Design and Analysis of Imagery System of Laser Scanning

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ABSTRACT

This paper expounds the operation principle of laser scanning imagery system,after analyzing the light source, transmitter,receivewere and the continuous analogue electric signal which are in the laser scanning imagery system,a laser scanning imagery system is designed, the composition and main parts of the system were expounded. The performance referance date were reviewed.The characteristics of this systerm is that it not only can scanned but also can collect reflecting coefficient information and can do laser ranging.This paper analyze and disguess the scanning imagery system and the key technology of laser weapon, finally the applicating prospects of the system are described.

Keywords: Laser scanning ; Imagery system ; Transmitter and receiver; Detector

1. INTRODUCTION

In the 1960s, the legendary and mysterious laser was born. In a short span of several decades, it penetrate into all areas of our society. Laser is a new interdisciplinary technology,it is not only belong to electronics but also the photonics technology. The most significant characteristic of the laser technology is the wide permeability in other technologies. The invention of the laser, has provided a new impetus for scientific and technological's development. Hitherto , laser ranging ,the laster guided weapon, laser communications, laser scanning imaging system, as well as a "death ray" laser weapons have been used in the army[1].Because of the high directivity,the divergence angle of the beam is minor; the monochromaticity and minor pulse are the great advantage,it can rule out the interference from the backgrund or ground's clutter,so the laser scanning imaging system can observe the low target,and laser scanning imaging system can work as real-time reconnaissance in day and night.the laser scanning imaging system is a modern high-tech military equipment.

2. THE WORKING PRINCIPLE OF LASER SCANNING IMAGING SYSTEM

Laser scanning imaging system is a systerm of airborne laser imaging system which can provide a three-dimensional topographic images, and its working principle is based on the scaning to the target scene with the laser beam,the laser radiation from the receive scene, producing a continuous analog signal,feeding back to the TV-type display,changing the continuous analog signal into a image which is can display the target scene.At the same time,using the periodic signal modulate laser beams,then comparing the phase of the laser signal reflected from the ground with the baseline phase,so getting the slope distance to the ground. slope distance combine with the two-dimensional image,so getting the data information of the three-dimensional images of the ground.

2.1 Target speed and the principle of distance measuring

The measurement of target speed, can be getted by measuring the Doppler frequency shift of echo signal form the target. Doppler frequency shift f_s can be expressed through the following formula:

$$f_s \approx \frac{2v}{\lambda} \qquad (1)$$

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v is the target radial velocity; λ is the laser wavelength. By (1) radial velocity of targets can be calculated. Figure 1 gives the relationship of f_s、v、λ through the three curves. f_s can be getted by the method of measuring the frequency with the method of Doppler carrier,that is to measure using coherent receiver; also f_s can be getted by measuring vice carrier frequency with the method of Doppler,that is to say doing the vice carrier frequency with the lasing,receiving the echo signal with the noncoherent detection receiver,then getting the f_s after frequency mixing between coherent reference signal and vice carrier frequency.

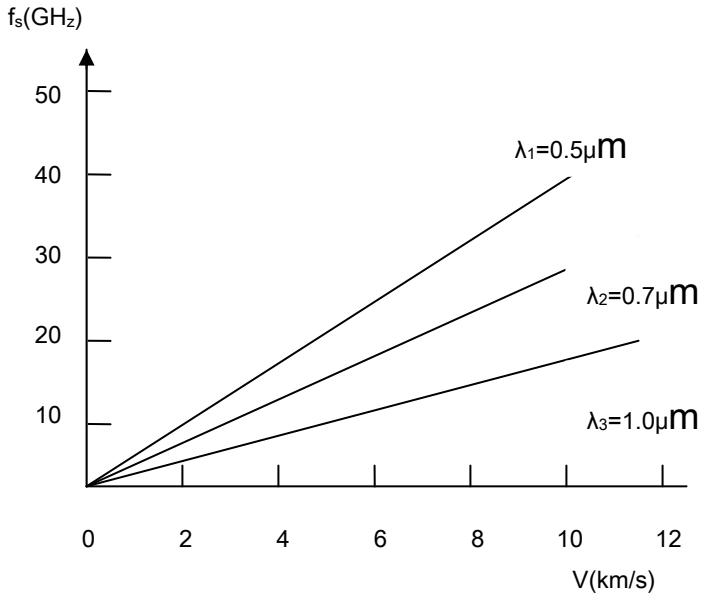

Fig.1 The relationship between fs, v, λ

With an ideal linear frequency modulation continuous wive, the distance and speed can be measured at the same time. For received signal of fixed target will have a time delay; for moving targets (such as the face direction's goal, the slope of the frequency is negative), then Doppler frequency shift between the transmit signals and receive signals is positive, if the slope of sweep linearity is positive, the Doppler frequency shift is negative. For the departure goal , the Doppler frequency shift is opposite with the the face goal.

