

Gated MCP framing camera system

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ABSTRACT

A picosecond gated MCP framing camera system is presented. The camera with four parallel microstripline cathode has longer measuring time range and better gain uniformity. The camera is equipped with a pinhole-array adjustment system and other practical accessories for laser plasma experiment. The measured spatial resolution of the camera is 15lp/mm with 10% modulation and the exposure time ranges from 60ps to 100ps with different gain. The whole system was used at the 11# laser facility and got some results of several target type during laser plasma experiment.

Keywords: MCP gating, framing camera, picosecond

1. INTRODUCTION

Picosecond gated MCP framing camera has been developing rapidly during the last ten years and become an important diagnostic equipment for laser plasma experiment^[1-7]. We had reported a gated MCP framing camera using a single meander microstripline cathode with exposure time of 100ps and 60ps^[1,2]. In this paper, a more functional gated MCP framing camera system is presented. With four parallel microstripline cathode, this camera has a longer measuring time range and better gain uniformity. And some factors of operating during laser-plasma experiment was taken into account in system designing and constructing. The camera is also equipped with a pinhole-array adjustment system and other practical accessories for laser plasma experiment.

2. DESIGN AND WORKING PRINCIPLE

The configuration of the camera system is shown in Fig 1. It consists of a proximity focused MCP imager with four parallel microstripline cathode, a control unit, and a mechanical system for pinholes mounting and adjustment. During laser plasma experiment, the pinhole-array or pinhole grating produces many X-ray images on the microstripline cathode which is coated on MCP, these X-ray images are converted to electrons and gated by high voltage gating pulse generated by control unit. The gated electron images are converted to optical images by the phosphor screen and then recorded by film or CCD. The time interval between different microstripline cathode can be adjusted by varying the length of the cable connecting pulse generator and imager.

The camera system has been designed for time resolved research of laser plasma. It can be used to get images and spectra(with pinhole grating) with 20X to 2X amplification. And the distance between cathode to target could be prolonged to 1.8 meters with an additional vacuum system to get better spectral resolution when coordinated with pinhole grating.

The MCP of the imager is 56mm in diameter and 0.5mm in thickness, and the channel diameter is 12 μm . The width of the four microstripline cathode is 6mm. The fiber-optic face plate is coated with P20 phosphor screen. The pinholes system with its two orthogonal arranged stepping motors can adjust the pinholes precisely to the correct position. The control unit provides all the power supply of the camera system.

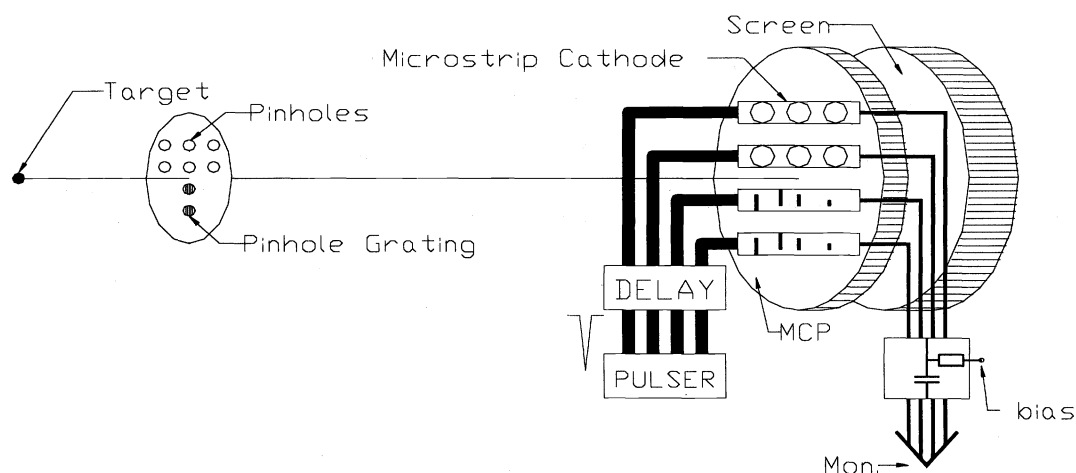


Fig 1. Schematic diagram of the camera

The pinholes can be driven either by manual or computer controls. A movable illuminating light equipped in the imager made it easy for observing the pinholes and microstripline cathode on MCP so benefit it very much of the adjustment of pinhole-array. The images on screen is recorded with a film contacting the face plate, and a 2044X2033 TE/CCD system is under developing. The whole camera system is designed for using under the experiment environment of 11# and 12# high power laser facilities.

