Development of an 8K-class 3D Shooting System for Microscopic Surgery and the World's First Shooting

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ABSTRACT

An 8K-class 3D shooting system for microscopic surgery is developed. The system equips two small UHD cameras with 5120 (H) x 4320 (V) pixels and 59.94 Hz frame rate. The world's first shooting using the system was conducted and fine 8K3D video of the surgery is successfully displayed after editing.

1 INTRODUCTION

The wonderful 8K broadcasting has started in Japan and provided a highly realistic experience for the viewers, since December 2018.

8K system is also applicable to many fields other than broadcasting, such as art, science and education. Medical application of 8K is one of the most hoped-for fields. 8K enables for doctors and nurses to watch very fine blood vessels, nerves, skins and threads for surgery. This will contribute to progress of medical practice. Several organization and companies have already started development of 8K equipment and services for medical application. We have also developed 8K systems for medical application and conducted several 8K shooting of surgeries [1]. However, 8K shooting of microscopic surgery had not been achieved, because the shooting has special and difficult requirements for the shooting system.

We developed an 8K-class 3D shooting system for microscopic surgery and conducted the world's first 8K-class 3D shooting of microscopic surgery, using the system. The developed system and aspect of the shooting is described in this paper.

2 TYPE OF SURGERY, THEIR 8K SHOOTING AND NECESSITY FOR 3D SHOOTING

There are some types of surgery.

Open surgery is the surgical method which has been conducted since the birth of surgery and has long history. In the method, surgeon opens the body of patient, watches the affected area by his eyes and performs operation using his hands and instruments in his hands. 8K shooting of open surgery can be performed in a similar way to some TV program production. Note, however, that a large surgery room is needed because 8K equipment is large, and that cleanness and safety of the equipment are required. We have already conducted the 8K shooting of five open surgeries since 2014.

8K3D shooting of open surgery can also be performed in a similar way to normal 8K3D video production. We have many experiences of 8K3D video production.

Endoscopic surgery is the surgical method in which surgeon cuts some small holes in the body of patient, inserts an endoscope camera in one of the holes, watches a video monitor connected to the camera and performs operation using instruments inserted through other holes. The diameter of rigid endoscope is from 4 to 10 mm in general. Rigid endoscope used for abdominal surgery is referred to as laparoscope.

Endoscope camera is strongly required to be lightweight and small, because surgeon or assistant must hold the camera in their hand during the operation. All current 8K cameras for video production are not suitable for this use, because they are heavy and large. We have already conducted the 8K shooting of four endoscopic surgeries since 2016, using an 8K camera, a camera crane and a special assistant for the crane operation. Kairos Co., Ltd. has developed a small and lightweight 8K rigid endoscope camera and put it into the market since 2017 [2].

3D shooting of endoscopic surgery is desired, because the surgeon gets a sense of depth for the affected area mainly through the video of the endoscopic camera. 8K3D shooting of endoscopic surgery is however very difficult, because the diameter of the endoscope is small and optical resolution necessary for 8K3D shooting cannot be obtained.

Microscopic surgery is the surgical method in which surgeon opens the body of patient, watches the affected area through a surgical microscope and performs operation using instruments in his hands. The method is often used in neurosurgical operation, eye surgery and ontological surgery, because the affected parts in those surgery are small.

3D shooting of microscopic surgery is desired, because the surgeon is watching optical 3D image of the surgical field through the surgical microscope during the operation. Accordingly, 8K3D shooting of microscopic surgery is strongly desired to put 8K to use for precise record of the surgery and/or educational materials for young doctors.

However, there are requirements for the 8K3D shooting system. Surgical microscope is heavy and surgeon often moves the microscope during the operation. The microscope so includes an auto-weight-balancing mechanism to avert weight strain

to the surgeon. 8K camera must be lightweight to enable the mechanism to be available and small to avoid interference to the surgeon's movement.

3 DEVELOPMENT OF THE SHOOTING SYSTEM

We have developed an 8K-class stereoscopic 3D shooting system. The system is shown in Fig. 1. The system includes two cameras attached to the microscope and two workstations for camera control and video recording. They are for each image of the left (L) and right (R) eye.

We started the development with searching a camera which satisfies the requirements. We assumed ZEISS PENTERO 900 as the microscope, which is a popular microscope in neurosurgical operation. Requirements from the microscope are that the weight including a camera, a lens mount and cables must be under 1 Kg, and that the size of the camera should be within cube 10 cm on a side. These requirements are very difficult for 8K cameras.

