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Generation Method Of Laser Beam Riding Guidance Information Field Based On Optical Phased Array

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Abstract. Laser beam riding guidance was a new concept of guidance technology put forward in 1970s. It is widely used in various laser guided weapon systems. The technology of generating information field in the laser beam riding guidance system is the key of the system. However, the traditional laser beam riding guidance technology needs complex mechanical devices for the generation of guidance information field, optical zoom control and so on. There are many problems, such as the complex structure and it is difficult to guarantee the precision. In this paper, Optical Phased Array (OPA) is used to explore a new method of generating laser beam riding information field, which can realize the non-inertia and rapid deflection control of the beam.

1 Introduction

Laser beam riding guidance[1] is a commonly used technology for gun launched missiles. The basic process is that the shooter operates the sight guidance instrument, and aims at the target in the field of view. The laser beam is transmitted to the target by the coaxial laser with the sight (the laser beam is the guidance information field through the space coded modulation). After the missile enters the laser guidance information field, it can constantly adjust its direction so that it will continue to fly in the direction of the target until it hits the target[2].

The guidance device is the focus of the laser beam riding guidance system. The traditional guidance devices include target sighting device, laser and guiding beam forming device. The guiding beam forming device includes a mechanical modulating disk system and an optical zoom system. The function of the modulation disk is to encode the space frequency of the laser beam emitted by the laser and form the guidance information field. The modulation disk system includes two parallel modulation plates for the frequency coding of the pitch direction and the yaw direction [3-4]. A schematic diagram of the modulation disk system is shown in figure 1.

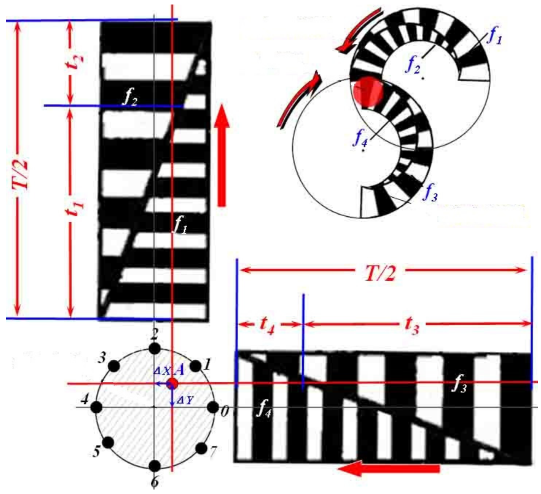

Figure 1. Modulating disk system

The modulation disk system consists of two parallel modulation disks, of which one is for pitch frequency coding and the other one is for yaw frequency coding. On the edge of the two modulation disks are the half-circle grating fringes which are transparent and opaque. The center of the grating pattern coincides with the center of the modulation disk. The two reticles have been rotated at the same speed and opposite direction. Because the phase difference is π, when the laser emits a continuous laser beam, the two modulation disks cut the laser beam in the first half period and the second half period in turn, and encode the pitch and yaw direction information of the laser beam, forming five modulation beams with the frequency. Figure 2 shows that the process of missile flies in the information field.

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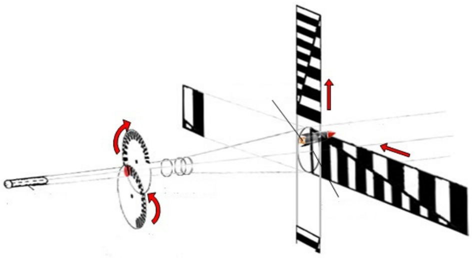


Figure 2. Process of Missile flies

Optical phased array technology is a new type of beam deflection control technology which started in the last century [5-6]. It uses a programmable phase array element whose principle is the real-time phase modulation to realize the wavefront control of the light wave and complete the deflection of the beam. Because of the online programmable of optical phased array, it can achieve more flexible, more accurate and faster non mechanical beam control. It has many advantages such as strong anti-interference and high resolution[7].