3. CONSTRUCTION OF THE SYSTEM

The configuration of four parallel microstripline cathode imply that four separate high voltage pulses are needed to gate the four microstripline. Compared to the single meander line type we developed, the key technical factor in designing and constructing the four microstripline camera is the identical response of the four parallel microstripline. It means one must keep the identical response of the four cathodes, identical waveform of the four gating pulses, identical transmission characteristics of the four microstripline, and minimized jitter between the gating pulses to get a good synchronicity.

As for the whole system design, because of the difficulty in adjusting the pinhole-array in laser plasma experiment, a mechanical unit for pinhole adjustment is needed.

1. MCP imager

For the laser-plasma researches, it is sometimes required to do the measurement of the plasma with different spectra range at same time or do measurement of time range of several nanoseconds. To meet this demand we developed the four microstripline cathode camera. With the length of the coaxcable connecting the pulse circuit to imager be same, one can take the measurement of comparing the images of different spectra range. Varying the length of the four cable, the measurement time range could be extended to several nanoseconds.

The MCP used in our camera is 56mm in diameter and 0.5mm in thickness. And the four microstripline coated on MCP is 6mm in width, the resultant transmission impedance is about 17Ω . To match the 50Ω connectors and pulse generator, an microstripline exponential transformer is utilized to change the impedance from 50Ω to 17Ω at the input end of the four microstripline and change the impedance from 17Ω to 50Ω at the output end. The transformer is manufactured on a special PCB(Printed Circuit Board) which has approximately same dielectric constant with MCP. So the microstripline on PCB and MCP matched not only on impedance but also on dimension. It gives much convenience in connecting the microstriplines on PCB to MCP. The whole configuration of transformers and microstriplines on PCB and MCP is shown in Fig 2.

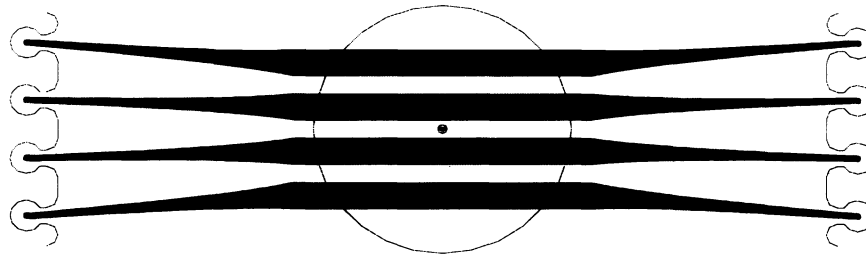


Fig 2. Microstriplines on PCB and MCP

As discussed at the beginning of this section, the identical response of the four microstripline is necessary of the camera. For the imager it means the spectral response of the four cathodes and the transmission characteristics of the four microstripline should be identical. So it is very important in the manufacturing and mounting the four microstripline on MCP and PCB. We examine the consequent transmission characteristics with TDR(time domain reflectivity). From the TDR results shown in Fig 3, it can be seen that the transmission characteristics of the four microstripline shows little difference.

The fiber-optic faceplate is coated with P20 phosphor screen. The distance between the output surface to phosphor is 0.5mm. And the output surface of MCP is coated with a dielectric layer to raise the breakdown voltage of MCP/screen gap^[8]. The observed static spatial resolution of the camera is 15lp/mm of 10% modulation when the phosphor screen is applied with 3.5KV voltage.

