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A New Image Signal Transfer Method using Laser in Artificial Retina

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Abstract - **A new optical link method for the retinal prosthesis is proposed. A laser diode system was chosen to transfer image into the eye and the new optical system was designed and evaluated *in silico* and *ex vivo*. The use of laser diode array in artificial retina system makes system simple by deleting signal processing part inside of the eyeball. The designed optical system is enough to focus laser beam on photodiode array in 20 × 20 application on simulation using Code V program, and about 200 ㎛ focusing of laser beam was possible on experiment with porcine eye**.

***Keywords* - vision prosthesis, artificial retina, laser diode array**

I. INTRODUCTION

The artificial retina is a kind of neural prosthesis proposed to substitute electrical circuits and electrode array for unhealthy photoreceptor cells, which convert daily light (optical signals) to electrical signals. In artificial retina system, it is necessary to transfer electrically converted visual image information to electrode array on the retina to stimulate remained retinal neural cells. The signal transfer method, which links the extraocular part of the artificial retina system and the intraocular part of the system is required. The RF (Radio Frequency) link method, optical link method, and some other methods have been researched so far [1-3] (Figure 1).

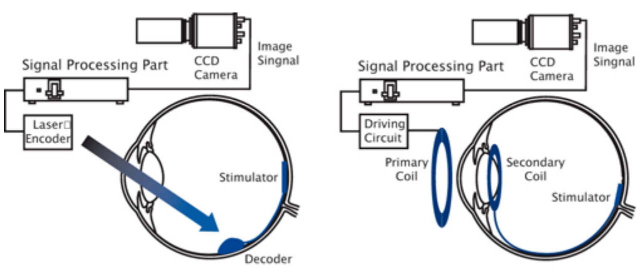

Figure 1. The schematic diagram of signal transfer methods in artificial retina system. Optical link method (left) and radio frequency method (right).

Even if image information and power for electrode stimulation are transferred simultaneously, in other words, the power is modulated by the image signal, the process that separates the image signal and power is needed. An intra-ocular signal processing part delivers electric power to each electrode according to the image information. Therefore, all of these methods have disadvantages in that an intraocular signal processing part should be in the eyeball and thereby the intraocular part of the prosthesis becomes larger and more complex. Moreover, potentially harmful heat might be inevitably generated because of intraocular power control for stimulating the whole electrode array. In addition, the RF method is sensitive to electromagnetic interference. The small and restricted capacity of eyeball prefers to perform the acquisition and the processing of visual images externally. Thus we propose new prosthesis system without necessity for the intraocular signal processing part. Figure 2 shows the schematic diagram of the proposed system.

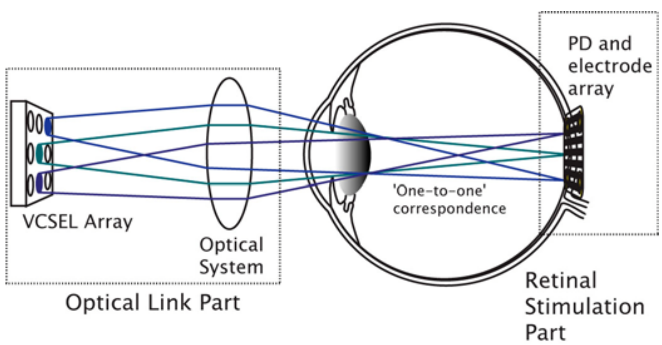

Figure 2. The schematic diagram of VCSEL-assisted signal transfer method

The VCSEL (Vertical Cavity Surface Emitting Laser) array in front of eye makes one-to-one correspondence to the integrated PD (photodiode) and electrode array in the eye, and each laser emits beam with adequate power according to the visual image information acquired by CCD camera. Each PD in the PD and electrode array is illuminated by corresponding laser, and electrical signal from electrode can stimulate the remained retinal neural cells with adequate intensity. Hereby each pixel information of the visual image can be reconstructed on corresponding electrode stimulation. In this method, the optical power of each laser is used as the image signal of each pixel. Therefore the separation of power and signal and the control of power flow is not required. By this scheme, retinal prosthesis system can be simplified and reduced in weight. To verify the feasibility of this system, computer simulation on simple optical system and *ex vivo* experiments were done.

