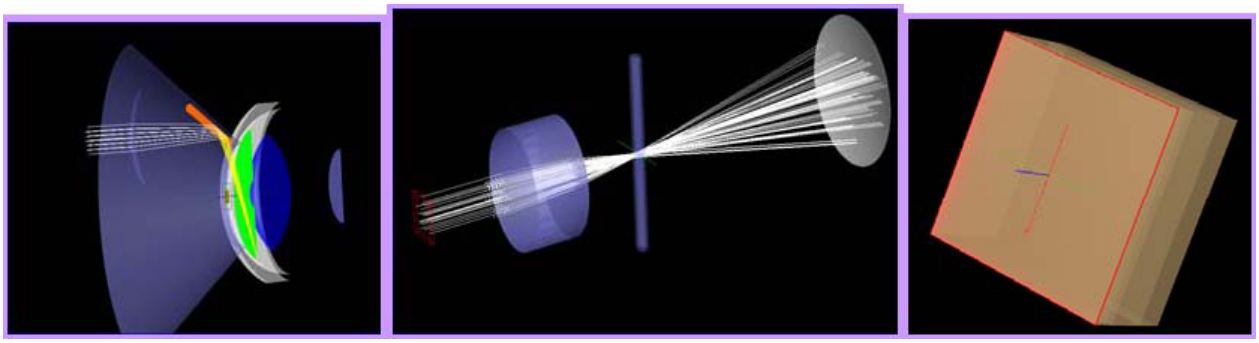
FRED Features – BioMedical
特色 – 生物醫學

From non-invasive procedures to ultra-sensitive diagnostic instrumentation, photonic devices play a indispensable role in today's bio-medical industry. For the last quarter century, 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 by enabling its members to participate more fully in the process. FRED combines a GUI interface, where geometry creation and visualization are intuitive, with a powerful computational engine capable of satisfying the most demanding requirements. The relevance of FRED to the bio-medical 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.

從非侵入性的醫療程序，以及超靈敏的診斷儀器，光子器件在今天的生物醫藥產業中，發揮不可或缺的作用。過去的四分之一世紀裡，資深光學工程師借助先進的軟件工具與適時的設計，將這些新技術引進市場。然而 Photon Engineering 公司堅信其光學工程軟件產品 FRED，可以幫助並加快創新的步伐，使生物醫學界的成員，更能直接、充分地參與這一進步的過程。FRED 結合人機界面(GUI)，可任意建構幾何圖形，並可直接由此介面中獲得其物件外觀，並擁有可滿足此一精密設計需求的強大計算引擎之能力。而最能表達呈現 FRED 與生物醫藥產業相關性的幾個熟悉但創新的應用範例：諸如前房視鏡、激光誘導螢光毛細管、以及人體皮膚模型。



Biomedical Optics Example 1: Gonioscopy Lens
生醫光學元件 範例 1：前房角鏡

The ability to monitor the iridocorneal angle is a critical factor in the diagnosis and treatment of glaucoma. To measure this angle between the iris and the internal surface of the cornea, a gonioscope must illuminate these surfaces through the entrance of the eye and efficiently collect the returning light.

An essential element in simulating the operation of a gonioscope is an accurate model of the human eye. Figure 1 below shows a view of the anterior portion of the human eye constructed in FRED. This particular eye model is based upon a reference model of the eye attributed to Smith & Atchison and Schwiergling [2]. The material properties for this eye model have been obtained from Tuchin [3]. All essential elements of the eye are included in this model; the front and rear surfaces of the cornea, the iris, the eye lens and aqueous humor. Several complete eye models can be found in the Samples folder of the FRED installation directory.

Should elements of the eye model require alteration, the complete collection of parameters used in their definition are available from multi-tab dialog boxes such as the one shown in Figure 2.

The user has direct access to curvatures, apertures, trimming, positioning, materials, scatter, coatings, and visualization properties in a central location in the FRED interface.

在診斷和治療青光眼的過程中，能否監測虹膜和角膜角度是一個關鍵因素。要量測這個虹膜和角膜內表面的夾角，必須使用前房角鏡，通由眼睛的入口處，照亮這些表面，並且能高效率的收集返回的光線。

一個精確的人眼模型，是進行前房角鏡模擬運算中不可或缺的元件。以下圖 1 所顯示的是以 FRED 建構的人眼前庭部份的構造。此一特定的人眼模型，是根據 Smith & Atchison 以及 Schwiergling 所提出的人眼參考模型。此人眼模型的材料性質，則取材自 Tuchin。而所有眼睛的主要元件，也都包含於此模型中，包括：角膜的前方和後方表面、虹膜、晶狀體和水漾液。數種完整的人眼模型可於 FRED 安裝後目錄的範例資料夾下獲得。

