An enhancement method of waveform simulation in dual-color laser field imaging based on Internet of Things

Jing Yin¹ · Xiao-lin Xu¹ · Xiao-hua Xiong¹ · Zbigniew Marszałek²

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Abstract

In view of the fact that the existing methods are easy to be affected by nonlinear factors in the incident process of the light source, resulting in the received shock wave inconsistent with the reality and large calculation error, a two-color laser field imaging waveform simulation and enhancement method based on the Internet of things is proposed. According to the automatic transformation characteristics of augmented reality technology, the waveform simulation control process of two-color laser field imaging is constructed. The Gaussian distribution characteristics are used to analyze the target, the optical grid and double oscillation device are used to control the results, the spectrum Fourier transform is used to adjust the phase of the waveform, and finally the simulated modulated laser waveform is output. Through the comparison of laser waveform spectrum and peak value, the results show that this method is closest to the actual laser waveform, saves calculation time, and has good practical application effect.

Keywords Augmented reality technology · Dual-color laser field · Laser imaging · Waveform simulation · Waveform phase control

1 Introduction

Internet of things is the product of the rapid development of information technology, also known as sensor network technology, which can realize intelligent identification and accurate management of targets. The Internet of things is becoming an indispensable part of daily life, supporting a variety of emerging services and applications [1]. Laser generation has promoted the development of many emerging technologies. Nowadays, the development of lasers plays an important role in scientific research or daily life. Among them, the most critical research is the interaction between laser waves and matter. All laser wave physics and laser wave chemical phenomena are the interaction between laser waves and matter [2]. Therefore, studying the relationship between laser waves and matter is not only a key subject in

the fields of physics and chemistry, but also research subjects in the fields of biology, electronics, and medical.

At this stage, the enhancement of waveform simulation in dual-color laser field imaging can effectively clarify the correlation between the laser and the substance, and enhance the laser imaging effect. For the problem of the simulation enhancement result being unsatisfactory and deviating from the actual situation, the relevant research scholars proposed the enhancement method for grating-layer laser waveform simulation. By adjusting the thickness of the air layer, the filter device can complete the adjustment of the waveform simulation length to 75 nm, and the line width is not greater than 1 nm. Then, the resonant wavelength adjustable filter device with an intermediate waveform length of 1.55 m is perpendicular to the transmitting device and integrated, completing the waveform simulation enhancement. The results show that the method is simple, but the enhancement efficiency is not high, there is a large error between the calculation results and the actual results, and the practical application effect is poor [3]. Wang et al. dealt with the problem that the bandwidth channel will be interfered in the process of simulating laser imaging waveforms by adding a frame delay array. Analog laser imaging waveforms of four parallel channels are constructed firstly. The microwave laser

✉ Zbigniew Marszałek
zbigniew.marszalek@polsl.pl

¹ Shanghai Polytechnic University, Shanghai 201209, China

² Faculty of Applied Mathematics, Silesian University of Technology, 44100 Gliwice, Poland

sub-filter device of each channel has the characteristics of second-order phase. The analog waveform signal is passed through the filter device by the impulse-limited response filter device, a multi-channel frequency modulation signal obtained are sent to the linear array of each channel, and fiber dispersion is used to adjust the delay of each channel signal to complete the beam simulation enhancement. The calculation process of this method is complex, it is easy to produce deviation in the actual calculation process, which is greatly different from the actual waveform, and the practical application effect is poor [4]. Wavelet forms are very efficient in IoT imaging systems to simplify objects for further processing [5] and dynamic systems positioning over time interval spectra [6].

Based on this, this article uses the Internet of Things technology to perform enhancement of waveform simulation in dual-color field laser imaging, and uses Gaussian distribution and Cartesian coordinate system to obtain the simulated laser waveform in this process. Then, the length and phase of the waveform are adjusted and the auxiliary waveform simulation is enhanced by using spectral light grid and dual oscillation equipment, Fourier transform, etc. Experiments show that the waveform spectrum and peak value of the proposed method are basically consistent with the actual laser waveform. The practical application effect is good.

