Refractive Laser Systems and Recent Upgrades

Each laser listing includes information on recent upgrades and new technologies available.

COMPILED FROM INFORMATION PROVIDED BY INDUSTRY REPRESENTATIVES

STAR S4 IR

Advanced Medical Optics, Inc. (Santa Ana, California)

New methods for treating visual aberrations with laser vision correction have reduced complications, and many problems may now be corrected without additional treatment. Custom wavefront-guided procedures have significantly contributed to success rates. Custom wavefront-guided surgery allows for more precise detailed treatment planning and gives surgeons superior precision when treating patients' unique aberrations.

Rated the most effective advanced laser treatment available by a Marketscope 2006 Annual Refractive Surgeon Survey, the Advanced CustomVue procedure, delivered on the Star S4 IR excimer laser system (Figure 1), provides surgeons with the flexibility and ability to customize treatment for individual patients.

Courtesy of Advanced Medical Optics, Inc.

Figure 1. A surgeon performs refractive surgery with the Star S4 IR.

Highest resolution, superior accuracy. The Star S4 IR excimer laser system is the first US Food and Drug Administration (FDA)-approved, fully automated, noncontact method of alignment for the Advanced CustomVue treatment to the corneal site. The Advanced CustomVue procedure is driven by the WaveScan WaveFront System, which allows physicians to customize treatment for each individual, according to the unique characteristics of the patient's eye. Leveraging the Fourier algorithm, unique to Advanced Medical Optics, Inc., the Advanced CustomVue treatment delivers the highest available resolution of the wavefront error by using 100% of available Hartmann-Shack data points. This method can accurately reconstruct the wavefront error for up to a 7-mm pupil.

Leveraging advancements like iris registration (IR), Fourier algorithms, and ActiveTrak technology to ensure precise ablation, the Advanced CustomVue procedure has earned a broad range of wavefront-guided approvals.

The IR feature of the Star S4 IR is a fully automated noncontact method of aligning and registering wavefront-guided corrections for the Advanced CustomVue procedure. It centers and aligns the treatment, independent of pupil centroid shift, reducing the impact of cyclotorsional movement and provides precise ablation placement. By linking a patient's diagnostic information with the treatment itself, IR provides accurate align-

ment and placement.

The Star S4 IR excimer laser system features variable spot scanning technology and the variable repetition rate pulse-packing proprietary algorithm—another feature unique to Advanced Medical Optics, Inc. Variable spot scanning produces variable beam sizes from 0.65 mm to 6.5 mm, while the variable repetition rate algorithm varies the laser's repetition rate from 6 Hz to 20 Hz. By continually changing the size and placement of the laser beam, the Star S4 IR laser delivers Fourier shapes in optimal ablation time. This capability reduces thermal effects on the cornea and allows surgeons to perform the procedure quickly to maximize patient safety.

Additionally, the system uses ActiveTrak three-dimensional active eye tracking with automatic centering—the first FDA-approved tracker in the industry to track x, y, and z eye movements. These features enable accurate delivery of the Advanced CustomVue procedure, the only FDA-approved custom wavefront-guided treatment for individuals with high myopia of up to -11.00 D of sphere and up to 3.00 D of cylinder.

Maximum benefit for patients and surgeons. Using the Star S4 IR, surgeons can deliver the broadest range of wavefront-guided treatments to patients. Outside of the United States, 99.75% of the population are potential candidates for the Advanced CustomVue procedure. The Star S4 IR does not require pharmacological dilation. It tracks on the natural pupil, and the accurate iris alignment matches the wavefront image with the cornea at the point of treatment. The system conserves tissue by optimizing treatment times and minimizing thermal effects on the cornea. Patients benefit from safe and precise individualized procedures, and surgeons can deliver corrections with greater flexibility and accuracy. Because the system is easy to use, doctors can maximize practice efficiency and workflows.

Advanced Medical Optics, Inc., is uniquely positioned to provide the broadest range of wavefront-guided treatments. The company also now offers a femtosecond laser option with the IntraLase system. With comprehensive physician support and customer service, Advanced Medical Optics, Inc., provides the complete refractive solution.

For more information, call +1 800 246 VISX, or visit www.VISE.com or www.amo-inc.com.

LADARVISION SYSTEM

Alcon Laboratories, Inc. (Fort Worth, Texas)

The LadarVision System (Figure 2) is the most advanced laser vision correction platform available today, consisting of the Ladar6000 Excimer Laser and the LadarWave Aberrometer. In October 2002, the LadarVision System became the first laser platform to gain FDA approval for wavefront-guided ablations. It remains the only system with an FDA-approved claim that its tracking device improves the accuracy of corneal shaping. Wavefront-guided custom procedures allow you to measure and treat aberrations throughout the optical system. Some aberrations, specifically higher-order aberrations, went undetected and untreated with conventional correction methods. Now, you can treat factors relating to both quantity and quality of vision. Providing patients with the benefits of truly customized vision correction calls for the precision capture, match, and treat technology that only the LadarVision System provides.