After the frequency mixing between echo signal and the reference signal in the non-linear detector, the zero beat output $f_{b.}$ can be getted which is proportional to the target distence. If the round-trip transit time between signal and target is less than the modulation period 1/f, the largest single-valued distance is

$$s_{\max} = \frac{c}{8 f_m} \qquad (2)$$

In the formula,f is modulating frequence,the relationship between beat frequency and target distance is

$$f_b = \frac{4sf_m\Delta f}{c} \quad (3)$$

In the formula, Δf is the entire width of shift frequency.

2.2 Target tracking

Before the the target tracking ,target must be aimed at in general, so that the target are in the search field. because the laser beam scans field is smaller,it can not be quickly covered by the requirement airspace, in order to make laser scanning imaging system have wide search field and aim at target, a mirror can be installed on imaging systems, so it can achieve coarse alignment to target; and then a laser beam will be able to narrow the search as the site to scan, detect, intercept and track the target in the narrow field.

2.3 The principle of objective imaging

In laser scanning imaging system, the beam angle of diffraction limitθ_s can be written as

$$\theta_s = \frac{a\lambda}{D} \quad (4)$$

θ_s is beam angle of the diffraction limit; a is a factor of hole shape, and its value is 1 <a <3; λ for the laser wavelength; D is the effective scanning aperture in the scanning direction. If the beam issued by D cover angle is θ. within angle θ, the number of diffraction limit spot is

$$M = \frac{\theta}{\theta_s} = \frac{D\theta}{a\lambda} \quad (5)$$

Do line scan step by step,so the line images is formed in frame time.after Scanning any cell, and linear array moved a certain angle, you can scan the entire screen, and then these pixels are get together,so a target image reproduction is formed.

3. LASER SCANNING IMAGING SYSTEM'S DESIGN AND ANALYSIS

3.1 Design of laser scanning imaging system

Laser scanning imaging system is mainly composed of laser sources, receivers, transmitters, storage and display devices of the video signal and so on. System of scanning imaging is shown in figure 2.

3.2 Analysis the function of the various parts of laser scanning imaging system

The choice of laser source: the main source used in the laser scanning imaging system is: GaAs、Ar^+、CO_2、Nd：YAG optical maser and so on. These optical maser have different feature when they act as light source in scanning imaging system.The optical maser of Ar^+ can send laser with wavelength of 0.488 μm and 0.5145 μm ,this wavelength have good spectral matching with high efficiency detector,and the target image is clear;however this light souce is larger,have low effection on the transduction,so the scaning imaging systerm is complex, larger volume, high-power consumption.

Because the laser wavelength of the Ar^+ optical maser is in the visible range,so the observers on the other ground can easily find the laser scanning imaging systems. GaAs send laser wavelength is 0.85 μm , which coincides with the peak response of silicon photodetectors,have good hidden,have small size,have high effection.At the same time, plant leaves and the man-made objects have different reflectivity to the laser of GaAs,so,it is easier to find the hidden aim.The drawback of this light source is the limitied Power,which is limit the scanning distance. GaAs laser beam have large

divergence angle, in the two directions of orthogonal X, Y are often inconsistent,so the optical systerm is more complex. CO_2 laser's output power is high, with high conversion efficiency, continuous output power is range of tenswatt to myriawatt, impulse output power is range of kilowatt to 10^5W, the conversion efficiency beteween electric and light is 15~20%,but the increase of working gas's temperature can induce the decreasing of laser gain,the decaying of output power,most of them change electric into heat. Helium - neon laser is the first gas laser,having many laser spectrum in the visible and infrared field,the most important is 0.6328 μm 、1.15 μm and 3.39 μm. under 0.6328 μm laser, the density of N_e^* (2P4) is lower than N_e^* (3S2), and 3S2 have long life ,having many advantages,but the volume is large.

