ASAP TECHNICAL PUBLICATION
BRO4314_AHEM (NOVEMBER 7, 2008)

Using the Advanced Human Eye Model (AHEM)

BIO Toolkit interactive script for ASAP

This technical publication describes how to use the Advanced Human Eye Model™ (AHEM™), a BIO Toolkit™ interactive script for the Advanced Systems Analysis Program (ASAP®) from Breault Research Organization (BRO). AHEM is used with ASAP to model light propagation in accurate, stereoscopic human eye models. More specifically, AHEM is a personal binocular eye modeling system, inclusive of refraction, diffraction, and scatter. The purpose of this document is to:

- Create personalized eye models to help design ophthalmic optics and instrumentation
- Simulate ailments or surgery-induced changes
- Explore vision research questions, and
- Assist clinicians in planning treatment or analyzing clinical outcomes

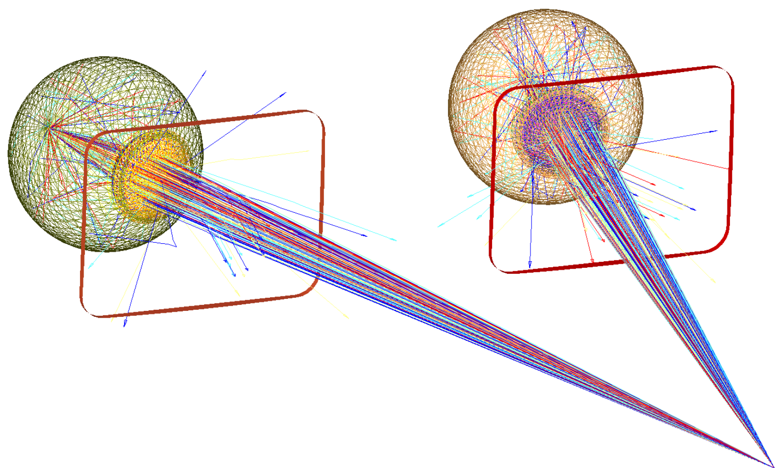

Figure 1 Output view of Advanced Human Eye Model (AHEM)

TIP ***Articles on AHEM are available in the BRO Knowledge Base at www.breault.com/AHEMdocs.***

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Goals for modeling the eye

The goal of modeling the eye is to input whole eye optical properties to create a complete custom virtual eye model. While eye models have existed for some time, they are simplified versions of the eye and consist of parameters that are generalized over populations. Calculations for refraction, such as spectacle and contact lens fitting, and for intraocular lens implants are based on simplified models.

Reasons to model the eye

Many reasons exist to model the eye. Some of the more common reasons include:

- Clinical optometry
- Ophthalmic diagnostics and refractive surgery
- Design of intraocular, spectacle, and contact lenses
- Optical instrumentation and bio-optical engineering
- Vision research
- Education

Instrumentation is available to acquire biometry for the individual eye. For instance, ocular wavefront aberrometers can describe whole eye aberrations, corneal topography can describe corneal surfaces, Scheimpflug and Pentacam systems can describe anterior segment geometry, and ultrasound systems can measure axial length. Biometry is available to describe a personal visual system up to the retina. By using these types of instruments, we can model realistic retinal image quality.

Capabilities of AHEM

Aberrations, reflection, diffraction, absorption, and scatter all degrade retinal image quality. A model that includes all these factors increases realism and provides personalization with biometry. Since people generally see with two eyes, a binocular model integrated into one visual system adds another level of realism. A model that can be integrated and exported with other opto-mechanical systems developed elsewhere is also desirable. These are all capabilities of AHEM.

Installing AHEM

To install AHEM in ASAP, you must have ASAP and the BIO Toolkit.