Our wavefront device—the LadarWave—detects, measures, and displays optical characteristics of the eye, allowing for a better understanding of how to treat a patient with complete customization. The LadarWave device creates the wavefront map that serves as a guide for a patient's treatment, and it lays the groundwork for registration, an essential prerequisite of truly customized vision correction.

Courtesy of Alcon Laboratories, Inc.

Figure 2. The LadarVision System.

Our tracking device is the only one with an FDA claim stating that it improves the accuracy of corneal shaping. It provides the industry's only space-stabilized image to maintain registration and alignment throughout the customized ablation procedure.

The Ladar6000 Excimer Laser provides more surgeon control for improved overall system performance, patient flow, and consistency. A new illumination system provides excellent visibility.

The LadarVision System was the first eye surgery system that the FDA approved for wavefront-guided customized ablation. Offering patients true custom eyes requires the precision capture, match, and treat technology only the LadarVision System delivers.

Capture. The LadarWave CustomCornea Wavefront device sends low-energy laser light into the dilated eye. The light reflects off of the retina and enters the device, which measures both lower- and higher-order aberrations. The LadarWave device takes five wavefront measurements and automatically chooses the best three to create a composite wavefront map.

Match. The wavefront data are then transferred to the Ladar6000 Excimer Laser, the first FDA-approved system using wavefront data to guide the laser treatment. The LadarTracker tracking system engages, creating a space-stabilized image for precise alignment and treatment. The wavefront map is computer matched to the centration photo and prepared for automatic registration with the excimer laser.

Treat. Automatic registration and closed-loop tracking help ensure that the ablation is delivered to the proper location on the eye. The 0.8-mm Gaussian small-spot beam works within the parameters of the ablation profile to address higher- and lower-order aberrations and create a smooth corneal surface. Only the LadarVision System captures a unique wavefront map, computer matches this data to the eye's position, and maintains precise alignment throughout the treatment. This process addresses both lower- and higher-order aberrations, improving the quantity and the quality of the patient's vision.

Alcon Laboratories, Inc. provides not only the technology, but also leading-edge business support to grow your practice and take maximum advantage of the opportunities that fully customized procedures provide. For more information, visit www.alcon.com.

ZYOPTIX 217z100

Bausch & Lomb (Rochester, New York)

This laser's (Figure 3) technically advanced features and optimized performance have been widely recognized by European refractive surgeons. The system represents a new standard for delivering exceptional outcomes in personalized treatments. Combined with the Zyoptix diagnostic workstation, the laser provides unparalleled benefits to both the surgeon and patient for preoperative information, treatment options, and enhanced safety features.

Laser features. The Zyoptix 217z100 laser encompasses key refinements and features that enhance predictability, accuracy, and safety including (1) IR technology, (2) a state-of-the-art, multidimensional, dynamic eye-tracking system, and (3) a higher frequency laser source.

The IR feature was designed with patient safety in mind. A map of the entire iris is created to form a unique patient identification file that is stored with the patient's treatment data. This ensures that the right patient and correct eye are treated by identifying the patient treatment file based on his/her iris. IR will also serve as the basis for the new Advanced Control Eyetracking (ACE) upgrade, which will be available later this year. Zyoptix ACE is designed to further improve the accuracy and predictability of outcomes, compensating for intraoperative eye movement. Zyoptix ACE features include:

- Dynamic compensation for intraoperative cyclotorsion;
- Adjustment for static cyclotorsion between upright diagnoses versus supine treatment position;
- Four-dimensional tracking (ie, x, y, z, rotation) with a sampling rate of 240 Hz and response time of 6.6 ms; and
- Compensation for pupil shift in cases where pharmacologic dilation may be required.

The Zyoptix 217z100 laser has a 100-Hz laser source, allowing for treatment twice as fast as the previous system. Additionally, refined algorithms reduce overall treatment times by 50%, decreasing flap-open time and minimizing variability due to the effects of dehydration of the stromal bed.

