The Unique Optical System of the LENSAR Laser System

The technology behind Augmented Reality imaging and how it benefits laser cataract surgery.

This is the third in a series of articles on the LENSAR Laser System based on videos produced on behalf of LENSAR, Inc. Videos relating to this series may be found on Eyetube.net or by following the QR code at the right. This installment describes why Stephen Klyce, PhD, believes the LENSAR Laser System's proprietary Augmented Reality imaging system provides superior clinical benefits to surgeons than traditional imaging systems.

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The imaging system is one of the cornerstones upon which all surgical lasers are built. In the new field of laser cataract surgery, most femtosecond lasers are designed around an imaging system that uses optical coherence tomography (OCT). One of the most significant ways in which the LENSAR Laser System (LENSAR, Inc.) differentiates itself from other femtosecond lasers designed for cataract surgery is its proprietary Augmented Reality 3-D imaging system.

THE DIFFERENCE BETWEEN AUGMENTED REALITY IMAGING AND TRADITIONAL OCT

Laser imaging systems that are designed around OCT generally have very high spatial resolution. However, there are two technical issues that can lead to error in femtosecond laser spot placement with these devices: spatial image distortion and sparse data. Because of the scanning method used by OCT, a raw image must be corrected for geometric warping and for refractive distortions.[1] In addition, only one or two image planes of the eye's anterior segment are processed, which requires extensive extrapolation to obtain an estimate of the lens' surface position (Figure 1). Uncertainty in anterior segment biometry may lead to an incomplete capsulotomy or capsular rupture during fragmentation.

The LENSAR Laser System uses a proprietary imaging technology called *Augmented Reality*, which was originally designed for use in computer-assisted robotic surgery (Da Vinci; Intuitive Surgical). Similar to the camera used in magnetic resonance imaging, the LENSAR Laser features a rotating camera that takes images from up to eight positions and from two angles around the eye's optical axis. It is the only femtosecond laser for cataract surgery with this unique rotating camera.

The LENSAR Augmented Reality imaging system circumvents the uncertainty of the OCT approach through the use of automatic optical calibration and by using the same optical pathway for both the treatment beam and the imaging beam. The system applies optical ray-tracing and uses biometric data from 16 cross-sectional images in order to create a 3-D model of the eye. The quality of this 3-D image is enhanced using variable-rate scanning—faster scanning over highly reflective interfaces, such as the corneal surface, and slower scanning in the region of the posterior capsule. This strategy provides exceptional contrast to digitally capture all the relevant structures in the anterior segment. These data provide corneal thickness, anterior chamber depth, the curvature radii for both the anterior and posterior cornea as well as for the anterior and posterior lens capsules, and the lens thickness. The LENSAR Laser's imaging system captures

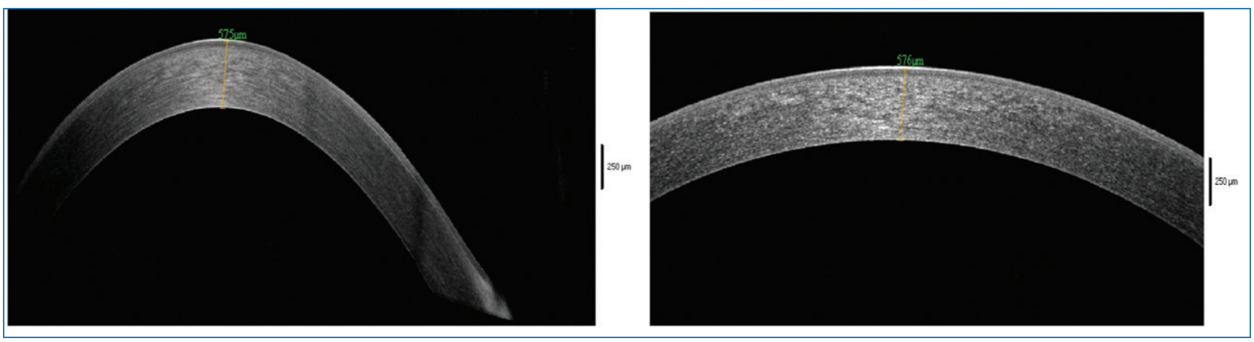

Figure 1. A distorted raw OCT image (A) of the central cornea compared to a calibrated version of the same image (B). Calibration accounts for the refractive properties across the cornea. Resolution in itself is insufficient for imaging.

