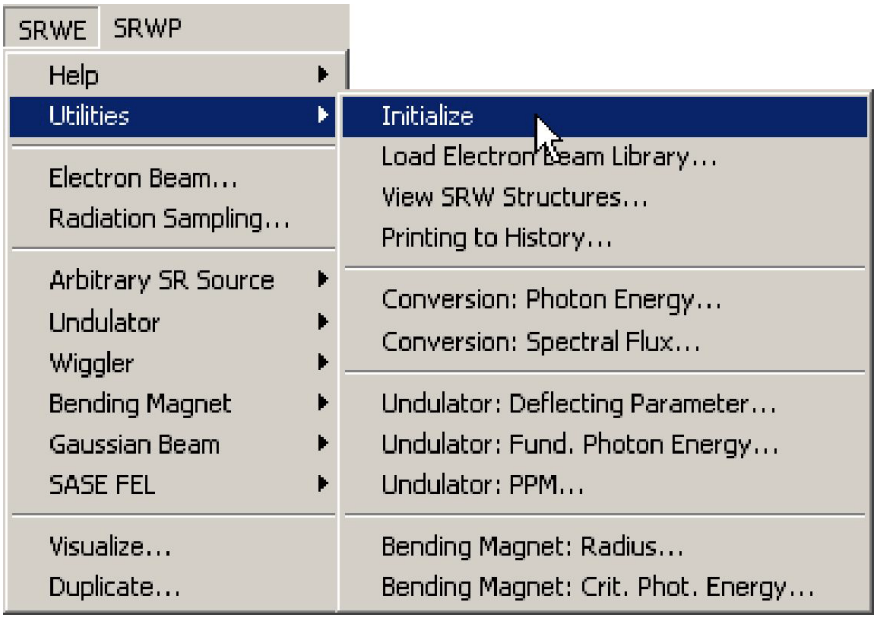
We assume that you have successfully installed the SRW on your computer, following the instructions in the "ReadMe.txt" file supplied with the distribution package. Run Igor Pro. Menu items "SRW..." should appear in the Igor menu. Select in one of the SRW sub-menus an example dedicated to the power density computation. During the execution of the example, a window giving some explanations on the content of the computation being made should appear on your screen. Please read the explanations and make sure that everything goes as prescribed (you can also find the text of the explanations in section "Examples"). If everything goes well, at the end of the computation you should obtain a (set of) graph(s) displaying the results, which should fit the explanations.

If you have passed this step successfully, you are ready to perform your own computation.

Computation of SR Power Density Step by Step

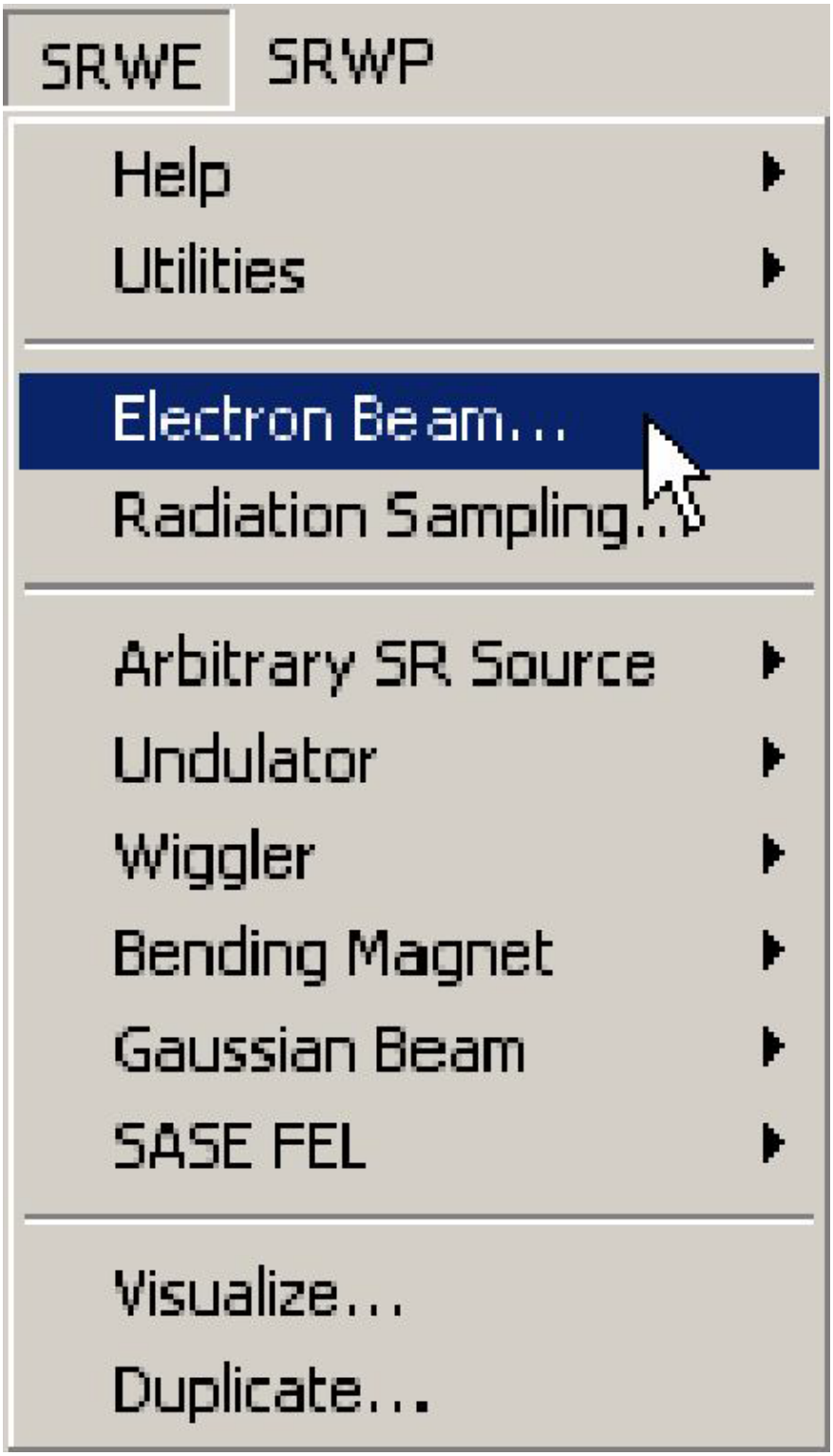
The following are steps one needs to make in order to perform the computation of SR power density from Arbitrary Magnetic Field source. For particular Undulator, Wiggler and Bending Magnet sources the computation of the power density should be done by direct analogy.

1) **Initialize** SRW.



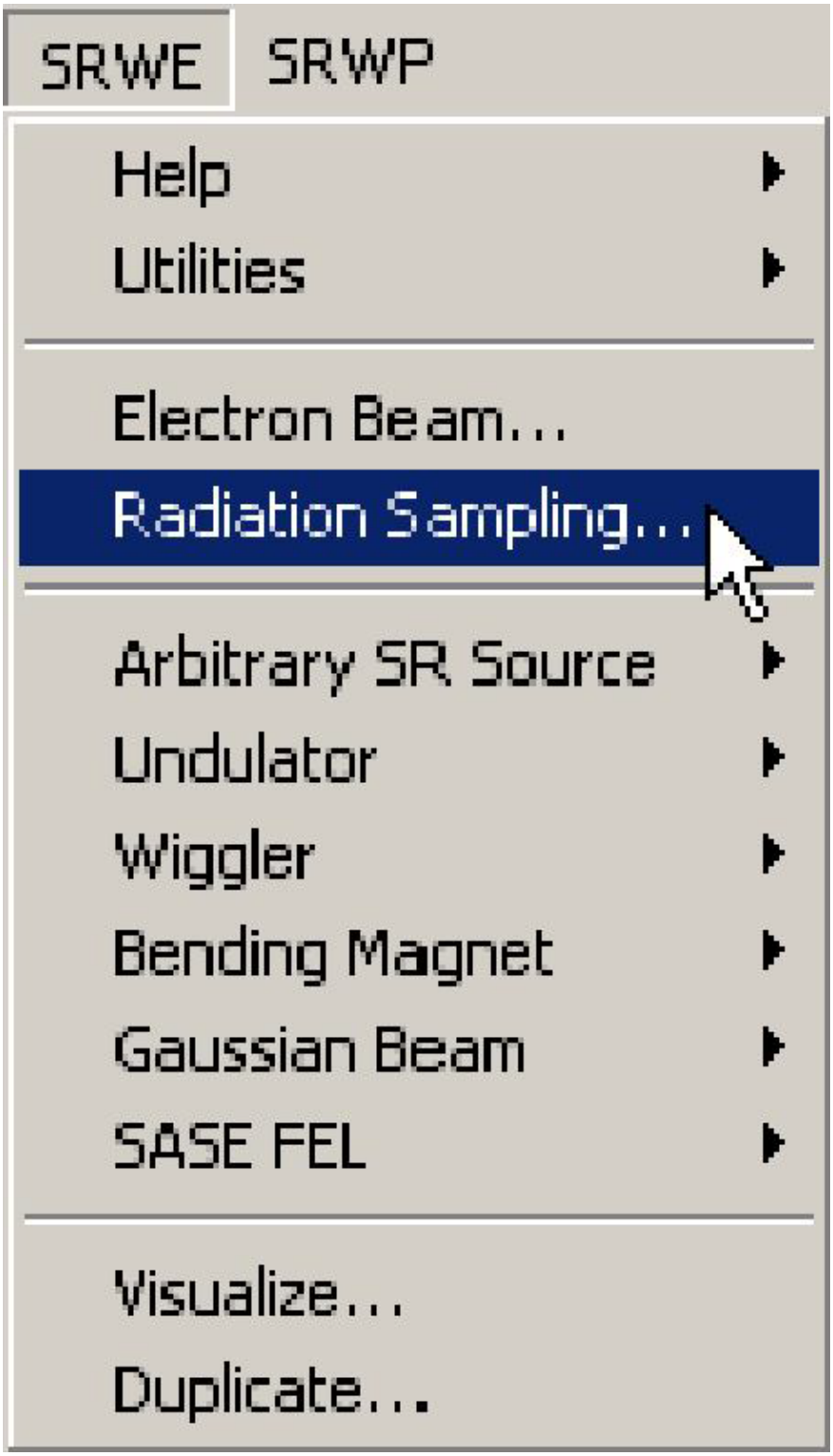
In any Igor experiment, the initialization should be done only once, before you start to work with the SRW. It is not recommended to make more than one initialization in the same experiment.

2) Define **Electron Beam**.



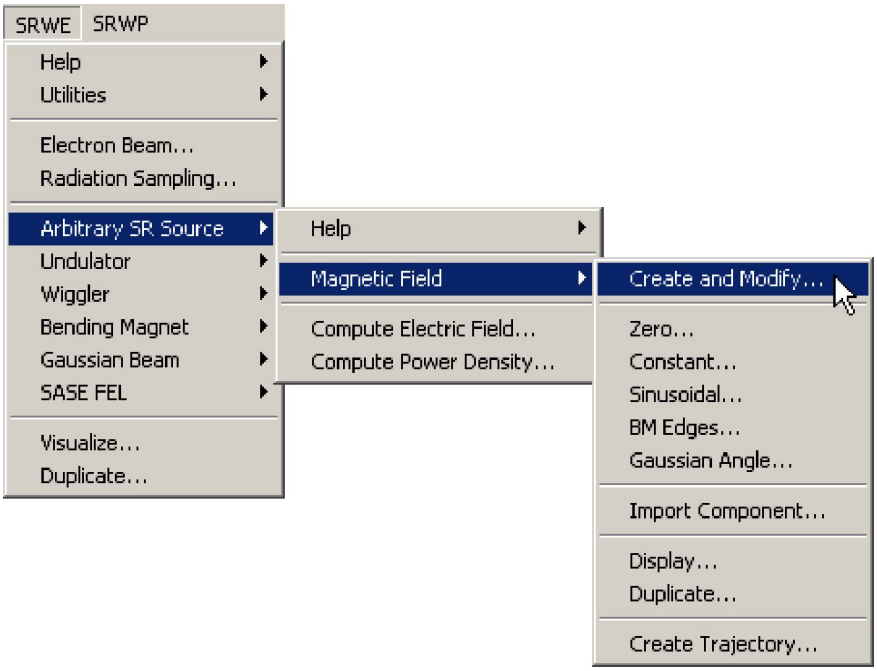
Here one defines all the parameters of the electron beam. See the Reference Manual records for the dialog box "Electron Beam" and the macro commands **SrwElecFilament** and **SrwElecThick** for details. It is important to properly set up both "filament" and "thick" beam parameters for this mode of computation.

3) Define **Radiation Sampling**.



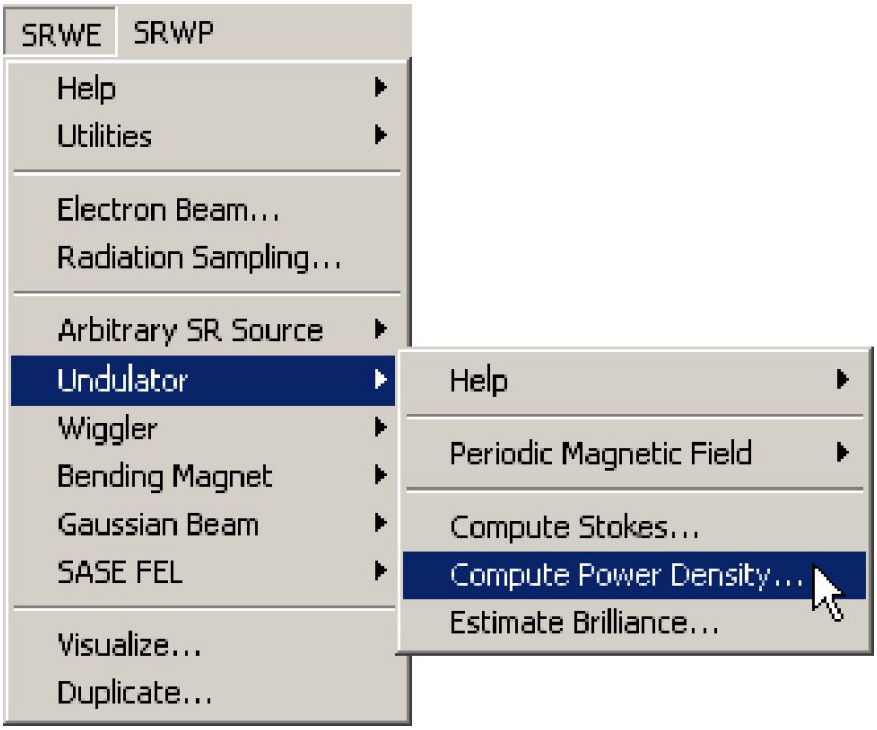
Here one defines the longitudinal position of the observation plane, ranges of transverse positions and number of points where the radiation will be computed. For details on the Radiation Sampling definition, see the Reference Manual topic **Radiation Sampling** and the records on the macro commands **SrwSmpCreate** and **SrwSmpScanXZE**.

4) Define Arbitrary or Periodic **Magnetic Field**.



Here one sets up all parameters of the arbitrary or periodic magnetic field. For details on the magnetic field definition, see the Reference Manual records on macro commands **SrwMagFieldCreate**, **SrwMagZero**, **SrwMagConst**, **SrwMagSin**, **SrwMagEdge**, **SrwMagGsnAng**, **SrwMagImportCmpn**, **SrwMagPerCreate2D**, **SrwMagPerAddHarm**.

5) **Compute** SR Power Density.



This is where the radiation is computed. For details of the computation, see the sections "Assumptions", "Problems and Limitations", "Theoretical Notes" below and the Reference Manual records on the macro command **SrwPowCreate**.

6) **Visualize** the SR component of interest.

This is where one plots the data on computed power density. We note that the power density computation results can be also plotted immediately after the computation by the macro **SrwPowCreate** (see the Reference Manual record for that macro).

IMPORTANT: It is important to make several cycles of computation with different values of precision parameter (macro **SrwStoWigCreate**). The independence, at a given precision level, of the computation results on the precision parameter is

the necessary validity condition for the results (however, it is not at all a sufficient condition...).

Assumptions

The following **assumptions** are made when computing the **SR Power Density**:

- Electrons are relativistic.
- Radiation from different electrons is incoherent: the flux is proportional to the number of electrons.

Examples

- **UR Power Density**

This example computes the SR power per unit surface produced by finite-emittance electron beam of ESRF (energy 6 GeV, current 200 mA, horizontal and vertical emittances 3.9 nm and 0.039 nm, beta functions 35.6 m and 2.5 m), injected through a planar undulator (total length 3.2 m, period 35 mm, deflection parameter 2.2). The observation plane is located at 30 m distance from the undulator. The units of the computed power density are W/mm^2.

- **ER Power Density**

This example computes power density distribution of SR emitted by electron beam (energy 2.5 GeV, current 200 mA, horizontal and vertical emittances 20 nm and 0.2 nm) in the fringe magnetic fields of bending magnet edges bounding a 6 m long straight section. The observation plane is located at 20 m from the middle of the straight section.

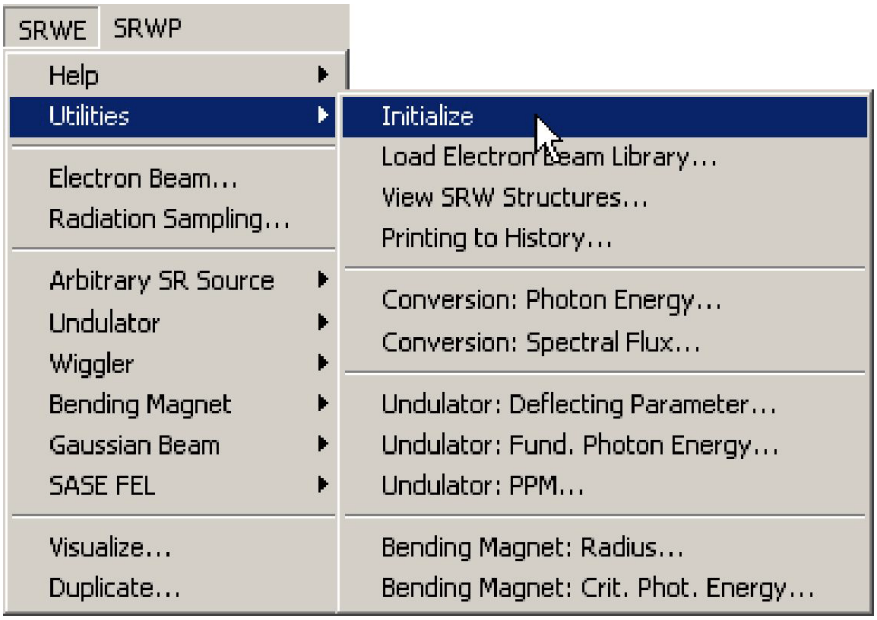
Gaussian Beam

Introduction

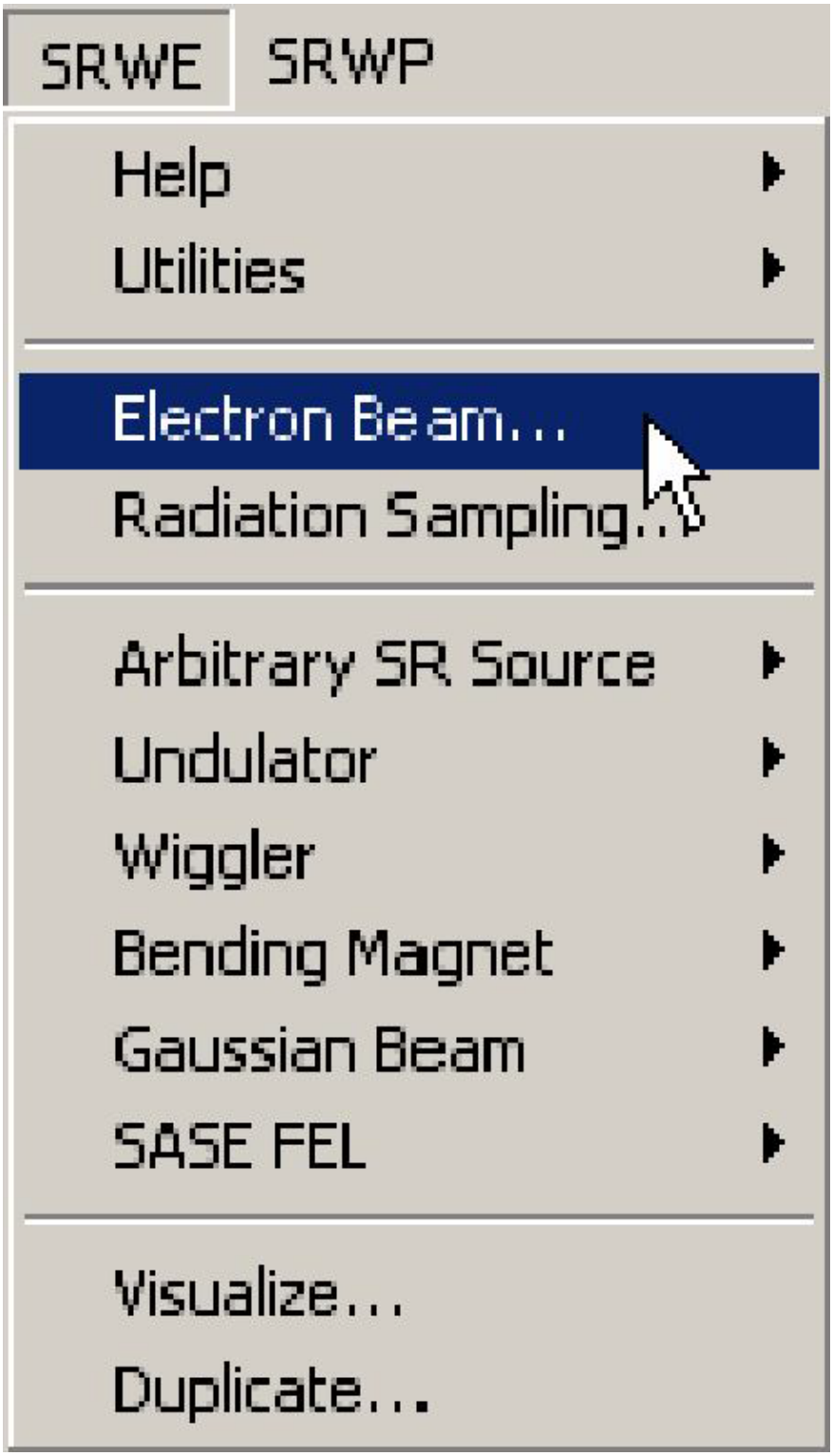
One can use this approximation for preliminary simulations of radiation sources other than synchrotrons / storage rings, e.g. conventional lasers and FELs.

Gaussian Beam Computation Step by Step

The following are the steps one needs to make in order to perform the computation of spectral angular distributions of wiggler radiation. 1) **Initialize** SRW.

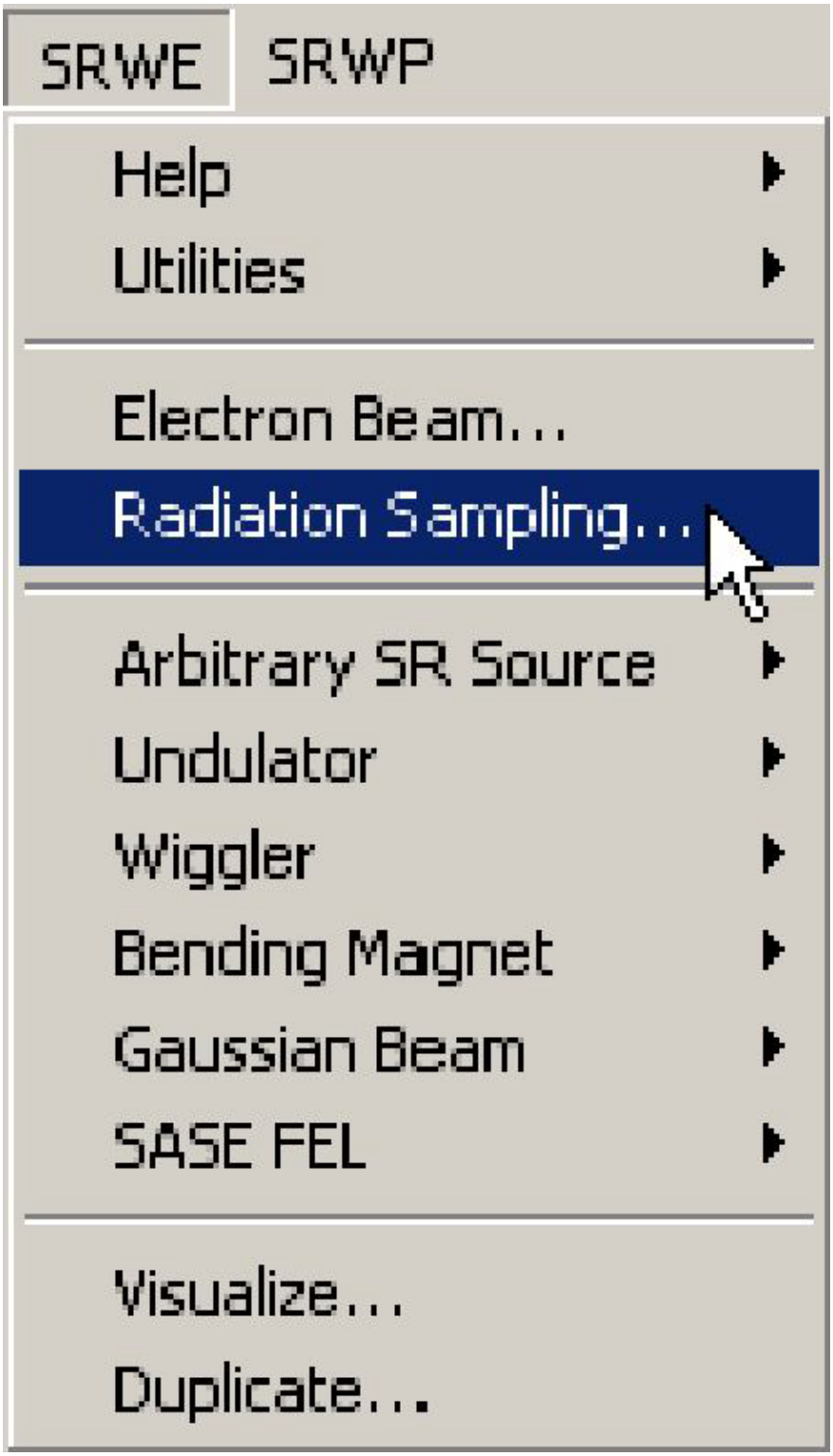


2) Define **Electron Beam**.



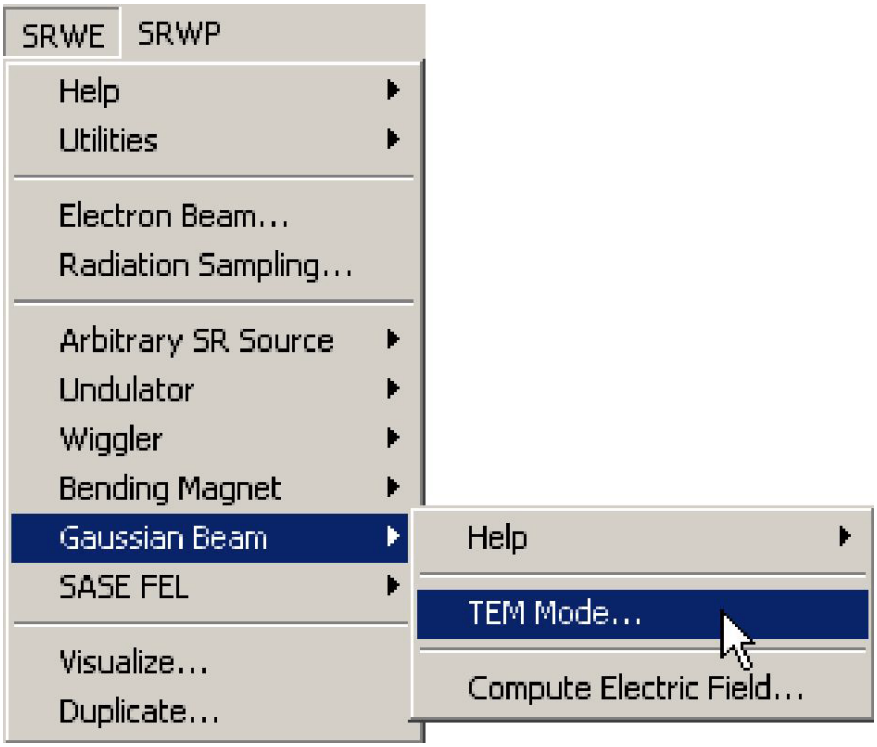
In this type of computation, the Electron Beam structure is used to define initial average transverse positions and angles of the Gaussian beam.

3) Define **Radiation Sampling**.



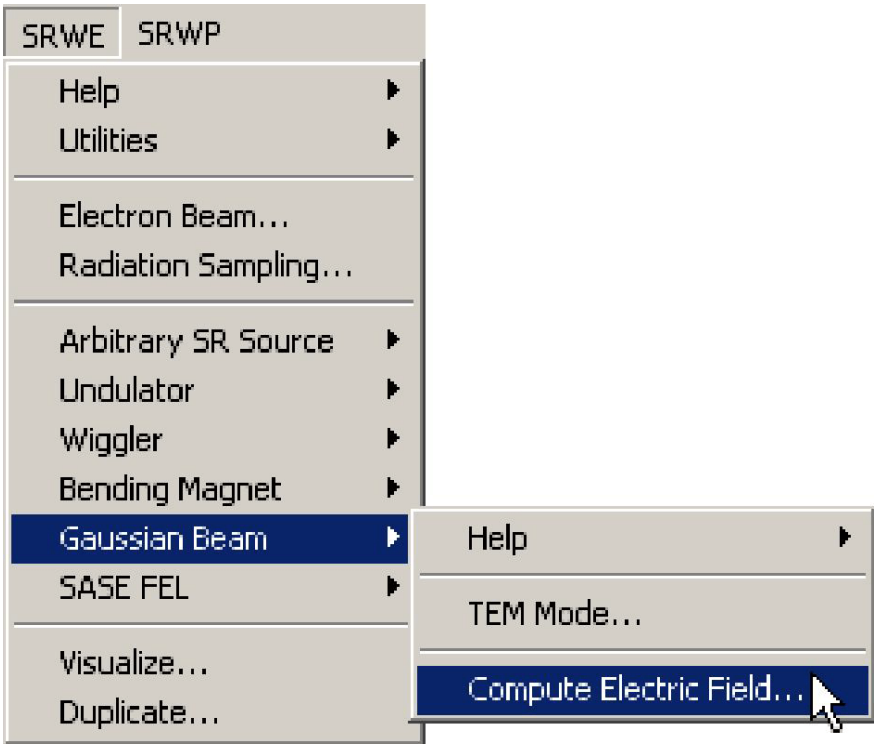
Here one defines the longitudinal position of the observation plane, ranges of transverse positions and number of points where the radiation will be computed. For details on the Radiation Sampling definition, see the Reference Manual topic **Radiation Sampling** and the records on the macro commands **SrwSmpCreate** and **SrwSmpScanXZE**.

4) Define parameters of the **Gaussian Beam** mode.



See Reference Manual record on the macro **SrwGsnBeam** for details.

5) **Compute** Gaussian Beam wavefront.



See Reference Manual record on the macro **SrwGsnBeamCreate** for details.

6) **Visualize** the computed wavefront component of interest.

Examples

- **Gaussian Beam Definition and Propagation**
- This is a simple illustration of initial computation and propagation of a Gaussian wavefront. First, a "Gaussian beam" source (10 μm RMS diameter of the waist) is created, and the initial wavefront (12.4 keV photon energy) is

calculated analytically at 20 m from the source.

- Next, the wavefront is propagated numerically through 300 m long drift space. The propagation is performed in "automatic" mode, so that the code attempts to steer automatically transverse range and resolution of the propagated wavefront (the final resolution is such that the wavefront is suitable for further propagation).
- After this, another wavefront is computed analytically at 320 m from the source and is compared with the wavefront propagated numerically. Small differences between the numerical and analytical results can be seen only in logarithmic scale.
- Note that numerical wavefront propagation allows to simulate effects of apertures and various optical elements and is not at all limited by the case of Gaussian beam.

SASE FEL: Wavefront Amplification

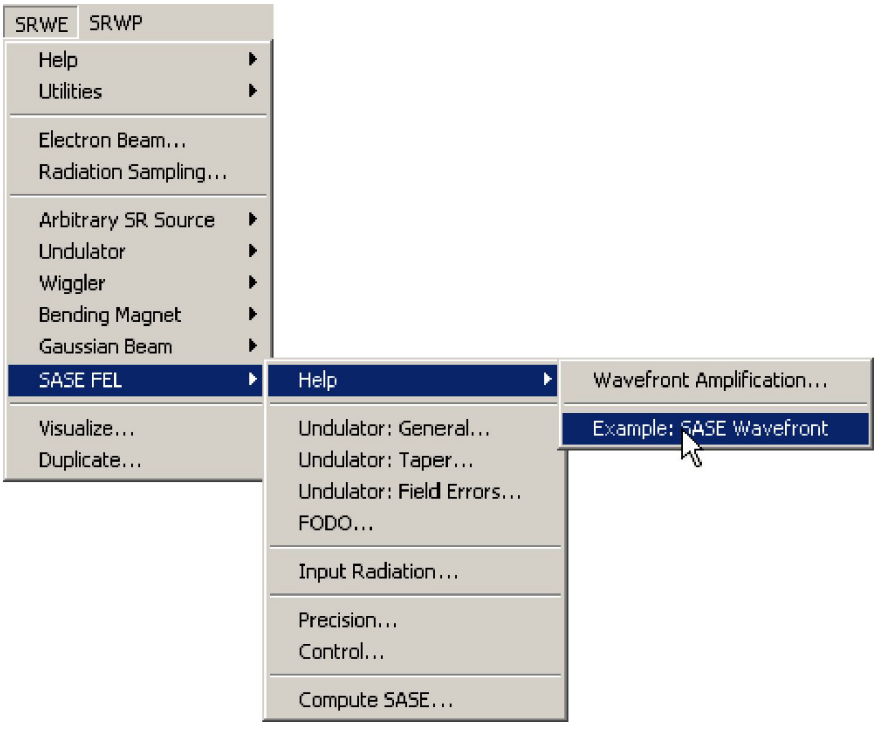
Introduction

This type of computation can be used to simulate Self-Amplified Spontaneous Emission (SASE) in Free-Electron Lasers (FEL). The implementation is mainly based on the Genesis 3D code developed at DESY by S.Reiche et. al. For better inter-operation with other parts of SRW, this FORTRAN code was converted (with minor modifications) to C and re-compiled as a shared library.

The SASE computation in SR\W is currently limited by a numerical solution of the steady state paraxial FEL equations at the approximation of slowly varying amplitude of the radiation field. If electron beam and FEL undulator parameters, together with the wavelength of observed radiation, are tuned properly, one can simulate the radiation wavefront amplification in the undulator due to interaction with the electron beam. The wavefront (i.e. complex electric field) obtained after this simulation, can be used for further manipulations / propagation through optical elements using the methods of Fourier optics implemented in the SRWP.

Getting Started

A good starting point can be the example of SASE computation distributed with the SRW:

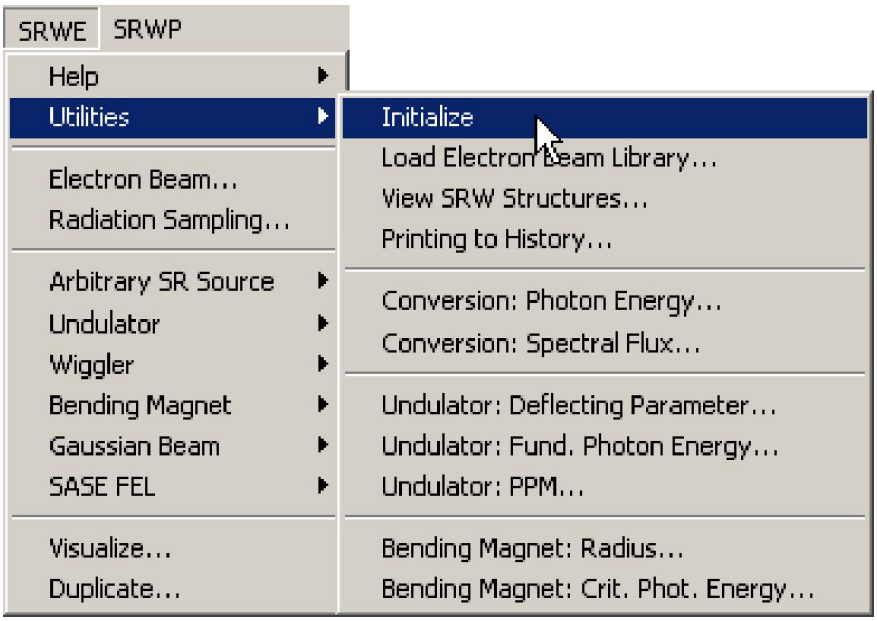


During the execution of the example, a window with some explanations should appear. Please read the explanations and make sure that everything goes as described (you can also find the text of the explanations in the section **Examples**). At the end of the computation you should obtain a set of graphs displaying the results, which should fit the explanations.

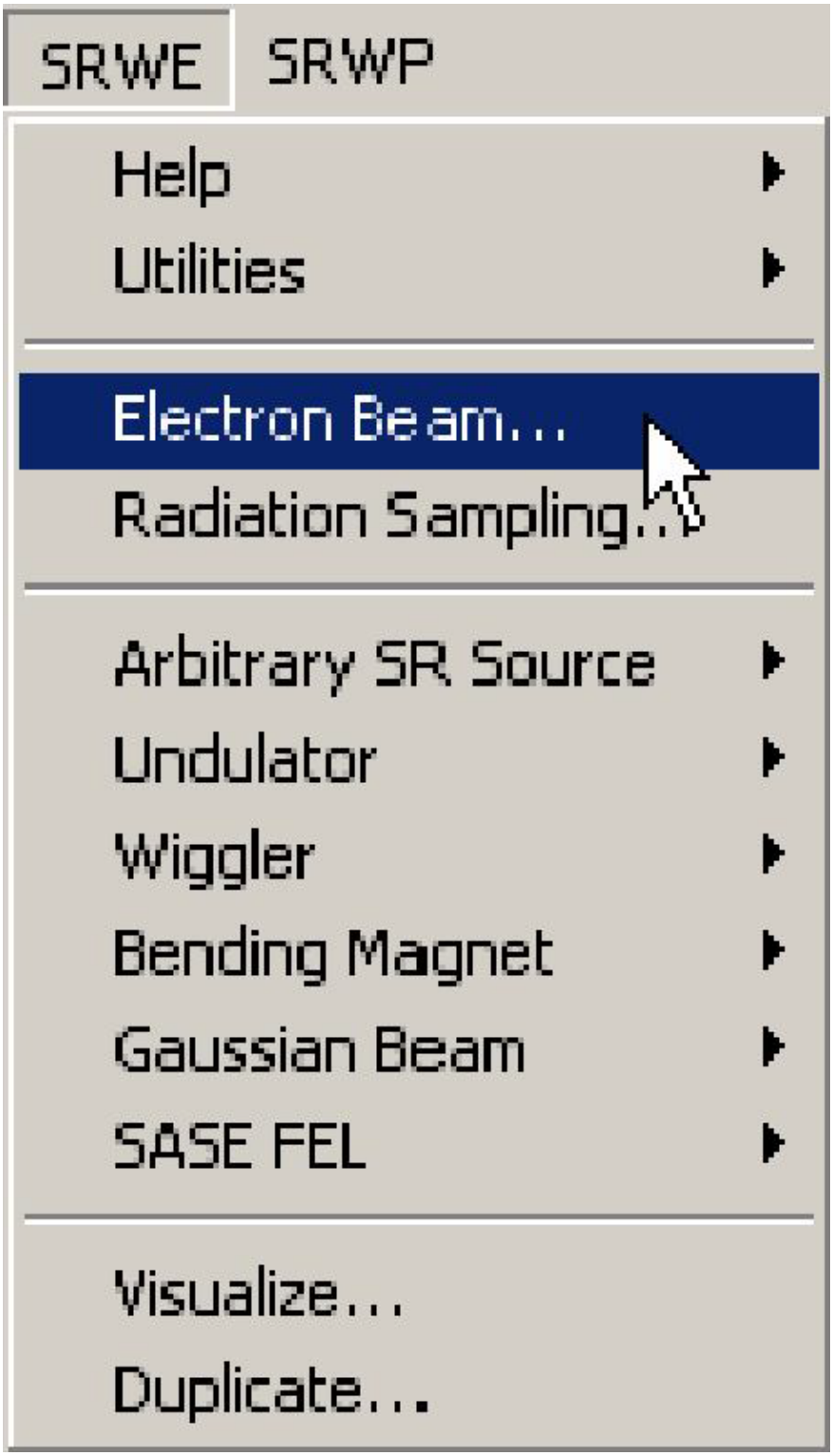
You may want to vary some parameters of this example and watch the results. Such exercise is a good and recommended way to proceed. Some knowledge in macro programming within Igor Pro is nevertheless needed. To try, please select from the the Igor menu "Windows->Other Windows->SRW Example SASE...". A window with a procedure containing the macro calls of the example should appear. We suggest to modify the name of this procedure and save it to another file before starting to play with parameters.

SASE Computation Step by Step

1) **Initialize** SRW.

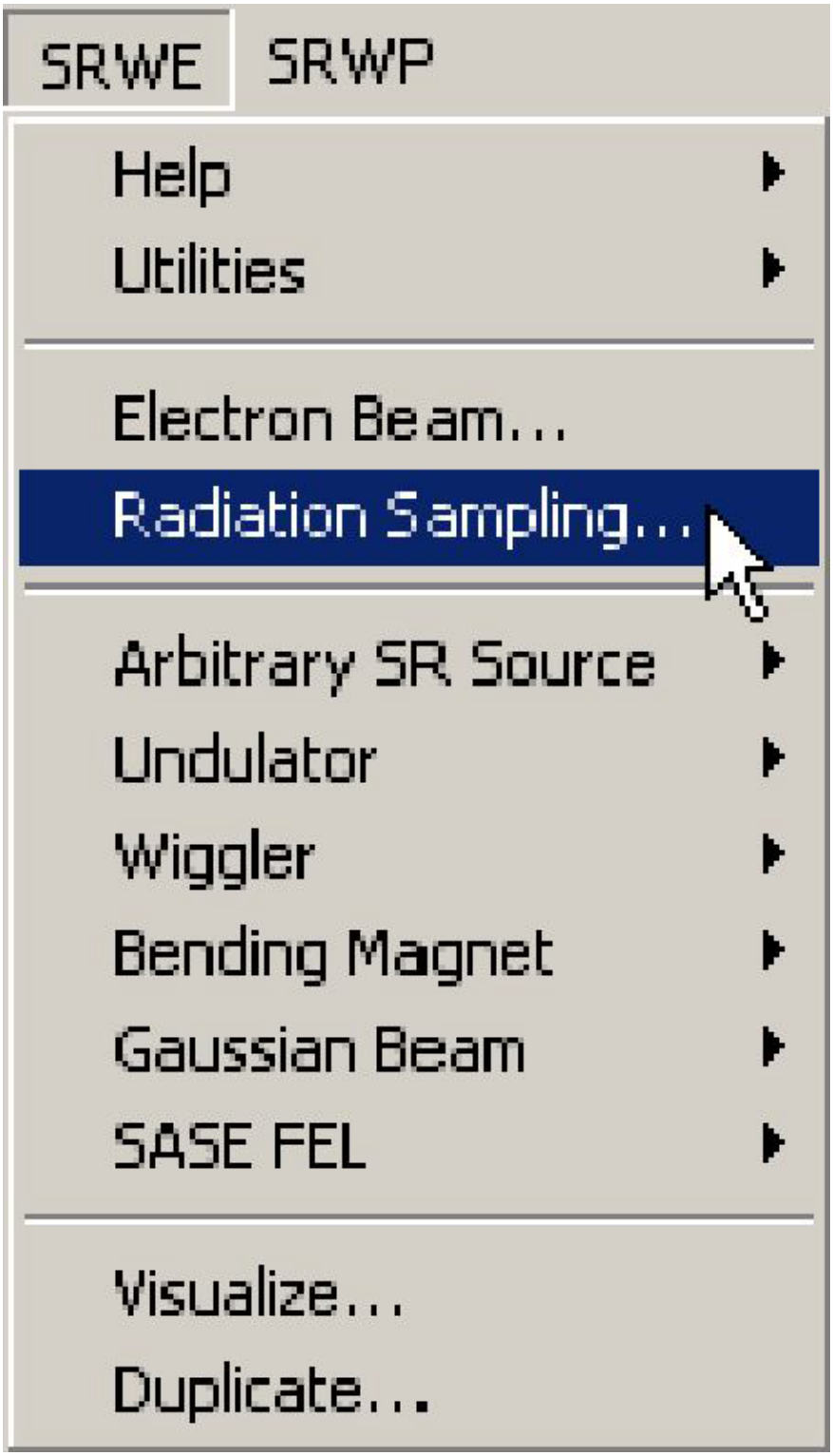


2) Define **Electron Beam**.



