How Wavefront Coding Is Revolutionizing The World Of Optics

University of Colorado

By deliberately distorting the light rays that strike an object and processing the intercepts with a special algorithm, CDM Optics creates perfectly focused images with an astounding depth of field.

If you look at the blurry image that CDM Optics' high-tech equipment produces, you might think, "Even I can take a better picture than this." But keep in mind that's only the first step. With a little electronic finessing the image is transformed into a sharply focused photograph with remarkable depth of focus — up to ten times greater than any top-ranked camera can produce.

Using innovative optics and algorithms, CDM Optics technology enhances the performance of camera systems by increasing the depth of field and correcting optical aberrations that typically occur with standard cameras. It also drastically reduces the size, weight and cost of an optical system.

Today nearly every field that relies on optics and lenses, such as astronomy, transportation, life sciences, manufacturing, shipping and distribution, security and military operations, could benefit from CDM Optics technology.

The company was founded by Thomas Cathey, a professor of electrical engineering at University of Colorado at Boulder

(CU), Edward Dowski, one of Cathey's Ph.D. students, and R.C. "Merc" Mercure, a successful entrepreneur with a doctorate in physics from CU.

The initial research and development work was conducted at CU's imaging systems laboratory in the department of electrical and computer engineering. Funding for the initial research at the University of Colorado leading to the invention of Wavefront Coding™ was provided by the National Science Foundation. startup funding leading to the commercialization of the technology at CDM Optics, Inc., was provided by Small Business Innovation Research Grants, grants from the State of Colorado and from the Department of Energy's Rocky Flats Initiative. In 2005 CDM Optics was purchased by OmniVision Technologies, Inc., a California-based company that produces image sensors for markets around the world. As its subsidiary, CDM Optics develops imaging equipment for cell phones, infrared sensors, night vision surveillance systems, iris identification systems, and biological and medical research.

How the Technology Works

Wavefront technology basically codes a stream of light by passing it through a special lens and then decodes it by signal processing, with a computer.

"We came up with the idea of deliberately distorting the light rays by passing them through a lens that's shaped like a saddle — relatively flat in the middle, but with scalloped edges," says Cathey. "The result is a specific optical aberration, which looks like a blurry image."

Although it doesn't look like it's worth 1,000 words, the picture is packed with data that can be decoded by the computer. The image is blurry because the light rays are spread out, which keeps them from being focused in a single plane. Each point of light, wherever it strikes the object, becomes a fixed point in space and a data point. Image processing then removes the blur point-by-point using an algorithm in the computer. The result is a perfectly focused image with a much greater depth of field.

"If you took a picture of a picket fence with a regular camera," says Mercure, "the first picket is in focus, the second picket is slightly out of focus, the third is blurry, etc. If you took the same picture with our equipment, those three pickets, as well as the next six or seven, will all be in focus."

There are big advantages to CDM Wavefront Coding Cameras that use Wavefront Coding won't need the extra, built-in mechanisms that correct for standard lens aberrations, or curvature changes due to changes in temperature, which means fewer lens elements, smaller size and lower manufac- turing costs.

For scientists, CDM Optics systems in microscopes will allow them to focus over a wider and deeper area. For example, researchers at the National Cancer Institute can focus on a single living cell with one image, rather than relying on multiple images that represent different cross sections through the cell. This makes it easier to track rapid changes in the cell structure and speeds up the rate of research.

Photographers will be able to take better-quality, more detailed photos because they won't have to worry about focusing precisely on a specific plane. "When people take a picture with an auto-focus camera, there is a one- or two-second delay as they wait for the camera to focus," says Mercure. "Our technology eliminates that delay and makes the camera truly a 'point and shoot.'"

Future Is Clear

Although CDM Optics is now a subsidiary of OmniVision, it continues to be part of the Boulder community and

contributes to the local economy. CDM Optics' close working relationship with researchers at the University of Colorado at Boulder have resulted in the licensing of newer and value-added technologies that are being developed by the company.

OmniVision recently released a digital camera chip for back-up and parking-assist cameras in cars and trucks — a natural application for Wavefront Coding. OmniVision and CDM Optics are also developing the next generation of machinevision devices, such as scanners.

"Because of the increased depth of field, barcode scanners using wavefront technology will be able to read labels on curved and slanted surfaces," says Dowski.

These scanners can also be used for light assembly and inspecting electronic circuits.

Iris recognition is rapidly becoming the biometric application of choice in areas where security is a top concern, such as airports, border crossings, and high-level public and private office buildings. Although it's the most accurate way to recognize an individual, the process can be very slow.

> *People often have to wait in long lines to position their eye within a small area of restricted focus. Wavefront Coding can significantly enlarge that area of focus, which makes it easier to position people for iris identification.*

"Federal agencies such as Homeland Security and the Department of Defense are looking at Wavefront Coding as a way to capture iris images at much greater distances than current technology can," says Mercure. "People may simply be able to pass through this 'space' as they walk by from five or six feet away."

Other research projects involve medical/biotech applications. Olympus Optical of Tokyo is studying CDM Optics' technology as a way to create extended-depth-offield endoscopes — instruments used for close examination inside patients' bodies. It may even be possible in the future to restore vision in the elderly using Wavefront technology.

"In this case, Wavefront Coding optics would be built into contact lenses or even surgically attached to corneal tissue," says Mercure. "This would not make everyday scenes more recognizable, but it could provide patterns of light that the brain could learn to decipher."

This story was originally published in 2007.