II. METHODOLOGY

A. Optical system design & computer simulation

The ‘Code V’ program was used as an optical system simulator and schematic human eye model was selected (Figure 3).

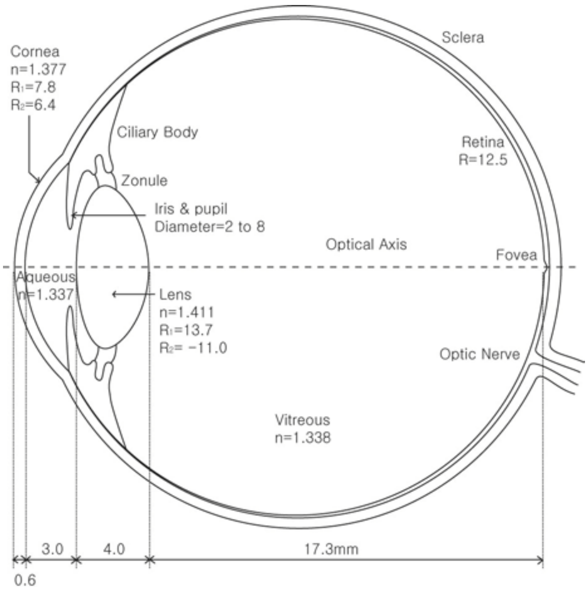

Figure 3. Schematic eye model used in computer simulation

The VCSEL array, the integrated PD and electrode array was assumed as 20 × 20, and the size of each integrated PD and electrode is 50 μm × 50 μm square. The other assumptions include that each PD has no spacing, each VCSEL has 100 μm spacing, and the laser beam emitted by VCSEL is Gaussian beam with 10° diverging angle. On the basis of these assumptions, the adequate optical system was designed in order to focus laser beams on the PD array. Because the laser was chosen as a light source, chromatic aberration was disregarded. The ray tracing method and the point spread function were used for the quantitative evaluation of the designed optical system.

B. Ex vivo *evaluation of designed system*

The spot size and the focusing profile of laser beam were evaluated in *ex vivo* experiment. To measure the spot size on the retina directly and accurately, special setting was devised (Figure 4). The backside of the posterior pole of enucleated porcine eye was windowed and the laser beam passing through the window was measured at the close back of the eye. Roundly opened posterior pole was protected by thin glass to preserve the internal contents of the eye and the refractive error of the eye was corrected using appropriate trial lenses on the basis of retinoscopic examination. The JDS uniphase He-Ne laser (Coherent Inc. Santa Clara, CA, U.S.A.) was used instead of VCSEL array because VCSEL array emitting sufficient optical power is not yet available. Thus the spot of He-Ne laser was reduced to 20 μm to simulate VCSEL. The profile of laser spot on posterior pole was measured through BeamMaster™ PC Knife-edge Beam Profiler system (Coherent Inc. Santa Clara, CA, U.S.A.).