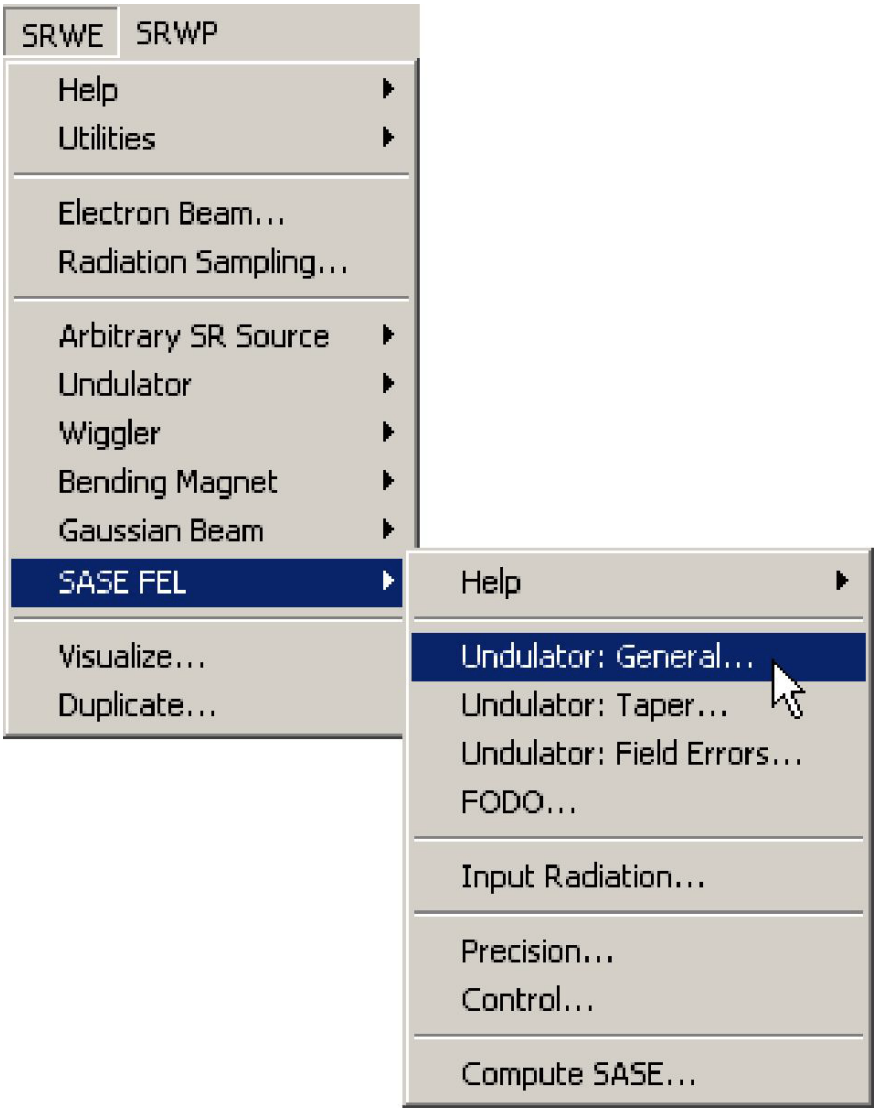
Here one defines necessary parameters of the electron beam. See the Reference Manual records for the dialog box "Electron Beam" and the macro commands **SrwElecFilament** and **SrwElecThick** for details. It is important to properly set up finite-emittance beam parameters for this type of computation.

3) Define **Radiation Sampling**.



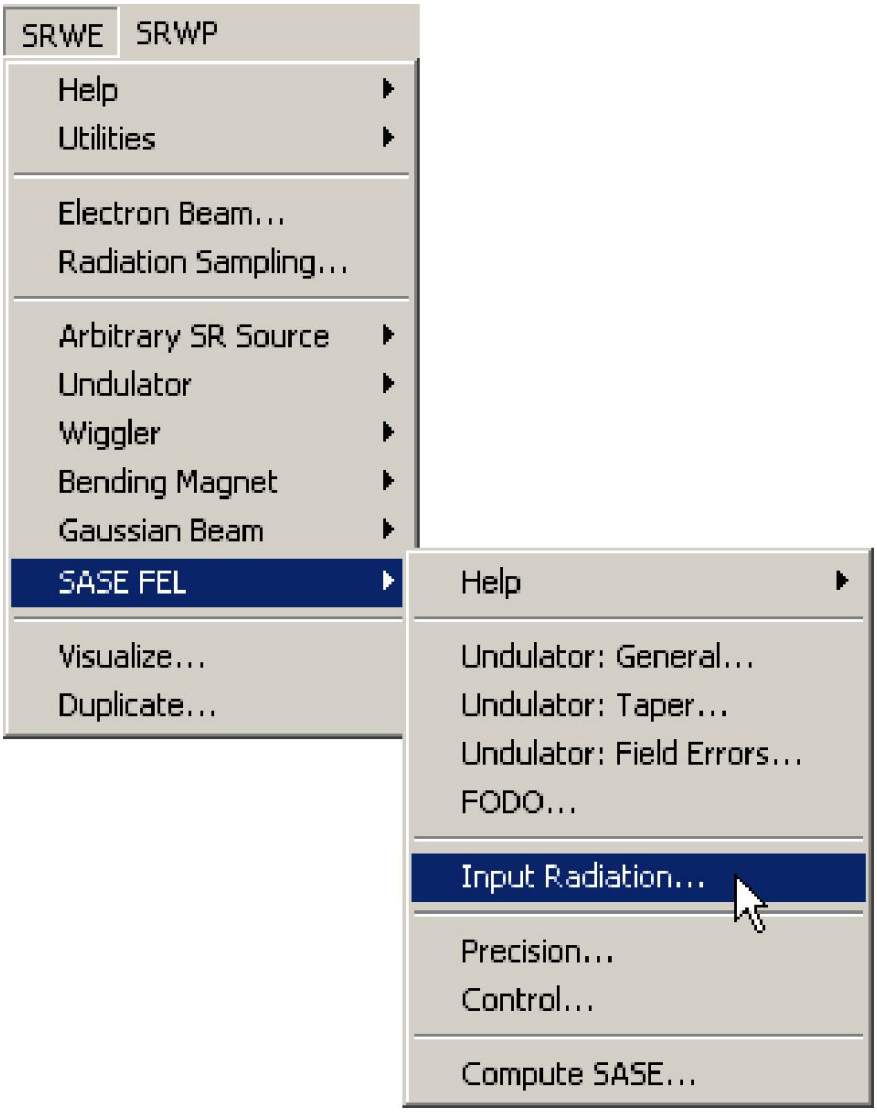
Here one defines the longitudinal position of the observation plane, ranges of transverse positions and photon energy and number of points where the radiation will be computed. For details on the Radiation Sampling definition, see the Reference Manual topic **Radiation** Sampling and the records on the macro commands **SrwSmpCreate** and **SrwSmpScanXZE**.

4) Define parameters of SASE **Undulator** (and focusing structure, if necessary).



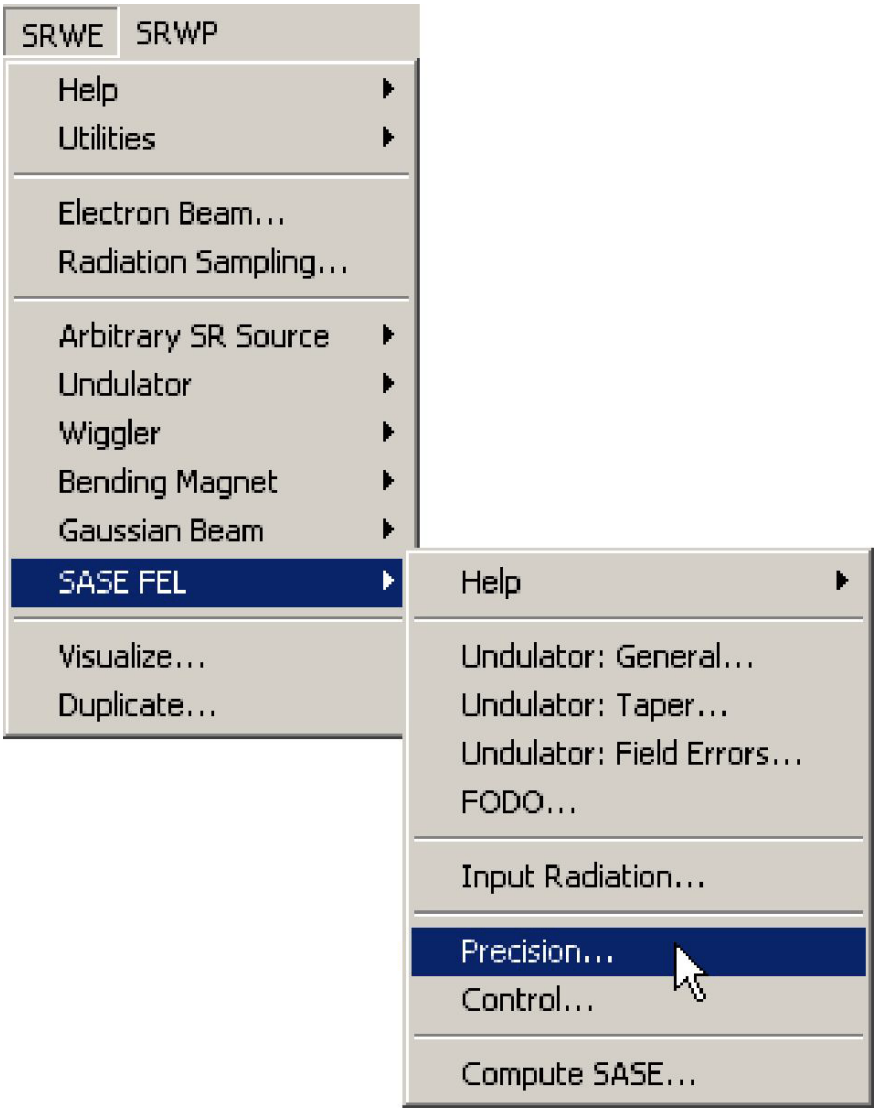
See Reference Manual record on the macros **SrwSASEUndCreate**, **SrwSASEUndTaperAdd**, **SrwSASEUndErrAdd** and **SrwSASEFODOAdd** for details.

5) Define **Initial Radiation** wavefront.



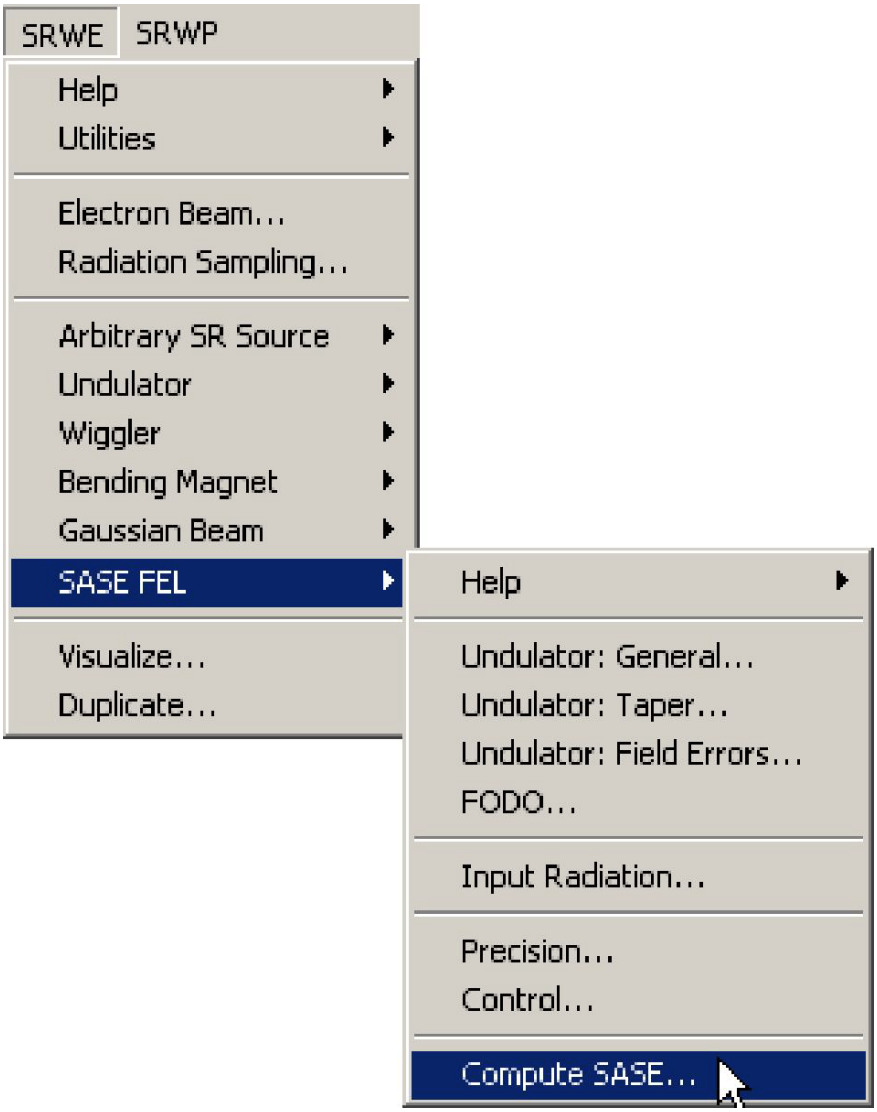
See Reference Manual record on the macro **SrwSASEInRadGsn** for details.

6) Define **Precision** and computation **Control** parameters.



See Reference Manual record on the macros **SrwSASEPrecMain**, **SrwSASECntrl** for details.

7) **Computer** SASE



See Reference Manual record on the macro **SrwWfrSASECreate** for details.

8) **Visualize** the computed wavefront component of interest.

Examples

- **SASE Wavefront**
- This is an illustration of a steady-state SASE computation and further propagation of the SASE wavefront in free space. The parameters generally correspond to the DESY XFEL project: electron energy ~ 25 GeV, peak

current ~5000 A, undulator period ~ 50 mm, resonant radiation wavelength ~ 1 Å. The initial wavefront is assumed to be Gaussian with its waist at the beginning of the undulator. The SASE computation is mainly based on the GENESIS 3D code developed at DESY (this FORTRAN code was converted to C and integrated with other parts of SRW).

- As the computation progresses, several characteristics of the SASE wavefront, including power, RMS size of the power density distribution and bunching factor, are displayed in graphs vs longitudinal position (zero longitudinal position corresponds to the end of undulator). One can observe exponential growth of the radiation power, until a saturation happens. In the saturation mode, the radiation power fluctuates (since a portion of energy is transferred back and forth between the radiation and the electron beam).
- After the exit from the undulator, the wavefront is further propagated by 500 m in free space. The intensity distributions at the exit of the undulator and after the drift space should be plotted in graphs at the end of the computation. Due to oscillatory behavior of the power gain after the saturation, the intensity profiles of the propagated wavefront possess fringes, which can be interpreted as resulting from the interference between radiations from those intervals of the electron beam path where the emitted power is higher.
- We note that the computation in this example does not take into account a number of important factors and processes (e.g. time dependence, stochastic "origin" of the SASE, "competition" of modes, possible degradation of transverse coherence, etc.), and therefore can be used for qualitative estimations only. *Absolute values of the computed spectral flux density are very imprecise, and therefore can not be used for comparisons with other sources.*

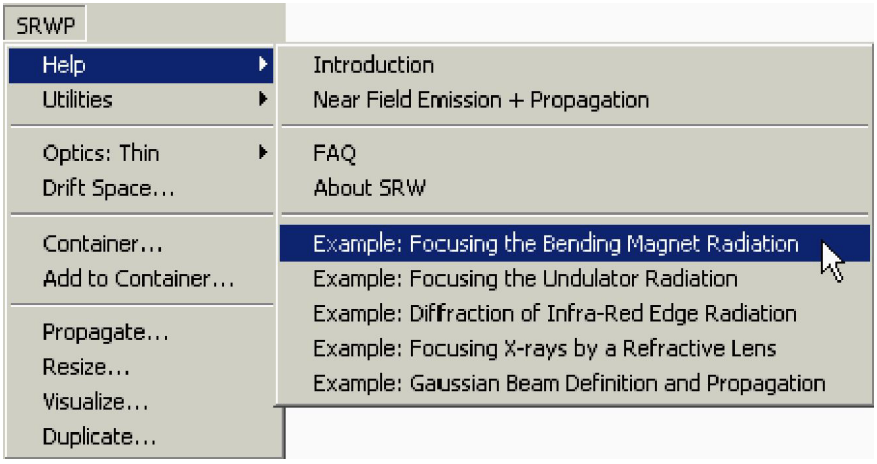
Wavefront Propagation

Introduction

This mode of computation is essentially the Near Field computation described earlier, yet with the observation plane positioned somewhere after a sequence of lenses, mirrors, drift spaces and diffracting apertures... It is therefore more **powerful**, but also much more complicated. In fact, we **strongly advise** anyone interested in such a computation to study, experience and fully understand the Near Field computation before jumping into the additional complexity of performing a propagation. Depending on the wavelength and characteristics of optical components, the accurate propagation of a wavefront may require enormous amount of memory to the point that it cannot be done on your platform unless you strongly reduce the range of observation.

Getting Started

We assume that you have successfully installed the SRW on your computer and that you are familiar with the Near Field computation. The next step is to run one of the examples included in the SRW using the following menu:



Beware that Igor must have at least 32M available to perform successfully each of the examples. In particular, Macintosh users should properly set-up the memory partition for Igor before starting to use the propagation in SRW.

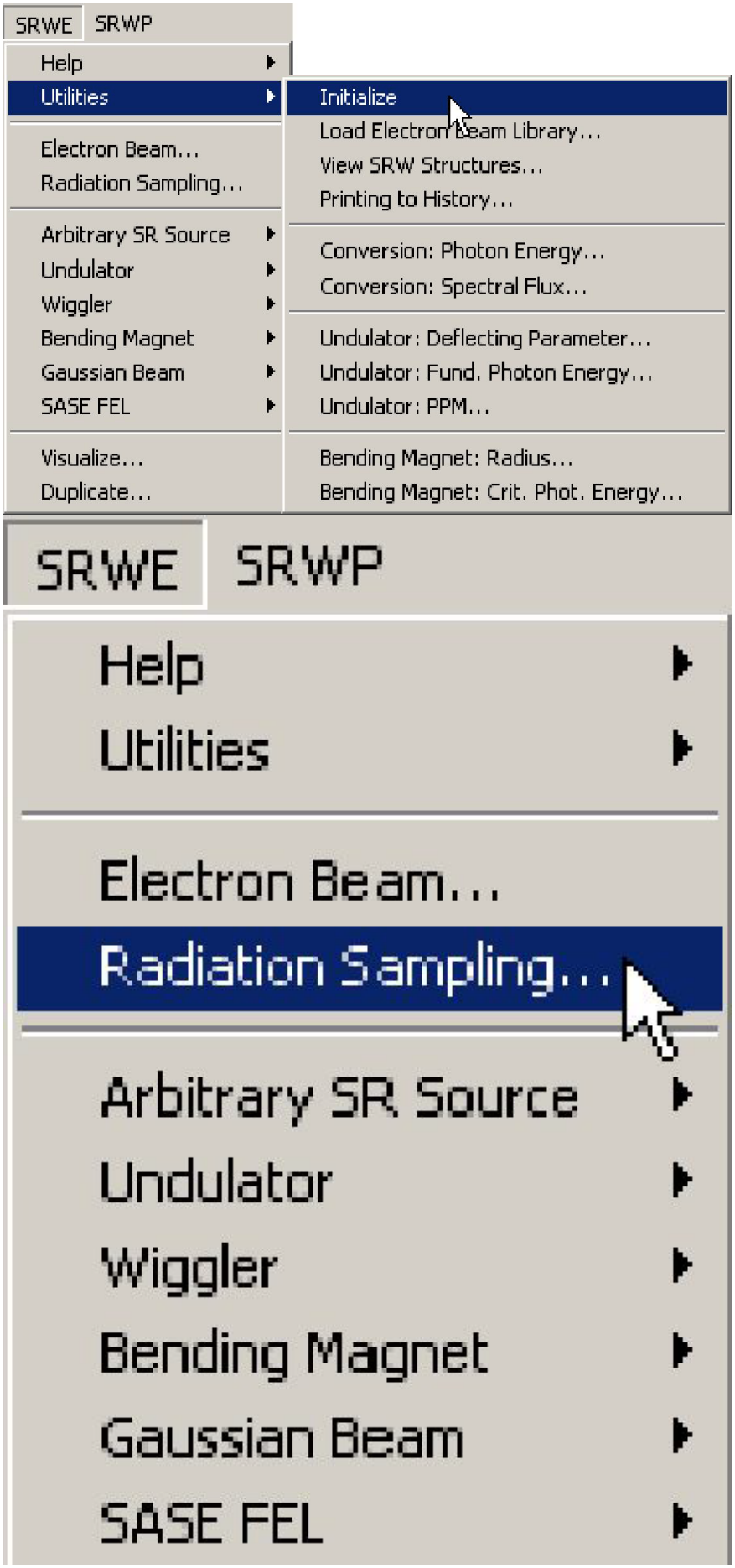
During the execution of the example, a window giving some explanations on the content of the computation being made should appear on your screen. Please read the explanations and make sure that everything goes as prescribed (you can also find the text of the explanations in the section Examples). If everything goes well, at the end of the computation you should obtain a set of graphs displaying the results, which should fit the explanations.

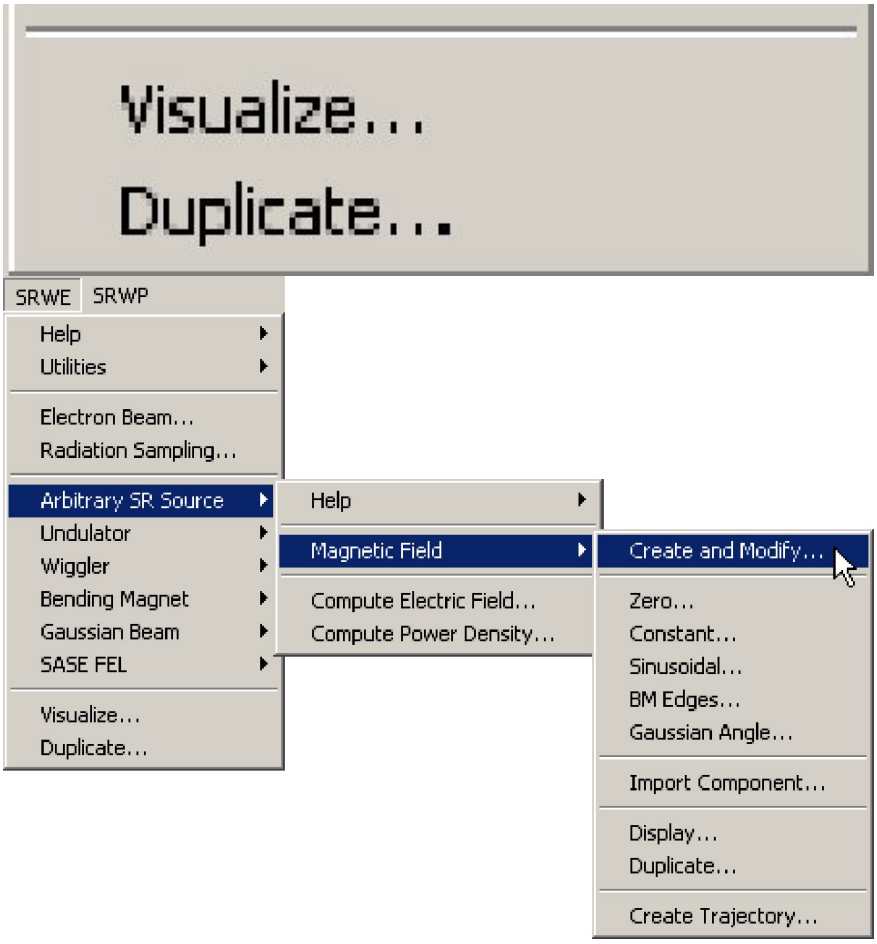
If you have passed this step successfully, you are ready to perform your own computation. The following section briefly describes the main steps one needs to make in order to perform the Near Field computation and then propagation of the SR wavefront.

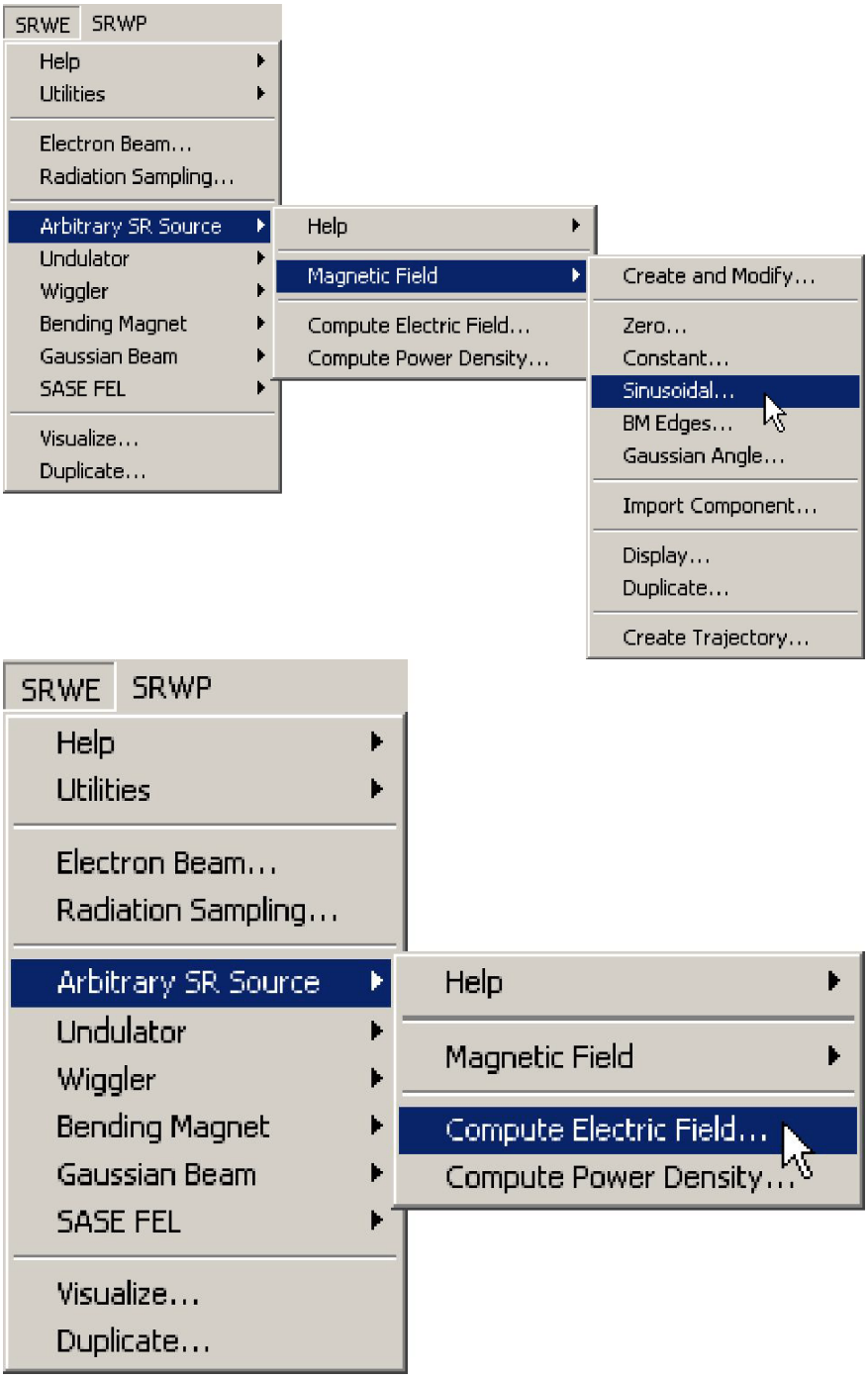
Wavefront Propagation Step by Step

This mode of computation includes creation of the initial wavefront (e.g. using SRWE), and the simulation of its further propagation through optical components.

1) **Initialize** SRW.


SRWE
SRWP
Help
Utilities
Electron Beam...
Radiation Sampling...
Arbitrary SR Source
Undulator
Wiggler
Bending Magnet
Gaussian Beam
SASE FEL
Visualize...
Duplicate...
Initialize
Load Electron Beam Library...
View SRW Structures...
Printing to History...
Conversion: Photon Energy...
Conversion: Spectral Flux...
Undulator: Deflecting Parameter...
Undulator: Fund. Photon Energy...
Undulator: PPM...
Bending Magnet: Radius...
Bending Magnet: Crit. Phot. Energy...


Visualize...
Duplicate...
SRWE
SRWP
Help
Utilities
Electron Beam...
Radiation Sampling...
Arbitrary SR Source
Undulator
Wiggler
Bending Magnet
Gaussian Beam
SASE FEL
Visualize...
Duplicate...
Help
Magnetic Field
Compute Electric Field...
Compute Power Density...
Create and Modify...
Zero...
Constant...
Sinusoidal...
BM Edges...
Gaussian Angle...
Import Component...
Display...
Duplicate...
Create Trajectory...

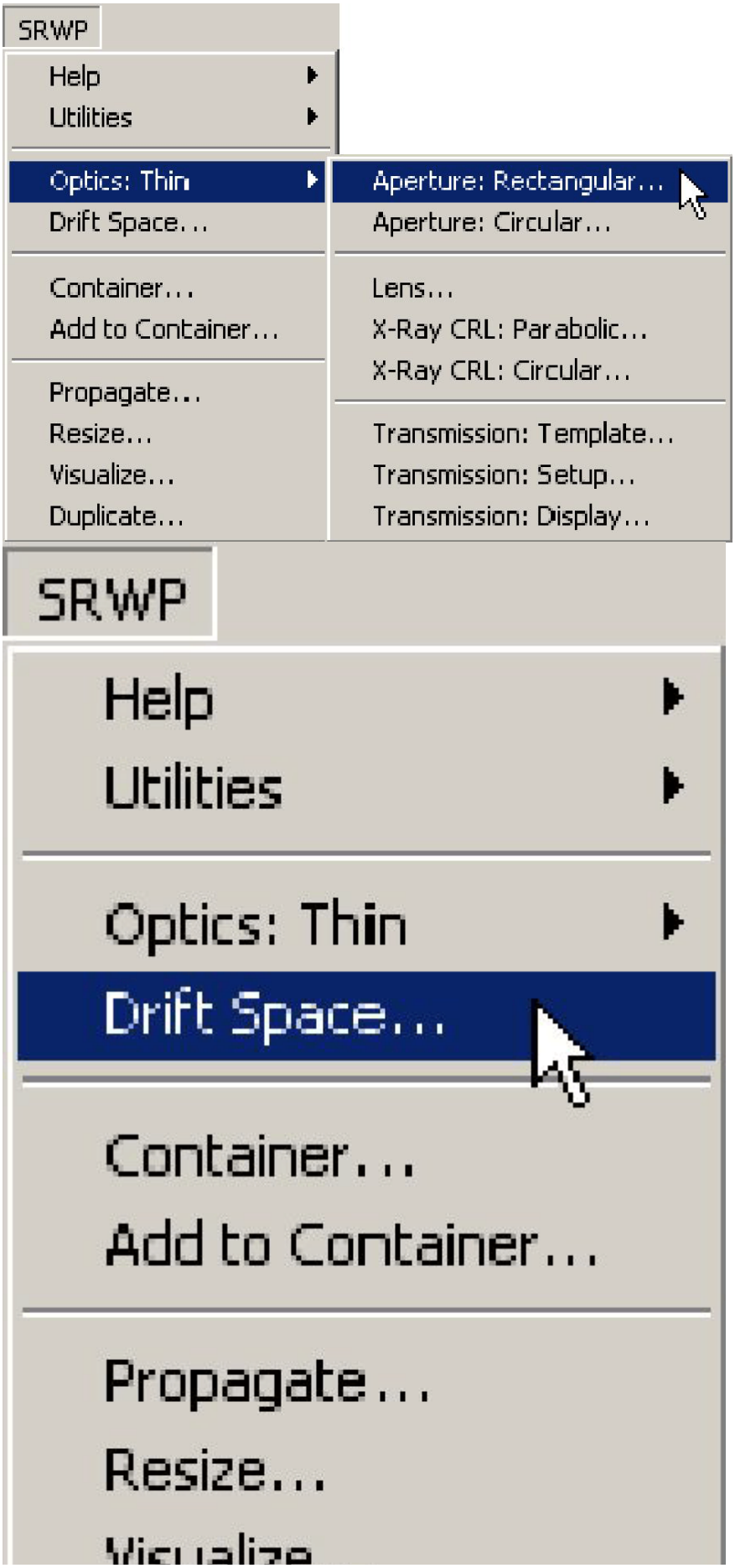


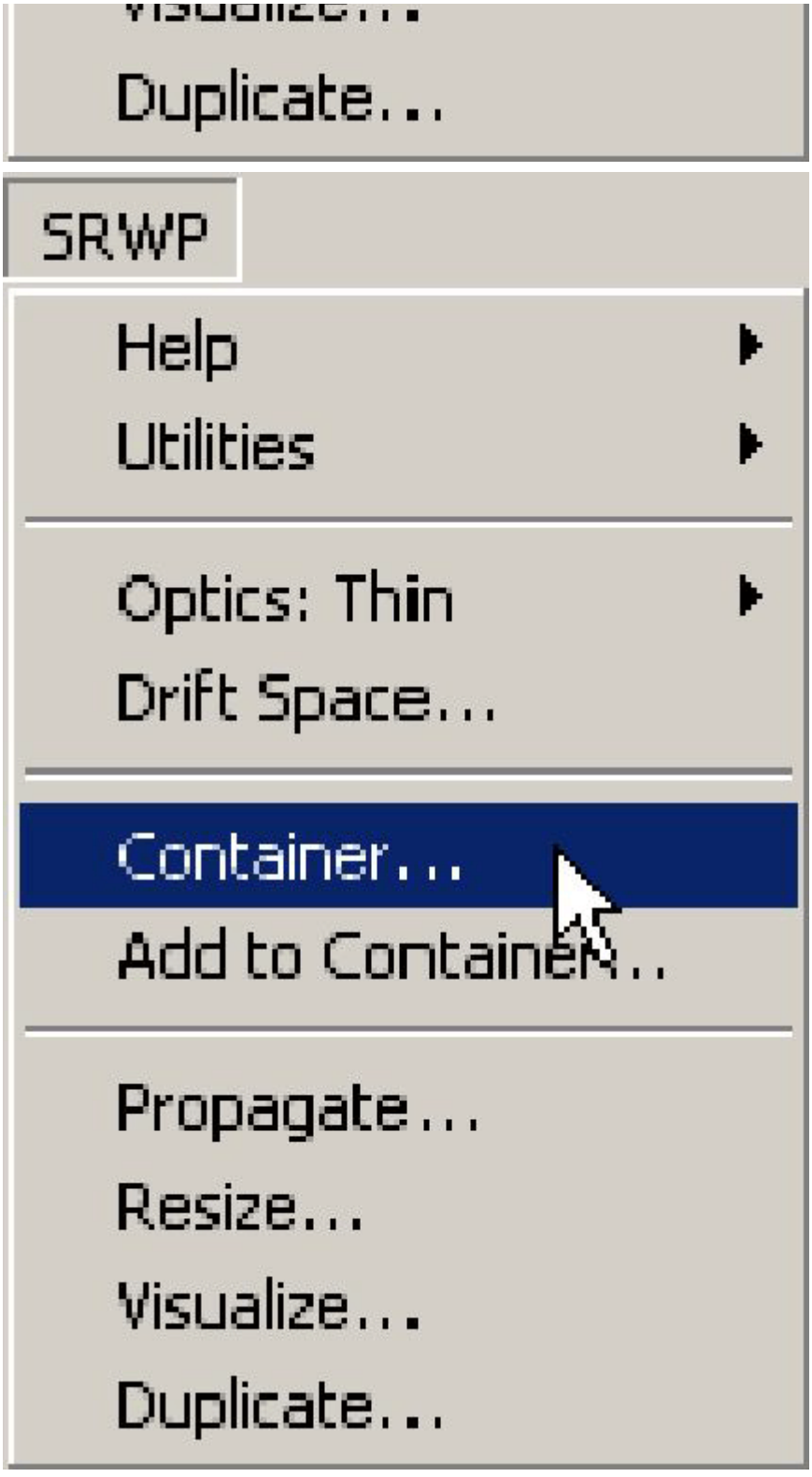
See SRWE section for the comments to all relevant menu items, dialogs and macros.

3) OPTIONAL: **Visualize** the radiation component of interest.

This is where one plots the data associated with a particular polarization. For details on options of visualization of single-electron or multi-electron SR components see the Reference Manual record for the dialog box "Visualize" and the macro command SrwWfr2Int.

4) Define **Optical Component**(s), for example:


SRWP
Help
Utilities
Optics: Thin
Drift Space...
Aperture: Rectangular...
Aperture: Circular...
Lens...
X-Ray CRL: Parabolic...
X-Ray CRL: Circular...
Transmission: Template...
Transmission: Setup...
Transmission: Display...
Container...
Add to Container...
Propagate...
Resize...
Visualize...
Duplicate...
SRWP
Help
Utilities
Optics: Thin
Drift Space...
Container...
Add to Container...
Propagate...
Resize...
Visualize



This is where one sets up all optical components the wavefront should be propagated through. For details on the optical component(s) definition, see the Reference Manual records for the macro commands **SrwOptDrift**, **SrwOptApertRect**, **SrwOptApertCirc**, **SrwOptThinLens**, **SrwOptMirSpher**, **SrwOptCont**, **SrwOptContAdd**.

5) OPTIONAL: **Resize** the Wavefront.

The Resize procedure is dedicated to: make a propagation of the wavefront in manual mode; check the accuracy of propagation in automatic mode and (if necessary) prepare the wavefront for visualization. For details on resizing of the wavefront, see the Reference Manual record on the macro command **SrwWfrResize**.

6) **Propagate** Wavefront through the Optical Component(s).

Please, beware of the problems and limitations of the propagation method used (see the section **Problems and Limitations** below). For details on the wavefront propagation, see the sections "**Special Notes on Propagation**" and "**Theoretical Notes**" below, and the Reference Manual record on the macro command **SrwWfrPropagate**.

7) Repeat the Step 3 to **visualize** the radiation component of interest after the propagation.

IMPORTANT: It is important to make several cycles of propagation with different sampling/resolution of the initial wavefront. The independence, at a given precision level, of the computation results on the sampling/resolution of the initial

wavefront is the necessary condition for the validity of the results (however, it is not at all a sufficient condition...).

As described in the section concerning Near Field Computation, you may avoid using the menu calls by writing your own macros.

Assumptions

The assumptions used in this computation are essentially the same as those used in the Near Field computation. We however, emphasize that:

- The observation angles are much smaller than 1 radian.
- The distances at which the diffraction is treated, are much larger than the radiation wavelength.
- The conductivity of diffracting objects is zero.

Problems and Limitations

Memory and Wavefront dimensions.

The main limitations of the wavefront propagation method used in the current version of the code come from a very strong consumption of memory with the increase of the wavefront dimensions. Let's assume that one needs to propagate a wavefront at a wavelength lambda, computed on a square aperture with transverse dimensions a x a located at a distance R from the source. Then, to resolve well the electric field of the wavefront, one needs roughly the following amount of memory:

```
expression p43_1
```

This makes around 30 MB for the wavefront of 10 cm x 10 cm transverse size at 1 micron wavelength and 10 m distance from the source. In cases of a strong demagnification or a propagation in space over a long distance, more memory is needed.

We are working on, and have partially implemented an improved version of the wavefront propagation, which is much less memory demanding compared to what is indicated above. This improved method is applied when the wavefront has more-or-less constant instant radius within its transverse dimensions.

We have successfully tried various cases of the SR propagation on a PC with 64 MB of RAM under Windows NT Workstation 4.0, for example:

- Propagation of Infra-Red Edge Radiation from central part or edges of bending magnets, computed at 1 m from geometrical source point, through a 2 cm x 2 cm aperture and drift space of 10 m length.
- 10 : 1 imaging of visible range bending magnet SR with a 5 cm diameter lens located at 10 m from the geometrical source point.
- 10 : 1 imaging of a central cone of undulator radiation at ~10 keV with a focusing element located at 30 m from the center of undulator.

Special Notes on Propagation

- **Use Automatic Radiation Sampling**

It is strongly recommended that the SR wavefront is computed with the option "Use Automatic Radiation Sampling" (dialog box "Compute SR Electric Field" or macro **SrwWfrCreate**) set to "Yes", before making any propagation. With this option, the horizontal and vertical point numbers specified in the Radiation Sampling structure are ignored. Instead, the code uses such point numbers that correspond to the minimum required for further propagation of the wavefront with the given ranges of horizontal and vertical position. An Oversampling Factor, which can be

<1 or="">1, allows to manually steer the point numbers with respect to the above criterion. In all cases, only the numbers of points are changed, whereas the ranges of transverse positions remain unchanged.

This version of the code provides two methods of propagation of the SR Wavefront: manual and "automatic" (which is, unfortunately, still far from perfection...).

- **Manual Mode**

The propagation is performed in the manual mode if the option "Auto-Resize Wavefront?" (macro **SrwWfrPropagate**, menu call SRWP "Propagate...") is set to "No". In this mode, the user is fully responsible for the electric field sampling range and numbers of points.

Please take into account that at the propagation, the electric field should be properly sampled both in the Coordinate and Angular transverse representation (the latter is used for propagation through a drift space, see the section "Theoretical Notes"). The increase of the horizontal (vertical) range in the Coordinate representation by padding zeros will increase the horizontal (vertical) resolution (i.e., reduce the step size) in the Angular representation, and vice versa.

A too small number of points will result in a wavefront with a phase shift between two adjacent points larger than Pi/2 resulting in a loss of information. This will, very likely, give erroneous results at further propagation. A too large number of points for a small observation range in Coordinate representation may also be inefficient: it may strongly increase the range of the electric field in Angular representation without improving the resolution in that representation, so the propagation of such wavefront may give erroneous results too. Besides, it may lead to a very Since the propagation through any Optical Component tends to modify the size and / or oscillation rate of the electric field in the Coordinate and Angular representation, practically each step of the propagation in the manual mode requires Resizing before and / or after it, with proper horizontal and vertical Range and Resolution Resizing factors. For details on the resizing, see the Reference Manual record on the macro command **SrwWfrResize** (menu call SRWP "Resize...").

Try to visualize intermediary results as frequently as possible (macro **SrwWfr2Int**, menu call SRWP "Visualize...") when making the propagation in the manual mode. One can watch the real component of the electric field (choose "Re(E)" in pop-up menu "Extract..." in the dialog box "Visualize") to figure out whether the wavefront is well sampled or not.

Thus, the propagation in the manual mode is not at all a straightforward procedure. Therefore we recommend it only to the users experienced in the methods of Fourier optics, if they are not satisfied with, or want to check the results obtained in the "automatic" mode.

- **"Automatic" Mode**

The propagation is performed in the "automatic" mode if the option "Auto-Resize Wavefront?" (macro **SrwWfrPropagate**, menu call SRWP "Propagate...") is set to "Yes". In this mode, before and / or after propagation of the electric field through each optical component, the wavefront is automatically resized based on the results of preliminary propagation of the first- and secondorder statistical moments of radiation, and test pre-propagations in 1D.

The "automatic" mode can work properly only if the initial wavefront is sampled well enough to resolve the smallest fringes of the electric field. To ensure this, at the creation of the wavefront, one should set the option "Use Automatic Radiation Sampling" in the dialog box of the macro **SrwWfrCreate** to "Yes", and specify the Oversampling Factor in that dialog box on the order of one.

How to check or improve the precision of the results obtained by the propagation in the "automatic" mode?

One can do this by applying the Resolution resizing to the wavefront before the propagation, and repeating the propagation after that. In most cases, there is no need to check the effect of resizing the Range before the propagation, because the automatic method is capable of steering it in the process of propagation. Generally, if the propagation results are stabilized at increasing the Resolution resizing before the propagation, this is a good sign about the precision.

It is important to keep in mind that the Resolution resizing is done using an interpolation method, and therefore it can not increase the precision infinitely, especially if the initial wavefront is not well sampled. Re-computation of the SR wavefront with larger Oversampling Factor is always advantageous in terms of precision with respect to the corresponding Resolution resizing. Yet as a rule, it is much slower...

We note that the resizing for the purposes of checking and / or improving the precision of propagation is better done using the "Normal" resizing method (see the dialog box of the macro **SrwWfrResize**, menu call SRWP "Resize...).

Please take into account that the sampling of the wavefront which is sufficient for the propagation, may appear insufficient for watching all the details of the intensity distribution obtained after the propagation. Such a situation may occur when propagating the wavefront after a focusing lens to the waist (image plane). One can reasonably improve the resolution in this situation by applying the resizing of the wavefront **after** the propagation, with the Resolution resizing factors larger

than 1. In the cases of the resolution resizing of the wavefront in the waist, the "Special" resizing method normally gives better results (for details, see the Reference Manual record on the macro **SrwWfrResize**). A negative consequence of the manual resolution resizing of the propagated wavefront is that this wavefront may then appear not good for further propagation (if any). One can solve this problem by duplicating the propagated wavefront before making any manual manipulations with it (macro **SrwWfrDupl**, menu call SRWP "Duplicate...").

The next message is that at the propagation in the "automatic" mode, very large amounts of memory can be demanded from the operating system for the allocation. On Mac OS, if the memory partitioning for the Igor Pro appears insufficient, the SRW can crash the Igor Pro. The Windows NT version of the SRW is safer in this respect. We estimate the minimal memory partition for the Igor Pro on Mac OS, required for the SR propagation, to be 32 MB (note that the SR computation which does not involve the propagation, can be performed on a considerably smaller amount of memory).

The following case of propagation may require the most valuable amount of memory:

- propagation through a large drift space with no focusing.

We hope that with time, we'll be able to improve the "automatic" method of the SR propagation, if this type of computation appears to be of users' interest.

- **An Example of Propagation with Comments**

This section illustrates a typical case of propagation using the "automatic" mode. Assume that Electron Beam "Beam_ebm", Magnetic Field "Field_mag", Radiation Sampling "Smp_obs" and a container of Optical Components "Optics_bli" are defined as described in the section "Wavefront Propagation Step by Step". Also assume that the container of optical components "Optics_bli" includes at least one drift space. The following are the actions one should make in order to create the SR wavefront and propagate it through the optical components. ...

1. This computes the SR wavefront with the option "Use Automatic Radiation Sampling", so the wavefront is suitable for further propagation: SrwWfrCreate("W","Beam_ebm","Field_mag","Smp_obs",2,1) (menu call SRWP "SR Source->Create...")

