Ray file import

by Juergen Kanz, November 2021

```
In[ ]:= Clear["Global`*"]
```

Introduction

Ray files are a typical mean to describe the spatial near-field light distribution of LED and other kinds of light sources for optical design purposes. Non-imaging optics for lighting, automotive, medical devices, and other application areas are more or less the standard now for engineering tasks regarding design.
Near-field photometric and or radiometric measurements are done with special equipment from Radiant Vision Systems or TechnoTeam. Both companies have their software products to transform the measured data into application formats for optical design software.

The intention for this notebook is to show a way to import ASCII ray files as distributed by LED manufacturers for their products. The files for specific optic design software are typically stored as binary files without public available format descriptions.

Due to the high documentation level of OSRAM semiconductors, I decided to take a ray file package from this company.

Download OSRAM files for optical simulation

Download of the chosen LED OSRAM ray File package via https://www.osram.com/apps/download-center/?path=%2Fos-files%2FOptical+Simulation%2FLED/OSCONIQ/OSCONIQ%20E/OS-CONIQ%20E2835/GW%20QTLQS1.LM. Select an ASCII file (either _ASCII.zip or _TraceProText.zip).

	Filename	Size	Date
	CAD_GW_QTLQS1_LM_20210611.zip	131 KB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_100M_ASAP.zip	3.8 GB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_ASAP.zip	217.4 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_ASCII.zip	234.0 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_Eulumdat.zip	841 KB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_IES.zip	842 KB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_IESTM25.zip	990.7 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_LightTools.zip	217.4 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_Lucidshape.zip	217.4 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_OSRAM.zip	220.4 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_Photopia.zip	217.4 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_Simulux.zip	217.4 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_Speos.zip	255.1 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_TraceProBin.zip	217.4 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_TraceProText.zip	234.5 MB	11.6.2021
	rayfile_GW_QTLQS1_LM_20210611_Zemax.zip	217.4 MB	11.6.2021

In case the user takes the _TraceProText file, the general process as described below remains the same. The difference is to skip some header lines before the pure data as discussed below can be processed.

The downloaded ASCII Zip-file contains the following datasets:

Name	Größe	Gepackt	Typ	Geändert	CRC32
..			Dateiordner		
rayfile_GW_QTLQS1_LM_yellow_500k_20210611_ASCII.TXT	36 289 277	10 993 103	TXT-Datei	10.06.2021 21:01	9CE77134
rayfile_GW_QTLQS1_LM_yellow_100k_20210611_ASCII.TXT	7 257 362	2 190 254	TXT-Datei	10.06.2021 21:01	92CB1239
rayfile_GW_QTLQS1_LM_yellow_5M_20210611_ASCII.TXT	362 885 346	109 089 611	TXT-Datei	10.06.2021 21:01	A0FF78BE
rayfile_GW_QTLQS1_LM_blue_500k_20210611_ASCII.TXT	36 397 558	11 020 604	TXT-Datei	10.06.2021 20:38	F4A70107
rayfile_GW_QTLQS1_LM_blue_100k_20210611_ASCII.TXT	7 379 694	2 178 086	TXT-Datei	10.06.2021 20:38	F6F02321
rayfile_GW_QTLQS1_LM_blue_5M_20210611_ASCII.TXT	363 972 300	108 997 466	TXT-Datei	10.06.2021 20:38	47ACD89B
GW_QTLQS1_LM_20210611_info.pdf	825 325	722 229	Adobe Acrobat Do...	11.06.2021 06:08	6C1192F0
GW_QTLQS1_LM_20210611_geometry.STEP	123 980	18 603	STEP-Datei	11.06.2021 05:18	E16A70EE
GW_QTLQS1_LM_20210611_geometry.SLDPRT	93 854	89 823	SLDPRT-Datei	11.06.2021 05:18	CE9D4D1D
GW_QTLQS1_LM_20210611_geometry.IGS	233 044	23 479	IGS-Datei	11.06.2021 05:19	5BE9ECF2
GW_QTLQS1_LM_4000K_yellow_20210611_spectrum.txt	2 312	551	TXT-Datei	10.06.2021 18:56	646D769E
GW_QTLQS1_LM_4000K_blue_20210611_spectrum.txt	1 122	291	TXT-Datei	10.06.2021 18:56	E9A3C611
disclaimer_20210611.txt	2 528	1 101	TXT-Datei	26.03.2013 09:21	9A288B7E