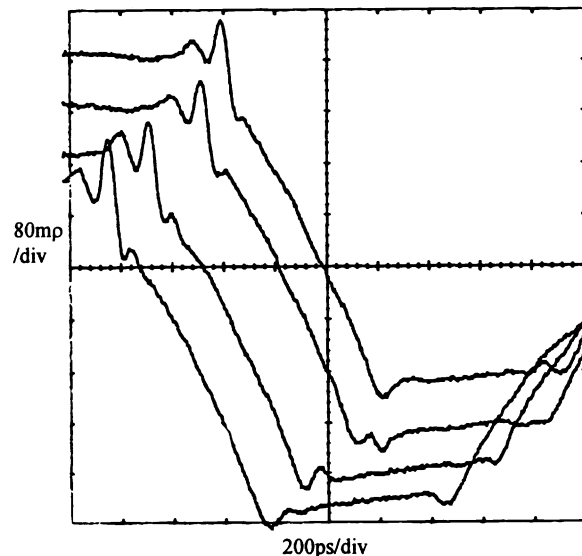


Fig3. Measured TDR of the four microstripline

2. Gating pulses

The key specification of the framing camera is the exposure time, which is mainly determined by the gating pulse. We had generated the gating pulse by a diode circuit which is driven by a step pulse generated by an avalanche transistor circuit^[9].

For the four strip-cathode camera, it is very important to make it equal of the four gating pulses. It means the identical waveform and fixed time sequence of the four pulses. We had tried to use four separate circuit to generate the pulses, but it is impossible to keep the time sequence of the four pulses because of the jitter of the circuit. And it is very difficult to adjust the four pulses to same waveform. Because the instability and jitter is mainly caused by the first stage circuit, we tried to using one avalanche transistor circuit to drive four diode circuit to get the four gating pulses.

The high voltage pulses circuit used in the camera is shown in fig 4. It is a three stage circuit. By using avalanche transistors, the first stage circuit^[10] with its two parallel output ports produce two step pulses. The pulses is 3KV in amplitude but the rising edge is not smooth. The pulses is then improved to be more suitable to drive the last stage by the second stage circuit of avalanche diode, with its amplitude being increased, rising edge being amended and width being reduced. The two modified step pulses is transformed to four short pulses by the last stage circuit of avalanche diode. Two diode circuit is used to generate the four pulses.

The jitter between pulses is determined by the stability of two diode circuit of 2nd and 3rd stage. Only the first stage of avalanche transistor is applied with power, the passive circuit of 2nd and 3rd stage possess a good stability and induce little jitter. So the jitter between pulses will be small.

As shown in fig 4, one diode circuit generates two gating pulses from two symmetrically arranged capacitors. So it is very easy to adjust the capacitors to get two identical pulses from one diode circuit. The four gating pulses is obtained by choosing two suitable diode circuit.

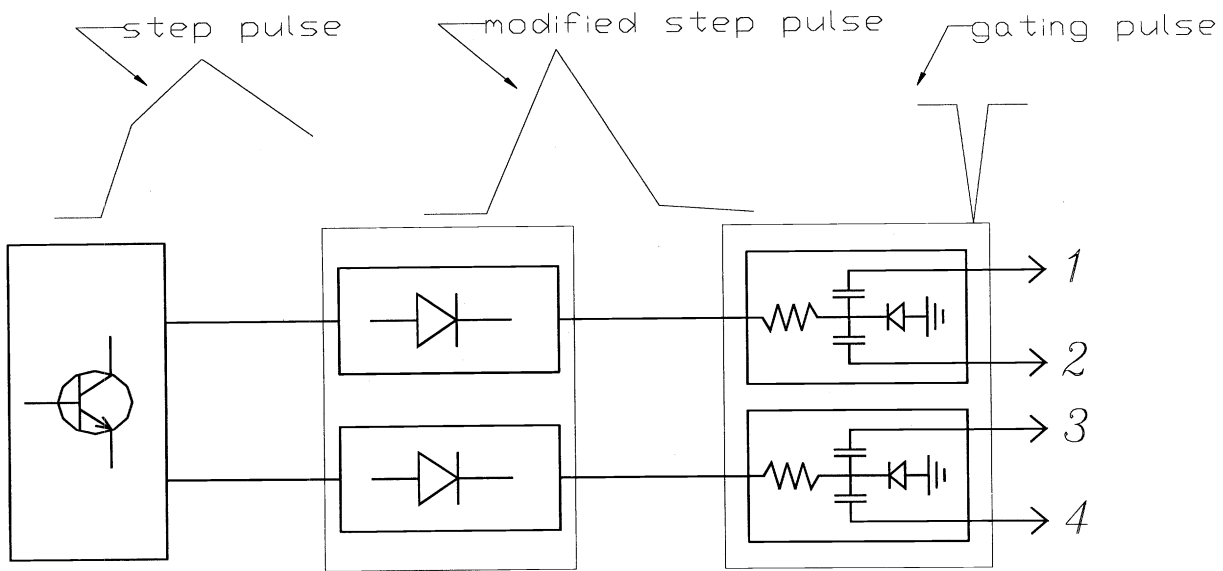


Fig 4. Schematic diagram of the pulser

Two of the four pulses is shown in fig 5, the other two pulses comes from the same diode circuit with the two displayed in the fig. The measure was taken by TEK 11801A oscilloscope. The generated four gating pulses is 280ps FWHM and 2.5 kv amplitude on 50Ω load.