2. This visualizes the intensity of the initially computed radiation (OPTIONAL):

   SrwWfr2Int("W_rad","I",1,1,8,1,5,0,0,2) (menu call SRWP "Visualize...")

3. This propagates the wavefront through the optical component in the "automatic" mode. The initial wavefront is chosen to be duplicated before the propagation:

SrwWfrPropagate("W_rad","Optics_bli",1,2,"Wd") (menu call SRWP "Propagate...")

1. This visualizes a characteristic intensity component of the propagated SR:

SrwWfr2Int("Wd_rad","J",2,1,3,1,5,0,0,2) (menu call SRWP "Visualize...")

1. This resizes the propagated wavefront in order to increase the resolution, if necessary. Note that this trick works only in the cases of focusing. Also note that in such cases, the "Special" resizing method typically gives better results (OPTIONAL):

SrwWfrResize("Wd_rad",2,1,4,1,4,1,"Wd") (menu call SRWP "Resize...")

1. Do this step only if you have done the step #5:

Repeat #4 in order to see the propagated intensity distribution with better resolution. If you notice any qualitative differences (other than the increase of resolution may result in) between the intensities obtained at this step and earlier at the step #4, this means that the increase of resolution by post-resizing does not work properly in this case. A possible reason is insufficient sampling of the initial wavefront.

Do the following steps if you want to check or improve the accuracy of the propagation.

1. This resizes the initial wavefront in order to check the accuracy of propagation by repeating it with a more dense sampling. Note that for this purpose, the resizing is better done using the "Normal" method. The initial Wavefront is chosen to be duplicated before the resizing (as an alternative, one could re-compute the initial wavefront with larger Oversampling Factor; this would be more precise, yet in most cases slower):

SrwWfrResize("W_rad",1,1.,1.3,1.,1.3,2,"Wd") (menu call SRWP "Resize...")

1. Repeat the steps #3, #4, #5, #6. If, by comparing the final intensities of the propagated SR before the resizing at the step #7 and after it, you are not satisfied with the stability of the propagation results, repeat the step #7 with larger values of the Resolution Resizing factors, and steps #3 - #6, until the propagation results are stabilized.

Sooner or later, this loop may be stopped by the memory limitation (see the section "Problems and Limitations"). Windows users will feel this when the code will start to swap at the basic operations (resizing and propagation), and a warning message will appear in the History window. For Mac users this limitation may appear even more evident: the SRW may crash the Igor Pro in the case of insufficient memory (minimum 32 MB should be set for the Igor Pro when using the propagation-related computation).

We hope that before this will happen, you'll be able to get some useful results... If this is not the case, you can try to repeat the same computation with a smaller horizontal and / or vertical radiation sampling ranges of the initial wavefront.

- **Radiation Sampling Range as a Default Aperture**

There is a default optical component, which is present in any case of propagation, for any definition of a "beamline". This optical component is a rectangular aperture (i.e. diaphragm) with dimensions and location defined by the Radiation Sampling parameters (longitudinal position, horizontal and vertical center and ranges, menu call SRWP "Radiation Sampling..."), for which the initial SR was computed.

For example, if one has computed the SR for the horizontal and vertical sampling ranges ax and az at the longitudinal position y, and makes a propagation of the SR through a drift space of the length L, this means that one actually computes the SR diffraction on a rectangular aperture ax x az located at the longitudinal position y, as observed at the position y + L.

- **The Simpler the Better**

We do not advise you to start the propagation-related computation with a complicated set-up of a "beamline" (i.e., container of optical components). Very probably, the current version of the code will not be able to properly drive the propagation through a large collection of optical components at once. It is much safer to start from a simple case, such as:

- (Aperture +) **Drift Space** (to simulate the SR diffraction on a slit/aperture);
- (Aperture +) **Thin Lens + Drift Space** (to simulate the SR focusing).

Only if you are satisfied with the consistency of the results for these simple cases, you can try to continue developing your "beamline" (add more optical components, optimize parameters, etc.).

Theoretical Notes

- **Propagation of the SR Wavefront**

Assume that we have computed, in frequency domain, the near-field SR electric field in a transverse plane located at some distance from the "source" (for example, using the method described in the chapter "Near Field Computation"). Now we need "to propagate" this electric field through a number of optical components, to another transverse plane.

The SR Wavefront propagation is implemented in the frame of the Scalar Diffraction Theory using CPU-efficient methods of Fourier Optics. In assumption of small angles and distances considerably larger than wavelength, the transverse components of electric field of the diffracted Synchrotron Radiation can be computed from the electric field at an aperture causing the diffraction by the well-known Huygens-Fresnel principle:

```
expression p47_1
```

where ?? is a surface within the diffracting aperture, S is a distance from a point on this surface to the observation point. This can be shown by applying the integral theorem of Helmholtz and Kirchhoff (see M.Born, E.Wolf, Principles of Optics, 4th ed., Pergamon Press (1970), p. 377) to the Synchrotron Radiation represented, for example, as described in the chapter "Near Field Computation".

If ?? is a plane normal to optical axis (assume Y axis of a Cartesian frame), then

```
expression p47_2
```

where (x1,y1,z1) and (x2,y2,z2) are coordinates of a point on the ?? plane and on the observation plane respectively, and the above Fresnel formula is a convolution type integral, which can be quickly computed by applying the convolution theorem and the 2D Fast Fourier Transforms. This gives a CPU-efficient method of propagation of all the wavefront at once (to be more precise, the transverse components of the electric field) through a drift space of any length.

The propagation of the transverse electric field through an optical element from a transverse plane before the element to a plane immediately after it, in many cases can be well described by multiplication of the electric field by a function of transverse coordinates. In the simplest case of a thin lens this function is well-known. In more complicated cases, one can apply physical considerations or analytical methods (for example, the stationary phase method) to derive the proper transformation of the electric field.

The main advantage of this method of the wavefront propagation is speed. A 2D wavefront can be propagated for the time from several seconds to one minute, which is normally much faster than the time needed for its initial creation (i.e., the Near-Field SR computation). This allows to perform computations with several optical components at once, make various optimizations of a beamline, etc. Practically, however, the applicability of this method is limited by a very strong consumption of memory with the increase of the wavefront size (see the section "Problems and Limitations"). We are working on improving the propagation method of SRW in this respect.

We would like to appreciate the ideas and way of thinking suggested in the paper by K.-J. Kim (Nucl. Instr. and Meth., A246 (1986), pp. 71-76), which we have extensively used at realization of the Propagation related part of SRW.

- **Thick Electron Beam**

The method of computation of the intensity profile generated by a thick beam is very similar to that of the Near Field Computation.The Matrix T now transfers the second-order moments from one optical component to another. The single-electron intensity profile after propagation is convoluted by a Gaussian with the RMS equal to the propagated second-order moment ?? (see the "Theortical Notes" for the "Near Field Computation" above).

This method is typically valid for intensity distributions of the focused SR (provided that the size of the focusing element aperture is much larger than the transverse size of the electron beam and magnetic field is transversely uniform in the region of the SR emission). However, it can be totally wrong if the optical component over which some propagation has been performed is strongly diffracting the radiation. One should therefore be very cautious when performing the multi-electron convolution.

Examples

- **Focusing the Bending Magnet Radiation**

- In this example a 6 GeV electron is propagated through a bending magnet with the vertical field of 0.85 T. The trajectory of the electron is displayed in a graph.
- The wavefront of the radiation at the energy of 3 eV is sampled over a rectangular aperture of 10 x 30 mm at a distance of 20 m from the bending magnet. The intensity with horizontal polarization is displayed as an image. It shows the usual pattern of bending magnet radiation, almost independent of the horizontal position. The vertical angle is significantly larger than 1/gamma since the photon energy is much smaller than the critical energy.
- The wavefront is then propagated through a simple beamline made of a focusing lens (1.81 m focal length) followed by a 2 m drift space in order to make a 10:1 imaging between the bending magnet and the image plane. The linear horizontally and vertically polarized intensities observed after the lens and the drift space are displayed as images. The images show a single and double spot (for horizontal and vertical polarization components respectively). The axis of the lens has been intentionally displaced by 0.05 mm from the plane of the electron beam. As expected, the image is vertically displaced by 1.1 x 0.05 mm.
- The filament electron beam intensity is convoluted with Gaussian particle distribution of a "thick" electron beam. A graph shows together vertical polarization components corresponding to the filament and thick electron beam. This illustrates the possibility of using the vertical polarization component of the focused bending magnet SR for more precise estimation of the vertical electron beam size (Å.Andersson, "Electron beam profile measurements and emittance manipulation at the MAX-laboratory", Ph.D. thesis work).
- A number of parameters have been intentionally selected to limit the CPU time and memory requirements in this example. If you want to execute the same computation with different parameters, read the following topics.

If you want to make further computation... You may want to vary some parameters of this example and watch the resulting images. Such an exercise is a good and recommended way to develop your own skills and understanding on the way the computation is done in SRW. Some knowledge in macro programming within Igor Pro is nevertheless needed. If you fill ready for the adventure, select the menu "Windows", Sub- Menu "OtherWindows", topics "SRW Example BM SR Focusing.ipf". A window appears showing the content of a macro which is the full and complete description of all computations made in this example. All lines starting with // are comments, the first important instruction is "SrwElecFilament("E",6,0.2,0,0,0,0,0)" which creates a filament electron beam of 6GeV, 200 mA etc... "SrwMagFieldCreate("BM",0,3,1000)" creates a set of field waves to describe the magnetic field of the bending magnet, and so on.

We suggest that you save this procedure file under a different name. In the newly saved macro file, rename the "proc SrwExamImagBm()" into something like "macro MyMacro()". Select the Command Window, a brief compilation takes place, and "MyMacro" can now be called directly from the "Macros" menu of Igor.

You can now make any modification inside MyMacro and be sure that it will not interfere with other functions and procedures of SRW. If you are an experienced user of Igor Pro, you will easily find a large number of different ways to copy the content of the "proc SrwExamImagBm()" into some of your own procedure files.

To start with physics, we would suggest that you make the following simple modifications:

- Change the aperture of collection of the radiation and watch the size of the spot. Beware that the larger the collection range the larger memory is needed.
- Change the energy of the radiation. The larger the energy the more points will be needed to correctly sample the initial Wavefront resulting in the need of more memory and CPU time.
- Look at the image away from the image plane and watch the variation of the sizes in front or behind of the image plane
- Change the focal length and the magnification ratio.

After each modification, re-execute the whole macro and compare the results. Save your work frequently to an experiment file on your disk. To save memory and space on your screen, it is recommended to kill the windows between successive executions since new windows are systematically re-generated.

The Wavefront propagation may consume a lot of memory, but it is not greedy in CPU time. The CPU time is only important at the first wavefront computation which needs to be done with a correct spatial sampling. It is therefore advisable, if you only want to change some propagation parameters. to re-use the same initial wavefront. It may dramatically shorten the response time. Use "Duplicate Wavefront" option at propagation and resizing (see the Reference Manual records for the macro **SrwWfrPropagate**, **SrwWfrResize**, **SrwWfrDupl**).

Please have a look at the sections "Wavefront Propagation Step by Step" and "Special Notes on Propagation", where more details and recommendations for the propagation are given.

- **Focusing the central cone of Undulator Radiation**
    - In this example, a 6 GeV electron is propagated through a 46 x 35 mm conventional undulator with K=2.2. The spectrum is first computed on axis of the undulator to identify the energy of various harmonics.
    - The wavefront of the central cone of the third harmonic of the spectrum at 8.1 keV is computed at a distance of 10 m from the source and its intensity is displayed as an image.
    - This wavefront is then focused by a 5 m focal length lens and further propagated to 8, 10 and 12 m from the lens. The 10 m point gives the minimum spot size and corresponds to a 1:1 imaging from the source. At 8 and 12 m from the lens, the radiation is out of focus and a larger spot size is observed. To help comparing the cases of propagation, a vertical cut of the intensity is made in each of the three cases and the corresponding profiles are placed in a single plot.
    - The filament electron beam intensity is convoluted with Gaussian particle density distribution of the "thick" electron beam.

    - If you want to make further computations with different parameters, read the chapter "Wavefront Propagation" of the SRW documentation and see the advises given in the example "Focusing the Bending Magnet Radiation".
    - By varying the photon energy within a small range around the on-axis harmonic peak (8.0 - 8.15 keV), one may see a number of interesting features of the UR focusing. For example, one may see that the exact central cone of the undulator radiation can be not at all an optimum for the focusing: a small "undulator ring" can give considerably larger peak intensity in the image plane...
- **Propagating Undulator Radiation through a Two-Slit Interferometer**
    - In this example, a 7 GeV electron beam passes through a planar undulator (70 periods of 33 mm) with K=2.16. The single-electron spectrum is first computed on the undulator axis to verify energy of the fundamental harmonic.
    - Monochromatic wavefront of undulator radiation central cone (fundamental harmonic) is computed at 30 m distance from the undulator and its intensity is displayed as an image.
    - This wavefront is then propagated through an ideal lens (with focal distance equal to half distance from the undulator), followed by two vertically-separated centered slits, and by drift space - to the plane of 1 : 1 imaging.
    - Single-electron and multi-electron intensity distributions are considered in the image plane. Interference fringes are clearly seen in vertical cut of the single-electron intensity distribution. The multi-electron intensity distribution is estimated by convolution of the single-electron intensity distribution with a 2D Gaussian.
- **Diffraction of Infra-Red Edge Radiation**
    - This example computes the diffraction of the IR Edge Radiation on a rectangular aperture at 124 μm wavelength for the parameters of the SOLEIL ring.
    - The IR ER is first computed on a 20 mm x 10 mm rectangular aperture at 0.7 m longitudinal offset from downstream bending magnet edge. The intensity distribution vs transverse coordinates, and the horizontal (median plane) intensity profile are shown.
    - The radiation is propagated through a 5 m length drift space. The final intensity distribution vs transverse coordinates, and the horizontal (median plane) intensity profile of the diffracted ER are displayed in graphs.
- **Focusing X-rays by a Refractive Lens**
    - In this example, 25 keV synchrotron radiation from a bending magnet (magnetic field 1.6 T, electron energy 6 GeV and zero transverse emittance) is focused in vertical plane by a refractive lens with circular holes. There is no focusing in horizontal plane.
    - The following are the main parameters of the lens. Material: Be, hole diameter: 0.8 mm, number of holes: 113. This makes the focal distance

of ~3.25 m. Wall thickness between the holes is 0.1 mm. The lens is located at 4.5 m longitudinal position from the geometrical source point.

- The radiation is first computed on a rectangular aperture of 0.05 mm x 0.4 mm at the longitudinal position of the lens. Then a propagation through the lens and a drift space of 11.4 m, to the vertical waist, is performed. Intensity profiles of the radiation in transverse plane at the waist are shown in graphs.
- In vertical plane, the intensity profile of the focused radiation is dominated by a spherical aberration (long "tails"). This aberration can be dramatically reduced by placing a slit limiting the vertical aperture in front of the lens. As an alternative, one can use a lens with parabolic holes.
- Since there is no focusing in horizontal direction, the horizontal intensity profile in the observation plane is generally a result of diffraction on the input aperture. It's possible to place another identical lens, yet focusing in horizontal plane, immediately after the one used. This would result in a 2D focal spot with comparable dimensions.

Reference Manual

Initialization

Before any computation with SRW, it should be initialized by a special macro.

SrwInit

Definition:

Proc SrwInit()

Action:

Creates a set of global variables in Igor which are necessary for proper functioning of the SRW.

Details:

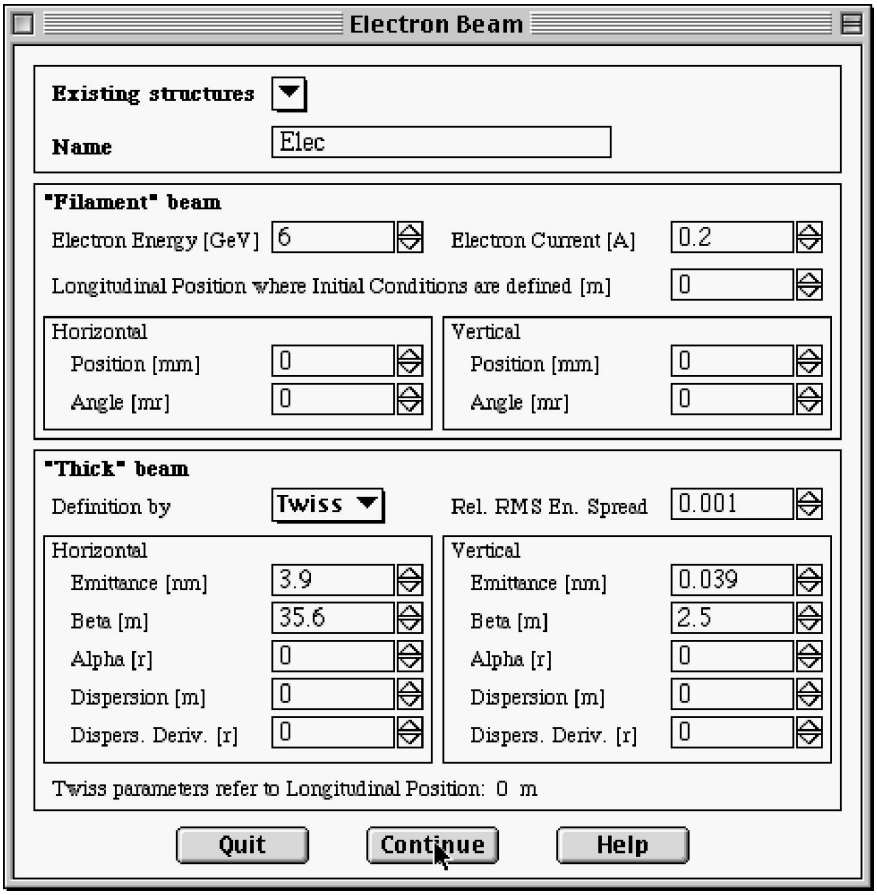
1. The SRW initialization is essential when you start a new experiment in Igor. However, there is no need to initialize SRW (moreover, it is not at all recommended to do this) when you open and continue to work with an old experiment, where you have already performed the SRW initialization.

Electron Beam Definition

The electron beam definition means definition of "Filament" (single-electron) and "Thick" (emittance-related) parameters of the electron beam.

SrwElecDialog

Dialog Box:



Definition:

Proc SrwElecDialog(mode)

Variable mode

Action:

Displays a dialog box and invokes proper SRW macros for setting up an Electron Beam structure, which is a set of "Filament" electron beam parameters including: average energy, current, initial horizontal and vertical coordinates and angles at some longitudinal position; and a set of "Thick" beam characteristics which can be defined via emittances and Twiss parameters of the magnet lattice, or via second-order statistical moments of particle distribution in the electron beam.

Details:

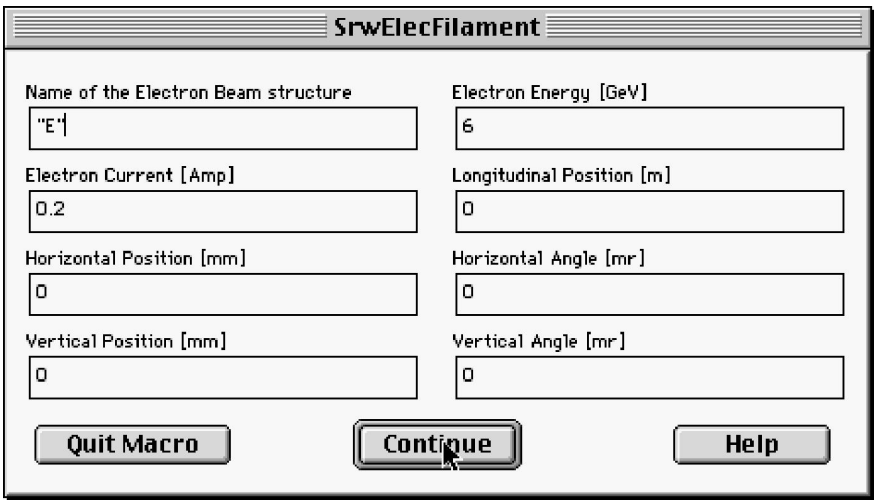
1. We do not advise to use this macro at programming in Igor macro language. It is dedicated only to facilitate the dialog-driven style of computation in SRW.
2. The layout of the dialog box depends on the input parameter mode: mode=0 shows all the parameters that may be necessary for further computation of Synchrotron Radiation; mode=1 and 2 show only the parameters which can be used at wavefront computation from Gaussian Beam and Isotropic Source respectively.
3. In most SR computation methods, the first and second-order moments of particle distribution in the electron beam are used. The dialog box allows to define the second-order moments both explicitly and through the emittance

and Twiss parameters. The values of the first and secondorder moments (Twiss parameters) should refer to the same longitudinal position.

4. The full name of the Electron Beam structure (numeric wave) is generated according to the following rule: = + "_ebm", where "_ebm" is the type identifier of an Electon Beam structure.
5. Depending on the settings chosen in the dialog box, this macro invokes one or several lowlevel macros of SRW that can be used at programming in Igor macro language: **SrwElecFilament**, **SrwElecThick**, **SrwElecThickMom**. The invoked macros are printed in the Igor History window with the input parameters values used. For more details please refer to the Reference Manual records for these macros.

SrwElecFilament

Dialog Box:



Definition:

Proc SrwElecFilament(name,en,cur,s0,x,xp,z,zp)

String name

Variable en,cur,s0,x,xp,z,zp

Action:

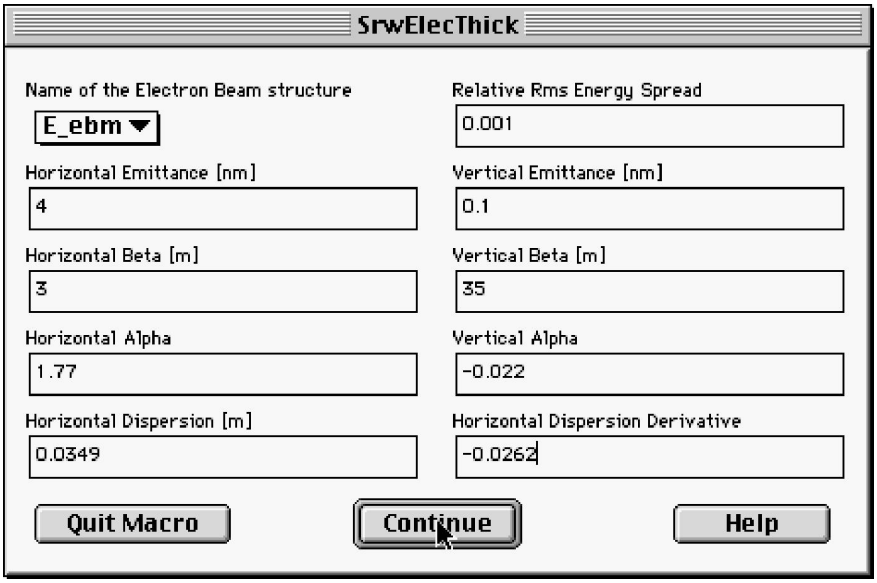
Creates an Electron Beam structure with the name "name" and sets up the "Filament" beam parameters: Energy in GeV (en), Current in A (cur), transverse coordinates and angles of the beam at the Longitudinal Position s0: Horizontal Position in mm (x), Horizontal Angle in mr (xp), Vertical Position in mm (z) and Vertical Angle in mr (zp).

Details:

1. The Electron Beam structure created is actually a numeric wave that holds all the electron beam parameters.
2. The full name of the Electron Beam structure (numeric wave) was generated according to the following rule: = + "_ebm", where "_ebm" is the type identifier of an Electon Beam structure.

SrwElecThick

Dialog Box:



Definition:

Proc SrwElecThick(name,sige,emx,emz,betax,betaz,alphax,alphaz,etax,etaxp)

String name

Variable sige,emx,emz,betax,betaz,alphax,alphaz,etax,etaxp

Action:

Sets up emittance-related parameters for the existing Electron Beam structure with the name "name": Relative RMS Energy Spread (sige), Horizontal Emittance in nm (emx), Vertical Emittance in nm (emz), the values of the magnet lattice functions: Horizontal Beta in m (betax), Vertical Beta in m (betaz), Horizontal Alpha (alphax), Vertical Alpha (alphaz), Horizontal Dispersion function in m (etax) and its Derivative (etaxp).

Details:

1. The values of the lattice functions should correspond to the Longitudinal Position (s0) specified in the Filament beam parameters dialog box (macro SrwElecFilament).
2. The lattice functions are needed to derive from the transverse emittances and energy spread the second-order moments of particle distribution in the beam, which are used at computation of the Thick beam effect on the SR distributions. Eventhough the lattice function values are not actually the electron beam parameters, for simplicity, we decided to place them together with the beam emittances and energy spread.
3. The values of RMS sizes and divergences of the electron beam, computed from the lattice parameters, emittances and energy spread, are printed in the Igor's History window.

SrwElecThickMom

Definition:

Proc SrwElecThickMom(name,sige,sigx,sigz,sigxp,sigzp,mxxp,mzzp)

String name

Variable sige,sigx,sigz,sigxp,sigzp,mxxp,mzzp

Action:

Sets up second-order moments of particle distribution in the electron beam for the existing Electron Beam structure with the name "name": relative RMS energy spread (sige), horizontal and vertical RMS size (sigx,sigz), horizontal and vertical RMS angular divergence (sigxp,sigzp), and horizontal and vertical mixed moments "position-angle" (mxxp,mzzp).

Details:

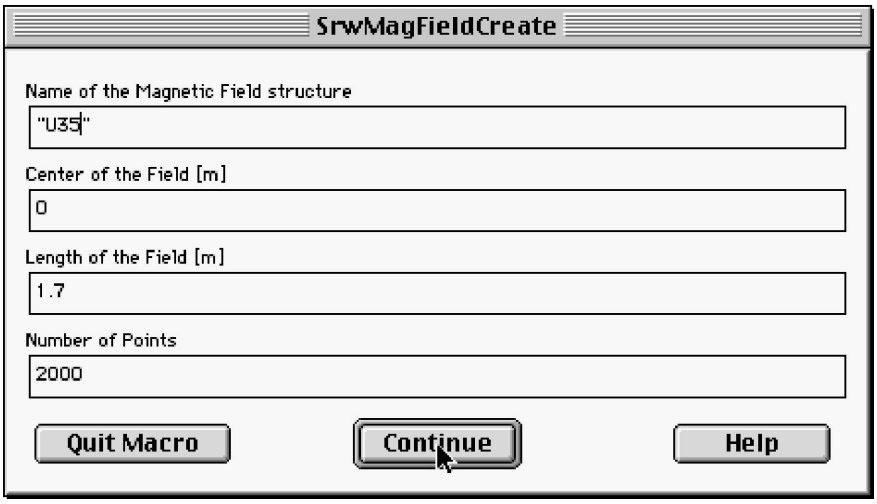
1. The values of the second-order moments should refer to the the same longitudinal position as the first-order moments ("filament" beam parameters) specified in the Electron Beam dialog box or macro SrwElecFilament.

Arbitrary Magnetic Field

The magnetic field definition means execution of several SRW macros which create the Magnetic Field structure and set up Horizontal and Vertical Field components vs longitudinal position. The Magnetic Field structure is used at the Synchrotron Radiation computation.

SrwMagFieldCreate

Dialog Box:



Definition:

Proc SrwMagFieldCreate(name,cen,len,npts)

String name

Variable cen,len,npts

Action:

Creates a Magnetic Field structure with the name "name" and sets up a longitudinal position of Center of the Field in m (cen), Length of the Field (i.e., longitudinal range of the field definition) in m (len), and a Number of Points over longitudinal position (npts) where the field is defined.

Details:

1. The magnetic field has only transverse components and it is uniform in transverse directions.
2. The Magnetic Field structure created is actually a text wave that keeps the names of two numeric 1D waves describing Horizontal and Vertical components of the field. This waves are automatically created and set to zero by this macro.
3. The full name of the Magnetic Field structure (text wave) was generated according to the following rule: = + "_mag", where "_mag" is the type identifier of a Magnetic Field structure. The full names of the Horizontal and Vertical field components were generated according to the following rule: = + ("BX" or "BZ") + "_fld", where "BX" ("BZ") corresponds to Horizontal (Vertical) field component, "_fld" is the type identifier of a Magnetic Field Component wave.
4. Horizontal and Vertical components of the field can be set up independently, using dedicated SRW macros or by importing the field data manually, however the Center of the Field, Length of the Field and the Number of Points is the same for the Horizontal and Vertical components.

SrwMagZero

Dialog Box:

Definition:

Proc SrwMagZero(name)

String name

Action:

Sets to zero Horizontal or Vertical Component of the magnetic field with the name "name".

Details:

1. The Field Component to be modified is taken from the pop-up menu of the dialog box. The pop-up menu suggests all the existing Field Components. The names of the suggested Field Components were generated automatically at the creation of the corresponding Magnetic Field structures

by the macro **SrwMagFieldCreate**, according to the name decoration rules described in the reference record for that macro.

SrwMagConst

Dialog Box:

Definition:

Proc SrwMagConst(name, bconst)

String name

Variable bconst

Action:

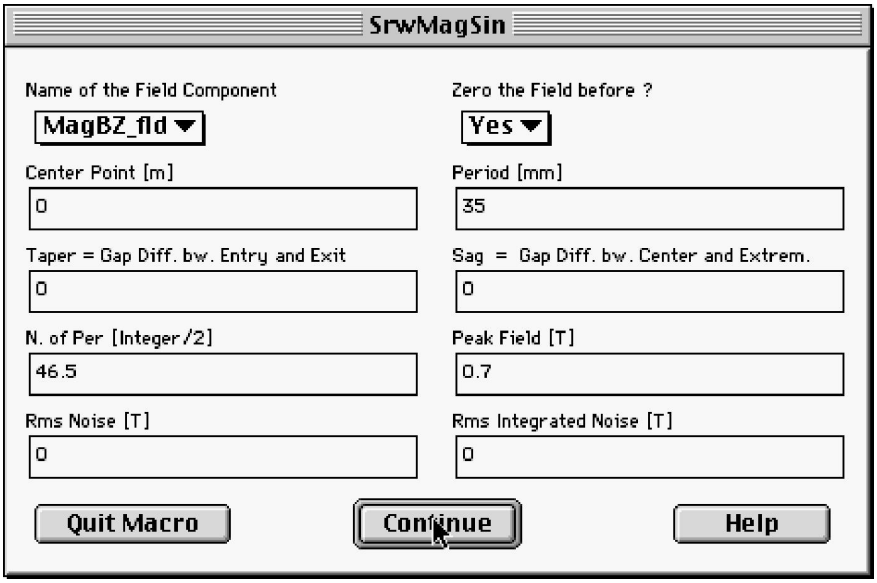
Sets Horizontal or Vertical Component of the magnetic field with the name "name" to a constant value in T (bconst).

Details:

1. The Field Component to be modified is taken from the pop-up menu of the dialog box. The pop-up menu suggests all the existing Field Components. The names of the suggested Field Components were generated automatically at the creation of the corresponding Magnetic Field structures by the macro **SrwMagFieldCreate**, according to the name decoration rules described in the reference record for that macro.

SrwMagSin

Dialog Box:



Definition:

Proc SrwMagSin(name,zero,scen,per,taper,sag,nper,bpeak,bnoise,bnoisei)

String name

Variable zero,scen,per,taper,sag,nper,bpeak,bnoise,bnoisei

Action:

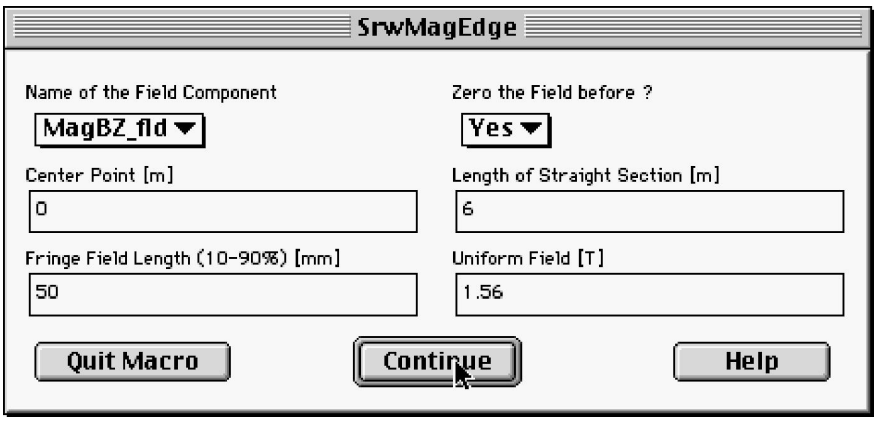
Adds a sine wave to the magnetic Field Component with the name "name" (selected from the existing Field Component waves). The selected wave can be initially set to zero or not. The following parameters should be specified: Center Point of the sine wave in m (scen), Period in mm (per), Taper in mm, which is approximately the magnetic gap difference of an undulator from Entry to Exit (taper), Sag in mm, which is the magnetic gap difference of an undulator from Center to Extremity (sag), Nunber of Periods (nper), Peak Field in T (bpeak), RMS Gaussian Noise in T (bnoise), RMS Integrated Noise in T (bnoisei).

Details:

1. The Sag parameter introduces a quadratic variation of the Peak Field value between Center and Extremities, such as the one generated by a girder sustained from both extremities and bent under the weight of the blocks or the magnetic force between magnet jaws.
2. The Field Component to be modified is taken from the pop-up menu of the dialog box. The pop-up menu suggests all the existing Field Components. The names of the suggested Field Components were generated automatically at the creation of the corresponding Magnetic Field structures by the macro **SrwMagFieldCreate**, according to the name decoration rules described in the reference record for that macro.

SrwMagEdge

Dialog Box:



Definition:

Proc SrwMagEdge(name,zero,scen,strsect,frsize,bconst)

String name

Variable zero,scen,strsect,frsize,bconst

Action:

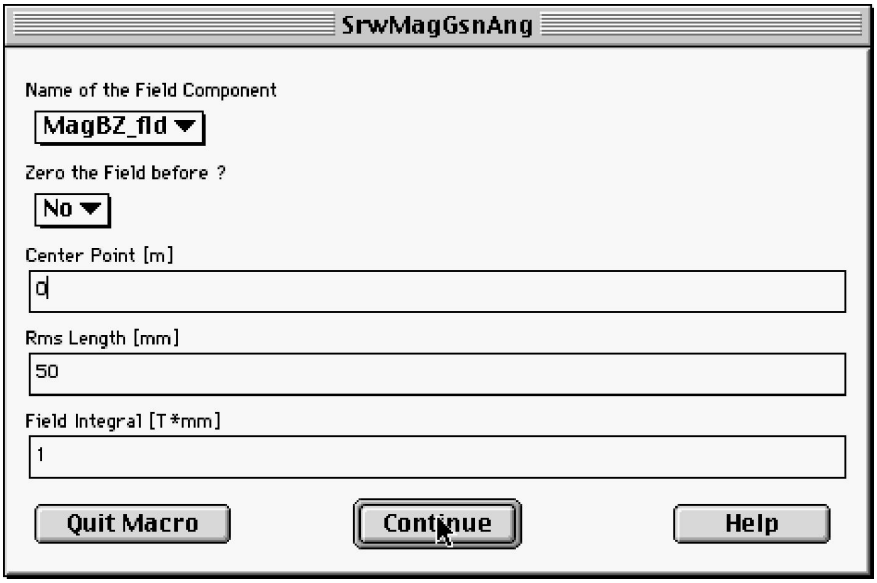
Adds two smooth steps simulating the Edge Field of bending magnets bounding one straight section, to the magnetic Field Component wave with the name "name" (selected from the existing Field Component waves). The selected wave can be initially set to zero (zero=1) or not (zero=2). The following parameters should be specified: Center Point of the Edge Field wave in m (scen), Length of Straight Section between the two edges in m (strsect), Fringe Field Length (i.e., a length at which the edge fringe field varies from 10 to 90%) in mm (frsize), and the Uniform Field in the bending magnets in T (bconst).

Details:

1. The Field Component to be modified is taken from the pop-up menu of the dialog box. The pop-up menu suggests all the existing Field Components. The names of the suggested Field Components were generated automatically at the creation of the corresponding Magnetic Field structures by the macro **SrwMagFieldCreate**, according to the name decoration rules described in the reference record for that macro.

SrwMagGsnAng

Dialog Box:



Definition:

Proc SrwMagGsnAng(name,zero,scen,sigma,bint)

String name

Variable zero,scen,sigma,bint

Action:

Adds Gaussian shape magnetic field wave simulating the field of a single steering magnet, to the magnetic Field Component wave with the name "name" (selected from the existing Field Component waves). The selected wave can be initially set to zero (zero=1) or not (zero=2). The following parameters should be specified: Center Point in m (scen), RMS Length (i.e., RMS size of the Gaussian) in mm (sigma), Field Integral (over the longitudinal coordinate from minus to plus infinity) in T*mm (bint).

Details:

1. The Field Component to be modified is taken from the pop-up menu of the dialog box. The pop-up menu suggests all the existing Field Components. The names of the suggested Field Components were generated automatically at the creation of the corresponding Magnetic Field structures by the macro **SrwMagFieldCreate**, according to the name decoration rules described in the reference record for that macro.

SrwMagGsnDipole

Definition:

Proc SrwMagDipole(FldName,Zero,Scent,Len,FringeSize,Bconst)

String FldName

Variable FldName,Zero,Scent,Len,FringeSize,Bconst

Action:

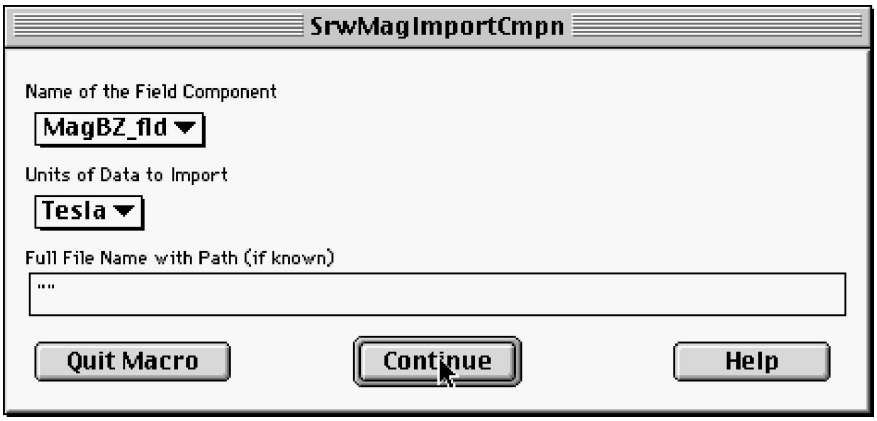
Adds a Dipole Magnet field to the magnetic field component wave with the name "FldName" (selected from the existing field component waves). The selected wave can be initially set to zero (Zero=1) or not (Zero=2). The following parameters should be specified: Center Point in m (Scent), Iron Length in m (Len), Fringe Field length (i.e., a length at which the edge fringe field varies from 10 to 90%) in mm (FringeSize), and the Uniform Field in the bending magnets in T (Bconst).

Details:

1. The field component to be modified is taken from the pop-up menu of the dialog box. The popup menu suggests all the existing field components. The names of the suggested field components were generated automatically at the creation of the corresponding magnetic field structures by the macro **SrwMagFieldCreate**, according to the name decoration rules described in the reference record for that macro.

SrwMagImportCmpn

Dialog Box:



Definition:

Proc SrwMagImportCmpn(wname,units,fname)

String wname

Variable units

String fname

Action:

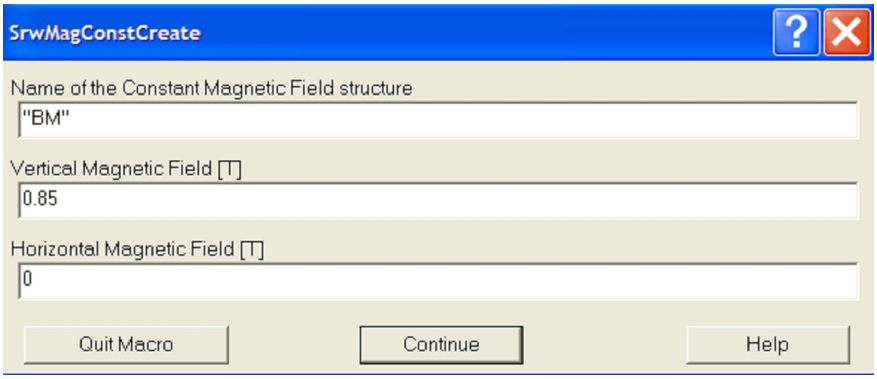
Imports Magnetic Field data from an external text file into Horizontal or Vertical Field Component wave with the name "name" (selected from the existing Field Component waves). The units of the data to import can be Tesla or Gauss. This should be specified by the parameter units ("Tesla": units=1; "Gauss": units=2). A user can specify a Full Name with Path of the text file with data to be imported, if this name is known exactly (for example, fname="MyDisk::MyFolder:MyFile"). If it is not the case, the fname string should be left empty (fname="").

Details:

1. Before executing this macro, a user has to create a Magnetic Field structure by the macro **SrwMagFieldCreate**, where he needs to specify a longitudinal position of Center of the Field, Length of the Field (i.e., longitudinal range of the field definition), and Number of Points for the data to be imported. The specified **Number of Points should be exactly the same** as in the data file.
2. Format of the external data file. The external data file should be a **text (ASCII)** file containing **one column** of decimal floating point numbers (i.e. each number from a new line) representing the values of one component (horizontal or vertical) of the magnetic field. These field values are assumed to correspond to **equidistant points** over the longitudinal coordinate. The sampling parameters, i.e., Center, Length of the Field and the Number of Points over the longitudinal coordinate were defined by the macro **SrwMagFieldCreate** that created the Magnetic Field structure one component of which is filled by the data from the file. At the top or at the bottom of the data file, there can be a number of strings of characters starting from non-number character (text comments). These strings are ignored at the data import. The following is a fragment of a valid data file. ... Vertical field (Tesla). Measured 15 Jan 1998... 0.0144 0.3401 0.6396 0.8629 0.9833 0.9865 0.8722 ...
3. The Field Component to be filled by the imported data is taken from the pop-up menu "Name of the Field Component" of the dialog box. The pop-up menu suggests all the existing Horizontal and Vertical Field Components. The names of the suggested Field Components were generated automatically at the creation of the corresponding Magnetic Field structures by the macro **SrwMagFieldCreate**, according to the name decoration rules described in the reference record for that macro.
4. If the need is to import only one component of magnetic field , this can be done in two steps:
5. Create a Magnetic Field structure using the macro **SrwMagFieldCreate** by specifying the name for the structure and proper sampling parameters. At the creation, the horizontal and vertical Field Component waves are set to zero.
6. Import the data from an external file to the vertical Magnetic Field Component wave which belongs to the Magnetic Field structure created. For this, the macro **SrwMagImportCmpn** should be used. If the other Field Component is not zero and should be imported as well, one needs to repeat the last step for that component. Please note that the data for the other Field Component should correspond to exactly the same sampling parameters (Center, Length of the Field and the Number of Points) as the previous Component. These parameters were specified by the macro **SrwMagFieldCreate**.
7. After the Import of a Field Component is done, it is recommended to display it in a Graph by using the macro **SrwMagDisplayField**.
8. If you have failed to Import your Magnetic Field data by means of this macro, please refer to the section **How to Import Magnetic Field Data into SRW** in the chapter Frequently Asked Questions, where other possible methods of importing the data into SRW are discussed.

SrwMagConstCreate

Dialog Box:



Definition:

Proc SrwMagConstCreate(name, bv, bh)

String name

Variable bv, bh

Action:

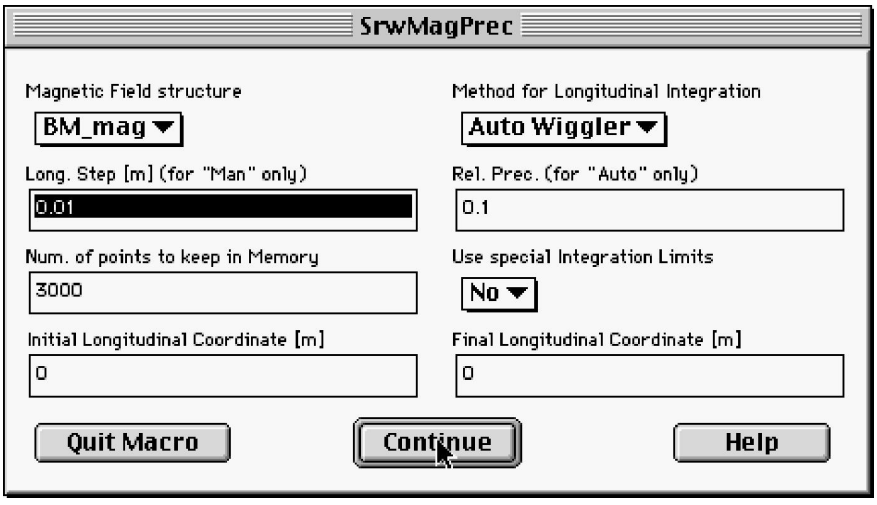
Creates a constant magnetic field structure with the name "name" possessing vertical and horizontal field components (bv, bh).

Details:

1. One of the two field components can be zero.

SrwMagPrec

Dialog Box:



Definition:

Proc SrwMagPrec(name,meth,step,prec,ptsave,lim,sdep,sfin)

String name

Variable meth,step,prec,ptsave,lim,sdep,sfin

Action:

Sets Longitudinal Integration Method and precision parameters to be used at computation of Synchrotron Radiation generated in the Magnetic Field described by the structure with the name "name". The Longitudinal Integration Method can be "Manual" (meth=1), "Auto Undulator" (meth=2) or "Auto Wiggler" (meth=3). The following precision parameters should be specified: Step of Longitudinal Integration in m (used only for the "Manual" method, step), Relative Precision (used only for "Auto Undulator" or "Auto Wiggler" methods, prec), Number of points to keep in Memory at the integration (ptsave). One should also specify whether any special Integration Limits that differ from the Magnetic Field definition limits (set up by the macro **SrwMagFieldCreate**) should be used at the Longitudinal Integration (lim=2) or not (lim=1). The Initial and Final Longitudinal Coordinates (sdep and sfin) are taken into account only if one has chosen to Use special Integration Limits (lim=2).

