

The Curse of Prince Lambert

... explained in easy words

The IODC 2021
Illumination
Design Problem

Prince Lambert, old and tired ...

... was cursed by an evil sorcerer and dispersed into more than a million pieces.

All that's left of him is

- the pieces (a ray file)
- the curse (a cube box with 220 x 220 x 220 mm)



The original
Prince Lambert

1x1mm²



220mm

That's what is left of him:
Just a TM-25 rayfile.



You are the good wizard

Your task is to reassemble the prince and put him back into his $1 \times 1 \text{ mm}^2$ bed (located at the origin).

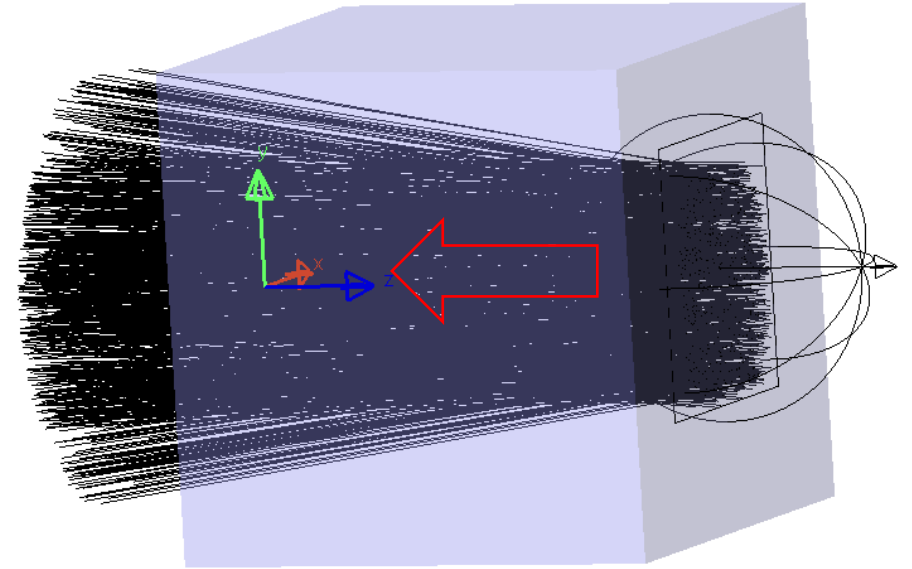
Merit function is the flux collected at a $1 \times 1 \text{ mm}^2$ receiver located the origin.

- Your tools are
 - A magic wand, made of pure diamond
 - A cylinder, 5 mm diameter, 200 mm length, $n = 2.417$, free of absorption
 - A crystal ball, made of expensive glass
 - A sphere, 200 mm diameter, $n = 2.000$, free of absorption
- As a wizard, you can cut and polish and assemble to sub-nanometer precision, with perfect surfaces.