1. **Install ASAP on your machine if you have not already done so. Do not open ASAP.**
2. **Install the BIO Toolkit from the BIO Toolkit installation disc, and enter the provided password if requested. Open ASAP from the Start menu under Programs> ASAP or from the desktop icon.**

***NOTES** The BIO Toolkit installer also adds links to the Knowledge Base for documentation under Start> Programs>ASAP BIO Toolkit> Documentation> AHEM.*

If you need to uninstall AHEM, select Start> Programs>ASAP BIO Toolkit> Uninstall.

DESIGN AND OPTIMIZATION MODES

AHEM has two modes: design and optimization. The design mode is the default, stepping through screen prompts relevant to the modeling task. In optimization mode, screen prompts are no longer used. The user has completed design mode, and requires optimization of selected design variables to meet desired design objectives.

This document steps you through the design mode using the default settings.

TIPS ***If AHEM is already loaded, right-clicking the ASAP workspace and selecting*** **Start autorun** ***also runs AHEM. A launch dialog prompts for settings to load.***

If the launch screen is not displayed, AHEM may still be in optimization mode from a previous session. in the Command Input window, enter `EYEOPTIMIZE=0` ***to return to the design mode, and reload AHEM.***

Design mode—building an eye model

1. Start ASAP and load AHEM from the File menu: File> Project> Load.
2. Browse to the AHEM project flle in the ASAP installation folder: Programs> ASAP.
3. Select AHEM.apf, and select Open.

AHEM proceeds to autorun in ASAP. In design mode, the launch dialog prompts you for a settings file type.

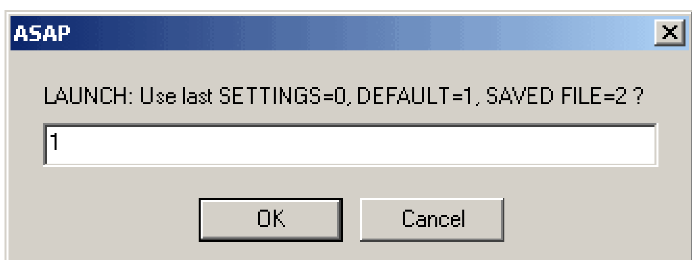


Figure 2 AHEM launch dialog prompts for a model settings file type. Enter 1 for first-time use.

4. Enter 0, 1, or 2, where the last settings = 0, default = 1, and saved file = 2.
5. Click **OK** or press Enter to continue.

NOTE ***If you enter*** **2** ***in the launch dialog, you are prompted for a file name to load. Use uppercase with no spaces nor a file extension.***

SAVING THE FILE

A dialog prompts you for a file name to which your settings are saved (Figure 3).