2 Acquisition of simulation waveform in dual-color laser field imaging

2.1 Emission source of dual-color laser field imaging

According to the acquisition process of waveform simulation in dual-color laser field imaging [7], if the laser device is selected as the *QNd*: YAG solid-state laser device, the length of the sent simulated laser waveform can pass through the atmospheric window [8], and the sent simulated laser waveform conforms to Gaussian distribution characteristics in both time and space. Then it can obtain:

$$\begin{aligned} I(r) &= \frac{1}{2\pi d^2} \exp(-r^2/2d^2) \\ P(t) &= 2\pi \delta \exp(-2\delta) \\ d &= z \tan \theta_T \end{aligned} \quad (1)$$

In the formula, $I(r)$ represents the simulated emission intensity of the dual-color laser field imaging waveform to the center of the light source, $P(t)$ represents the waveform emission power at time t , d represents the diameter of the light source, z represents the distance of the light source along the optical axis, and θ_T represents the light source divergence angle on the center energy $1/e$ of the light source, r represents

the distance from the point on the light source to the center, E represents the energy of the simulated waveform of dual-color laser field imaging, and δ represents the root mean square width of the laser waveform.

2.2 Target object of light source in dual-color laser field imaging

The target object that emits the light source is extremely cumbersome. Basically, the target object is regarded as a stack of multiple linear planes and tiny undulations. For this reason, the rectangular coordinate system method is used to further analyze the target object of the light source [9].

The intersection of the midpoint of the beam and the horizontal line of the ground is set as the origin of the coordinate; the light source's movement direction is set to the x -axis direction; the zenith direction is set to the y -axis direction; the right-hand screw rule is set as the axis z and the coordinate system is as a horizontal coordinate system; the direction of the midpoint of the dual-color laser field source is set as the x' axis, the y' axis and y are set to overlap; and the z' axis is set to be the same as the Z axis. This coordinate system is regarded as the measurement coordinate system [10] Fig. 1.

At the same time it can set: ϕ represents the angle produced by changing the zenith direction to the waveform axis of dual-color laser field imaging, clockwise is positive, otherwise, it is negative. For this reason, the transformation link between the two coordinate systems can be obtained as:

$$\begin{aligned} x' &= x \cos \phi - z \sin \phi \\ y' &= y \\ z' &= x \sin \phi + z \cos \phi \end{aligned} \quad (2)$$

Fig. 1 The spatial relationship between the peak value of the incident laser waveform from the light source and the ground target object

The target object on the laser source basically adopts the horizontal coordinate system method, which is represented as

$$h(x, y) = x \tan \sigma_{//} + y \tan \sigma_{\perp} + \Delta h(x, y) + h_0 \quad (3)$$

Where, $h(x, y)$ represents the peak range of the target object, $\sigma_{//}$ and $\sigma_{\perp}$ represent the angle between the horizontal and vertical motion trajectories of the target object, $\Delta h(x, y)$ describes the microscopic roughness of the target object, and h_0 describes the degree of offset. The target object is transformed into the measurement coordinate system, namely

$$h(x', y') = \tan(\phi + \sigma_{//}) \cdot x' + \cos(\phi + \sigma_{//}) \cdot y' + \frac{\tan \sigma_{\perp} \cos \sigma_{//}}{h_0 \cos \sigma_{//}} \Delta h'(x', y') + \cos(\phi + \sigma_{//}) \quad (4)$$

2.3 Waveform peak measurement

Currently, the simulation peak method of dual-color laser field imaging waveform basically uses peak measurement equipment [11]. When the emitting laser source is incident on the crystal, the receiving device receives the average reflected energy value, and it is obtained:

$$n_s = [\rho \cos(\sigma + \phi) T_0^2] \pi h^v z^2 \eta_q \eta_r E A_r \quad (5)$$

At the same time, it is concluded that the waveform analog signal of dual-color laser field imaging will be broadened in the time domain, and the broadening value is described as:

$$\sigma_t = \frac{2z}{c} \tan(\sigma + \phi) \Delta \theta \quad (6)$$

Where, ρ represents the reflection factor of the incident crystal, h^v represents the energy of the light source, η_q represents the light source efficiency of the peak measuring device, η_r represents the transmission probability during the process of receiving the dual-color laser field source, σ represents the average tilt angle of the target object, and $\tan^2 \sigma = \tan^2 \sigma_{//} + \tan^2 \sigma_{\perp}$, $\Delta \theta$ represents the observation angle, when θ is taken as 6 times, $\Delta \theta = 6\theta_T$ is obtained, A_r represents the aperture of the receiving port, and T_0 represents the atmospheric attenuation coefficient.

