



| The European Synchrotron

OASYS, is it a mirage?

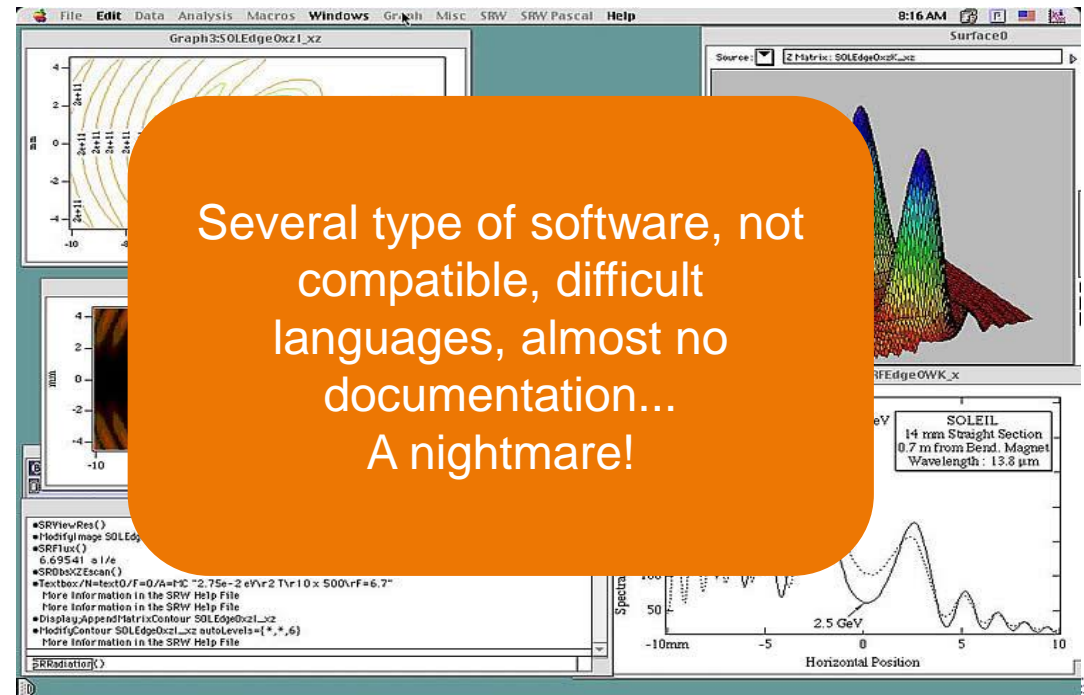
Laura Torino
DEELS 2019, 05/06/2019

SR SIMULATION SOFTWARE

The Synchrotron Radiation (SR) is strongly used by the beam diagnostics community to perform different type of measurements (emittance, position, energy, power load...)

It is useful to simulate SR generation, propagation, and absorption.

- X-ray Oriented Program (XOP)
- SHADOW/SHADOWUI
- Synchrotron Radiation Workshop (SRW)
- ...





Manuel Sanchez del Rio (ESRF) and
Luca Rebuffi (APS)

“The implemented software architecture allows to obtain not only an intuitive and **very-easy-to-use** graphical interface, but also provides high flexibility and **rapidity for interactive simulations**, allowing to make quick configuration changes to compare multiple beamline configurations” *

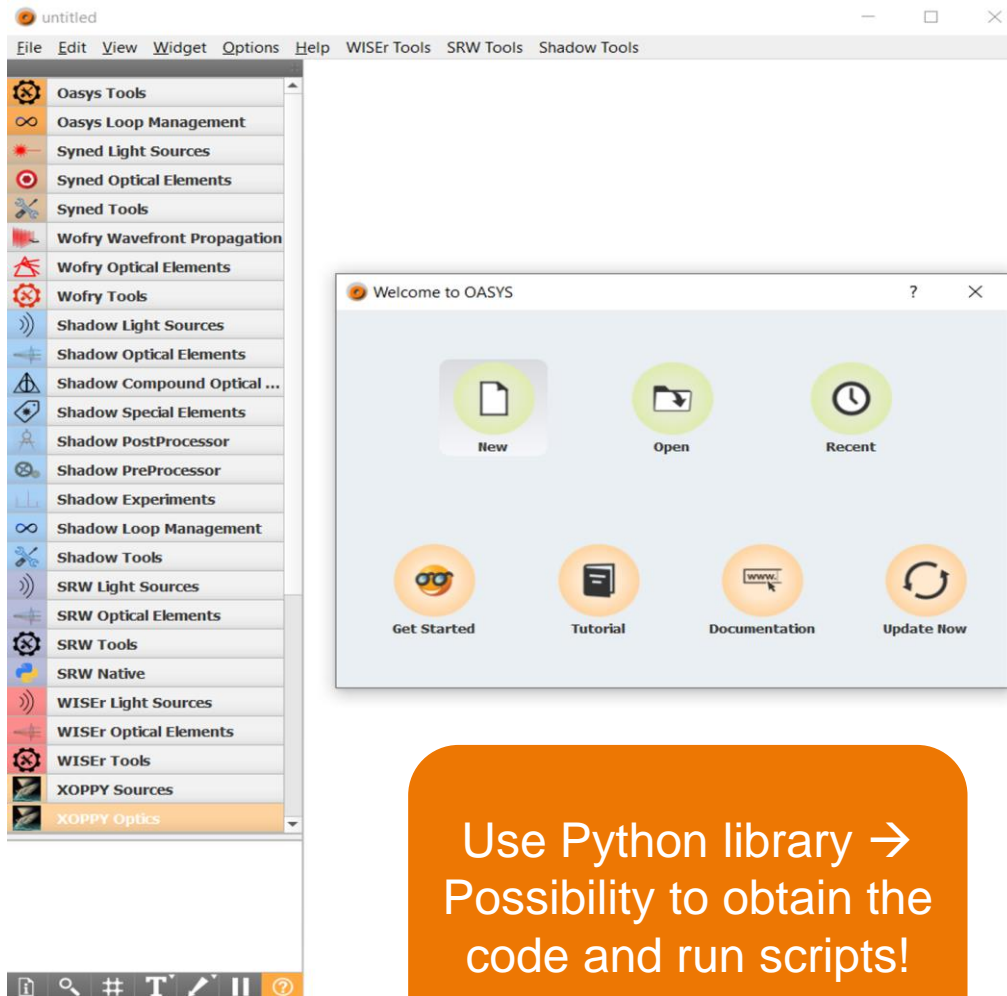
Graphical environment for optical
(and more) simulation:

- Python based
- Module adds-on
- Communicating packages



* <https://www.aps.anl.gov/Science/Scientific-Software/OASYS>

Graphical User Interface available for Windows, Linux, macOS



Use Python library →
Possibility to obtain the
code and run scripts!

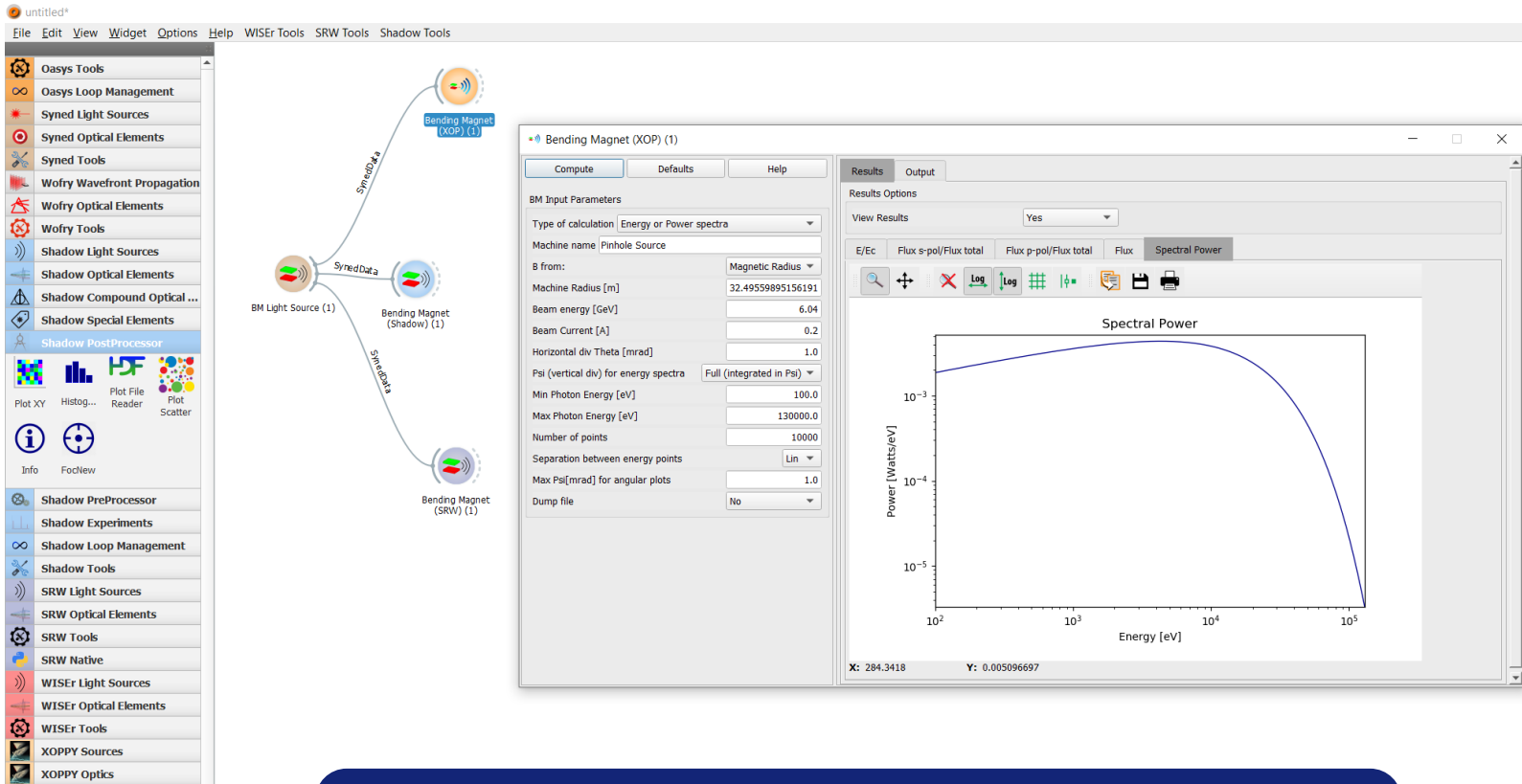
- **Wofry:** Simple optical wavefront (plane, spherical, Gaussian) propagation tool
- **Shadow:** Ray tracing simulations + Hybrid: to introduce diffraction (quick and dirty)
- **SRW:** Generation and optical propagation of SR wavefront
- **XOPY:** Generation and transmission/absorption of SR spectra

