The day when SLM will be incorporated into contact lenses!

~A science fiction-like door to a dream future built by spatial light modulators. ~

Rapid progress has been made in optical devices, and coupled with nanotechnology, it is now possible to fabricate optical elements with microstructures smaller than the wavelength of light. With this principle in mind, Professor Yasuhiro Takaki of Tokyo University of Agriculture and Technology is conducting advanced research on human-friendly 3D displays, holographic contact lens displays, and digital holography. In this interview, we talked to Professor Takaki about his advanced holographic research using Santec's spatial light modulators.

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Professor Yasuhiro Takaki, Department of Electrical and Electronic Engineering, Tokyo University of Agriculture and Technology.

Researching an Ideal 3D Display Method Using Wavefront Regenerative Holography

When he was a student, he started with research on "computer-generated holograms," and is now mainly working on human-friendly stereoscopic displays, digital holography as a stereoscopic camera, holographic contact lens displays, and other stereoscopic displays.

There are two approaches to stereoscopic displays: "light ray reproduction type" and "wavefront reproduction type. In the ray reproduction type, the same ray of light as that emitted from an object is reproduced and appears as a three-dimensional image.

In contrast, "wavefront reproduction" holography treats light as waves.
In the wavefront reproduction type, it is said that an ideal three-dimensional image can be displayed by controlling the phase and altering the progress of the wave.

Holography can be broadly classified into two types: optical and electronic. The optical method records interference fringes of light on a film to reproduce a three-dimensional image, while the electronic method uses an electronic display device to represent interference fringes. However, when reproducing stereoscopic images electronically, an extremely high resolution of approximately 100 x 100 times the resolution of an 8K display is required.
Therefore, we are conducting research to cover the insufficient resolution by using a "Spatial Light Modulator (SLM)," which has a higher frame rate than that of ordinary displays, in a time-resolved manner.

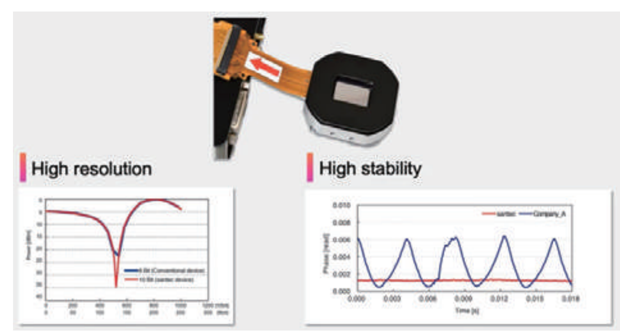
Why did Takaki Lab choose Santec's SLM?

Initially, Professor Takaki had introduced an SLM made by a German manufacturer , but when he actually used it, he found that it was difficult to handle due to issues with the linearity of the phase modulation of the light, and it was also troublesome to correct.

I happened to be interested in OCT (Optical Coherence Tomography) for another research project, and while researching wavelength tunable lasers, I came to know about Santec. Santec delivered a phase-modulated spatial light modulator "SLM-100" to the Takaki Lab, and that was the beginning of the relationship. Later, Santec also introduced the SLM-200, which has improved performance. Professor Takaki looks back 10 years ago.

This "SLM-200" uses a reflective LCOS (liquid crystal on silicon) liquid crystal as its core device, with a resolution of 1920 x 1200 dots, 10-bit (1024 gradation), and excellent phase stability of 0.001π rad.
One advantage about using Santec's SLM is that it also guarantees sufficient linearity of the phase modulation. When I asked a student to check the phase characteristics, I was surprised to find that they were perfectly linear. Another good point was the prompt response to any problems. With an overseas product, it would have taken several months to get back, during which time our research would have been interrupted.

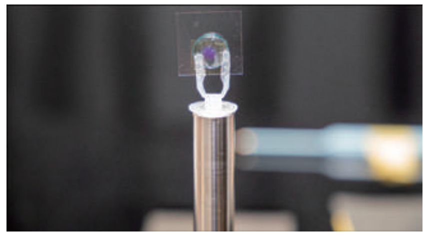
Santec's SLM-200 reflective spatial light modulator



It has a resolution of WUXGA (1920 x 1200), 10-bit (1024 shades) and excellent phase stability (0.001π rad.).

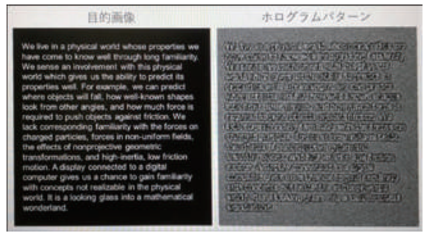
Not the World of Science Fiction! Holographic Contact Lens Displays for Human Augmentation.

Takaki Laboratory is currently using the SLM-200 for two major research projects, one of which is to create three-dimensional images by displaying computer-generated hologram patterns on the SLM. In order to create a three-dimensional image, the SLM modulates the phase, but not the amplitude, so the light is not attenuated and can be displayed brightly.