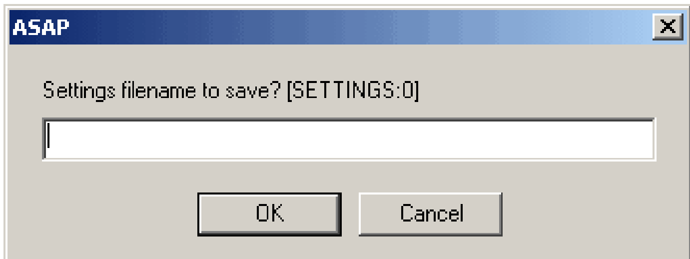


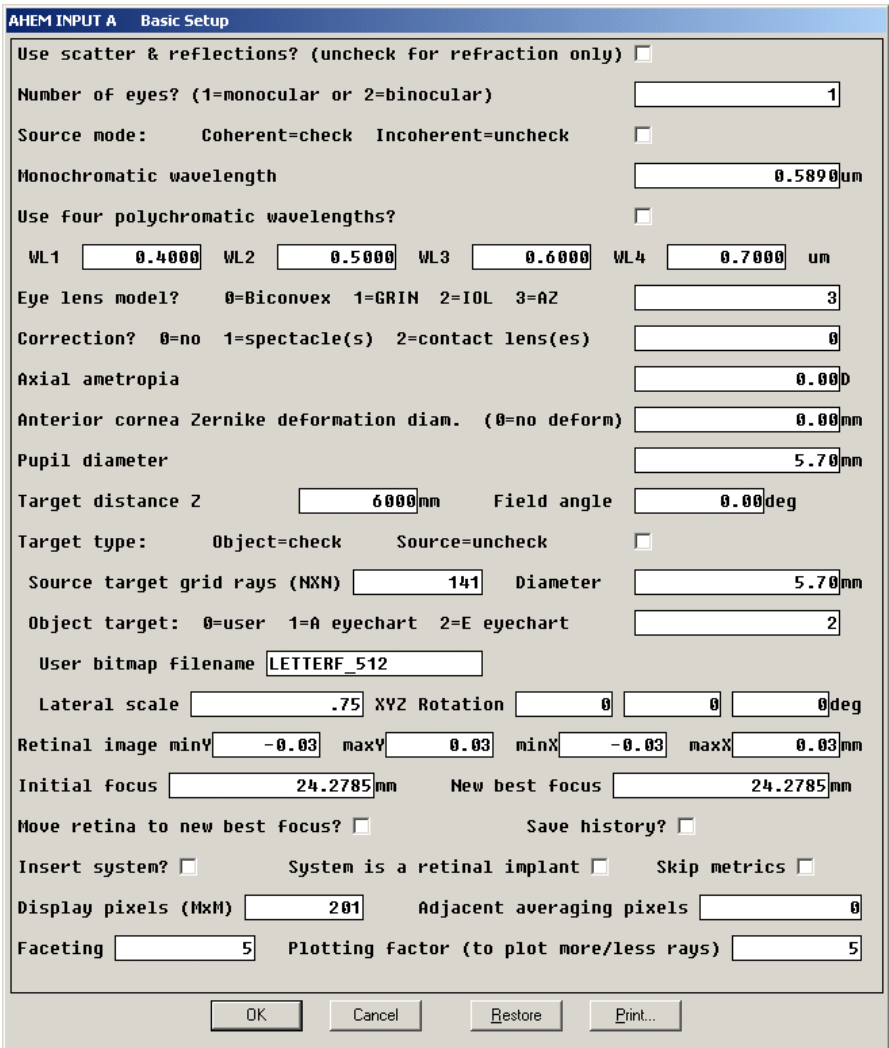
Figure 3 AHEM file name dialog directs output of the model settings for later use

The file name of the last settings file is displayed. You can conveniently save and reload settings files until iterations of the model are complete. For example, as you are working on a particular model, you can simply press the Enter key during each repetitive run. This eliminates entering file names every time. When the model is satisfactory, BRO recommends saving to a unique settings file name. The saved settings file can be reloaded in a future AHEM session.

- Click **OK** or press Enter.

SETTING UP AHEM

The first main input screen is **AHEM INPUT A Basic Setup** (Figure 4). The settings loaded from the launch dialog (Figure 2) are displayed and can also be modified. You have many choices of how to direct the setup of the model. Click **OK** or press Enter to proceed. See Table 1 “AHEM INPUT A Screen” on page 6 for an explanation of the fields.