EXAMPLE - COMMON SOURCE GENERATION

The screenshot displays the OASYS software interface. On the left is a vertical toolbar with various tool categories: Oasys Tools, Oasys Loop Management, Syned Light Sources (containing BM Light Source, Undul... Light..., and Wiggler Light...), Syned Optical Elements, Syned Tools, Wofry Wavefront Propagation, Wofry Optical Elements, Wofry Tools, Shadow Light Sources, Shadow Optical Elements, Shadow Compound Optical..., Shadow Special Elements, Shadow PostProcessor, Shadow PreProcessor, Shadow Experiments, Shadow Loop Management, Shadow Tools, SRW Light Sources, SRW Optical Elements, SRW Tools, SRW Native, WISer Light Sources, WISer Optical Elements, WISer Tools, XOPPY Sources, and XOPPY Optics. The main window shows the 'BM Light Source' configuration dialog. It includes a 'Send Data' button and a 'Reset Fields' button. The 'Light Source Setting' section contains a 'Read/Write File' area with a text field for 'Syned File Name/URL' (set to 'torino/Oasys/EBS_BendingMagnet.json') and buttons for 'Read Syned File' and 'Write Syned File'. Below this is a 'Light Source Name' field (set to 'Pinhole Source') and an 'Electron Beam/Machine Parameters' section with fields for Energy [GeV] (6.04), Energy Spread (0.000937), Ring Current [A] (0.2), and a dropdown for 'Electron Beam Properties' (set to 'From Size/Divergence'). The 'BM Parameters' section includes fields for Radius [m] (32.49559895156191), Magnetic Field [T] (0.62), and Length [m] (0.38).

Possibility to create and save different source, common for all the different software, by defining lattice characteristics and beam parameters

EXAMPLE - SOURCE GENERATION - XOP



XOP → Generation of the SR spectra

EXAMPLE - SOURCE GENERATION - SHADOW

The screenshot displays the SHADOW software interface. On the left is a vertical toolbar with various tool categories. The main workspace shows a schematic of a beamline with a 'BM Light Source (1)' and three 'Bending Magnet' elements: 'Bending Magnet (XOP) (1)', 'Bending Magnet (Shadow) (1)', and 'Bending Magnet (SRW) (1)'. A 'SynchroData' node connects the source to the magnets. A 'Bending Magnet (Shadow) (1)' window is open, showing simulation parameters. The 'Number of Rays' field is circled in blue and set to 1,000,000. The 'Basic Setting' tab is active, showing Monte Carlo and Energy Spectrum options. The 'Plots' section contains three plots: a 2D intensity map in the X,Z plane, a line plot of intensity vs. Frequency, and a line plot of intensity vs. X (μm). The 'Info' panel on the right provides summary statistics.

Parameter	Value
Intensity	1000000.000
Total Rays	1000000
Total Good Rays	1000000
Total Lost Rays	0
FWHM X [μm]	25.3530
FWHM Z [μm]	20.4667

SHADOW → Random generation of a given number of rays with an energy distributed according to the SR spectra

EXAMPLE - SOURCE GENERATION - SRW

The screenshot displays the SRW software interface. On the left is a vertical toolbar with various tool categories such as 'Oasys Tools', 'Wofry Wavefront Propagation', and 'Shadow PostProcessor'. The main workspace shows a workflow diagram with three components: 'BM Light Source (1)', 'Bending Magnet (XOP) (1)', and 'Bending Magnet (SRW) (1)', connected by 'SynchroData' links.