We have also measured the jitter of the circuit with TEK SCD 1000 oscilloscope. The measured jitter between pulses and triggering signal is 50ps, and jitter between different pulses is very small and cannot be measured precisely. So the four gating pulses show a good synchronicity.

3. Other constructions

The photograph of the camera system is shown in Fig 6. The MCP imager is sealed on flannel under a shielding case. The shielding case is fixed on the flannel and covers MCP preventing MCP from noise light and electro-magnetic interference during laser-plasma experiment. An UV light and a movable illuminating light is mounted in the shielding case. The pinhole device is also fixed on the outside of shielding case. The pinhole array is mounted at the left end of the taper. Two orthogonal arranged stepping motors is used to adjust the pinholes precisely to the correct position. There is also a rotate device in front of the stepping motors to adjust the alignment of the pinhole-array. A conducting film camera can be seen on the back of the flannel. The control unit provides all the power and controls for the camera, including voltage to phosphor screen, gating pulses to MCP, bias and static checking voltage of MCP, control signals for stepping motors, and power for UV light and illuminating light for pinholes.

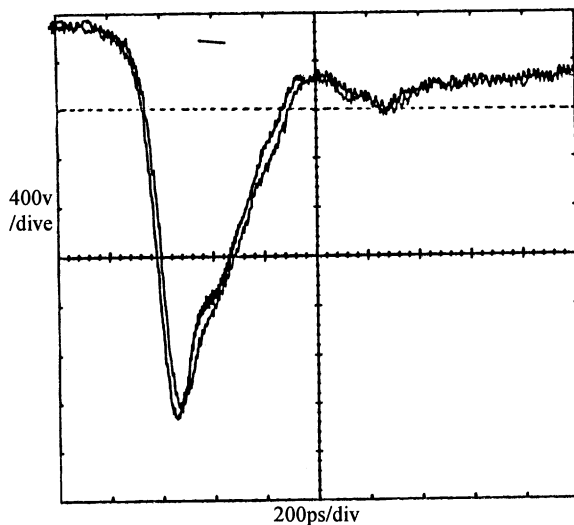


Fig 5. Measured gating pulses

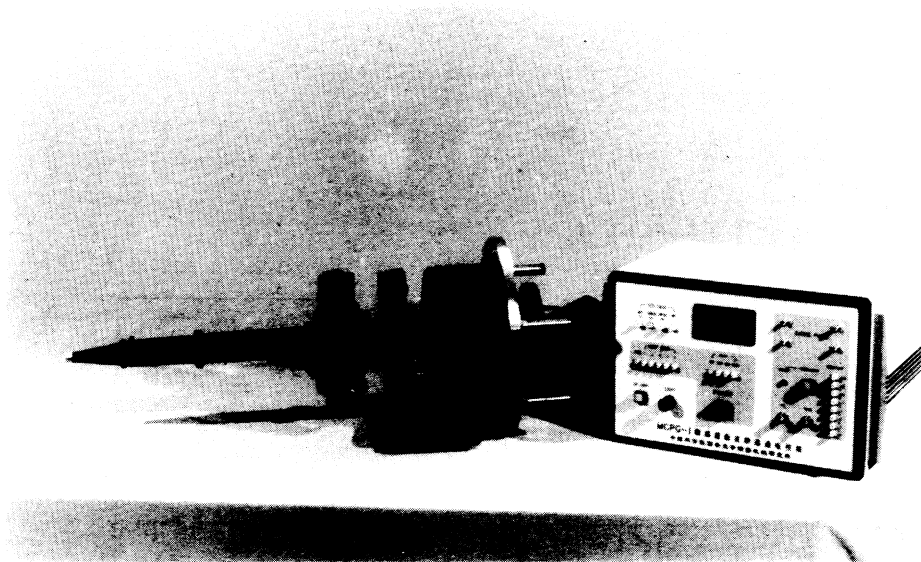


Fig 6. Photo graph of the camera system

The distance between MCP and phosphor screen is 0.5mm. During laser-plasma experiment, sometimes the vacuum is not high enough to operate the camera at its full parameters. We had designed a three grade of the voltage applying to the MCP/screen gap of 2.6KV, 3.5KV and 4.5KV. The camera can be operated with 2.6KV and without breakdown of MCP/screen gap at vacuum of 7.5×10^{-5} Torr. And the voltage can be set to 4.5KV at high vacuum of 2×10^{-5} Torr to get the best gain and spatial resolution. The measured static spatial resolution is 15lp/mm with 10% modulation at voltage of 3.5KV.