AHEM INPUT A Basic Setup

Use scatter & reflections? (uncheck for refraction only) ☐

Number of eyes? (1=monocular or 2=binocular) 1

Source mode: Coherent=check Incoherent=uncheck ☐

Monochromatic wavelength 0.5890 um

Use four polychromatic wavelengths? ☐

WL1 0.4000 WL2 0.5000 WL3 0.6000 WL4 0.7000 um

Eye lens model? 0=Biconvex 1=GRIN 2=IOL 3=AZ 3

Correction? 0=no 1=spectacle(s) 2=contact lens(es) 0

Axial ametropia 0.00 D

Anterior cornea Zernike deformation diam. (0=no deform) 0.00 mm

Pupil diameter 5.70 mm

Target distance Z 6000 mm Field angle 0.00 deg

Target type: Object=check Source=uncheck ☐

Source target grid rays (NXN) 141 Diameter 5.70 mm

Object target: 0=user 1=A eyechart 2=E eyechart 2

User bitmap filename LETTERF_512

Lateral scale .75 XYZ Rotation 0 0 0 deg

Retinal image minY -0.03 maxY 0.03 minX -0.03 maxX 0.03 mm

Initial focus 24.2785 mm New best focus 24.2785 mm

Move retina to new best focus? ☐ Save history? ☐

Insert system? ☐ System is a retinal implant ☐ Skip metrics ☐

Display pixels (MxM) 201 Adjacent averaging pixels 0

Faceting 5 Plotting factor (to plot more/less rays) 5

OK Cancel Restore Print...

Figure 4 AHEM INPUT A Basic Setup screen with default settings. Settings can be changed and saved.

Table 1 AHEM INPUT A Screen

Property	Property Description
Use scatter & reflections? (uncheck for refraction only)	Select if analyzing a system to include scatter from scatter models and Fresnel reflections. A subsequent input screen prompts for scatter and reflection data. Deselect to compute only rays that refract forward to the retina.
Number of eyes (1=monocular or 2=binocular)	Enter 1 to model only one eye, or enter 2 to model two eyes simultaneously.
Source mode: Coherent=check Incoherent=uncheck	Select the box for a coherent source using the ASAP mode, **`BEAMS COHERENT DIFFRACT`**, for physical optics and wave propagation. Deselect to use the optics mode, **`BEAMS INCOHERENT GEOMETRIC`** for scattering and faster speed.
Monochromatic wavelength	Enter a single wavelength for a source.
Use four polychromatic wavelengths?	Select to use the wavelengths specified on the next line in microns. Wavelengths are photopically weighted. Deselect to use the monochromatic wavelength.
WL1, WL2, WL3, WL4 um	Enter the four wavelength values.
Eye lens model?	Enter 0, 1, 2, or 3. A lens model is specified. Subsequent input screens prompt for data relevant to the lens choice. Default settings for each lens are optimized in geometry for emetropization (smallest retinal spot size).
0=Biconvex	Simple spherical biconvex lens controlled in shape by dioptric power and refractive index.
1=GRIN	A 13-layered gradient index lens.
2=IOL	An intraocular lens.
3=AZ	Arizona accommodative eye model lens and eye geometry.
Correction?	Enter a correction value of 0, 1, or 2.
0=no	No extraocular corrective optics are used.
1=spectacle(s)	Subsequent screens prompt for spectacle correction data.
2=contact lens(es)	Subsequent screens prompt for contact lens correction data.

Table 1 AHEM INPUT A Screen

Property	Property Description
Axial ametropia	Enter a value. Diopters of axial ametropia may be input to create an elongated (myopic) or shortened (hyperopic) eye. A positive value creates an axial myope. A negative value creates an axial hyperope.
Anterior cornea Zernike deformation diam. (0=no deform) __ mm	Enter a value. A diameter greater than zero creates a deformed anterior corneal surface of the specified diameter in mm. The base surface of the cornea is specified in the subsequent AHEM Input D# prompt screen. Another subsequent screen, AHEM Input G, prompts for Zernike coefficients in University of Arizona ordering in waves or microns of the monochromatic wavelength. Note: If you are using OSA or other Zernike ordering, be sure to convert coefficients beforehand.
Pupil diameter __ mm	Enter a value for the inner hole of the iris.
Target distance Z __ mm	Enter a value from the corneal anterior vertex.
Field angle __ deg	Enter a value to rotate the eye in degrees with respect to the target.
Target type:	
Object=check	Select to use an object target, such as an eyechart or user object target specified by user bitmap file name. The bitmap file must be in the working folder.
Source=uncheck	Deselect to use a source target.
Source target grid rays (NXN)__ Diameter __ mm	Enter a value of NxN rays, and enter a value for the diameter.
Object target 0=user 1=A eyechart 2=E eyechart	Enter the number 0, 1, or 2.
User bitmap filename	Enter a name for the bitmap file.
Lateral scale	Enter a value to scale the object target in XY.
XYZ Rotation __ __ __ deg	Enter a value to rotate the object target in degrees.
Retinal image min Y __ maxY__ min X __max X __ mm	Specify minimum and maximum XY extents in mm for a window size to observe the retinal image.