Diagnostics. The Zyoptix diagnostic workstation is intrinsically linked with the laser system. Corneal topography and wavefront analysis are combined in this modular workstation, featuring the Orbscan IIz Corneal Topographer with Zywave Wavefront Analyzer. The latest-generation Zyoptix Advanced Personalized Technologies (APT) speeds the diagnostic process, enabling faster and easier data transfer and processing with a tenfold increase in data storage. The main elements to Zyoptix APT include the following: (1) no-dilation Zyoptix (NoDiZy) is an advanced algorithm that eliminates the need to pharmacologically dilate pupils in the majority of personalized treatments. This reduces preoperative work-up for same-day procedures, allowing more efficient patient throughput. (2) The Zyoptix Advanced Nomogram creates a personalized nomogram based on each patient's higher-order aberrations to improve the predictability of visual outcomes. Application of this nomogram has shown 96.4% of patients achieving a predictability of outcome within ±0.50 D.[1] (3) Zyoptix treatment calculator software standardizes the transition zone for more predictable outcomes and allows surgeons to compare and select either personalized, aspheric, or tissue-saving treatment options. (4) The proprietary Zyoptix TruLink customer network support system allows direct transfer of diagnostic data from the diagnostic workstation to the Zyoptix 217z100 laser with a simplified software user interface, easier acquisition, and storage. (5) TruLink also optimizes system

Courtesy of Bausch & Lomb

Figure 3. The Zyoptix 217z100.

functionality through remote monitoring, proactive service maintenance, and the option for data back-up.

Zyoptix treatments options. Three treatment options are available with the Zyoptix platform. (1) Zyoptix Personalized: This option combines wavefront and topography data, providing individualized treatment plans that take into account existing higher-order aberrations as well as compensate for surgically induced aberrations. This option uses iris recognition technology for accurate treatment placement. (2) Zyoptix Aspheric: The second treatment is based on topography data and generates a treatment profile designed to preserve the natural asphericity of the cornea. Clinical data showed a 77% reduction in surgically induced spherical aberration, resulting in better visual outcomes versus standard LASIK. (3) The last option is Zyoptix Tissue Saving, which produces a treatment profile that removes approximately 15% less tissue than Planoscan treatments. This treatment type is particularly beneficial in patients with thin corneas or mixed astigmatism.

In summary, the Zyoptix 217z100 Laser System combines advanced diagnostic instruments and software with a high-tech laser to offer surgeons a comprehensive range of treatments, and most importantly, exceptional visual outcomes to patients. For more information, visit www.bausch.com.

MEL 80

Carl Zeiss Meditec AG (Jena, Germany)

For each step in the refractive laser surgery workflow, Carl Zeiss Meditec provides best-of-class technology, from diagnostics to treatment planning and from flap creation to the actual refractive correction.

Customized vision correction. In late 2005, a new version of our CRS-Master, a third-generation system for customized refractive treatments, was launched. The CRS-Master plans individually optimized excimer laser treatments in connection with the MEL 80 excimer laser (Figure 4). Integrated diagnostics help to achieve optimal treatment planning. At the same time, measurement data, from which the CRS-Master creates a complete treatment program for the MEL 80, is delivered.

Features like the (1) OcuLign eye registration for perfect treatment positioning and (2) topography-guided treatment options, which incorporate several new approaches for the correction of complex corneal irregularities, set a new standard in customized vision correction.

Now, topography-guided treatments address symptoms caused by corneal irregularities in an even more targeted manner, especially zone enlargements and decentration corrections after previous refractive surgery.

Courtesy of Carl Zeiss Meditec AG

Figure 4. The MEL 80 excimer laser.

Follow-ups after corneal transplantation and therapeutic applications are also addressed.

One unique feature is a completely new algorithm that yields an automatic detection of the visual axis, including compensation for the angle kappa.

OcuLign eye registration is another innovation of the new CRS-Master. From diagnosis to calculation and treatment, the exact positioning on the eye remains consistent. Before surgery, the MEL 80 automatically detects anatomical reference points and iris structures of the patient's eye and precisely directs the treatment to the source of the measurement data. Eye rotation or change in pupil size between measurement and treatment will, thus, not affect the result.

The new version of the CRS-Master has been well received by the market, and the majority of MEL 80 customers opt for the CRS-Master as well.

MEL 80 features. The MEL 80 laser features prolate optimization. Aberration-optimized algorithms accurately calculate how much energy is needed to create a precise aspheric ablation. It uses an exceptionally small spot (0.7 mm) Gaussian beam profile to produce high-quality corneal ablations—precise and even—while protecting the surrounding tissue. This beam profile results in a smoother surface for improved patient comfort and better visual outcomes. Additionally, the MEL 80 uses a thermally optimized laser firing pattern to protect the stroma despite the high ablation speed.

Closed-loop energy control system. This safety features ensures that the amount of energy in each pulse of the laser has been calibrated to exactly the right level—so the energy level you initially calibrate is the same energy level that reaches the patient's eyes.