The control unit outputs four gating pulses of 2.5kv amplitude and 280ps FWHM to gate MCP. Apart of varying the voltage on MCP/screen gap, the gain of the camera can also be adjusted by applying bias on MCP, which can be seen in fig 1. The camera is designed with 5 grades MCP bias voltages. The measured exposure time of the camera ranges from 60ps to 100ps with different MCP bias be set with 90V to -90V.

The adjustment device for pinhole is set up by two orthogonal arranged stepping motors. The distance of one step is 5 μ m and the limits of the adjustment of stepping motors is ± 3 mm. An additional manual adjuster has a bigger adjust range of ± 13 mm. The stepping motor is controlled by a control box or a microcomputer connected to the control unit. The alignment of pinhole-array can be adjusted by a rotate device. The magnification of pinhole image can be changed by adjust the telescopic shaft.

During pinholes adjustment, the illumination of pinholes and MCP is sometimes difficult because of the complex environment of the chamber. We had installed a movable illuminating light in the shielding case. And a center mark was made at the center of MCP. The pinholes can be easily observed when the light is moved on the axis of target/MCP. The center mark and microstripline on MCP can be illuminated when the light is moved aside of axis. An UV light is installed in the camera made it convenient for in-situ examination of the camera.

The transmission time from center of MCP to the output end is precisely calibrated by oscillate. One can observe the outputted gating pulse with XRD or PIN signal in a oscilloscope. It is very useful in adjusting the synchronicity of camera and the x-ray signal. It can be also used to resolve the time sequence of measured images and laser or x-ray.

4. Application

The camera system was used in the 11# high power laser facility to take time-resolved measurement of laser-plasma. The magnification of the pinholes camera is 10 and the distance from target to MCP cathode is 568mm. The diameter of the pinholes is $\sim 30\mu$ m. Fig 6 is the photographs of the measured laser-plasma evolution of several target type. The time sequence of the twelve frames in each photograph from upper-left corner to lower-right corner is 0, 55ps, 110ps, 500ps, 555ps, 510ps, 1ns, 1.055ns, 1.11ns, 1.5ns, 1.555ns, 1.61ns.

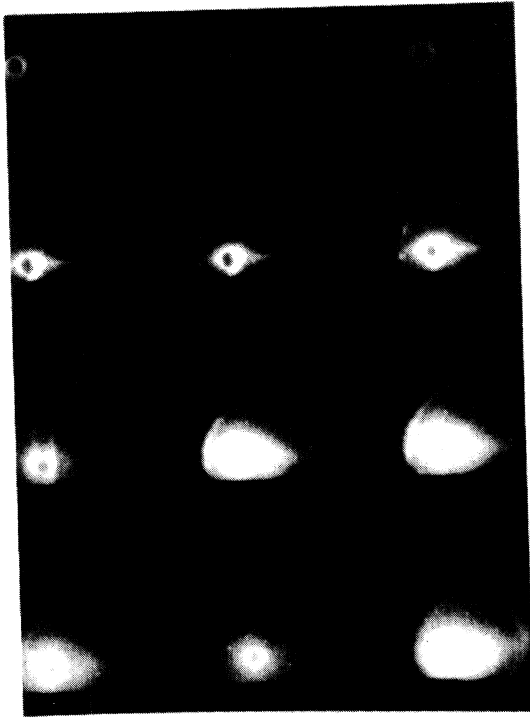


Fig 7a. Gold foil target(perpendicular view)