In[ ]:=
```
TextGrid[{{" ", " "},
  {"rayfile_GW_QTLQS1...yellow...500k...ASCII",
   "a ray dataset with 500 000 yellow rays in ASCII"},
  {"rayfile_GW_QTLQS1...blue...100k...ASCII",
   "a ray dataset with 100 000 blue rays in ASCII"},
  {"rayfile_GW_QTLQS1...blue...5M...ASCII",
   "a ray dataset with 5 000 000 blue rays in ASCII"},
  {" ", " "},
  {"GW_QTLQS1..._info.pdf",
   "a Pdf file with important technical information about the LED"},
  {"GW_QTLQS1..._geometry", "CAD files with LED geometry in different formats"},
  {" ", " "},
  {"W_QTLQS1..._yellow..._spectrum", "a spectrum data file of the yellow rays"},
  {" ", " "}}]
```

Out[ ]=

rayfile_GW_QTLQS1...yellow...500k...ASCII	a ray dataset with 500 000 yellow rays in ASCII
rayfile_GW_QTLQS1...blue...100k...ASCII	a ray dataset with 100 000 blue rays in ASCII
rayfile_GW_QTLQS1...blue...5M...ASCII	a ray dataset with 5 000 000 blue rays in ASCII
GW_QTLQS1..._info.pdf	a Pdf file with important technical information about the LED
GW_QTLQS1..._geometry	CAD files with LED geometry in different formats
W_QTLQS1..._yellow..._spectrum	a spectrum data file of the yellow rays

Import Spectral Intensity Distributions

The spectra of OSRAM Opto Semiconductors white LEDs have at least two local maxima due to the specific generation of white light. The peak in the blue wavelength range has a narrow width and a peak wavelength around 450 nm. The peak in the yellow wavelength range has a wider distribution with a peak wavelength around 540 – 600 nm, depending on the LED type.
Due to the different angular characteristics of rays in the “blue” and “yellow” parts of the spectrum, a separation of the ray model into two parts is necessary.
Therefore, two ray files are delivered with each white LED, one ray file for the blue and one ray file for the yellow part of the spectrum. Both ray files have the same global coordinate origin and must be placed in the simulation software at exactly the same (x,y,z) coordinates. To use the ray files in a simulation, the user has to consider the following points:

1. “Blue” and “yellow” ray files must be placed at the same (x,y,z) coordinates.
2. Simulation should run simultaneously for the two ray files, as for two overlapping sources.
3. The luminous flux contributions of both ray files must be set appropriately.

The **peak wavelength** is defined as the single wavelength where the radiometric emission spectrum of the light source reaches its maximum. More simply, it does not represent any perceived emission of the light source by the human eye, but rather by photo-detectors.

The **dominant wavelength** is defined as the single wavelength that is perceived by the human eye. Generally one light source consists of multiple wavelength spectra from the light source rather than one single wavelength. Our brains turn those multiple spectra into a single color of light consistent with a single specific wavelength which is what we see when we look at the light. That’s the light source’s Dominant wavelength.

Import of the “Blue” spectra

```
In[ ]:= (* Path to be modified *)
spectrumBlue = Import[
   "e:\\Users\\juerg\\Documents\\Mathematica\\Light&Optics\\RayfileImport\\GW_QTLQS1
     _LM_4000K_blue_20210611_spectrum.txt", "Data"];
```

Find the **peak** in the “Blue” spectrum. Results are in “Nanometers”

```
In[ ]:= pos = First@Flatten[Position[spectrumBlue, Max[spectrumBlue[[All, 2]]]]];

In[ ]:= lambdaMaxBlue = spectrumBlue[[pos, 1]]

Out[ ]= 470.
```

Import of the “Yellow” spectra

```
In[ ]:= (* Path to be modified *)
spectrumYellow = Import[
   "e:\\Users\\juerg\\Documents\\Mathematica\\Light&Optics\\RayfileImport\\GW_QTLQS1
     _LM_4000K_yellow_20210611_spectrum.txt", "Data"];
```