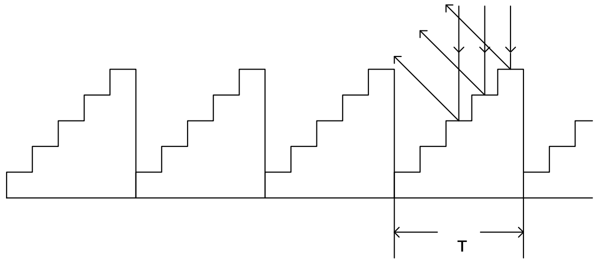
In this paper, a new beam deflection control method is adopted to replace the traditional mechanical beam control. The optical phased array technology is combined with the laser beam driving guidance technology to realize the accurate control of the laser beam direction and the generation of the information field. The system avoids the traditional mechanical information field generating device. This method has important research value and significance for improving the stability and accuracy of laser beam driving guidance system.

2 Deflection principle of liquid crystal phased array

The principle of liquid crystal spatial light modulator (LCSLM) controlling the beam propagation direction deflection is similar to the blazed grating. When the wavelength is constant, the phase is proportional to the optical path[8-9].

$$L = n_e \bullet l \qquad (2.1)$$

l is the thickness of LC， n_e is refractive index of unusual light. For a certain LCSLM device, the thickness of the liquid crystal layer is a fixed value. When the incident beam is projected on the LCSLM surface, a specific voltage signal is applied to the liquid crystal cell in the LCSLM device, causing size of the n_e changes. It causes the phase tilt of incident light wave and beam deflection control [10]. Figure 3 shows the principle of the blazed grating. Due to the sine characteristic of the light wave, it has no influence on the distribution of light field in its far field by the 2π and 2π integer times addition and subtraction to its phase. Add inclined phase to liquid crystal molecular unit and calculate 2π remainder, the periodic arrangement of the stepped phase distribution shown in the graph can be generated, the period is T .



Firgue 3. Blazed grating

Assuming that the incident light is parallel light, the amplitude of complex amplitude is equal to 1. When the light wave is vertically incident to the surface of the liquid crystal cell, it deflects after reflection. In a T period, the phase difference between Adjacent steps is

$$\Delta\varphi = \frac{2\pi}{\lambda} \bullet \Delta n \bullet 2l \qquad (2.2)$$

λ is the working wavelength, Δn is the refractive index difference between adjacent steps, l is the thickness of the liquid crystal layer in the liquid crystal phased array. In each period,the complex amplitude function of light wave after deflection is equal to

$$t(x,y) = \sum_{n=0}^{N-1} rect\left(\frac{x-nd}{d}\right) \exp\left(ik\frac{2\pi}{\lambda} \bullet \Delta n \bullet 2l\right) \qquad (2.3)$$

d is the center distance between two adjacent steps, assume the width of the LCD pixel unit is also d , N is the number of steps in a T period.

Assume the blazed angle of blazed grating in LCSLM is φ， and $f_0 = \frac{2\sin\varphi}{\lambda}$. Because the value of φ is small, it can be obtained based on geometric relations. $\Delta n l_0 \approx d_1 \sin\varphi$， substituted into (2.3) has

$$t_0(x,y) = \sum_{n=0}^{N-1} rect\left(\frac{x-nd}{d}\right) \exp\left(i2\pi k d_1 f_0\right) \qquad (2.4)$$

Make FFT transformation for $t(x,y)$, the complex amplitude distribution of liquid crystal phased array can be obtained in one period.

$$T_0(x,y) = F\left[t_0(x,y)\right] = d_1 \sin c\left(d_1 f_x\right) \frac{\sin\left[\pi\left(f_x - f_0\right) N d_1\right]}{\sin\left[\pi\left(f_x - f_0\right) d_1\right]} \qquad (2.5)$$

$f_x = \frac{\sin\theta}{\lambda}$ is frequency domain independent variable， θ is the diffraction angle of the LCSLM.

