

COMPUTATION OF SYNCHROTRON RADIATION

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INTRODUCTION

Open Source Code for Advanced Radiation Simulation (OSCARS) [1] an open source software developed at Brookhaven National Laboratory.

OSCARS is a general purpose code for the computation of radiation from charged particles in motion. Primary uses are for synchrotron and accelerator facilities where photon density distributions and heat loads on accelerator and beam-line equipment is of great interest. This software allows for the calculation of these properties on arbitrary shaped surfaces in 3 dimensions for arbitrary E&M field configurations in 3D.

CAPABILITIES

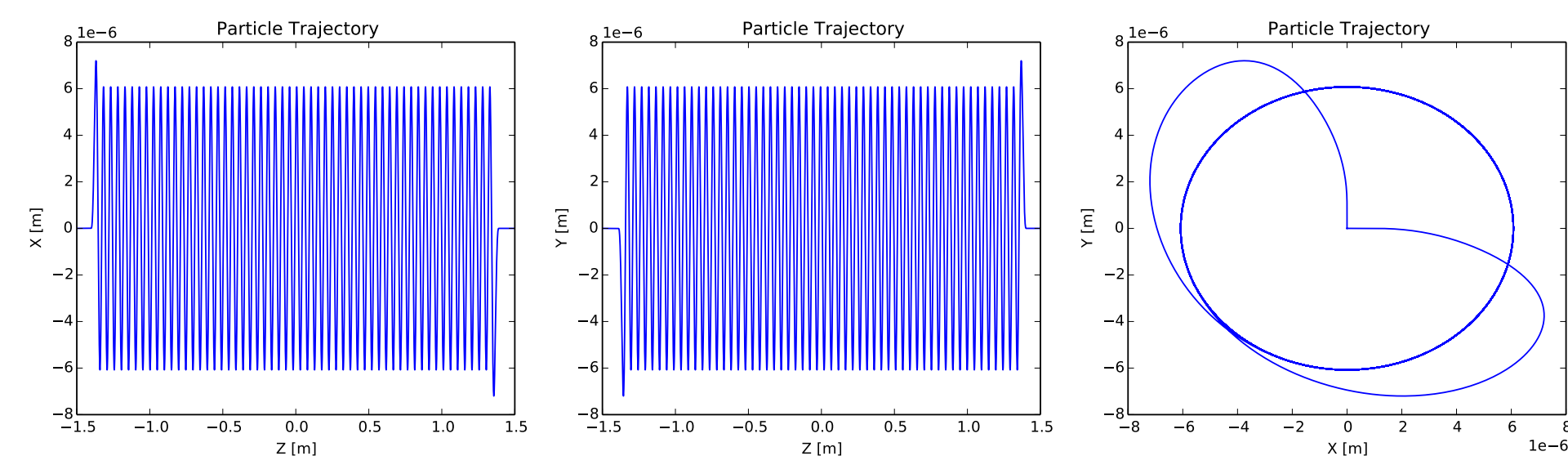
With a simple and powerful user interface:

- Trajectories in E&M fields
- Calculation of spectra
- Calculation of flux densities
- Calculation of power densities
- Perform these calculations on arbitrary geometries in 3D
- Valid in the near-field, far-field, non-relativistic, and relativistic regimes

TRAJECTORY

Particle trajectory calculations are done using a 4th-order Runge-Kutta method. The equation of motion is the relativistic Lorentz equation given below where $\vec{p} = \gamma m_0 \vec{v}$

$$\frac{d\vec{p}}{d\tau} = q(\vec{E} + \vec{v} \times \vec{B}) \quad (1)$$



FLUX DENSITY

The spectrum and flux densities are calculated from the electric field in the frequency domain given in equation 2, which is derived from a Fourier transform of the Liéard-Wiechert potentials. It is valid in the near-field and for relativistic and non-relativistic particles alike. The field is calculated in all three spatial dimensions.

$$\vec{E}(\vec{r}, \omega) = \frac{ie\omega}{4\pi\epsilon_0 c} \int_{-\infty}^{+\infty} \frac{\vec{\beta} - \hat{n}(1 + \frac{ic}{\omega D})}{D} e^{i\omega(\tau + \frac{D}{c})} d\tau \quad (2)$$