An experiment to confirm the principle of holographic contact lens display.A holographic film made of photopolymer is attached to a contact lens.

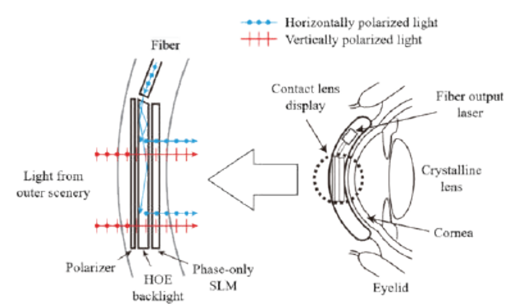
An experiment to confirm the principle of holographic contact lenses using SLM-200, displaying a three-dimensional image at a distance of 0.5 m. Characters displayed in red are lined up.



On the left is the desired image. On the right is a computed hologram pattern. When this pattern is displayed on the SLM, the desired image appears.

Professor Takaki is using this technology to develop a new "holographic contact lens display," which is attracting attention from various quarters. The SLM is mounted on contact lenses and is being used as a display device for AR, although when you think of devices for AR, you may think of head-mounted displays (HMD) such as Microsoft HoloLens 2 or Google Glass, Holographic contact lens displays have a completely different structure. (Photo left)

In conventional HMDs for AR, the display is located next to the eye, and the image is combined with the scenery of the outside world using a half-mirror or beam combiner. The holographic contact lens display has an SLM inside the lens, and the user sees the digital image and the scenery of the outside world through the SLM. the eye focuses on the 3D image by displaying a hologram pattern on the SLM. Since it is a three-dimensional display, for example, when navigating, if there are multiple intersections, it is possible to display which one it is by matching the depth of the intersection," said Professor Takaki. (Photo right)



Structure of a holographic contact lens display. Contact lenses are about 0.15 mm thick, but SLMs and polarizers can be several micrometers thick.

An image generated by hologram technology is superimposed on an actual landscape. Not only still images, but also moving images can be displayed.

＊1 Microsoft HoloLens2 is a registered trademark of Microsoft Corporation. ＊2 Google Glass is a registered trademark of Google Inc.

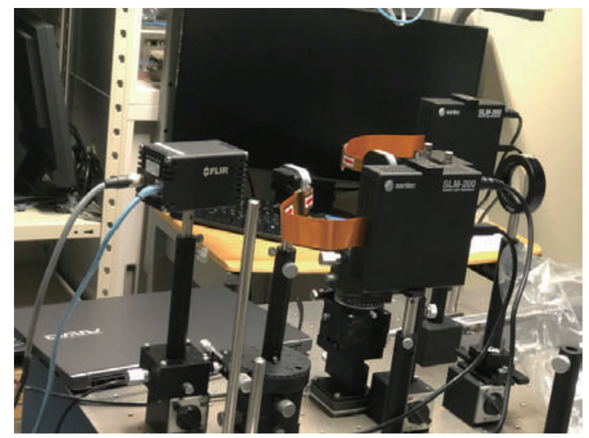
SLMs also consume very little power, as do LCDs. It would also be possible to mount a small all solid-state battery and charge the battery at night and operate without power during the day. In any case, the contact lens-type design eliminates the need to wear it on the head or restrict the field of view, as is the case with conventional AR devices.

If the entire cornea is covered with a holographic contact lens display, it will be possible to display images over the entire field of vision. Furthermore, in the future, they will be connected to computers and will be able to superimpose various digital information on the real world, contributing to the realization of a society that integrates physical and cyber space. Eventually, it may be possible to acquire the ability to expand human vision.

Some holographic TVs are close to 100% energy efficient!

Another focus of the Takaki Laboratory is to create holographic TVs with energy efficiency (diffraction efficiency) close to 100% using phase-modulated SLMs. Professor Takaki believes that this will help solve the environmental problems caused by energy consumption, which is now an issue. For holographic TV, you need to use two SLMs. Wavefront reproduction has two degrees of freedom, amplitude and phase, but if we try to realize it with only one phase distribution, we will have only one degree of freedom, which will be difficult to control. Therefore, we are currently conducting research on how to successfully control SLMs using two SLM phase distributions with a computer and an algorithm," says Professor Takaki.)

There are great expectations for glasses-free stereoscopic TVs for the home, and we are conducting our research with the hope that when stereoscopic TVs become widespread in the future, they will reduce energy use in society as a whole.



An optical system that uses two Santec SLM-200s simultaneously to control the amplitude and phase of light. This will enable the creation of holographic TVs.

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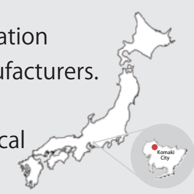
We develop, manufacture, and sell optical communication components to optical transmission equipment manufacturers.
We also provide spatial light modulators using LCOS technology to the fields of optical measurement, optical processing, and optical information processing.



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