In summary, the laser device is sent to the surface of the target object for crystal reflection, and transported to the field of view of the receiving device. After the photoelectric conversion function of the peak measurement equipment, the low filtering of the filtering equipment and the quantization process of the digital instrument, the analog laser waveform is obtained [12].

3 Waveform simulation enhancement analysis of dual-color laser field imaging

3.1 Wave length adjustment

The wavelength of simulated laser imaging has a certain impact on the obtained waveform. Through phase modulation, the two-color laser field imaging waveform is longer and the spectrum is wider, which is conducive to improving the accuracy of simulated laser waveform. For the uniform gain medium of dual-color laser field imaging, the waveform transmission equation, that is, the inversion population equation is as follows:

$$\frac{\partial I(z, t)}{\partial t} = \sigma N(z, t) I(z, t) \quad (7)$$

$$\frac{\partial N(z, t)}{\partial t} = \frac{F\sigma}{h\omega} N(z, t) I(z, t) \quad (8)$$

In the formula, $I(z, t)$ represents the light intensity required for dual-color laser field imaging, $N(z, t)$ represents the number of inverted particles, σ is the stimulated emission interface, and F is the saturation factor.

That is, the total modulus of the number of inverted particles in the gain medium is $N_{tot}(t) = \int_{z=0}^{z=L} nN(z, t) dz$, the gain in the amplification process is $G(t) = \exp(\sigma N_{tot}(t))$, and the saturated energy flux is $J_{sat} = \frac{h\omega}{F\sigma}$, then:

$$\frac{dN_{tot}(t)}{dt} = -\frac{1}{J_{sat}\sigma} (I_{tot}(t) - I_{in}(t)) \quad (9)$$

Assuming that the light field of dual-color laser imaging is $E_0(t) = A_0 \exp(j2\pi\nu_0 t)$ before modulation, A_0 is the light field amplitude, and ν_0 is the light field frequency. Any modulation signal can be expressed as a superposition of infinite sinusoidal signals, such as:

$$m(t) = \sum_{k=1}^{\infty} r_k \sin(2\pi\nu_k t + \phi_k) \quad (10)$$

In the formula, the amplitude of the k -th waveform sine signal is r_k , the phase is ϕ_k , and the frequency is ν_k .

The modulated light field is:

$$E_m(t) = E_0(t) \exp \left[j \sum_{k=1}^{\infty} r_k \sin(2\pi\nu_k t + \phi_k) \right] \quad (11)$$

In addition to the initial frequency ν_0 , the dual-color laser field imaging waveform after modulation also has a frequency component of $\nu_i = \nu_0 + \sum_{k=1}^{\infty} k\nu_k$, and the corresponding amplitude is:

$$A_i = \sum_{k=1}^{\infty} \prod_{k=1}^{\infty} (-1)^n J_{n_k} \exp(jn_k \phi_k), i = 1, 2, \dots, +\infty \quad (12)$$

That is, the phase modulation makes the dual-color laser field imaging waveform longer and the spectrum wider.

The dual-color laser field imaging device uses a laser grating as a feedback and frequency control device [13]. The device will obtain that the wavelengths of analog laser imaging are all within the resonant wavelength of the grating.

$$\lambda = 2n_{eff}L \quad (13)$$

Where, n_{eff} represents the refraction probability of a dual-color laser field imaging device, and L represents the operating cycle of the device. When the temperature and stress factors change, the grating period of the device or the refraction probability of the core will also change, causing the Bragg intermediate wavelength of the dual-color laser field imaging to shift [14]. Because the harmonic interval of the single-oscillation device is fixed, the process uses a double-oscillation device with a customizable intermediate wavelength, and completes the wavelength acquisition in the $[-4 \text{ nm}, 4 \text{ nm}]$ interval through the laser switch conversion operation mode. The intermediate wavelength of these two oscillators is selected as 1051.9 nm and 1052.6. The harmonic interval is $[-0.5 \text{ nm}, 0.5 \text{ nm}]$, the control wavelength can cover $[1050.2, 1054.9]$ and the actual harmonic shape interval of this process is $[1050.4, 1054.8]$. The harmonic shape after adjustment is basically consistent with the actual harmonicity, which is close to reality [15].