Technically, you have to

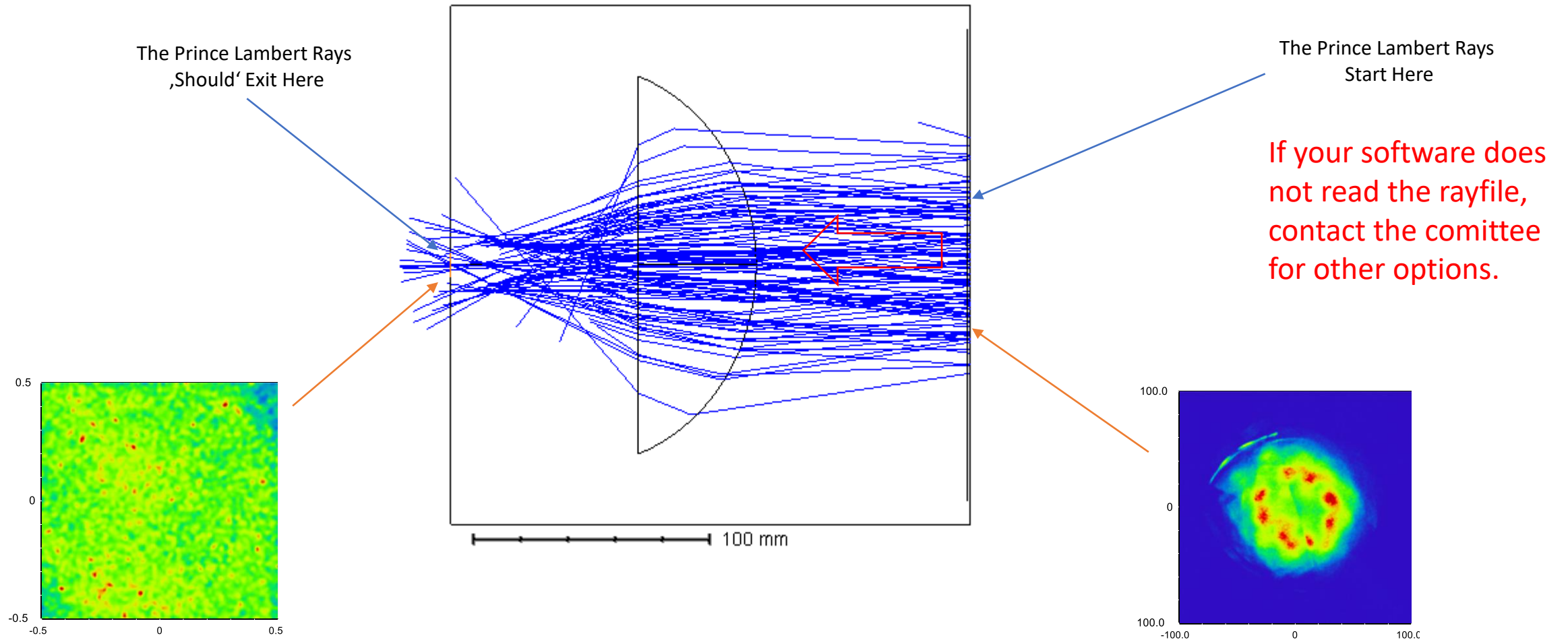
- guess the optical system inside the box
- set up the system with elements that would fit into the sphere and wand
- trace the provided rayfile *backwards* through your system
- collect as much light as possible in the 1mm² square in the origin



Specifications

- No absorption, no reflective coatings, no scattering
- Medium inside the box is air ($n=1.0$), except for the pieces of optics you provide there
- No more than 10000 pieces cut out of sphere and wand
- All surfaces: 100% transmission / 100% TIR
- Nothing outside the box of $(220 \text{ mm})^3$ allowed
- The rayfile is located with ray origins at the right face of the box
- $1 \times 1 \text{ mm}^2$ receiver, located at the left vertex of the box, in air
- Wavelength 550 nm, no conversion allowed

For example ... We guess it's a single lens :



In this example, result is less than 1%:

- You need to try harder.

Prince Lambert vs Duke Radiance

To evaluate your guess at what is contained in the box, there are two steps.

Step 1) Prince Lambert

- This is the required part of the problem submission.
- Just trace Prince Lambert rays through your system and compute the power at the $1 \times 1 \text{mm}^2$ bed. Your goal is to maximize the power.