Table 1 AHEM INPUT A Screen

Property	Property Description
Initial focus __ mm	The initial focus for the system is calculated through initial ocular surfaces and media. This is an alterable axial length from the corneal vertex to the retina.
New best focus __ mm	If changes are made to the ocular surfaces and media, a new best focus is calculated.
Move retina to new best focus?	Select to move. This is comparable to emetropization, where the retina grows to coincide with the position of best focus. Deselect to leave retina as is.
Insert system?	Select to create a subsequent prompt to insert an additional optical or opto-mechanical system with which the eye will interface.
System in a retinal implant?	Select if the inserted system is a retinal implant. This supports imaging onto both the implant and the surrounding retina in the retinal image window.
Skip metrics	Select to bypass the default metrics graphics generation.
Display pixels MxM	Enter pixel resolution for the retinal image window.
Adjacent averaging pixels	Enter the number of adjacent pixels to be averaged with a primary pixel within the retinal image. This applies to data smoothing.
Faceting	Enter a value for the faceting level of object graphics.
Plotting factor (to plot more/less rays)	Enter a value. Lower numbers plot fewer rays and higher numbers plot more rays. All rays are traced, but the drawing of the quantity of rays on the graphics is controlled here.
OK	Select to accept the settings and close the dialog.
Cancel	Select to close the dialog without saving the settings.
Restore	Select to restore original values to the settings.
Print	Select to print the settings to a designated printer.

Lens and geometry settings

Based on user selections in Input A, branching to subsequent input screens occurs. Models with additional features such as scattering, lens correction, imported systems, or binocular settings require more input. For example, if you select two eyes in the Input A screen, subsequent screens for eye1 and eye2 are displayed.

***TIP** Additional AHEM configurations are demonstrated in the BRO Media Gallery at www.breault.com/AHEMdemos.*

With the default settings file chosen, the next input screen is displayed: **AHEM Input D3 AZ lens and eye geometry settings** (Figure 5).

- The first few lines of this screen are relevant to eye lens choice.
- The remaining input specifies eye geometry except for the last two lines.
- The last two lines are dedicated to computing field energy through a volume or a three-dimensional point spread function (3D PSF), constrained by retinal window size and through focus depth. The 3D PSF is resolved with display pixels

and number of slices. If zero slices are specified, the 3D PSF is *not* generated. Also, the 3D PSF is only available in coherent source mode.