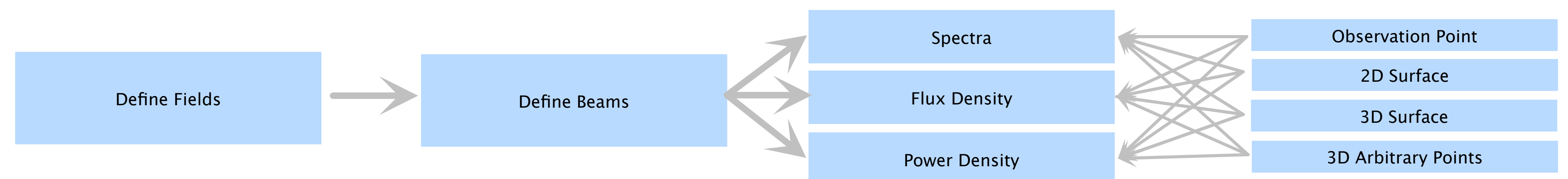
POWER DENSITY

The power density $P(\vec{x})$ is calculated as the power radiated and given by the equation

$$\frac{qI}{16\pi^2\epsilon_0 c} \int_{-\infty}^{\infty} \frac{\vec{n} \times ((\vec{n} - \vec{\beta}) \times \frac{\vec{a}}{c})}{(1 - \vec{\beta} \cdot \vec{n})^5} \frac{1}{|\vec{r}|^2} (\hat{n} \cdot \hat{S}) d\tau$$

WORK-FLOW

Easily define fields, particle beams, surfaces, and points in 3 dimensions in arbitrary directions, positions, and orientations. All computations can be run in single and multi-particle mode.



Fields	Beams	Computations	Objects
Dipole Fields	Allow multiple beams	Single-particle	Easy Translation
Gaussian Fields	Beam $\epsilon_{v,h}$ and $\beta_{v,h}$	Multi-particle	Easy Rotation
Undulators, Wigglers	Built-in particles	Mixed-particle	2D, 3D Surfaces
Any user function	User defined particle	MPI enabled	Arbitrary 3D Surfaces
3D Input files	Any direction	Grid compatible	Arbitrary 3D points