如果有需要對人眼模型的元件進行修改，一完整的多參數匯集的輸入對話視窗能給予使用者有效的定義其特性，如圖 2 所示。

使用者可以直接在 FRED 人機化界面中存取曲率、孔徑、微調、定位、材質，散射，鍍膜與中心位置上視覺化的物件特性。

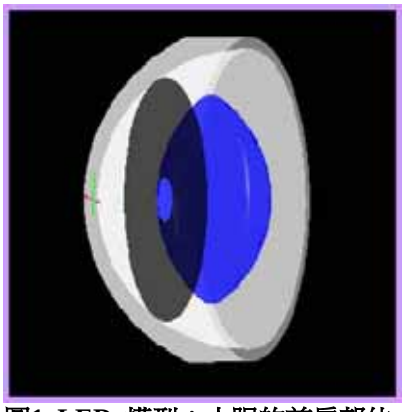


圖1. LED 模型：人眼的前房部位

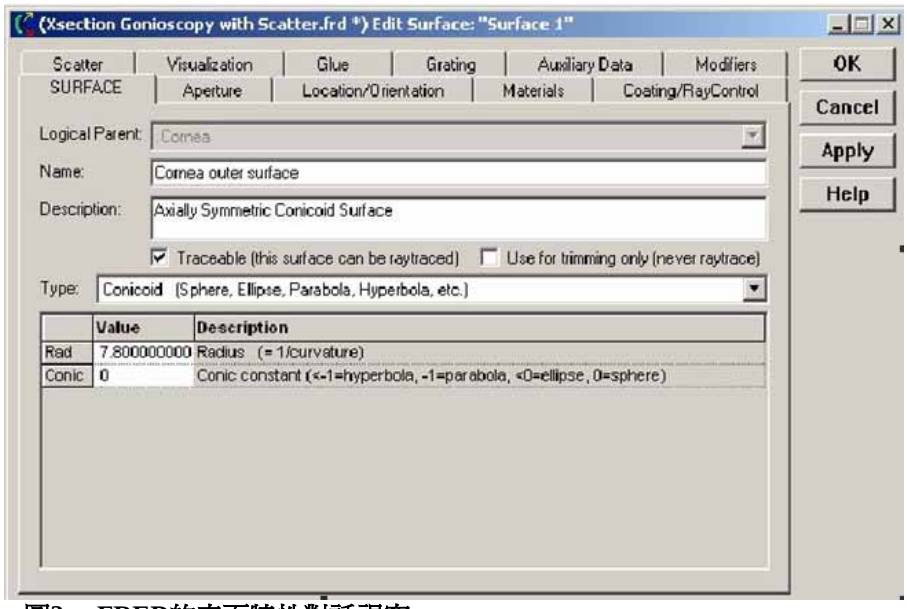


圖2. FRED的表面特性對話視窗

With the eye model readily available, the next step in building this simulation will incorporate a gonioscopy lens. FRED offers trouble-free import of lenses designed in CodeV, Zemax or Oslo. Positioning of the goniolens with respect to the cornea a simple operation in FRED. FRED maintains a local coordinate system for each surface. Objects, as they are added to a model, can be located relative to other objects. Figure 3 below shows the placement of the gonioscopy lens being set with respect to the cornea outer surface.

In practice, this lens is coupled to the cornea by introducing an index matching fluid between these surfaces. FRED has a unique “gluing” feature which allows for easy insertion of this matching layer. Contacting these surfaces is as simple as entering the edit mode for the rear surface of the goniolens, opening the Glue tab, selecting the cornea anterior surface as the surface to be glued to, and finally selecting the material to use for gluing. This operation is shown in Figure 4 below. Figure 5 shows the complete geometric model

.

在人眼模型能被運用時，下一步將要建構前房角鏡頭的模擬。FRED 可以輕鬆的從 CodeV、ZEMAX 或 OSLO 匯入所設計的透鏡。在 FRED 中經由一個簡單的操作，就可以將前房角鏡定位在眼角膜上。FRED 對於每個表面，都存在一個局部坐標系統。當加入任何一個物件時，可以相對地定位於其他的物件。如圖 3 所示，前房角鏡頭被置於相對於眼角膜的外表面。

在實作上，此前房角鏡是藉由一種表面間的指數匹配液耦合到角膜上。FRED 具有獨特的"膠粘"特性，可以很容易地插入這個指數匹配層。接觸這些表面的操作非常的簡單：進入前房角鏡後表面的編輯模式，打開"Gule"的目錄選項，選擇角膜前表面作爲"膠粘"面，最後選擇要粘合的材料。其操作如圖 4 所示。圖 5 爲完整的幾何模型。

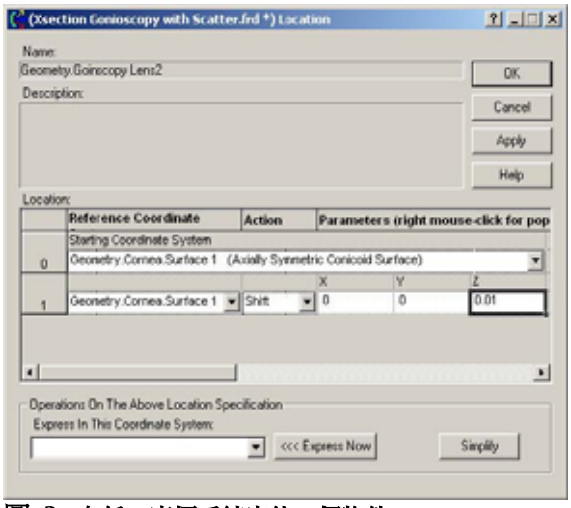


圖 3. 在任一座標系統定位一個物件.

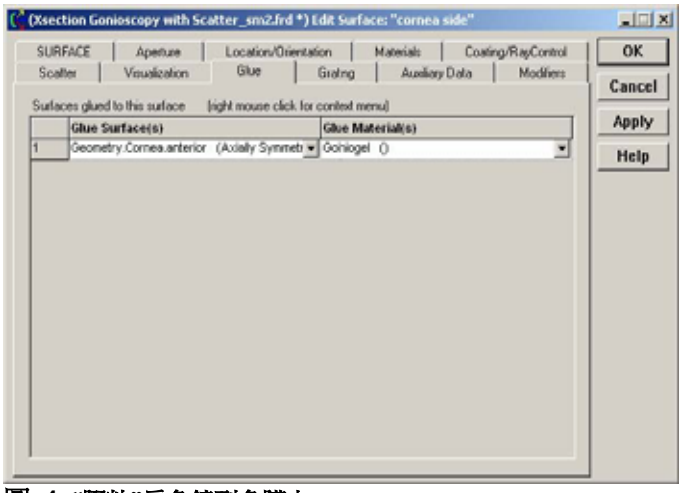


圖 4. “膠粘”房角鏡到角膜上.