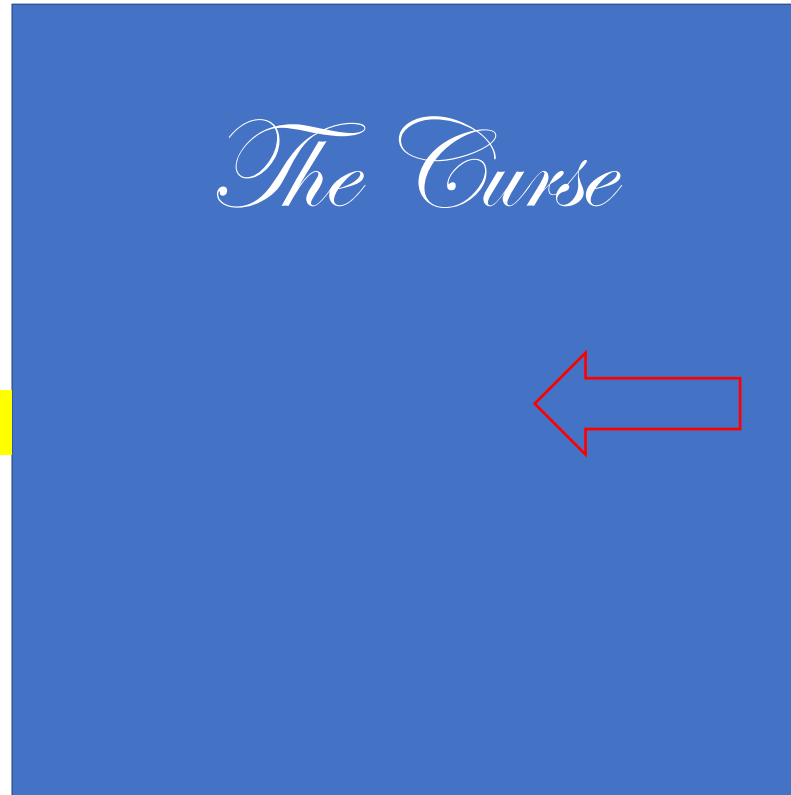
Step 2) Duke Radiance

- This is the optional part of the problem submission and only used in the event of a tie.
 - A tie occurs if the best results from Step 1 are within 1% of one another.
- Just trace rays from the output to the bed and compute the figure of merit to compare individual rays. Your goal is to minimize the figure of merit.
- Performing the Duke Radiance calculations may give you further information, but it is not required that you perform that calculation.

To Compute the Duke Radiance Figure of Merit, Send Output rays back through your system

Traced rays are compared to
DukeRadiance_AtBed.1.txt rays

Compare Ray by Ray to
Calculate the Duke Radiance
Figure of Merit



DukeRadiance_Output.1.txt
rays are trace backward from Z=220

Duke Radiance Files

- Two ray source files
 - DukeRadiance_AtBed.1.txt is for rays starting at the left side of the box
 - DukeRadiance_Output.1.txt is for the corresponding rays as they exit the box.
- The files contain header information, but are mainly a list of rays showing X,Y,Z,L,M,N,Magnitude, and Wavelength for each ray.
 - The wavelength is provided so that when you you can tell which ray in one file corresponds to the same ray in the other file. The wavelength won't matter to the trace since the index of refraction for elements in the box is constant as a function of wavelength.

X	Y	Z	L	M	N	Magnitude	Wavelength
-0.4950	-0.4950	0	0.612000	-0.353300	0.707556	1	500.01
-0.4850	-0.4950	0	-0.432700	-0.249800	0.866239	1	500.02
-0.4750	-0.4950	0	0.556300	0.663000	0.500960	1	500.03
-0.4650	-0.4950	0	0.120800	-0.332000	0.935512	1	500.04
-0.4550	-0.4950	0	-0.778100	0.137200	0.612974	1	500.05
X	Y	Z	L	M	N	Magnitude	Wavelength
32.9716	16.2259	220	-0.155088	0.000377	0.987901	1	500.01
-24.1626	11.7618	220	-0.082219	0.092655	0.992298	1	500.02
34.9319	32.1410	220	-0.037065	-0.172764	0.984266	1	500.03
11.2180	13.8881	220	-0.133812	0.005304	0.990993	1	500.04
28.8205	13.4595	220	-0.011608	-0.007683	0.999903	1	500.05

First 5 rays in
DukeRadiance_AtBed.1.txt

First 5 rays in
DukeRadiance_Output.1.txt

Duke Radiance Figure of Merit

- You trace the Duke Radiance Output rays back through your system, collect them at the bed, and compare them with the AtBed file rays.
 - Use the wavelength to verify that you are comparing the correct rays.

- The Figure of Merit is

$$FOM = \sum_{i=1}^{20000} (X_i - x_i)^2 + (Y_i - y_i)^2 + (L_i - l_i)^2 + (M_i - m_i)^2.$$

- x_i, y_i, l_i, m_i are the traced positions and directions at $Z=0$ (e.g., from your trace)
 - X_i, Y_i, L_i, M_i are the ideal positions and directions at $Z=0$ (e.g., from the file)
- In case of an ideal fit, FOM is zero for the ray
- If your traced ray does not reach the 1X1 bed, add 10.
- The goal is to minimize the FOM!