We selected ADIMEC S-25A80 as the camera. It is a small ultra-high definition (UHD) camera and has 5120 pixels both in horizontal (H) and vertical (V) direction. The active pixels are variable and frame rate is adjustable up to 80 Hz. We use the camera with active pixels of 5120 (H) x 4320 (V) and a frame rate of 59.94 Hz. 8K system has 7680 (H) x 4320 (v) pixels. The vertical active pixels of the camera are full to 8K. The horizontal active pixels are two-third of 8K. The pixels however seem to be enough, because the surgical field of the microscopic surgery is like square. It is therefore considered that 5120 (H) x 4320 (V) pixels are substantively equivalent to 8K for the shooting of microscopic surgery. The weight of the camera is about 560 g and size is under cube 10 cm on a side, including the lens mount. The camera is a single-sensor color camera with a Bayer color filter.

Fig. 1 The developed system.
Left : A surgical microscope with two small UHD cameras
Right : Two workstations for camera control and recording

Fig. 2 shows the configuration of the system. The UHD cameras are attached to the microscope through lens adaptors prepared by ZEISS for 3D shooting and T-F mount adaptors for mount conversion.

The cameras use CoaXPress QUAD as the signal interface. An AVAL DATA APX-3664 frame grabber board corresponding to the interface and a high speed 2TB SSD are used in each workstation for video

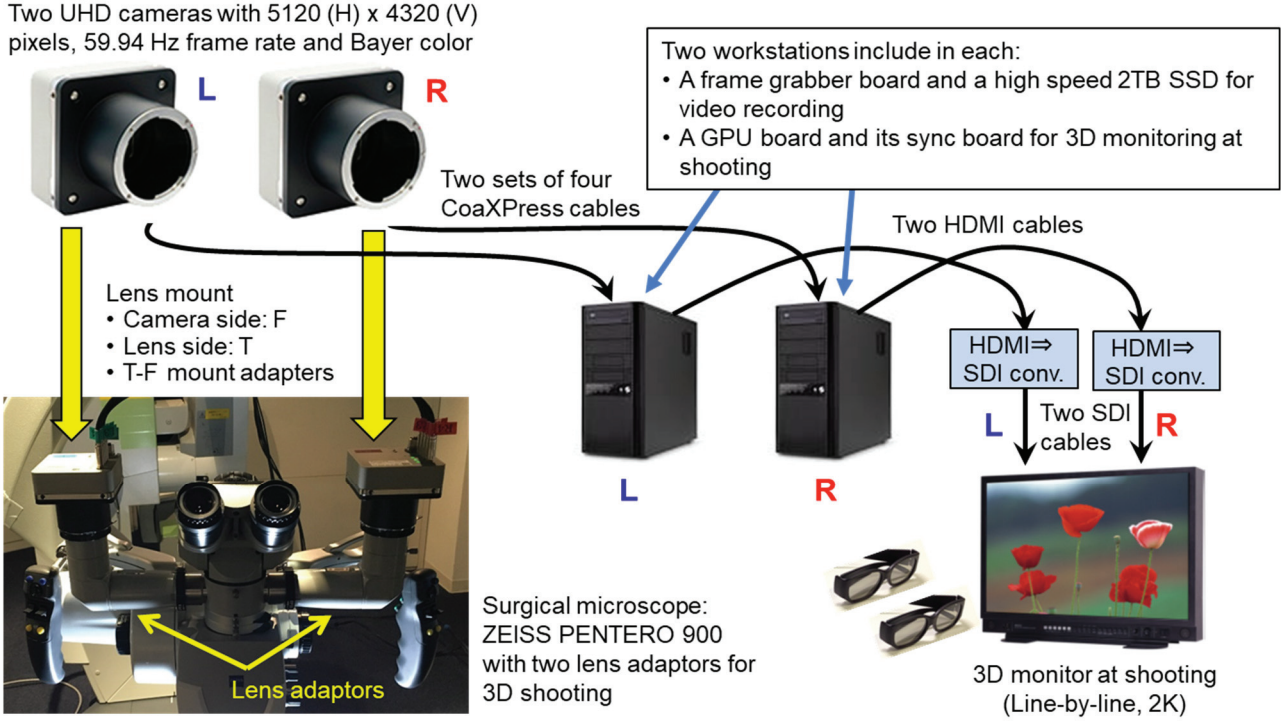


Fig. 2 Configuration of the developed 8K-class 3D shooting system.

recording. The workstations also control the parameters and operation of the cameras through the interface.

A GPU board and its sync board are also included in each workstation for 3D monitoring at the shooting. The system cannot output UHD images simultaneously with the shooting or recording, so the monitoring is performed using an ASTRODESIGN SM-3324 2K3D monitor. The monitor can display 2K3D image with line-by-line 3D displaying method which uses polarized glasses for 3D watching.

4 THE SHOOTING OF THE SURGERY

The world's first 8K-class 3D shooting of microscopic surgery was conducted, using the developed system, at Juntendo University Urayasu Hospital in this year. The surgery is a neurosurgical operation referred to as "Clipping for brain aneurysm."