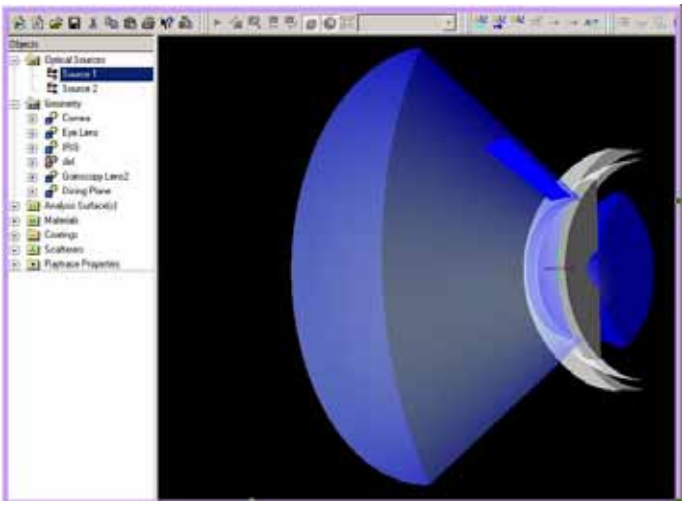


圖5. FRED系統內前房角鏡和人眼模型的剖面圖

With the geometry for the model now complete, the next step in preparing this simulation is to create the light source will illuminate the anterior chamber of the eye (between the inside of the cornea and the iris). Standard gonioscopy procedures indicate the need for a slit source to produce optimum illumination. Shown in Figure 6 is FRED Source dialog box used to create rays for tracing. The Positions/Directions tab allows the user to set the number of rays, source dimensions and angular properties.

幾何模型建構完成後，模擬程序準備的下一步驟是建構光源，照亮眼睛前房（在角膜和虹膜之間）。標準前房角鏡的程序指出，所需的最理想照明光源爲狹縫光源。於圖 6 展示的爲 FRED 光源設定對話視窗。Positions/Directions 目錄選項可允許使用者設定所需的光線數、光源的尺寸和角度的特性。

For more in-depth analysis, the user may require the source have a particular spectral content or be apodized in angle or position. These along with many other aspects of a source definition are found amongst the various tabs in the Source dialog box. The user could choose the standard CDF the wavelengths as shown in Figure 7 or digitize the source spectra from a graphic such as a spectral curve as shown below in Figure 8. Note that in both cases, FRED can color rays according to their individual wavelengths for easier visualization.

爲進行更深入的分析，使用者或許需要的光源爲具有特殊的光頻譜資訊、切趾角度或位置。這些操作以及許多其他關於光源的定義，都可以在 Source 對話視窗的各種目錄選項找到。使用者可以選擇如圖 7 所顯示的標準 CDF 波長，或如同圖 8 所示的來數位化光源光譜曲線。注意這兩個實例，FRED 可將不同的波長以顏色區別，而易於觀看。

圖 6. Source對話框的位置/方向目錄選項.

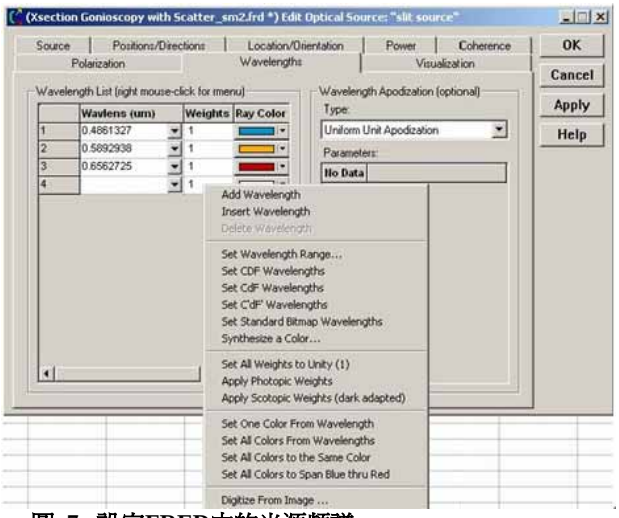


圖 7. 設定FRED中的光源頻譜

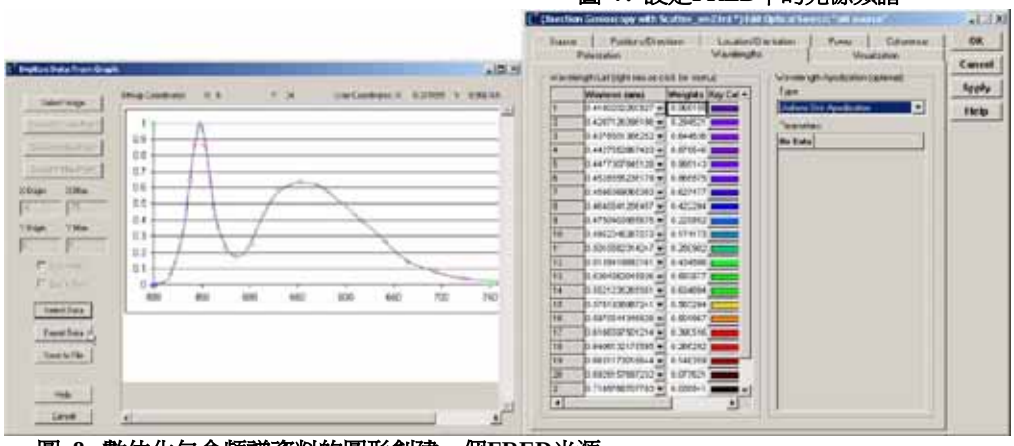


圖 8. 數位化包含頻譜資料的圖形創建一個FRED光源

Adding an apodization to the source definition is also a straightforward operation. The Power tab of the FRED Source dialog offers several pre-defined apodizations along with the option for customized profiles. Shown in Figure 9 is an example of Gaussian spatial apodization typical of a laser diode or LED:

After position the source to achieve the optimal illumination, a supplemental optic may be desirable to image light exiting the goniolens. FRED offers the convenience of choosing from hundreds of stock lenses in seven popular vendor catalogs. The completed and raytraced model is shown in Figure 10.