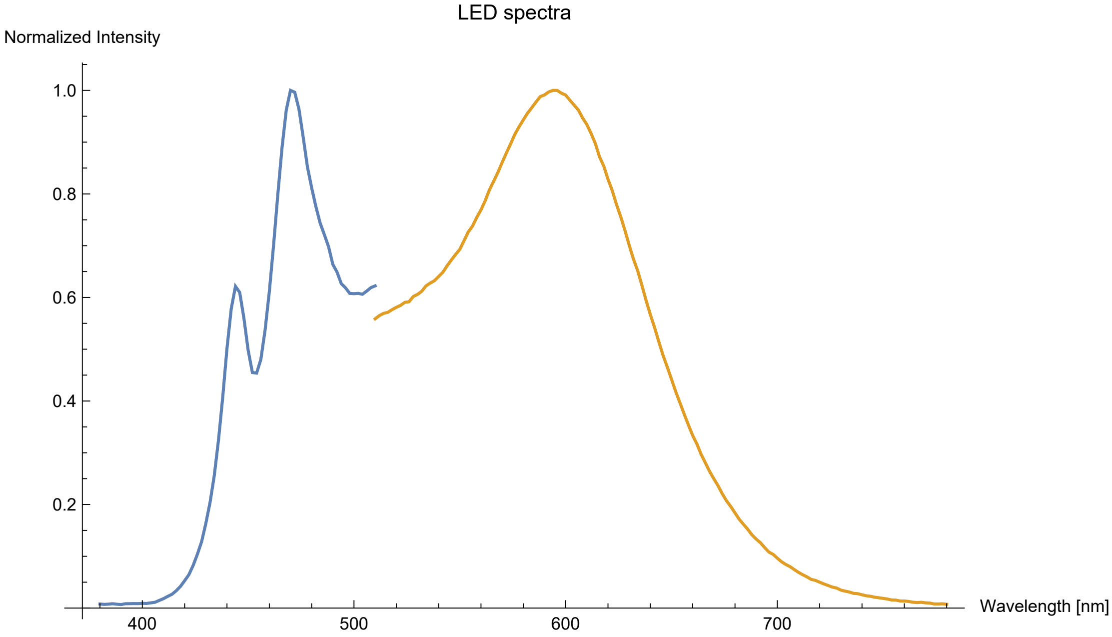
Find the **peak** in the “Yellow” spectrum. Results are in “Nanometers”

```
In[ ]:= pos = First@Flatten[Position[spectrumYellow, Max[spectrumYellow[[All, 2]]]]];

In[ ]:= lambdaMaxYellow = spectrumYellow[[pos, 1]]

Out[ ]= 594.
```

Spectrum Plot

In[◦]:=
```
ListLinePlot[{spectrumBlue, spectrumYellow}, PlotLabel → "LED spectra",
 AxesLabel → {"Wavelength [nm]", "Normalized Intensity"}, ImageSize → Large]
```

Out[◦]=



Due to the separate handling of the “Blue” and “Yellow” spectra, in line with a normalization, the result is not acceptable for a full spectrum.

The following image is taken from “GW_QTLQS1_LM_20210611_info.pdf” which is part of the zip-file and shows the full spectrum.

