Improvement and Implementation of Phase Laser Range Finder

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Abstract. the advantages of the laser's monochromatic, bright, directional stability and coherence are good, and it is widely spread and applied in the field of precision measurement. In this paper, the method of laser phase distance measurement, based on the characteristics of laser ranging, has made a relative improvement on the basis of the original, which can ensure the accuracy of measurement, reduce the consumption of system resources, and can improve the system response speed. Through simulation, the method of phase laser measurement is used to achieve the expected results, and it can be used to design the corresponding program according to the application requirements.

Introduction

Using laser monochromatic, high brightness, directional stability and the characteristics of good coherence, can achieve high precision measurement requirements. According to the requirements of the measurement, the phase laser range finder by measuring the continuous amplitude modulation signal, that is to be measured in the distance to and from the phase difference, the indirect measurement of signal propagation time, according to the calculated distance measurement[1,2]. This method can reach millimeter level measurement accuracy.

Principle of phase laser range finder

The phase difference of the phase difference between the phase laser range finder and the measurement range of T is as follows: L:

$$L=\frac{1}{2}ct \tag{1}$$

$$t=\frac{\varphi}{\omega}=\frac{2\pi N+\Delta\varphi}{2\pi f}=(N+\frac{\Delta\varphi}{2\pi})\frac{1}{f} \tag{2}$$

To (2) into (1) - type

$$L=\frac{1}{2}ct=\frac{1}{2}c(N+\frac{\Delta\varphi}{2\pi})\frac{1}{f}=\frac{\lambda}{2}(N+\frac{\Delta\varphi}{2\pi}) \tag{3}$$

Type C for light propagation in air. φ is the phase difference of the modulation of the optical signal in the air. ω is the angular frequency of the modulated optical signal. N is a positive integer. f is the frequency of the modulated signal. λ is the wavelength of the modulation signal. $\Delta\varphi$ is less than one cycle of f's phase difference.

In the actual measurement process, N can not be determined by a single frequency. When the distance is $L<\lambda/2$, the N can be determined from 0, then the distance L is measured:

$$L=\frac{\lambda}{2}\cdot\frac{\Delta\varphi}{2\pi}=\frac{\lambda\cdot\Delta\varphi}{4\pi} \tag{4}$$

The accuracy of the $\Delta\varphi$ can be directly influenced by the accuracy of the measurement results when the modulation frequency is constant. It seems very difficult to obtain high frequency difference frequency signal directly. However, in the phase of the laser ranging method, it can be used to get a low frequency signal with a frequency close to the *F* reference signal and the received signal. Such a measurement of the phase difference of a low frequency signal is relatively easy, but also to ensure the accuracy of measurement[3].

System components and signal acquisition

Phase laser ranging is realized by the phase difference between the modulated light and the reflected light reflected by the target. From the measurement of the distance between the requirements and the realization of the principle can know: to get high accuracy, strong anti-interference measurement results, it is required to ensure that the transmitted signal and echo signal detection of synchronization, symmetry. In order to obtain more accurate measurement results, the authenticity of the acquired difference frequency signal is guaranteed. And reduce the environmental error and the delay error caused by the system design. The need to design a set of internal and external optical path detection system, which is used to ensure the synchronization of the optical path and the symmetry of the internal and external optical path[4]. Internal and external optical path measurement system is shown in fig.1.

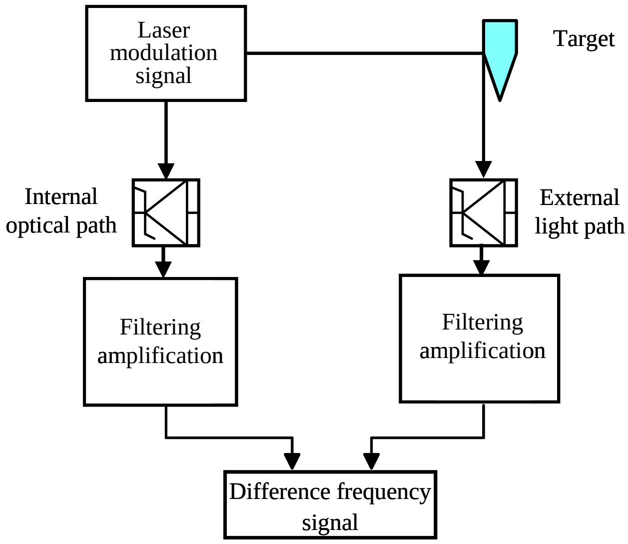

Fig. 1. internal and external optical circuit system diagram

Figure.1 shows that the circuit design to ensure the reliability of the optical path of the photoelectric detector, reliability, difference frequency signal to obtain the authenticity, stability and sensitivity of the photoelectric detector, the sensitivity of the response is also a direct relationship, so the reasonable choice of the photoelectric sensor is also the key to ensure the accuracy of measurement. The main basis of the photoelectric detector is working wavelength, and the sensitivity, noise and broadband[5]. In order to achieve the expected technical performance, the following principles can be used for reference and selection:

First, the choice of the optoelectronic device must be matched with the spectral characteristics of the photoelectric system which is constructed by the signal excitation source. Related light source and device configuration are shown in table 1.