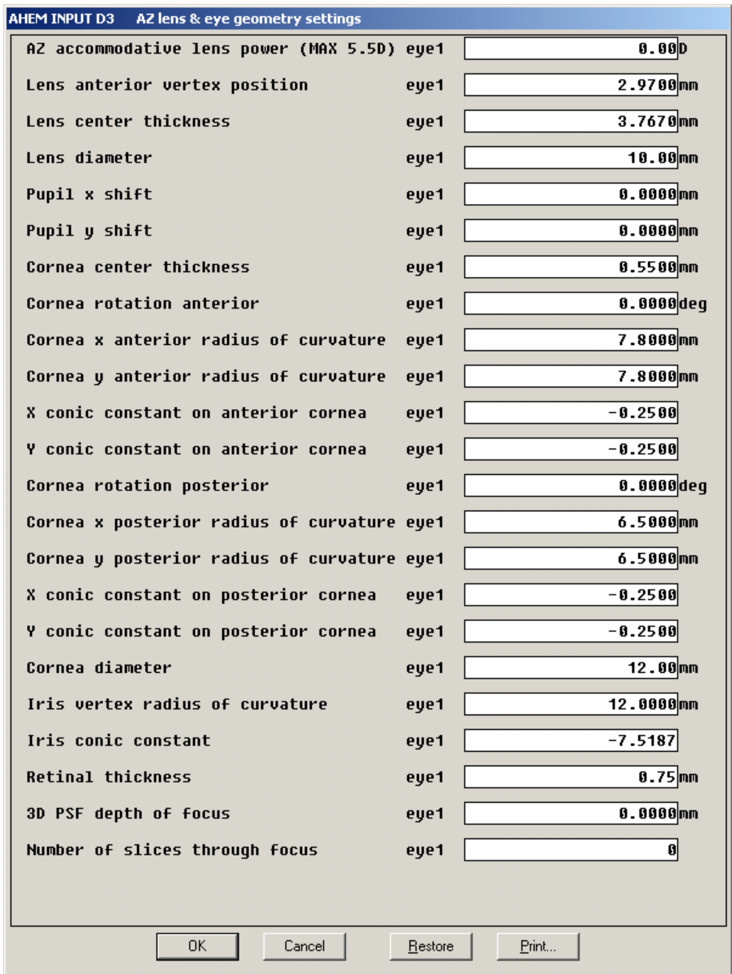


Figure 5 AHEM Input D3 AZ lens and eye geometry settings—D# screens are depending on Input A. Geometry of the eye is displayed and may be modified.

1 Enter values for each property, or accept the defaults.

The default settings file requires only two main input screens.

2 Click **OK** or press Enter to proceed.

Ray tracing commences immediately after AHEM Input D3.

Metrics and graphics

Tabular metrics are shown in the ASAP Command Output window. Object ray/flux information is shown and metrics produced are FWHM1 (full width half maximum) and PCT50ENCNRG1 (50% encircled energy) of the retinal image PSF for eye1. INITIALFOCUS1 (initial focus) and NEWBESTFOCUS1 (new best focus) for eye1 are also output. Any optical metric, analysis, or graphic that ASAP produces is available to you.

You can do post processing even after the raytrace is complete. However, for the default settings, five graphics are automatically produced.

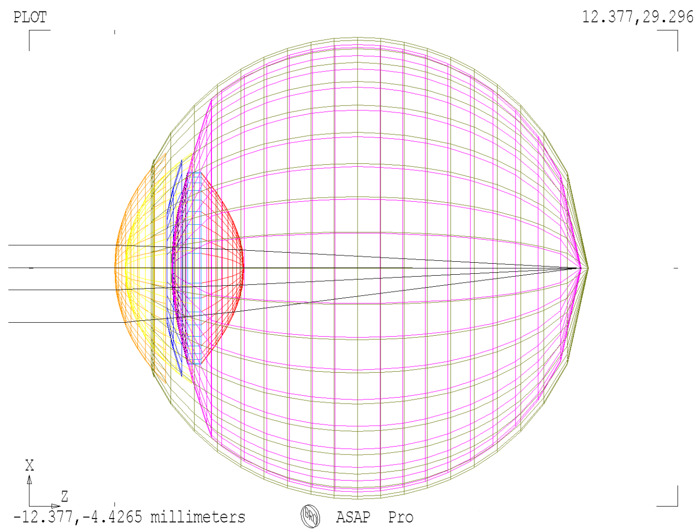


Figure 6 Cross-section of advanced human eye model. Default faceting level set low at 5 for high-speed rendering.