增加光源所定義的切趾也是一簡單的操作流程。在 FRED 中光源對話視窗內的 Power 目錄選項中，提供了數種可預先定義切趾的選項，以供定製所需的光源輪廓。圖 9 爲展示一高斯特殊切趾類型的 laser diode(雷射二極體;激光二極管)或 LED 的典型範例：

在置入光源之後，開始去最佳化照明狀態後，一額外的顏色視學用於影像光線經過前房角鏡後能讓使用者易於觀看。FRED 提供數百種慣用的透鏡在七種熱門廠商資料庫中。此完整的光線追跡模型如圖 10 所示。

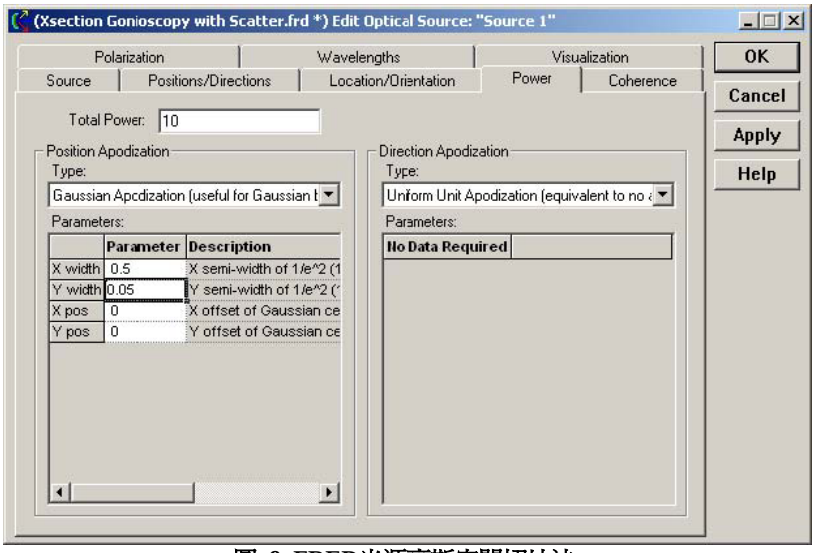


圖 9. FRED光源高斯空間切址法.

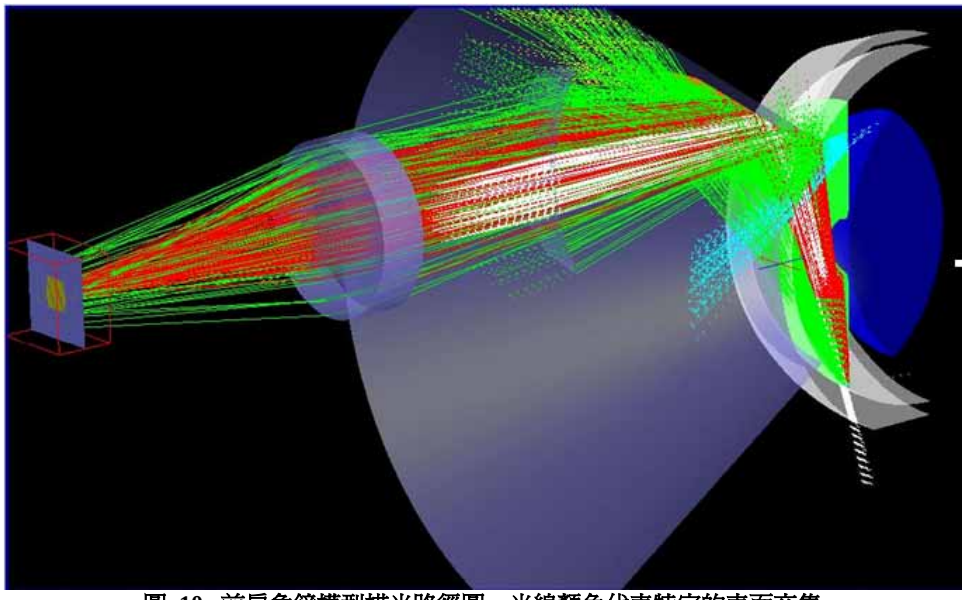


圖 10. 前房角鏡模型描光路徑圖。光線顏色代表特定的表面交集

In this rendering, rays are not colored according to wavelength. FRED has the ability to assign a chosen color to a ray that strikes a given surface under any of four distinct conditions: reflection, transmission, scattering or diffraction. In Figure 11, rays scattering from the cornea rear surface are changed to **green** and those scattering from the iris to **red.**

As an example of analyses available in FRED, spot diagrams at the lens focus are shown for rays scattered from the iris and inside the cornea in Figure 12. The upper plot and lower plots contrast the difference between a flat and curved irises as shown on the right. As expected we can see the image shearing with the smaller or closed angle in the lower chart.

在此文中，光線的顏色並不是根據波長而訂定的。FRED 具有當光線碰擊到表面時，能將 4 種不同的情形以顏色區別出來：反射、穿透、散射或繞射。如圖 11 ，從角膜後方表面散射的光線可改爲綠色，而從虹膜散射的光線爲紅色。

作爲 FRED 中一個分析的範例，如圖 12 爲透鏡焦點的斑點圖，期能展示光線在虹膜與角膜內的散射情形。上圖與下圖對照著如右所示的平面與曲面的虹膜的差異。正如我們所期許的，在影像的擷取中我們能觀看出下圖具有一較小或封閉的角度。

