# Optimizing for a Target Distribution

## INTRODUCTION

This knowledge base article will demonstrate how to use FRED Optimum's optimization capability to modify a system and achieve a desired irradiance distribution.  The system being modified is a PMMA light pipe.  Six variables control the shape of the light pipe and the optimization merit function aberration is the RMS difference between the current light distribution and the ideal light distribution.  The optimization merit function aberration is a user-defined script.

## SYSTEM LAYOUT

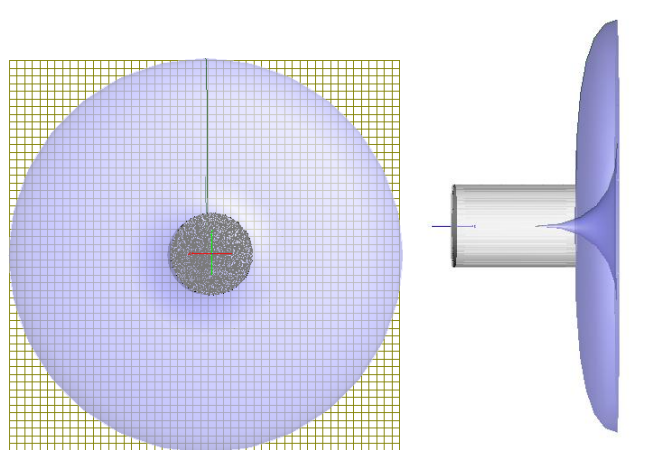The rear and profile views of the light pipe geometry are shown in Figure 1.



Figure 1 - Light pipe geometry rear (left) and profile (right) views.

As shown below in Figure 2, two surfaces in the light pipe are surfaces of revolution formed from two $2^{nd}$ degree NURB curves.  The optimization process uses the positions and weights of some of the control points as variables in the optimization process to deform the shapes of the light pipe surfaces.  Shown schematically, the green dots are the control points that will be manipulated during the optimization.

Analysis surface

Random plane emitter

Surface of revolution created from a NURB curve of degree 2.  The control points for the curve are shown schematically to the right.  The control point in green is used in the optimization.

CP1

Surface of revolution created from a NURB curve of degree 2.  The control points for the curve are shown schematically to the right.  The control points in green are used in the optimization.
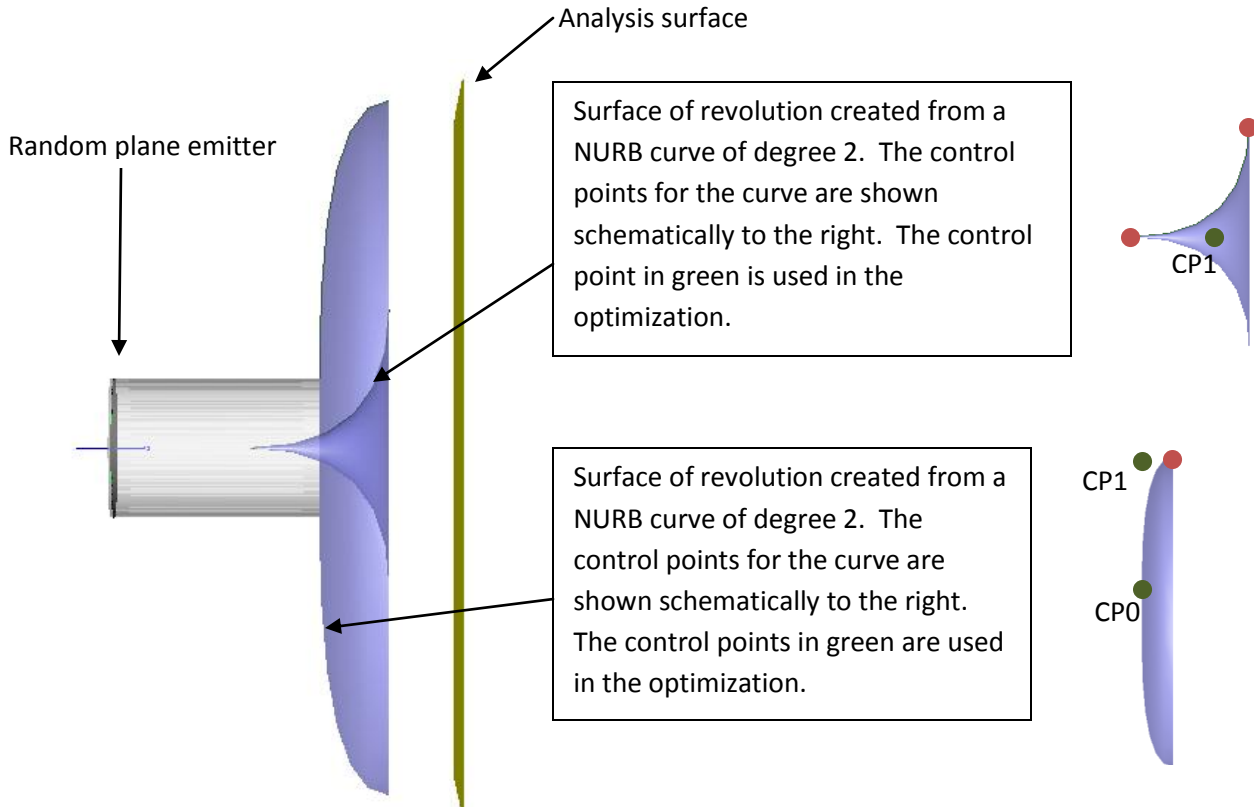
CP1