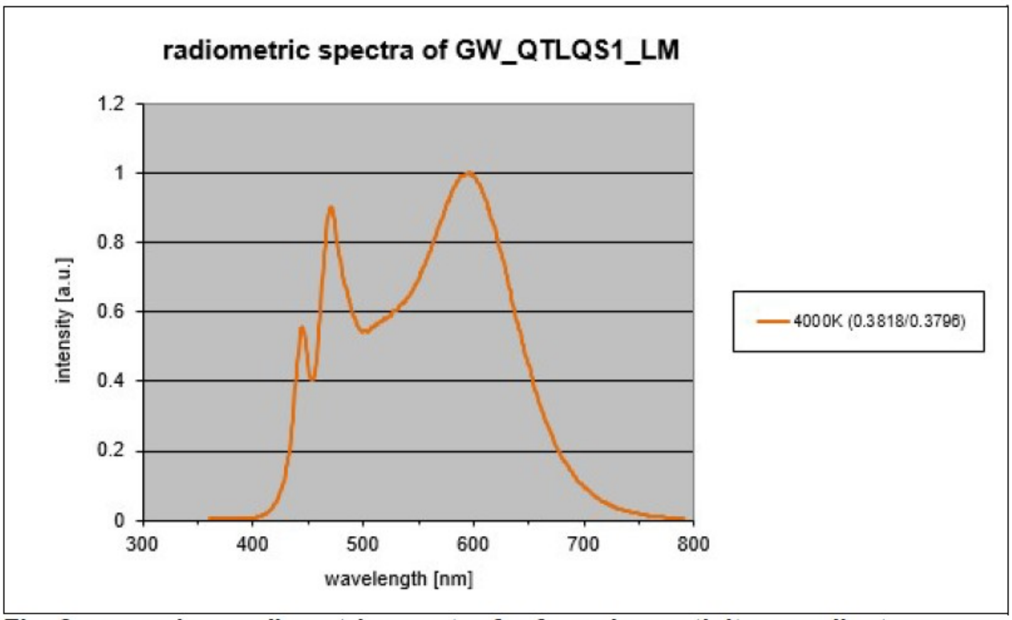


Fig. 2: exemplary radiometric spectra for four chromaticity coordinate groups

The two spectra have to be aligned with OSRAM picture for a full spectrum, which can be used for further processing.

In[•]:=
```
lastBlue = Last@spectrumBlue
```
Out[•]=
```
{510., 0.6224}
```

In[•]:=
```
firstYellow = First@spectrumYellow
```
Out[•]=
```
{510., 0.5587}
```

In[•]:=
```
factor = firstYellow⟦2⟧ / lastBlue⟦2⟧
```
Out[•]=
```
0.897654
```

The factor here is finally a correction factor for the spectra alignment.

In[•]:=
```
adjustedBlueSpectrum = spectrumBlue;
```

We multiply the intensities of the blue rays with the factor for alignment.

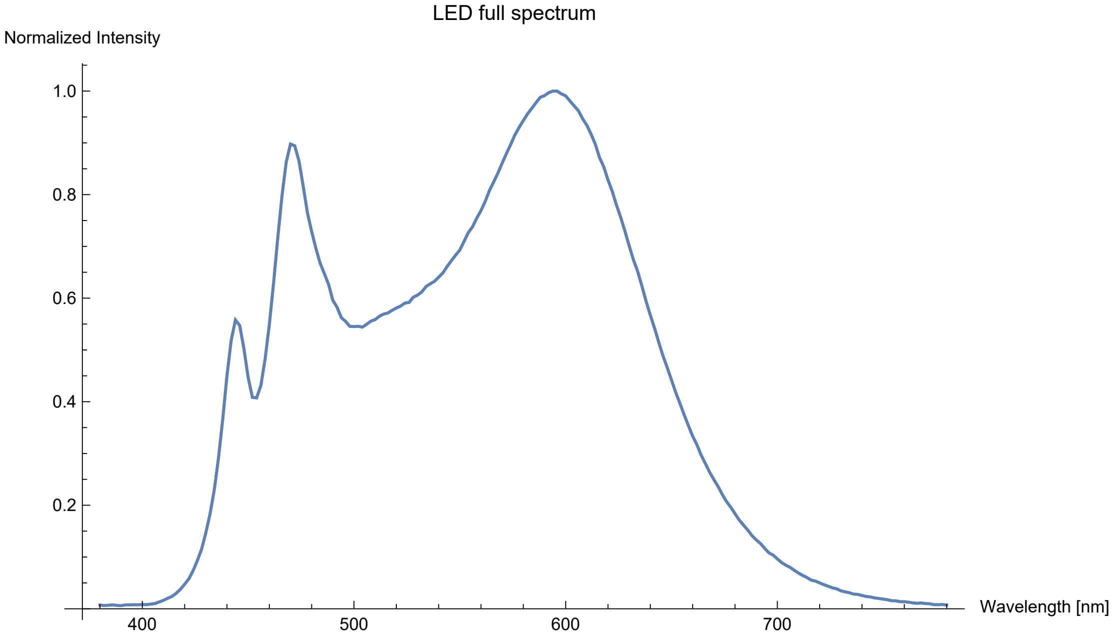
In[•]:=
```
adjustedBlueSpectrum⟦All, 2⟧ = spectrumBlue⟦All, 2⟧ * factor;
```

In[•]:=
```
spectrumYellow = Rest[spectrumYellow];
```

In[•]:=
```
ledFullSpectrum = Union[adjustedBlueSpectrum, spectrumYellow];
```

In[•]:=
```
ListLinePlot[{ledFullSpectrum}, PlotLabel → "LED full spectrum",
 AxesLabel → {"Wavelength [nm]", "Normalized Intensity"}, ImageSize → Large]
```

Out[•]=



Now we have a full spectrum of the LED.

