

# LASER ARCS FOR ASTIGMATIC CORRECTION

The approaches of five femtosecond laser systems.

## Femto LDV

BY NIRAJ DESAI, MD



The Femto LDV Z6 (Ziemer Ophthalmic Systems) can create clear corneal and arcuate incisions, LASIK flaps, a variety of lamellar cuts, and pockets for corneal inlays and intracorneal ring segments. Not yet approved by the FDA, the Femto LDV Z8 laser will also be capable of phacofragmentation and capsulotomy. Notably, the imaging for and planning of arcuate incisions with the Z8 will differ from what is described herein, because the newer device should employ live optical coherence tomography guidance via clever integration within the existing handpiece mounted on an articulating arm.

## PROGRAMMING

Arcuate incisions—both limbal relaxing incisions (LRIs) and astigmatic keratotomies—can be performed with or without the clear corneal incisions as a part of laser cataract surgery. Both penetrating and intrastromal arcuate incisions are possible. In addition, the Z6 can create up to three individual arcuate incisions in addition to asymmetric arcuate incisions, should there be a clinical need for them.

The programming of the arcuate incisions is fairly straightforward and is guided by a graphical user interface (Figure 1). For a demonstration by Dr. Desai, watch the video at [Eyetube.net/?v=upali](http://Eyetube.net/?v=upali).

The user interface allows the surgeon to customize several dimensions of the arcuate incisions, including

- span (measured in degrees)
- diameter up to 10 mm (LRI vs astigmatic keratotomy)
- anterior and posterior depth (allowing for a penetrating or intrastromal design)
- energy modulation (higher energy for scarred corneas)

## PERFORMING THE INCISIONS

In order to accurately place the arcuate incisions, prior to applying the handheld patient interface, the surgeon pre-operatively marks the cornea at the horizontal axes while the patient is seated upright. Intraoperatively, the surgeon

marks the central cornea under the microscope to help achieve centration of the paired arcuate incisions around the chosen center. After the patient interface (Figure 2) is applied and suction is achieved, aligning the horizontal marks ensures that the arcuate incisions are in the appropriate axis. The Z6 laser handpiece uses applanation, so arcuate incisions are placed perpendicular to the corneal surface.

A live camera image visible on the system's large screen shows the location of the incisions relative to the limbus and pupil. The incisions can be rotated, but the diameter or depth cannot be changed in the live image view; the surgeon can change them by going back in the planning



Figure 1. Arcuate incision screen.



Figure 2. Patient interface and handpiece. To see the system in action, watch the video at [Eyetube.net/?v=olegi](http://Eyetube.net/?v=olegi).

process. Because optical coherence tomography imaging is not integrated in the Z6, the depth of the LRIs must be planned beforehand with the aid of pachymetry.

## CONCLUSION

The mobile Femto LDV Z6 platform uses low energy (nJ range), a high pulse repetition rate, and a short pulse width to achieve small, overlapping laser spots, resulting in consistent cuts and low energy delivery to the tissue. Clinically, I find this translates to a reduced opaque bubble layer and that it largely maintains corneal transparency around and under the cuts. Of note, when paired with clear corneal incisions, the arcuate cuts are made first, followed by the more peripheral clear corneal incisions. Overlap of the clear corneal incisions and arcuate cuts is not possible, which prevents the dissection of tissue between the two cuts that might result in suboptimal architecture.

## LenSx Laser

BY CATHLEEN M. McCABE, MD



Treating astigmatism at the time of cataract surgery can be challenging. Every step that can be controlled more precisely has the potential to improve visual acuity outcomes and patients' satisfaction. The LenSx Laser (Alcon) has enabled me to plan and create arcuate incisions with a precision I could not achieve manually.

## PROGRAMMING

The LenSx Laser is a part of a cataract refractive suite that assists with planning and executing astigmatic correction. The Verion Image Guided System (Alcon) begins with a preoperative image and data acquisition station. I use this device to measure dynamic keratometry, the position and diameter of the limbus, white-to-white horizontal distance, pupillometry, the corneal reflex position, and the location of the visual axis. This information, along with the measured biometric data from the Lenstar LS900 (Haag-Streit; these data can be directly uploaded) or IOLMaster (Carl Zeiss Meditec), is then compiled in the patient reference unit. The reference unit software allows me to combine different ways of treating astigmatism. I can alter the location of the corneal incision, manipulate limbal relaxing incisions (LRIs), add a toric IOL to minimize residual astigmatism, and make adjustments for ocular anatomy and/or my surgical preferences. A sliding bar adjusts the treatment from just LRIs to full toric IOL treatment or a combination of both (Figures 1 and 2). In my experience, this powerful preoperative planning tool continues to become

**“Every step that can be controlled more precisely ... [can] improve outcomes.”**  
—Cathleen M. McCabe, MD

even more accurate as I complete the feedback loop by entering patients' postoperative refractive data. The software uses these data to refine nomograms and improve outcomes over time.