Atmospheric control. The CCA plus plume evacuation system reduces the incidence of beam masking, therefore ensuring accurate ablation. It also protects the surgeon and staff.

Courtesy of Carl Zeiss Meditec AG

Figure 5. The VisuMax femtosecond laser.

In August 2006, the US FDA approved the MEL 80 excimer laser for myopic corrections. Outcomes like 41% of patients seeing better than 20/12.5 uncorrected underline the superior performance of the MEL 80. We have already entered the next study phases to expand the range of approved indications in the United States.

VisuMax femtosecond system. Parallel to the excimer platform's product enhancements, successful clinical testing with our VisuMax femtosecond system (Figure 5) has also occurred. With the addition of this femtosecond system, Carl Zeiss Meditec AG now provides a complete system solution for refractive laser surgery. The combination of the VisuMax femtosecond flap preparation and MEL 80 excimer treatment by a common pivoting patient bed provides an efficient clinical workflow and tangible patient comfort.

Due to the minimal gas bubble formation in the VisuMax femtosecond flap interface, there is no waiting time required for the subsequent MEL 80 eye-tracker operation. The VisuMax femtosecond laser parameters result in precise and predictable flap geometry as well as prevent light-induced side effects.

We are convinced that we are just starting to explore the potential of femtosecond lasers in corneal surgery, and we expect a rapid evolution of this technology—both in outcomes and indications. The enhancement of the clinical capabilities is one main focus of our clinical research. For more information, visit www.meditec.zeiss.com.

PULZAR Z1

CustomVis (Perth, Australia)

This solid state refractive laser (Figure 6) is designed, manufactured, marketed, and serviced by CustomVis. Most surgeons agree that solid-state is the future for refractive lasers. With approximately 10,000 eyes treated with excellent results and fast approaching 20 installations of the Pulzar Z1, we now believe there is proof that solid state is ready to replace excimer lasers in the refractive laser surgery industry.

The Pulzar Z1 has a 213-nm wavelength generated by transmitting the 1,064-nm Nd:YAG laser beam through three nonlinear crystals. The 213-nm wavelength is advantageous because (1) the ablation rate is less dependent on tissue hydration, (2) it produces clean and smooth ablated surfaces, (3) reduces the thermal effect and collateral damage, and (4) is a more efficient form of tissue ablation (Figure 7).

Advantages of solid-state laser. Our Pulzar Z1 has many advantages over excimer lasers, including:

- Stable homogenous beam energy;
- Longer laser source lifetime;
- Improved reliability and efficiency;
- Low power consumption;
- Improved beam quality;
- Greater pulse-to-pulse stability;
- Extremely fast turn-on-to-ready period;
- Fewer consumables, (ie, no gas and fewer fluence plates required);
- No purchase or handling of toxic gas required;
- Long optic life (ie, fewer optic changes required over laser life); and
- Extremely fast and accurate eye tracking (1-kHz closed loop).

Eye tracking. The Pulzar Z1 features three eye-tracking technologies: (1) fast analogue limbus-based eye-tracker with a 1-kHz closed-loop response, (2) video eye tracker for extra accuracy and redundancy, and (3) video gaze tracker (GazeTrak) to check patient fixation.

Cyclorotation. Intelligent pattern recognition technique (Iris Pattern Recognition Technique [IPRT] and Limbus Registration) is used to determine the patient's cyclorotation angle.

Flying Gaussian beam spot of 0.6 mm. The Pulzar Z1 has a 0.6-mm quasi-Gaussian–shaped flying spot, which is one of the smallest and ideal spot sizes on the market in the refractive industry.

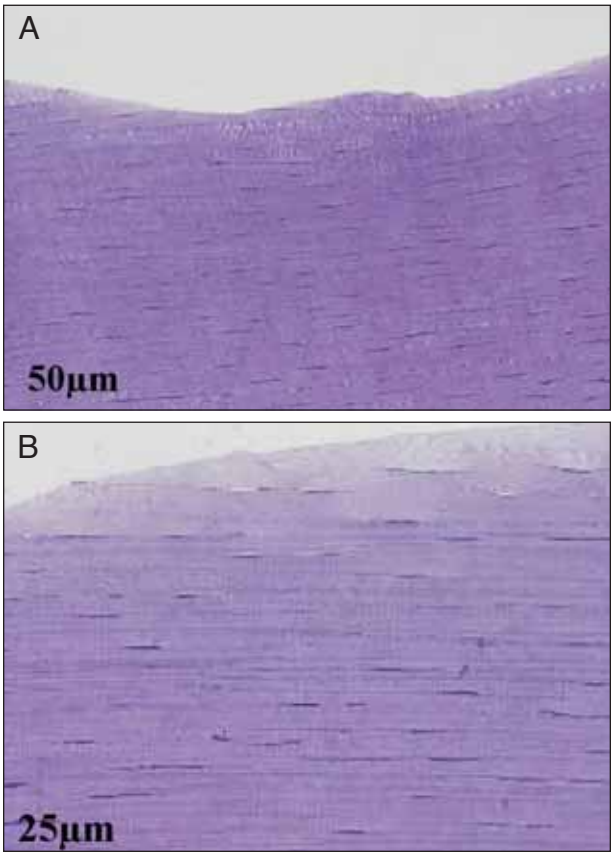
CrystalScan. The Pulzar Z1 is equipped with CrystalScan, a high-performance ultra-fast solid-state scanning technology.