Save the ledFullSpectrum as a CSV file and make use of it in a spectrum analysis software/notebook.

In[•]:=
```
Export["ledFullSpectrum.csv", ledFullSpectrum]
```
Out[•]=
```
ledFullSpectrum.csv
```

Load photometric rays

Import Blue-Rays

The following line of code shows how to import a blue ray dataset with 100k rays. It is not a problem to read the 5M (5 million) ray files as well with Mathematica.

In[ ]:=
```
(* Path has to be modified *)
rawdata = Import[
   "e:\\Users\\juerg\\Documents\\Mathematica\\Light&Optics\\RayfileImport\\rayfile_GW
     _QTLQS1_LM_blue_100k_20210611_ASCII.TXT", "Table"];
```

In[ ]:=
```
rawdata[[1]]
```

Out[ ]=
```
{X_Pos, Y_Pos, Z_Pos, X_Vec, Y_Vec, Z_Vec, Flux}
```

In[ ]:=
```
TextGrid[{{"Explanation:", " "},
  {"X_Pos", "The origin x coordinate of a ray"},
  {"Y_Pos", "The origin y coordinate of a ray"},
  {"Z_Pos", "The origin z coordinate of a ray"},
  {" ", " "},
  {"X_Vec", "The x coordinate of the direction vector"},
  {"Y_Vec", "The y coordinate of the direction vector"},
  {"Z_Vec", "The z coordinate of the direction vector"},
  {" ", " "},
  {"Flux", "The energy of the ray"},
  {" ", " "}}]
```

Out[ ]=

Explanation:	
X_Pos	The origin x coordinate of a ray
Y_Pos	The origin y coordinate of a ray
Z_Pos	The origin z coordinate of a ray
X_Vec	The x coordinate of the direction vector
Y_Vec	The y coordinate of the direction vector
Z_Vec	The z coordinate of the direction vector
Flux	The energy of the ray

It is not possible to work with underline characters in column names, hence we take them out.

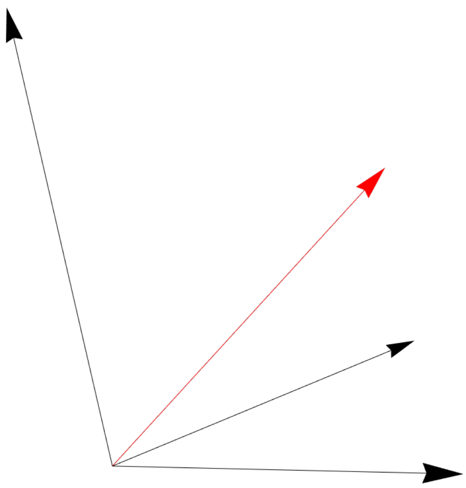
In[ ]:=
```
header = {"Xpos", "Ypos", "Zpos", "Xvec", "Yvec", "Zvec", "Flux"}
```

Out[ ]=
```
{Xpos, Ypos, Zpos, Xvec, Yvec, Zvec, Flux}
```

Simplified drawing of a vector from {Xpos,Ypos,Zpos} to {Xvec,Yvec,Zvec}

In[∘]:=
```
orig = {0, 0, 0};        (* Xpos, Ypos, Zpos *)
axes = {{1, 0, 0}, {0, 1, 0}, {0, 0, 1}};   (* Coordinate system *)
pt = {0.5, 0.5, 0.5};  (* Xvec, Yvec, Zvec *)
Graphics3D[{Arrow[{orig, #}] & /@ axes, {Red, Arrow[{orig, pt}]}}, Boxed → False]
```

Out[∘]=



Import Blue-Rays Part 2

In[∘]:=
```
rawdata2 = Rest[rawdata];
```

All vector data are scaled, just to make them visible in the 3D graphic below.