Table 1. Selection of optoelectronic devices for systems

Selected measurement band	Optional device
Ultraviolet band	Photo multiplier tube and matched ultraviolet diode
Visible light band	Photosensitive resistance, silicon light apparatus and photo multiplier tube
Infrared signal band	Photosensitive resistance
Near infrared band	Silicon materials and photovoltaic devices

Secondly, in order to ensure the position of the photoelectric device and the incident light, the photoelectric device can be matched with the incident light. The frequency response characteristics of the photoelectric device are matched with the electrical characteristics of the incident light. The response of the photoelectric device is matched with the electrical characteristics of the following circuit, so that the maximum conversion coefficient, linear range, signal to noise ratio and fast dynamic response can be obtained. Otherwise, it will damage the photosensitive device, interfere with the detection circuit, the impact of the measurement results[6].

Phase measurement and implementation of differential frequency signal

Phase Measurement. Measurement system by mixing to obtain the difference frequency signal and need the differential frequency signal correlation, to for recording, calculation and analysis, so it is necessary to obtain the difference frequency signal through the fast Fourier transformation, from the transformation of the selected specific points to obtain the value of the tangent of the specific frequency phase, through anyway shear for get the desired phase value, in digital signal processing, this method has universality, can reduce the amount of calculation and computation time[7].

In the case that the system resources are very abundant and do not have to over take into account the accuracy of measurement, it can be directly applied, and there are plenty of information available for inspection and application. When the system demands high, the resource is tight, the frequency of the signal is fixed, the frequency of the laser ranging is fixed, and the characteristics of the resource can be reasonably designed. On this basis, the processing method of the detection signal has been improved and optimized.

Fixed signal frequency f with sampling frequency f_s, so that the following relationship between the two:

$$m = \frac{f_s}{f} \tag{5}$$

$$k_0 = \frac{N}{m} \tag{6}$$

The m and k_0 are positive integers, and N is the sample points.

On the premise of meeting the relational (5), (6), the single frequency signal $\cos(\frac{2\pi}{N}mn)$, after a fast Fu Liye transform:

$$x(k) = \begin{cases} \frac{N}{2}, & k = m, N-m \\ 0, & \text{Other} \end{cases}$$

On the formula, the frequency of f only in the m and N-m time to have the value, the other time is 0, so it only needs to be carried out at the m point. In laser ranging, compared with the integer arithmetic, floating-point arithmetic and trigonometric calculations need many periods of time and system resources, under the premise of ensuring the accuracy of, in the controllable range, the value cosine and tangent [0: $2\pi(N\text{-}1)/N$] were quantified, obtained by look-up table, this avoids the repeated calculations.

The phase extraction is generally used in the case of no account of the resource consumption, the Mathematical Library of the tangent function has a higher accuracy and a certain error handling mechanism. But in the preparation of the underlying C standard library, to achieve the function of the cut, the need for thousands of clock cycles, the operation will cause a stack of errors. If you can control the accuracy of the range, reduce the system's internal consumption, re design a set of methods to calculate the tangent function, which will greatly improve the performance of the system and the sensitivity of the measurement[8].

Because the value range of the tangent function arctan(x) is between （$-\infty, +\infty$), using the following formula:

$$\arctan(x) + \arctan(\frac{1}{x}) = \frac{\pi}{2}, \ (x > 0) \tag{7}$$

$$\arctan(x)+\arctan(\frac{1}{x})=-\frac{\pi}{2},\ (x<0) \tag{8}$$

Mathematically, the arctangent function can find a polynomial approximation, but it must be to achieve the ideal of faster convergence speed, the traditional Taylor series need to reach out 5000, in order to ensure that errors are given, the epsilon $\varepsilon=10^{-4}$, so Taylor series not suitable for the laser measuring distance system application, and Chebyshev polynomial has a faster convergence speed.

$$\arctan(x)=2\sum_{n=0}^{\infty}\frac{(-1)\exp(n)q\exp(2n+1)}{2n+1}T_{(2n+1)}(x) \tag{9}$$

When $q=1/(1+\sqrt{2})$, $x\in[-1, 1]$, $T_0(x)=1$, $T_1(x)=x$, $T_{n+1}(x)=2Xt_N(x)-T_{n-1}(x)$, Chebyshev two and three, before three and four approximation results of comparison, such as shown in fig.2.