Details:

1. About the Methods of Longitudinal Integration. There are three Methods of Longitudinal Integration for the Synchrotron Radiation computation.
   - "Manual" is a simplest one-pass longitudinal integration with fixed step size. In this method, the computation is based on the Longitudinal Step value (variable step, input box "Long. Step [m]"). This method is very sensitive to the Longitudinal Integration Limits (especially in the cases when magnetic field is not zero at the edges of the integration interval).
   - "Auto Undulator" is a simple "automatic" integration, mostly suitable for Undulator-type cases (when the required sampling density is more or less uniform along the electron trajectory). In this method, the computation is based on Relative Precision value (variable prec, input box "Rel. Prec."). This method is very sensitive to the Longitudinal Integration Limits (especially in the cases when magnetic field is not zero at the edges of the integration interval).
   - "Auto Wiggler" is a more sophisticated method. In was developed to optimize the SR computation in Wiggler-type cases (when the required density of sampling is strongly different for different parts of the trajectory). It is efficient also for the Edge Radiation, for complicated field configurations with drift spaces, etc. In this method, the computation is based on Relative Precision value (variable prec, input box "Rel. Prec."). This method is not very sensitive to the Longitudinal Integration Limits: it tries to find the proper integration limits automatically (depending on the observation point and other parameters). A user should only care that the field definition range (set by the macro **SrwMagFieldCreate**) is large enough for the given SR observation range.
   - "Auto Wiggler" is a more universal method and it normally requires less efforts from user than the other methods, however in some cases, the user may "steer" the other methods (by tuning step/precision/limits) to work faster than the "Auto Wiggler".
2. Number of points to keep in memory (ptsave) is not a crucial parameter. It does not affect the precision; it may only affect the CPU time.

SrwMagDisplayField

Dialog Box:

Definition:

Proc SrwMagDisplayField(name)

String name

Action:

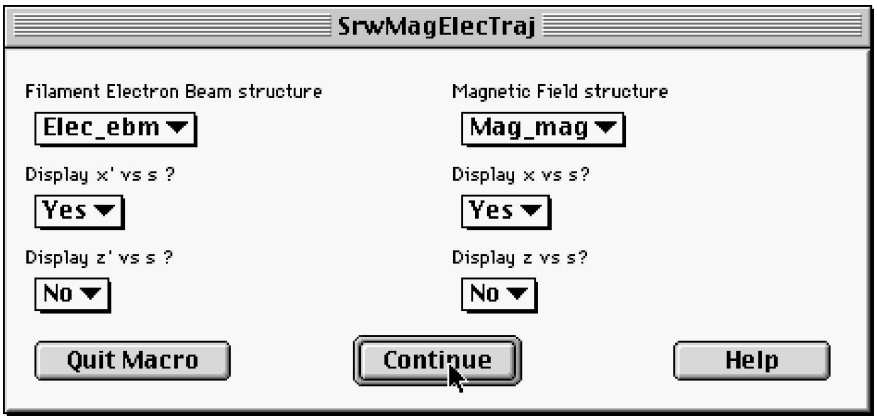
Displays the Magnetic Field Component with the name "name" in a Graph.

Details:

1. The Field Component to be displayed is taken from the pop-up menu of the dialog box. The pop-up menu suggests all the existing Field Components. The names of the suggested Field Components were generated automatically at the creation of the corresponding Magnetic Field structures by the macro **SrwMagFieldCreate**. See the reference record for this macro for the naming details.

SrwMagElecTraj

Dialog Box:



Definition:

Proc SrwMagElecTraj(elname,magname,disxan,disxcr,diszan,diszcr)

String elname,magname

Variable disxan,disxcr,diszan,diszcr

Action:

Displays the average trajectory of the Electron Beam defined by the structure "elname" in the Magnetic Field defined by the structure "magname". A user should specify whether the following components should be displayed in Graphs vs the Longitudinal coordinate: Horizontal Angle ("No": disxan=1; "Yes":

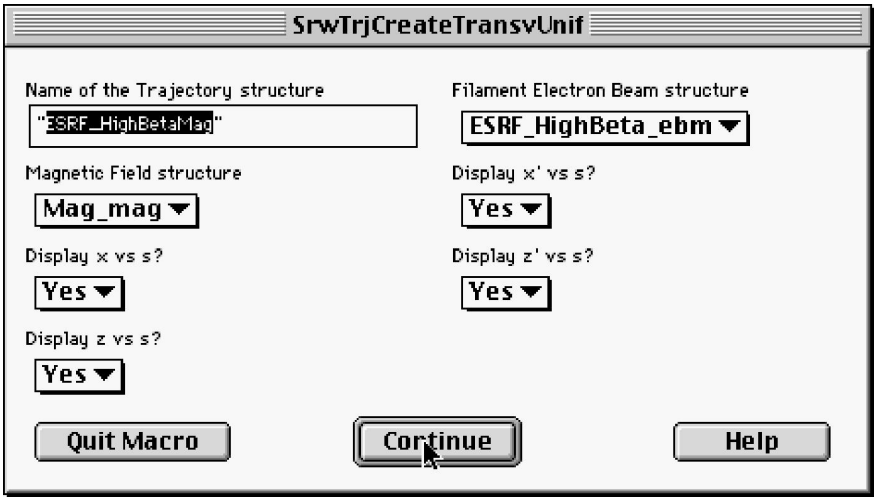
disxan=2); Horizontal Coordinate ("No": disxcr=1; "Yes": disxcr=2); Vertical Angle ("No": diszan=1; "Yes": diszan=2); Vertical Coordinate ("No": diszcr=1; "Yes": diszcr=2).

Details:

1. This macro is used only to visualize the trajectory. There is no need (other than this) to execute it before the SR computation.

SrwTrjCreateTransvUnif

Dialog Box:



Definition:

Proc SrwTrjCreateTransvUnif(trjname,elname,magname,disxan,disxcr,diszan,diszcr)

String trjname,elname,magname

Variable disxan,disxcr,diszan,diszcr

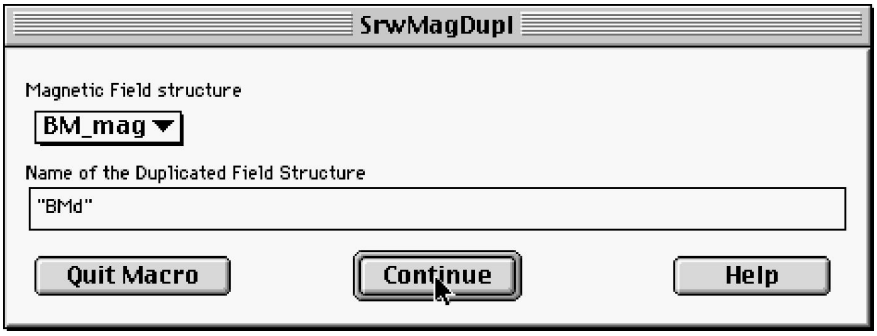
Action:

Creates a Trajectory structure and computes a trajectory of a filament electron beam described by the structure "elname" in transversely uniform magnetic field described by the structure "magname". The computed trajectory vs longitudinal position can be displayed in graphs or not: Horizontal Angle ("No": disxan=1; "Yes": disxan=2); Horizontal Coordinate ("No": disxcr=1; "Yes": disxcr=2); Vertical Angle ("No": diszan=1; "Yes": diszan=2); Vertical Coordinate ("No": diszcr=1; "Yes": diszcr=2).

Details:

SrwMagDupl

Dialog Box:



Definition:

Proc SrwMagDupl(name,named)

String name,named

Action:

Duplicates the Magnetic Field structure with the name "name" by creating a structure with the name "named".

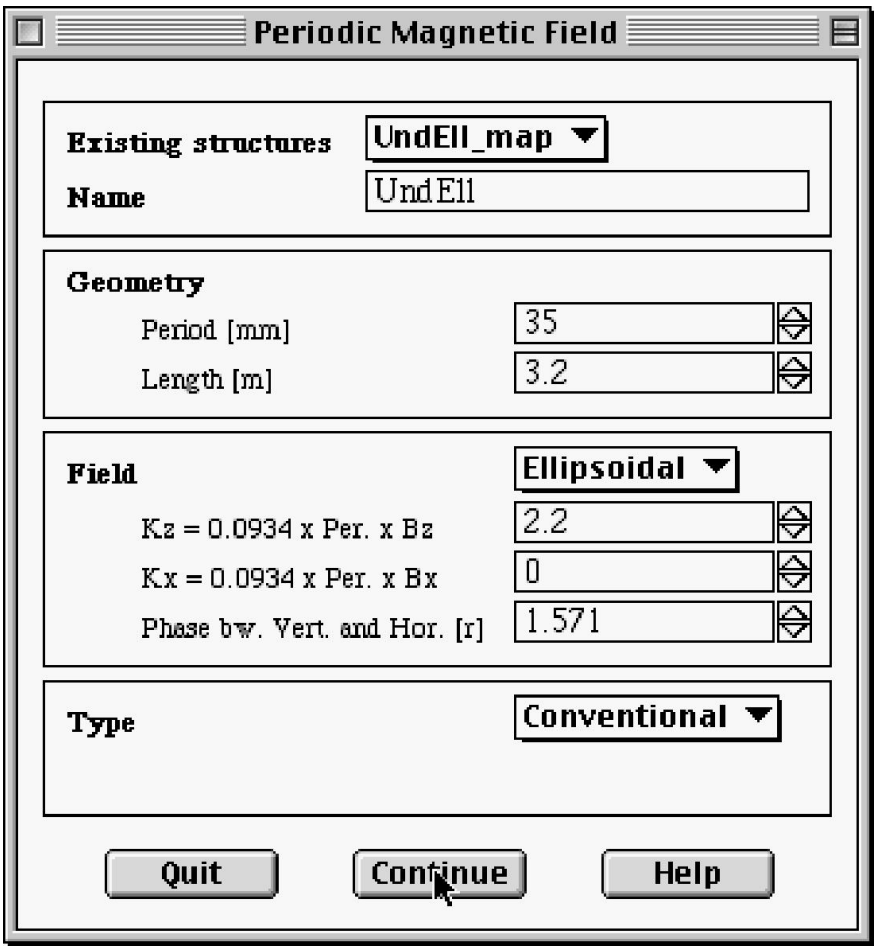
Details:

1. The Magnetic Field structure (text wave) is duplicated together with the 1D numeric waves defining Horizontal and Vertical field components. The full names of the duplicated text- and numeric waves are generated according to the rules described in the reference record for the macro **SrwMagFieldCreate**.

Periodic Magnetic Field

SrwMagPerCreateDialog

Dialog Box:



Action:

Creates or modifies a Periodic Magnetic Field structure, i.e. sets up undulator parameters, including period, length, plane of the field (vertical, horizontal or both), deflection parameter(s), phase shift between vertical and horizontal field (if necessary), type of undulator (conventional, tapered, optical klystron, infinite) and extra relevant parameters.

Details:

1. We do not advise to use this macro at programming in Igor macro language. *It is dedicated only to facilitate the dialog-driven style of computation in SRW.*
2. The Periodic Magnetic Field structure created is actually a text wave that keeps main parameters of an undulator and the name(s) of one or more other text waves describing harmonics of the periodic magnetic field.
3. This macro creates the main harmonic of the periodic magnetic field, which may have both vertical and horizontal components. All the rest harmonics of vertical and/or horizontal magnetic field (if any) can be set up and added to the Periodic Magnetic Field structure using the macro **SrwMagPerAddHarm**.
4. If the type of undulator was chosen to be "Tapered Undulator", it is essential to specify a proper taper parameter which is defined as a relative change of instant resonant photon energy from the entrance of undulator to its exit multiplied by number of periods.

5. If the type of undulator was chosen to be "Optical Klystron", it is essential to specify a proper optical klystron parameter, which is defined as Nd/N = dF/Pi/N, where dF is the phase shift in dispersion section of the optical klystron for the photon energy equal to the on-axis resonant value of the first harmonic, N is total number of periods (twice the number of periods in each of two sections of the optical klystron).
6. The full name of the Periodic Magnetic Field structure (text wave) was generated according to the following rule: = + "_map", where "_map" is the type identifier of a Periodic Magnetic Field structure. The full names of the Periodic Magnetic Field Harmonic structure was generated according to the following rule: = + "_fha", where "_fha" is the type identifier of a Periodic Magnetic Field Harmonic structure.
7. This macro invokes another macro of SRW that can be used at programming in Igor macro language: **SrwMagPerCreate2D**. The invoked macro is printed in the Igor History window with the input parameters values used.

SrwMagPerCreate2D

Definition:

Proc SrwMagPerCreate2D(name,per,kz,kx,len,phx,undtyp,tappar,okpar)

String name

Variable per,kz,kx,len,phx,undtyp,tappar,okpar

Action:

Creates a Periodic Magnetic Field structure with the name "name" and sets up the main harmonic of the periodic magnetic field. The following parameters should be specified: period in mm (per), vertical and horizontal deflection parameters (kz, kx), total length in m (len), phase shift of horizontal magnetic field with respect to vertical (phx), type of the undulator (undtyp=1 for conventional, 2 for tapered, 3 for optical klystron, 4 for infinite), extra parameters for the cases of tapered undulator (tappar) and optical klystron (okpar).

Details:

1. The Periodic Magnetic Field structure created is actually a text wave that keeps main parameters of an undulator and the name(s) of one or more other text waves describing harmonics of the periodic magnetic field.
2. This macro creates the main harmonic of the periodic magnetic field, which may have both vertical and horizontal components. All the rest harmonics of vertical and/or horizontal magnetic field (if any) can be set up and added to the Periodic Magnetic Field structure using the macro **SrwMagPerAddHarm**.
3. If the type of undulator was chosen to be "Tapered Undulator", it is essential to specify a proper taper parameter which is defined as a relative change of instant resonant photon energy from the entrance of undulator to its exit multiplied by number of periods.
4. If the type of undulator was chosen to be "Optical Klystron", it is essential to specify a proper optical klystron parameter, which is defined as Nd/N = dF/Pi/N, where dF is the phase shift in dispersion section of the optical klystron for the photon energy equal to the on-axis resonant value of the first

harmonic, N is total number of periods (twice the number of periods in each of two sections of the optical klystron).

5. The full name of the Periodic Magnetic Field structure (text wave) was generated according to the following rule: = + "_map", where "_map" is the type identifier of a Periodic Magnetic Field structure. The full names of the Periodic Magnetic Field Harmonic structure was generated according to the following rule: = + "_fha", where "_fha" is the type identifier of a Periodic Magnetic Field Harmonic structure.

SrwMagPerCreate2D_

Definition:

Proc SrwMagPerCreate2D_(name,per,kz,kx,len,phx)

String name

Variable per,kz,kx,len,phx

Action:

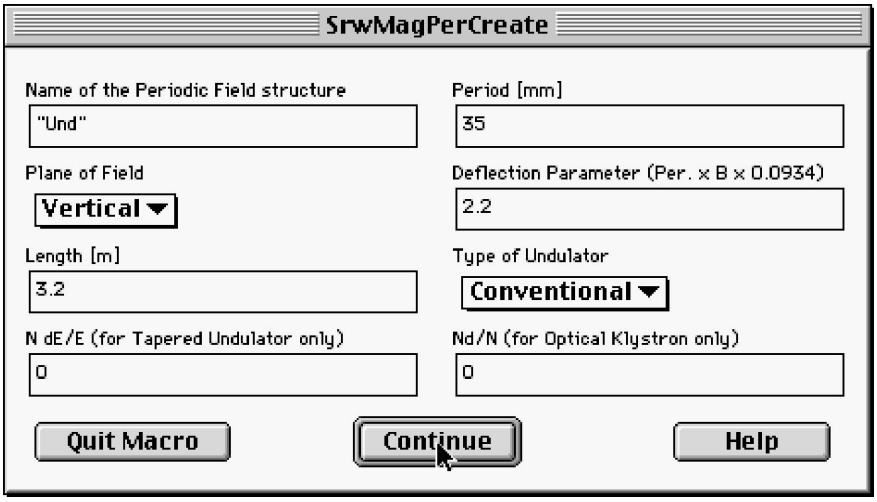
Creates a Periodic Magnetic Field structure with the name "name" and sets up the main harmonic of the periodic magnetic field. The following parameters should be specified: period in mm (per), vertical and horizontal deflection parameters (kz, kx), total length in m (len), phase shift of horizontal magnetic field with respect to vertical (phx).

Details:

1. The Periodic Magnetic Field structure created is actually a text wave that keeps main parameters of an undulator and the name(s) of one or more other text waves describing harmonics of the periodic magnetic field.
2. This macro creates the main harmonic of the periodic magnetic field, which may have both vertical and horizontal components. All the rest harmonics of vertical and/or horizontal magnetic field (if any) can be set up and added to the Periodic Magnetic Field structure using the macro **SrwMagPerAddHarm**.
3. The full name of the Periodic Magnetic Field structure (text wave) was generated according to the following rule: = + "_map", where "_map" is the type identifier of a Periodic Magnetic Field structure. The full names of the Periodic Magnetic Field Harmonic structure was generated according to the following rule: = + "_fha", where "_fha" is the type identifier of a Periodic Magnetic Field Harmonic structure.

SrwMagDupl

Dialog Box:



Definition:

Proc SrwMagPerCreate(name,per,plane,k,len,undtyp,tappar,okpar)

String name

Variable per,plane,k,len,undtyp,tappar,okpar

Action:

Creates a Periodic Magnetic Field structure with the name "name" and sets up the main harmonic of the periodic magnetic field. The following parameters should be specified: period in mm (per), plane of the field (plane=1 for vertical, 2 for horizontal), deflection parameter (k), total length in m (len), type of the undulator (undtyp=1 for conventional, 2 for tapered, 3 for optical klystron, 4 for infinite), extra parameters for the cases of tapered undulator (tappar) and optical klystron (okpar).

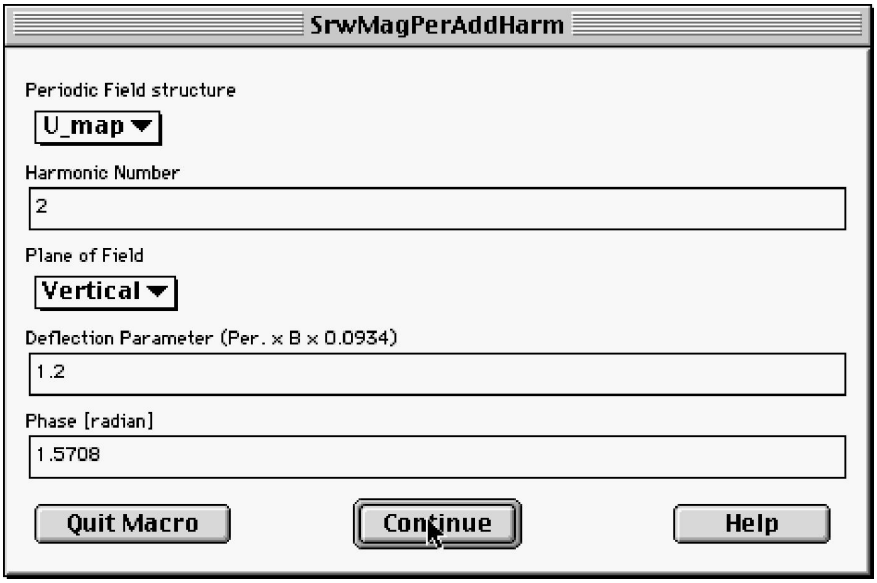
Details:

1. The Periodic Magnetic Field structure created is actually a text wave that keeps main parameters of an undulator and the name(s) of one or more other text waves describing harmonics of the periodic magnetic field.
2. This macro creates one (main) harmonic of the periodic magnetic field. All the rest harmonics of vertical and/or horizontal magnetic field (if any) can be set up and added to the Periodic Magnetic Field structure using the macro **SrwMagPerAddHarm**.
3. If the type of undulator was chosen to be "Tapered Undulator", it is essential to specify a proper taper parameter which is defined as a relative change of instant resonant photon energy from the entrance of undulator to its exit multiplied by number of periods.
4. If the type of undulator was chosen to be "Optical Klystron", it is essential to specify a proper optical klystron parameter, which is defined as Nd/N = dF/Pi/N, where dF is the phase shift in dispersion section of the optical klystron for the photon energy equal to the on-axis resonant value of the first harmonic, N is total number of periods (twice the number of periods in each of two sections of the optical klystron).

5. The full name of the Periodic Magnetic Field structure (text wave) was generated according to the following rule: = + "_map", where "_map" is the type identifier of a Periodic Magnetic Field structure. The full names of the Periodic Magnetic Field Harmonic structure was generated according to the following rule: = + "_fha", where "_fha" is the type identifier of a Periodic Magnetic Field Harmonic structure.

SrwMagPerAddHarm

Dialog Box:



Definition:

Proc SrwMagPerAddHarm(name,harm,plane,k,phase)

String name

Variable harm,plane,k,phase

Action:

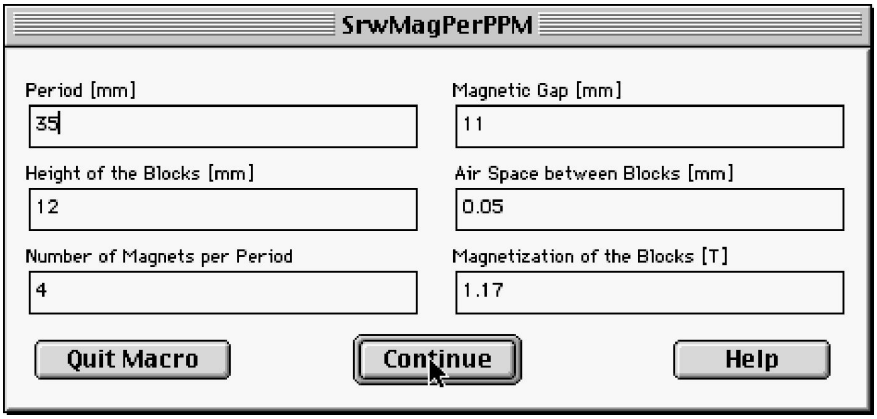
Creates a periodic magnetic field harmonic and adds it to the Periodic Magnetic Field structure with the name "name". The following parameters should be specified: harmonic number (harm), plane of the field (plane=1 for vertical, 2 for horizontal), deflection parameter (k), and initial phase of the harmonic in radian (phase).

Details:

1. Note that after creation by the macro **SrwMagPerCreate**, the undulator has already the harmonic 1 (main), which is assumed to have zero phase. Any harmonic created and added to the Periodic Magnetic Field structure by the macro **SrwMagPerAddHarm** has to have the phase specified with respect to the main harmonic. The harmonic number can be 1,2,... .
2. The full name of the Periodic Magnetic Field Harmonic structure was generated according to the following rule: = + "_fha", where "_fha" is the type identifier of a Periodic Magnetic Field Harmonic structure.

SrwMagPerPPM

Dialog Box:



Definition:

Proc SrwMagPerPPM(per,gap,height,air,mpper,br)

Variable per,gap,height,air,mpper,br

Action:

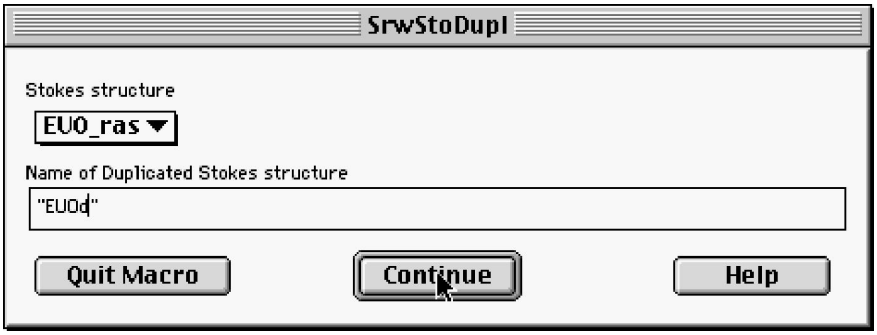
Computes and prints to Igor History window the values of peak field and deflection parameter of a pure permanent magnet undulator. The following input parameters of should be specified: period in mm (per), magnetic gap in mm (gap), height of magnet blocks in mm (height), air space between blocks in mm (air), number of magnet blocks per period (mpper), magnetization of the blocks in Tesla (br).

Details:

1. To compute magnetic field from a pure permanent magnet undulator, the Halbach formula is used (see the paper: K. Halbach, Nucl. Instr. and Meth., 187 (1981), pp. 109-117).

SrwMagPerDupl

Dialog Box:



Definition:

Proc SrwMagPerDupl(name,named)

String name,named

Action:

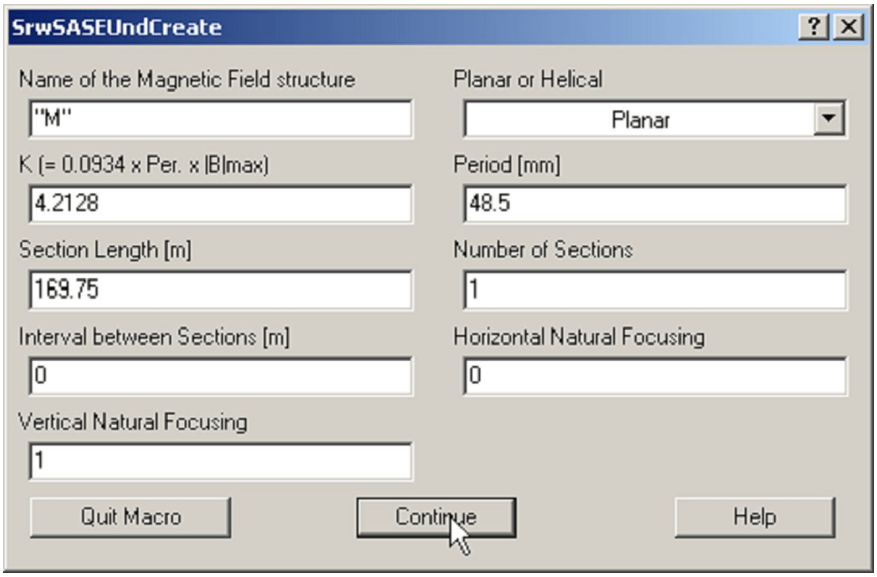
Duplicates the Periodic Magnetic Field structure with the name "name" by creating a structure with the name "named".

Details:

1. The Magnetic Field structure (text wave) is duplicated together with all the harmonic structures constituting in it.

SrwSASEUndCreate

Dialog Box:



Definition:

Proc SrwSASEUndCreate(mname,typ,k,per,seclen,nsec,intsec,nfocx,nfocy)

String mname

Variable typ,k,per,seclen,nsec,intsec,nfocx,nfocy

Action:

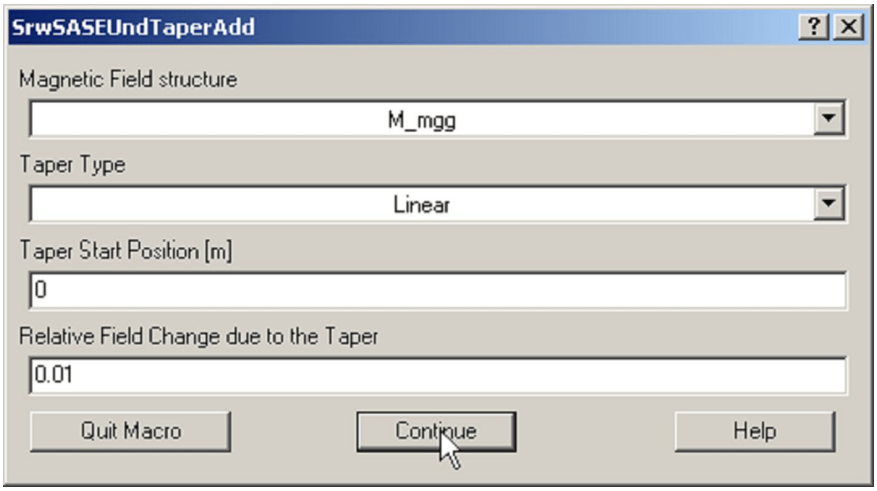
Creates Magnetic Field structure (for SASE computation) with the name "mname" and sets up periodic magnetic field of an undulator. The following parameters should be specified: type of the undulator (planar or helical, typ=1 or 2 respectively), deflection parameter (k), period in mm (per), length of one section in m (seclen), number of sections (nsec), interval between sections in m (intsec), horizontal and vertical natural focusing of the undulator (nfocx,nfocy).

Details:

1. This macro sets up ideal sinusoidal magnetic field of an undulator. After calling this macro, one can call the macros **SrwSASEUndTaperAdd**, **SrwSASEUndErrAdd** and **SrwSASEFODOAdd** to add/setup taper, undulator field errors and FODO lattice parameters, if necessary.

SrwSASEUndTaperAdd

Dialog Box:



Definition:

Proc SrwSASEUndTaperAdd(mname,typ,start,par)

String mname

Variable typ,start,par

Action:

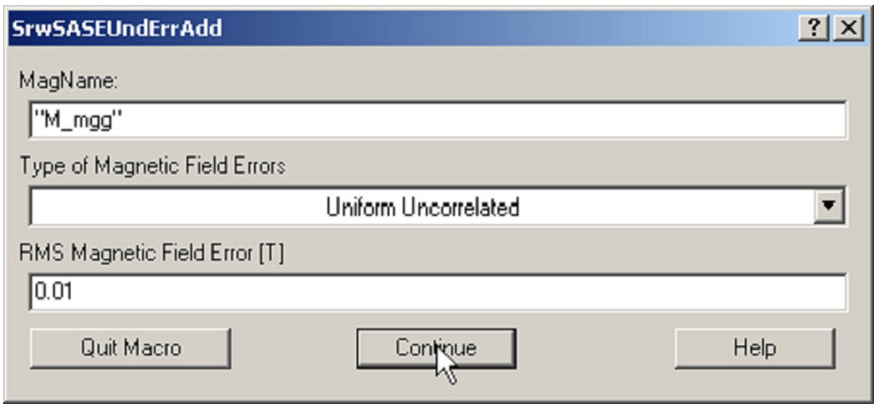
Sets up taper parameters for SASE undulator Magnetic Field structure with the name "mname": taper type (linear or quadratic, typ=1 or 2 respectively), taper start position in m with respect to the beginning of the undulator (start), and relative magnetic field change due to the taper (par).

Details:

1. This macro is called after the macro **SrwSASEUndCreate**, which creates the Magnetic Field structure for SASE computation.

SrwSASEUndErrAdd

Dialog Box:



Definition:

Proc SrwSASEUndErrAdd(mname,typ,par)

String mname

Variable typ,par

Action:

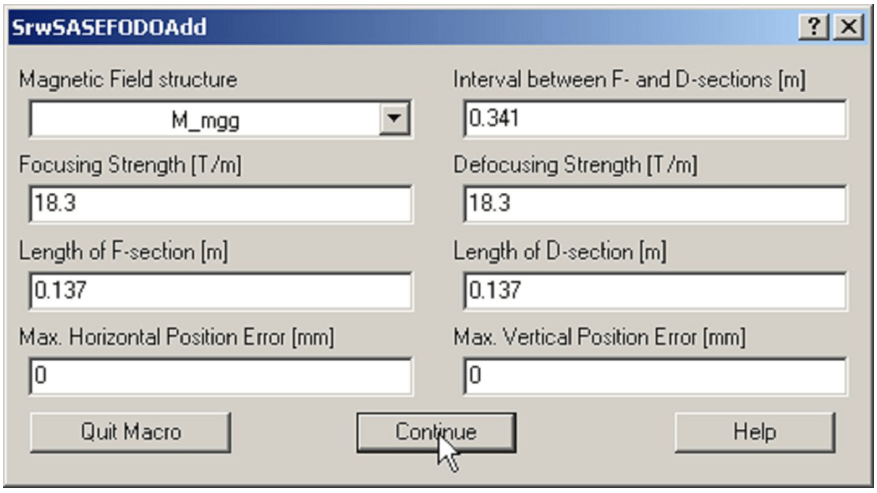
Sets up magnetic field error parameters for SASE undulator Magnetic Field structure with the name "mname": type of the error (uniform uncorrelated, uniform correlated, Gaussian uncorrelated, Gaussian correlated: typ=1,2,3,4 respectively), and RMS error value in Tesla (par).

Details:

1. This macro is called after the macro **SrwSASEUndCreate,** which creates the Magnetic Field structure for SASE computation.

SrwSASEFODOAdd

Dialog Box:



Definition:

Proc SrwSASEFODOAdd(mname,drift,qf,qd,lf,ld,dx,dz)

String mname

Variable drift,qf,qd,lf,ld,dx,dz

Action:

Sets up FODO lattice parameters for Magnetic Field structure (for SASE computation) with the name "mname": interval between focusing and defocusing quadrupoles in m (drift), focusing and defocusing quadrupole strengths in T/m (qf,qd), effective lengthes of the focusing and defocusing quadrupoles in m (lf,ld), maximum errors in horizontal and vertical positions of the quadrupoles in mm (dx,dz).

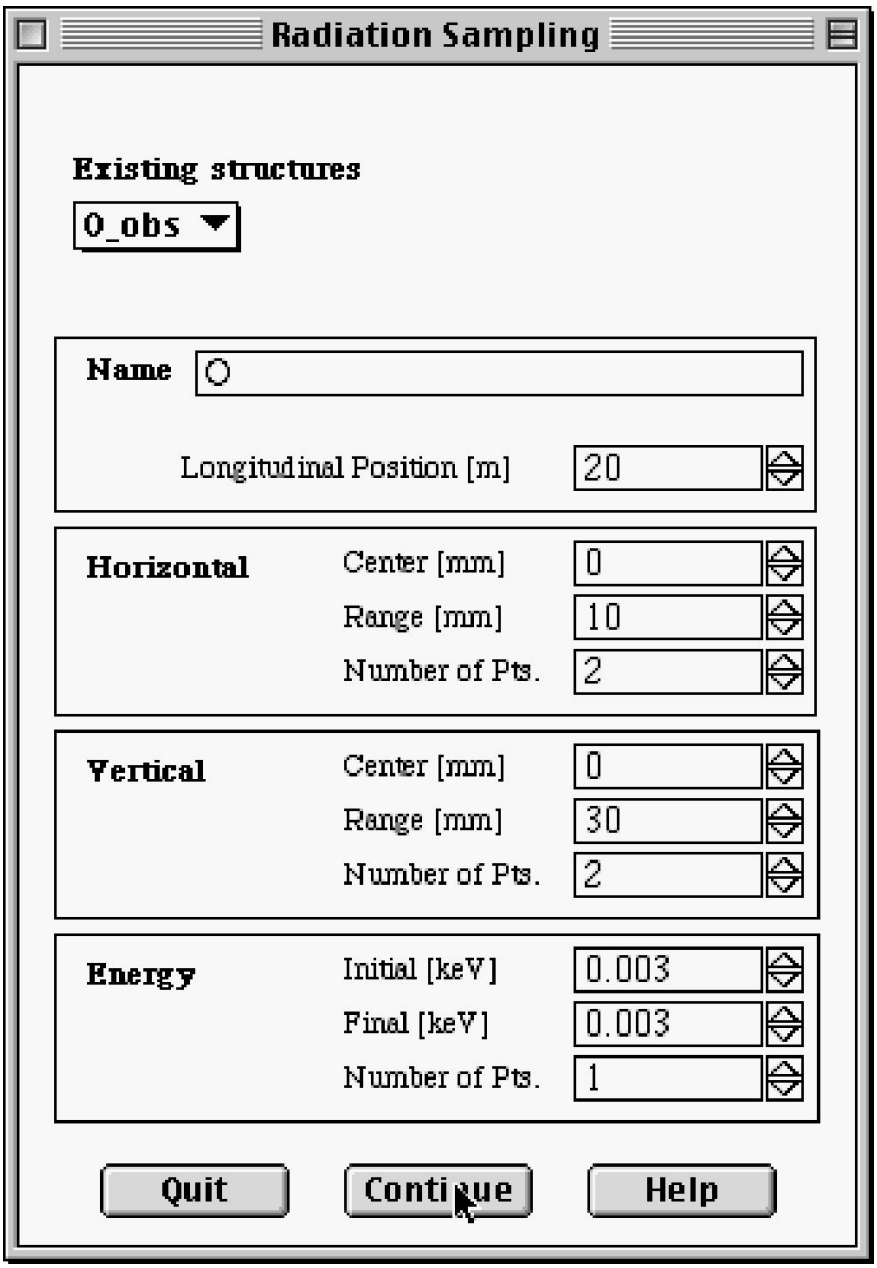
Details:

1. This macro should be called after the macro SrwSASEUndCreate, which creates the Magnetic Field structure for SASE computation.

Radiation Sampling

SrwRadSamplDialog

Dialog Box:



Definition:

Proc SrwRadSamplDialog(name,named)

String name,named

Action:

Displays a dialog box and invokes proper SRW macros for setting up a Radiation Sampling structure, which is a set of sampling parameters over Transverse Coordinates and Photon Energy and a single value of the Longitudinal Position for the radiation electric field or spectral flux per unit surface. This structure should be used at Synchrotron Radiation computation.

Details:

1. We do not advise to use this macro at programming in Igor macro language. It is dedicated only to facilitate the dialog-driven style of computation in SRW.
2. This macro invokes two low-level macros of SRW that can be used at programming in Igor macro language: SrwSmpCreate and SrwSmpScanXZE. The invoked macros are printed in the Igor History window with the input parameters values used. For more details please refer to the Reference Manual records for these macros.
3. The sampling is equidistant with respect to Horizontal and Vertical Position and Photon Energy. In general case, the Radiation Sampling defines a cube of data that corresponds to a single value of Longitudinal Position. This means that in most cases a computation is performed on a rectangular grid consisting of nx x nz x ne points (nx different values of Horizontal Position, nz values of Vertical Position and ne values of Photon Energy, where nx, nz and ne are the Numbers of Points entered in the dialog box). These points are equidistantly placed within the Horizontal and Vertical Ranges xr, zr around the Center positions xc, zc, within the Initial and Final photon energy values ei, ef: xc - xr/2 <= x <= xc + xr/2, zc - zr/2 <= z <= zc + zr/2, ei <= e <= ef. If nx = 1 and/or nz = 1 and/or ne = 1, the computation is performed for one value of horizontal position x = xc and/or vertical position z = zc and/or photon energy e = ei; the corresponding Range and/or Final photon energy parameters are not taken into account in these cases. Thus, one can define a scan over only one or two (of three) coordinates by specifying "Number of Pts.: 1" for the coordinate(s) over which the scan is not done. The values of nx <= 0, nz <= 0, ne <= 0 are forbidden.
4. We note that the above default meaning of the Radiation Sampling parameters may slightly differ for some modes of computation. In such cases the differences are pointed out in the Reference Manual records for the macros doing particular computations.
5. The "Existing structures" pop-up menu suggests all the existing (if any) Radiation Sampling structures for modification. When an existing structure is selected, its parameters are shown in the corresponding edit boxes. A user can change any of the parameters and press "Continue". If a new name was specified (edit box "Name"), this will create a new structure, if not, this will modify the old one.
6. Please note that in the pop-up menu, the full names of the existing structures are shown. Each of these names was automatically generated from the name specified by user at creation of the structure, according to the following rule: = + "_obs", where "_obs" is the type identifier of a Radiation Sampling structure.
7. The Radiation Sampling dialog box accepts Photon Energy only in keV. The macro **SrwUtiPhotEnConv** (menu call "Utilities->Photon Energy Conversion...") helps to convert other photon energy / wavelength units to keV.

SrwSmpCreate

Definition:

Proc SrwSmpCreate(name,dist)

String name

Variable dist

Action:

Creates a Radiation Sampling structure with the name "name" and sets up a Longitudinal Position in m (dist).

Details:

1. The Radiation Sampling structure created is actually a numeric wave that holds the values of all the sampling parameters.
2. The full name of the Radiation Sampling structure was generated according to the following rule: = + "_obs", where "_obs" is the type identifier of a Radiation Sampling structure.

SrwSmpScanXZE

Definition:

Proc SrwSmpScanXZE(name,xc,xr,nx,zc,zr,nz,ei,ef,ne)

String name

Variable xc,xr,nx,zc,zr,nz,ei,ef,ne

Action:

Sets up parameters of a Radiation Sampling structure with the name "name": Center, Range (in mm) and Number of Points for Horizontal coordinate (xc,xr,nx), Center, Range (in mm) and Number of Points for Vertical coordinate (zc,zr,nz), Initial and Final value (in keV) and Number of Points for Photon Energy (ei,ef,ne).

Details:

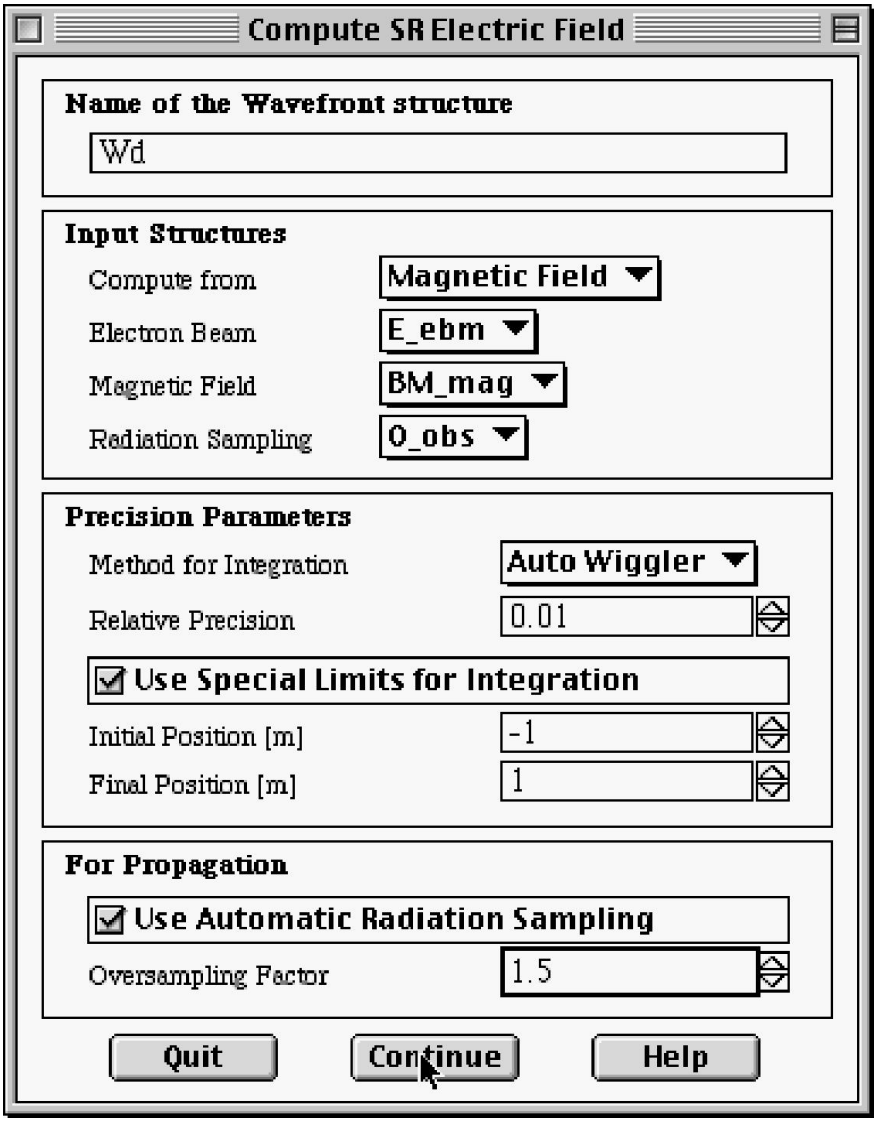
1. The sampling defined by the macro SrwSmpScanXZE is assumed to be equidistant with respect to Horizontal and Vertical Position and Photon Energy. In general case, the Radiation Sampling defines a cube of data that corresponds to a single value of Longitudinal Position. This means that in most cases a computation is performed on a rectangular grid consisting of nx x nz x ne points (nx different values of Horizontal Position, nz values of Vertical Position and ne values of Photon Energy, where nx, nz and ne are the Numbers of Points entered in the dialog box). These points are equidistantly placed within the Horizontal and Vertical Ranges xr, zr around the Center positions xc, zc, within the Initial and Final photon energy values ei, ef: xc - xr/2 <= x <= xc + xr/2, zc - zr/2 <= z <= zc + zr/2, ei <= e <= ef. If nx = 1 and/or nz = 1 and/or ne = 1, the computation is performed for one value of horizontal position x = xc and/or vertical position z = zc and/or photon energy e = ei; the corresponding Range and/or Final photon energy parameters are not taken into account in these cases. Thus, one can define a scan over only one or two (of three) coordinates by specifying "Number of Pts.: 1" for the coordinate(s) over which the scan is not done. The numbers of points nx <= 0, nz <= 0, ne <= 0 are forbidden.

SR Computation

This section describes the macro commands dedicated for SR computation.

