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<td>Citation</td>
<td>Shinoj, V. K., Murukeshan, V. M., Baskaran, M., &amp; Aung, T. (2014). Note: A gel based imaging technique of the iridocorneal angle for evaluation of angle-closure glaucoma. Review of Scientific Instruments, 85(6), 066105-.</td>
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<td>Date</td>
<td>2014</td>
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Note: A gel based imaging technique of the iridocorneal angle for evaluation of angle-closure glaucoma

V. K. Shinoj, V. M. Murukeshan, M. Baskaran, and T. Aung

Citation: Review of Scientific Instruments 85, 066105 (2014); doi: 10.1063/1.4882335
View online: http://dx.doi.org/10.1063/1.4882335
View Table of Contents: http://scitation.aip.org/content/aip/journal/rsi/85/6?ver=pdfcov
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Noninvasive medical imaging techniques have high potential in the field of ocular imaging research. Angle closure glaucoma is a major disease causing blindness and a possible way of detection is the examination of the anterior chamber angle in eyes. Here, a simple optical method for the evaluation of angle-closure glaucoma is proposed and illustrated. The light propagation from the region associated with the iridocorneal angle to the exterior of eye is considered analytically. The design of the gel assisted probe prototype is carried out and the imaging of iridocorneal angle is performed on an eye model. © 2014 AIP Publishing LLC [http://dx.doi.org/10.1063/1.4882335]
The variations in the real and imaginary part of $\theta_3$ are plotted using Eq. (3) for various incident angles (40°–90°) and outside medium indices ($n_3$). The obtained result is shown in Figure 2. In order to have a good view of the trabecular meshwork region, the incident angle is estimated to be within 50°–65° using Snell’s law. When the outside medium index is air ($n_3 = 1$) or media with indices close to one, the transmitted angle ($\theta_3$) becomes imaginary as depicted in Figure 2. In this case, the complex angle represents the existence of total internal reflection (TIR) at the cornea-air interface. This obstructs the lateral view of iridocorneal angle region. By changing the outside medium index ($n_3$), the TIR can be avoided. Therefore, to have a clear view of TM region, the immediate media outside the corneal region has to be tailored. Different ocular gel media are available in the market that can be used to track light from the ICA region back to the exterior of the corneal region. In order to avoid further TIR at the gel-air interface, the angle of incidence at this interface has to be minimized. In this viewpoint, we propose an objective lens based probe configuration as shown in Figure 3 where a mirror is employed at the distal end to alter the angle of incidence at the gel-air interface.

A schematic of the proposed configuration is shown in Figure 3(a). The imaging of opposite iridocorneal angle is performed on an ocular eye model (OEM-7; Ocular Instruments Inc., Bellevue, WA) without and with gel. The photograph of eye model is given in Figure 3(b). The eye model includes natural surfaces of human eye including anterior chamber and crystalline lens. A fiber-optic broadband light source is collimated and redirected to illuminate the iridocorneal region. The light reflected from the ICA region is collected through an objective lens and directed to a CCD camera (PL-A741; PixeLINK, Ottawa, Canada). A long working distance (20 mm), infinity-corrected objective lens (Mitutoyo; 20X, 0.4NA) is employed in this study.

The photograph of distal end is given in Figure 3(c). A mirror is used to redirect the beam to the objective lens. The mirror can be rotated to have a clear view of the ICA region.

FIG. 1. Schematic diagram showing light transmission from the region of iridocorneal angle to the exterior of eye.

FIG. 2. The variations in the (a) real and (b) imaginary part of $\theta_3$ are plotted using Eq. (3) for various incident angles ($\theta_1$) and at various filling material indices.

FIG. 3. (a) Schematic of the proposed experimental setup, (b) photograph of Ocular Imaging Eye Model (OEMI-7), and (c) photograph of the distal end of the proposed system.
The imaging of the region is performed without gel at different objective planes and the obtained result is shown in Figures 4(a)–4(d). It shows that the ICA region view is restricted due to the total internal reflection at the cornea-air interface as expected from the analytical results (Figure 2). A sterile coupling gel (Vidisic gel; Mann, Germany), of refractive index 1.338, was applied to a glass cover slip and pressed to the coupling gel (Vidisic gel; Mann, Germany), of refractive index 1.338, was applied to a glass cover slip and pressed to the gel-filled coupling medium is formed as shown in Figure 3. This would minimize reflection of light by refractive index matching, thereby optimizing light transmission. In this scheme, the angle of incidence at the gel-air interface is a minimum such that light can be guided to the camera through the objective lens. The results obtained in the presence of gel are shown in Figures 4(e)–4(h). These figures were taken at objective planes corresponding to those in Figures 4(a)–4(d), respectively. The width of the iridocorneal angle region is indicated using arrows, between the margin of cornea and base of iris.

An optical method to examine the iridocorneal angle region that will be promising in the evaluation of angle-closure glaucoma is proposed and illustrated. The light transmission from the anterior chamber to the exterior of eye is analytically considered using Snell’s law. Based on this, an experimental probe system is developed for imaging the iridocorneal angle region. The images saved into the computer allow the clinicians to evaluate and compare the changes in angle if such examinations are to be done over a period of time which would be particularly advantageous in tracking both disease progression as well as treatment effects.

The authors acknowledge the financial support received through NMRC (NIG09nov001) and A*Star-SERC (Grant No. 112 148 0003). The authors also acknowledge the facilities provided through COLE, NTU.