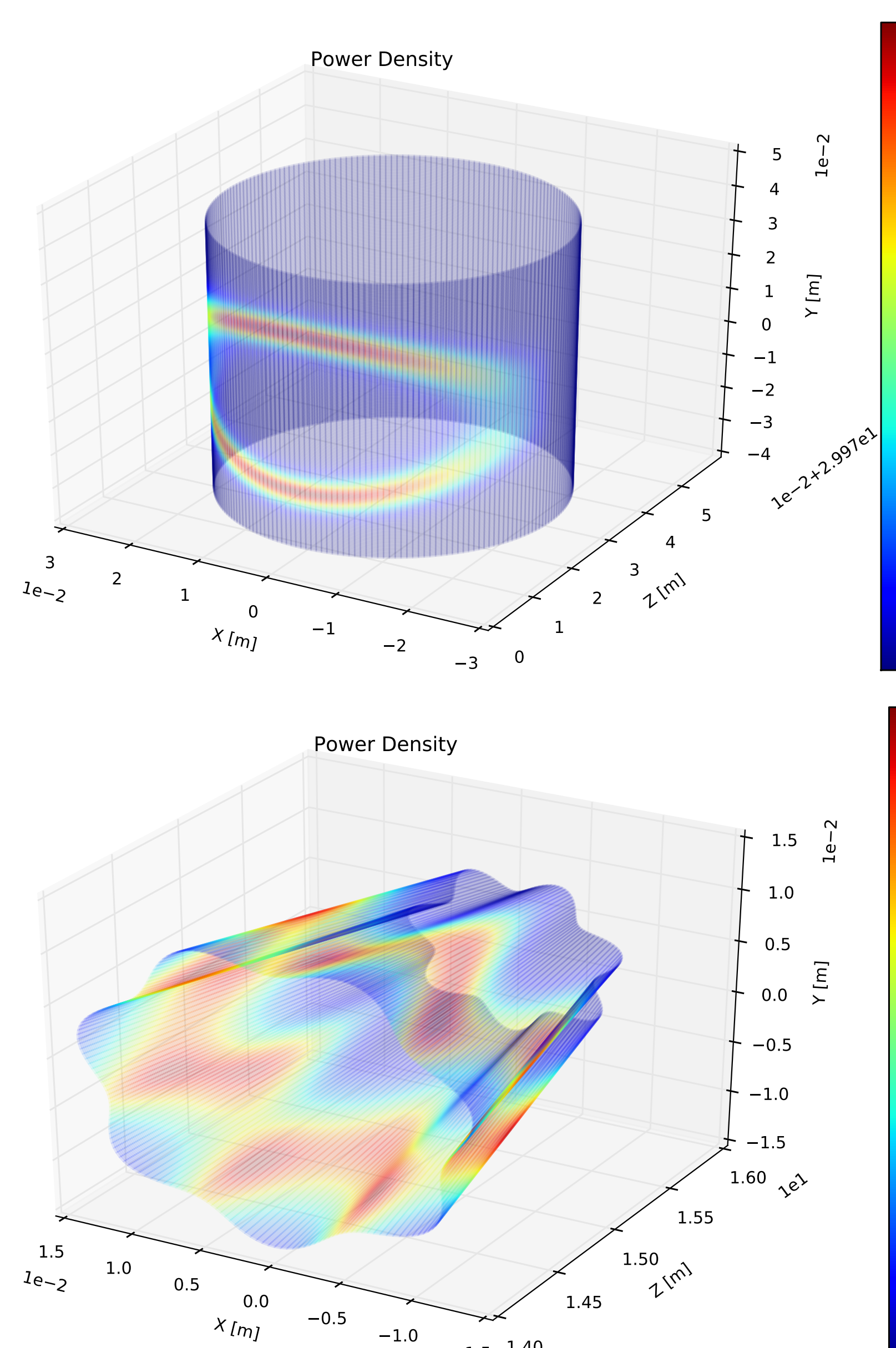
EXAMPLES

The following examples make use of a planar undulator U49 ($\lambda = 0.049$ [m], $B_{\max} = 1$ [T]) and a similar elliptically polarizing undulator (EPU49) with B_v and B_h phase shifted by $\phi = \pi/2$.

The beam parameters are similar to the NSLS-II 6.6 [m] straight with $\epsilon_v = 0.008$ [nm rad], $\epsilon_h = 0.9$ [nm rad], $\beta_v = 0.8$ [m], $\beta_h = 1.5$ [m], $E = 3$ [GeV], and $\Delta E/E = 0.001$, pointing in the $+\hat{z}$ direction.

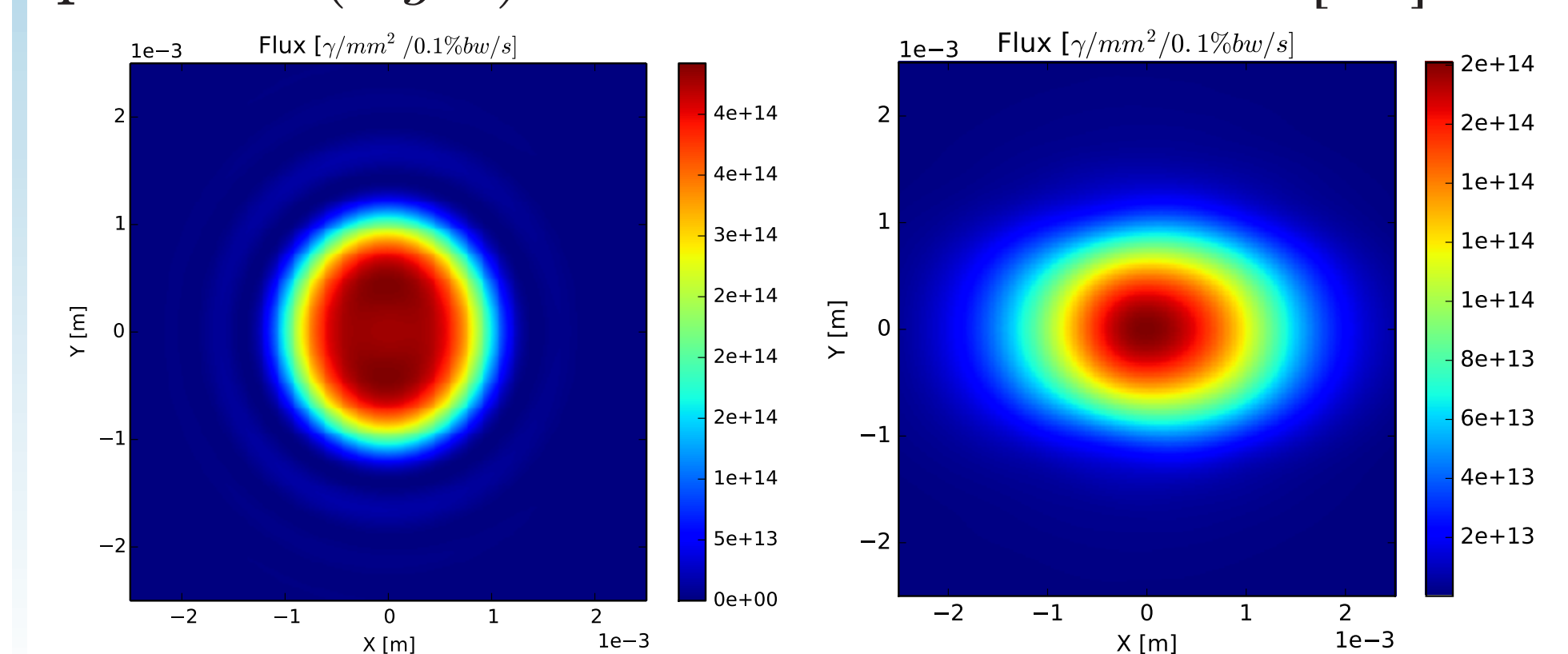
POWER DENSITY 3D

OSCARS is capable of calculating power density distributions on arbitrary geometries in 3D. Shown below are the power density distributions from the example EPU49 on a cylinder (top) and as seen on a corrugated and tapered beam-pipe (bottom).