SrwWfrCreateDialog

Dialog Box:



Definition:

Proc SrwWfrCreateDialog(mode)

Variable mode

Action:

Displays a dialog box and invokes proper SRW macros for the computation of the near-field electric field of synchrotron radiation in frequency domain. The following parameters should be entered/chosen in the dialog box:

- Name of the electric field Wavefront structure to contain the computation results;
- Basic input structures:

    - a switch specifying whether the computation is done from magnetic field or from electron trajectory;
    - names of Electron Beam and Magnetic Field structures in the case of computation from magnetic field, or name of Trajectory structure in the case of computation from electron trajectory;
    - name of Radiation Sampling structure;
- Precision parameters:
    - method for longitudinal integration (Manual / Auto Undulator / Auto Wiggler);
    - step of integration (in the case of manual integration method) or relative precision (in case of automatic integration method);
    - a switch specifying whether integration limits that differ from the limits of definition of the magnetic field or electron trajectory should be used at the integration or not ("Use Special Limits for Longitudinal Integration");
    - initial and final position of the longitudinal integration (if different integration limits were chosen to be used);
- Extra parameters for propagation (available only if parameter mode is not zero):
    - switch specifying whether the numbers of points in horizontal and vertical directions, where the electric field is computed, should be automatically deduced to enable further propagation of the wavefront ("Use Automatic Radiation Sampling"), or the numbers of points in horizontal and vertical directions are exactly those specified in the Radiation Sampling structure;
    - an oversampling factor with respect to the minimal sampling allowing the wavefront propagation (if automatic radiation sampling was chosen to be used).

Details:

1. We do not advise to use this macro at programming in Igor macro-language. This macro is dedicated only to facilitate the dialog-driven style of computation in SRW.
2. There are three Methods of Longitudinal Integration available for Synchrotron Radiation computation:
3. "Manual" is a simplest one-pass longitudinal integration with fixed step size. In this method, the computation is based on the Longitudinal Step value (variable step, input box "Long. Step [m]"). This method is very sensitive to the Longitudinal Integration Limits (especially in the cases when magnetic field is not zero at the edges of the integration interval).
4. "Auto Undulator" is a simple "automatic" integration, mostly suitable for Undulator-type cases (when the required sampling density is more or less uniform along the electron trajectory). In this method, the computation is based on Relative Precision value (variable prec, input box "Rel. Prec."). This method is very sensitive to the Longitudinal Integration Limits (especially in the cases when magnetic field is not zero at the edges of the integration interval).
5. "Auto Wiggler" is a more sophisticated method. In was developed to optimize the SR computation in Wiggler-type cases (when the required density of

sampling is strongly different for different parts of the trajectory). It is efficient also for the Edge Radiation, for complicated field configurations with drift spaces, etc. In this method, the computation is based on Relative Precision value (variable prec, input box "Rel. Prec."). This method is not very sensitive to the Longitudinal Integration Limits: it tries to find the proper integration limits automatically (depending on the observation point and other parameters). A user should ideally care only that the magnetic field (or trajectory) definition range is large enough to cover all the region(s) where the SR can be generated. "Auto Wiggler" is a more universal method and it normally requires less efforts from user than the other methods, however in some cases, the user may "steer" the other methods (by tuning step/precision/limits) to work faster than the "Auto Wiggler".

6. It is important to make several cycles of the SR computation with different values of the precision parameters. After each cycle of computation, the results can be visualized (menu "Visualize..."). Independence of the computation results on the precision parameters (at a given accuracy level) is the necessary condition for the validity of the results. More deep information about the Near-Field SR computation method used can be found in the section "Theoretical Notes" of the chapter "Near Field Computation".
7. The electric field of synchrotron radiation can be computed from the input Magnetic Field and Electron Beam structures or from a Trajectory structure. For an electron travelling in a transversely-uniform magnetic field (which is an appropriate approximation for many SR sources), the SR computation from the trajectory gives the same results as the computation from the magnetic field. However, if the transverse magnetic field is not uniform along the electron trajectory (that may happen, for example, in a very long insertion device or in a quadrupole lenses), the computation from the trajectory is a more correct and only recommended method.
8. In the case of transversely-uniform magnetic field, a Trajectory structure can be created from Magnetic Field and Electron Beam structures by the macro SrwTrjCreateTransvUnif (menu call "...Arbitrary Magnetic Field -> Create Trajectory..."). In a more general case, the Trajectory structure describing properly computed electron trajectory should be supplied by user.

   Format of the Trajectory structure.

   The Trajectory structure is a TEXT wave with the following records in its fields:

   - **0 - name of a scaled 1D numerical wave defining the Horizontal Position [m] vs Longitudinal**

     Position [m];

- # 1 - name of a scaled 1D numerical wave defining the Vertical Position [m] vs Longitudinal

  Position [m];

- # 2 - ascii string representing a decimal number of the Electron Energy;

- # 3 - ascii string representing a decimal number of the Electron Current.

9. This macro performs computation of the SR electric field, but it does not visualize the computation results. To visualize the results, i.e., to extract and plot the SR component of desired polarization, one needs to invoke the Visualize dialog box (menu "Visualize...") and specify proper settings there.
10. The SR electric field is computed for the filament electron beam, i.e. only filament electron beam parameters specified in the Electron Beam dialog box (or by the macro **SrwElecFilament**) are taken into account at this stage. These parameters are: energy, current and initial transverse coordinates and angles of the electron trajectory together with the longitudinal position to which they relate.
11. Please make sure that the **initial transverse coordinates and angles of the electron trajectory together with the longitudinal position to which they relate agree with the magnetic field definition and the radiation sampling range.**

    For example, in order to get the maximum of the central cone of Undulator Radiation at zero transverse position, one needs to set to zero the initial transverse coordinates and angles of the electron trajectory at the longitudinal position before the undulator, where the magnetic field is zero or almost zero (but not out of the magnetic field definition range !).

12. The SR Intensity distributions that correspond to a "thick" (finite-emittance) electron beam can be obtained at the stage of visualization of the SR computation results using the Visualize dialog box (menu "Visualize..."). A convolution method is applied for this. See the reference record for the Visualize dialog box and the chapter "Near Field Computation" for more details.
13. If the user has chosen to "Use Automatic Radiation Sampling" (see the dialog box), then the Horizontal and Vertical Point Numbers specified in the Radiation Sampling structure are ignored. Instead, the code uses such

Horizontal and Vertical Point Numbers that correspond approximately to the minimum required for further propagation of the Wavefront with the Range of horizontal and vertical position defined by the Radiation Sampling structure. The Oversampling Factor, which can be <1 or="">1, allows to manually steer the numbers of points with respect to the above criterion.

14. In order to program more types of computation or manipulations with the SR Wavefront which are not implemented in SRW, one may find it necessary to use directly the SRW Wavefront structure (for example, to access the SR electric field data, etc.). For such a case we note, that the Wavefront structure is a 1D TEXT wave that keeps in its first two fields the names of two complex 3D waves describing the horizontal and vertical components of the SR electric field in frequency domain. Each of these complex 3D waves contains a cube of the complex electric field data in which:
    - ROWS correspond to the scan vs Photon Energy;
    - COLUMNS correspond to the scan vs Horizontal Position;
    - LAYERS correspond to the scan vs Vertical Position. The units of the computed electric field are (Photons/s/0.1%bw/mm^2)^(1/2) (to facilitate extraction of the spectral flux per unit surface in Photons/s/0.1%bw/mm^2).
15. Other fields of the Wavefront structure (1D TEXT wave) contain more information necessary for manipulations with the wavefront, among which there are names of two numeric waves of Statistical Moments of the computed horizontal and vertical polarization components of the radiation. By viewing the Statistical Moments of the computed SR (menu "Utilities->View SRW Structures...", structures ending by "_mom"), one can get a lot of useful information about the SR Wavefront: integrated spectral flux (in Photons/s/0.1%bw), RMS sizes and divergences (don't mix this with the RMS sizes and divergences of the electron beam!), etc.
16. The full name of the Wavefront structure was generated according to the following rule:

    \ = \ + "_rad", where "_rad" is the type identifier of a Wavefront structure.

    The full names of the Horizontal and Vertical electric field component waves were generated according to the following rule:

    \ = \ + ("X" or "Z") + "_rae",

    where "X" ("Z") corresponds to Horizontal (Vertical) electric field component, "_rae" is the type identifier of an Electric Field Component wave.

    The full names of the waves of Statistical Moments of Horizontal and Vertical electric field were generated according to the following rule:

    \ = \ + ("X" or "Z") + "_mom",

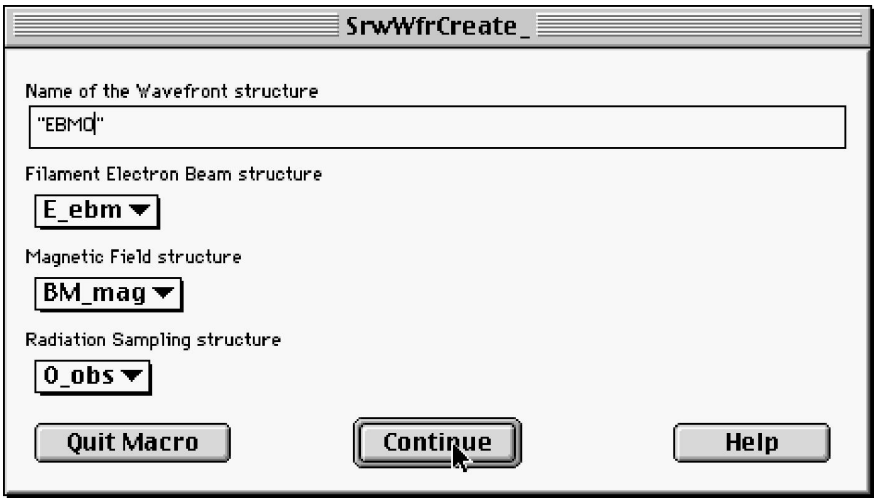
    where "X" ("Z") corresponds to Horizontal (Vertical) electric field component, "_mom" is the type identifier of a wave of Statistical Moments of the electric field.

17. Depending on the settings chosen in the dialog box, this macro invokes one or several lowlevel macros of SRW that can be used at programming in Igor

macro language: **SrwMagPrec**, **SrwWfrCreate_**, **SrwWfrCreate**, **SrwWfrCreateFromTrj_**, **SrwWfrCreateFromTrj**. The invoked macros are printed in the Igor History window with the input parameter values used.

SrwWfrCreate_

Dialog Box:



Definition:

Proc SrwWfrCreate(wfname,elname,magname,smpname)

String wfname,elname,magname,smpname

Action:

Creates a SR Wavefront structure with name "wfname", i.e. computes the horizontal and vertical components of the near-field electric field of Synchrotron Radiation in frequency domain, produced by a filament electron beam defined by the structure "elname" in magnetic field defined by the structure "magname", according to the radiation sampling parameters defined by the structure "smpname".

Details:

1. The Mode of Integration for the SR computation is specified by the macro SrwMagPrec (menu call "(Arbitrary) Magnetic Field->Mode of Integration..."). It is important to make several cycles of the SR computation with different values of the integration parameters specified by that macro (see the Reference Manual record on that macro for details about different Modes of Integration). After each cycle of computation, the results can be visualized (menu call "Visualize..."). Independence of the computation results on the integration parameters (at a given precision level) is the necessary condition for the validity of the results. More deep information about the Near-Field SR computation method used can be found in the section "Theoretical Notes" of the chapter "Near Field Computation".
2. This macro performs computation of the SR electric field, but it does not visualize the computation results. To visualize the results, i.e., to extract and plot the SR component of desired polarization, one needs to invoke the

Visualize dialog box (menu call "Visualize...") and specify proper settings there.

3. The SR electric field is computed for the filament electron beam, i.e. only filament electron beam parameters specified in the Electron Beam dialog box (or by the macro **SrwElecFilament**) are taken into account at this stage. These parameters are: energy, current and initial transverse coordinates and angles of the electron trajectory together with the longitudinal position to which they relate.
4. Please make sure that the initial transverse coordinates and angles of the electron trajectory together with the longitudinal position to which they relate agree with the magnetic field definition and the radiation sampling range.

   For example, in order to get the maximum of the central cone of Undulator Radiation at zero transverse position, one needs to set to zero the initial transverse coordinates and angles of the electron trajectory at the longitudinal position before the undulator, where the magnetic field is zero or almost zero (but not out of the magnetic field definition range !).

5. The SR Intensity distributions that correspond to a "thick" (finite-emittance) electron beam can be obtained at the stage of visualization of the SR computation results using the Visualize dialog box (menu "Visualize..."). A convolution method is applied for this. See the reference record for the Visualize dialog box and the chapter "Near Field Computation" for more details.
6. The Wavefront structure created is actually a text wave that keeps the names of two complex 3D waves describing horizontal and vertical components of the electric field, two numeric waves with the values of the first- and second-order statistical moments of the computed radiation and some other information necessary for manipulations (propagation, resizing) with the wavefront. The manipulations modify the wavefront structure (electric field, moments and other relevant parameters).
7. The full name of the Wavefront structure was generated according to the following rule:

   \ = \ + "_rad",

   where "_rad" is the type identifier of a Wavefront structure.

   The full names of the Horizontal and Vertical Electric Field component waves were generated according to the following rule:

   \ = \ + ("X" or "Z") + "_rae",

   where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_rae" is the type identifier of an Electric Field Component wave. The full names of the waves of Statistical Moments of Horizontal and Vertical Electric Field were generated according to the following rule:

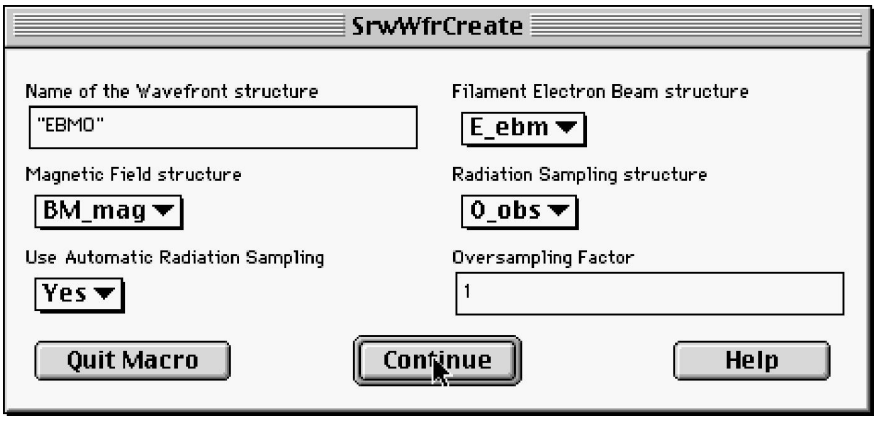
   \ = \ + ("X" or "Z") + "_mom",

   where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_mom" is the type identifier of a wave of Statistical Moments of Electric Field.

8. By viewing the Statistical Moments of the computed SR (menu "Utilities->View SRW Structures...", structures ending by "_mom"), one can get a lot of useful information about the SR Wavefront: integrated flux (number of photons), RMS sizes and divergences (don't mix this with the RMS sizes and divergences of the electron beam!), etc.

SrwWfrCreate

Dialog Box:



Definition:

Proc SrwWfrCreate(wfname,elname,magname,smpname,autosmp,smpfact)

String wfname,elname,magname,smpname

Variable autosmp,smpfact

Action:

Creates a SR Wavefront structure with name "wfname", i.e. computes the horizontal and vertical components of the near-field electric field of Synchrotron Radiation in frequency domain, produced by a filament electron beam defined by the structure "elname" in magnetic field defined by the structure "magname", according to the radiation sampling parameters defined by the structure "smpname". The user can choose to "Use Automatic Radiation Sampling" for further Wavefront propagation or not (autosmp=2 or 1 respectively) and specify an Oversampling Factor with respect to the minimal sampling required for the Wavefront propagation (smpfact).

Details:

1. The Mode of Integration for the SR computation is specified by the macro **SrwMagPrec** (menu call "Magnetic Field->Mode of Integration..."). It is important to make several cycles of the SR computation with different values of the integration parameters specified by that macro (see the Reference Manual record on that macro for details about different Modes of Integration). After each cycle of computation, the results can be visualized by the macro **SrwWfr2Int** (menu call "Visualize..."). Independence of the computation results on the integration parameters (at a given precision level) is the necessary condition for the validity of the results (however, it is not at all a sufficient condition...). More deep information about the Near-Field SR

computation method used can be found in the section "Theoretical Notes" of the chapter "Near Field Computation".

2. This macro performs computation of the SR electric field, but it does not visualize the computation results. To visualize the results, i.e., to extract and plot the SR component of desired polarization, one needs to invoke the Visualize dialog box (menu call "Visualize...") and specify proper settings there.
3. The SR electric field is computed for the filament electron beam, i.e. only filament electron beam parameters specified in the Electron Beam dialog box (or by the macro SrwElecFilament) are taken into account at this stage. These parameters are: energy, current and initial transverse coordinates and angles of the electron trajectory together with the longitudinal position to which they relate.
4. Please make sure that the **initial transverse coordinates and angles of the electron trajectory together with the longitudinal position to which they relate agree with the magnetic field definition and the radiation sampling range.**

   For example, in order to get the maximum of the central cone of Undulator Radiation at zero transverse position, one needs to set to zero the initial transverse coordinates and angles of the electron trajectory at the longitudinal position before the undulator, where the magnetic field is zero or almost zero (but not out of the magnetic field definition range !).

5. The SR Intensity distributions that correspond to a "thick" (finite-emittance) electron beam can be obtained at the stage of visualization of the SR computation results using the Visualize dialog box (menu "Visualize..."). A convolution method is applied for this. See the reference record for the Visualize dialog box and the chapter "Near Field Computation" for more details.
6. If the user has chosen to "Use Automatic Radiation Sampling" (see the dialog box), then the Horizontal and Vertical Point Numbers specified in the Radiation Sampling structure are ignored. Instead, the code uses such Horizontal and Vertical Point Numbers that correspond approximately to the minimum required for further propagation of the Wavefront with the Range of horizontal and vertical position defined by the Radiation Sampling structure. The Oversampling Factor, which can be <1 or="">1, allows to manually "steer" the numbers of points with respect to the above criterion.
7. Please note that the computation of the SR wavefront which is suitable for further Propagation may take a lot of CPU time (up to several 10s of minutes at 200 MHz) and memory (0 - 10 MB). The larger is the Sampling Range of the wavefront to be propagated, the larger is the Number of Points where the SR should be computed (much stronger than linearly).
8. The Wavefront structure created is actually a text wave that keeps the names of two complex 3D waves describing Horizontal and Vertical components of the electric field, two numeric waves with the values of the first- and second-order Statistical Moments of the computed radiation and some other information which is necessary for manipulations (propagation, resizing) with

the wavefront. The manipulations modify the Wavefront structure (Electric Field, Moments and other relevant parameters).

9. The full name of the Wavefront structure was generated according to the following rule:

   \ = \ + "_rad",

   where "_rad" is the type identifier of a Wavefront structure.

   The full names of the Horizontal and Vertical electric field component waves were generated according to the following rule:

   \ = \ + ("X" or "Z") + "_rae",

   where "X" ("Z") corresponds to Horizontal (Vertical) electric field component, "_rae" is the type identifier of an Electric Field Component wave.

   The full names of the waves of Statistical Moments of Horizontal and Vertical electric field were generated according to the following rule:

   \ = \ + ("X" or "Z") + "_mom",

   where "X" ("Z") corresponds to Horizontal (Vertical) electric field component, "_mom" is the type identifier of a wave of Statistical Moments of electric field.

10. By viewing the Statistical Moments of the computed SR (menu "Utilities->View SRW Structures..."), one can get a lot of useful information about the SR Wavefront: integrated flux (number of photons), RMS sizes and divergences (don't mix these with the RMS sizes and divergences of the electron beam!), etc.

SrwWfrCreateFromTrj_

Definition:

Proc SrwWfrCreateFromTrj_(wfname,trjname,smpname,mode,prec,diflim,sdep,sfin)

String wfname,trjname,smpname

Variable mode,prec,diflim,sdep,sfin

Action:

Creates a SR Wavefront structure with name "wfname", i.e. computes the horizontal and vertical components of the near-field electric field of Synchrotron Radiation in frequency domain emitted from a filament electron beam trajectory described by the structure "trjname", according to the radiation sampling parameters defined by the structure "smpname". The user needs to specify mode of longitudinal integration (mode=1/2/3: "Manual"/"Auto Undulator"/"Auto Wiggler"), step for manual integration or relative precision for automatic integration (prec), whether any special integration limits that differ from the trajectory definition limits should be used at the longitudinal integration (lim=2) or not (lim=1). The initial and final longitudinal positions (sdep and sfin) are taken into account only if one has chosen to use special integration limits (lim=2).

Details:

1. This macro performs computation of the SR Electric Field, but it does not visualize the computation results. To visualize the results, i.e., to extract and plot the SR Intensity Distribution of desired polarization, or other SR characteristics, one needs to execute the macro **SrwWfr2Int** (menu call "Visualize...") with proper settings.
2. The SR Electric Field is computed for the Filament Electron Beam, i.e. only Filament Electron Beam parameters specified by the macro **SrwElecFilament** are taken into account at this stage. These parameters are: energy, current and initial transverse coordinates and angles of the electron trajectory together with the longitudinal position to which they relate.
3. For details on the methods for longitudinal integration see the Reference Manual record on the macro **SrwMagPrec**.
4. The Wavefront structure created is actually a text wave that keeps the names of two complex 3D waves describing Horizontal and Vertical components of the Electric Field, two numeric waves with the values of the first- and second-order Statistical Moments of the computed radiation and some other information which is necessary for manipulations (propagation, resizing) with the wavefront. The manipulations modify the Wavefront structure (Electric Field, Moments and other relevant parameters).
5. The full name of the Wavefront structure was generated according to the following rule:

   \ = \ + "_rad",

   where "_rad" is the type identifier of a Wavefront structure.

   The full names of the Horizontal and Vertical Electric Field component waves were generated according to the following rule:

   \ = \ + ("X" or "Z") + "_rae",

   where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_rae" is the type identifier of an Electric Field Component wave.

   The full names of the waves of Statistical Moments of Horizontal and Vertical Electric Field were generated according to the following rule:

   \ = \ + ("X" or "Z") + "_mom",

   where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_mom" is the type identifier of a wave of Statistical Moments of Electric Field.

6. By viewing the Statistical Moments of the computed SR (menu "Utilities->View SRW Structures..."), one can get a lot of useful information about the SR wavefront: integrated flux (number of photons), RMS sizes and divergences (don't mix these with the RMS sizes and divergences of the electron beam!), etc.

SrwWfrCreateDialoSrwWfrCreateFromTrjg

Definition:

Proc

SrwWfrCreateFromTrj(wfname,trjname,smpname,mode,prec,diflim,sdep,sfin,autosmp,smpfact)

String wfname,trjname,smpname

Variable mode,prec,diflim,sdep,sfin,autosmp,smpfact

Action:

Creates a SR Wavefront structure with name "wfname", i.e. computes the horizontal and vertical components of the near-field electric field of Synchrotron Radiation in frequency domain emitted from a filament electron beam trajectory described by the structure "trjname", according to the radiation sampling parameters defined by the structure "smpname". The user needs to specify mode of longitudinal integration (mode=1/2/3: "Manual"/"Auto Undulator"/"Auto Wiggler"), step for manual integration or relative precision for automatic integration (prec), whether any special integration limits that differ from the trajectory definition limits should be used at the longitudinal integration (lim=2) or not (lim=1). The initial and final longitudinal positions (sdep and sfin) are taken into account only if one has chosen to use special integration limits (lim=2). The user can choose to "Use Automatic Radiation Sampling" for further wavefront propagation or not (autosmp=2 or 1 respectively) and specify an Oversampling Factor with respect to the minimal sampling required for the wavefront propagation (smpfact).

Details:

1. This macro performs computation of the SR Electric Field, but it does not visualize the computation results. To visualize the results, i.e., to extract and plot the SR Intensity Distribution of desired polarization, or other SR characteristics, one needs to execute the macro **SrwWfr2Int** (menu call "Visualize...") with proper settings.
2. The SR Electric Field is computed for the Filament Electron Beam, i.e. only Filament Electron Beam parameters specified by the macro **SrwElecFilament** are taken into account at this stage. These parameters are: energy, current and initial transverse coordinates and angles of the electron trajectory together with the longitudinal position to which they relate.
3. For details on the methods for longitudinal integration see the Reference Manual record on the macro **SrwMagPrec**.
4. The Wavefront structure created is actually a text wave that keeps the names of two complex 3D waves describing Horizontal and Vertical components of the Electric Field, two numeric waves with the values of the first- and second-order Statistical Moments of the computed radiation and some other information which is necessary for manipulations (propagation, resizing) with the wavefront. The manipulations modify the Wavefront structure (Electric Field, Moments and other relevant parameters).
5. If the user has chosen to "Use Automatic Radiation Sampling" (see the dialog box), then the Horizontal and Vertical Point Numbers specified in the Radiation Sampling structure are ignored. Instead, the code uses such Horizontal and Vertical Point Numbers that correspond approximately to the minimum required for further propagation of the wavefront with the Range of

horizontal and vertical position defined by the Radiation Sampling structure. The Oversampling Factor, which can be <1 or="">1, allows to manually "steer" the numbers of points with respect to the above criterion.

6. The full name of the Wavefront structure was generated according to the following rule:

   \ = \ + "_rad",

   where "_rad" is the type identifier of a Wavefront structure.

   The full names of the Horizontal and Vertical Electric Field component waves were generated according to the following rule:

   \ = \ + ("X" or "Z") + "_rae",

   where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_rae" is the type identifier of an Electric Field Component wave.

   The full names of the waves of Statistical Moments of Horizontal and Vertical Electric Field were generated according to the following rule:

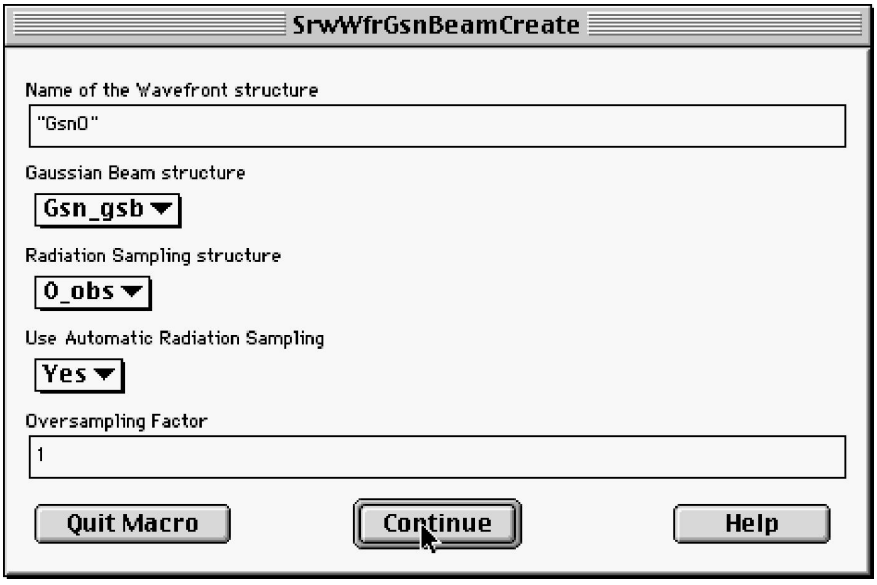
   \ = \ + ("X" or "Z") + "_mom",

   where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_mom" is the type identifier of a wave of Statistical Moments of Electric Field.

7. By viewing the Statistical Moments of the computed SR (menu "Utilities->View SRW Structures..."), one can get a lot of useful information about the SR wavefront: integrated flux (number of photons), RMS sizes and divergences (don't mix these with the RMS sizes and divergences of the electron beam!), etc.

SrwWfrGsnBeamCreate

Dialog Box:



Definition:

Proc SrwWfrGsnBeamCreate(wfname,gbname,smpname,autosmp,smpfact)

String wfname,gbname,smpname

Variable autosmp,smpfact

Action:

Creates a Wavefront structure with name "wfname" and fills it by the electric field data (in frequency domain) simulating a Gaussian beam defined by the structure "gbname", according to the radiation sampling parameters defined by the structure "smpname". The user can choose to "Use Automatic Radiation Sampling" for further wavefront propagation or not (autosmp=2 or 1 respectively) and specify an Oversampling Factor with respect to the minimal sampling required for the wavefront propagation (smpfact).

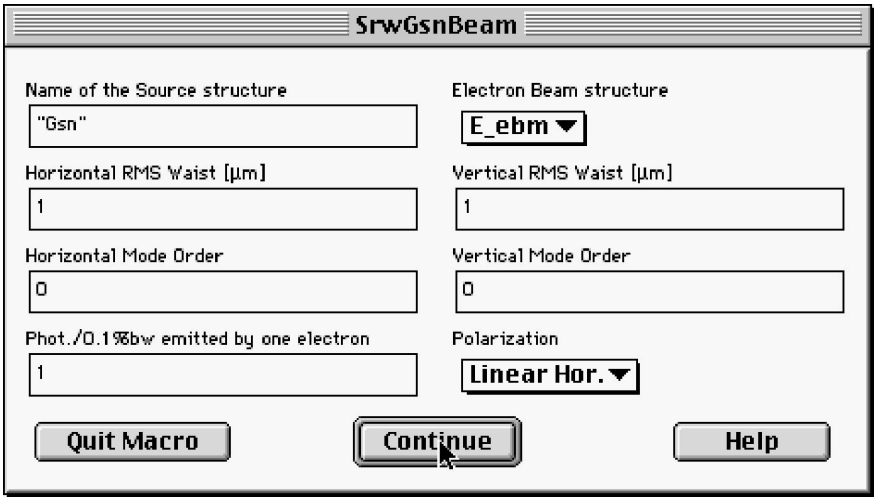
Details:

1. Before calling this macro, one needs to set up a Gaussian Beam structure by executing the macro **SrwGsnBeam** (menu call "...TEM Mode...").
2. This macro performs computation of electric field of a Gaussian beam, but it does not visualize the computation results. To visualize the results, i.e., to extract and plot the Singleelectron or Multi-electron intensity distribution of desired polarization, or other wavefront characteristics, one needs to execute the macro **SrwWfr2Int** (menu call "Visualize...") with proper settings.
3. If the user has chosen to "Use Automatic Radiation Sampling" (see the dialog box), then the Horizontal and Vertical Point Numbers specified in the Radiation Sampling structure are ignored. Instead, the code uses such horizontal and vertical point numbers that correspond approximately to the minimum required for further propagation of the Wavefront with the Ranges of horizontal and vertical position defined by the Radiation Sampling structure. The Oversampling Factor, which can be <1 or="">1, allows to manually steer the numbers of points with respect to the above criterion.
4. The Wavefront structure created is actually a text wave that keeps the names of two complex 3D waves describing Horizontal and Vertical components of the Electric Field, two numeric waves with the values of the first- and second-order Statistical Moments of the computed radiation and some other information which is necessary for manipulations (propagation, resizing) with the Wavefront. The manipulations will further modify the Wavefront structure (Electric Field, Moments and other relevant parameters).
5. The full name of the Wavefront structure was generated according to the following rule: = + "_rad", where "_rad" is the type identifier of a Wavefront structure. The full names of the Horizontal and Vertical Electric Field component waves were generated according to the following rule: = + ("X" or "Z") + "_rae", where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_rae" is the type identifier of an Electric Field Component wave. The full names of the waves of Statistical Moments of Horizontal and Vertical Electric Field were generated according to the following rule: = + ("X" or "Z") + "_mom", where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_mom" is the type identifier of a wave of Statistical Moments of Electric Field.

6. By viewing the Statistical Moments of the computed radiation (menu "Utilities->View SRW Structures..."), one can get a lot of useful information about the Wavefront: integrated spectral flux (number of photons), RMS sizes and divergences (don't mix with the RMS sizes and divergences of the electron beam!), etc.

SrwGsnBeam

Dialog Box:



Definition:

Proc SrwGsnBeam(gbname,elname,wx,wz,mx,mz,phot,polar)

String gbname,elname

Variable wx,wz,mx,mz,phot,polar

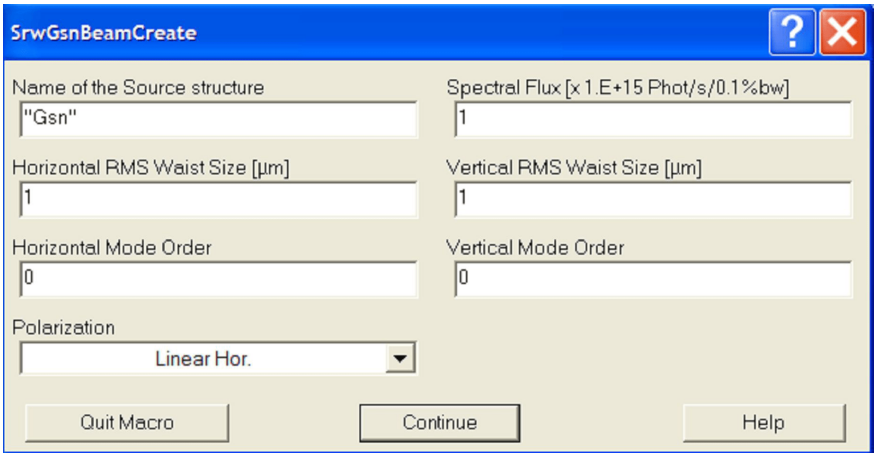
Action: Creates a Gaussian Beam structure with name "gbname" and fills it with the following parameters: name of the Electron Beam structure defining the location and orientation of the Gaussian beam ("elname"), horizontal and vertical RMS waist sizes of the Gaussian beam at the "source point" (wx,wz), horizontal and vertical orders of the Gaussian beam modes (mx,mz), number of photons per 0.1% bandwidth emitted by one electron (phot), and the electric field polarization (polar).

Details:

1. The Electron Beam structure defines position and orientation of the gaussian beam source in space.
2. The spectral power of the source if deduced from the number of photons per 0.1% bandwidth emitted by one electron and the current value specified in the Electron Beam structure. Different electrons are assumed to emit incoherently.
3. Possible choices of the polarization are: Linear Horizontal, Linear Vertical, Linear 45 deg., Linear 135 deg., Circular Right and Circular Left.

SrwGsnBeamCreate

Dialog Box:



Definition:

Proc SrwGsnBeamCreate(gbname,flux,wx,wz,mx,mz,polar)

String gbname

Variable flux,wx,wz,mx,mz,polar

Action:

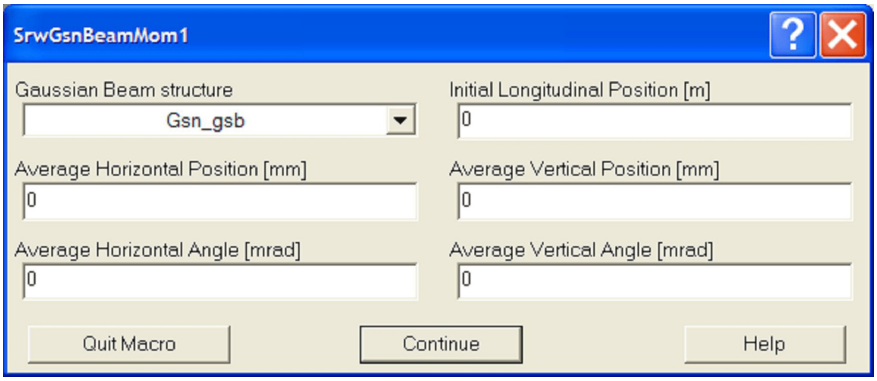
Initiates a Gaussian Beam structure with name "gbname" and fills it with the following parameters: total spectral flux of the Gaussian beam, i.e. total number of photons per second per 0.1% relative spectral bandwidth (flux), horizontal and vertical RMS waist sizes of the Gaussian beam at the "source point" (wx,wz), horizontal and vertical orders of the Gaussian beam modes (mx,mz) and the electric field polarization (polar).

Details:

1. If the initial average transverse positions and angles of the Gaussian beam are not zero, one can setup these values by calling the macro **SrwGsnBeamMom1**.
2. The Gaussian beam time structure can be specified by the macro **SrwGsnBeamTime**.
3. Possible choices of the polarization are: Linear Horizontal, Linear Vertical, Linear 45 deg., Linear 135 deg., Circular Right and Circular Left.
4. To calculate the Wavefront corresponding to this Gaussian beam structure, at a given longitudinal position with a given sampling, one should call the macro **SrwWfrGsnBeamCreate**.

SrwGsnBeamMom1

Dialog Box:



Definition:

Proc SrwGsnBeamMom1(gbname,s0,x0,z0,xp0,zp0)

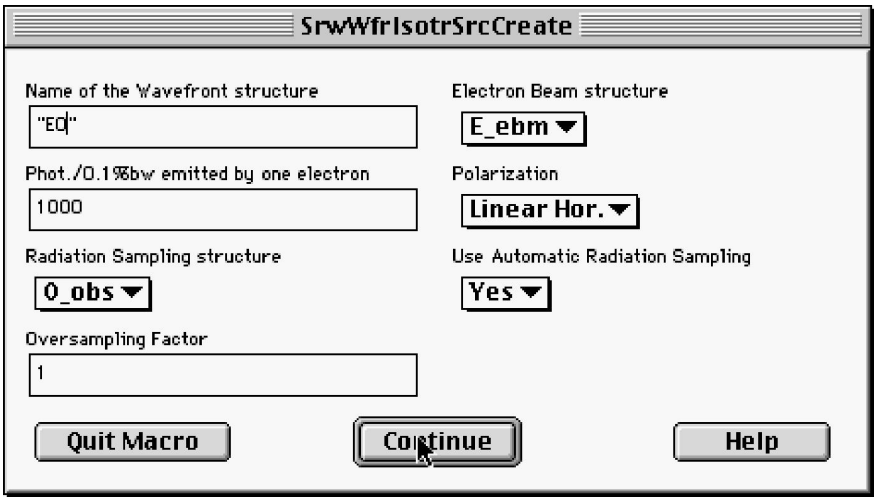
String gbname

Variable s0,x0,z0,xp0,zp0

Action: Specifies, for a Gaussian beam named "gbname", initial average transverse coordinates (x0, z0, in mm) and angles (xp0, zp0, in mrad), at longitudinal position s0 (in m).

SrwWfrIsotrSrcCreate

Dialog Box:



Definition:

Proc SrwWfrIsotrSrcCreate(wfname,elname,phot,polar,smpname,autosmp,smpfact)

String wfname,elname

Variable phot,polar

String smpname

Variable autosmp,smpfact

Action: Creates a Wavefront structure with name "wfname" and fills it by the electric field data (in frequency domain) simulating an isotropic source. The location of the source is specified by the Electron Beam structure with name

"elname". The user needs to specify number of photons per 0.1% bandwidth emitted by one electron (phot), electric field polarization (polar), the name of the Radiation Sampling structure for the wavefront ("smpname"). One can choose to "Use Automatic Radiation Sampling" for further wavefront propagation or not (autosmp=2 or 1 respectively) and specify an Oversampling Factor with respect to the minimal sampling required for the wavefront propagation (smpfact).

Details:

1. The Electron Beam structure defines position and orientation of the source in space.
2. The spectral power of the source if deduced from the number of photons per 0.1% bandwidth emitted by one electron and the current value specified in the Electron Beam structure. Different electrons are assumed to emit incoherently.
3. Possible choices of the polarization are: Linear Horizontal, Linear Vertical, Linear 45 deg., Linear 135 deg., Circular Right and Circular Left.
4. This macro performs computation of electric field of a Gaussian beam, but it does not visualize the computation results. To visualize the results, i.e., to extract and plot the Singleelectron or Multi-electron intensity distribution of desired polarization, or other wavefront characteristics, one needs to execute the macro **SrwWfr2Int** (menu call "Visualize...") with proper settings.
5. If the user has chosen to "Use Automatic Radiation Sampling" (see the dialog box), then the Horizontal and Vertical Point Numbers specified in the Radiation Sampling structure are ignored. Instead, the code uses such horizontal and vertical point numbers that correspond approximately to the minimum required for further propagation of the wavefront with the Ranges of horizontal and vertical position defined by the Radiation Sampling structure. The Oversampling Factor, which can be <1 or="">1, allows to manually steer the numbers of points with respect to the above criterion.
6. The Wavefront structure created is actually a text wave that keeps the names of two complex 3D waves describing Horizontal and Vertical components of the Electric Field, two numeric waves with the values of the first- and second-order Statistical Moments of the computed radiation and some other information which is necessary for manipulations (propagation, resizing) with the Wavefront. The manipulations will further modify the Wavefront structure (Electric Field, Moments and other relevant parameters).
7. The full name of the Wavefront structure was generated according to the following rule:

   \ = \ + "_rad",

   where "_rad" is the type identifier of a Wavefront structure.

   The full names of the Horizontal and Vertical Electric Field component waves were generated according to the following rule:

   \ = \ + ("X" or "Z") + "_rae",

   where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_rae" is the type identifier of an Electric Field Component wave.

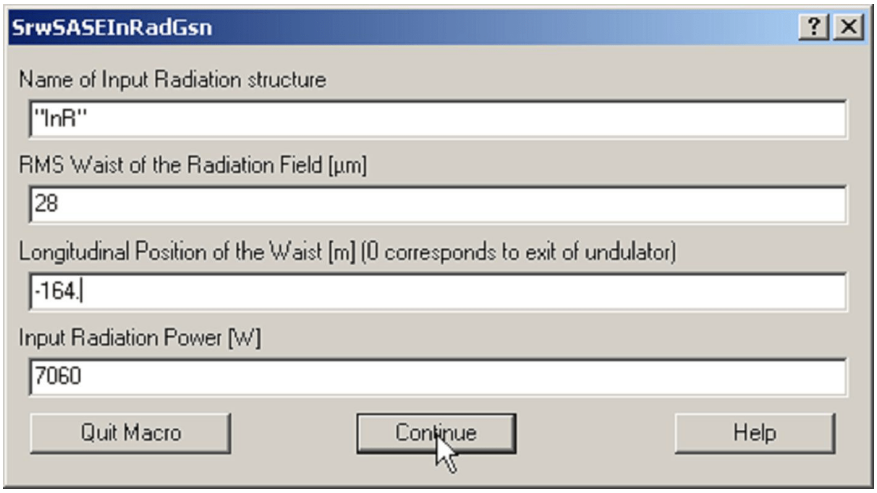
The full names of the waves of Statistical Moments of Horizontal and Vertical Electric Field were generated according to the following rule:

\ = \ + ("X" or "Z") + "_mom",

where "X" ("Z") corresponds to Horizontal (Vertical) Electric Field component, "_mom" is the type identifier of a wave of Statistical Moments of Electric Field.

SrwSASEInRadGsn

Dialog Box:



Definition:

Proc SrwSASEInRadGsn(inrname,w,wpos,pow)

String inrname

Variable w,wpos,pow

Action:

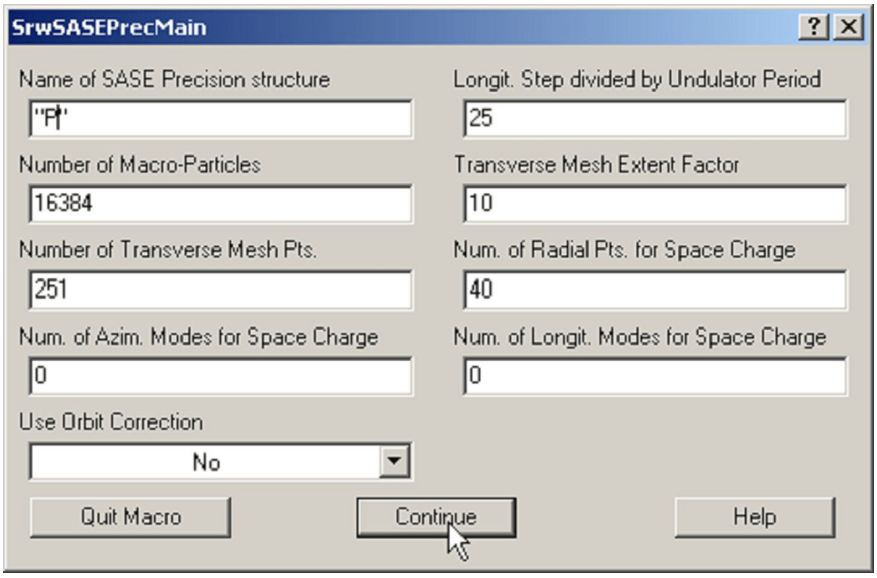
Creates a Gaussian beam Input Radiation structure for SASE computation with name "inrname" and fills it with the following parameters: RMS waist of the radiation field (w), longitudinal position of the waist in m (wpos), radiation power in W (pow).

Details:

1. This macro defines the Input Radiation as a Gaussian beam (TEM00 mode).
2. Zero longitudinal position corresponds to the end of the SASE undulator.

SrwSASEPrecMain

Dialog Box:



Definition:

Proc SrwSASEPrecMain(pname,delz,npart,rmax0,ncar,nptr,nscr,nscz,iorb)

String pname

Variable delz,npart,rmax0,ncar,nptr,nscr,nscz,iorb

Action:

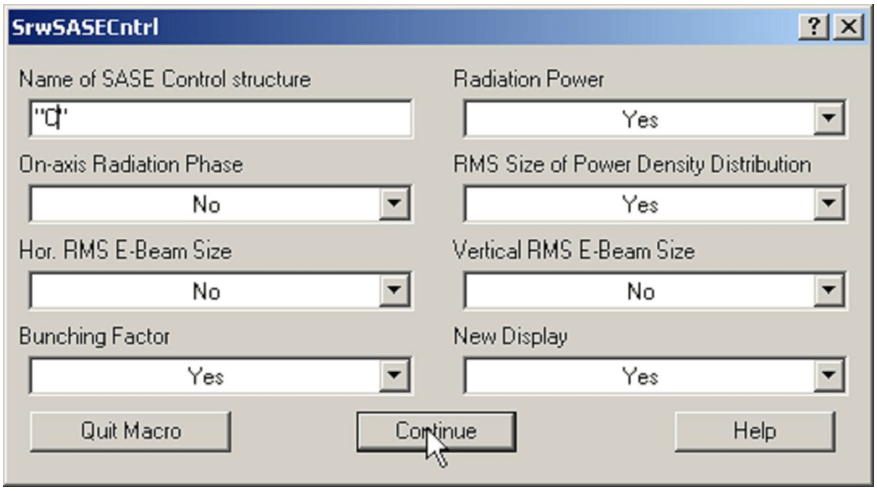
Creates a Precision structure for SASE computation with name "pname" and fills it with the following parameters: longitudinal step in units of undulator period (delz), number of macroparticles (npart), transverse mesh extent factor (rmax0), number of transverse mesh points in horizontal and vertical directions (ncar), number of radial grid points where the space charge field is evaluated (nptr), number of azimuthal modes for space charge computation (nscr), number of longitudinal modes for space charge computation (nscz). One can choose to use or not to use orbit correction at the computation (iorb=2 or 1 respectively).