The complex amplitude reflection function is extended to all effective regions of the whole liquid crystal phased array.

$$t(x) = \sum_m \delta\left(x - mNd_1\right) * t_0(x) \qquad (2.6)$$

If $t(x)$ is made fast FFT transform, the result of the substitution of FFT (2.5) can be obtained.

$$\bar{E} = \frac{1}{N}\sum_{m} \sin c\left(d_1 f_x\right) \frac{\sin\left[\pi\left(f_x - f_0\right) N d_1\right]}{\sin\left[\pi\left(f_x - f_0\right) d_1\right]} \delta\left(f_x - \frac{m}{N d_1}\right) \tag{2.7}$$

This is the result of one-dimensional complex amplitude distribution of liquid crystal phased array diffraction. According to $f_x = \frac{\sin\theta}{\lambda}$, $f_0 = \frac{2\sin\varphi}{\lambda}$, and the grating equation of vertical irradiation with light wave $Nd_1 \sin\theta = m\lambda$, Formula (2.7) can be written as

$$\bar{E} = \sum_{m} \left\{ \frac{\sin\frac{m\pi}{N}}{m\pi} \bullet \frac{\sin\left[\pi\left(m - \frac{2Nd_1\sin\varphi}{\lambda}\right)\right]}{\sin\left[\pi\left(m - \frac{2Nd_1\sin\varphi}{\lambda}\right)/N\right]} \right\} \delta\left(f_x - \frac{m}{Nd_1}\right) \tag{2.8}$$

For the m diffractive light , $f_x = \frac{m}{Nd_1}$, that is $\frac{\sin\theta}{\lambda} = \frac{m}{Nd_1}$. Order $m = 1$, the expression of the first order diffraction angle of LCSLM can be obtained

$$\theta = \sin^{-1}\left(\frac{\lambda}{Nd_1}\right) \tag{2.9}$$

It can be seen from the formula (2.9) that the size of the first order diffraction angle of LCSLM is related to the working wavelength λ, the number of steps N in a blaze cycle and the width of the liquid crystal pixels d_1 . For a specific liquid crystal phased array device, the working wavelength and the width of the pixel unit are fixed, so the size of the diffraction angle θ is only related to the number of steps N , and it is inversely proportional. Because most of the energy after LCSLM diffraction is concentrated in the first order diffraction light, the angle of the first order diffraction angle is usually regarded as the deflection angle of the LCSLM beam.

3 System and experiment

The core device used in this paper is HEO1080P liquid crystal spatial light modulator（LCoS）, which is a reflecting LSM constructed by HOLOEYE company. The object is shown in Figure 4.

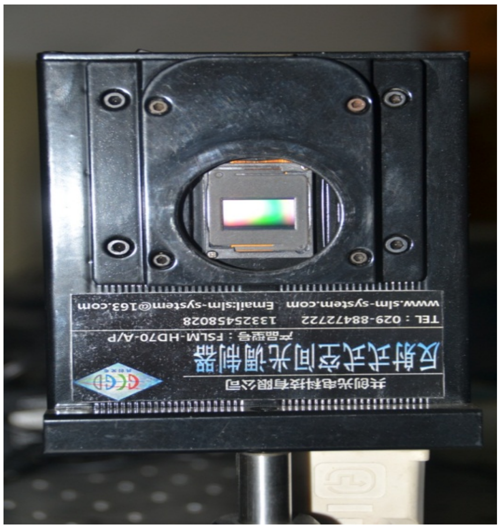


Figure 4. HEO1080P spatial light modulator

The Specific parameters of HEO1080P is shown in Table 1.

Table 1. HEO1080P parameters

modulation style	pure phase modulation
phase range	0- 2π
resolution	1920x1080
pixel interval	8μm
Filling factor	>87%
diffraction efficiency	>60%
Optical path type	Reflection type
frame rate	60 Hz

The system optical path is shown in Figure 5.