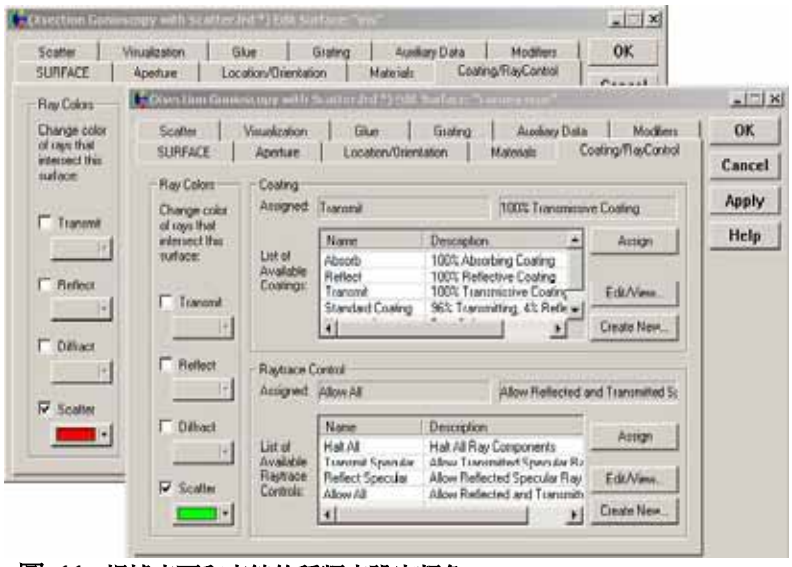


圖 11. 根據表面和交線的種類來設定顏色.

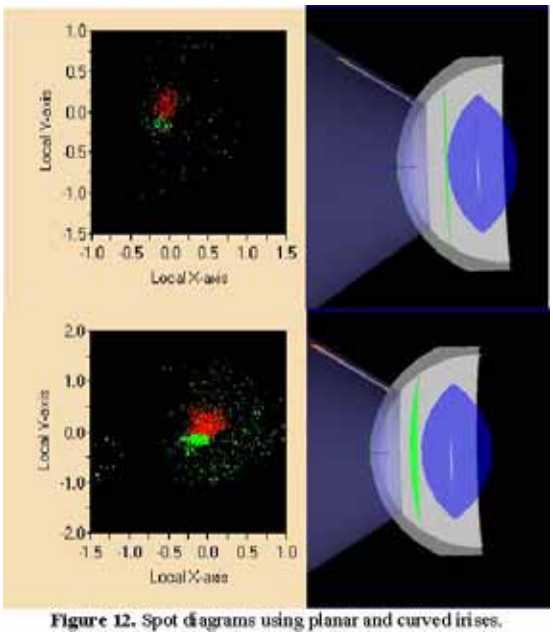


Figure 12. Spot diagrams using planar and curved irises.

圖 12. 使用平面和曲面虹膜的點狀圖

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.

Biomedical Optics Example 2: Laser Induced Fluorescence – Capillary Electrophoresis
生醫光學元件 範例 2：雷射誘發螢光 - 毛細管電泳

Capillary electrophoresis is a powerful technique used in genetic analysis and protein characterization. A collimated laser beam is focused into a glass capillary column where material to be analyzed flows under the influence of an electric potential. When specific particles or compounds pass through the illuminated volume, they fluoresce with a characteristic spectra. This example illustrates how FRED implements the phenomena of fluorescence through a specialized feature in its scattering library.

In Figure 13, a collimated rayset representing an ultraviolet laser beam is focused by an objective lens into a glass capillary filled with fluid. The mirror at top right is used to enlarge the illuminated volume by reflecting unused laser light back into the capillary on a slightly different but overlapping trajectory. This larger illumination volume serves to increase the fluorescent signal being collected. Optics oriented perpendicular to the laser illumination path collect the fluorescent light for analysis.

毛細管電泳是一種功能強大的技術，常用於基因分析和蛋白質鑑定。將一準直雷射光束聚焦到一個玻璃毛細管柱，材料流動的情形在電壓的影響下被分析。當特定微料或混合物通過雷射光照亮的區域，它們將發出具特殊的光頻譜的螢光。範例闡述FRED由其散射資料庫如何實現螢光現象的特定特色。

在圖 13 中 ，一束準直光線組，代表一紫外線雷射光束，經由一個物鏡，聚焦在充滿液體玻璃毛細管上。圖右上方的鏡子是用來反射未使用的雷射光，經過重疊但略爲不同的軌跡，反射回到原來的毛細管，藉以放大照亮的區域。這放大區域的光照體積用以增加被收集的螢光訊號。光學上以垂直於雷射照明光路的螢光收集爲分析之目的。

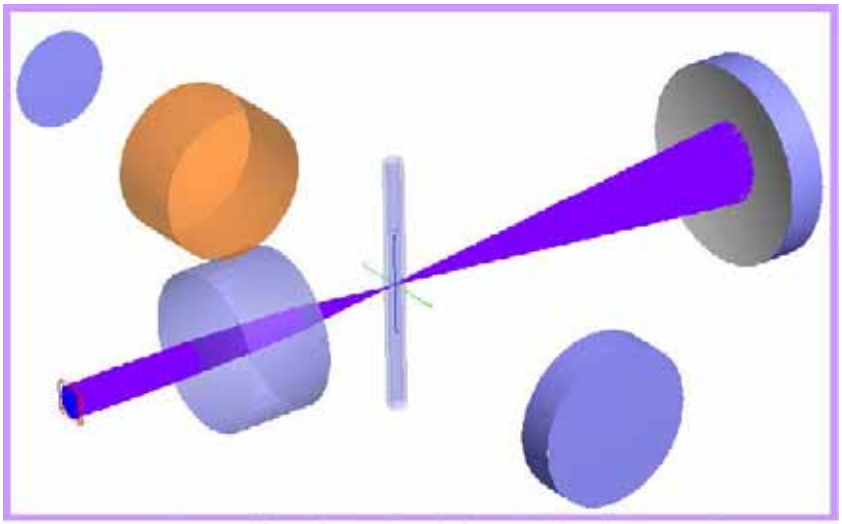


Figure 13. Capillary Electrophoresis layout with collection optics.
圖 13. 毛細管電泳系統光件配置圖

A close-up view of a particle flowing through the laser illumination path in the capillary can be seen in Figure 14. The key element of this simulation will be an ability in FRED to assign fluorescent properties to such particles. The physical process of fluorescence involves conversion of light at one wavelength to that of a longer wavelength. An intrinsic feature of FRED essential to modeling fluorescence is that wavelengths are assigned to rays on an individual basis. When coupled with the flexibility of FRED 's scripted scatter model feature, the path to a practical simulation of fluorescence becomes evident. Given a particular emission spectra, a scripted scatter model can be constructed that reassigns ray wavelengths by interpreting the emission curve in terms of probability.