Details:

1. The precision parameters specified by this macro are mainly inherited from the GENESIS 1.3 SASE code developed at DESY by S.Reiche et. al. For more information, one can refer to the GENESIS 1.3 documentation available from the DESY web site (see section "Mesh Parameters" in this documentation).

SrwSASECntrl

Dialog Box:



Definition:

Proc SrwSASECntrl(cname,ipow,iphase,irsize,iehsize,ievsize,ibunch,idisp)

String cname

Variable ipow,iphase,irsize,iehsize,ievsize,ibunch,idisp

Action:

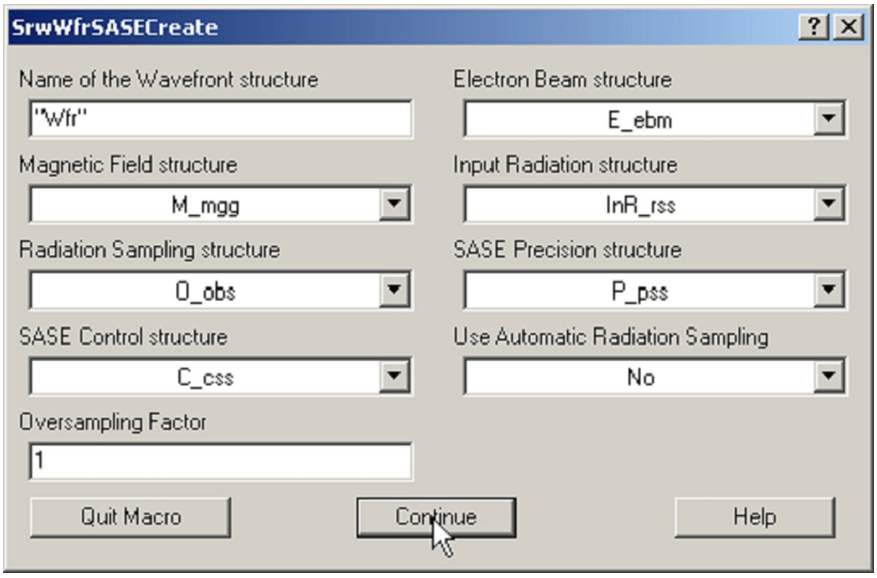
Creates a SASE computation Control structure with name "cname" and fills it with the values of "switch" variables, indicating whether particular SASE characteristics should be displayed in graphs vs longitudinal position as the computation progresses or not. The following characteristics can be displayed: radiation power (ipow=2), on-axis radiation phase (iphase=2), RMS size of the power density distribution (irsize=2), horizontal RMS size of the electron beam (iehsize=2), vertical RMS size of the electron beam (ievsize=2), bunching factor (ibunch=2). One can specify whether the control characteristics should be displayed in new windows (idisp=2), or in already existing windows (if any).

Details:

1. The structure created by this macro should be passed as argument to the macro SrwWfrSASECreate, which performs the SASE computation.

SrwWfrSASECreate

Dialog Box:



Definition:

Proc

SrwWfrSASECreate(wfname,elname,mname,inrname,smpname,pname,cname,asmp,fsmp)

String wfname,elname,mname,inrname,smpname,pname,cname

Variable asmp,fsmp

Action:

Performs steady state SASE computation and produces, as a result of this computation, the Radiation Wavefront (i.e. complex electric field) structure with name "wfname". The SASE computation is performed for the electron beam defined by the structure "elname", in magnetic field of an undulator defined by the structure "mname", with the initial wavefront defined by the structure "inrname". The final wavefront is computed at a grid and at a longitudinal position defined by the radiation sampling structure "smpname". The SASE Precision and Control structures (with names "pname" and "cname" respectively) must be supplied. The user can choose to "Use Automatic Radiation Sampling" for further Wavefront propagation or not (asmp=2 or 1 respectively) and specify an Oversampling Factor with respect to the minimal sampling required for the Wavefront propagation (fsmp).

Details:

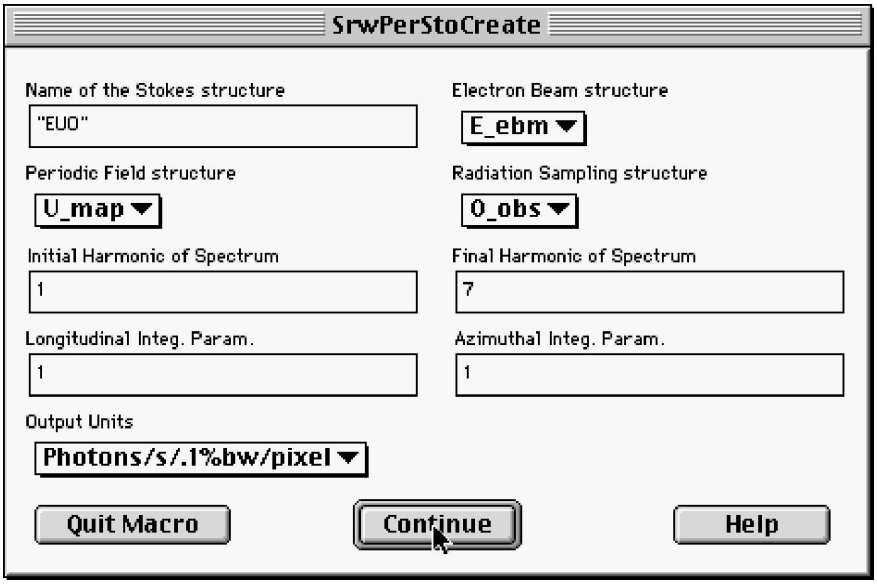
1. The implementation the SASE computation is based on the GENESIS 3D code developed at DESY by S.Reiche et. al. For better inter-operation with other parts of SRW, this FORTRAN code was converted (with minor modifications) to C and re-compiled as a shared library.
2. The SASE computation in SRW is currently limited by numerical solution of the steady state paraxial FEL equations at the approximation of slowly varying amplitude of the radiation field. If electron beam and FEL undulator parameters, together with the wavelength of observed radiation, are tuned properly, one can simulate the radiation wavefront amplification in the

undulator due to interaction with the electron beam. The wavefront (i.e. complex electric field of the radiation) obtained after this simulation, can be used for further manipulations / propagation through optical elements using the methods of Fourier optics implemented in the SRWP.

3. This computation does not take into account a number of important factors and processes (e.g. time dependence, stochastic "origin" of the SASE, "competition" of modes, possible degradation of transverse coherence, etc.), and therefore can be used for qualitative estimations

SrwPerStoCreate

Dialog Box:



Definition:

Proc
SrwPerStoCreate(stoname,elname,magname,smpname,hst,hfin,ps,pphi,flxun)

String stoname,elname,magname,smpname

Variable hst,hfin,ps,pphi,flxun

Action:

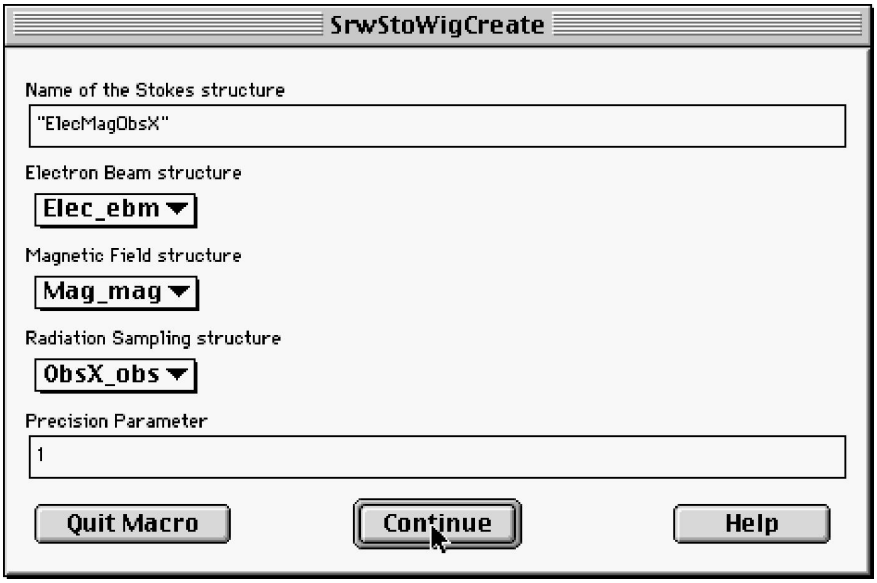
Creates a SR Stokes Components structure with name "stoname", i.e. computes Stokes components of radiation produced by electron beam described by the structure "elname" in periodic magnetic field described by the structure "magname", according to the radiation sampling parameters defined by the structure "smpname". The following additional parameters should be specified: first and last harmonic numbers of the UR spectrum to be taken into account at the computation (hst and hfin respectively), precision parameters for longitudinal and azimuthal integration (ps and pphi respectively), and physical units for the Stokes parameters to be computed (flxun=1 for Photons/s/.1%bw per pixel, 2 for Photons/s/.1%bw/mm^2).

Details:

1. This macro computes photon flux collected within a rectangular slit. The slit parameters are specified by the Radiation Sampling structure (see macros **SrwSmpCreate** and **SrwSmpScanXZE**). If numbers of points in horizontal and vertical directions of the Radiation Sampling structure are equal to 1, then the slit sizes are assumed to be equal to the corresponding (horizontal and vertical) ranges specified in the Radiation Sampling structure. If numbers of points in horizontal and vertical directions are nx > 1 and nz > 1, then the photon flux is collected separately in nx x nz pixels of equal size. In horizontal direction, the pixels size is dx = xr/(nx - 1), and pixel center coordinates are xi = i*dx + xc - xr/2, i = 1,2,...,nx, where xr and xc are, respectively, the horizontal range and center specified in the Radiation Sampling structure. The relations for the vertical direction are identical. Thus, at sufficiently small pixel sizes, the computed entity tends to the intensity distribution (i.e., flux per unit surface). The computation results may be expressed in units of Photons/s/.1%bw per pixel or Photons/s/.1%bw/mm^2.
2. The computation precision can be tuned by two parameters (ps and pphi), one of them responsible for longitudinal, the other one for azimuthal integration. By changing the parameters, one proportionally changes the numbers of points at the corresponding integration. The values of the precision parameters are set by default to 1. This corresponds to a reasonable precision for many cases of computation with different e-beam emittances, slit sizes and observation directions. However, there is no guaranty that the precision parameters equal to 1 are optimal for each particular case of computation. Therefore, we strongly advise for any new case to repeat the computation several times with different values of the precision parameters (for example, to try 0.5 and 2 for each of the parameters) in order to make sure that the final results do not depend on them on an appropriate precision level. If you see that the results change when increasing the precision parameters, you need to proceed the increasing until the results are stabilized. On the other hand, you may find that for your case of computation the precision parameters' values smaller than 1 are appropriate. Then use these smaller values in order to reduce the computation time.

SrwStoWigCreate

Dialog Box:



Definition:

Proc SrwStoWigCreate(stoname,elname,magname,smpname,prec)

String stoname,elname,magname,smpname

Variable prec

Action:

Creates a SR Stokes Components structure with name "stoname", i.e. computes Stokes components of radiation produced by a thick electron beam described by the structure "elname" in magnetic field described by the structure "magname", according to the radiation sampling parameters defined by the structure "smpname". In addition, one should specify a precision parameter for the computation (prec).

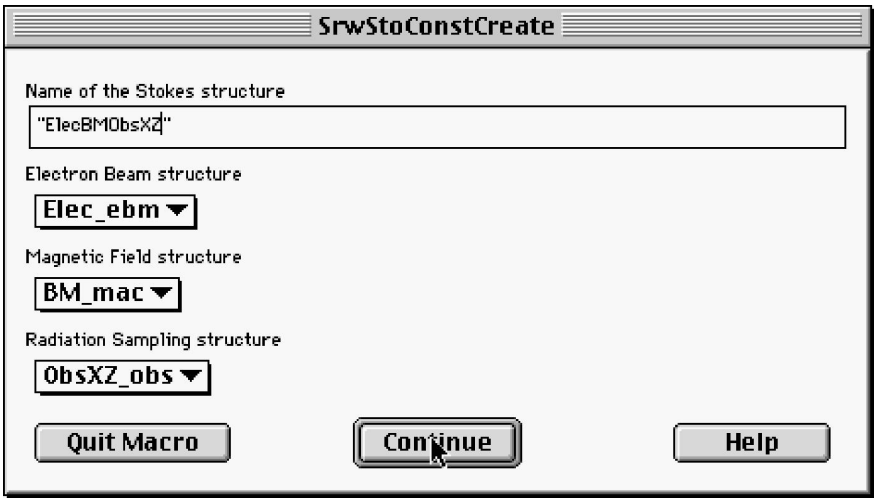
Details:

1. For this computation method to give correct results, the emission conditions should correspond to a wiggler case, i.e. the radiation is generally emitted from distinct separate parts of electron trajectory, and phase shift of the radiation between these trajectory parts is much larger than Pi.
2. The accuracy of computation can be tuned by the precision parameter prec. The value of the precision parameter is set by default to 1. This corresponds to a reasonable precision for many cases of computation with different magnetic fields. However, there is no guaranty that the precision parameter equal to 1 is optimal for each particular case of computation. Therefore, we strongly advise for any new case to repeat the computation several times with different values of the precision parameter (for example, to try 0.5 and 2) in order to make sure that the final results do not depend on it.
3. This macro accepts both periodic and arbitrary magnetic field. In the case of periodic magnetic field, the computation is performed using a far-field method, in the case of arbitrary field by a near-field method.

4. In this computation method, thick electron beam parameters are taken into account.

SrwStoConstCreate

Dialog Box:



Definition:

Proc SrwStoConstCreate(stoname,elname,magname,smpname)

String stoname,elname,magname,smpname

Action:

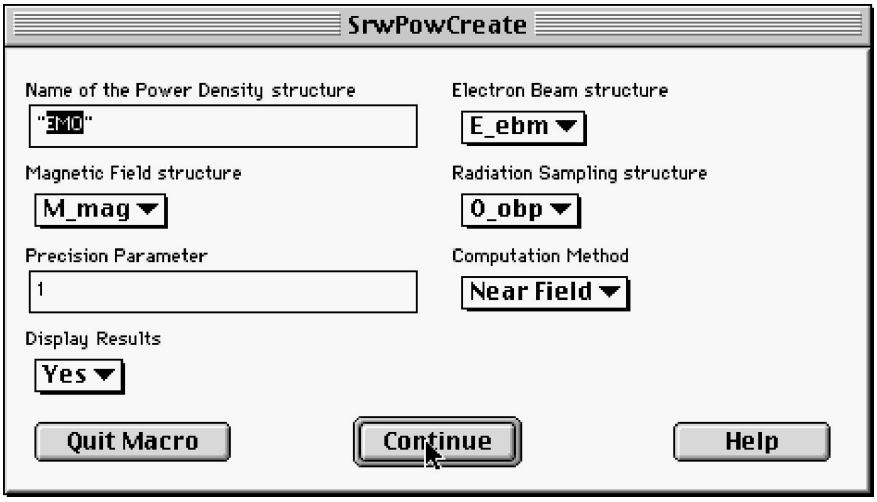
Creates a SR Stokes Components structure with name "stoname", i.e. computes Stokes components of radiation emitted by a thick electron beam described by the structure "elname" in constant magnetic field described by the structure "magname", according to the radiation sampling parameters defined by the structure "smpname".

Details:

1. The computation is based on analytical formulas describing the spectral-angular distribution of bending magnet radiation in far field.

SrwPowCreate

Dialog Box:



Definition:

Proc SrwPowCreate(powname,elname,magname,smpname,prec,meth,disp)

String powname,elname,magname,smpname

Variable prec,meth,disp

Action:

Computes power density of synchrotron radiation produced by electron beam described by the structure "elname" in magnetic field described by the structure "magname", according to the radiation sampling parameters defined by the structure "smpname". The following additional parameters should be specified: precision parameter (prec), computation method (meth=1 <"Near Field">, meth=2 <"Far Field">). The computation results can be immediately displayed in a graph (disp = 2) or not (disp = 1). The computed power density distribution is saved in a Power Density structure with the name "powname".

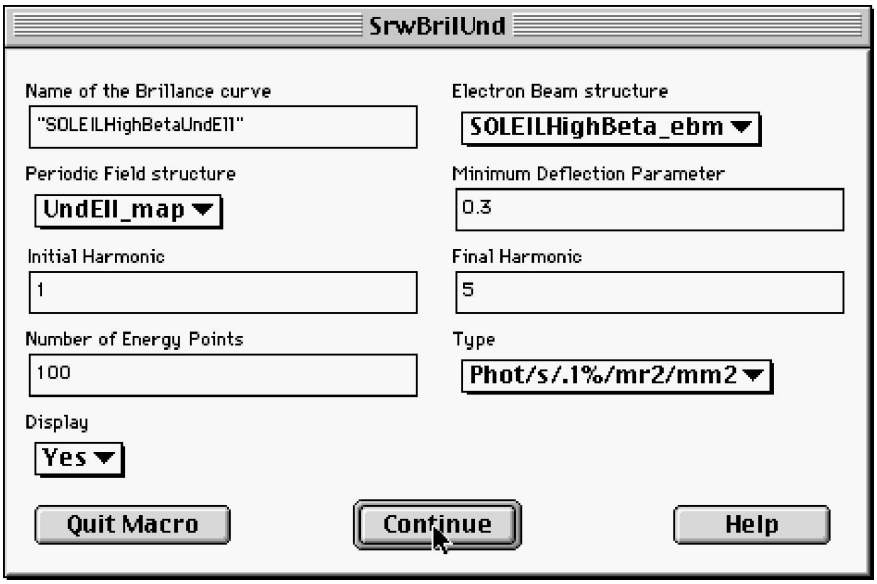
Details:

1. This macro computes the **Power Density** integrated over all photon energies (the photon energy parameters specified in the Radiation Sampling structure are ignored at this computation). The main use of this macro is to estimate heat load on optical components in a beamline.
2. The units of the computed **Power Density** are **W/mm^2**.
3. The computation precision can be tuned the precision parameter (prec). The value of the precision parameter is set by default to 1. This corresponds to a reasonable precision for many cases of computation with different magnetic field configurations. However, there is no guaranty that the precision parameter equal to 1 is optimal for each particular case of computation. Therefore, we strongly advise for any new case to repeat the computation several times with different values of the precision parameter (for example, to try values 0.5 and 2) in order to make sure that the final results do not depend on it on an appropriate precision level. If you see that the results change when increasing the value of the precision parameter, you need to proceed increasing it until the results are stabilized. On the other hand, you may find that for your case of computation the precision parameter value

smaller than 1 is appropriate. Then use this smaller value in order to reduce the computation time.

SrwBrilUnd

Dialog Box:



Definition:

Proc SrwBrilUnd(brilname,elname,magname,kmin,hmin,hmax,ne,typ,disp)

String brilname,elname,magname

Variable kmin,hmin,hmax,ne,typ,disp

Action:

Computes approximate brilliance curve vs photon energy for the UR produced by non-zero emittance electron beam described by the structure "elname" in periodic magnetic field described by the structure "magname". The following additional parameters should be specified: minimal value of deflection parameter defining the maximum photon energy value for the UR brilliance curve (kmin), minimal and maximal UR harmonic numbers to compute the brilliance for (hmin, hmax), number of photon energy point in the brilliance curve (ne), type of physical value to compute: brilliance (typ=3), spectral flux per unit solid angle (typ=2) or angular integrated spectral flux (typ=1). The results can be immediately displayed in a graph (disp=2) or not (disp=1). The computed brilliance curve is saved in a numerical wave with the name "brilname" (plus some extension).

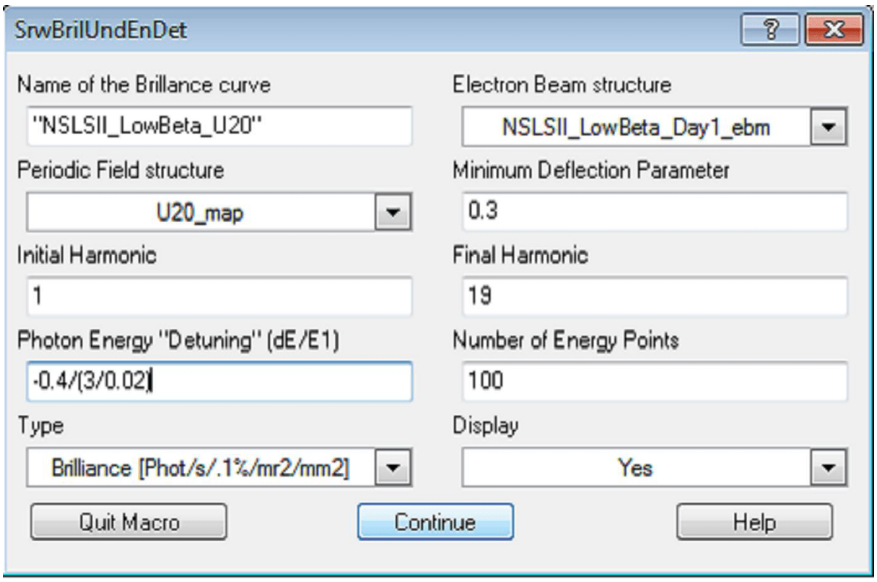
Details:

1. The computation of brilliance is only done (for the time being) for planar, helical and ellipsoidal undulators. For the planar undulator, the formulae used are those of K.-J.Kim presented in the X-ray Data Booklet Chapter 4 (PUB-400 from Lawrence Berkeley Lab). The formula has been straightforwardly generalized for the case of the ellipsoidal undulator. The computation does not make any distinction between the polarization components and only deals with the number of photons integrated over all states of polarization.

2. The Spectral flux per unit solid angle and the brilliance are computed in the direction of the electron beam. The computation is only done on the odd harmonics of the spectrum. The range of energies covered by each harmonics is limited on the low energy side by the deflection parameter values of the undulator selected and on the high energy side by the minimum deflection parameter value specified by the user. Contrary to the wiggler and bending magnet cases, the brilliance at any photon energy is recomputed for the particular K value which makes the energy of the selected harmonics to coincide with the photon energy of interest. This requires a continuous gap change (current change) for a permanent magnet (electro-magnet) undulator.
3. The reduction of brilliance due to the electron energy spread is not taken into account. In this respect, one must mention the absence of worldwide agreement on the method of computation of the undulator brilliance including electron energy spread. Nevertheless, the brilliance as defined here gives a fair indication on how a monochromatic beam is collimated and is therefore appropriate for a quick comparison of sources.

SrwBrilUndEnDet

Dialog Box:



Definition:

Proc SrwBrilUndEnDet(brilname,elname,magname,kmin,hmin,hmax,endet,ne,typ,disp)

String brilname,elname,magname

Variable kmin,hmin,hmax,endet,ne,typ,disp

Action:

Computes approximate brilliance curve vs photon energy for the UR produced by non-zero emittance electron beam described by the structure "elname" in periodic magnetic field described by the structure "magname". Takes into account electron beam energy spread and eventual "detuning" of the photon energy with respect to the on-axis resonant values of UR harmonics. The following additional parameters

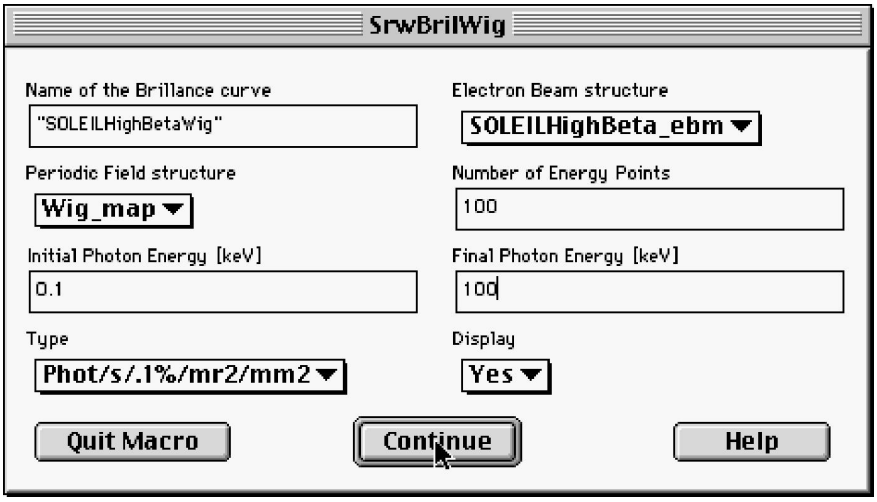
should be specified: minimal value of deflection parameter defining the maximum photon energy value for the UR brilliance curve (kmin), minimal and maximal UR harmonic numbers to compute the brilliance for (hmin, hmax), photon energy "detuning" parameter, defined as relative deviation of the photon energy from the resonant value of the fundamental harmonic (endet), number of photon energy point in the brilliance curve (ne), type of physical value to compute: brilliance (typ=3), spectral flux per unit solid angle (typ=2) or angular integrated spectral flux (typ=1). The results can be immediately displayed in a graph (disp=2) or not (disp=1). The computed brilliance curve is saved in a numerical wave with the name "brilname" (plus some extension).

Details:

1. The computation of brilliance can only be done for planar, helical and ellipsoidal undulators with sinusoidal magnetic fields. As different from the method presented in the "Synchrotron Radiation" article by K.-J. Kim in the "X-ray Data Booklet", this method takes into account electron beam energy spread, deviation of UR distributions (in the far field and "at the source") from Gaussian shape, as well as eventual "detuning" of the photon energy with respect to the onaxis resonant values of UR harmonics. The "detuning" parameter was introduced to take into account the fact that the peak UR flux is usually attained at some "red-shifted" photon energy with respect to the on-axis resonant value of a harmonic. The "detuning" parameter is defined for the fundamental harmonic as relative deviation of the photon energy from the on-axis resonant value (and it scales with a harmonic number for higher harmonics); a characteristic measure of this deviation is the relative bandwidth of the fundamental harmonic (i.e. inverse of the number of undulator periods); negative detuning parameter corresponds to a "red-shifted" photon energy with respect to the on-axis resonant value.
2. The Spectral flux per unit solid angle and the brilliance are computed in the direction of the electron beam. The computation is only done on the odd harmonics of the spectrum. The range of energies covered by each harmonics is limited on the low energy side by the deflection parameter values of the undulator selected and on the high energy side by the minimum deflection parameter value specified by the user. Contrary to the wiggler and bending magnet cases, the brilliance at any photon energy is recomputed for the particular K value which makes the energy of the selected harmonics to coincide with the photon energy of interest. This requires a continuous gap change (current change) for a permanent magnet (electro-magnet) undulator.

SrwBrilWig

Dialog Box:



Definition:

Proc SrwBrilWig(brilname,elname,magname,enpts,edep,efin,typ,disp)

String brilname,elname,magname

Variable enpts,edep,efin,typ,disp

Action:

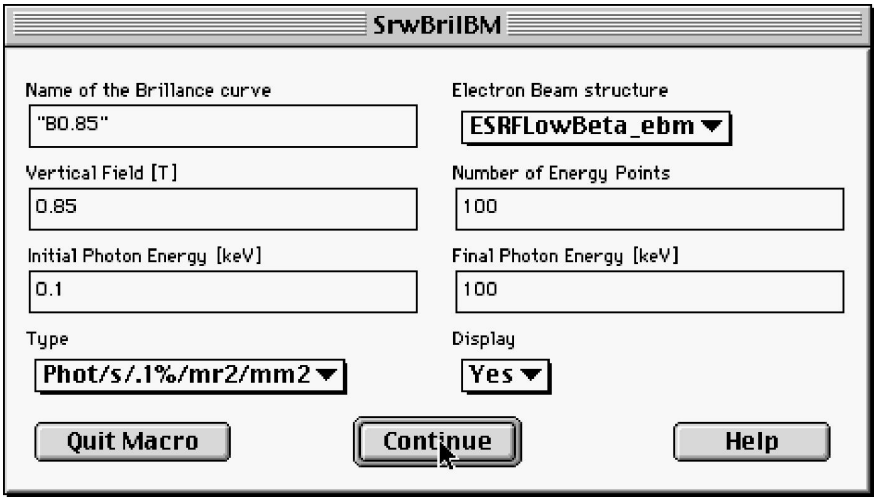
Computes approximate brilliance curve vs photon energy for the wiggler radiation produced by non-zero emittance electron beam described by the structure "elname" in vertical sinusoidal magnetic field described by the structure "magname". The following additional parameters should be specified: number of photon energy points in the brilliance curve (ne), minimal and maximal photon energy values (edep,efin), type of physical value to compute: brilliance (typ=3), spectral flux per unit solid angle (typ=2) or angularly integrated spectral flux (typ=1). The results can be immediately displayed in a graph (disp=2) or not (disp=1). The computed brilliance curve is saved in a numerical wave with the name "brilname" (plus some extension).

Details:

1. One assumes a vertical sinusoidal field wiggler, excluding (for the time being) the asymmetric and ellipsoidal wigglers. Three computations can be made: the spectral flux per unit horizontal angle, spectral flux per unit solid angle and surface (brilliance). They are all made on axis of the electron beam. The computations do not make any distinction between the polarization components and only deals with the numbers of photons integrated over all states of polarization.

SrwBrilBM

Dialog Box:



Definition:

Proc SrwBrilBM(brilname,elname,bz,enpts,edep,efin,typ,disp)

String brilname,elname

Variable bz,enpts,edep,efin,typ,disp

Action:

Computes approximate brilliance curve vs photon energy for bending magnet radiation produced by non-zero emittance electron beam described by the structure "elname" in constant vertical magnetic field (bz). The following additional parameters should be specified: number of photon energy points (ne), minimal and maximal photon energy values (edep,efin), type of physical value to compute: brilliance (typ=3), spectral flux per unit solid angle (typ=2) or spectral flux per unit horizontal angle (typ=1). The results can be immediately displayed in a graph (disp=2) or not (disp=1). The computed brilliance curve is saved in a numerical wave with the name "brilname" (plus some extension).

Details:

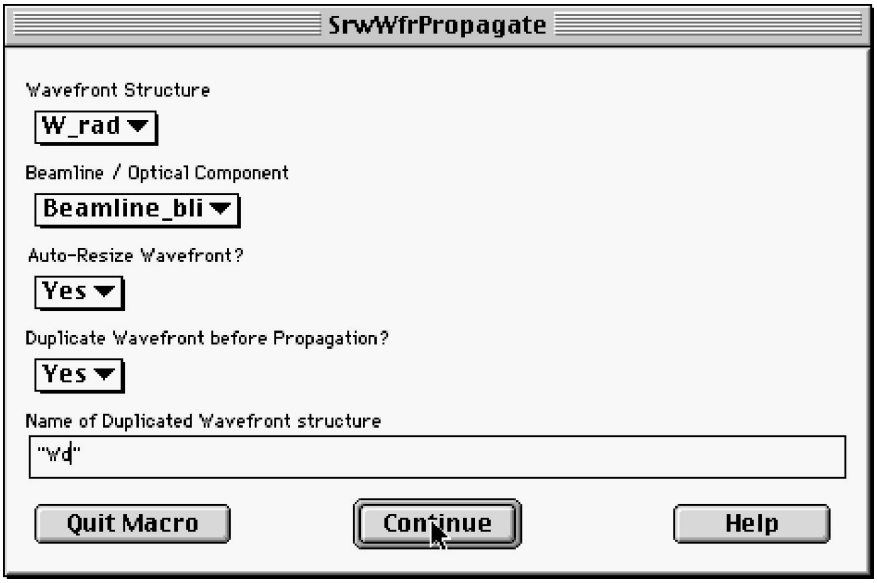
1. One assumes a constant vertical magnetic field. Three computations can be made: the spectral flux per unit horizontal angle, spectral flux per unit solid angle and the spectral flux per unit solid angle and surface (brilliance). They are all made on axis of the electron beam. The computations do not make any distinction between the polarization components and only deal with the number of photons integrated over all states of polarization.

Manipulations with the SR Wave Front

This section describes the macro commands dedicated for simulation of the Wavefront propagation through simple optical components, and other relevant manipulations with the wavefront. The propagation is performed in the frame of the Scalar Diffraction Theory, using CPU-efficient methods of Fourier Optics.

SrwWfrPropagate

Dialog Box:



Definition:

Proc SrwWfrPropagate(wfname,blname,meth,dpl,named)

String wfname,blname

Variable meth,dpl

String named

Action:

Propagates a Wavefront structure "wfname" through an Optical Component "blname". The wavefront can be automatically resized at the propagation or not (meth=1 or 2). It can also be duplicated before the propagation or not (dpl=2 or 1). If the wavefront was chosen to be duplicated, the Name of Duplicated Wavefront structure should be specified (named).

Details:

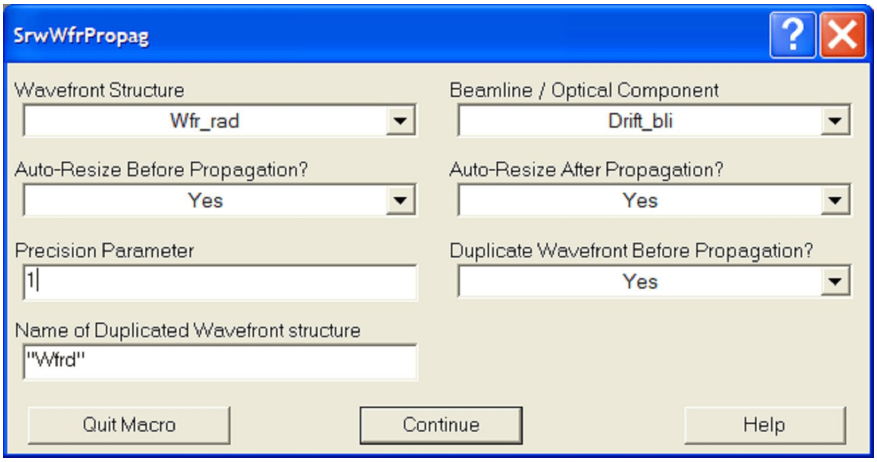
1. **Before making any serious computation involving the Wavefront propagation, please have a look at the chapter "Wavefront Propagation", where the theory of the Propagation method used, its advantages, problems and limitations are described. This will help you to avoid serious mistakes due to improper use of this code.**
2. The Optical Component can be a Container or any single component (ThinLens, Aperture, etc.). If a Container is chosen, this means that the propagation is performed one by one through each Optical Component in the Container, preserving the order according to which the components were placed to the Container.
3. If the user has chosen "Auto-Resize Wavefront", this means that the propagation will be performed in automatic mode, with a special correction of the wavefront sampling at each step of the propagation. For this mode to work properly, it is essential that the wavefront is sufficiently well sampled at its creation. To ensure this, one should set to "Use Automatic Radiation Sampling" with the "Oversampling Factor" not much smaller than 1 (see

dialog box "Compute SR Electric Field", menu call SRWP "SR Source -> Create Wavefront...").

4. One should have not less than 64 MB of RAM installed on one's system, to be able to get useful and consistent physical results with the propagation method used. Please note that at the propagation with the option "Auto-Resize Wavefront", very large amounts of memory can be demanded from the operating system for allocation. **Mac users: make sure that the memory partitioning for Igor Pro is set to at least 32 MB, before starting to use the propagation**, otherwise this macro may "crash" the Igor Pro. No special processing the memory allocation problems on Mac OS is done in the code. Windows NT users may feel safer in this respect.
5. If the Wavefront structure was chosen to be duplicated before Propagation, the Propagation will be performed on the duplicated structure, otherwise it will be performed on the initial structure, so the initial wavefront data will be overwritten.
6. The wavefront creation (initial computation) is typically a slower process than its propagation / resizing. And it is easy to "destroy" the wavefront data by an incorrect manipulation. Therefore, if memory conditions allow, we recommend to keep one copy of the initial wavefront.

SrwWfrPropag

Dialog Box:



Definition:

Proc SrwWfrPropag(wfname,blname,resbefore,resafter,prec,dpl,named)

String wfname,blname

Variable resbefore,resafter,prec,dpl

String named

Action:

Propagates a Wavefront named "wfname" through an Optical Component named "blname". The wavefront can be automatically resized before and after the propagation or not (resbefore=1 or 2, resafter=1 or 2). It can also be duplicated

before the propagation or not (dpl=2 or 1). If the wavefront was chosen to be duplicated, the name of Duplicated Wavefront structure should be specified (named), otherwise the last variable is not taken into account.

Details:

1. If the switch "Auto-Resize Before Propagation" (variable "resbefore") is equal to 1 ("Yes"), the wavefront is automatically resized before propagation through each optical element, trying to obtain the same sampling rate in the propagated electric field as it was in the electric field before the propagation. The resizing before the propagation may result in increase of the limits (transverse ranges) of the propagated wavefront. If the switch "Auto-Resize After Propagation" (variable "resafter") is equal to 1 ("Yes"), the wavefront limits will be automatically reduced after the propagation, by cutting the parts of the wavefront where intensity is less than given threshold. The default threshold value is on the order of 1e-03 with respect to the peak intensity in the wavefront; this value can be further reduced by choosing the "Precision Parameter" (variable "prec") larger than 1.

SrwWfrProp

Definition:

Proc SrwWfrProp(wfname,blname,resbefore,resafter,prec,undersamp,dpl,named)

String wfname,blname

Variable resbefore,resafter,prec,undersamp,dpl

String named

Action:

Propagates a Wavefront named "wfname" through an Optical Component named "blname". The wavefront can be automatically resized before and after the propagation or not (resbefore=1 or 2, resafter=1 or 2); it can be allowed to be propagated in "under-sampling" mode (with semi-analytical treatment) or not (undersamp=1 or 2). It can also be duplicated before the propagation or not (dpl=2 or 1). If the wavefront was chosen to be duplicated, the name of Duplicated Wavefront structure should be specified (named), otherwise the last variable is not taken into account.

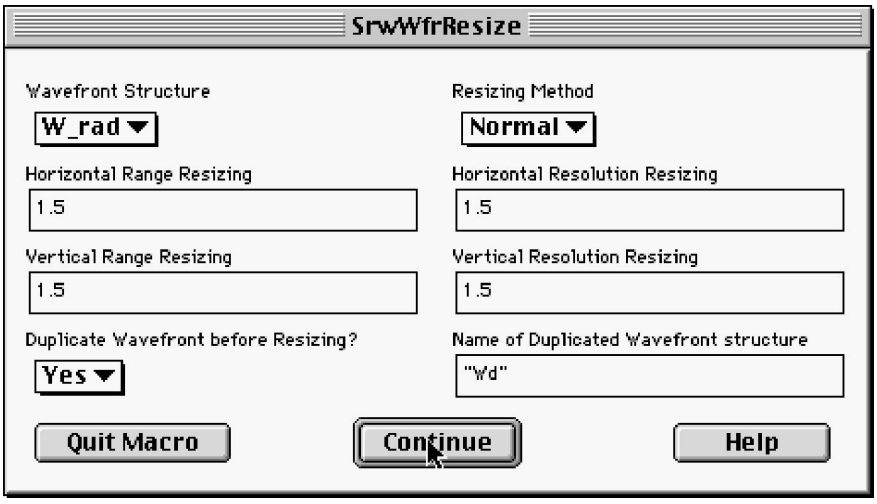
Details:

1. If the switch "Auto-Resize Before Propagation" (variable "resbefore") is equal to 1 ("Yes"), the wavefront is automatically resized before propagation through each optical element, trying to obtain the same sampling rate in the propagated electric field as it was in the electric field before the propagation. The resizing before the propagation may result in increase of the limits (transverse ranges) of the propagated wavefront. If the switch "Auto-Resize After Propagation" (variable "resafter") is equal to 1 ("Yes"), the wavefront limits will be automatically reduced after the propagation, by cutting the parts of the wavefront where intensity is less than given threshold. The default threshold value is on the order of 1e-03 with respect to the peak intensity in

the wavefront; this value can be further reduced by choosing the "Precision Parameter" (variable "prec") larger than 1.

SrwBrilBM

Dialog Box:



Definition:

Proc SrwWfrResize(wfname,meth,kxran,kxres,kzran,kzres,dpl,named)

String wfname

Variable meth,kxran,kxres,kzran,kzres,dpl

String named

Action:

Resizes a Wavefront structure with the name "wfname". The resizing can be performed by two methods: "Normal" or "Special" (meth=1 or 2). The resizing can change horizontal and vertical Range and Resolution (i.e., sampling density) of the wavefront (variables kxran,kxres,kzran,kzres). The Wavefront structure can be duplicated before the resizing or not (dpl=2 or 1). If the wavefront was chosen to be duplicated, the Name of Duplicated Wavefront structure should be specified (named).

Details:

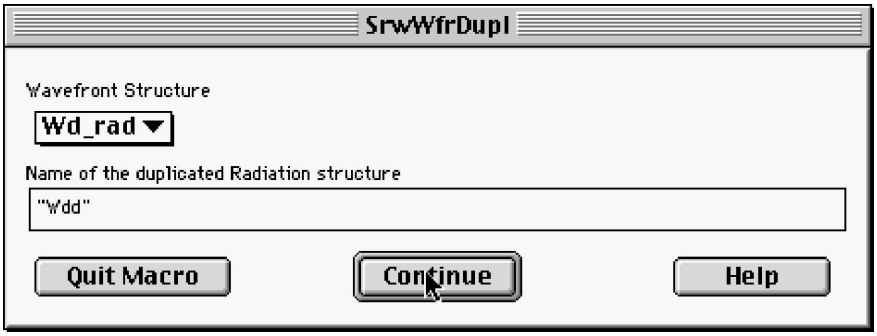
1. The resizing of the wavefront should be used when making the wavefront propagation in manual mode, checking the quality of the propagation in automatic mode or preparing the wavefront for computation of the multi-electron (Thick electron beam) intensity.
2. The resizing modifies the horizontal (vertical) Range of the wavefront proportionally to the entered Range Resizing factors. It modifies the horizontal (vertical) Resolution (i.e., sampling density) proportionally to the entered Resolution Resizing factors. Both Range Resizing and Resolution Resizing modify the horizontal and vertical point numbers of the wavefront.
3. There are two methods of the Resizing: "Normal" and "Special". The action of the "Normal" method is the following (depending on the values of the entered

Range and Resolution Resizing factors). If "Range Resizing" > 1, zeros are padded to the newly created outer parts of the wavefront. If "Range Resizing" < 1, the outer parts of the wavefront are truncated. If "Resolution Resizing" != 1, a smooth 2D interpolation is performed on the wavefront data. The "Special" method performs the corresponding operations on the "Fourier side". I.e., it makes direct FFT of the wavefront data before the Resizing operations, and inverse FFT after them.

4. The "Special" method is recommended only in cases when the Electric Field is very small or zero on the outer parts of the wavefront, and the central part of the wavefront (with non-zero Electric Field) is sampled poorly (so that the "Normal" method, which is simply using an interpolation, can not give good results). Such situations may appear at computation of the focused SR, when the SR wavefront is propagated to its waist.
5. Please take into account that in any case, the resizing does not make a new computation of the SR wavefront, it only manipulates with the one already computed. The Resolution Resizing of the initial wavefront is always inferior, in terms of precision, to the direct SR wavefront computation.

SrwBrilBM

Dialog Box:



Definition:

Proc SrwWfrDupl(name,named)

String name,named

Action:

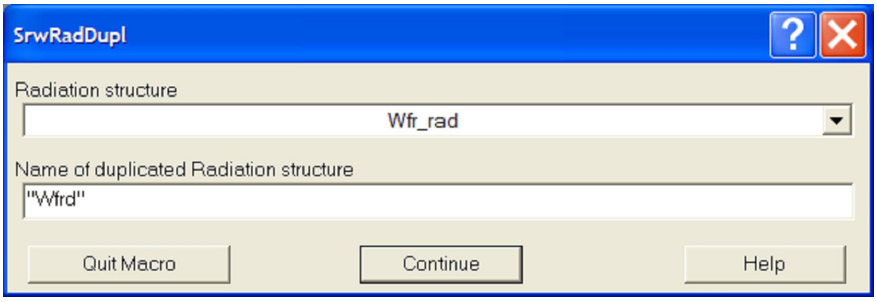
Duplicates a Wavefront structure with the name "name" by creating a structure of the same content with the name "named".

Details:

1. The Wavefront structure is duplicated together with all the constituting structures (waves): 3D complex waves with Horizontal and Vertical components of the Electric Field, the waves with the values of the first- and second-order Statistical Moments of the computed radiation, etc.

SrwRadDupl

Dialog Box:



Definition:

Proc SrwRadDupl(name,named)

String name,named

Action:

Duplicates a radiation structure with the name "name" by creating a structure of the same content with the name "named".

Details:

1. The Wavefront structure is duplicated together with all the constituting structures (waves): 3D complex waves with Horizontal and Vertical components of the Electric Field, the waves with the values of the first- and second-order Statistical Moments of the computed radiation, etc.