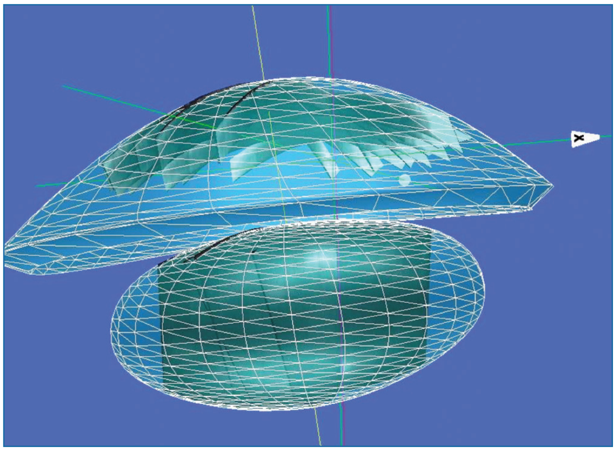

Figure 2. The LENSAR Laser's lens tilt compensation feature ensures that the treatment pattern (represented by the dark area within the lens) fits within the capsular bag without encroaching on the capsule if the lens is tilted from the optical axis.

these data from multiple angles, which gives it the unique capability to determine the degree of tilt of the lens (if any) from the optical axis. The laser is able to compensate for lens tilt during treatment (Figure 2) to help ensure capsulotomies that are free floating and perfectly formed nearly 100% of the time,[2] which in turn contributes to a more consistent effective IOL position.

The Augmented Reality technology uses superluminescent diode (SLD) illumination (Figure 3) and Scheimpflug imaging, which provide both high resolution and an enhanced depth of field. Together, the SLD and Scheimpflug imaging help generate a sharply focused image from the anterior corneal surface to the posterior lens capsule. This highly accurate image clearly shows surgeons the anatomy of the cataractous lens, regardless of the density. Thus, surgeons are able to characterize and grade the density of a cataract before entering the eye. Then, they can select the appropriate lens fragmentation pattern that will optimize the amount of energy the laser uses to emulsify the cataract. This is how the LENSAR Laser helps surgeons reduce the total amount of phaco energy used in the eye for minimally invasive, atraumatic surgery.

Finally, before corneal incisions are made, the cornea is imaged again to account for any inadvertent slight movement of the eye during the capsulotomy and fragmentation steps, thereby ensuring precise placement of the incisions.

ASSISTED SURGICAL PLANNING

The benefits of the LENSAR Laser do not stop with its unique imaging system, however. The laser's software continues to use the patient-specific ocular biometry

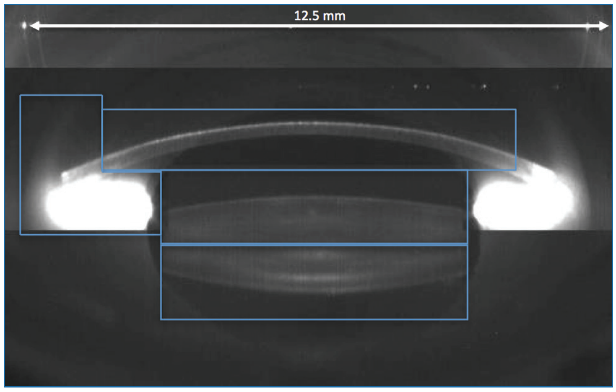

Figure 3. The Augmented Reality system uses a scanning super luminescent diode to expose the image of the anterior eye. The scan rate varies over different regions of the image.

gathered from the Augmented Reality system in its treatment algorithm, which may be further customized with the surgeon's preferred parameters. The treatment algorithm includes the surgeon's preferred incision site, the amount of lens tilt, the density of the nucleus, the surgeon's chosen fragmentation pattern, and the IOL to be implanted. Using the laser's intuitive user interface, the surgeon may also choose where to center the anterior capsulotomy—over the center of the pupil or over the optical axis of the crystalline lens—to further maximize the effective lens position.

Adding these parameters to the surgical plan does not add time to the procedure for the patient, however, because many of these surgeon preferences can be preprogrammed into the laser's software prior to treatment sessions. Thus, surgeons can commence treating the patient soon after completing the imaging step, because very little additional input is required. Some of the configurations that can be preprogrammed include the laser's height and the temporal or superior orientation between the surgeon and patient.

Advanced surgical imaging combined with laser surgery opens new avenues for more efficacious and less traumatic techniques for cataract surgery. Fidelity in biometry is a hallmark of Augmented Reality imaging—the result is unparalleled accuracy in femtosecond laser surgery. ■

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1. Westphal V, Rollins A, Radhakrishnan S, Izatt J. Correction of geometric and refractive image distortions in optical coherence tomography applying Fermat's principle. *Opt Express.* 2002;10:397-404.
2. Data on file, LENSAR, Inc.