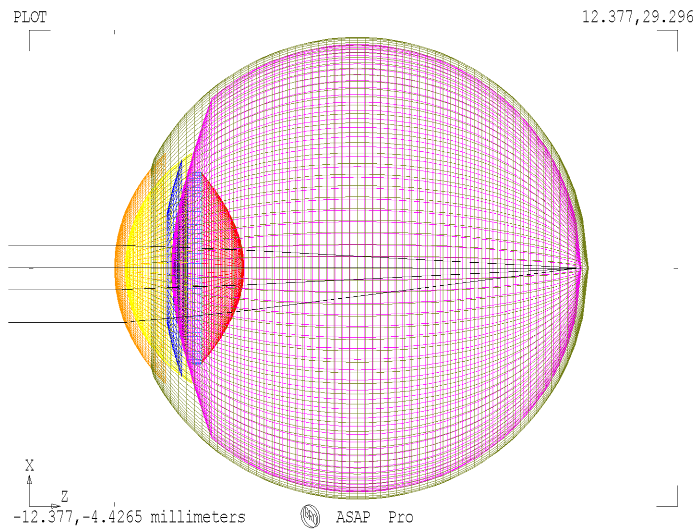


Figure 7 Same system as in Figure 6 but with level 15 faceting. Higher faceting, which takes slightly longer to render, produces a smoother and rounder graphic.

NOTE Faceting facilitates illustration and has no effect on imaging or metrics.

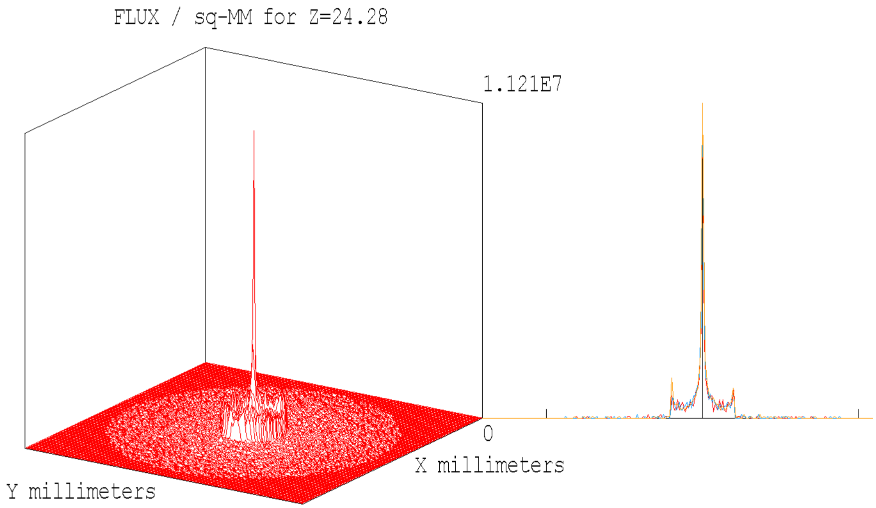


Figure 8 Isometric view of the retinal image PSF constrained by retinal window dimensions (left), and overlaid retinal image PSF X and Y cross-sections (right)