The 'Bending Magnet (SRW) (1)' window is open, showing the 'Wavefront Setting' tab. The 'Wavefront Parameters' section is circled in blue and contains the following values:

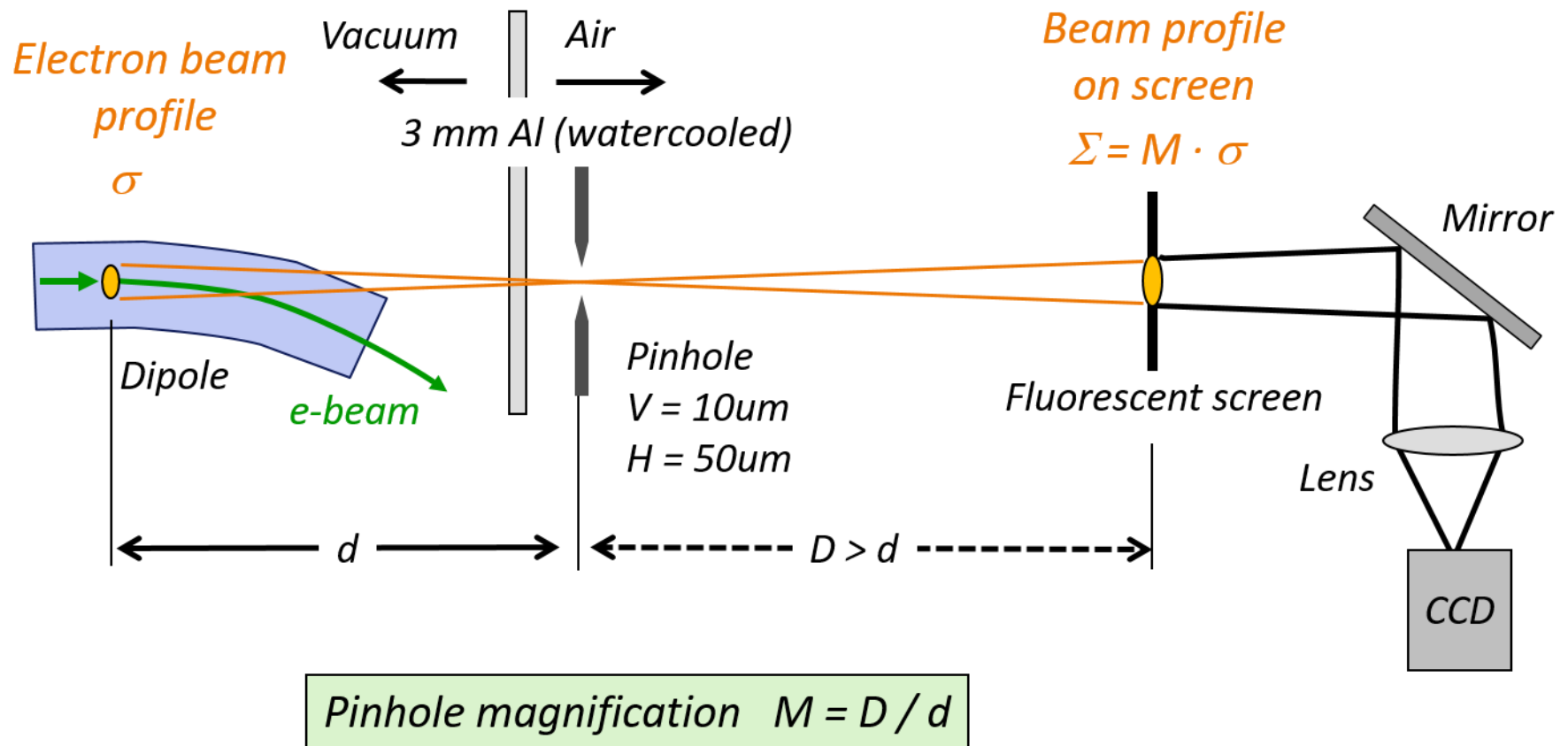
Parameter	Value
Photon Energy [eV]	60000.0
H Slit Gap [m]	0.0004
V Slit Gap [m]	0.0004
H Slit Points	500
V Slit Points	500
Propagation Distance [m]	4.0

The 'Plots' section shows three plots: 'Intensity SE' (a 2D intensity map), 'Phase SE' (a 2D phase map), and 'Intensity ME (Convolution)' (a 1D intensity profile). The 'Info' panel on the right displays the following statistics:

Statistic	Value
Total	4.929e+17
FWHM X [μm]	63.3267
FWHM Y [μm]	400.0000

SRW → Generation of the SR wavefront at a given energy and a given position

THE PINHOLE



F. Ewald, "Beam Size Monitoring at the ESRF: Comparison of different X-ray based techniques"

Topical Workshop on Emittance Measurements for Light Sources and FELs, Barcelona, 29-30 January 2018

EXAMPLE - PINHOLE - SHADOW

The screenshot shows the OASYS software interface. On the left is a toolbar with various tool categories like Oasys Tools, SRW Tools, and Shadow Tools. The main workspace displays a beamline layout with components: BM Light Source, Bending Magnet (Shadow), AI Window, Pinhole, and Plot XY (1). Arrows indicate the beam path from the light source through the bending magnet, AI window, and pinhole to the plot. A 'Loop Point (1)' is also visible. Below the main workspace, the 'AI' configuration window is open, showing parameters for the Aluminum (Al) window.