3.2 Optical waveform phase control

The formation of the dual-color laser field imaging wave is mainly based on the phase adjustment of the dual-color laser field imaging waveform of the Internet of Things technology. The signal generated by the radio frequency signal is passed through the analog RF signal of dual-color laser field imaging wave formed by the Internet of Things equipment, and the length of the analog waveform of dual-color laser field imaging is adjusted. The RF signal amplifying device is amplified and stored in the crystal, and the refraction probability of the crystal is changed due to the photoelectric effect, thereby changing the phase of the analog wave in dual-color laser field imaging [16]. The dual-color field of the incident simulated laser can be represented as:

$$E_{in} = A_0 \exp\left(-\frac{t^2}{2t_0^2}\right) \exp(i\varphi_0) \quad (14)$$

Where, A_0 represents the initial amplitude of the incident simulated laser wave, t_0 represents the initial pulse width of the laser wave, and φ_0 represents the initial phase of the laser

wave. If the enhanced radio frequency signal is adjusted by the sinusoidal phase, the dual-color field of the simulated laser wave is described as:

$$E_{out} = A_0 \exp\left(-\frac{t^2}{2t_0^2}\right) \exp[im \sin(2\pi f_m t + \varphi_{RF})] \quad (15)$$

Where, m represents the control depth, f_m represents the control frequency, and φ_{RF} represents the phase of the RF signal source. This process only needs to consider the occurrence of phase 1 and phase 2 regulation. Regarding the spectral width only relying on phase control, the laser waveform term is ignored in the traditional method [17], and the dual-color field after phase control can be described as:

$$a_0(t) = \exp[im \sin(2\pi f_m t)] \quad (16)$$

The dual-color laser field imaging wave is based on the spectral Fourier transform method, and the formula (17) is obtained.

$$A(f) = \int a_0(t) \exp(-i2\pi ft) dt \quad (17)$$

$$a_0(t) = \int A(f) \exp(i2\pi ft) df$$

Regarding the modulation of the waveform signal in dual-color laser field imaging, it has certain periodic characteristics, and the adjusted spectrum is obtained according to the discrete Dirac peak method.

$$A(f) = \sum_{k=-\infty}^{\infty} J_k(m) \delta(f - kf_m) \quad (18)$$

Where, $J_k(m)$ represents the k -th valence Bessel function, and $\delta(f - kf_m)$ represents the Dirac function. The band width $\Delta f = 2(m+1)f_m$ contains 98% of the energy of the dual-color laser field spectrum. If the second level of phase control occurs at the same time, the spectrum is considered to be the convolution of the two.

Figure 2(a) represents the spectrum of a dual-color laser field device, and the 4 dB laser spectrum bandwidth is 0.5 nm. According to Fig. 2, when the input power of the radio frequency signal is increased and the depth of control is increased, the side frequency power of the dual-color laser field spectrum increases, and the main peak power decreases. If the dual-color laser field spectrum after the first level of phase control has two main sidebands, they are distributed symmetrically, and the 4 dB spectral bandwidth is 1.8 nm. The spectral distribution is shown in Fig. 2(b); if it does not pass the first level phase adjustment, when only passing the second level phase adjustment, the dual-color laser field spectrum shows several sidebands, and the 4 dB spectral bandwidth is 2.4 nm. In this case, the spectrum is shown in Fig. 2(c); if two equal levels are passed after phase adjustment, the 4 dB laser spectrum bandwidth is 5.1 nm.