After preoperative planning, the next step is to mark the eye to account for cyclorotation when the patient lies flat under the laser. Prior to using the Verion system, I would mark the limbus at the slit lamp with the slit beam placed horizontally. I would apply marker ink to the tip of a cystotome and mark the limbus at 3 and 9 o'clock. This technique left a small ink mark that lasted for days or sometimes a week. I marked the location for toric IOL alignment in a similar fashion by rotating the slit beam to the appropriate axis on the axis gauge attached to the slit lamp. This method worked well and resulted in very small and accurately placed ink marks, but it was also very time consuming and interrupted patient flow on a surgery day.

With the Verion digital marker system, the “marks” are placed preoperatively in the clinic and do not interrupt



Figure 1. Sliding bar for astigmatic correction on the Verion Image Guidance System Reference Unit.

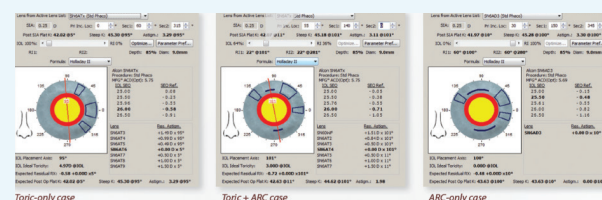


Figure 2. Three different plans for correcting astigmatism using the Verion Image Guidance software: toric only (left), toric and LRIs (middle), LRIs only (right).

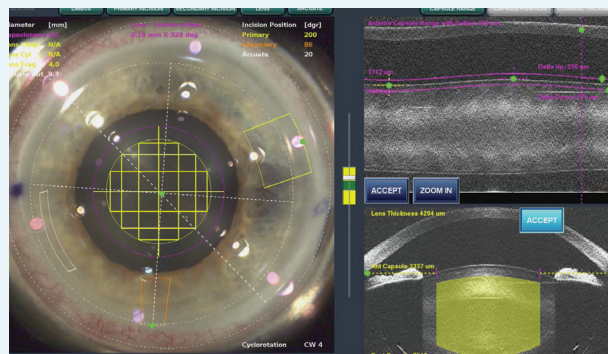


Figure 3. LenSx live optical coherence tomography image and surgical plan.



Figure 4. Slit-lamp image of a corneal arcuate incision created with the LenSx Laser.



Figure 5. Slit-lamp image of a corneal arcuate incision created with the LenSx Laser.

the flow at all. I then use the digital preoperative image to account for cyclorotation by registering this image to the predock image with the patient positioned under the LenSx Laser. Next, the predock image is registered to the docked image, and the surgical plan is automatically cyclorotated to match the position of the eye. The new 2.6 software allows side-by-side comparison of these images so that limbal vessel and iris features may be assessed, which reassures me that precise registration has been achieved.

Once the patient is docked and the image is registered, the LenSx software snaps the laser surgical plan in place. The corneal incisions, LRIs, capsulorhexis, and fragmentation pattern are populated and can be easily and quickly altered if I wish. In patients with a history of prior LASIK, for example, I like to move the LRIs peripherally so that they do not penetrate the corneal flap. This change is easy to accomplish; I just move the LRIs on the surgical planning screen of the laser system after docking (Figure 3).

## PERFORMING THE INCISIONS

The SoftFit patient interface offers the stability of a solid interface, which reduces the “noise” created by the patient’s small movements, without the distortion of corneal architecture (folds) seen with a completely rigid interface.<sup>1</sup> A live optical coherence tomography image provides real-time calculations of percentage depth, corneal thickness, and the length and position of corneal arcuate incisions. My usual settings are for a corneal arcuate incision with a 9-mm diameter at 85% depth. I find that the variable beam profile of the LenSx Laser optimizes cutting in different tissues. The numerical aperture adjusts to a wide beam profile for efficient and precise cutting through corneal tissue. The corneal arcuate incisions are readily identified and elegant in their precision when viewed with the slit lamp (Figures 4 and 5), and I can easily open them with a Sinskey hook to enhance flattening of the steep meridian if I note an undercorrection postoperatively. The effect of opening these incisions depends on how peripherally they are located and the length of the arc; longer arcs and a more central location have a greater flattening effect when opened. With intraoperative aberrometry, I can measure the effect of opening the LRIs in real time in the OR, and I have used this method for intraoperative fine-tuning.