AI Window Configuration Parameters:

- Element/Compound formula: Al
- Density [g/cm³]: 2.6989
- File for SHADOW (trace): AlWin.dat
- Minimum energy [eV]: 100.0
- Maximum energy [eV]: 20000.0
- Energy step [eV]: 100.0

Beam after the Al window.
 → Possibility to study the path of the survived x-rays by adding filters

The screenshot shows the 'AI Window' configuration panel and the resulting 'Energy' plot. The configuration panel includes 'General Options' (Automatic Execution checked), 'Position' (Basic Setting), 'Screen/Slit Shape', 'Aperturing' (No), and 'Absorption Parameters' (Absorption: Yes, Thickness: 0.003 m, Opt. const. file name: /torino/Oasys/AlWin.dat). The 'Energy' plot shows the 'Number of Rays weighted by |E_r + E_{in}|²' versus 'Energy [eV]'. The plot shows a sharp peak at approximately 40,000 eV, followed by a gradual decay. The 'Info' panel on the right provides summary statistics:

Intensity	613456.228
Total Rays	1000000
Total Good Rays	1000000
Total Lost Rays	0
FWHM [eV]	13996.6000

EXAMPLE - PINHOLE - SHADOW

untitled*

File Edit View Widget Options Help WISer Tools SRW Tools Shadow Tools

Oasys Tools
Oasys Loop Management
Syned Light Sources
Syned Optical Elements
Syned Tools
Wofry Wavefront Propagation
Wofry Optical Elements
Wofry Tools
Shadow Light Sources
Shadow Optical Elements
Shadow Compound Optical ...
Shadow Special Elements
Shadow PostProcessor
Shadow PreProcessor
Shadow Experiments
Shadow Loop Management
Shadow Tools
SRW Light Sources
SRW Optical Elements
SRW Tools
SRW Native
WISer Light Sources
WISer Optical Elements
WISer Tools
XOPPY Sources
XOPPY Optics

POWE... POWER CRY... INPRO
MARE MLayer f_0 $f'_0(x)$ $f''_0(x)$
 F_H σ σ_{xcom}
Ph Cross... XCOM POWD...
XRAYLIB
Xraylib

PreProcessor Data → PreProcessor Data #1
BM Light Source → SynedData → Beam → Input Beam → Al Window → Beam → Input Beam → Pinhole → Plot XY (1)
Loop Point (1)

Pinhole

General Options
 Automatic Execution
Run Shadow/Trace *Reset Fields*

Position Basic Setting Advanced Setting

Screen/Slit Shape
Aperturing Yes
Open slit/Solid stop aperture/slit
Aperture shape Rectangular
Slit width/x-axis [m] 3e-05
Slit height/z-axis [m] 1e-05
Slit center/x-axis [m] 0.0
Slit center/z-axis [m] 0.0

Absorption Parameters
Absorption No

Plots Output
Plotting Style
Select level of Plotting Detailed Plot
X,Z X,Z' X,X' Z,Z' Energy