在圖 14 中，爲微粒流經毛細管時經過雷射的照明光路的特寫。模擬中的關鍵成分將被 FRED 定義此微粒的螢光發光特性。此螢光發光的物理過程涉及波長轉換爲較長波長的光線。在 FRED 本身在模擬螢光的基本特色爲將波長分配在個別的根據成分。當結合 FRED 散射模型特色的 Script 靈敏性，獲使實際上模擬的螢光光路變的顯著。接著可獲得一特殊的激發光頻譜，當重置一波長光源時，Script 散射模型能被以機率論所得的激發曲線去建立出。

For the purposes of this example, particles in this simulation will be given the fluorescent properties of Rhodamine 6G, a widely used organic dye. The emission spectra[4,5] of R6G is shown in Figure 15. The resident digitizer in FRED lends itself quite nicely to generating a dataset from this graphic. That dataset becomes a part of a compiled Enable Basic routine resident in a Scripted Scatter Model. As a result, this fluorescence routine has no adverse impact on simulation time.

此範例的目的，微粒在此模擬中將被施以一廣泛使用的有機 Rhodamine 6G 的螢光特性。此 R6G 的激發頻譜如圖 15 所示。FRED 本身的數位化轉換器能給予其相當良好圖形數據集的產生。此數據集將變成能在 Scripted Scatter Model 中能被使用的一部分。因而這種螢光程式，對模擬時間不會有甚麼不良影響。

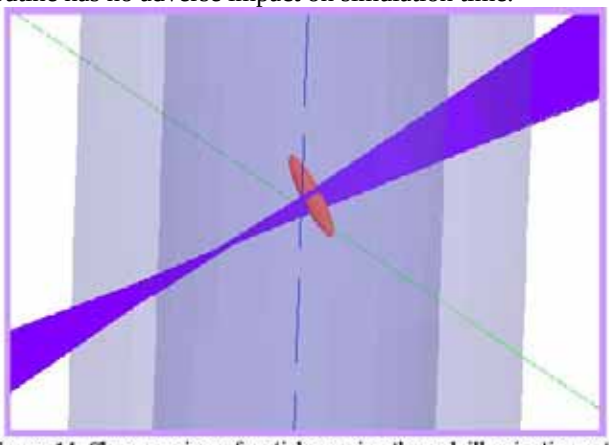


Figure 14. Close-up view of particle passing through illumination path.

圖 14. 粒子通過照明區域的放大圖

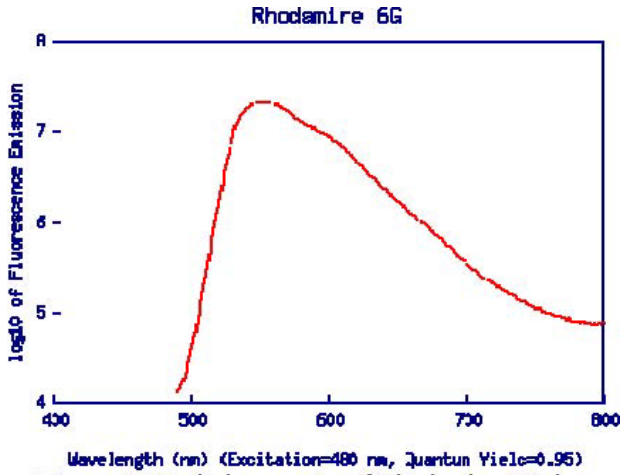


Figure 15. Emission spectra of Rhodamine 6G dye.

圖 15. Rhodamine 6G染料發射光譜

An essential ingredient in any simulation involving scatter is raytrace efficiency. Since valuable resources would be wasted tracing rays into the entire hemisphere, the ability to direct the fluorescence only towards the collection mirror and lens can translate into significant time savings. The Importance Sampling feature in FRED serves precisely this function. The dialog box shown in Figure 16 illustrates how easily this feature is implemented. Importance Sampling is implemented from the Scatter tab in the "Fluorescing Particle" Edit/View dialog as shown on the left in Figure 16. The Importance Sampling Specification on the right specifies that scattering occurs "toward an entity" which is selected from a dropdown menu containing all FRED entities

在模擬中的重要成分包涵光追跡的散射效率。由於有近整個半球在光追跡後的資料將被浪費所以將其顯示螢光發光的方向僅朝向收集的鏡子與透鏡的部份以節省運算時間。在 FRED 中重點取樣的特色用以提供一精確的性能。其對話視窗如圖 16 所示，爲說明如何輕易的執行此特色功能。重點取樣可由 Scatter 目錄選項的 Edit/View 對話視窗中執行"螢光激發的微粒"，如圖 16 左。重點取樣的規格在其右詳述散射的生成"朝向一實體"，在如圖 16 由的清單所提供的所有 FRED 的實體。