Fig. 2 Different levels of phase control results

In this case, the spectrum distribution is shown in Fig. 2(d). After changing the radio frequency power, the depth of control can be changed, and the waveform spectrum shape of the dual-color laser field imaging delivered by the process can be further transformed. The process sends out the dual-color laser field imaging spectrum with continuous adjustment in the wavelength range of 0.5 to 5.1 nm, with extremely high spectrum broadening performance of dual-color laser field.

The analog waveform will be obtained through the second-level waveguide phase control equipment to form a short-bandwidth dual-color laser field wave. The initial dual-color laser field waveform is transmitted along the laser transportation channel, and the energy value of the dual-color laser field waveform is increased by approximately 80 nJ after the third-level amplification device. When the dual-color laser

field imaging waveform formed by channel 2 is activated, the second-level amplitude control device performs two time-domain noise control on the initial shaping laser waveform. Therefore, the output energy of the obtained laser waveform is 16nJ, and the 15 μm dual-color field amplification device is used to process the laser waveform, and finally a micro-focus level analog dual-color laser field waveform with a certain bandwidth and time shaping function is obtained, that is, the simulated and regulated laser waveform [18].

3.3 Application based on Augmented Reality Technology

Augmented reality technology is a kind of technology in the simulation reality method, which is to add simulation

data through the actual environment to affect the sensory organs [19]. Using this technology can get more assistance data about the operating environment and objects, and build a good perception. With this perception, the operator can undoubtedly make extremely accurate and efficient judgments, and better control the waveform simulation of dual-color laser field imaging. Based on this characteristic, it is assumed that augmented reality technology can be applied to the waveform simulation of dual-color laser field imaging, which can significantly improve the application and operating efficiency of the laser waveform simulation control process [20].

First of all, the use of augmented reality technology can achieve two transformations, making the operation process more intuitive and concise. The first kind of transformation is as: through simulation in the three-dimensional space presented by the dual-color field, the dual-color laser field waveform analog signal data is obtained, which can transform the control operation into the interactive process of the target object in the dual-color field and the simulated object [21]. The second kind of transformation is as: the user's operation of the dual-color laser field waveform simulation can be automatically transformed in real time into sending the receiving device control instructions. Taking into account the characteristics of the target object, this interactive form can be mastered by the target object in a very short time, and it is easy to be used and promoted.

Secondly, augmented reality technology can make the interaction process more efficient and safer. The purpose of virtual reality technology is to isolate the target object from the surrounding real environment in order to provide an immersive mode; and the display content of augmented reality technology is built on the theory of the surrounding reality environment. For this reason, when using augmented reality technology to control the operation process, the target object can see the surrounding details at the same time, and directly do some panel operations without repetition, and the simulation result is closer to reality.

The original image can be regarded as composed of the illuminating light image $L(x, y)$ and the reflection image $R(x, y)$ that characterizes the essential properties of the object. The relational expression of the I component can be expressed as:

$$S_I(x, y) = L(x, y) \cdot R(x, y) \quad (19)$$

In the formula: $S_I(x, y)$ is a known quantity. The I component of the input image can be regarded as the product of the incident light image and the I component of the reflected image, and the I component is relatively independent of the H component and the S component. The principle of multi-scale algorithm is applied to the I component:

$$r_{MSRI}(x, y) = \sum_{k=1}^K W_k [\log S_I(x, y) - \log (G_k(x, y) * S_I(x, y))] \quad (20)$$

In the formula: K represents the number of scales, and ω_k represents the relative weight of the scale k , and satisfies $\sum_{k=1}^K \omega_k = 1$. And on this basis, it performs adaptive global adjustment to reduce the degree of distortion of the waveform, that is, to increase the characteristics of the image that affect the waveform through the global adjustment of the image histogram [22, 23], so that the maximum value of the waveform characteristics of the image at (x, y) is:

$$S(x, y) = \max (S_r(x, y), S_g(x, y), S_b(x, y)) \quad (21)$$

In the formula, $S_r(x, y)$, $S_g(x, y)$ and $S_b(x, y)$ respectively represent the different values of the image waveform characteristics, and the image is adjusted globally, expressed as:

$$S^* = S^{\frac{1}{\gamma}} \quad (22)$$

Where: $\frac{1}{\gamma} = \min \left(1, \frac{1}{6} \bar{S}_{at} + \frac{2}{3} \right)$ represents the degree of curvature of the global dynamic range waveform, $\bar{S}_{at}$ is the average value of the overall amplitude of the image in the logarithmic domain, that is, $\bar{S}_{at} = \frac{\sum_{pet} \log (S(P))}{N}$, N is the number of image pixels. The lower the value of $\bar{S}_{at}$ is, the greater the degree of waveform change is. The saturation is adjusted by extracting the change characteristic information of the waveform and using it as an adaptive factor. The adaptive factor is:

$$\alpha = K \sum_x^m \sum_y^n |i(x, y) - \bar{i}(x, y)| \quad (23)$$

In the formula, $\bar{i}(x, y)$ is the average value of the image waveform characteristics, and $i(x, y)$ is the original value of the image waveform characteristics. Combining the maximum value information of the original image waveform and using the adaptive factor α can adjust the waveform characteristics. The adjustment is:

$$S'(x, y) = s_{\min} + \alpha \frac{[s(x, y) - s_{\min}]^2}{s_{\max} - s_{\min}} \quad (24)$$

By analyzing the weight basis function of adaptive detail enhancement to determine the enhancement area, the weight basis function is:

$$f(x) = \frac{1}{\alpha + \left(\frac{T}{|x|}\right)^\beta} \quad (25)$$

In the formula: β is the attenuation speed parameter, which is used to assist in the control of the waveform simulation enhancement range. The greater the attenuation speed is, the waveform simulation detail enhancement range is small, and vice versa, the enhancement range is large.

Assume that the noise mask function $m(i, j)$ contained in the dual-color laser field imaging waveform is used to measure the spatial details of the waveform, which is related to the local variance of the dual-color laser field imaging waveform, and the noise visibility function $v(i, j)$ is used to characterize the relationship between the noise visibility and the mask function, expressed as:

$$v(i, j) = \frac{1}{m(i, j)\omega + 1} \quad (26)$$

When the dual-color laser field imaging waveform is simulated and enhanced, the enhancement coefficient obtained in the incompatible area of the waveform is different. Let g_L be the low gain value of the waveform. According to the noise function, in a certain waveform feature point (i, j) in the image, when $v(i, j) \rightarrow 0$, the enhancement coefficient of the waveform feature point needs to be a larger value $g(i, j) \rightarrow g_H$, so the problem of noise enhancement is not required to consider additionally when enhancing; and when $v(i, j) \rightarrow 1$, the enhancement coefficient needs to be a smaller value $g(i, j) \rightarrow g_L$, so as to prevent the noise from being over-enhanced and affecting the waveform. Based on the above considerations, the enhancement coefficient formula is determined as:

$$g(i, j) = g_L + (1 - v(i, j)) * (g_H - g_L) \quad (27)$$

In order not to suppress the enhancement information of the dual-color laser field imaging waveform, g_L is usually set to a value of 1 [24]. In order to moderately enhance the waveform and avoid the effect of excessive enhancement, g_H is usually selected as 2.5 [25].

4 Analysis of experimental results

4.1 Comparison of waveform spectrum enhancement in dual-color laser field imaging

In order to verify that the method in this paper is closer to the real situation, we use the grating layer controlled light wave propagation coupling wave method proposed in reference [3] and the beamforming technology based on variable

Fig. 3 Comparison of laser waveform spectrum by using different methods and actual laser waveform spectrum

Fig. 4 Comparison of laser waveform spectrum by using different methods and actual high-order harmonic spectrum

linear frequency modulation pulse signal proposed in reference [4] to obtain the enhanced analog waveform of two-color laser field imaging for comparative study.

Figure 3 shows the comparison between the laser waveform spectrum of different methods and the actual laser waveform spectrum, so as to judge the difference between the laser waveform spectrum of different methods and the actual laser waveform spectrum.