X,Z
100
50
0
-50
-100
-150 -100 -50 0 50 100 150
X / mm

Frequency
0.0 2.5 5.0

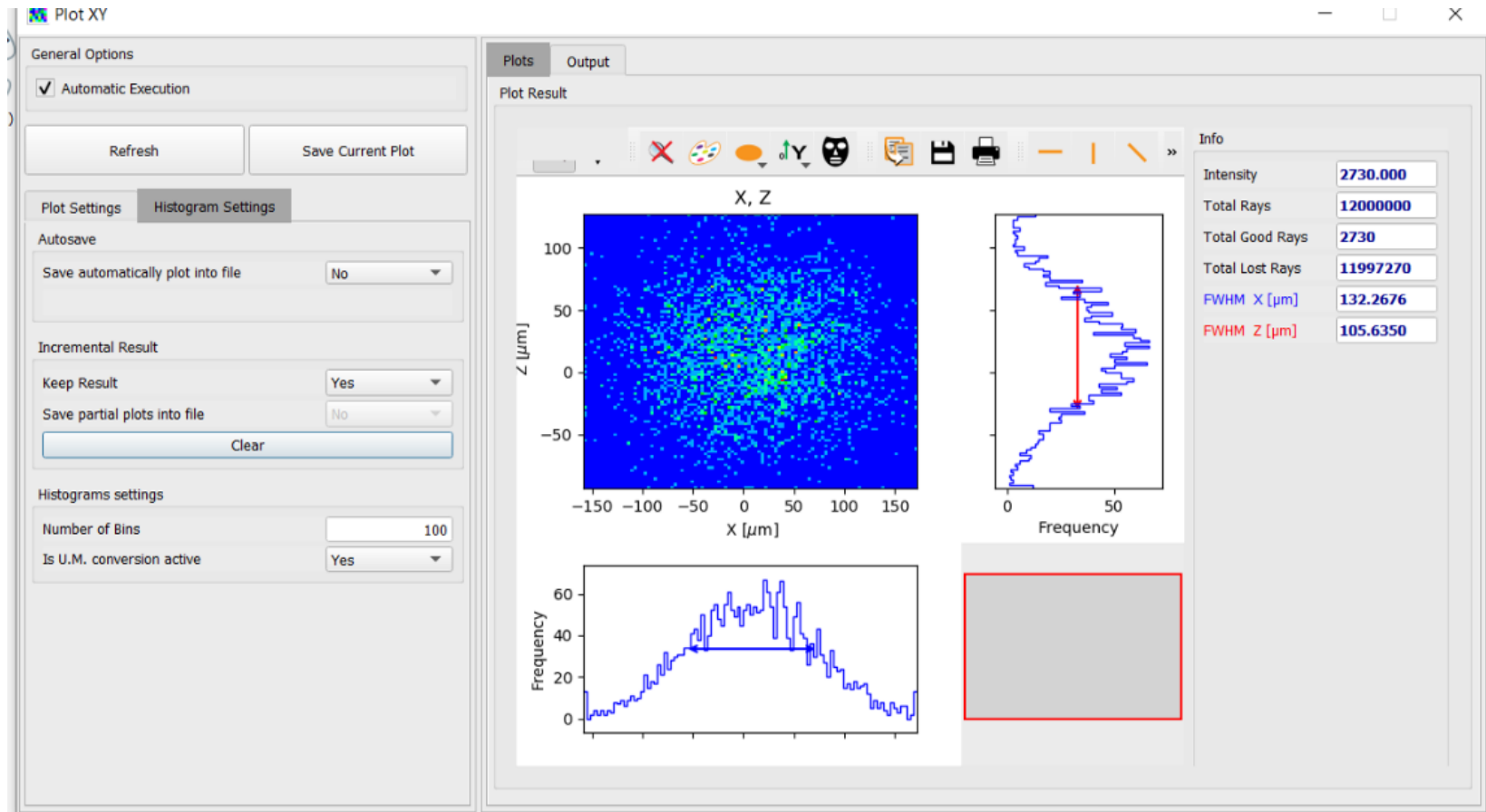
Frequency
0 2 4 6

Info
Intensity 143.983
Total Rays 1000000
Total Good Rays 228
Total Lost Rays 999772
FWHM X [μm] 159.5447
FWHM Z [μm] 80.6398

Possibility of defining slits or obstacles and to propagate the x-rays

Computation might be heavy depending on the number of rays
→ Possibility to define a loop and iterate the source generation

EXAMPLE - PINHOLE - SHADOW



NOTE: Very heavy for the computer!

Possibility to retrieve the python script and run it into a cluster!

EXAMPLE - PINHOLE - SHADOW

The screenshot displays the ShadowTools software interface. On the left is a vertical toolbar with various tool categories such as Oasys Tools, Wofry Tools, Shadow Light Sources, and Shadow PostProcessor. The main workspace shows a simulation diagram with components: BM Light Source, Bending Magnet (Shadow), AI Window, Pinhole, and Plot XY (1). Connections are labeled with 'Beam -> Input Beam' and 'Taper'. A red circle highlights an 'Info' button on the right side of the diagram. Below the diagram, an 'Info' window is open, showing a 'Python Script' tab. The script contains comments and code for initializing shadow3, creating a beam, and defining variables. A red circle highlights the 'Python Script' tab in the Info window.

```
#!/usr/bin/env python3
# Python script to run shadow3. Created automatically with ShadowTools.make_python_script_from_list().
import Shadow
import numpy

# write (1) or not (0) SHADOW files start.xx end.xx star.xx
lwrite = 0

# initialize shadow3 source (oe0) and beam
beam = Shadow.Beam()
oe0 = Shadow.Source()
oe1 = Shadow.OE()
oe2 = Shadow.OE()

# Define variables. See meaning of variables in:
# https://raw.githubusercontent.com/srio/shadow3/master/docs/source.nml
# https://raw.githubusercontent.com/srio/shadow3/master/docs/oe.nml
"
```

Python 3.7.3 (default, Mar 27 2019, 17:13:21) [MSC.v.1915 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
(PythonConsole)
>>>

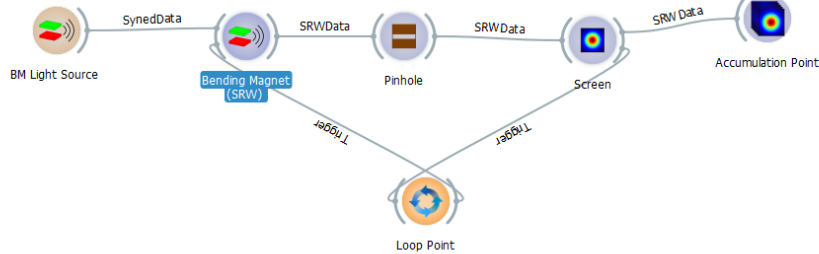
On the “Info” buttons it is possible to find several info on the simulation and the Python script!