## CONCLUSION

Using a femtosecond laser allows me to better control variables and to more precisely and reproducibly correct my patients’ astigmatism. I look forward to even greater integration of planning, guidance, and intraoperative aberrometry data as these systems evolve.

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## Catalys

BY SHACHAR TAUBER, MD



The incisional management of astigmatism at the time of cataract surgery is highly dependent on accurate keratometry, appropriate marking, and reproducible incisions. Each step carries challenges that the Catalys femtosecond laser (Abbott Medical Optics) helps ophthalmologists to address.

### PROGRAMMING

Some surgeons are gifted in their ability to make incisions manually, but for others, including myself, the ability to make a square-edged, perfectly constructed incision each time is a great advantage. The Catalys system allows the user to customize every aspect of incisions, including optical zone diameter, depth, length, and angle. Arcuate incisions (AIs) can be paired or single; anterior, penetrating, or intrastromal; and based on the pupil's center or limbus. Alternatively, the position may be customized based upon a particular topography. The laser provides real-time pachymetry, so incisions are always created at the programmed depth and dimensions, making it much easier for me to consistently produce the desired refractive results for my patients.

I usually make intrastromal paired arcs at an 8-mm optical zone and centered on the limbus. I set the laser to create the intrastromal incisions at a depth of 20% below the epithelium to 20% above the endothelium.

For me, the ability to perform intrastromal AIs rather than anterior penetrating incisions is a major clinical advantage. Because they are less invasive than penetrating incisions, intrastromal AIs are more comfortable for patients and minimize the risk of infection. Intrastromal AIs allow me to make tiny, nonrefractive laser marks to guide positioning of a toric IOL. I recently began using intrastromal AIs to manage postkeratoplasty astigmatism. Transplant patients who are not good candidates for penetrating incisions due to ocular surface or other corneal disease can now enjoy better vision with this approach.

I feel fortunate to have access to well-developed nomograms for the Catalys laser, including an intrastromal AI nomogram from Julian Stevens, MRCP, FRCS, FRCOphth, that takes into account total corneal power, corneal cylinder, the angle of the steep meridian, and the patient's age (available online at [www.femtoemulsification.com](http://www.femtoemulsification.com)).

### PERFORMING THE INCISIONS

To my mind, high-quality, three-dimensional optical coherence tomography (OCT) imaging and the use of that imaging to guide the automated placement of incisions,

capsulotomy, and lens are one of the most appealing aspects of this laser. Accurate identification of the epithelium and endothelium, for example, helps prevent an accidental penetration of either the anterior or posterior cornea.

Real-time, streaming OCT that was introduced as part of the latest software upgrade (cOS3) provides an even better view, allowing me to see the effects of corneal incisions as they occur. Most importantly, it is now easier for me to detect movement of the patient's eye (Figure 1) and to reposition the incisions back to the intended meridian if necessary. OCT scans during incision confirmation refresh at a rapid rate of 0.5 to 2 Hz.

In addition to the image processing speed, treatment time is also faster, but I recommend not worrying about the "shot clock" with this laser. Certainly, I always want surgery to be efficient, but I have the luxury with the Catalys system of being able to take time if needed to re-image or reposition planned incisions. Because its liquid optics interface is