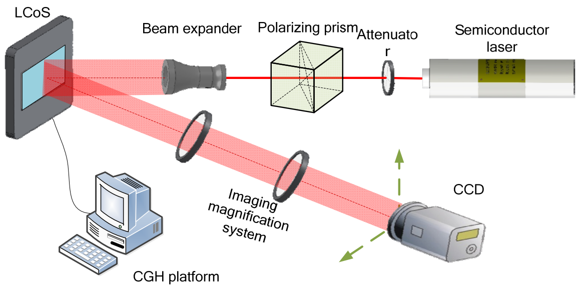


Figure 5. System optical path

The optical components are placed on the optical test platform according to the optical path design, and the positions between the components are carefully adjusted. The diode laser (1) launches the laser, obtains the line polarized light through the partial prism (2), and the beam enlargement mirror (3) carries out the 1:5 beam of the laser beam, projecting to the LCoS panel (5). In experiment, LCoS was connected with CGH platform through DVI serial port. The computer output mode is set as a double screen display mode, and LCoS is used as an extension screen of the computer, and the Fourier gray fringe pattern of computer output is displayed directly. After the laser beam is reflected, diffraction phenomenon occurs, and the information field pattern can be reconstructed in the far field. In the laboratory environment, the Fourier lens (7) is added to the diffractive optical path to eliminate the two phase factor in the Finel diffraction, and the Fourier transform spectrum of the diffracted light field can be obtained on the rear focal plane of the lens, which is the clear pattern of the information field. The function of the second lenses (9) in the reproducing light path is to magnify the reproduced patterns for easy observation. Figure 6 shows the experimental platform.

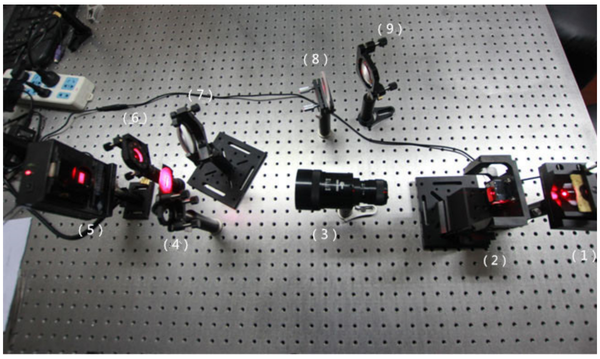


Figure 6. Experimental platform

Figure 7 (a) is a binary image， 7 (b) is its gray hologram, and 7 (c) is the intersecting surface image of laser beam by the modulation of the system, which reproduces the original binary image. The higher order diffraction image is not captured here, only the first order diffraction image is preserved. The spot in the image is the zero level spot in the diffraction process. In the actual optical path, the zero order spot and the conjugate symmetry can be filtered out by adding a spatial filter, and the original image can be retained.

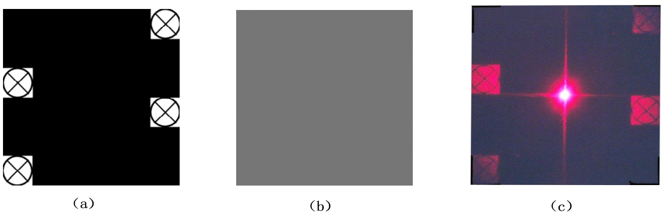


Figure 7. Experimental result

4 Summary

In this paper, we use liquid crystal phased array method to study the technology of information field generation. The principle of the traditional laser beam driving guidance is introduced first. Then, the principle of optical phased array is analyzed. The experimental results verify the feasibility of generating laser beam guidance information field based on the method of liquid crystal phased array. The intersecting surface image of the information field is a series of periodic variations of the vertical stripe, and the binary images of the same pattern with the intersecting surface image of the information field are generated by the computer, and the gray hologram of the information field is calculated. The photoelectric reproduction is the desired information field beam. This method has a great advantage over the traditional methods.

References

1. Wang Kuangbiao. Current status, key technologies and development of laser guided weapons. (2007)
2. Zhen Jianwei, Wu Lili, Li Jinming. The development and battlefield application of laser beam riding guidance mechanism ammunition.(2017)
3. Qian Yixian,et al. Research of Eneoding and Modulation Technology on Laser Beam-riding Guidance.(2006)
4. Li Na, Wang Hong. Design of modulation disk for laser-beamriding guided sighting instrument.(2011)
5. McManamon P. An overview of optical phased array technology and status.(2005)
6. Dorschner T A, Friedman L J, Holz M, et al.. An optical phased array for lasers. (1996)
7. Zhang Jian, Xu Lin, Wu liying, Liu Xiang, Zhang Jinchang. Programmable beam deflection of liquid crystal optical phased array. (2008)
8. Xiao Wenben. Research on beam deflection control technology based on liquid crystal optical phased array.(2013)
9. Cai Dongmei, Xue Lixia, Ling Ning, Jiang Wenhan. Characteristics of phase only liquid crystal spatial light modulator.(2007)
10. Zhao Xiangjie. Key technologies and applications of liquid crystal phase control arrays.(2014)