CP0

**Figure 2 – Side view of the light pipe showing the two surfaces being modified during the optimization.  The green dots are control points being modified during the optimization.**

A random plane emitter is embedded in the cylindrical tube portion of the light pipe.  In the starting configuration, the irradiance distribution at the analysis surface is shown in Figure 3.
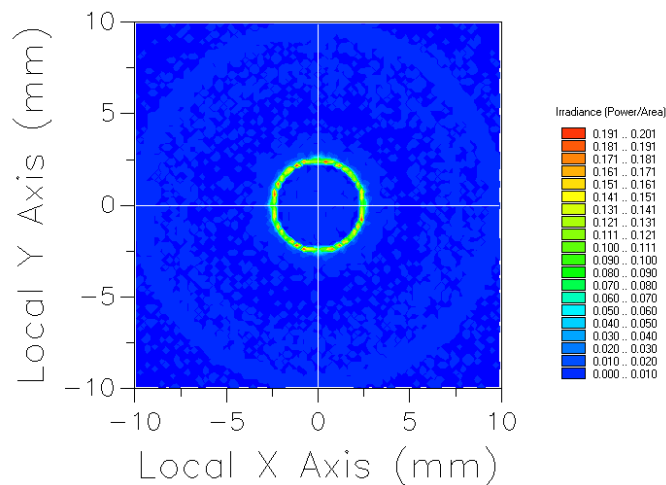


**Figure 3 - Analysis surface irradiance distribution for the starting configuration.**

The desired distribution to be achieved after optimization is shown in Figure 4.
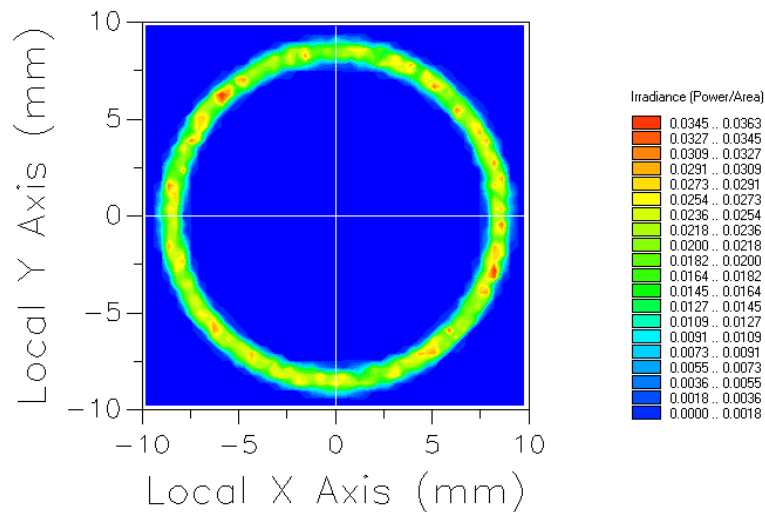


**Figure 4 - Desired distribution to be achieved after optimization.**

Notice in the FRED file that there is a second source called IdealDistribution with an associated analysis plane called IdealAnalysis.  In the FRED model this source represents the ideal distribution to be achieved at the end of the optimization as shown in Figure 4.

## OPTIMIZATION VARIABLES

As mentioned previously, the variables in the optimization will be the positions and weights of several control points in the base curves defining the surfaces of revolution in the light pipe. The variables are listed below and can be accessed within the FRED file itself by navigating to Menu > Optimize > Define/Edit.

| Variable | Lower Limit | Upper Limit | Fraction Step |
|---|---|---|---|
| Geometry.Shell.Curve 1 | | | |
| CP 0 Z-position | -4 | 1 | 0.5 |
| CP 1 Y-position | 0 | 10 | 0.5 |
| CP 1 Weight | 0 | 2 | 0.5 |
| Geometry.TIRSurf.Curve 2 | | | |
| CP1 Y-position | 0 | 4 | 0.5 |
| CP1 Z-position | -4 | 0 | 0.5 |
| CP1 Weight | 0 | 2 | 0.5 |
| CP2 Z-position | -4 | 0 | 0.5 |

