Optik 126 (2015) 3181–3184

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Experimental research on multiple-slit streak tube imaging lidar

Jianfeng Sun[a,*], Jinbo Liu[b], Qi Wang[a]

[a] National Key Laboratory of Science and Technology on Tunable Laser, Harbin Institute of Technology, Harbin 150080, China
[b] Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian, China

ARTICLE INFO

Article history:
Received 15 June 2014
Accepted 16 July 2015

Keywords:
Lidar
Streak tube
Flash imaging
Multiple-slit

ABSTRACT

Multiple-slit streak tube imaging lidar is a promising flash imaging instrument, for its high frame rate, accuracy range resolution and large field-of-view. In this paper, the lidar system establishment and experimental research on multiple-slit streak tube imaging lidar in Harbin Institute of Technology is presented. Experiments in laboratory and outfield test show that this lidar could get 48 × 48-pixel intensity and range images. After careful calibration and testing, clear intensity and range images of two targets 648 m and 95 m away were got.

1. Introduction

Multiple-slit streak tube imaging lidar (MS-STIL) is a promising flash imaging lidar, it is widespread concerned recently for its high frames rate, accuracy range resolution and large field-of-view (FOV), and used in many fields [1] such as terrain investigation, underwater exploration, obstacle avoidance and so on. Knight introduced the principle of MS-STIL in 1989 [2] for the first time. Gleckler [3] presented some possible applications of MS-STIL in 2000. Gelbart presented a flash imaging lidar based on multiple-slit streak tube and experiment results of imaging to a target 10 m away in laboratory of Arête associate [4], USA, 2002; and airborne experiment of imaging to a vehicle under Tree 100 m far away and mine-like targets in ocean were carried out. Harbin Institute of Technology (HIT) had constructed a MS-STIL system since 2008 [5,6], outfield test shows that it can get images of targets 700 m away, and images basically indicated the range, spatial and intensity information of target.

2. System principle and structure

MS-STIL is an innovated lidar system on the basis of STIL [2,3,7]; it makes use of the effective cathode area sufficiently to obtain more information than STIL. Its outstanding advantage is that it can get four-dimensional (intensity + 3 dimensional space) image of target by one pulse, which can improve system's frame rate effectively.

MS-STIL is consisted of multiple-slit streak tube, laser, transmit and receive lens, remapping optical fibers, CCD camera and data processing system. System basic principle is: a laser beam illuminates to targets, and targets reflected light is focused on the front-end of remapping fiber optics by receive lens, remapping fiber optics is an image converter which will transform target image to a number of stripe images, and these stripe images are cone-coupled to photocathode of streak tube through an optical taper, streak tube will detect time and intensity information of incident light, then intensity and range (time) information of target are extracted by data processing system, and finally 48 × 48-pixel intensity and range images are yielded. The principles of some key units of the system such as streak tube, remapping fiber optics are shown in Figs. 1 and 2.

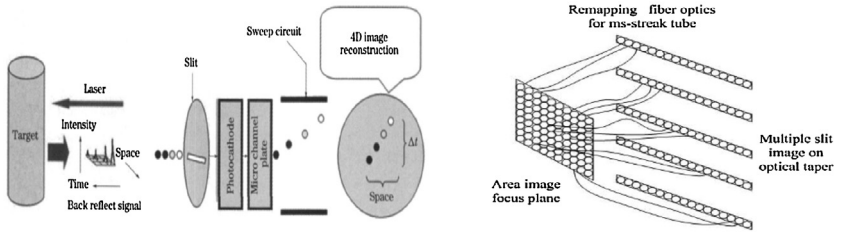
Streak tube is a photoelectric detector usually used in ultrafast measurement, and its temporal resolution is up to 100 attoseconds [8] until now, however in MS-STIL such precise temporal resolution is not necessary, as streak tube temporal resolution is relative to lidar range resolution [4,5], usually 100 ps resolution (0.015 m) is enough for target structure detection. Remapping fiber optics is used to sample the area image on the input end and remap it to stripe images on the output end, its structure and image transformation effects are shown in Fig. 2.