Hinge protection. This available special feature may be programmed to protect

Courtesy of CustomVis

Figure 6. Pulzar Z1 is a solid-state refractive laser.

Courtesy of CustomVis



Figures 7A and 7B. Note the smooth ablation surface and no thermal damage with the Pulzar Z1 at both 50 µm (7A) and 25 µm (7B).

the hinge in LASIK or Epi-LASIK treatments.

Autocentration and autocalibration. The laser's software provides an automated beam-centration procedure that automatically checks and corrects for laser misalignment. The system calibration is an automated procedure that ensures accuracy of the system's laser output and automatically adjusts the internal operating parameters.

Freedom to select the treatment center. The Pulzar Z1 allows the surgeon to select the treatment center (ie, pupil center, corneal vertex, other locations deemed appropriate) for standard treatments according to their preference.

Customized treatments. Zcad Treatment is an intelligent surgical planning system used to create a unique treatment plan for each eye. The Zcad has special features that include topography-guided or combined topography- and wavefront-guided treatments, optical zones from 2 mm to 9 mm for sphere and cylinder available for all treatment types, and flexibility for fine adjustments in refraction in 0.01-D steps. Another feature is corneal asphericity customization. Pulzar standard treatments are designed to maintain the preoperative asphericity of the cornea.

The Zcad system provides the flexibility to select the postoperative corneal asphericity. Custom treatments take a corneal topography scale parameter that weighs the influence of the topography on the treatment plan from zero (topography is used only for preoperative keratometry and vertex position) to one (full topography-based plan). Furthermore, surgeons may program treatments in any cylinder notation, because the software automatically converts it into the most tissue-saving ablation pattern. The depth offset feature allows surgeons to save tissue or ablate additional tissue, if the need arises (eg, PTK treatments).

Tracey and CustomVis Pulzar Z1. iTrace visual function analyzers (Figure 8) have been specifically configured to export iris/limbus reference images, topography, and wavefront aberrometry data to the Zcad surgical planning software. The Tracey Visual Function Analyzer uses a fundamental thin beam principle of optical ray tracing and combines it with the EyeSys corneal topography.

iTrace can:

- Rapidly measure one point at a time, to avoid overlapping or data confusion;
- Project 256 points into a pupil between 2 mm and 8 mm;
- Obtain a high dynamic range (-15.00 D to 15.00 D);
- Measure light rays going into the eye;
- Detect the retinal location of each thin beam going into the eye to generate a true retinal spot pattern;
- Separate corneal aberrations from lens aberrations using the ability to register with corneal topography;
- Measure more highly aberrated eyes;
- Provide true correspondence of wavefront map to corneal position; and
- Take an IR reference image at the same time as wavefront.

Courtesy of CustomVis

Figure 8. The iTrace visual function analyzer.

LASERSOFT

Katana International AG (Teltow, Germany)

The LaserSoft system (Figure 9) is an all-solid-state system that shares only a few basic principles with the excimer laser systems. Currently, LaserSoft presents several significant examples of technical evolution in refractive surgery and offers innovative technology to benefit the patient and the operating physician.

Features. Lasersoft is a nanosecond-pulse, Q-switched, diode-pumped laser with a repetition rate of 2 kHz. A sequential optical frequency conversion with nonlinear crystals shifts the wavelength of the laser radiation to nanometers (range, 208-210). The laser radiation is emitted as a fundamental Gaussian beam. Because the infrared laser resonator generates the Gaussian distribution—and is not altered by nonlinear conversion processes—no additional beam-forming elements are necessary, as in an excimer laser. The measured shot-to-shot stability is 1.4% (root mean square) in the deep ultraviolet; this high precision is due to the continuous wave pumping with laser diodes at the beginning of the conversion chain. The peak fluence of this spot is 350 mJ/cm^2, resulting in the maximum ablation rate for cornea-specific absorption. In contrast to excimer lasers, the LaserSoft solid-state laser has no gas discharge, circumventing the instabilities in output radiation that are related to the stochastic nature of the discharge process. The solid-state approach reduces the requirements for maintenance costs, providing high stability and a long lifetime.