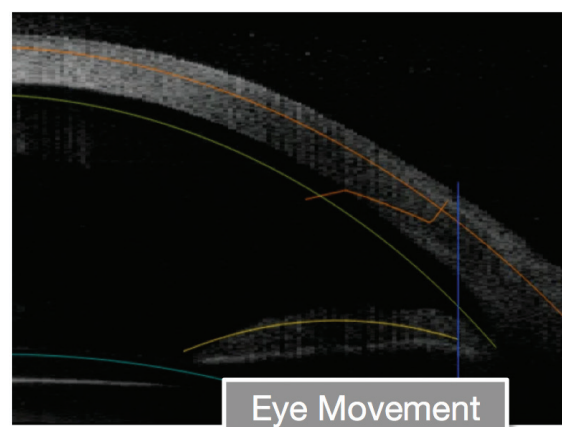
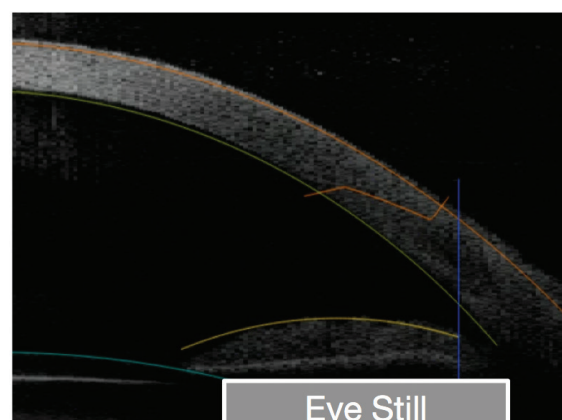


Figure 1. Slight movements can affect incisional accuracy. With streaming OCT, surgeons can easily visualize and reconfirm the correct position during the laser procedure.

nonapplanating and increases IOP by only about 10 mm Hg during docking, I do not feel concerned about the amount of time that the patient is under the laser.

## CONCLUSION

As the Catalys laser system evolves, I look forward to the next iteration of the software, with features that further streamline and enhance the precision of astigmatic ALs.

## Lensar Laser System

BY DENISE VISCO, MD



Astigmatism is common among patients undergoing refractive cataract surgery. Some studies have estimated the incidence of preoperative astigmatism to be nearly 87%, with 22% of these patients having 1.25 D or more.<sup>1</sup> Uncorrected astigmatism, no matter the degree, decreases patients' UCVA and can considerably affect their quality of life.<sup>2</sup>

Correcting cylinder at the time of cataract surgery is therefore to their benefit.

Although some surgeons use manual techniques such as limbal relaxing incisions to correct astigmatism, others such as myself find the procedure to be cumbersome and inaccurate. Incisions made manually with preset blades risk corneal perforation, can have variable results, and may create irregular astigmatism. Conversely, arcuate incisions made with a femtosecond laser allow for the precise and reproducible correction of corneal astigmatism at the time of cataract surgery.

## PROGRAMMING

### Lens Management

The Lensar Laser System's recently approved Streamline features (Lensar) can be generalized into two categories: lens management and astigmatism management. In order to facilitate precise laser delivery, the device's cataract density imaging system uses augmented reality technology to collect a range of biometric data. The platform uses this information to create a sophisticated three-dimensional reconstruction of the actual anatomy of the patient's eye, thus enabling the precise placement of laser pulses. These biometric data are measured in the x-, y-, and z-axes, and the unique lens tilt detection feature determines and corrects for even the smallest amount of lens tilt from the optical axis.<sup>3</sup> The Streamline features automatically determine the density of the cataract and categorize it on a scale of one to four. Then, automatic fragmentation patterns of the lens and nucleus are recommended based on preprogrammed, surgeon-customized patterns (Figure 1).

### Astigmatism Management

Through the use of fully automated, wireless technology and iris registration, the Lensar System with Streamline offers remarkably accurate and precise arcuate incision planning. The depth of the incision is uniform for its entire length, something that is impossible to attain through manual manipulations.<sup>4,5</sup>

Streamline allows me to enter a customized and preprogrammed nomogram based on my preferences that both

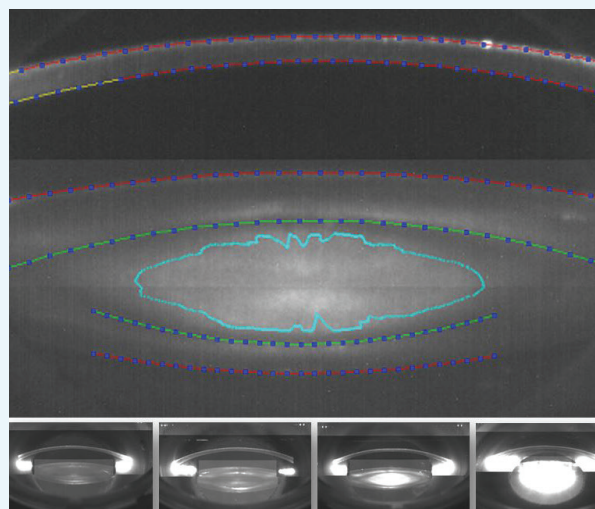


Figure 1. The cataract density imaging virtually partitions the lens to analyze nuclear and epinuclear density.