3. Experimental devices and results

Laboratory experiment of imaging to target 39 m away was carried out, a frequency-doubled Nd:YAG laser with wavelength of 532 nm, pulse width of 10 ns, is used as a transmitter, laser beam is expanded to 2° × 2° field of view, a whiteboard 39 m away in the aisle and the wall (42 m) behind it were illuminated by laser beam,

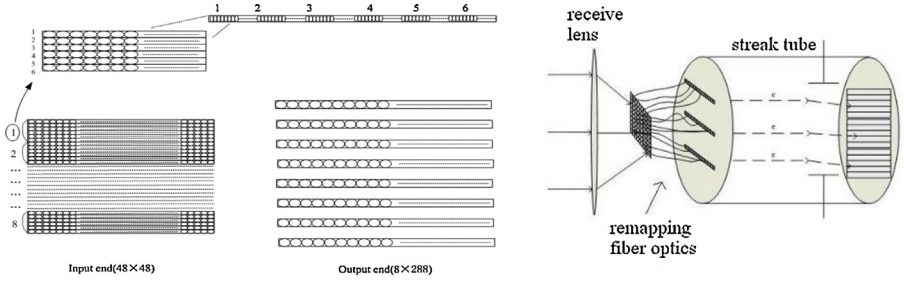
* Corresponding author. Tel.: +86 045186413164.
E-mail address: sjf@hit.edu.cn (J. Sun).

http://dx.doi.org/10.1016/j.ijleo.2015.07.077
0030-4026/



(a) Streak tube (b). Remapping fiber optics

Fig. 1. Principle of streak tube and remapping fiber optics.



(a) Remapping fiber optics design drawing for MS-STIL; (b) Basic principle of MS-STIL;

Fig. 2. MS-STIL flash lidar structure and principle.

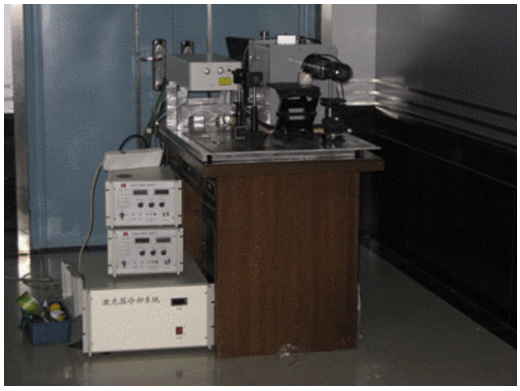


Fig. 3. Multiple streak tube imaging lidar system.

receive lens focused the reflected light from the target on the front-end of remapping fiber optics, a CCD with 480 × 480 pixels captures the stripe images from streak tube's screen. The lidar system was illustrated in Fig. 3, and target chosen was shown in Fig. 4.

Fig. 4 shows a CCD image resulting from a single laser flash when the streak tube works in static mode, which will show the intensity information of target. As the image of targets focused on front-end of remapping fiber optics by lens is usually not big enough to fulfill it, and there are some disfigurements about the optic fibers, which result in absence of some stripe images or some parts of them (Fig. 5).

And then, the streak tube was adjusted to streak mode to get dynamic image of the target, which will display the range and intensity information of target, the stripe image captured by CCD is shown by Fig. 6. The streak tube was triggered synchronal at the same frequency as laser, 100 Hz, so that each laser pulse generates each CCD image, and the CCD image provides 30 range pixels for each of the 2304 spatial pixels of the mapped flash lidar data.

Target images were obtained by de-noising dynamic image, extracting range and intensity information, and remapping the stripe image to area image. Intensity and range images were shown in Figs. 7 and 8. The whiteboard and wall behind it were obviously distinguishable in intensity and range images; especially in the range image their range difference was clear indicated by false color. The rectangle area marked in Figs. 7 and 8 by dotted line was the whiteboard, and the bilateral parts were the wall behind it. The metal door handle with high reflectivity was notable in inten-

Fig. 4. Whiteboard at 39 m away.

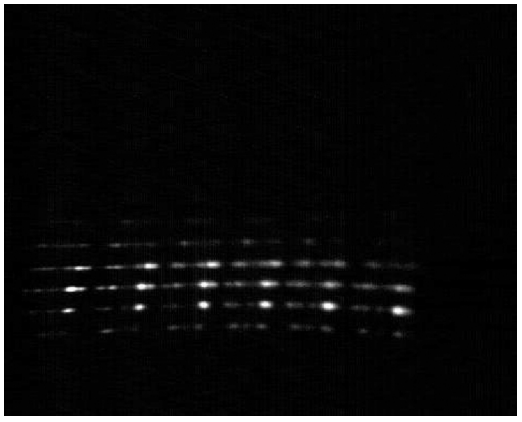


Fig. 5. Static stripe image.