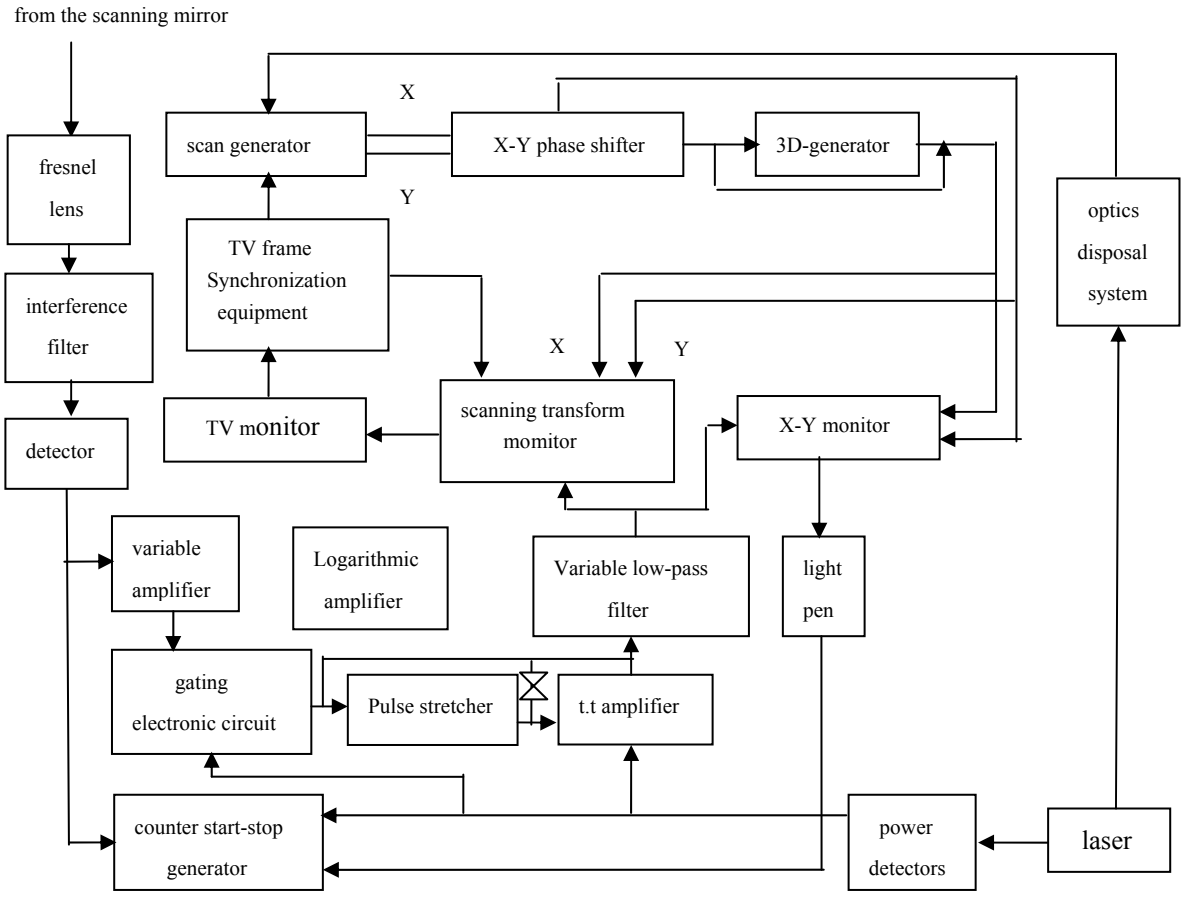

Fig.2 System of laser scanning imagery

Ruby laser is a typical three-level system,with a higher pump threshold. overall efficiency is about 0.2%,the output divergence angle is about1~5 $mrad$, the width of the line is about 0.01~0.1 nm, the width is larger, that is because the laser is generally multi-mode operation, which resulted in larger width of spectral lines; On the other hand ,in the work process, the crystal temperature changes caused the change of wavelength. For continuous wave laser Nd: YAG can produce tenswatts of output power. near-infrared laser with emission wavelength of1.06 μm , because it belongs to a

four-level system,have a higher efficiency, can be accepted by scanning imaging system. However, such lasers' output have a peak structure, laser monochrome is poor, the linewidth is increased with the pump level. By the above-mentioned characteristics of lasers, Nd:YAG is more suitable.

The transmitter of Scanning imaging system is consists of two parts: The first is collimator optical system; Second is scanning devices. Collimating optical system is to change the laser beam into diameter which is meet a certain requirement with the angular divergence. How to design collimation system have a greater impact to the performance of the whole system,it is a key technology. in the designing, a short focal length lens will be used to focuse Gaussian beam,which can get a very small waist spot, and then using a long focal length lens to achieve collimating, change its direction, get collimating parallel-beam.Scanning imaging system's Resolution is deceived by laser spot which is fall on the target.the scanning optical system is crucial to the performance indicators of the entire system.

In the scanning systems, rotor high-speed scanning can match with pulse laser light source with Larger pulse interval,but when the interval is less than microsecond,the linear speed is different achieve the demond of pulse light source,which is powed by electricity,with large moment of inertia.with the rotating mirror scanning, it is easier to achieve optical pulse interval ($< \mu s$ level) ,but in one circle of the rotating mirror only a fan-shaped can be recorded,the Curtate and residual amplitude phenomeno is existence,and the number of amlitude is few.this systerm uses a right-angle prism mirror,it can scaning in 360 degree,match with pulse laser light source,can record sequence map on the rotor in the 360 degree.With the larger collimator optical system, the little divergence angle beam is getted,the resolution of this systerm is increased,but the volume,the weight,and the cost are increased.So when designing,its need to consider carefully.