SrwWfrDelConfirm

Dialog Box:

Definition:

Proc SrwWfrDelConfirm(name)

String name

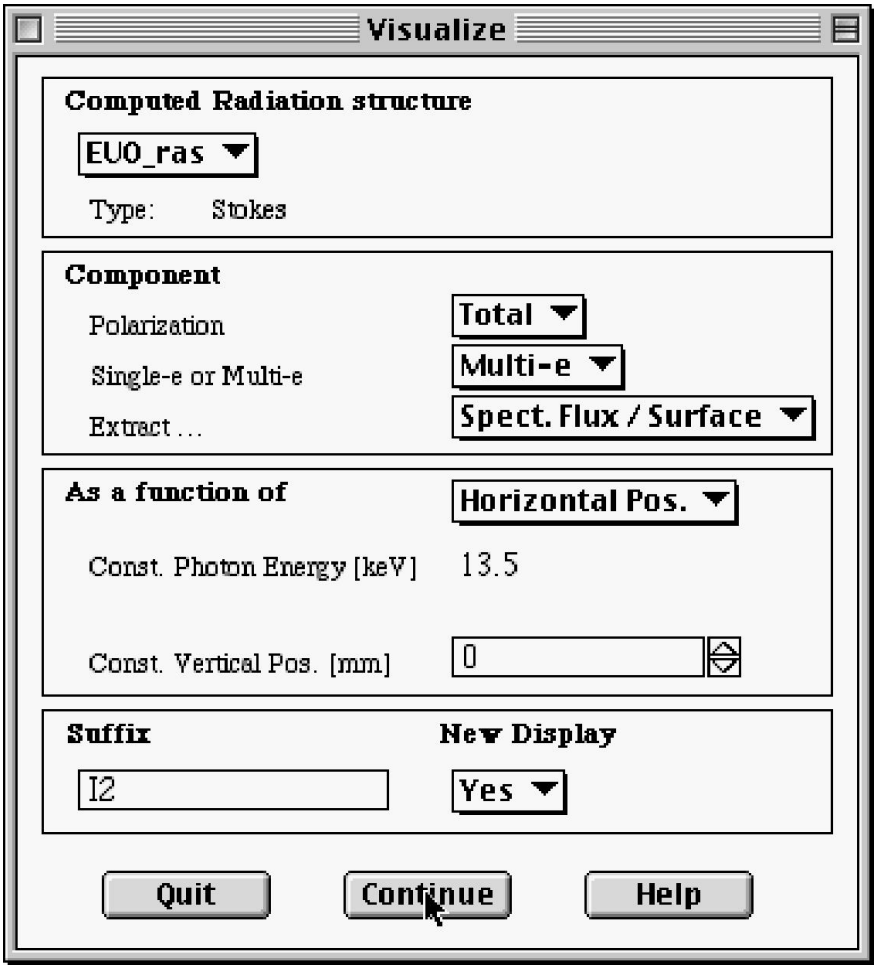
Action:

Deletes the Wavefront structure named "name", together with all constituent sub-structures.

Visualizing the Intensity

SrwVisualizeDialog

Dialog Box:



Definition:

Proc SrwVisualizeDialog()

Action:

Displays a dialog box and invokes proper SRW macros for visualizing the SR computation results, i.e., extracting from a computed SR structure an Intensity Distribution of desired polarization component.

The user needs to specify the polarization component of interest, whether the Single-electron or Multi-electron intensity should be extracted, as a function of which coordinates: Horizontal and/or Vertical and/or Photon Energy the extraction should be done. If the extraction should be done vs only one or two coordinates of the possible three, one needs to specify the value(s) of the coordinate(s) which are constant (en,x,z). The user can specify a suffix, i.e. a string of characters that will be appended to the full name of the extracted data wave. Finally, the user has to specify whether the extracted data wave should be immediately plotted in a graph or not.

Details:

1. We do not advise to use this macro at programming in Igor macro language. It is dedicated only to facilitate the dialog-driven style of computation in SRW.
2. Possible options for the component to be extracted (visualized) depend on the type of computed radiation (for example, power density does not allow to

specify any particular polarization, etc.).

3. Possible polarizations are: Linear Horizontal, Linear Vertical, Linear 45 degree, Linear 135 degree, Circular Right and Circular Left.
4. The units of the extracted Spectral Flux per Unit Surface are Photons/s/(0.1%bw)/mm^2.
5. Note on extraction of Single-electron and Multi-electron SR components. Some of the SR computation methods implemented in SRW produce electric field or stokes components of radiation emitted by single electron ("filament" electron beam), other methods produce the stokes components calculated originally for finite-emittance ("thick") electron beam. In the former case (i.e., when the computed radiation structure contains the single-electron SR data) the dialog box may suggest to extract both the single-electron ("filament" electron beam) or multi-electron ("thick" electron beam) component of the radiation. If the multi-electron component is chosen to be extracted, the code performs a convolution over horizontal and vertical coordinates of the single-electron SR data with a 2D Gaussian. The widths of this Gaussian are given by the electron beam sizes propagated, using the rules of the second-order moments propagation, to the same observation plane as the single-electron SR. The parameters of the "thick" electron beam are defined by the Electron Beam dialog box (menu "...Electron Beam...") or by the macro **SrwElecThick**.

   This method of calculation of multi-electron intensity is valid only at a number of constraints, including:

   - transversely uniform magnetic field;
   - linearity of the optical components the wavefront was propagated through;
   - small contribution of diffraction on apertures.

     It works well for several important cases like:

   - intensity distributions of SR emitted in transversely-uniform magnetic field computed at some longitudinal position with no propagation;
   - intensity distributions in the image plane of focused SR.

     However, we would like to point out that **no special checking is done in the code to ensure that this method of computation of multi-electron SR components is valid in each particular case of SR emission or propagation.** Such a checking should be done by the user. For this, one may perform a number of propagation tests with offsets of the filament electron beam in transverse position/angle, or apply theoretical considerations.

6. Don't forget to choose "New Display" -> "Yes", otherwise the extracted SR component wave will not be plotted.
7. The full name of the wave containing the extracted SR component is generated according to the following rule:

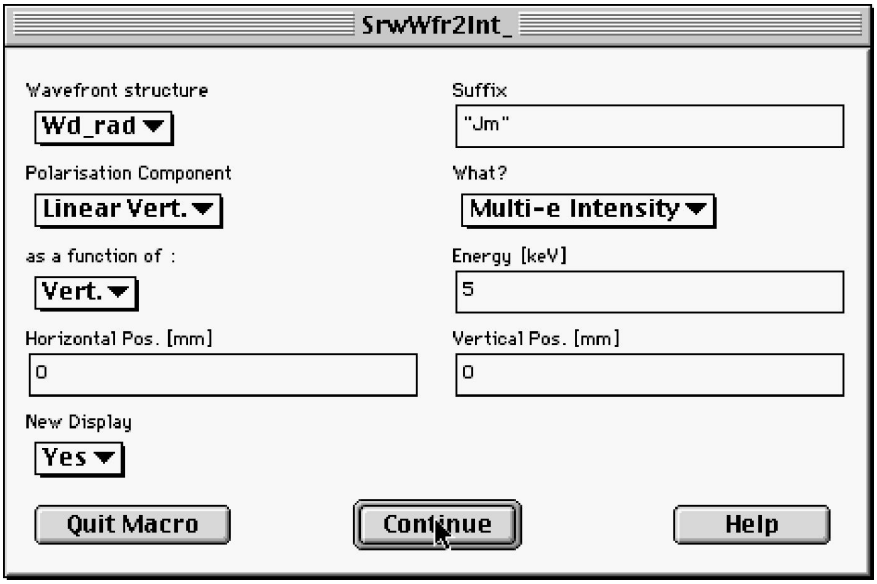
   \ = \ + + \ + + ("_x" or "_z" or "_e" or "_xz" or "_ex" or "_ez" or "_exz").

The "_x" or "_z", etc. is appended to the name depending on the type of the plot (vs which coordinate(s) the data was extracted).

8. Depending on settings in the dialog box, this macro invokes one or several low-level macros of SRW that can be used at programming in the Igor macro language: **SrwWfr2Int**, **SrwSto2Int**, **SrwSto2PolRate**, **SrwPow2Int**. The invoked macros are printed in Igor History window with the input parameters values used.

SrwWfr2Int_

Dialog Box:



Definition:

Proc SrwWfr2Int_(name,suf,polcmp,inttype,plottype,en,x,z,disp)

String name,suf

Variable polcmp,inttype,plottype,en,x,z,disp

Action:

Visualizes the SR computation results, i.e., extracts from the computed SR Wavefront structure with the name "name" to a separate wave the Intensity Distribution of desired SR polarization component. The user can specify a suffix, i.e. a string of characters that will be appended to the full name of the extracted data wave (suf). He needs to specify the polarization component of interest (polcmp), whether the Single-electron or Multi-electron intensity or Electric Field or phase should be extracted (inttype), as a function of which coordinates: Horizontal and/or Vertical and/or Photon Energy (variable plottype) the extraction should be done. If the extraction should be done vs only one or two coordinates of the possible three, one needs to specify the value(s) of the coordinate(s) which are constant (en,x,z). Finally, the user has to specify whether the extracted data wave should be immediately plotted in a graph or not (disp).

Details:

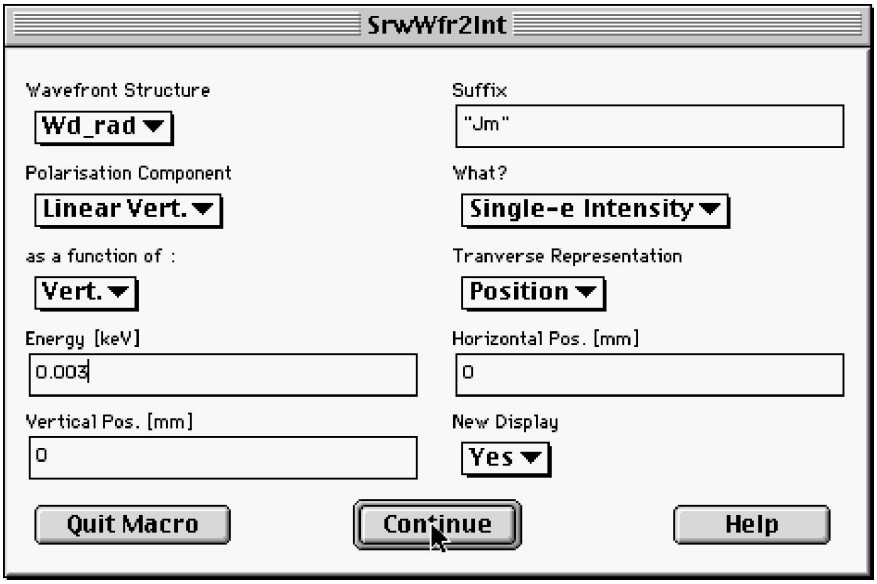
1. Possible Polarizations are: Linear Horizontal, Linear Vertical, Linear 45 degree, Linear 135 degree, Circular Right and Circular Left.
2. The units of the extracted **Intensity** are **Photons/s/mm^2/(0.1%bw)**.
3. The user can choose to extract **Single-electron** (Filament Electron Beam) or **Multi-electron** ("thick" electron beam) Intensity. If the Multi-electron Intensity is chosen, the code performs a convolution over Horizontal and Vertical coordinates of the Single-electron Intensity with a 2D Gaussian. The widths of this Gaussian are given by the electron beam sizes propagated, using the rules of the second-order moments propagation, to the same observation plane as the Single-electron SR. The initial parameters of the "thick" electron beam are defined by the macro **SrwElecThick**.
4. The implemented computation method of Multi-electron Intensity is valid only in the cases when the magnetic field is transversely uniform in the regions where the SR is emitted.
5. Don't forget to choose "New Display" = "Yes", otherwise the extracted wave will not be plotted.
6. The full name of the extracted Intensity wave was generated according to the following rule:

   \ = \ + + \ ++ ("_x" or "_z" or "_e" or "_xz" or "_ex" or "_ez" or "_exz").

   The "_x" or "_z", etc. is appended to the name depending on the type of the plot (vs which coordinate(s) the data was extracted).

SrwWfr2Int

Dialog Box:



Definition:

Proc SrwWfr2Int(name,suf,polcmp,inttype,plottype,repr,en,x,z,dist)

String name,suf

Variable polcmp,inttype,plottype,repr,en,x,z,dist

Action:

Visualizes the SR computation results, i.e., extracts from the computed SR Wavefront structure with the name "name" to a separate wave the Intensity Distribution of desired SR polarization component. The user can specify a suffix, i.e. a string of characters which will be appended to the full name of the extracted data wave (suf). He needs to specify the polarization component of interest (polcmp), whether the Single-electron or Multi-electron intensity or Electric Field or phase should be extracted (inttype), in which Transverse Representation: Position or Angle (variable repr), as a function of which coordinates: Horizontal and/or Vertical and/or Photon Energy (variable plottype) the extraction should be done. If the extraction should be done vs only one or two coordinates of the possible three, one needs to specify the value(s) of the coordinate(s) which are constant (en,x,z). Finally, the user has to specify whether the extracted data wave should be immediately plotted in a Graph or not (dist).

Details:

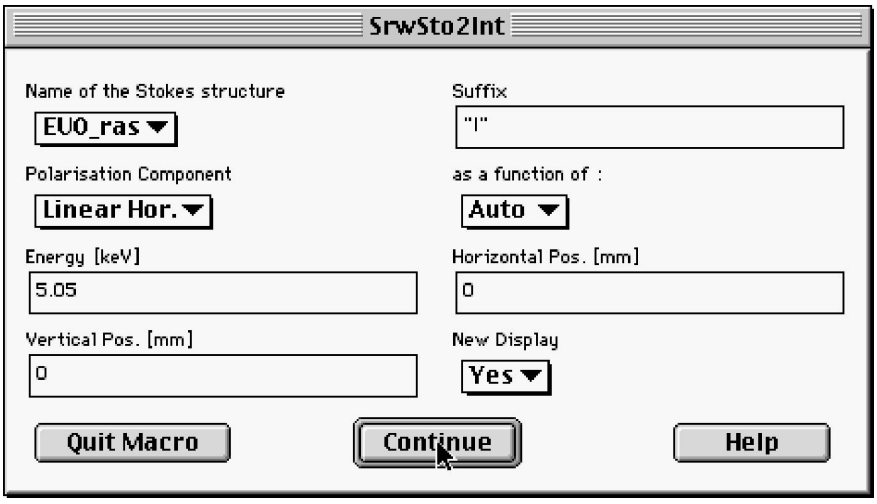
1. Possible Polarizations are: Linear Horizontal, Linear Vertical, Linear 45 degree, Linear 135 degree, Circular Right and Circular Left.
2. The units of the extracted Intensity are Photons/s/mm^2/(0.1%bw).
3. The user can choose to extract Single-electron (Filament Electron Beam) or Multi-electron ("thick" electron beam) Intensity. If the Multi-electron Intensity is chosen, the code performs a convolution over Horizontal and Vertical coordinates of the Single-electron Intensity with a 2D Gaussian. The widths of this Gaussian are given by the electron beam sizes propagated, using the rules of the second-order moments propagation, to the same observation plane as the Single-electron SR. The initial parameters of the "thick" electron beam are defined by the macro **SrwElecThick**.
4. The implemented computation method of Multi-electron Intensity is valid only at a number of constraints, including:
5. transversely uniform magnetic field;
6. linearity of the optical components the wavefront was propagated through;
7. small contribution of the diffraction on apertures. It works for several important cases like:
8. SR intensity distributions computed directly, with no propagation;
9. intensity distributions in image planes of the focused SR. However, we would like to point out that **no special checking is done in the code to ensure that this method of computation of multi-electron SR components is valid in each particular case of SR emission or propagation**. Such a checking should be done by the user. For this, one may perform a number of propagation tests with offsets of the filament electron beam in transverse position/angle, or apply theoretical considerations.
10. The Angular Transverse Representation is not fully supported in this version of the code.
11. Don't forget to choose "New Display" = "Yes", otherwise the extracted wave will not be plotted.
12. The full name of the extracted Intensity wave is generated according to the following rule:

    \ = \ + + + + ("_x" or "_z" or "_e" or "_xz" or "_ex" or "_ez" or "_exz").

The "_x" or "_z", etc. is appended to the name depending on the type of the plot (vs which coordinate(s) the data was extracted).

SrwSto2Int

Dialog Box:



Definition:

Proc SrwSto2Int(name,suf,polcmp,plottype,en,x,z,disp)

String name,suf

Variable polcmp,plottype,en,x,z,disp

Action:

Visualizes the SR computation results, i.e., extracts from the computed SR Stokes Components structure with the name "name" to a separate wave, the Intensity Distribution of desired SR polarization component. The user can specify a suffix, i.e. a string of characters that will be appended to the full name of the extracted data wave (suf). He needs to specify the polarization component of interest (polcmp), as a function of which coordinates: horizontal and/or vertical and/or photon energy (variable plottype) the extraction should be done. If the extraction should be done only vs one or two coordinates of the three possible, one needs to specify the value(s) of the coordinate(s) which are constant (en,x,z). Finally, the user has to specify whether the extracted data wave should be immediately plotted in a graph or not (disp).

Details:

1. Possible Polarizations are: Linear Horizontal, Linear Vertical, Linear 45 degree, Linear 135 degree, Circular Right and Circular Left.
2. The units of the extracted Spectral Flux per Unit Surface are Photons/s/mm^2/(0.1%bw).
3. If "New Display" is chosen to be "Yes", the extracted intensity wave will be plotted in a graph, otherwise it will be only created, without plotting.
4. The full name of the extracted Intensity wave is generated according to the following rule:

\ = \ + + \ + + ("_x" or "_z" or "_e" or "_xz" or "_ex" or "_ez" or "_exz").

The "_x" or "_z", etc. is appended to the name depending on the type of the plot (vs which coordinate(s) the data were extracted).

SrwSto2PolRate

Definition:

Proc SrwSto2PolRate(name,suf,polcmp,plottype,en,x,z,disp)

String name,suf

Variable polcmp,plottype,en,x,z,disp

Action:

Visualizes the SR computation results, i.e., extracts from the computed SR Stokes Components structure with the name "name" to a separate wave, the Polarization Rate of desired SR polarization component. The user can specify a suffix, i.e. a string of characters that will be appended to the full name of the extracted data wave (suf). He needs to specify the polarization component of interest (polcmp), as a function of which coordinates: horizontal and/or vertical and/or photon energy (variable plottype) the extraction should be done. If the extraction should be done only vs one or two coordinates of the three possible, one needs to specify the value(s) of the coordinate(s) which are constant (en,x,z). Finally, the user has to specify whether the extracted data wave should be immediately plotted in a graph or not (disp).

Details:

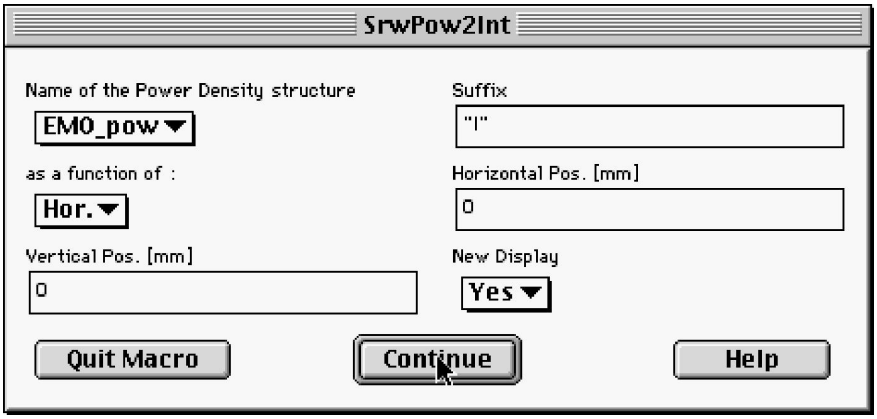
1. Possible Polarizations are: Linear Horizontal, Linear Vertical, Linear 45 degree, Linear 135 degree, Circular Right and Circular Left.
2. The values the extracted Polarization Rate should be between 0 and 1.
3. If "New Display" is chosen to be "Yes", the extracted polarization rate wave will be plotted in a graph, otherwise it will be only created, without plotting.
4. The full name of the extracted Intensity wave is generated according to the following rule:

   \ = \ + + \ + + ("_x" or "_z" or "_e" or "_xz" or "_ex" or "_ez" or "_exz").

   The "_x" or "_z", etc. is appended to the name depending on the type of the plot (vs which coordinate(s) the data were extracted).

SrwPow2Int

Dialog Box:



Definition:

Proc SrwPow2Int(name,suf,plottype,x,z,disp)

String name,suf

Variable plottype,x,z,disp

Action:

Visualizes the SR power density computation results, i.e., extracts from the computed SR Power Density structure with the name "name" to a separate wave, a profile of the Power Density distribution vs desired coordinates. A user can specify a suffix, i.e. a string of characters that will be appended to the full name of the extracted data wave (suf). He needs to specify as a function of which coordinates: horizontal and/or vertical the extraction should be done. If the extraction should be done only vs one of two possible coordinates, one needs to specify the value of the coordinate which is constant (x or z). Finally, the user has to specify whether the extracted data wave should be immediately plotted in a graph or not (disp).

Details:

1. The units of the extracted **Power Density are W/mm^2**.
2. If "New Display" is chosen to be "Yes", the extracted intensity wave will be plotted in a graph, otherwise it will be only created, without plotting.
3. The full name of the extracted Intensity wave is generated according to the following rule:

   \ = \ + + \ + + ("_x" or "_z" or "_xz").

   The "_x" or "_z", etc. is appended to the name depending on the type of the plot (vs which coordinate(s) the data were extracted).

SrwRadIntensInteg

Dialog Box:

\

Definition:

Proc SrwRadIntensInteg(name, rname, inttype, disp, emin, emax, xmin, xmax, zmin, zmax)

String name, rname

Variable inttype, disp, emin, emax, xmin, xmax, zmin, zmax

Action:

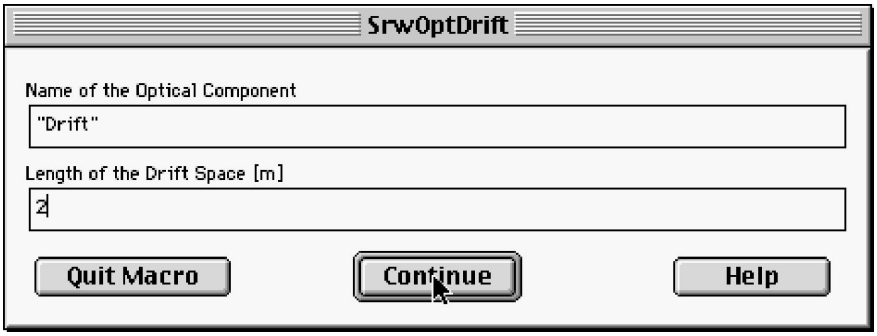
Integrates radiation intensity (spectral flux per unit surface or power densit distribution) over photon energy or horizontal or vertical position.

Optical Elements

This section describes macro commands defining Optical Components which can be used to simulate propagation of Synchrotron Radiation over a Beamline. We support only a few Optical Components for the moment, however, we hope that this collection will grow with time.

SrwOptDrift

Dialog Box:



Definition:

Proc SrwOptDrift(name,len)

String name

Variable len

Action:

Creates a Drift Space structure with the name "name" and sets up a longitudinal Length for it in m (len).

Details:

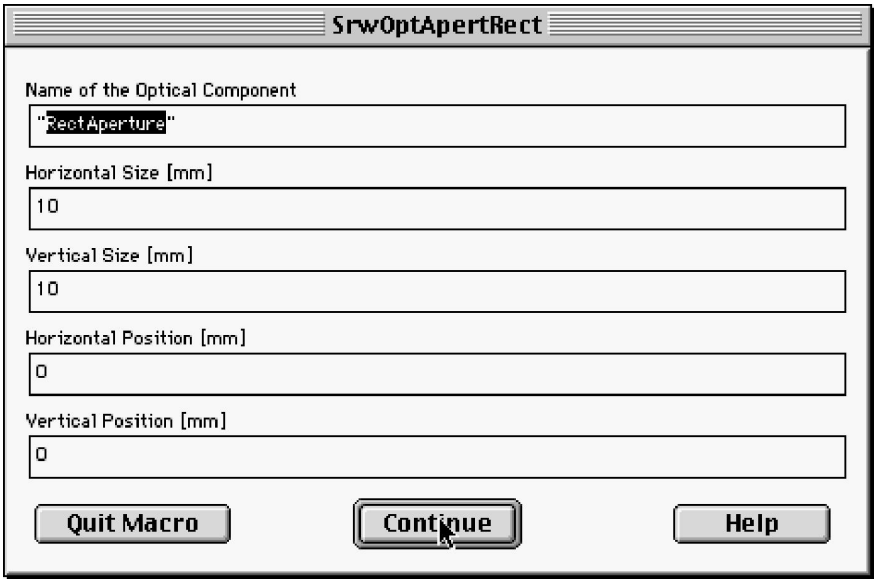
1. Drift Space is a linear optical media with refraction n=1. The Length of the Drift Space means its duration along optical axis.
2. The full name of the Optical Component structure was generated according to the following rule:

   \ = \ + "_bli",

   where "_bli" is the type identifier of an Optical Component structure.

SrwOptApertRect

Dialog Box:



Definition:

Proc SrwOptApertRect(name,dx,dz,x,z)

String name

Variable dx,dz,x,z

Action:

Creates a Rectangular Aperture (or a diaphragm) structure with the name "name" and sets up Horizontal and Vertical Sizes and Position of its center in mm (dx,dz,x,z).

Details:

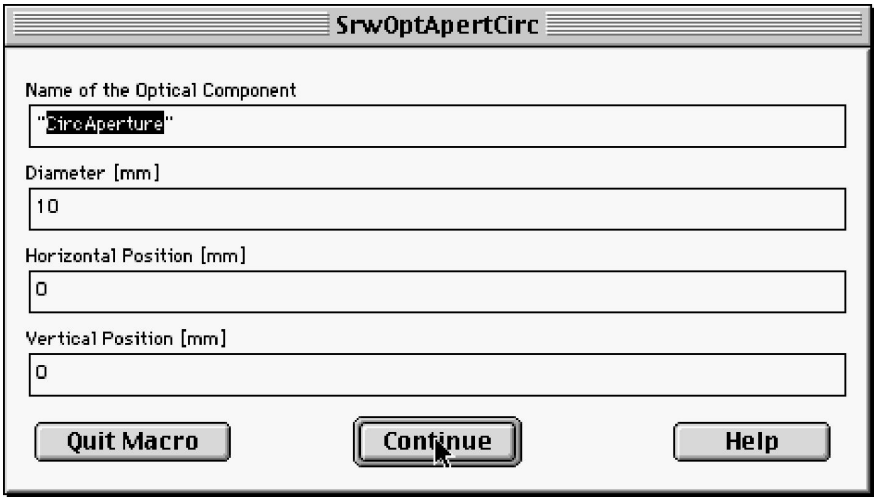
1. Rectangular Aperture has no longitudinal size. It is perpendicular to optical axis.
2. The full name of the Optical Component structure was generated according to the following rule:

   \ = \ + "_bli",

   where "_bli" is the type identifier of an Optical Component structure.

SrwOptApertCirc

Dialog Box:



Definition:

Proc SrwOptApertCirc(name,d,x,z)

String name

Variable d,x,z

Action:

Creates a Circular Aperture (or a diaphragm) structure with the name "name" and sets up Diameter and Horizontal and Vertical Position of its center in mm (d,x,z).

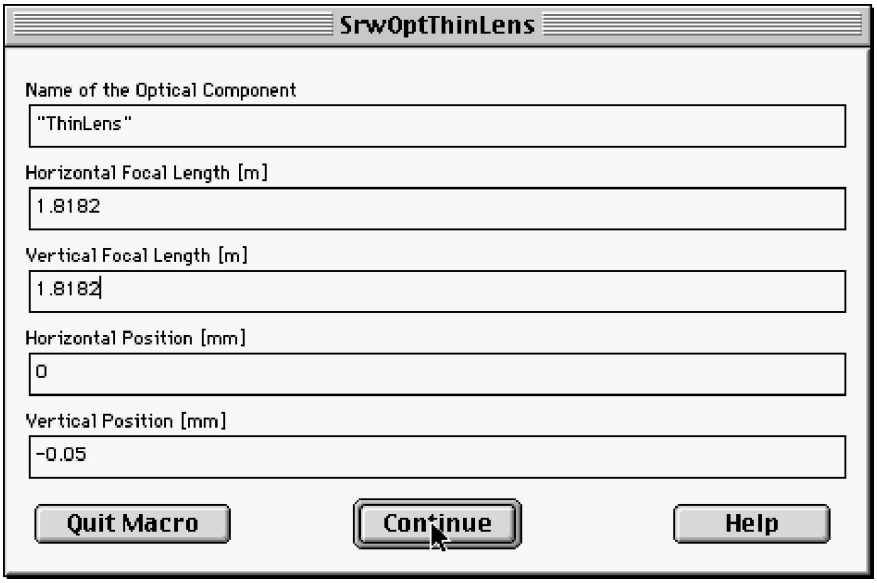
Details:

1. Circular Aperture has no longitudinal size. It is perpendicular to optical axis.
2. The full name of the Optical Component structure was generated according to the following rule:

   \ = \ + "_bli",

   where "_bli" is the type identifier of an Optical Component structure. **SrwOptThinLens**

Dialog Box:



Definition:

Proc SrwOptThinLens(name,fx,fz,x,z)

String name

Variable fx,fz,x,z

Action:

Creates a Thin Lens structure with the name "name" and sets up Horizontal and Vertical Focal Length and Position of its center in mm (fx,fz,x,z).

Details:

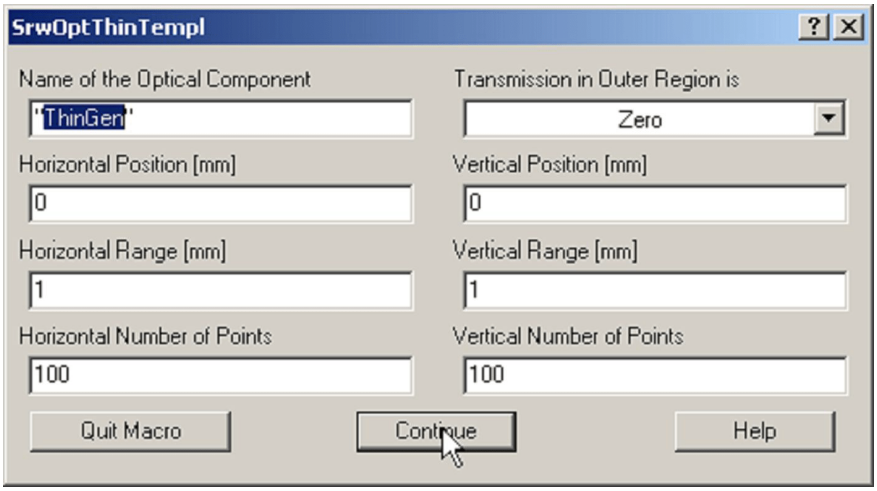
1. Thin Lens allows horizontal-vertical astigmatism. Horizontal and Vertical Focal Lengths can be essentially different.
2. By default, transverse dimensions of the Thin Lens are assumed to be the same as the ranges of the computed SR (defined by the Radiation Sampling structure for the Near Field computation). Rectangular or Circular Apertures can be used to simulate different transverse size/shape of the lens (macro SrwOptApertRect and **SrwOptApertCirc**). For this, the apertures should be placed into the same Container just before or immediately after the Thin Lens (macro **SrwOptCont** and **SrwOptContAdd**).
3. Thin Lens has no longitudinal size. It is perpendicular to optical axis.
4. The full name of the Optical Component structure was generated according to the following rule:

   \ = \ + "_bli",

   where "_bli" is the type identifier of an Optical Component structure.

SrwOptThinTempl

Dialog Box:



Definition:

Proc SrwOptThinTempl(name,out,xc,zc,xr,zr,nx,nz)

String name

Variable out,xc,zc,xr,zr,nx,nz

Action:

Creates a Thin Generic optical component structure with the name "name" and an empty complex transmission wave for this component. The user needs to specify whether the transmission in the external part of transverse plane (outside the optical component) should be assumed zero or the same as at the border of the component (out = 1 or 2), horizontal and vertical center positions in mm (xc,zc), ranges in mm (xr,zr) and point numbers of the 2D complex transmission wave in horizontal and vertical directions (nx,nz).

Details:

1. This macro creates a structure (text wave) and a 2D complex wave for further set up of Thin optical component, i.e. component which can be characterized by two functions of transverse coordinates describing the Amplitude Transmission and Phase Shift in each point of the transverse plane.
2. The full name of the optical component structure (text wave) was generated according to the following rule:

   \ = \ + "_bli",

   where "_bli" is the type identifier of an Optical Component structure.

   The full name of the 2D complex wave was generated according to the following rule:

   \ = \ + "_bgt",

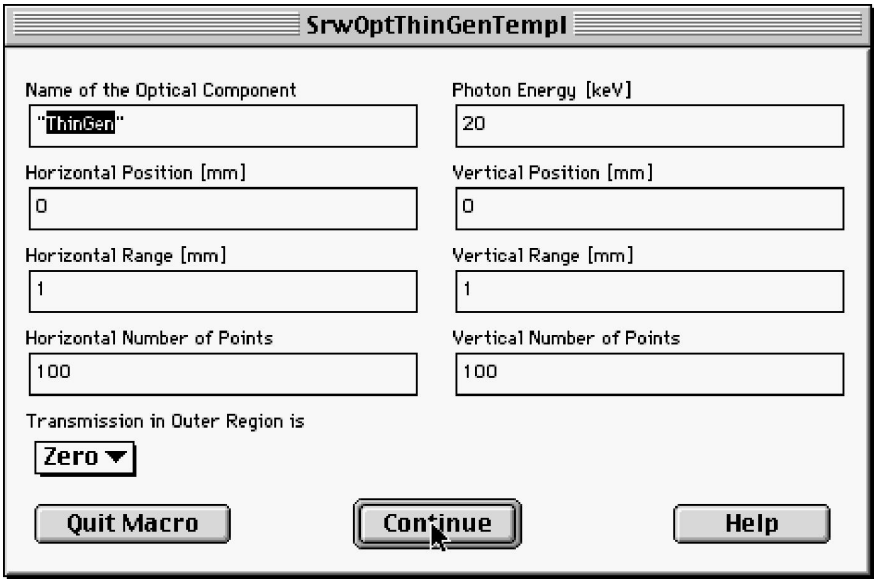
   where "_bgt" is the type identifier of an 2D complex wave characterizing a Thin optical component.

3. After this macro, the Thin optical component still is not ready for the use in propagation. User needs to finish the set up of the component by filling-in the 2D complex wave created by this macro. The real part of this wave should be

the Amplitude Transmission, and the imaginary part of it the Optical Path Difference for each point of the grid defined by this macro. The final set up of the Thin component can be done using the macro **SrwOptThinSetup** (where user needs to submit the names of functions defining the amplitude transmission and the optical path difference) or manually, using the Igor Pro macro language.

SrwOptThinGenTempl - obsolete

Dialog Box:



Definition:

Proc SrwOptThinGenTempl(name,en,xc,zc,xr,zr,nx,nz,out)

String name

Variable en,xc,zc,xr,zr,nx,nz,out

Action:

Creates a Thin Generic optical component structure with the name "name" and an empty complex transmission wave for this component. The user needs to specify Photon Energy in keV (en), horizontal and vertical center positions in mm (xc,zc), ranges in mm (xr,zr) and point numbers of the 2D complex transmission wave in horizontal and vertical directions (nx,nz). The transmission in the external part of transverse plane (out of the ranges xr,zr) can be treated as zero or the same as at the border of the component (out = 1 or 2).

Details:

1. This macro creates a structure (text wave) and a 2D complex wave for further set up of a Thin Generic optical component, i.e. component which can be characterized by two functions of transverse coordinates describing the Amplitude Transmission and Phase Shift introduced by the optical component in each point of the transverse plane.
2. The full name of the optical component structure (text wave) was generated according to the following rule:

\ = \ + "_bli",

where "_bli" is the type identifier of an Optical Component structure.

The full name of the 2D complex wave was generated according to the following rule:

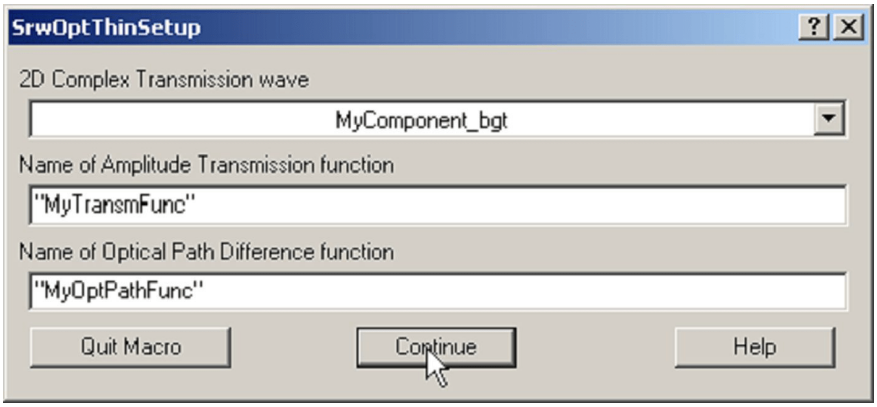
\ = \ + "_bgt",

where "_bgt" is the type identifier of an 2D complex wave characterizing a Thin Generic optical component.

3. After this macro, the Thin Generic optical component still is not ready for the use in Propagation. The user needs to finish the set up of the component by filling-in the 2D complex wave created by this macro. The real part of this wave should be the Amplitude Transmission, and the imaginary part of it the Phase Shift for each point of the grid defined by this macro. In general case, the final set up of the Thin Generic component can be done using the macro **SrwOptThinGenSetup** (where user needs to submit the names of the user-defined functions for the amplitude transmission and phase shift) or manually, using the wave assignment mechanisms of the Igor Pro macro language.
4. There is a number of special optical components built on the basis of the Thin Generic component, for example Refractive Lenses for X-ray (see macros **SrwOptThinGenSetupXrayLensCirc**, **SrwOptThinGenSetupXrayLensParab**). Each of these components require creation of a template, i.e. execution of this macro, before the final set up.

SrwOptThinSetup

Dialog Box:



Definition:

Proc SrwOptThinSetup(wname,trfun,optpathfun)

String wname,trfun,optpathfun

Action:

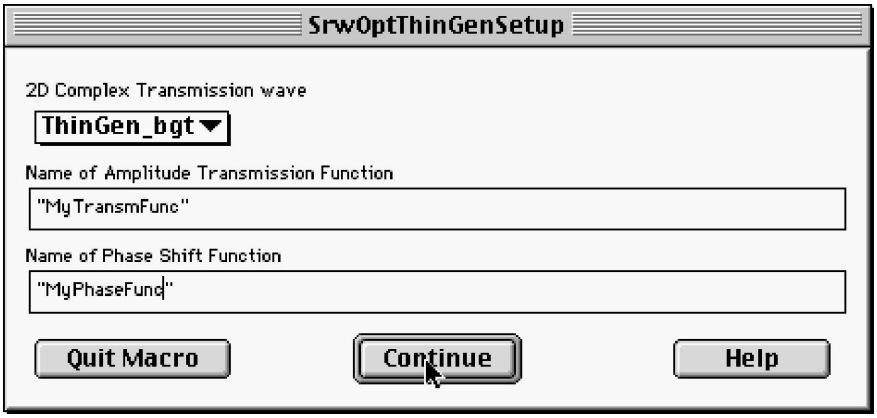
Sets up a Thin Generic optical component by filling-in its 2D complex wave with the name "wname" using the user-defined functions with names "trfun" (for Amplitude Transmission) and "optpathfun" (for Optical Path Difference).

Details:

1. The user-defined function with the name "trfun" should be a real function of two real arguments (x,z) returning the Amplitude Transmission for the point with transverse coordinates (x,z). The user-defined function with the name "optpathfun" should be a real function of two real arguments (x,z) returning the relative Optical Path Difference (Optical Path Difference = Phase Shift / Wave Number) for the point with transverse coordinates (x,z). The functions should be written in Igor Pro macro language in a procedure file of user's experiment and compiled before calling this macro.
2. When writing the Amplitude Transmission and Optical Path Difference functions, a mechanism of Igor global variables can be used to pass any extra parameters to these functions in addition to their two arguments (x,z). For example, optical component material and/or geometry parameters can be defined as global variables which can then be used by the Amplitude Transmission and Optical Path Difference functions.
3. This macro should be called only after the macro **SrwOptThinTempl**, where the 2D complex wave for the Amplitude Transmission and Optical Path Difference is created.

SrwOptThinGenSetup - obsolete

Dialog Box:



Definition:

Proc SrwOptThinGenSetup(wname,trfun,phfun)

String wname,trfun,phfun

Action:

Sets up a Thin Generic optical component by filling-in its 2D complex wave with the name "wname" using the user-defined functions with names "trfun" (for Amplitude Transmission) and "phfun" (for Phase Shift).

Details:

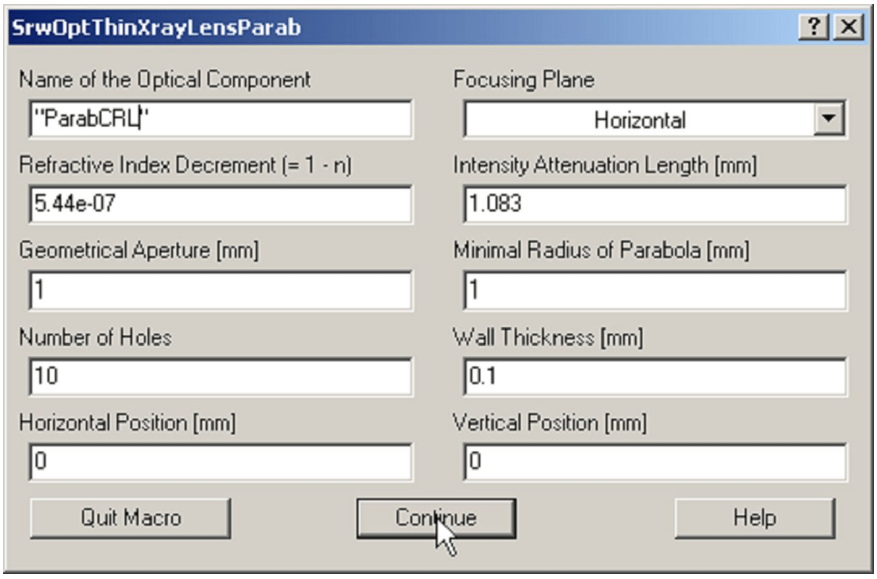
1. The user-defined function with the name "trfun" should be a real function of two real arguments "trfun(x,z)" returning the Amplitude Transmission for the point with transverse coordinates (x,z). The user-defined function with the name "phfun" should be a real function of two real arguments "phfun(x,z)" returning the Phase Shift for the point with transverse coordinates (x,z). The

functions should be written in Igor Pro macro language in a procedure file of user's experiment and compiled before calling this macro.

2. When writing the Amplitude Transmission and Phase Shift functions, a mechanism of Igor global variables can be used to pass any extra parameters to these functions in addition to their two arguments (x,z). For example, optical component material and/or geometry parameters can be defined as global variables which are used by the Amplitude Transmission and Phase Shift functions (see how this is done for refractive X-ray lenses in SRW: macro **SrwOptThinGenSetupXrayLensCirc** and relevant functions).
3. This macro should be called only after the macro **SrwOptThinGenTempl**, where the 2D complex wave for the Amplitude Transmission and Phase Shift is created.

SrwOptThinXrayLensParab

Dialog Box:



Definition:

Proc SrwOptThinXrayLensParab(name,focpl,delta,attlen,ap,rmin,nh,d,xc,zc)

String name

Variable focpl,delta,attlen,ap,rmin,nh,d,xc,zc

Action:

Sets up an X-ray Refractive Lens with Parabolic holes, as a special case of a Thin optical component. User needs to specify: name of the component to be created ("name"), plane of the focusing (focpl), refractive index decrement (delta) and attenuation length in mm (attlen) of the lens material, geometrical aperture in mm (ap), radius at the tip of parabola in mm (rmin), number of holes (nh), the wall thickness between holes in mm (d), horizontal and vertical position of the lens center in mm (xc,zc).

Details:

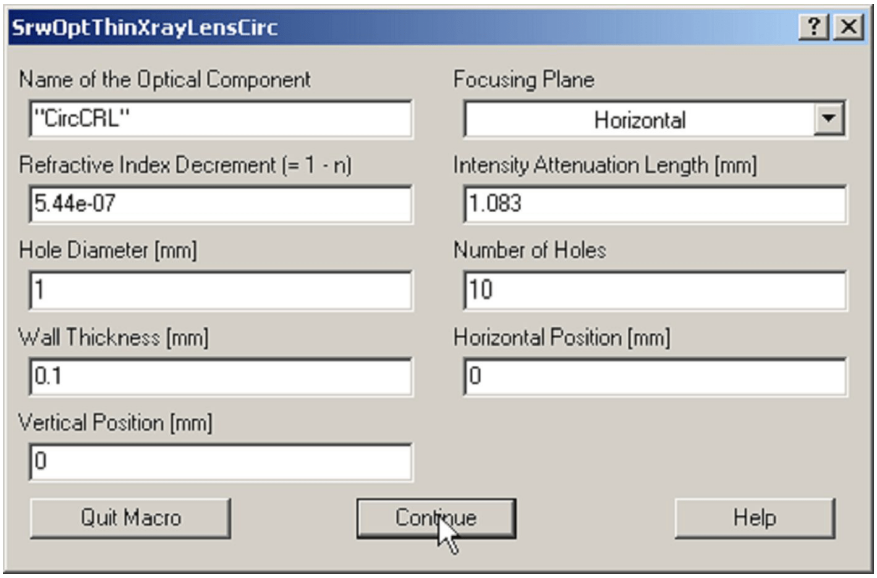
1. The theory of refractve lenses for X-rays is described in the papers:

- A.Snigirev, V.Kohn, I.Snigireva, B.Lengeler, "A compound refractive lens for focusing highenergy X-rays", Nature, 1996, vol.384, p.49;
- P.Elleaume, "Optimization of compound refractive lenses for X-rays", Nucl. Instr. and Meth., 1998, vol.A412, p.483;
- B.Lengeler et. al., "Imaging by parabolic refractive lenses in the hard X-ray range", J. Synchrotron Rad., 1999, vol.6, p.1153.

2. This macro creates a template of a Thin optical component by calling the macro **SrwOptThinTempl**, and then sets it up by calling **SrwOptThinSetup**. User may apply this approach to simulate his own optical component.

