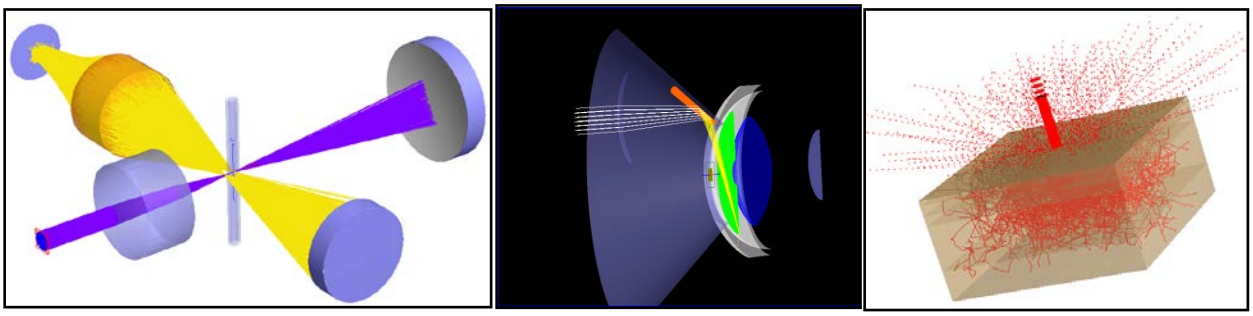
FRED Biomedical Application Note



Introduction

From non-invasive procedures to ultra-sensitive diagnostic instrumentation, photonic devices play an indispensable role in today's biomedical industry. Timely design and delivery to market of these new technologies has been possible only with the aid of sophisticated software tools and experienced optical engineers. Photon Engineering firmly believes that its optical engineering product FRED can help accelerate the pace of innovation in the biomedical community. FRED combines an intuitive graphical user interface with a powerful computational engine capable of satisfying the most demanding requirements. The relevance of FRED to the biomedical industry can best be expressed by presenting several familiar yet innovative applications such as a gonioscope, laser-induced fluorescence in a capillary, and a human skin model.

Biomedical optics applications

Gonioscopy lens

The ability to monitor the iridocorneal angle (the angle between the iris and the internal surface of the cornea) is a critical factor in the diagnosis and treatment of glaucoma. A gonioscope can measure this angle by illuminating the eye and collecting reflected light.

To begin simulating the gonioscope, an accurate human eye model is required[1]. A model based on relevant references is available in the Samples folder of FRED.[2,3] (Figure 1) All essential elements of the eye are included: front and rear surfaces of the cornea, iris, eye lens, and aqueous humor. To modify any aspect of the eye model, simply double-click each element to open a multi-tab dialog box.

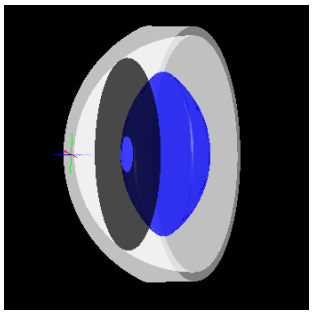


Figure 1. FRED model: anterior portion of the human eye.

The next step is to model the gonioscopy lens. FRED allows import of lenses designed in CodeV, Zemax or Oslo. FRED maintains a local coordinate system for each surface, which allows positioning of the goniolens with respect to the cornea. In practice, the lens is coupled to the cornea using index matching fluid. FRED has a unique "gluing" feature which allows for easy insertion of this layer. To contact the surfaces, enter edit mode for the rear surface of the goniolens (Figure 2). Click the Glue tab and select the *Cornea outer surface* as the surface to be glued to. Finally, select the material to use for gluing.

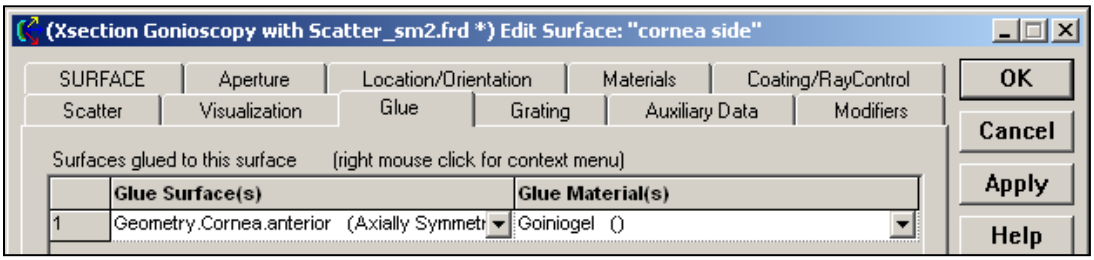


Figure 2. "Gluing" the goniolens to the cornea.