Small scanning spot of 0.2 mm. This allows complex ablation profiles and corrections of the finest corneal irregularities, which enables accurate flap positioning. The majority of excimer lasers available on the market feature a 1-mm flying spot; the smallest is 0.65 mm, compared with LaserSoft's 0.2 mm.

Gaussian profile/beam. The Gaussian intensity distribution of the beam is maintained up to the target plane, where it has a 0.25-mm beam diameter. A Gaussian intensity distribution on the cornea yields the possibility of overlapping the single-ablation spots to a cumulative ablation profile, which is smoother than the ones generated by spots with a flat-top profile.

High repetition rate up to 2000 Hz. Due to the high repetition rate, the energy per pulse is lower than in standard excimer treatments, therefore, ablation generates greatly reduced shock waves. Additionally, clinical results showed that the temperature rise in the stroma is low (eg, 0.8° vs 7° with other lasers), which we believe is the reason that we have not observed any haze with patients treated at this point.

There is no audible sound due to ablation or laser discharge. This silent environment is reassuring to the patient and reduces the risk of noise-induced abrupt motions.

Courtesy of Katana International AG

Figure 9. The Katana LaserSoft system shares a few basic principles with the excimer laser.

Utilizing the usual excimer laser repetition rates, a 0.2-mm spot size would result in a long treatment time. To maintain this time within acceptable limits, and thanks to its technical features, the repetition rate of a solid-state laser is higher than in excimer lasers. The current scheme of LaserSoft can be easily extended to a repetition rate of 3 kHz, and possibly to 5 kHz, with some more promising engineering advances on the horizon.

210-nm wavelength. Water and balanced saline solution absorb the wavelength of 210 nm Ca—seven times less than the 193 nm used by excimer lasers. This means that the fluid on the corneal stroma has little or no effect on the LaserSoft ablation rate, thus increasing accuracy and protecting the remaining tissue. Changes of the ambient humidity do not affect the ablation rate.

Eye tracking. To fully exploit the opportunities provided by custom ablation, the LaserSoft's fast laser needs to be coupled with a fast eye tracker. The LaserSoft eye tracker is not video based, and therefore,

does not have speed limitations imposed by frame rates of charge-coupled device cameras. Its nondigitaling continuous tracking is only limited by the large bandwidth of analog electronics (less than 0.2 ms latency, corresponding to 5-kHz repetition rate), ensuring a reliable centration of ablation for x and y directions. This fast eye-tracking system does not require pupil dilation.

Aspheric ablation profile. The current ablation profiles of the LaserSoft system are designed to (1) preserve the strongly aspheric physiological corneal curvature and (2) minimize the induced spherical aberration. Reflection losses and fluence values for angles of incidence of the ablating laser radiation are also taken into account in the ablation algorithm. The larger the treatment zone, the more elliptical the beam becomes, and the more reflection we get. This effect can be anticipated, and additional pulses are being set in the periphery. This effectively creates large optical zones and maintains the original asphericity of the cornea. To compute placement of the single laser pulses in the target plane, the measured single-shot ablation profiles are added to achieve the corresponding desired profile for correction.

LaserSoft dual. The future of LaserSoft's solid-state laser platform will combines a dual system of UV- and IR-laser microkeratome (now investigated) to improve safety, reduce the risk of blade flap-related aberrations, and allow for cost savings, compared with either individual laser system.

EC-5000CX SERIES (CX/CXII/CXIII)

Nidek Co., Ltd. (Gamagori, Japan)

The Nidek excimer laser line is designed to reshape the cornea for PRK or LASIK, to reduce or eliminate either myopia or hyperopia with or without astigmatism. The latest model, the CXIII (Figure 10), is US FDA-approved.

Features. The CXIII, one of the first slit-scanning excimer lasers, has a 200-Hz eye tracker, a plume evacuator, a three-dimensional motorized joystick—with improved illumination and aiming beams—that provides precise laser beam delivery control. The system has advanced ergonomics, with a smaller footprint and greater versatility than previous models. The personal computer unit and hardware modules of the CXIII are integrated into the main console. A new heads-up display on the arm of the laser allows the surgeon to view the patient's eye from a 7-inch monitor on the arm of the laser.

The ablation rate is 0.6 µm (60 Hz), and the laser delivery parameters are automatically calculated by entering the basic data into the system. During the ablation procedure, the personal computer unit continuously monitors the system parameters.