EXAMPLE - PINHOLE - SRW

untitled*

File Edit View Widget Options Help WISer Tools SRW Tools Shadow Tools

- Oasys Tools
- Oasys Loop Management
- Syned Light Sources
- Syned Optical Elements
- Syned Tools
- Wofry Wavefront Propagation
- Wofry Optical Elements
- Wofry Tools
- Shadow Light Sources
- Shadow Optical Elements
- Shadow Compound Optical ...
- Shadow Special Elements
- Shadow PostProcessor
- Shadow PreProcessor
- Shadow Experiments
- Shadow Loop Management
- Shadow Tools
- SRW Light Sources
- SRW Optical Elements
- SRW Tools
 - SRW Oasys Surfac...
 - Height Profile...
 - DABAM Height...
 - SRW Reflec...
 - Accum... Point
 - SRW Wavef...
 - SRW Wavef...
 - From Wofry ...
 - Wofry To Wofry ...
 - Info
- SRW Native
- WISer Light Sources
- WISer Optical Elements
- WISer Tools
- XOPPY Sources
- XOPPY Optics



Generation of the source until the first slit (just before the pinhole)

Bending Magnet (SRW)

Run SRW Source Reset Fields

Light Source Setting Wavefront Setting

Propagation

Wavefront Parameters

Photon Energy [eV]	60000.0
H Slit Gap [m]	0.0004
V Slit Gap [m]	0.0004
H Slit Points	500
V Slit Points	500
Propagation Distance [m]	4.0

Precision Parameters

Calculation Method	Auto
Relative Precision	0.01
Longitudinal position to start integration (effective if < zEndInteg) [m]	0.0
Longitudinal position to finish integration (effective if > zStartInteg) [m]	0.0
Number of points for trajectory calculation	50000
Use "terminating terms" (i.e. asymptotic expansions at zStartInteg and zEndInteg) or not	No
Sampling factor for adjusting nx/ny (effective if > 0)	0.0

Plots Output

Output Plot Setting

Plot Results Yes (Total Polarization) Propagation Mode Element by Element (Native)

Intensity SE Phase SE Intensity ME (Convolution)

Intensity SE [ph/s.1%bw/mm²]

Info

Total	4.929e+17
FWHM X [μm]	63.3267
FWHM Y [μm]	400.0000

EXAMPLE - PINHOLE - SRW

The image displays the SRW (Synchrotron Radiation Workshop) software interface. On the left is a vertical toolbar with various tool categories: Oasys Tools, Oasys Loop Management, Syned Light Sources, Syned Optical Elements, Syned Tools, Wofry Wavefront Propagation, Wofry Optical Elements, Wofry Tools, Shadow Light Sources, Shadow Optical Elements, Shadow Compound Optical..., Shadow Special Elements, Shadow PostProcessor, Shadow PreProcessor, Shadow Experiments, Shadow Loop Management, Shadow Tools, SRW Light Sources, SRW Optical Elements, and SRW Tools. The SRW Tools section includes icons for SRW Oasys Surface, Height Profile, DABAM Height, SRW Reflect, Accumulation Point, SRW Wave, SRW Wave, Wofry From, Wofry To, and Wofry Info.

The main workspace shows a beamline layout with the following components: BM Light Source, Bending Magnet (SRW), Pinhole, Screen, and Accumulation Point. Data flow is indicated by arrows labeled 'SynedData', 'SRWData', and 'Trigger'. A blue callout box labeled 'Slit (pinhole)' points to the Pinhole element. An orange callout box on the right contains the text: 'No needs of definition of "containers"!'. Below the main workspace, a detailed 'Pinhole' configuration window is open, showing 'General Options' (Automatic Execution checked), 'Propagate Wavefront' button, and various parameters for drift spaces, auto-resizing, and propagation precision. The 'Plots' tab is active, showing 'Intensity SE' plots. The main plot is a 2D intensity map with axes from -200 to 200. A secondary plot shows a sharp peak at 0. A third plot shows a frequency spectrum with a peak at 1.0. An 'Info' panel on the right displays the following data:

Parameter	Value
Total	4.562e+14
FWHM X [μm]	29.6593
FWHM Y [μm]	8.8176

EXAMPLE - PINHOLE - SRW

untitled*

File Edit View Widget Options Help WISer Tools SRW Tools Shadow Tools

Oasys Tools
Oasys Loop Management
Syned Light Sources
Syned Optical Elements
Syned Tools
Wofry Wavefront Propagation
Wofry Optical Elements
Wofry Tools
Shadow Light Sources
Shadow Optical Elements
Shadow Compound Optical ...
Shadow Special Elements
Shadow PostProcessor
Shadow PreProcessor
Shadow Experiments
Shadow Loop Management
Shadow Tools
SRW Light Sources
SRW Optical Elements
SRW Tools
SRW Oasys Surfac...
Height Profile...
DABAM Height...
SRW Reflec...
Accum...
SRW Wavef...
SRW Wavef...
From Wofry ...
SRW To Wofry ...
Info
SRW Native
WISer Light Sources
WISer Optical Elements
WISer Tools
XOPPY Sources
XOPPY Optics

BM Light Source SynedData Bending Magnet (SRW) SRWData Pinhole SRWData Screen SRWData Accumulation Point 30%
Loop Point