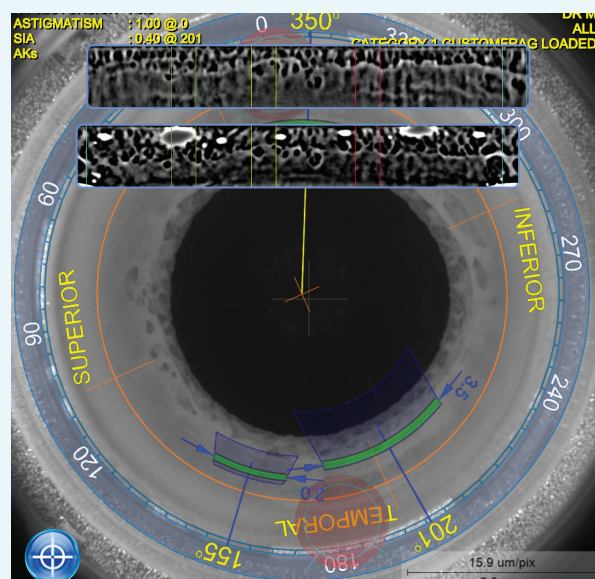


Figure 2. Iris registration matches features of the pre- and intraoperative images to compensate for cyclotorsion and accurately place arcuate incisions, thus eliminating the surgeon's need to mark the eye.



## AT A GLANCE

- The mobile Femto LDV Z6 platform uses low energy, a high pulse repetition rate, and a short pulse width to achieve consistent cuts and low energy delivery to the tissue.
- The LenSx Laser is a part of a cataract refractive suite that assists with planning and executing astigmatic correction.
- High-quality, three-dimensional optical coherence tomography imaging and the use of that imaging to guide the automated placement of incisions, capsulotomy, and lens are an appealing aspect of the Catalys laser.
- The Lensar Laser System's recently approved Streamline upgrade features true iris registration and customized nomogram programming to automate precise astigmatic correction.
- The Victus Femtosecond Laser Platform allows live-action, optical coherence tomography-guided planning of up to two independently configurable arcuate incisions.

saves time and eliminates the possibility of transcription errors. Based on the patient's biometric measurement and my preferred treatment parameters, the system automatically generates incision specifications for depth, length, and location, which, in my experience, greatly improves the accuracy of astigmatic correction. Furthermore, I find that being able to modify the nomogram to account for surgically induced astigmatism increases the precision of the applied treatment.

### PERFORMING THE INCISIONS

Through wireless integration with the Cassini (i-Optics), Streamline offers iris registration based on iris features rather than limbal blood vessels. In my experience, the result is improved axial alignment in astigmatic treatment. Iris images taken while the eye is docked on the Lensar Laser are compared and confirmed with images taken at point of capture on the Cassini to ensure the accurate placement of corneal incisions, with the system automatically compensating for cyclorotation. I no longer need to mark the eye preoperatively (Figure 2).

Before creating the incisions, the eye is rescanned to account for any hydration changes or movement. Small movements in fixation can occur with all laser platforms

during capsulotomy and fragmentation, which are performed prior to astigmatic treatment with the Lensar Laser System. I find that a repeat scan—just before incision placement—increases the effectiveness of the laser's performance.

### CONCLUSION

As they evolve, femtosecond lasers will allow surgeons to correct increasingly smaller amounts of astigmatism with greater accuracy. Essentially, this technology decreases guesswork, reduces the chance of error, and augments precision to improve the refractive results of astigmatism management.

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5. Teuma EV, Bott S, Edelhauser HF. Sealability of ultrashort-pulse laser and manually generated full-thickness clear corneal incisions. *J Cataract Refract Surg*. 2014;40(3):460-468.

## Victus

BY JEFFREY WHITMAN, MD



I find that several unique features of the Victus Femtosecond Laser Platform (Bausch + Lomb) deliver outstanding precision, efficiency, and results.

### PROGRAMMING

An advanced swept-source optical coherence tomography (OCT) imaging system provides high-resolution, live-action imaging of the entire procedure, allowing me to predefine all aspects of arcuate incisions in real time. Compared with conventional time-domain detection techniques, this technology offers faster imaging and greater sensitivity with an unprecedented responsive video frame rate. I can use this feature to determine the placement of corneal incisions, measure corneal thickness, and customize the arc length and diameter as well as the incision angle, depth, or depth ratio. The high-resolution imaging of the swept-source OCT permits automatic recognition of all relevant eye structures to facilitate treatment planning and execution, thereby reducing overall treatment times (Figure 1).