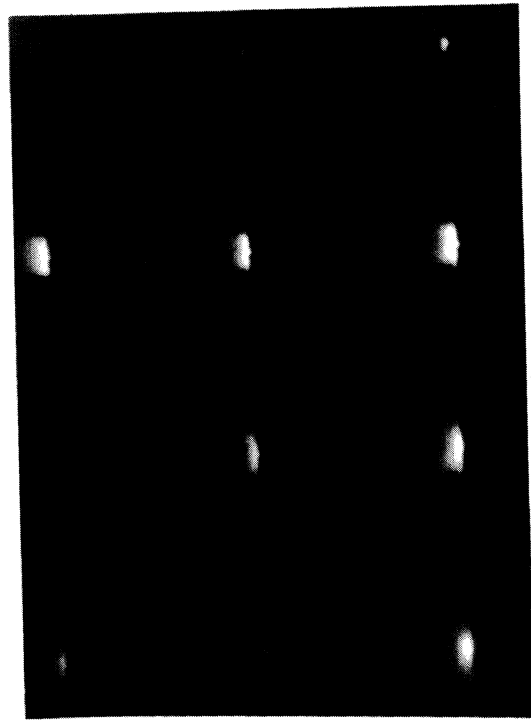


Fig 7b. Gold foil target(tangential view)

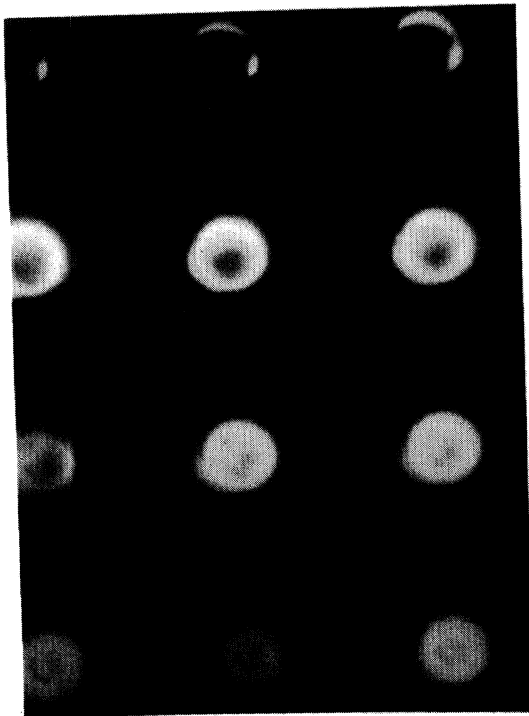


Fig 7c. Cylinder target

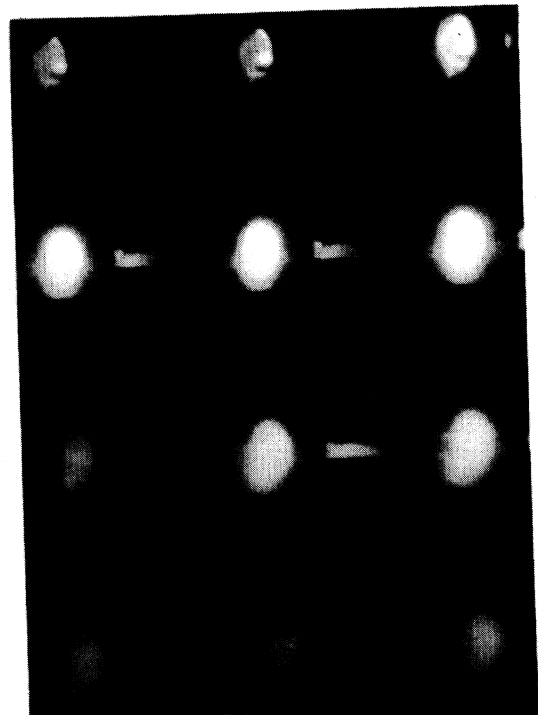


Fig 7d. Slit target

It can be seen in fig 1 that there is a dark spot at the center of the target. Before the measurement of the target, we had shot a very weak small laser (about 0.5J). And a tiny hole was made in a 40 μ m thick gold foil. So the consequent measurement of the following shot shows a dark spot at the center. During the experiment, we had used the camera getting six images with the laser energy of 0.5J. The result shows the high sensitivity of the camera. The experiment also revealed that the camera system has a large dynamic range and good stability, and is very convenient to operate.

4. ACKNOWLEDGMENT

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