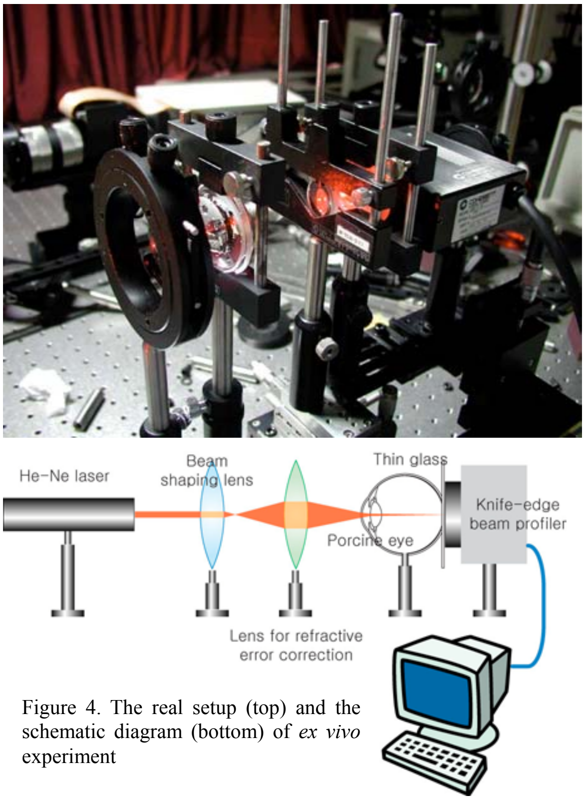

Figure 4. The real setup (top) and the schematic diagram (bottom) of *ex vivo* experiment

III. RESULTS

The designed optical system was sufficient to focus laser spot in 20 × 20 application according to the simulation. Figure 5 shows that the proposed optical link method is enough to focus each laser beam on each corresponding PD in the PD array.

As the distance of the PD from the center of the array increased, the spot was distorted by coma phenomenon. However, the design criteria was satisfied even in the square edge of the 20 × 20 PD array.

In the experiment using enucleated porcine eye, the spot size of the laser on the posterior pole could be reduced to about 200 μm. This is the equivalent resolution of the 20/300,

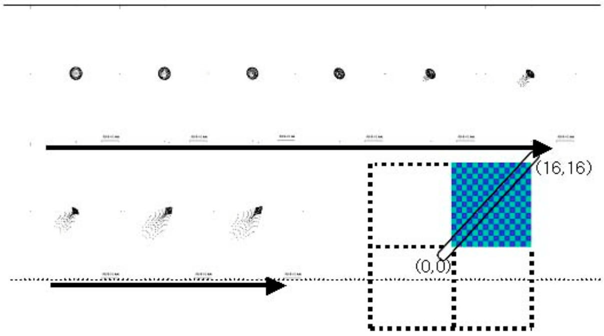

Figure 5. The result of the computer simulation of designed optical system by Code V program. The every other simulated laser beam spots on the PD array along diagonal pixels. The scale bar indicates 50 ㎛.

i.e. 'counting finger' visual acuity in human. Figure 6 shows the measured laser beam profile on the posterior pole of the retina. The Gaussian profile of the laser beam was maintained except the base level, which was increased by scattering inside the eyeball.

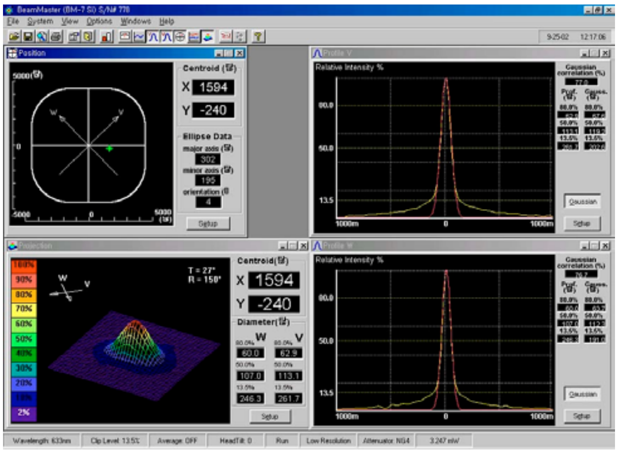

Figure 6. The beam profile of the laser on posterior pole of the retina by BeamMaster™ PC Knife-edge Beam Profiler system. The yellow line indicates measured beam profile and the red line indicates fitted Gaussian profile.

IV. Conclusion

The new optical link method for the transferring of the image signal and the power into the eye is proposed. This method has advantages such as the simple implementation, the less heat generation, and robustness to electromagnetic interference. To verify the feasibility of the proposed optical link, simple optical system was designed and tested in schematic human eye model by Code V program. Each laser beam of VCSEL array could be focused on each 50 ㎛×50 ㎛ PD of integrated PD and electrode array. *Ex vivo* experiment using porcine eye showed that the laser focusing would be possible when using the proposed optical system. These results support the feasibility of the proposed new prosthesis system without necessity for the intraocular signal processing part by using VCSEL.

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