A custom treatment option, custom aspheric treatment zone (CATz), is available in Europe and Asia. Indications for the custom treatment are as follows: 0.50 D to -7.00 D for myopic refractive errors and 0.50 D to -4.00 D for astigmatic refractive errors. The company also anticipates FDA approval by the end of 2007 or January 1, 2008.

A new feature called *torsion error detection* is available in Europe. This feature compensates for involuntary minute rotational movements of the eye. Therefore, even if the eye moves slightly (eg, 95° off of the temporal or nasal plane), the excimer laser continues to track it as being on plane, and the laser beam stays focused on the plane of the eye without having any off-centered or off-temporal ablations.

Figure 10. The EC-5000 CX.

Nidek Co., Ltd. introduced and patented two groundbreaking methods for treating high astigmatism using the bitoric and cross-cylinder approaches that are widely recognized as optimal methods for reducing or eliminating high astigmatism with the excimer laser. The advantage of these methods includes lower tissue consumption, a more physiologic corneal topography, larger-effect optical zones, and greater postoperative stability.

Navex system. This technology is Nidek's customized refractive surgery platform. There are four parts to the Navex system: (1) NavFocus, which provides easy alignment with greater accuracy and precision, (2) NavScan, which helps create a uniform ablated surface and an optimized custom ablation with the highest precision, (3) NavWave, which uses the OPD-Scan II, OPD-Station, and FinalFit software to achieve optimal refractive treatments with greater precision, and (4) NavTome, which delivers a microsmooth operation using microkeratome technology. The OPD scan (the company's corneal topographer/wavefront aberrometer device) is linked to the EC5000, so that each patient's information may be fed into the laser. The OPD scan gives an enormous amount of information that the doctor can use to determine what the best treatment option is for the patient and know how much tissue to ablate or how much correction needs to be made on the eye.

ALLEGRETTO WAVE/ WAVE EYE-Q/CONCERTO

WaveLight AG (Erlangen, Germany)

The Allegretto Wave was the first laser platform to specifically incorporate wavefront principles. The first global wavefront-guided treatment was performed in 1999 with the Allegretto Wave; it is now the most successfully sold WaveLight laser. Additionally, it was the first European laser to receive US FDA approval, and it is the only laser available worldwide that enables Wavefront Optimized treatments.

Its 200-Hz ablation rate enables fast corrections, meaning only 4 seconds per diopter at a fully corrected 6.5-mm optical zone. The Gaussian beam profile, in combination with an ultra-thin spot size of 0.68 mm (FWHM), creates large true optical zones that result in improved night vision. With the integrated PerfectPulse Technology, every laser pulse is completely controlled from generation to the point when it contacts the cornea. This is possible through the combination of several state-of-the-art technologies including a (1) closed-loop energy control for constant laser pulse energy throughout the treatment, (2) thermally optimized ablation pattern for preventing heating effects on the cornea, (3) advanced spot scanning eye tracker for smoothest surface quality, and (4) systematic peripheral pulse placement.

The advanced NeuroTrack feature ensures active optokinetic eye tracking to control cyclotorsion. NeuroTrack forces the eye to stabilize the retinal image for achievement of perfect vertical and horizontal orientation. Coupled with the equilibrium sense, the vestibular ocular reflex automatically rotates the eye back to compensate for possible head rotation.

An integrated plume evacuation eliminates all fumes in the operation field and provides constant laser energy.

The Allegretto Wave's customization capabilities include Wavefront Optimized, wavefront-guided, and topography-guided treatment modules. Custom Q for asphericity-guided and presbyopia correction is available (optional upgrade).

Eye-Q. This system (Figure 11) takes the proven Allegretto Wave technology one step further. A 400-Hz ablation rate enables extremely fast corrections: 2 seconds per diopter at a fully corrected 6.5-mm optical zone. In addition to Wavefront Optimized, wavefront-guided, and topography-guided treatment capabilities, the Eye-Q features Custom Q. This technology customizes the patient's asphericity, adjusts transition and optical zones in 0.1-mm steps, and enables changes to the refraction input in 0.01-D increments. Furthermore, Custom Q provides presbyopia treatment capabilities for various vision errors, while other companies only offer presbyopia solutions for hyperopes.

Courtesy of WaveLight AG

Figure 11. The Allegretto Wave Eye-Q.

The Eye-Q's integrated cross line projector provides the surgeon with exact head and eye position alignment (ie, cyclorotational prealignment). Its target diode, which generates a red light across the patient's face, shows the right position in horizontal and vertical direction coordination with manual marks.