Screen

General Options
 Automatic Execution

Propagate Wavefront Reset Fields

Optical Element Wavefront Propagation

Drift Space Before Drift Space After

Auto Resize Before Propagation No
Auto Resize After Propagation No
Relative precision for propagation with autoresizing (1.0 is nominal) 1.0
Propagator Quadratic Term Special ?
Do any resizing on fourier side using fit No
H range modification factor at resizing 1.0
H resolution modification factor at resizing 4
V range modification factor at resizing .5
V resolution modification factor at resizing 1.0
Optional
Orientation of the Output Optical Axis vector in the Incident Beam Frame: X 0.0
Orientation of the Output Optical Axis vector in the Incident Beam Frame: Y 0.0
Orientation of the Output Optical Axis vector in the Incident Beam Frame: Z 0.0
Orientation of the Horizontal Base vector of the Output Frame in the Incident Beam Frame: X 0.0
Orientation of the Horizontal Base vector of the Output Frame in the Incident Beam Frame: Y 0.0

Plots Output

Output Plot Setting

Plotting Range No Refresh

Intensity SE Phase SE Intensity ME (Convolution)

Intensity ME [ph/s/.1%bw/mm²]

Frequency

Info

Total	7.867e+13
FWHM X [μm]	829.4604
FWHM Y [μm]	42.5013

Multi-Electron with convolution → Not correct, just to an idea!

Possibility of loops sampling the single electron starting position from the phase space (slow)...

EXAMPLE - PINHOLE - SRW

untitled*

File Edit View Widget Options Help WISer Tools SRW Tools Shadow Tools

Oasys Tools
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Wofry Optical Elements
Wofry Tools
Shadow Light Sources
Shadow Optical Elements
Shadow Compound Optical ...
Shadow Special Elements
Shadow PostProcessor
Shadow PreProcessor
Shadow Experiments
Shadow Loop Management
Shadow Tools
SRW Light Sources
SRW Optical Elements
SRW Tools
SRW Native
SRW Python... Intensity Plot Degree of Coh...
WISer Light Sources
WISer Optical Elements
WISer Tools
XOPPY Sources
XOPPY Optics

BM Light Source → SynedData → Bending Magnet (SRW) → SRWData → Pinhole → SRWData → Screen → SRWData → Accumulation Point 30%

SRW Python Script (ME)

General Options

Automatic Execution

Refresh Script Reset Fields

SRW Native Code: ME

Sampling factor for adjusting nx, ny (effective if > 0) 1.0

Total Nr. of Electrons (Wavefronts) 500000

Nr. of Electrons (Wavefronts) to average on e (for MPI calculations) 5

Saving periodicity (in terms of Electrons) for the Resulting Intensity 20

SR calculation method (1 - undulator) 1

SR calculation relative accuracy 0.01

Output File Name output_srw_script_me.dat

Calculation Total Intensity

Python Script System Output

```
from oasys_srw.srwlib import *
from uti_plot import *
import numpy

# if not srwl_uti_proc_is_master(): exit()

#####
# LIGHT SOURCE

part_beam = SRWLPartBeam()
part_beam.lavg = 0.2
part_beam.partStatMom1.x = 0.0
part_beam.partStatMom1.y = 0.0
part_beam.partStatMom1.z = -0.19
part_beam.partStatMom1.xp = 0.0
part_beam.partStatMom1.yf = 0.0
part_beam.partStatMom1.gamma = 11819.985235008744
part_beam.arStatMom2[0] = 1.3502440000000002e-10
part_beam.arStatMom2[1] = 0.0
part_beam.arStatMom2[2] = 3.3196839999999995e-10
part_beam.arStatMom2[3] = 8.35396e-11
part_beam.arStatMom2[4] = 0.0
part_beam.arStatMom2[5] = 3.025e-13
part_beam.arStatMom2[10] = 8.77969e-07

magnetic_structure = SRWMagFldM(G=0.62, m=1, n_or_s='n', Leff=0.38)
magnetic_field_name = SRWMagFldM.arMagFldM.arMagFldM.arMagFldM.arMagFldM

Python 3.7.3 (default, Mar 27 2019, 17:13:21) [MSC v.1915 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
(PythonConsole)
>>>
```

Run Script Save Script to File

Provides python script for native Multi-Electron simulation → Can be manipulated and launched on a cluster!

OVERVIEW AND REFERENCES

OASYS is an intuitive SR generation and propagation software:

- Allows to perform quick simulations step by step
- Useful to “align” and optimize the main parameter
- Computationally heavy but provides Python scripts which might be modified and run in a cluster (after all the optimization has been done!)

You can find the software and the installation how-to in:

<https://github.com/oasys-kit>

The material for the First OASYS School, with some extremely useful slides and several examples can be found in:

https://github.com/oasys-kit/oasys_school

A second OASYS school is foreseen soon (in the US...)

Many thanks to M. Sanchez del Rio, R. Celestre, J. Reyes (ESRF),
L. Rebuffi (APS)