Laser scanning device have two ways to scan: First, line scan; Second, frame scan. Laser beam sweep the ground along a straight line which is perpendicular to the direction of the course, at the same time, the machine flight forward along the intended direction, so the beam will scan the objection along series of parallel lines,this is line scan.

the laser beam do deflection in two directions,which is similar to TV raster scan, known as the frame scan. what kind of scanning devices is choosen is mainly determined by the performance of the system. Need to take into account about the main parameters: scan speed, scan angle and scanning method. when the scanning speed is low, swing mirror can be used; when the scanning speed is high, choosing rotating the polygon mirror is right.

Scanning imaging system's receiver is consisted of receiving optical system and photo-electric detector. Its role is to detect laser radiation was reflected from the illuminate region, and convert it into a signal. In this system, selectinf an appropriate filter to reduce the impact of the background. For photoelectric detectors, the main consideration is the types and sizes of photoelectric detector when designing.

Scan imaging system's receiver's output signal can be feed to the display, displaying the image scene real-timely, so for the direct observation of the observer.

3.3 The main reference performance data

Optical master: Nd: YAG laser

Wavelength: 1.06 μm

Operation: continuous wave operation mode, TEM output 4.5W; pulse operation, use the sound-optical to change Q

Repetition rate: 25 kHz

output power: 1W

Scanning: fired scanner and receiving scanner synchronous

Scan rate : 1.5 rad / s

Scan range: 130^0

Horizontal deflection mirrors : 2.0×2.0 cm
Vertical deflection mirrors : 2.0×4.5 cm
Vertical scanning speed : 2 Hz
Receiving lens: the diameter is 20.5 cm, focal length is 18 cm of the Fresnel lens
Detector: Silicon avalanche photodiode
Display: two television monitor with2000 line
Recorder: Video signal tape recorder

4. APPLICATION AND PROSPECTS

Laser scanning imaging system's first study is in the, Perkin-Elmer companies of United States, and in 1963 the company made a patent application. Since the 70s, the development work of laser scanning imaging system are focused on two aspects: First is to develop other optical maser with other lights ource in the scanning imaging system; Second is develop three-dimensional imaging systems.

The application of laser scanning imaging system is very broad:

(1) This systerm is not only to scan, collect information of the reflection coefficient,but also to measure distance by laser,so can getting the information of distance. and then integrate the reflect information with the system information,getting the scene of three-dimensional images.

(2) The system can be used for night reconnaissance. As such detection devices do not need flash or other light source which can light a large area, but they can get very clear high-resolution images, so the machine viability is enhanced on other's over ground.

(3) The device can also be used to identify friends and enemies, mapping topographic, search in night and rescue ,and environmental protection and surveillance.

(4) With the development of the laser, infrared, low-light, television, fiber optics, holography , modern optical technology and their combine with computer technology, electronic technology, making the optoelectronic technology, laser scanning imaging technology are widespread in the reconnaissance, navigation, guidance, fire control, command, control, communications, and any other military applications. In the future war, a variety of threats will become increasingly serious, and therefore how to combat the threat of photoelectric is an important issue. The technical of laser weapons is difficulty, and development cycle is long, but also have risks. To develop a practical and effective scan imaging systems, laser weapons, three key technical issues need to resolve: first, to develop high-energy laser with sufficient energy and excellent beam; second is to develop a sophisticated tracking system; third is to develop anti-radiation beam sent control system; Fourth is to know laser propagation in the atmosphere and the damage mechanism of the laser to target.

Strategic laser weapons is an important component in the future.when developing the laser weapons, the country and the world are making great efforts to develop measures against laser weapons, so in the laser weapons,the confrontation betwween against the antiagainst tend to become fierce.

REFERENCES

[1] Zhang chengquan. Manual of foreign military laser equipment [M]. Beijing: Ordnance Industry Press, 1989.

[2] Wang zhijiang. Optical Technical Manual [M]. Beijing: Mechanical Industry Press, 1987.
[3] He Anzhi,Yandapeng.laser transient interference measure. Beijing: Mechanical Industry Press, 1993.
[4] Wang Qianqian,Liu jinghai, Lin Yuna. The determine of sampling parameters of Rosette scanning imaging system [J]. Infrared and Laser Engineering, 2002,31 (4) :338-340.
[5] Mei Suisheng. Optoelectronics technology [M]. Beijing: National Defense Industry Press, 1999.
[6] Dang KV, Kauffman. CL, Derzko ZI.SPIE ,1992,1686:126-134.