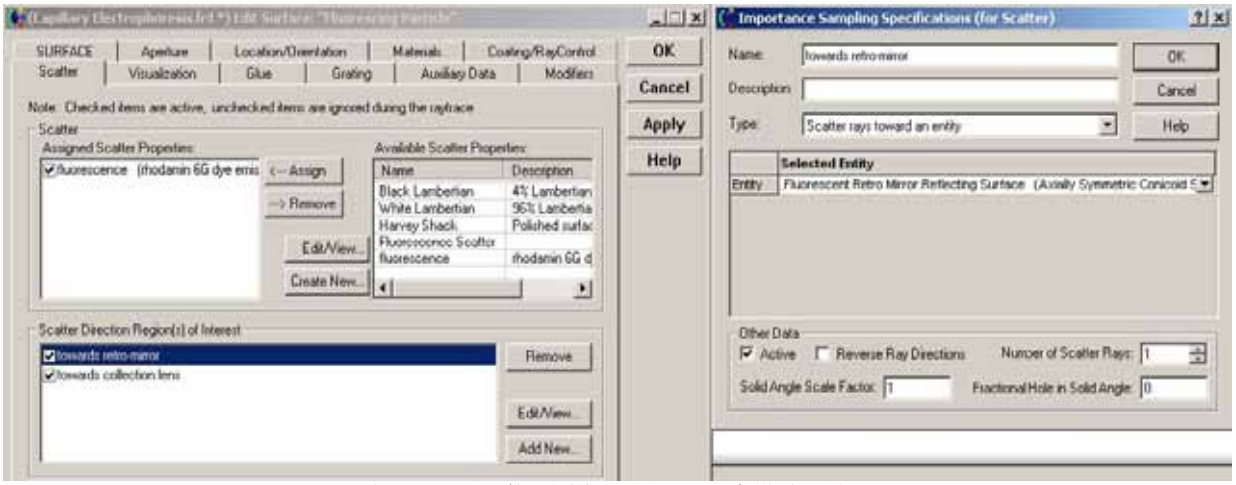


圖 16. 重要性取樣法：對於一實體之散射

A graphical representation of the complete simulation is shown below in Figure 17. Purple represents the illuminating path while the orange maps the fluorescence. While the ray colors shown here are approximate, it is possible with the Color Image feature in FRED to display the source and fluorescence colors in standard RGB representation.

圖17是完整模擬的圖示。紫色代表照明路徑，而橙色代表螢光。雖然這裡都以近似的方式來表現光線的顏色，我們也可以使用FRED的Color Image特色，以RGB標準表示法來顯示光源以及螢光的顏色。

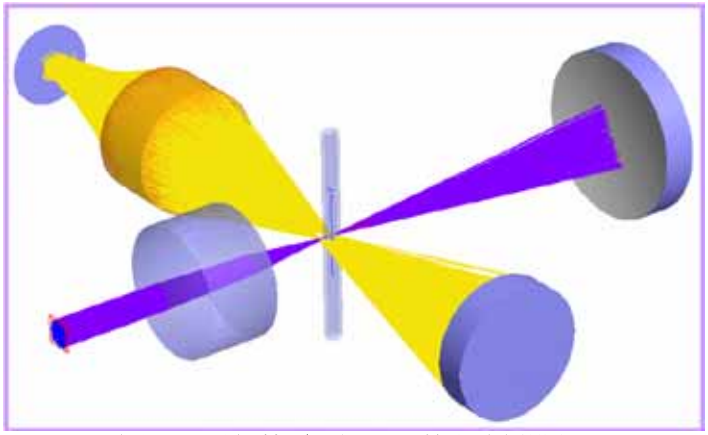


圖 17. 毛細管電泳照明及螢光路徑模擬.

Figure 18 shows RGB and chromaticity charts for the laser source (top) and the fluorescence captured by the collection optics (bottom).

圖表18顯示雷射光源(上圖)，以及由收集器所收集螢光(下圖)的RGB和色度圖。

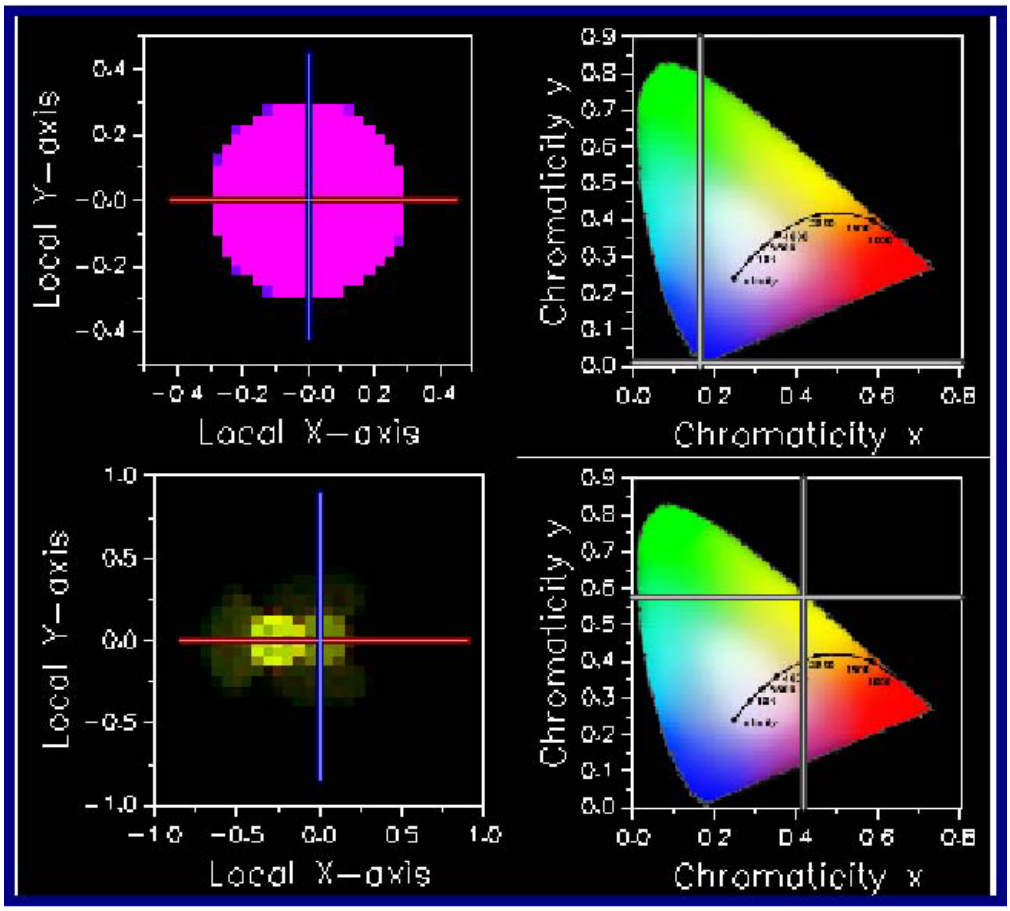


Figure 18. Color Image (RGB) representation of source and fluorescence.
圖 18. 光源及螢光的彩色影像(RGB)表示法