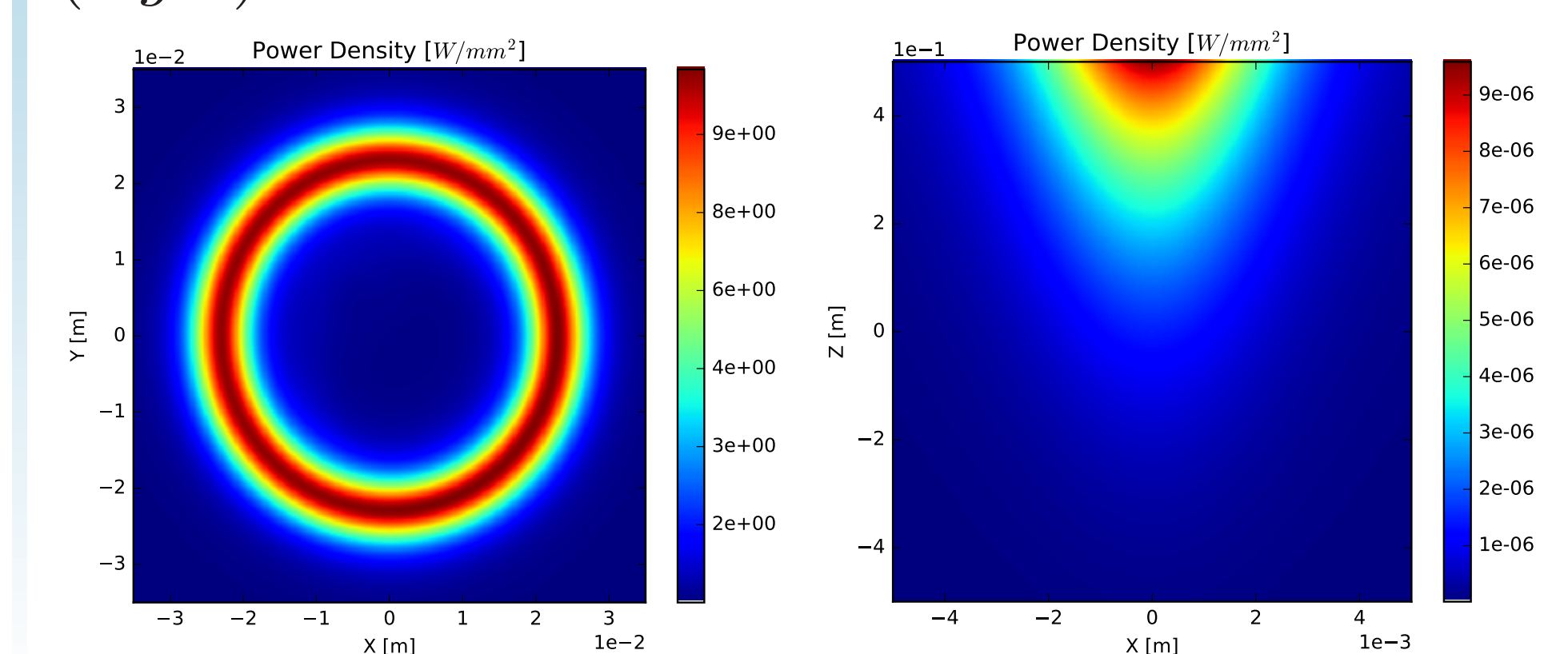
FLUX

Below is an example flux calculation for the example U49 for single-particle (left) and multi-particle (right) simulations at $E = 456$ [eV].



POWER DENSITY

This is an example of the power density calculated 30 [m] downstream of the example EPU49 on a flat surface perpendicular (left) and parallel (right) to the beam direction.



CONCLUSIONS

A new simulation code for advanced radiation simulation has been developed which is fast, powerful, flexible, and open source. Notably, this new simulation is capable of calculating power densities on arbitrary geometries in 3D.

SEE MORE

[1] <http://oscars.bnl.gov>



ACKNOWLEDGMENTS

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SPECTRA

The following is an example of the single-electron and multiple-electron spectra from U49.