In[∘]:=
```
scaler = 3;
rawdata2[[All, 4]] = rawdata2[[All, 4]] * scaler;
rawdata2[[All, 5]] = rawdata2[[All, 5]] * scaler;
rawdata2[[All, 6]] = rawdata2[[All, 6]] * scaler;
```

Get a blue ray dataset

In[∘]:=
```
blueRays = AssociationThread[header → #] & /@ Rest[rawdata2] // Dataset;
```

Import Yellow-Rays

In[∘]:=
```
(* Path has to be modified *)
rawdata = Import[
   "e:\\Users\\juerg\\Documents\\Mathematica\\Light&Optics\\RayfileImport\\rayfile_GW
     _QTLQS1_LM_yellow_100k_20210611_ASCII.TXT", "Table"];
```

In[∘]:=
```
rawdata2 = Rest[rawdata];
```

All vector data are scaled, just to make them visible in the 3D graphic below.

```
In[•]:= scaler = 3;
rawdata2[[All, 4]] = rawdata2[[All, 4]] * scaler;
rawdata2[[All, 5]] = rawdata2[[All, 5]] * scaler;
rawdata2[[All, 6]] = rawdata2[[All, 6]] * scaler;
```

Get a yellow ray dataset

```
In[•]:= yellowRays = AssociationThread[header → #] & /@ Rest[rawdata2] // Dataset;
```

Household-keeping

```
In[•]:= Clear[rawdata, rawdata2];
```

Few data from the ray data

The total number of rays loaded:

```
In[•]:= numRays = Length[blueRays] + Length[yellowRays]
Out[•]= 199 998
```

Energy sum of all yellow rays:

```
In[•]:= yellowFlux = Query[Total, "Flux"]@yellowRays
Out[•]= 0.272937
```

Energy sum of all blue rays:

```
In[•]:= blueFlux = Query[Total, "Flux"]@blueRays
Out[•]= 0.194883
```

```
In[•]:= energyOfRays = yellowFlux + blueFlux
Out[•]= 0.46782
```

According to the info.pdf the LED has a total LED Luminous flux of ϕ_v= 144 Lumen. Flux is set to a default of **131.39**/**12.11** the user has to adapt the flux setting with new *factors*.

Import CAD File of the LED Housing

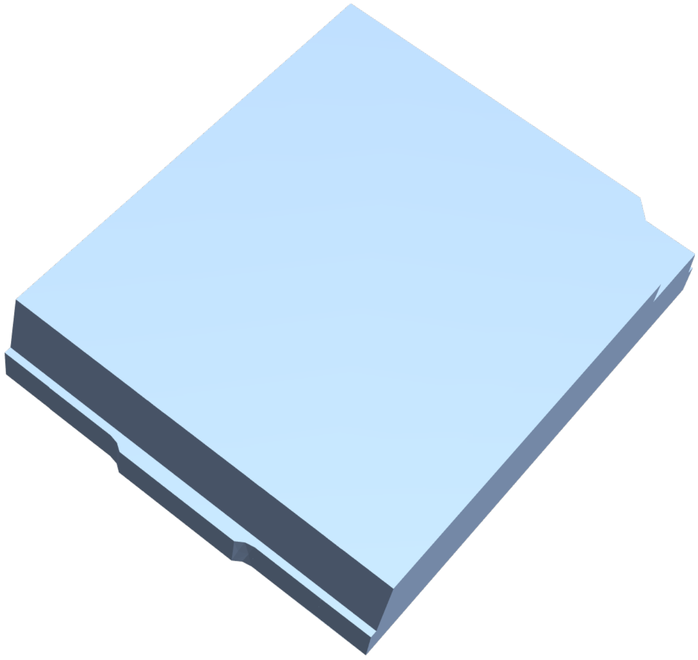
Many LED suppliers provide CAD-Files with the geometry of their products. The files are typically available in the following formats:

- .SLDPRT - SolidWorks Part file
- .IGS - Initial Graphics Exchange Specification
- .STEP - Standard for the exchange of product model data

I tried to import the STEP file into Mathematica with the OpenCascadeLink, but unfortunately, I failed. Hence, I imported the CAD-file in Rhino 3D and converted it into the common STL format for import.

In[ ]:=
```
(* Path has to be modified *)
ledhousing = Import[
  "e:\\Users\\juerg\\Documents\\Mathematica\\Light&Optics\\RayfileImport\\led.stl",
  "STL"]
```

Out[ ]=



3D Graphics

The rays are already randomly stored in the ray files. Hence, no additional shuffling is needed. For the graphical presentation, only fifty blue and yellow rays are randomly taken.