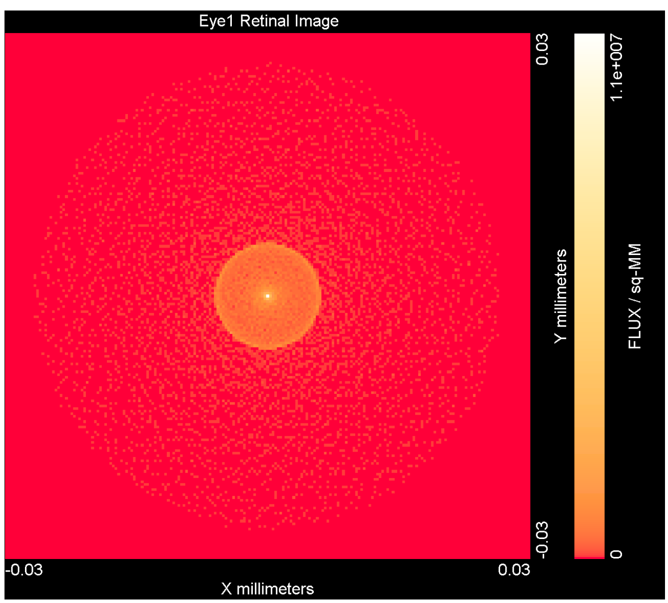


Figure 9 Aerial retinal image PSF

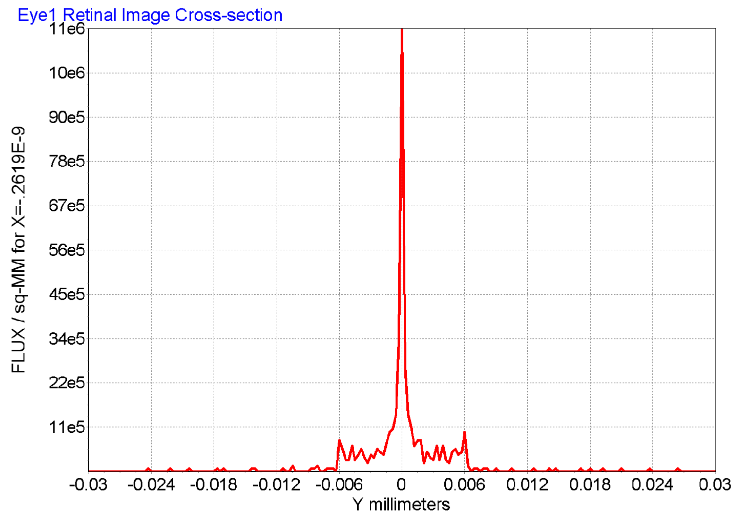


Figure 10 Retinal image PSF cross-section

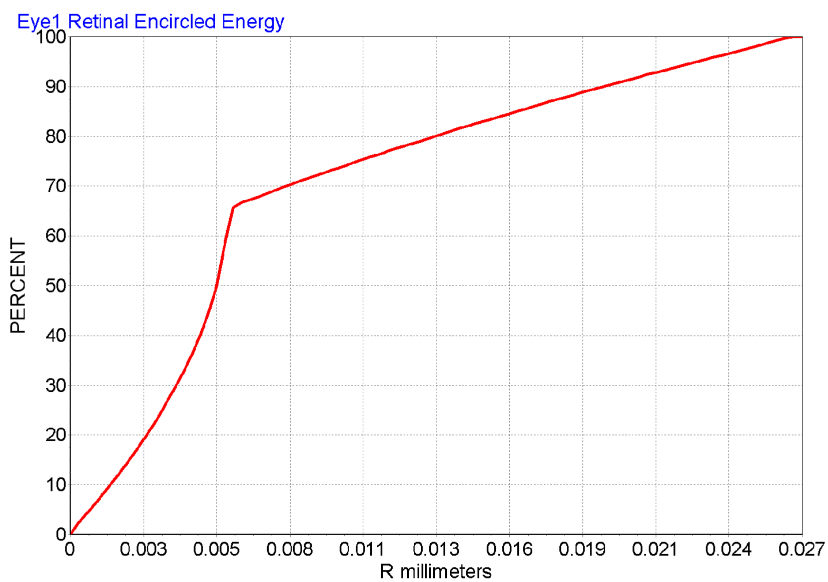


Figure 11 Retinal encircled energy

System output

COMPUTER-AIDED DESIGN (CAD) OUTPUT

The entire model can be exported in IGES or DXF CAD formats. One scenario involves entering these commands in the Command Input window:

```
CONSIDER ALL; CADEXPORT IGS MYEYE
```

This action creates an IGES file (myeye.igs) of the entire eye model for use in other CAD software. Selected parts of the model can be exported by using various options on the **CONSIDER** command, such as **CONSIDER EXCEPT...** or **CONSIDER ONLY...**

ASAP SYSTEM FILE EXPORT/IMPORT

The eye model may be exported as a system file by entering this command in the Command Input window:

```
SYSTEM TO MYEYE
```

A system file is created (myeye.sys) that can be recalled by another ASAP main file with the command:

```
SYSTEM FROM MYEYE
```

TIP ***Always perform the system recall early in the main file to prevent object/media/scatter model number/naming conflicts.***