SrwOptThinXrayLensCirc

Dialog Box:



Definition:

Proc SrwOptThinXrayLensCirc(name,focpl,delta,attlen,diam,nh,d,xc,zc)

String name

Variable focpl,delta,attlen,ap,rmin,nh,d,xc,zc

Action:

Sets up an X-ray Refractive Lens with Circular holes, as a special case of a Thin optical component. User needs to specify: name of the component to be created ("name"), plane of the focusing (focpl), refractive index decrement (delta) and attenuation length in mm (attlen) of the lens material, diameter of holes in mm (diam), number of holes (nh), wall thickness between the holes in mm (d), horizontal and vertical position of the lens center in mm (xc,zc).

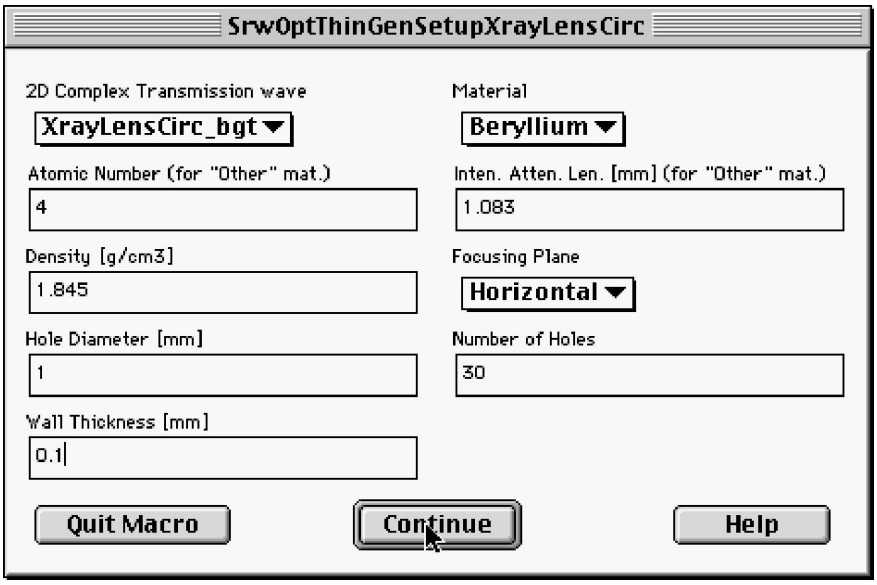
Details:

1. The theory of refractve lenses for X-rays is described in the papers:
2. A.Snigirev, V.Kohn, I.Snigireva, B.Lengeler, "A compound refractive lens for focusing highenergy X-rays", Nature, 1996, vol.384, p.49;
3. P.Elleaume, "Optimization of compound refractive lenses for X-rays", Nucl. Instr. and Meth., 1998, vol.A412, p.483;

4. This macro creates a template of a Thin optical component by calling the macro **SrwOptThinTempl**, and then sets it up by calling **SrwOptThinSetup**. User may apply this approach to simulate his own optical component.

SrwOptThinGenSetupXrayLensCirc - obsolete

Dialog Box:



Definition:

Proc SrwOptThinGenSetupXrayLensCirc(wname,mat,z,attlen,dens,focpl,diam,nh,d)

String wname

Variable mat,z,attlen,dens,focpl,diam,nh,d

Action:

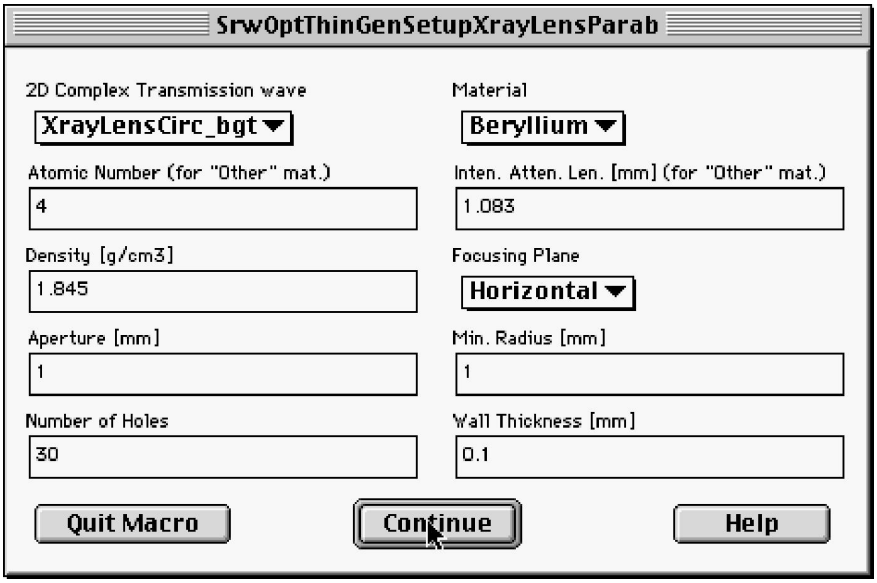
Sets up a Circular Holes Refractive Lens for X-rays as a special case of a Thin Generic optical component. The user needs to specify the following parameters: name of 2D complex wave to be filled ("wname"), material of the lens (choose from the supported materials (mat) or enter the parameters of any other material: atomic number (z), attenuation length (attlen) and density (dens)), in which (horizontal or vertical) plane the focusing takes place (focpl), diameter of the holes (diam), number of holes (nh), and the thickness of the wall between successive holes (d).

Details:

1. This macro should be called only after the macro **SrwOptThinGenTempl**, where the 2D complex wave for definition of Amplitude Transmission and Phase Shift is created.

SrwOptThinGenSetupXrayLensParab - obsolete

Dialog Box:



Definition:

Proc SrwOptThinGenSetupXrayLensParab(wname,mat,z,attlen,dens,focpl,ap,rmin,nh,d)

String wname

Variable mat,z,attlen,dens,focpl,ap,rmin,nh,d

Action:

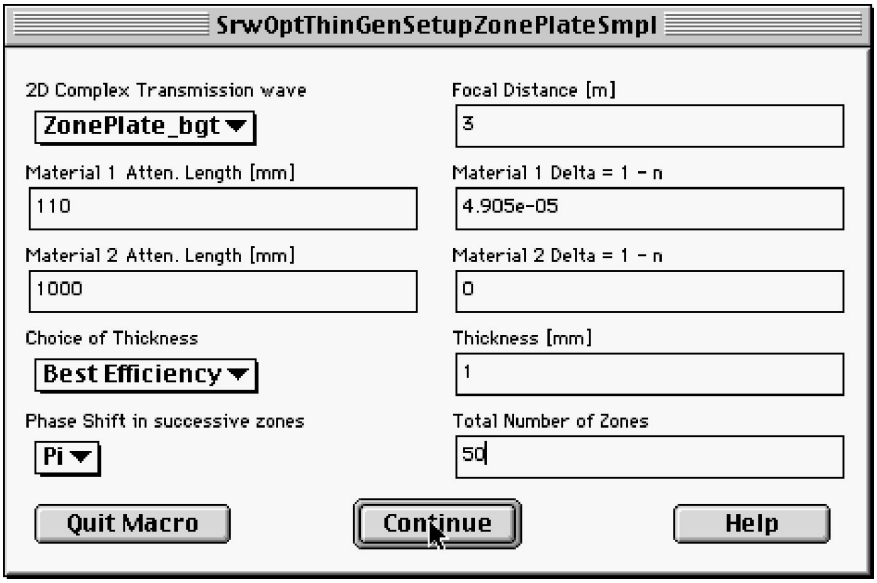
Sets up a Parabolic Holes Refractive Lens for X-rays as a special case of a Thin Generic optical component. The user needs to specify the following parameters: name of 2D complex wave to be filled ("wname"), material of the lens (choose from the supported materials (mat) or enter the parameters of any other material: atomic number (z), attenuation length (attlen) and density (dens)), in which (horizontal or vertical) plane the focusing takes place (focpl), aperture (ap), radius at the tip of parabola (rmin), number of holes (nh), and the thickness of the wall between successive holes (d).

Details:

1. This macro should be called only after the macro **SrwOptThinGenTempl**, where the 2D complex wave for definition of Amplitude Transmission and Phase Shift is created.

SrwOptThinGenSetupZonePlateSmpl

Dialog Box:



Definition:

Proc SrwOptThinGenSetupZonePlateSmpl(wname,foc,attl1,del1,attl2,del2,thicktr,thick,dph,n)

String wname

Variable foc,attl1,del1,attl2,del2,thicktr,thick,dph,n

Action:

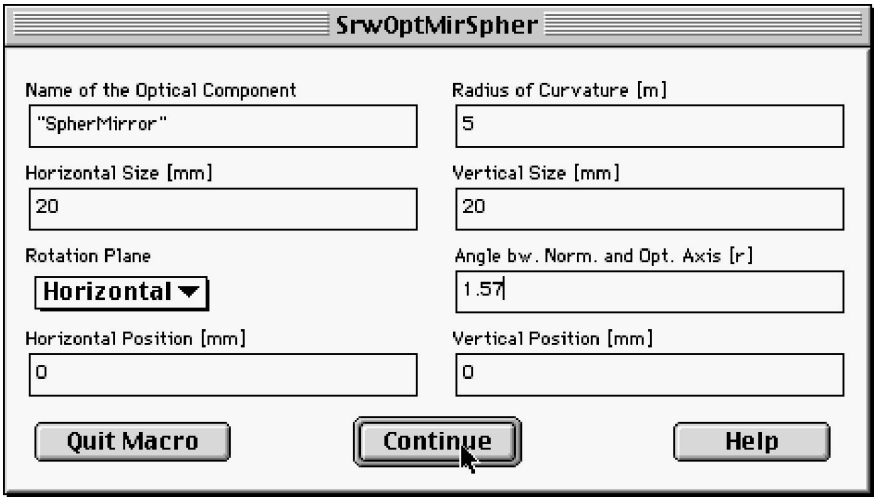
Sets up a Circular Zone Plate as a special case of a Thin Generic optical component. The user needs to specify the following parameters: name of 2D complex wave to be filled ("wname"), focal distance (foc), attenuation lengths and refraction indexes for the two materials constituiting in the zone plate (attl1,del1,attl2,del2), whether the thickness of the zone plate should be chosen for best efficiency (taking into account phase shifts produced by all the zones) or defined explicitly (thicktr = 1 or 2), the thickness value (thick, is used only if thicktr = 2), phase shift between successive zones (dph) and total number of zones (n).

Details:

1. This macro should be called only after the macro **SrwOptThinGenTempl**, where the 2D complex wave for definition of Amplitude Transmission and Phase Shift is created.

SrwOptMirSpher

Dialog Box:



Definition:

Proc SrwOptMirSpher(name,r,dx,dz,plane,theta,x,z)

String name

Variable r,dx,dz,plane,theta,x,z

Action:

Creates a Spherical Mirror structure with the name "name" and sets up Radius of Curvature of the Mirror surface in m (r) and Horizontal and Vertical Size in mm (dx,dz). The Mirror can be rotated in Horizontal (plane=1) or in Vertical Plane (plane=2), i.e. about Vertical or Horizontal axis respectively. The rotation angle (in r) is specified by the variable theta. The Horizontal and Vertical Position of the Mirror center (in mm) is specified by x and z.

Details:

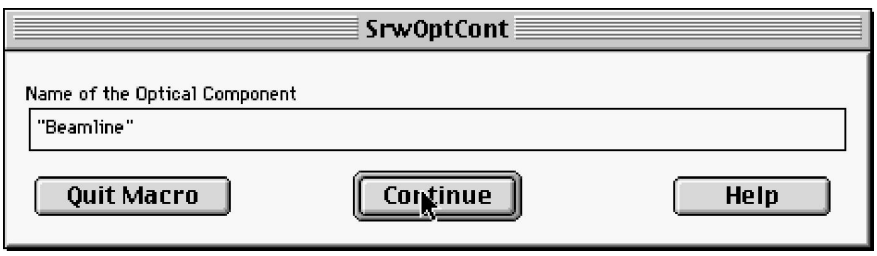
1. By default, the central surface normal vector of the Spherical Mirror is parallel to optical axis ("normal incident"). Rotation only in one of the two planes (Horizontal or Vertical, not both) is allowed. Please note that such rotation introduces an astigmatism by changing the horizontal and vertical focal distances of the mirror separately.
2. The full name of the Optical Component structure was generated according to the following rule:

   \ = \ + "_bli",

   where "_bli" is the type identifier of an Optical Component structure.

SrwOptCont

Dialog Box:



Definition:

Proc SrwOptCont(name)

String name

Action:

Creates a Container structure with the name "name".

Details:

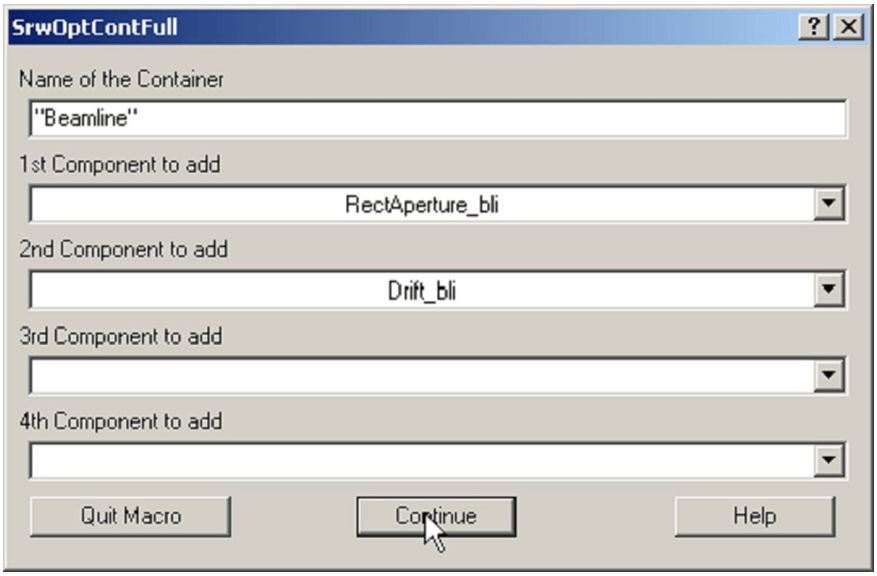
1. The Container is an individual Optical Component. Any Optical Component can be placed into the Container, except for that Container itself. If a Wavefront propagation (macro **SrwWfrPropagate**) is performed over a Container, this means that it is performed one by one over each Optical Component placed to the Container.
2. The order according to which the Optical Component are placed to the Container should be the same as for the real beamline being simulated.
3. The full name of the Optical Component structure was generated according to the following rule:

   \ = \ + "_bli",

   where "_bli" is the type identifier of an Optical Component structure.

SrwOptContFull

Dialog Box:



Definition:

Proc SrwOptContFull(name,name1,name2,name3,name4) String name,name1,name2,name3,name4

Action:

Creates a Container structure with the name "name", and adds up to 4 different optical components into the container, if their names ("name1","name2","name3","name4") are specified.

Details:

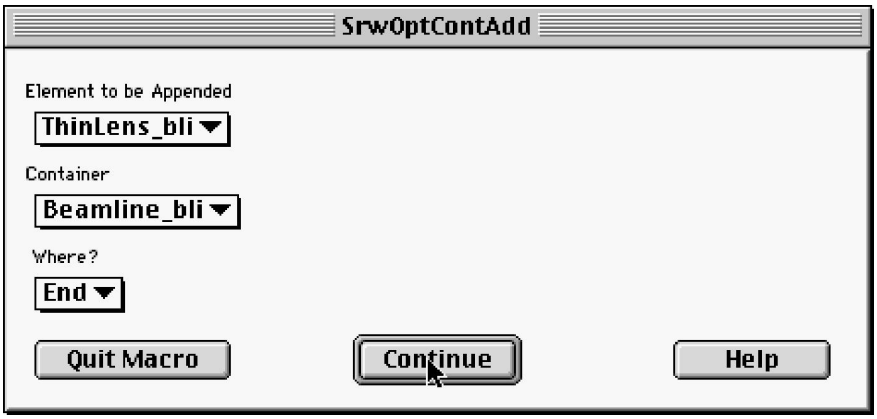
1. The Container is an individual Optical Component. Any Optical Component can be placed into the Container, except for that Container itself. If a Wavefront propagation (macro **SrwWfrPropagate**) is performed over a Container, this means that it is performed one by one over each Optical Component placed to the Container. The order according to which the components are placed into the Container should be the same as in the real beamline.
2. If no optical components to add are specified, the container will be created empty.
3. The full name of the Optical Component structure was generated according to the following rule:

   \ = \ + "_bli",

   where "_bli" is the type identifier of an Optical Component structure.

SrwOptContAdd

Dialog Box:



Definition:

Proc SrwOptContAdd(name,contname,where)

String name,contname

Variable where

Action:

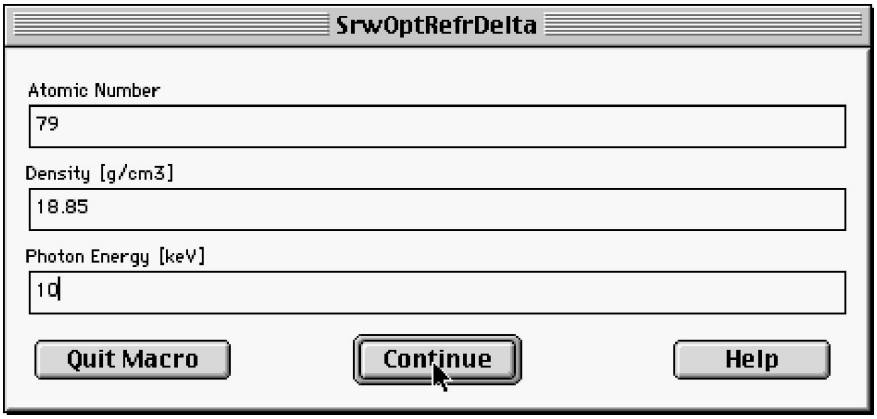
Adds an Optical Component with the name "name" to a Container with the name "contname". The Optical Component can be placed at the front (where=1) or at the end (where=2) of the container.

Details:

1. The order according to which the Optical Components are placed in a Container should be the same as for the real beamline being simulated.

SrwOptRefrDelta

Dialog Box:



Definition:

Proc SrwOptRefrDelta(z,dens,en)

Variable z,dens,en

Action:

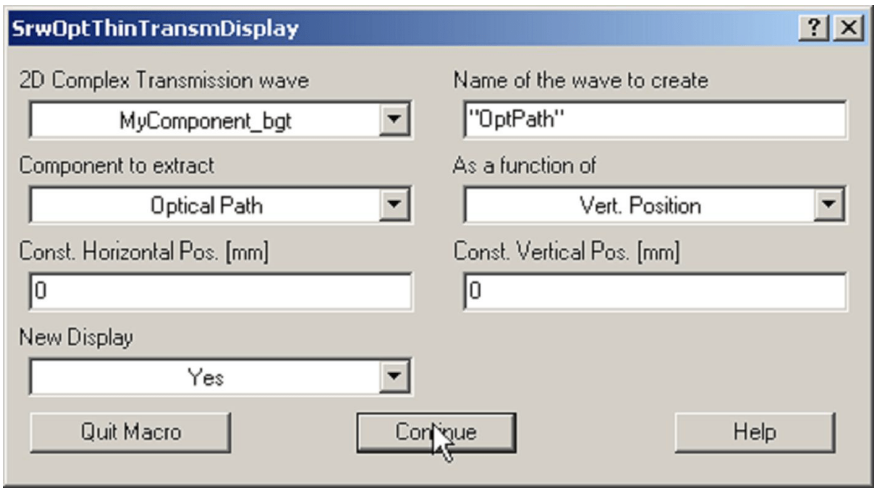
Estimates and prints in Igor history window the refraction index (delta = 1 - n) of a material with atomic number z, density in g/cm^3 (dens), at the photon energy in keV en.

Details:

1. The estimation is valid only for hard X-rays.

SrwOptThinTransmDisplay

Dialog Box:



Definition:

Proc SrwOptThinTransmDisplay(wname,extname,cmpn,plottype,x,z,disp)

String wname,extname

Variable cmpn,plottype,x,z,disp

Action:

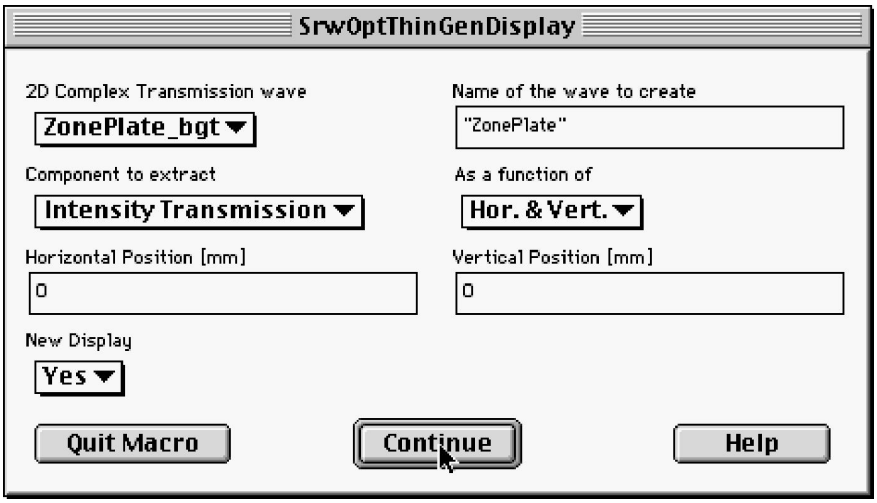
Extracts and displays characteristics of a Thin optical component, i.e. extracts from 2D complex wave with the name "wname" and plots in a graph the transmission or optical path as a function of transverse coordinates. The user needs to specify a name for the wave to be extracted ("extname"), characteristic of interest (cmpn), as a function of which coordinates: horizontal and/or vertical the extraction should be done (plottype). If the extraction should be performed vs only one of two coordinates, it is necessary to specify the value of the coordinate which remains constant (x or z). Finally, the user has to specify whether the extracted data wave should be immediately plotted in a graph or not (disp).

Details:

1. The following characteristics can be extracted: Amplitude Transmission, Intensity Transmission, Optical Path Difference.

SrwOptThinGenDisplay - obsolete

Dialog Box:



Definition:

Proc SrwOptThinGenDisplay(wname,extname,cmpn,plottype,x,z,disp)

String wname,extname

Variable cmpn,plottype,x,z,disp

Action:

Displays characteristics of a Thin Generic optical component, i.e. extracts from 2D complex wave with the name "wname" and plots in graphs transmission or phase shift as a function of transverse coordinates. The user needs to specify a name for the wave to be extracted ("extname"), characteristic of interest (cmpn), as a function of which coordinates: horizontal and/or vertical (variable plottype) the extraction should be done. If the extraction should be done vs only one of two coordinates, one needs to specify the value of the coordinate which is constant (x or z). Finally, the user has to specify whether the extracted data wave should be immediately plotted in a graph or not (disp).

Details:

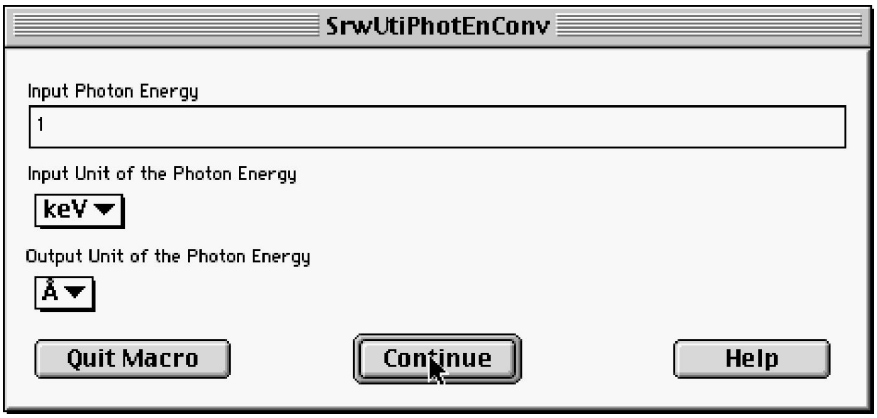
1. The following characteristics can be extracted: Amplitude Transmission, Intensity Transmission, Phase Shift, real and imaginary parts of the complex transmission.

Utilities

This section describes a few Utilities supplied with the current version of the SRW.

SrwUtiPhotEnConv

Dialog Box:



Definition:

Proc SrwUtiPhotEnConv(val,inun,outun)

Variable val,inun,outun

Action:

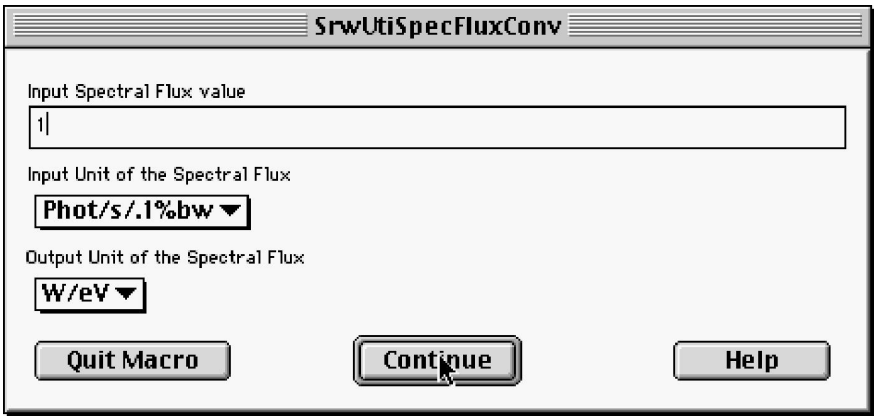
Converts different Photon Energy / Wavelength units one to another.

Details:

1. This macro helps to prepare input for the **Radiation Sampling** structure (menu call "Radiation Sampling..."), which accepts the Photon Energy only in keV. The conversion results are printed in the Igor History window.

SrwUtiSpecFluxConv

Dialog Box:



Definition:

Proc SrwUtiSpecFluxConv(val,inun,outun)

Variable val,inun,outun

Action:

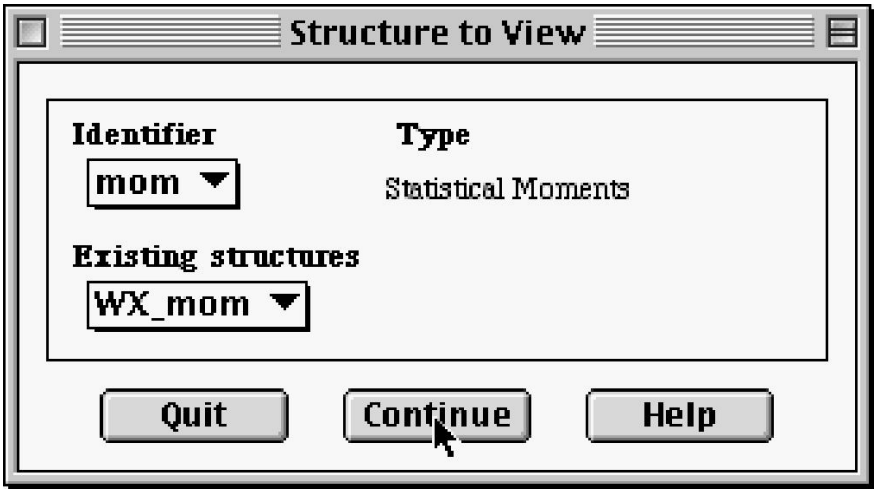
Converts different Spectral Flux units one to another.

Details:

1. The conversion results are printed in the Igor History window.

SrwUtiViewStructDialog

Dialog Box:



Definition:

Proc SrwUtiViewStructDialog()

Action:

Displays a dialog box and invokes a macro for viewing the content of SRW structures.

Details:

1. We do not advise to use this macro at programming in Igor macro language. It is dedicated only to facilitate the dialog-driven style of computation in SRW.
2. The "Type" pop-up menu shows the type identifiers of the SRW structures. Once a particular type is chosen, the other pop-up menu shows all the Existing structures of that type. After a necessary structure is chosen, one needs to press "Continue". This will open a table showing the structure content. Please note that by default, any modification made in the structure during the viewing will be ignored afterwards.
3. The following are the identifiers (name endings) of the general SRW structures:
    - "ebm" - Electron Beam;
    - "mag" - Magnetic Field (transversely-uniform, arbitrary vs longitudinal position);

- 3"fld" - horizontal or vertical Magnetic Field Component (arbitrary vs longitudinal position);
- "map" - Periodic Magnetic Field;
- "fha" - Periodic Magnetic Field Harmonic;
- "trj" - Trajectory of Electron Beam
- "obs" - Radiation Sampling (Observation);
- "gsn" - Gaussian Beam source;
- "rad" - Wavefront;
- "rae" - Electric Field Component of radiation;
- "ras" - Stokes Components of radiation;
- "mom" - Statistical Moments of radiation;
- "bli" - Beamline / Optical Component.

4. This mechanism can be used for viewing Statistical Moments of the computed SR wavefront (the Statistical Moments structure type identifier is "mom"). The transversely integrated Spectral Flux (Number of Photons/s/0.1%bw) is shown in the Moments structure as well.
5. After "Continue" is pressed, this dialog box calls the macro **SrwUtiViewStruct**.

SrwUtiViewStruct

Definition:

Proc SrwUtiViewStruct(name,modif)

String name;

Variable modif;

Action:

Opens a table showing parameters of a structure with the name "name". The variable "modif" specifies whether the structure can be modified at the viewing or not (modif=2 or 1).

SrwUtiTriggerPrint

Definition:

Proc SrwUtiTriggerPrint(onoff)

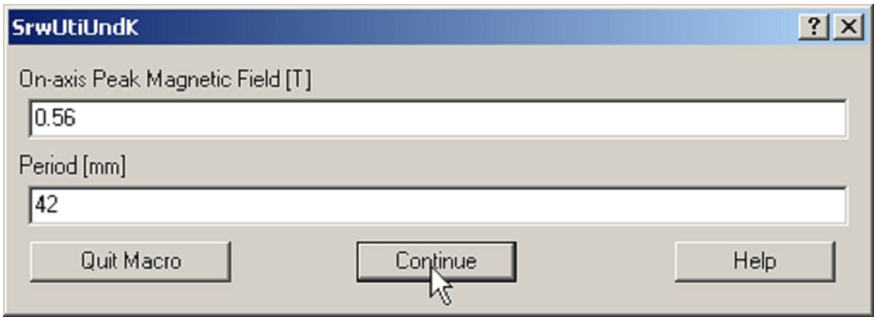
Variable onoff;

Action:

Allows (onoff = 1) or suppresses (onoff = 2) printing by SRW macros extra auxiliary information to the Igor History window.

SrwUtiUndK

Dialog Box:



Definition:

Proc SrwUtiUndK(b0,lambu)

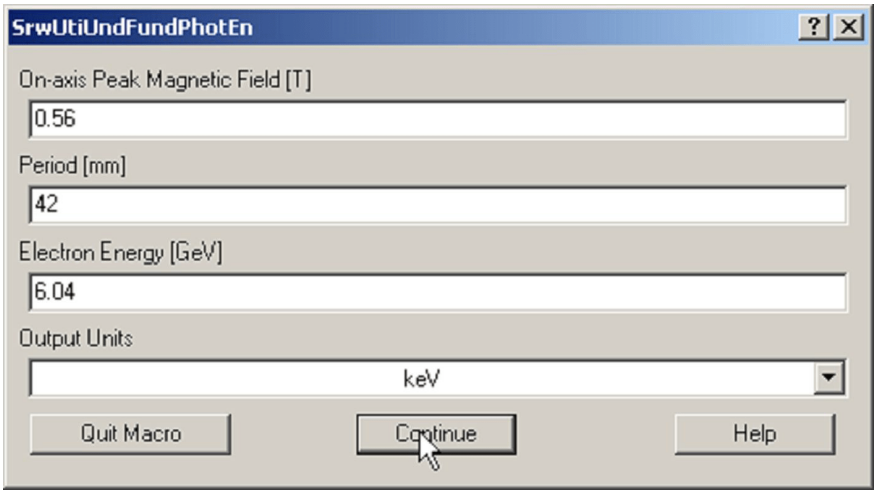
Variable b0,lambu

Action:

Calculates Deflecting Parameter of an undulator and prints the result into History window. User needs to specify on-axis peak magnetic field in T (b0) and the undulator period in mm (lambu).

SrwUtiUndFundPhotEn

Dialog Box:



Definition:

Proc SrwUtiUndFundPhotEn(b0,lambu,en,unit)

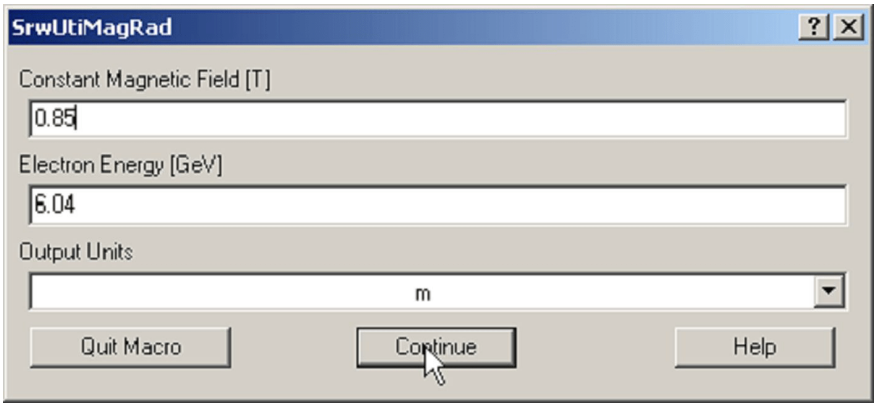
Variable b0,lambu,en,unit

Action:

Calculates Fundamental photon energy / wavelength of an undulator and prints the result into History window. User needs to specify on-axis peak magnetic field in T (b0), undulator period in mm (lambu), electron energy in GeV (en), units of the resulting photon energy / wavelength (unit=1,2,3,4,5,6,7 for keV,eV,1/cm,Å,nm,μm,mm respectively).

SrwUtiMagRad

Dialog Box:



Definition:

Proc SrwUtiMagRad(b0,en,unit)

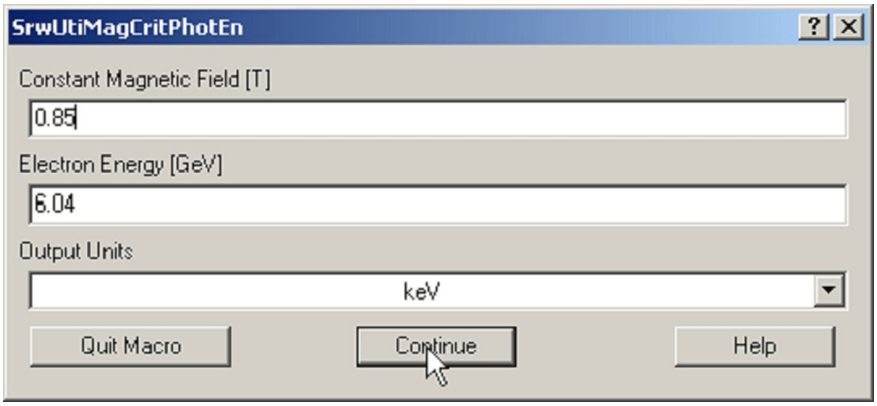
Variable b0,en,unit

Action:

Calculates magnetic radius of a bending magnet and prints the result into History window. User needs to specify constant magnetic field in T (b0), electron energy in GeV (en), units of the resulting radius value (unit=1,2,3 for mm,m,km respectively).

SrwUtiMagCritPhotEn

Dialog Box:



Definition:

Proc SrwUtiMagCritPhotEn(b0,en,unit)

Variable b0,en,unit

Action:

Calculates critical photon energy / wavelength of bending magnet SR and prints the result into History window. User needs to specify constant magnetic field in T (b0), electron energy in GeV (en), units of the resulting photon energy / wavelength (unit=1,2,3,4,5,6,7 for keV,eV,1/cm,Å,nm,μm,mm respectively).

Frequently Asked Questions

How to Import Magnetic Field Data into SRW ?

The simplest method to import an external Magnetic Field data into SRW is to use the macro **SrwMagImportCmpn** (menu call "(Arbitrary) Magnetic Field->Modify Component->Import..."). If this macro failed to import your data, your can try to do the import "manually", after reading the following section.

There is a number of ways one can import the values of the vertical and horizontal fields as a function of the longitudinal coordinate into SRW for a further processing. We assume here that you are familiar with Igor, at least that you know how to graph or edit a wave. If it is not the case, we urge you to experience the Igor tutorials which will introduce you to a number of capabilities of Igor. If you need to import the field data episodically, you can use the Method#1 or 2 described below. If you want to do it many times, the best is that you write your own macro for that, then you should concentrate on the Method#2.

Before you start

- You have to prepare your field data as two lists of field values corresponding to equidistant spacing of the longitudinal position. One is the vertical field component, the other is the horizontal one. Make sure that you have the **same number of points** for both field components and that the data of the two lists corresponds to the same longitudinal position. For debugging purposes, it is easier to deal with the field data in ASCII (Text) format rather than Binary. It is a good practice to watch your data in Microsoft Excel, because then it can be easily copied, manipulated and pasted into Igor and you have a full visual control on it.
- Next, you have to understand the way SRW is describing the magnetic field data. For each description of the magnetic field, SRW creates one text wave and two waves of double precision real numbers. The text wave holds the names of the two other waves together with some other information. The two real waves hold the vertical and horizontal field data.

Method#1: Your data is available in Text mode and you have Microsoft Excel available. The easiest (but difficult to automatize) way to import your data is the following.

1. Open your data in Microsoft Excel and organize it into two vertical columns, one for the vertical field and the other for the horizontal field.
2. Start Igor, Initialize SRW and execute the macro **SrwMagFieldCreate** (menu call "(Arbitrary) Magnetic Field->Create and Modify..."). In the dialog box, enter a name, followed by the longitudinal coordinate of the center of your field data (0 is a good default value), followed by the total range in meters of the longitudinal coordinate covered by your field data, followed by the number of points in each field components (the same as the number of points in Excel). After execution, all three waves have been generated. If you have entered the name "MyData" in the dialog box of the macro

SrwMagFieldCreate, then the waves "MyData_mag" (text wave), "MyDataBX_fld" (horizontal field) and "MyDataBZ_fld" (vertical field) have been created. "MyDataBX_fld" and "MyDataBZ_fld" have been initialized to 0.

3. Edit the waves "MyDataBX_fld" and "MyDataBZ_fld" one by one either from the Igor menu or by typing "Edit MyDataBX_fld MyDataBZ_fld" in the Command Window, Select the whole column holding the data of the wave and Erase it (Cut from the Menu Edit). Select the vertical field data in Microsoft Excel and Paste it into "MyDataBZ_fld" in the window being edited. Continue with the horizontal field (Paste data into "MyDataBX_fld").
4. Convert your field data to Tesla units by multiplying "MyDataBX_fld" and "MyDataBZ_fld" by a proper constant. For example, if your data are in Gauss, you should divide it by 10000. Type for this "MyDataBX_fld = MyDataBX_fld/10000" and "MyDataBZ_fld = MyDataBZ_fld/10000" in the Command Window.
5. The job is done. Check that everything is correct by executing the SRW macro SrwMagDisplayField("MyDataBX_fld") and SrwMagDisplayField("MyDataBZ_fld") or by typing "Display MyDataBZ_fld" and "Display MyDataBX_fld" in the Command Window. Check that the curves together with the units of both axes are correct.

Method#2: You do not want to copy/paste between Igor and Excel either because you have no Excel or because you want to automatize the process using macro commands of Igor.

1. You have to first study and experience various modes of importing waves into Igor and test them on your data until it works. See the Igor documentation for this. Depending on your data structure, it may be more or less easy do (Igor is rather smart so do not be afraid; the problems can come only with some special binary data format). At the end you should have in memory two waves, say "Bz" and "Bx" (or any other name that you have given) that holds your data. If you do not succeed, we advise you to convert your data into ASCII (Text) format using some other utilities and load it into Igor with the "Load General Text..." or "Load Delimited Text..." commands.
2. Set the longitudinal scale of "Bx" and "Bz" waves by the Menu "Data", sub-menu "Change Wave Scaling" of Igor. Display them in Igor (for example by typing "Display Bz" and "Display Bx" in the Command Window or through the Windows menu of Igor).
3. Do all the steps of the Method#1 except for the Copy/Paste between Igor and Excel.
4. Copy the content of the "Bx" and "Bz" waves into "MyDataBX_fld" and "MyDataBZ_fld" by typing "MyDataBZ_fld=Bz" and "MyDataBX_fld=Bx" in the Command Window.
5. Convert the field units in Tesla (if needed) as described in the Method#1.
6. Check the result by typing "Display MyDataBZ_fld" and "Display MyDataBX_fld" in the Command Window.
7. Watch the content of the History Window. It holds the text form of all the commands that you have invoked in these operations. Copying and editing its

content into a procedure file is a good way to write a Macro to automatize this task.

More Remarks

- If your field data points do not correspond to equidistant longitudinal coordinates, you can process them with the "Interpolate" macro of Igor. For this you have to import both the field data and the associated longitudinal coordinate of the points and run the "Interpolate" macro with the proper settings. You will obtain one wave for the vertical field and another wave for the horizontal field that you can further process according to the Method#2. Make sure that the vertical and horizontal field is interpolated for the same longitudinal coordinates.
- If you are an experienced user of Igor, we advise you to print and watch various macros where the SRW field data is created and manipulated (file "SRW MagField Gen.ipf" in the SRW Procedure folder).

Why electron trajectory appears tilted in an undulator and / or why there is no UR central cone at zero direction ?

SRW computes the electron trajectory from the following input data.

Electron Beam structure:

- electron beam energy;
- initial horizontal and vertical positions and angles of the filament electron beam specified at some longitudinal position.

Magnetic Field structure:

- horizontal and vertical magnetic field components tabulated vs longitudinal position and stored in 1D numerical waves.

If you have checked that your Magnetic Field structure is defined properly (at least, magnetic field plots created from menu "...Arbitrary Magnetic Field -> Display Field..." look correct), than the most probable reason of the trajectory tilt is improper definition of the initial horizontal and vertical electron positions / angles or the longitudinal position to which they relate (these parameters are entered in the dialog "Electron Beam" or by the macro **SrwElecFilament**).

For example, it is not at all always correct to assume that the transverse positions and angles of the electron trajectory are zero in the middle of an undulator (typically at zero longitudinal position). For an undulator structure with zero first field integral, it is much more safe to assume that the transverse positions and angles of the electron trajectory are zero at some longitudinal position before the undulator (yet not out of the magnetic field definition range!).

If the first field integral is not zero in your undulator, you can change (reduce) the trajectory tilt by varying the value(s) of the initial horizontal (vertical) angle(s) of the filament electron beam using the dialog "Electron Beam" or the macro

SrwElecFilament.

How can I take into account finite electron beam emittance at SR propagation ?

In the present version of the code, the finite e-beam emittance can be taken into account in the following way.

The features of your beamline may allow to accept that the intensity distribution due to the finite e-beam emittance is a result of convolution of the intensity distribution computed for the filament e-beam with the particle density distribution in the real e-beam. This happens, for example, in simplest schemes of the SR focusing. In any particular case, one can test whether this takes place or not by repeating the propagation for the filament e-beam with a small displacement in initial transverse coordinate and/or angle within the electron beam size and divergence, and watching whether it results only in a shift of the intensity profile after the propagation, or the shape of the profile is also affected. In the former case, one is more-or-less safe to assume the convolution formalism to be valid, and one can easily extract the intensity distribution due to finiteemittance electron beam using the SRW menu "Visualize...", by choosing "Multi-e Intensity" under "Single-e / Multi-e" field in the dialog box (for more details, please see the help for the macro **SrwWfr2Int**).

If the convolution formalism can not be applied, you can try to determine the multi-electron intensity by summing-up and averaging the intensity distributions obtained for the filament ebeam with different initial transverse positions and/or angles which satisfy the particle density distribution of the real e-beam (typically, Gaussian distribution is a good approximation). At this procedure, it may appear more CPU-efficient to move the beamline transversely with respect to the e-beam, than vice versa.

How can I simulate an optical element which is not yet implemented in SRW ?

In SRW starting from version 3.2.0, there is a "Generic Thin" optical element implemented. It approximates the transformation of the electric field from the transverse plane before the optical elements to the transverse plane immediately after it by multiplication of the field at any point of the wavefront by a 2D complex transmission function which, in general case, modifies both the phase and amplitude of the electric field.

If the "Thin" approximation is appropriate for your optical element, you need to do the following to simulate it.

1. Write in Igor Pro macro language two scalar functions of two scalar arguments, one of which returns the Optical Path Difference and the other one the Amplitude Transmission for any transverse position (two transverse

coordinates in natural frame) at propagation from the transverse plane before the optical element to the plane immediately after it.
2. Execute the macro **SrwOptThinTempl** (menu SRWP "Optical Element: Thin -> Transmission: Template...") which will create a template of a "Thin" element, i.e. optical element structure and a 2D complex wave to keep information on the Optical Path Difference and Amplitude Transmission. In this macro, you should give a name to your element and specify the transverse dimensions and center position for it.
3. To finish the setup of the optical element, execute the macro SrwOptThinSetup (menu SRWP "Optical Element: Thin -> Transmission: Setup..."), which will fill the 2D complex wave created at the step 2, using the Optical Path Difference and Amplitude Transmission functions prepared at the step 1.

Refractive Lenses for X-rays are implemented in IGOR part of the SRW using the mechanism described above. Have a look at the SRW procedure file where these elements are implemented. You can open this file using IGOR menu "Windows -> Procedure Windows -> SRW Optics ThinGen.ipf".

Alternatively, you can execute only the step 2 (i.e. create template with empty 2D complex wave), and then fill the 2D complex wave, using the IGOR macro language, with the data describing your optical element. *Real part of each point of this 2D complex wave should be the Amplitude Transmission, and imaginary part of it should be the Optical Path Difference introduced by the optical element (= /).*

You can check the results of setting up your optical element by displaying its characteristics (amplitude or intensity transmission, or optical path) by using the macro **SrwOptThinTransmDisplay** (menu SRWP: "Optical Element: Thin -> Transmission: Display...")