To create the light source for illumination, a *Detailed Optical Source* can be created (Figure 3).

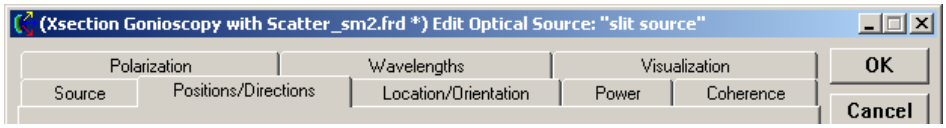


Figure 3. Detailed Optical Source dialog box. The Positions/Directions tab specifies source dimensions, number of rays, and angular emission properties. The Wavelengths tab provides options for spectral content. The Power tab sets total source power and specifies any spatial apodization.

The completed and raytraced model is shown in Figure 4. FRED has the ability to assign a color to rays in four distinct conditions: reflection, transmission, scattering or diffraction. Ray colors can be assigned under the Coating/Ray Control tab of a specific surface. In this example, rays scattering from the cornea rear surface are changed to green and those scattering from the iris to red.

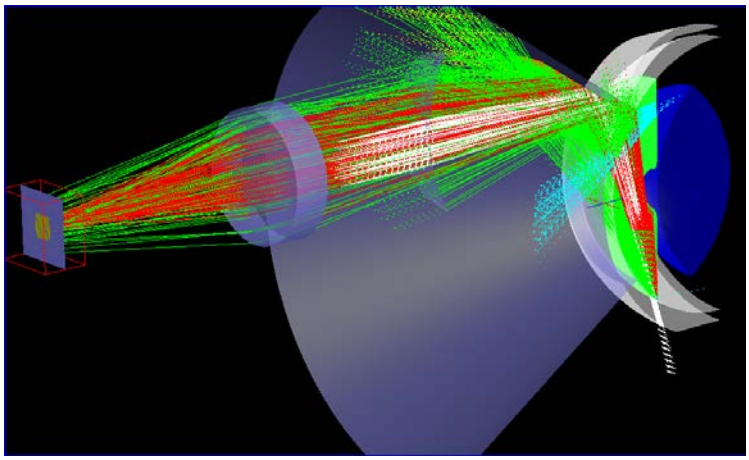


Figure 4. Goniolens model with raytrace paths. Ray colors indicate specific surface intersections.

Figure 5 shows spot diagrams at the lens focus for rays scattered from the iris and the cornea. The left and right plots contrast the difference between a flat and curved irises. As expected, we can see the image shearing with the curved iris in the left chart.

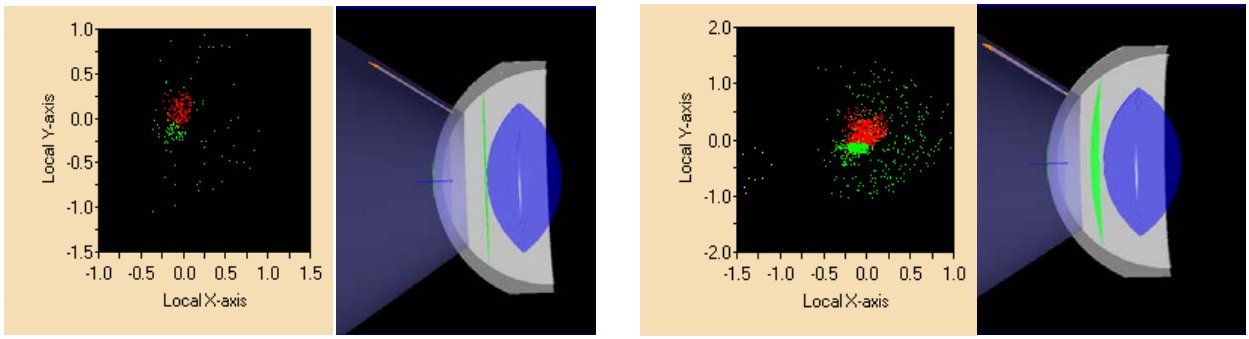


Figure 5. Spot diagrams using planar and curved irises.