After attaching the cameras to the microscope, the microscope and cameras were covered with transparent antibacterial sheet by the doctors, as shown in Fig. 3. We could not touch the cameras after the covering to keep cleanness. The surgeon moves the microscope using the black handles at the both sides, during the operation. Zoom (or magnification) and focus of the microscope are also adjusted by the surgeon-self using buttons in the handles. There are eye pieces of the microscope at the center. The surgeon watches the optical 3D image of the surgical field through these eye pieces.

The aspect of the surgery and shooting is shown in Fig. 4. The head of the patient is under the microscope. We asked the doctors to provide us with the start and stop timing of actual recording. About 25 minutes material of 8K-class 3D video was successfully recorded as the result. An example of the recorded image is shown in Fig. 5. The image covers the surgical field enough, as shown in the figure.

5 DISPLAY OF THE RECORDED VIDEO

Methods to display the recorded video on 8K3D display are also developed.

8K3D displays which are available today are only an 8K 120Hz DLP projector by DIGITAL PROJECTION /ASTRODESIGN and a 55-inch IPS-LCD 8K monitor with a 3D polarization filter [3]. The former displays 8K3D image with frame-sequential method and the viewer watches the image using shutter glasses. The latter displays 8K3D image with the line-by-line method.

We developed the methods of file-conversion and editing in several steps for each display and confirmed successful display of 8K3D image on both of the each. An example of the displayed 8K3D image with the line-by-line method is shown in Fig. 6. Rich three-dimensional ultra-high-definition images are displayed on the 55" 8K3D monitor.

The above displays are large. We have also developed a 15.6-inch 4K3D notebook PC with a 3D polarization filter since 2015. It is a handheld PC and can readily display

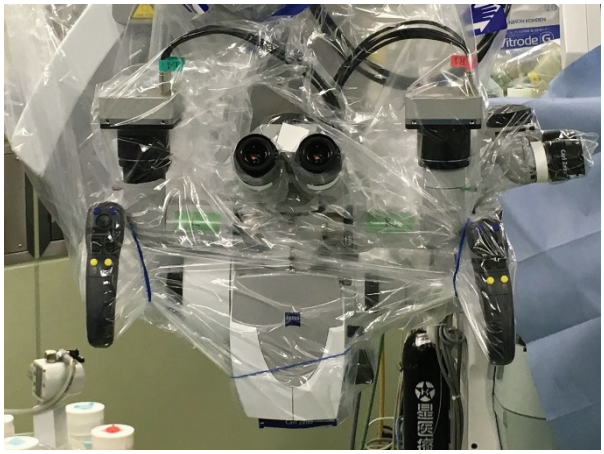
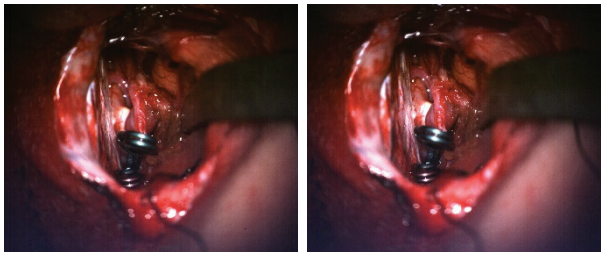


Fig. 3 The surgical microscope and cameras covered by antibacterial sheet.

Fig. 4 The 8K-class 3D shooting of the surgery.
at Juntendo University Urayasu Hospital, 2019



Left image **Right image**

Fig. 5 An example of the recorded image.
5120 (H) x 4320 (V) pixels for each image

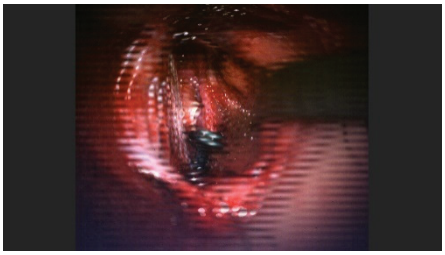


Fig. 6 An example of the displayed image.
7680 x 4320 pixels, line-by-line 3D

4K3D image with the line-by-line method. It has been developed for personal research or self-learning of doctors and/or interested persons. 4K3D image down-converted from the 8K3D is also successfully displayed on the PC, as shown in Fig.7

6 CONCLUSIONS

An 8K-class 3D shooting system for microscopic surgery has developed and the world's first 8K-class 3D shooting of microscopic surgery was conducted, using the system. Fine 8K3D video of the surgery has successfully displayed on 8K3D displays after editing. It is considered that the active pixels of the system, or 5120 (H) x 4320 (V) pixels, are almost equivalent to 8K for the shooting of microscopic surgery. 8K3D video recorded by the system will be useful as precise record of the surgery and/or educational materials for young doctors.

The developed system is rather experimental. However, it will lead to development of more practical 8K3D shooting system for microscopic surgery. I hope it will contribute to the future progress of medical practice.

Fig. 7 Down-converted 4K3D image displayed on the developed 15.6" 4K3D notebook PC.

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