Concerto. The Concerto is the flagship of the WaveLight laser family. It is the first laser system to fully integrate diagnostic and treatment capabilities into one laser platform. The Concerto combines safety, perfection, quality, and individuality to achieve excellent results and the highest vision quality.

All WaveLight treatment capabilities are integrated into the Concerto's comprehensive application range. Therefore, the laser system comes with complete equipment for Wavefront Optimized, wavefront-guided, topographic, and Custom Q treatments. Its exclusivity is highlighted by a combination of the following:

- A super-fast 500-Hz repetition rate resulting in 1.6 seconds per diopter treatment times at a fully corrected 6.5-mm optical zone. The corresponding short flap opening times enable minimized dehydration, excellent visual outcomes, and fast visual recovery;
- Online pachymetry provides precise, reliable, and contactless measurement of corneal thickness before, during, and after ablation;
- An integrated spectrometer measures the changes of corneal humidity during treatment;
- The treatment, including all laser parameters and the check-up results, may be stored online for system control, perfect documentation, and advanced surgery recording;
- Its service concept includes an online link—via modem—for fastest response of WaveLight's service department and quality control of technical parameters;

- An extra visitor's monitor with integrated clinic logo for watching the treatment by relatives or guests is included;
- The touch-sensitive glass panel for laser control, the integrated keyboard, the thin-film transistor monitor for checking the system, and the integrated video system with DVD recorder for surgical documentation provide the highest level of convenience and comfort. The Concerto offers an optional swivelling patient bed; and
- The Concerto provides an operation microscope with integrated data display for a simultaneous data control and access to all relevant information during surgery.

The laser unit and peripheral equipment are available in custom-made color combinations. The customized design concept includes the design of the clinic's entrance area and the Concerto operating room, including furnishing recommendations in three-dimensional finishing for harmonizing the color selection of the Concerto with the appearance of the institution.

ESIRIS EXCIMER LASER

Schwind eye-tech-solutions (Kleinostheim, Germany)

The Esiris (Figure 12) is a state-of-the-art sixth-generation excimer laser that integrates the technologic and application know-how of Schwind eye-tech-solutions. With a repetition rate of 200 Hz and a small spot size of 0.8 mm, the Esiris provides ideal conditions for highly precise treatments. This technology also ensures optimal performance of the 330-Hz eye tracker. The device follows eye movements with a short response time (ie, a few milliseconds). In combination with the Schwind Custom Ablation Manager software (Schwind-CAM) algorithm, the para-Gaussian spot provides for a smooth corneal surface. Algorithms applied for the calculation of the shot file provide an accurate reproduction of ablation volumes. As a result of an optimized spot distribution, the ablation pattern makes mild ablation possible without imposing thermal strain on the eye.

Aspherical treatments. The Schwind-CAM software module, ORK-CAM, integrates precise aspheric ablation profiles for spherocylindrical treatments and wavefront-based corrections on a corneal and ocular basis in one platform. Therefore, the induction of spherical aberrations during treatment may be prevented and/or, in the case of customized treatments, optimized. Additionally, the ORK-CAM considers energy losses due to curvatures of the cornea and the resulting corneal deformations and biomechanical influences on the treatment. A recent multicenter study conducted by international experts reported a retreatment rate of less than 2% for the spherocylindrical aberration-free treatments with the Esiris and ORK-CAM leading to reduced working time, optimized capacity utilization, and cost reduction.

Courtesy of Schwind eye-tech-solutions

Figure 12. The Esiris sixth-generation excimer laser.

Online pachymetry: The safety factor during refractive surgery. Available as optional equipment on the Esiris, online pachymetry further increases treatment safety. With the pachymetric procedure using Optical Coherence Pachymetry (OCP), simple, exact, and non-contact measurements of central corneal thickness during the entire treatment process may be performed. All operational steps are monitored during the treatment to ensure control over the corneal biomechanics (ie, ascertainment of flap thickness and supervision of residual stroma after the cut with the microkeratome, control of laser ablation, possible biomechanical changes of corneal tissue due to compression or dehydration). These features allow intervention in the shortest possible time—if necessary—to prevent complications. The measurement results may be documented and evaluated by means of a database function. The Esiris is equipped with an additional treatment monitor that facilitates at-a-glance data checks for therapy and treatment.

The working distance between the laser's arm and patient's eye is set at 295 mm, so the user may comfortably work with the microkeratome. With the option of a swivelling bed, the Esiris is equipped for use in combination with other medical systems. Automatic calibration facilitates rapid and secure preparation of the laser for treatment; the Esiris is ready for use within 15 minutes. ■

1. MacRae S. Advanced Nomogram Study. Paper presented at the American Society of Cataract and Refractive Surgery; San Diego, California; April 28-May 2, 2007.