Laser-induced fluorescence – capillary electrophoresis

Capillary electrophoresis is a technique used in genetic analysis and protein characterization. A collimated laser beam is focused into a glass capillary column where material flows under the influence of an electric potential. When particles pass through the illuminated volume, they fluoresce with a characteristic spectrum.

In Figure 6, a collimated rayset representing an UV laser beam is focused by an objective lens into a glass capillary filled with fluid. The mirror at top right enlarges the illuminated volume by reflecting unused light back into the capillary at a slightly different trajectory. The larger illumination volume increases the fluorescent signal. Optics oriented perpendicular to the illumination path collect fluorescent light for analysis.

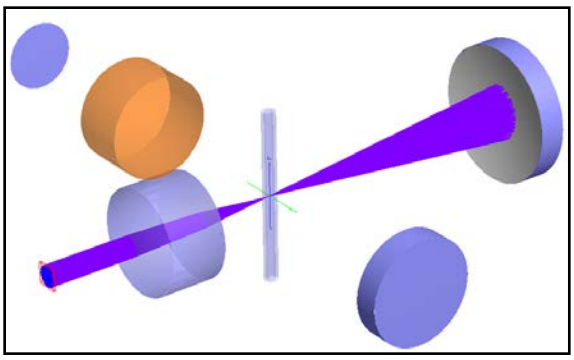


Figure 6. FRED model of capillary electrophoresis system with collection optics.

FRED can implement the phenomena of fluorescence through a specialized feature in its scattering library. A scripted scatter model can be constructed to reassign ray wavelengths by interpreting an emission curve in terms of probability. In this example, Rhodamine 6G, a widely used organic dye, will be used[4,5]. The spectrum is digitzed in FRED and included in a Scripted Scatter Model. More details on the script in this example can be found in the Help documents in FRED.

To save simulation time, only scattered rays reaching the detector should be traced. The Importance Sampling feature in FRED serves just this function. Select the fluorescing object in the model and click the Scatter tab. After assigning the Scripted Scatter property of fluorescence to this element, edit the Scatter Direction Region(s) of interest to be "Toward an Entity". Select the detector surface as this entity.

A graphical representation of the complete simulation is shown in Figure 7. Purple represents the illuminating path while the orange maps the fluorescence.

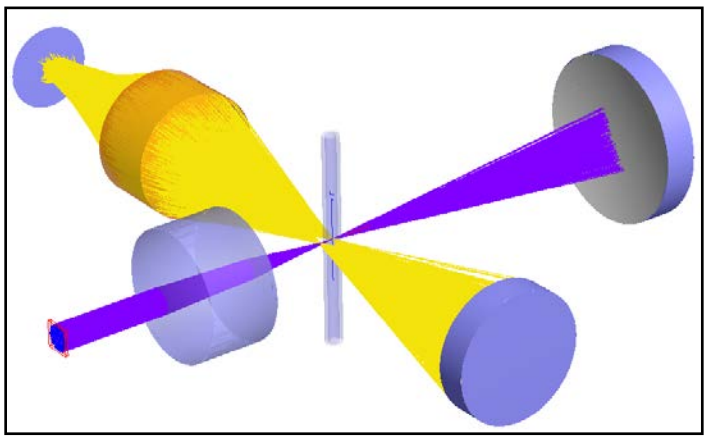


Figure 7. Capillary Electrophoresis simulation with illumination and fluorescence paths.

Human skin model

Human skin models are valuable aids in the design of non-invasive diagnostic devices and dermatological instruments. FRED offers the Henyey-Greenstein volume scatter model, which is recognized by the biomedical community as representative of scattering in human tissue. The volume scatter model is applied through a material definition in FRED (Figure 8). Once the material is defined, it can be assigned to entities in the model by the drag-&-drop method.