The device allows live-action, OCT-guided planning of up to two arcuate incisions independently configurable in terms of diameter, depth, position, and size. For symmetric arcuate incisions, if I enter incision 1 values, the incision 2 values change accordingly. To achieve an asymmetric approach, I set values for incision 1 and then change the values for incision 2.



## PERFORMING THE INCISIONS

High-contrast detail and clarity via OCT allow for real-time, image-guided adjustments of diameter, pachymetry, and depth ratio nonstop throughout treatment. With the pachymetry tool, I can use either a predefined arcuate incision depth or the magnified cross-sectional scan to measure total corneal pachymetry and cut to a defined depth percentage. I can also use this tool to change the depth ratio intraoperatively (Figure 2).

The unique docking system of the Victus maintains a liquid layer for the capsulotomy and nuclear fragmentation but converts to a full-contact interface for corneal applications to optimize stability and precision. When the arcuate incisions are being made, OCT aligns to the axis of the incisions' placement, allowing me to verify full corneal contact at the axis of treatment and to visualize the real-time creation of each incision. This feature is vital, because all corneal cutting

depths are based on the known location of the patient interface.

Advanced docking technology minimizes the possibility of eye tilt or distortion. The unique curved patient interface has a separate suction clip designed to fit most eyes without distorting the cornea. This is important, because corneal distortion or parallax can result in misplaced arcuate incisions. In my experience, the initiation of suction is precise, and pupillary alignment and tilt adjustment are easy. When the laser assembly docks, intelligent pressure sensors monitor the pressure between the docking device and the eye. A graphic display shows the symmetrical radial pressure, while the graphical user interface shows the vertical pressure. Using this three-dimensional pressure evaluation, I can center and stabilize the eye and select the optimal, procedure-specific downward pressure on the cornea. I also have the ability to compensate for cyclotorsion that may occur as the patient moves from a seated to a supine position or during the docking process.

I place the cursor over the arcuate incisions to rotate them into alignment with the steep axis. In cases where the white-to-white measurement mandates a larger or smaller diameter, I can independently change the position diameter intraoperatively. ■

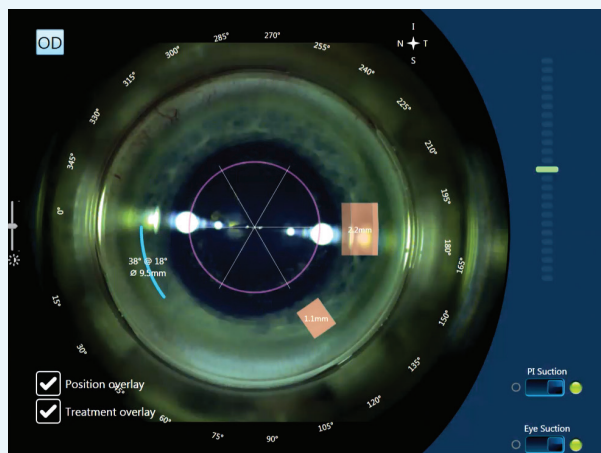


Figure 1. Arcuate incision (in blue) with width and optical zone notation.

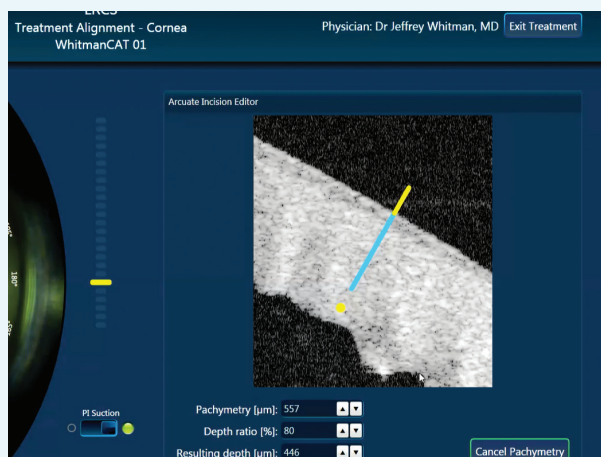


Figure 2. Swept-source OCT image of planned arcuate incision with notation of pachymetry and depth set at 80%.

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