In[ ]:=
```
blueRandomRays = RandomChoice[blueRays, 50];
```

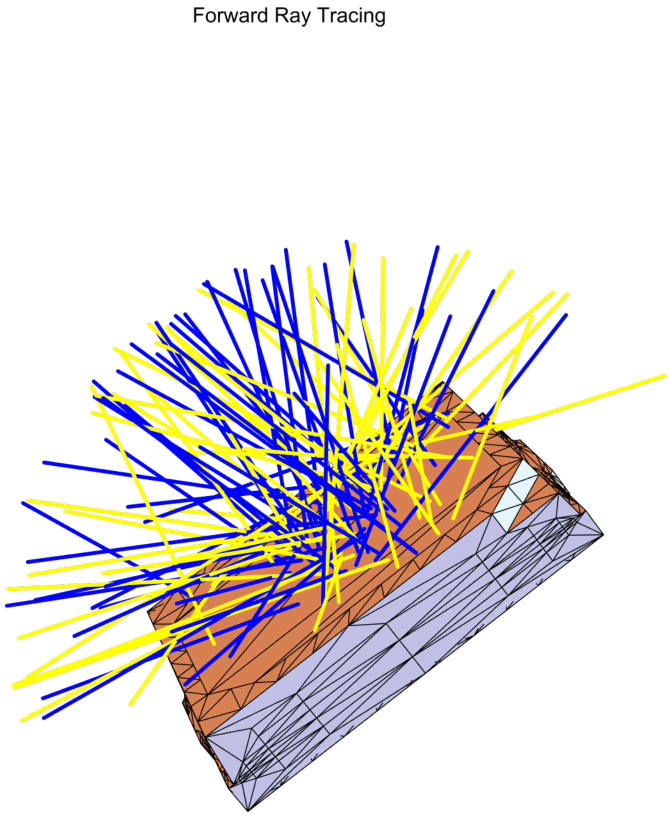
In[ ]:=
```
yellowRandomRays = RandomChoice[yellowRays, 50];
```

In[ ]:=
```
yellowLines =
  Table[Line[{{yellowRandomRays[[i, 1]], yellowRandomRays[[i, 2]], yellowRandomRays[[i, 3]]},
     {yellowRandomRays[[i, 4]], yellowRandomRays[[i, 5]], yellowRandomRays[[i, 6]]}}],
   {i, 1, Length[yellowRandomRays]}];
```

In[ ]:=
```
blueLines =
  Table[Line[{{blueRandomRays[[i, 1]], blueRandomRays[[i, 2]], blueRandomRays[[i, 3]]},
     {blueRandomRays[[i, 4]], blueRandomRays[[i, 5]], blueRandomRays[[i, 6]]}}],
   {i, 1, Length[blueRandomRays]}];
```

In[ ]:=
```
Graphics3D[{ledhousing, Blue, Thick, blueLines, Yellow, Thick, yellowLines},
 Boxed → False, PlotLabel → "Forward Ray Tracing"]
```

Out[ ]=



Summary

The author shows ways to import rays from ASCII files. Even the import of two times 5M rays was not a constraint to process the data. The next step could be the development of an environment for (forward) ray tracing to use Mathematica in the field of non-imaging optics with non-sequential ray tracing as well.

Resources

- OSRAM Product Page, https://www.osram.com/ecat/OSCONIQ%C2%AE%20E%202835%20GW%20QTLQS1.LM/com/en/class_pim_web_catalog_103489/prd_pim_device_18726922/, Last accessed 11/24/2021
- OSRAM RayFile Package for chosen LED, https://www.osram.com/apps/downloadcenter/?path=%2Fos-files%2FOptical+Simulation%2FLED/OSCONIQ/OSCONIQ%20E/OSCONIQ%20E2835/GW%20QTLQS1.LM, select: “rayfile_GW_QTLQS1_LM_20210611_ASCII.zip”, Last accessed 11/24/2021
- Wolfram Mathworld, “Direction cosine”, https://mathworld.wolfram.com/DirectionCosine.html, Last accessed 11/24/2021

- TechnoTeam Homepage, https://www.technoteam.de/, Last accessed 11/24/2021
- Radiant Vision Systems, https://www.radiantvisionsystems.com/, Last accessed 11/24/2021