1 Graphic obtained from http://omlc.ogi.edu/
2 R. F. Kubin and A. N. Fletcher, "Fluorescence quantum yields of some rhodamine dyes.," *J. Luminescence*, 27, 455-462, 1982

Biomedical Optics Example 3: Human Skin Model
生醫光學元件 範例 3：人體皮膚模型

Human skin models are valuable aids in the design of non-invasive diagnostic devices such as the oximeter as well as in the development of modern dermatological instruments. With the release of version 6.20, FRED now offers the Henyey-Greenstein volume scatter model recognized by the biomedical community as being representative of scattering in human tissue. There are numerous sources for the parameters associated with this model, namely an anisotropy factor ***g*** and the scattering and absorption coefficients μ_s and μ_a. In FRED, this volume scatter model is applied through a material definition shown in the dialog boxes shown here in Figure 19. Once such materials are defined, they can be assigned to various interfaces in a geometric model by the drag&drop method.

人體皮膚模型，在設計非侵入式診斷設備，如血氧飽和度計，以及在發展現代皮膚科儀器上，是極具價值的輔助設備。隨著 6.20 版本的發行，現在 FRED 提供 Henyey–Greenstein 體散射模型，此爲生物醫學界所認可，作爲人體組織散射代表的散射模型。有許多來源可以找到此模型的相關參數，即是說一個異性因子 ***g*** 和散射和吸收係數 μ_s 以及 μ_a。在 FRED 中，這個體散射模型的應用，是經由圖 19 所顯示對話視窗中材質的定義來施行。一旦定義了材質，他們可以用拖曳/施放的方法。將其指定到不同幾何模型的界面。

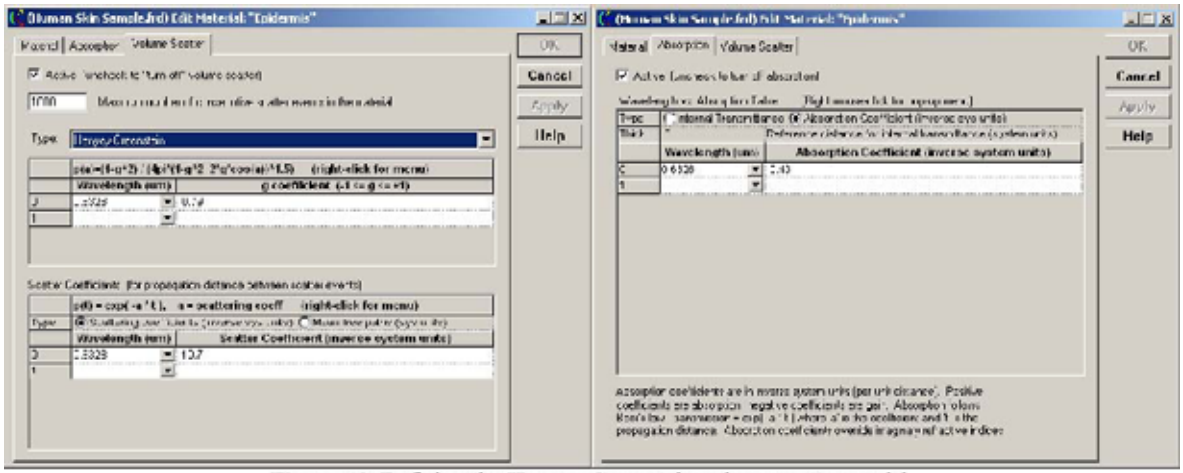


Figure 19. Defining the Henyey-Greenstein volume scatter model.

圖 19. Henyey-Greenstein體散射模型之定義

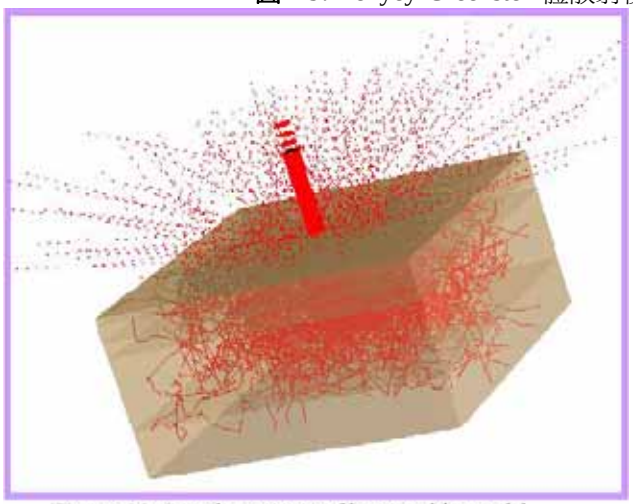


Figure 20. Sample raytrace of human skin model.

圖 20. 人體皮膚模型之樣本描光

FRED features pertinent to biomedical applications:

- Surface, Volume and user-defined Light Sources
- Lens, Mirrors, Prisms and Materials catalogs
- Surface Scatter
- Henyey-Greenstein Volume Scatter model
- Fluorescence simulation
- Importance Sampling
- Multi-threaded non-Sequential Raytracing
- Analysis Tools
- Graphic Visualization
-

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

與生物醫學應用相關的特性

- 面、體，以及使用者自訂的光源
- 透鏡、鏡面，稜鏡以及材質資料庫
- 面散射
- Henyey-Greenstein體散射模型
- 螢光模擬
- 多重非序列式描光
- 分析工具
- 視覺化圖像

如同這些生醫範例所顯現的，FRED 具有關鍵性和動態視覺顯現的建模能力、分析和圖形顯示能力。如果你有任何問題關於 FRED 的建模能力、分析你的生醫光學系統，請直接以電話或電子郵件跟我們聯絡。