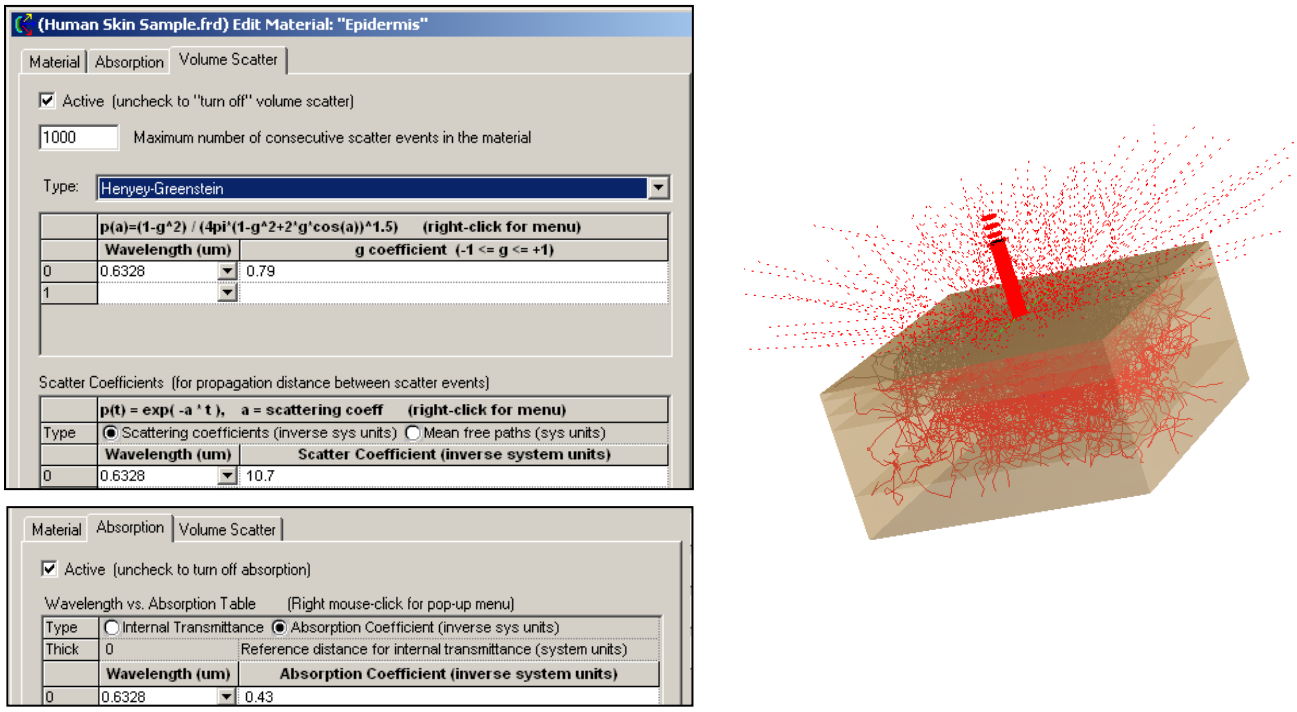


Figure 8. (Left) Defining the Henyey-Greenstein volume scatter model for a new material: top – scattering properties; bottom – absorption properties. (Right) Sample raytrace of a human skin model in FRED.

Conclusions

As demonstrated in these biomedical optical device examples, FRED has the critical and visually dynamic capabilities for modeling, analysis, and graphical display. If you have any questions regarding FRED's ability to model and analyze your biomedical optical system, simply contact us by phone or email.

References:

1. *The Eye and Visual Optical Instruments, G. Smith & D. Atchison, Cambridge University Press, 1997*
2. *Visual Optics Course Notes, Jim Schwiergling, Optical Sciences Center, University of Arizona, 2000.*
3. *Tissue Optics; Light Scattering Methods and Instruments for Medical Diagnostics, Valery Tuchin, SPIE Press, 2000.*
4. *Graphic obtained from http://omlc.ogi.edu/*
5. *R. F. Kubin and A. N. Fletcher, "Fluorescence quantum yields of some rhodamine dyes.," J. Luminescence, 27, 455-462, 198.*

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