Figure 4 shows an actual laser waveform and the simulated enhanced laser waveform under different methods. When the phase is $\varphi = 3\pi$, the dual-color field is used, and the surface state of the light source incident on the target is regarded as the initial state of the whole process. The

high-order harmonics of the four laser waveforms relative to the phase $\varphi = 3\pi$ are obtained by way of formula (11). The waveform spectrum is shown in Fig. 4.

As shown in Fig. 4, the formed high-order harmonic spectrum perfectly reflects the characteristics of the harmonic spectrum, but the surface state incident on the target is regarded as the initial state of the process, and the intensity range of the obtained high-order harmonic spectrum is only from 10 to 3 to 10⁻¹. The methods of reference [3] and reference [4] show that the intensity range of the higher harmonic spectrum is from 0 to 10⁻⁴, and the waveform simulation control of dual-color laser field imaging based on augmented reality technology obtains the harmonic intensity range only from 10 to 3 to 10⁻¹, and its waveform intensity change trend is basically consistent with the actual situation.

4.2 Comparison of waveform peak enhancement based on dual-color laser field imaging

As an example, the effectiveness of the method in this paper can be further verified. According to the time-frequency distribution of the dual-color laser field imaging waveform, the actual situation is compared and analyzed. Figure 5 shows the time-domain distribution of the high-order harmonic spectrum obtained under different methods and in actual operation.

Figure 5 shows the actual operation and different methods in the continuous laser process for 5 consecutive peaks, and the peaks are 390, 470, 600, 600, and 460 valent in turn. When the peak value is P_1 , the method in reference [3] finds that the peak value is 330 valent and the actual peak value is 60 valent difference, the method in reference [4] is 305

Fig. 5 Time domain differences between actual and different methods

valent and the actual peak price difference is 85 valent, and the obtained in this paper is 399 valent and the actual peak valent difference is only 9 orders; when the peak value is P_2 , the method in reference [3], the method in reference [4] and the method in this paper obtain the peak values of 309, 380, and 469 valent respectively. The method in this paper is basically the same as the actual value; when the peak is P_3 , the method of reference [3], the method of reference [4] and the method of this paper are different from the actual peak value of 20, 80, and 82 valent respectively; when the peak value is P_4 , the difference between the method of reference [4] and the actual is about 140 valent. The difference between the method in this paper and the actual is at least about 20 valent; when the peak value is P_5 , the difference between the methods in reference and the practice is 110 valent, and the difference between the method in this paper and the practice is 15 valent.

Therefore, the method in this paper is basically the same as the actual time domain situation in operating, and the structure of the five peaks is roughly unchanged, which can prove that the method in this paper is superior to the method in the reference [3] and the method in the reference [4]. This is because this method uses the Internet of things technology to enhance the waveform simulation in two-color field laser imaging, uses spectral Fourier transform to phase modulate the waveform, and calculates the enhanced waveform through convolution function to make the waveform close to the actual laser waveform.

5 Conclusions

This paper studies the situation that the received laser wave is inconsistent with the reality due to the influence of non-linear factors in the incident process of the light source. A simulation and enhancement method of two-color laser field imaging waveform based on Internet of things is proposed.

- (1). Based on augmented reality technology, the waveform simulation control process of two-color laser field imaging is constructed to obtain the waveform simulation signal. The spectrum Fourier transform is used to modulate the waveform, and the convolution function method is used to enhance the phase of the changed refraction waveform to obtain the refraction waveform.
- (2). Using this method in the experiment, in the continuous laser process, the harmonic intensity is only in the harmonic intensity range of 10⁻³ ~ 10⁻¹, the peak value of the continuous peak is 399 valence, and the actual peak difference is only 9 orders. It is proved that the waveform spectrum and peak value of the two-color laser field imaging proposed in this paper

are basically consistent with the actual laser waveform. It shows that this method has high accuracy and good practical application effect.

- (3). Due to time constraints, there is still room for improvement in this method. In the next research, we will focus on the regulation of laser waveform and analyze the generated harmonics, so as to further optimize the practical application effect of waveform simulation enhancement technology based on two-color laser field imaging.

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Declarations

The authors declared that the paper have no relevant financial or non-financial interests to disclose; no funding to support; data availability and ethics approval are all not applicable.

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