## OPTIMIZATION ABERRATION

The merit function aberration being used is a User-defined script, since there currently exists no default method for importing a target distribution into the optimizer.  The script used to implement the aberration to target a distribution is provided below with comments.

```
Sub EvalMzrAber( ByVal g_ana&, ByRef g_aber#, ByRef g_success As Boolean )

        'dimension all of the variables being used in the script

        Dim arnStats As T_ARN_2D_CELL_STATS

        Dim anaIdeal As Long

        Dim rndArn As Long, idealArn As Long, count As Long, ii As Long, jj As Long

        Dim data() As Double, totDiffPower As Double, totRndPower As Double, totIdealPower As Double

        Dim dAdirX As Double, dAdirY As Double, dAdirZ As Double

        Dim dBdirX As Double, dBdirY As Double, dBdirZ As Double

        Dim success As Boolean


        'Find node number of the ideal source analysis plane.  This script will use the irradiance
        distribution from this analysis surface to compare against with the irradiance distribution in the
        analysis surface of the light guide (given by g_ana in the script).

        anaIdeal = FindFullName( "Analysis Surface(s).IdealAnalysis" )


        'Store the ideal irradiance distribution in an ARN (Analysis Results Node) and normalize the
        power.  From the ARN we can easily transfer the data into and from a double array for
        manipulation using the ARNGetDataAsDoubleArray and ARNSetDataAsDoubleArray.

        count = IrradianceToARN( anaIdeal, "idealARN", idealArn )

        totIdealPower = ARNComputeTotalPower( idealArn )

        ARNGetDataAsDoubleArray idealArn, data()

        For ii = 0 To UBound(data,1)

                For jj = 0 To UBound(data,2)

                        data(ii,jj) = data(ii,jj)/totIdealPower

                Next jj

        Next ii
```

```
ARNSetDataAsDoubleArray idealArn, data()
```

*'Now we go get the irradiance distribution from the analysis surface at the exit of the light pipe (g_ana) and normalize its power.*

```
count = IrradianceToARN( g_ana, "randomARN", rndArn )

totRndPower = ARNComputeTotalPower( rndArn )

ARNGetDataAsDoubleArray rndArn, data()

For ii = 0 To UBound(data,1)

        For jj = 0 To UBound(data,2)

                    data(ii,jj) = data(ii,jj)/totRndPower

        Next jj

Next ii

ARNSetDataAsDoubleArray rndArn, data()
```

*'Now we difference the two irradiance results from the ideal analysis and the light pipe analysis using the command ARNLinearCombination. The results of the combination are stored in idealArn.  We also loop over the data values and take the absolute value to make all points positive.*

```
ARNLinearCombination( -1, idealArn, 1, rndArn )

ARNGetDataAsDoubleArray idealArn, data()

For ii = 0 To UBound(data,1)

        For jj = 0 To UBound(data,2)

                    data(ii,jj) = Abs( data(ii,jj) )

        Next jj

Next ii

ARNSetDataAsDoubleArray idealArn, data()
```

*'Finally, we get compute the statistics for the difference in the datasets and set the aberration return value g_aber to be the RMS.*

```
ARNCompute2DCellStatistics idealArn, arnStats

g_aber = Sqr(arnStats.AvgSqNonZeroCellVal)
```

*'Delete the ARN nodes when done (memory management)*

success = ARNDelete( idealArn )

success = ARNDelete( rndArn )


*'Perform a check such that a successful evaluation is when the power in the ARN containing the light pipe results is greater than zero.*

g_success = totRndPower > 0


End Sub


## OPTIMIZATION RESULTS

The comparison between the light pipe exit distribution and the target distribution are shown below for three optimization sets of 20 iterations each using all variables.
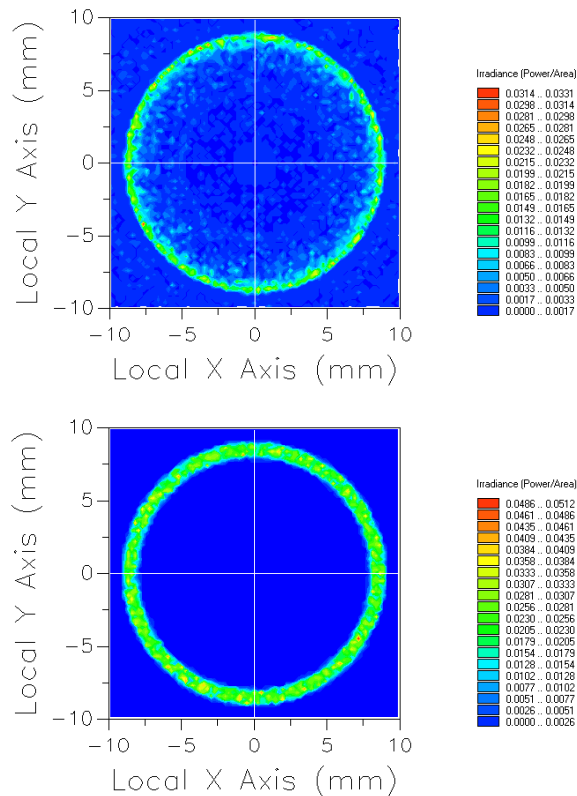


**Figure 5 - Irradiance distributions for the light pipe (Top) and ideal distribution (Bottom) after 3 sets of 20 optimization iterations.**