Adaptive Optics for Better Vision Correction

You wouldn’t use a buggy whip to improve your morning commute to the office, yet your eye doctor probably used 19th-century technology the last time you had your vision tested. Optical scientists at the University of Murcia (Spain) want to bring the measurement of eyesight correction into the 21st century with adaptive optics (AO).

OSA Fellow Pablo Artal and his colleagues have designed a binocular visual simulator that measures ocular aberrations of both eyes simultaneously (Opt. Lett. 34, 2628). The prototype uses a single wavefront sensor to assess both eyes without redundant equipment.

Traditionally, ophthalmologists and optometrists have directed their patients to look through an instrument known as a phoropter, which arranges sets of lenses in front of one eye at a time. The patient’s subjective assessment of the lenses’ effect on monocular vision tells the doctor what kind of low-order refractive error the eye has.

The phoropter can test only for basic defocus and astigmatism and ignores the binocular nature of vision, according to Artal. As the cost of spatial light modulators and other AO components has decreased, it has become more feasible to extend visual simulation to the binocular realm.

In the experimental setup, a low-power 780-nm diode laser illuminates the subject’s eyes, and reflected or backscattered light from the retinas passes through a liquid-crystal-on-silicon spatial light modulator and a Hartmann-Shack sensor. The researcher (and, perhaps someday, an optometrist or ophthalmologist) can “see” the subject’s visual acuity, as well as the incoming wavefronts from each eye, on a computer monitor.

Artal noted that the simulator uses only a single sensor and corrector but still manipulates the correction for each eye, giving binocular viewing without the need for paired optical components.

The AO system not only measures the optical aberrations of a subject’s eyes, but also simulates what the person’s vision will be like after it is corrected, according to Artal. For example, patients would find it useful to see a simulation of the likely results before having LASIK, intraocular lens implants or other permanent surgery.

“This can be very useful for patients to decide on the surgery and for doctors to customize the best procedure for a patient,” Artal said. The system could also introduce aberrations so that doctors could test for both far and near vision at simulated driving, computer and reading distances.

Unlike the phoropter, the AO visual simulator could test patients for higher-order aberrations such as spherical aberration and coma. These aberrations affect fewer people than defocus and astigmatism, but people tend to gain more spherical aberration as their eyes age, and eyeglasses don’t correct for it. In another example, people who have keratoconus, a cone-shaped deformity of the cornea, have lots of higher-order aberrations, especially coma.

The team will continue to study binocular vision in the lab, but the researchers are also interested in turning the simulator into a practical clinical instrument. They have started a small spinoff company to build a prototype for clinical trials.

— Patricia Daukantas
Scientists at Purdue University’s Center for Laser-Based Manufacturing (West Lafayette, Ind., U.S.A.) are developing a laser-based method to build longer-lasting human joint replacements. Modern hip and knee replacements typically have a titanium core coated with polymer for better biocompatibility. However, the coating degrades over time, resulting in the need for replacements every 10 to 12 years. Such surgeries are more difficult and painful when they are repeated, said Yung Shin, a mechanical engineering professor at Purdue who presented the work at the International Medical Device Expo’s Advanced Laser Applications Conference in San Jose, Calif., earlier this year.

To make an implant that more closely resembles natural bone, the researchers take ceramic powders such as the bone component hydroxyapatite, heat them with a near-infrared laser, and gradually deposit the material in thin layers on the surface of the metal substrate. Since there is no discrete boundary between layers, the process minimizes the separation problem, Shin said.

Not only can the maker build the artificial joint in a custom shape, but the composition can vary across the joint, the same way natural bone varies in composition. The new method could also slash the time for building a replacement joint from months to days.

DID YOU KNOW?

Since the advent of high-optical-quality synthetic diamonds a few years ago, researchers have been developing lasers that exploit the material’s superior properties. Now, two Australian scientists have created a diamond Raman laser with a conversion efficiency of 63.5 percent—the best yet.

“The conversion efficiency of diamond is very high at room temperature,” said Richard P. Mildren, a research fellow in photonics at Macquarie University (Sydney, New South Wales), who designed the laser with graduate student Alexander Sabella (Opt. Lett. 34, 2811). Last year, Mildren and two other investigators built the first diamond Raman laser (Opt. Express 16, 18950). However, the earlier version had only a fraction of the efficiency of other solid-state Raman lasers. The most recent diamond laser’s conversion efficiency is almost five times higher than the one in a comparable potassium gadolinium tungstate Raman laser, and the result was a laser that’s only 10 mm long, instead of many centimeters. The pump laser was a frequency-doubled Nd:YAG instrument with a pulse repetition rate of 5 kHz.

The team probably can’t boost the diamond laser’s efficiency much further, because, with a peak photon-conversion efficiency of 91 percent, the laser has almost as many photons coming in as it does going out, Mildren said. In the future, he would like to exploit diamond’s high thermal conductivity to boost the Raman laser’s average power. He will also explore extending the laser’s spectral range into the ultraviolet and infrared—regions that other Raman materials cannot access.

According to Mildren, potential applications for diamond Raman lasers may include infrared lasers for medical and surgical treatments and high-average-power lasers for industry.

Diamond Raman Lasers Gain Efficiency

Mildren and Sabella used a synthetic diamond grown by chemical vapor deposition, cut to a crystal path length of 6.7 mm. That’s seven times shorter than the one in a comparable potassium gadolinium tungstate Raman laser, and the result was a laser that’s only 10 mm long, instead of many centimeters. The pump laser was a frequency-doubled Nd:YAG instrument with a pulse repetition rate of 5 kHz.

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