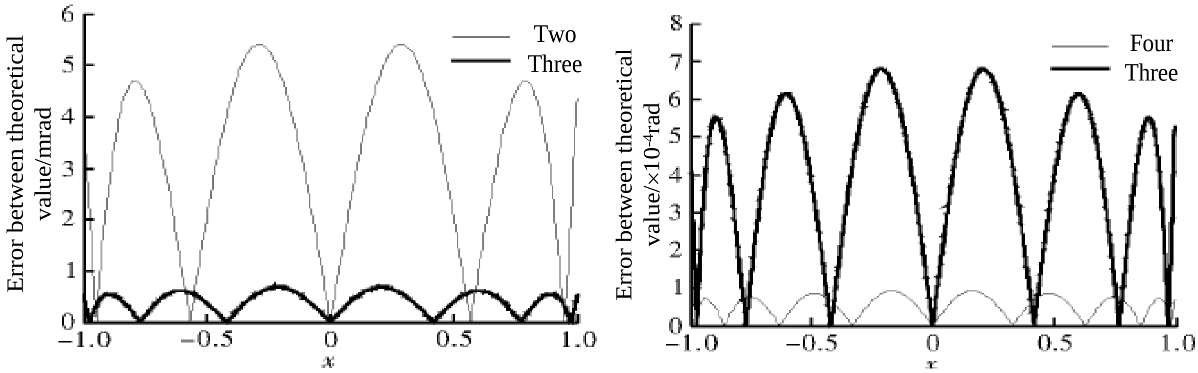

Fig. 2. comparison of simulation results of the different terms of Chebyshev polynomial

From fig.2 shows, Chebyshev polynomials in [- 1,1] range, errors are controlled in the range below, and has a very smooth error distribution. From the graph we can see, Chebyshev polynomial each additional a, approaching the accuracy will increase by an order of magnitude. It can be concluded that the Chebyshev polynomial approximation can get the error range of stable and fast convergence speed.

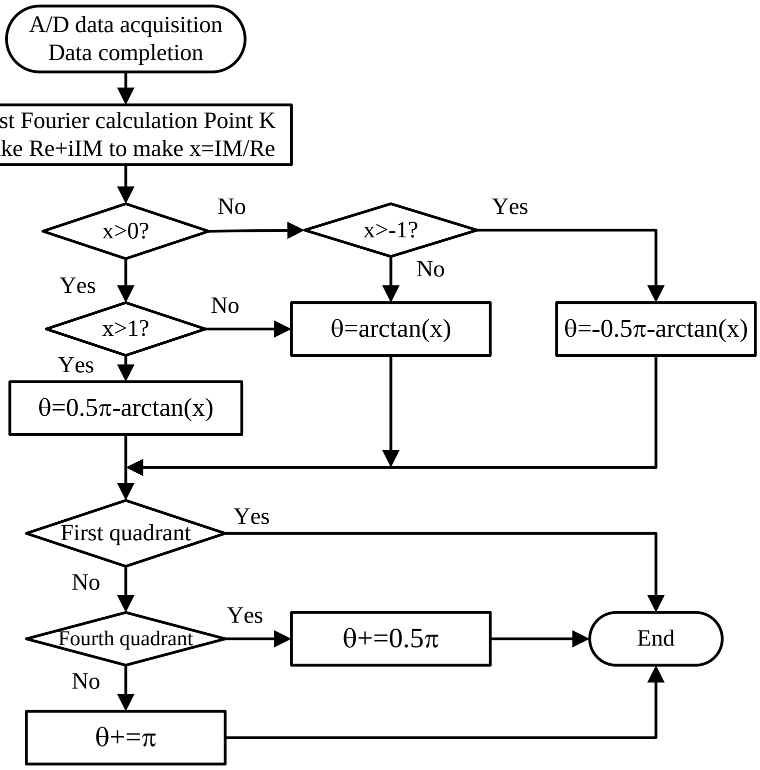

Fig. 3. the flow chart of the differential frequency signal after mixing and filtering

Realization principle. In the phase laser distance measuring system, through the A/D module completed the transformation and quantization of signal can be through interrupt complete calculation of the discrete Fourier transform of the k values according to the result of the calculation corresponds to the tangent value is obtained. The flow chart of the measurement signal is shown in fig. 3.

In practical laser ranging, phase change range [0, 2π], and the inverse tangent function arctan (x) phase change only (- 0.5π, 0.5π). So we must according to the sign of the real part and imaginary part of the Fourier transform Re+iIM judgment in which quadrant, then when the absolute value of X is less than 1, using a; when the absolute value is greater than 1, call type (7) and (8), so that obtain the phase value can be guaranteed in [0, 2π) within the scope of the changes, the completion of the revision of the arc tangent function. After the improvement of the experimental results, the variation of the error between the actual value of the simulation and the given theoretical value is shown in fig. 4. From the results of the measurements, the results of the measurements are seen in different phase errors, and the results are maintained in the range of 8 * 10-4rad.

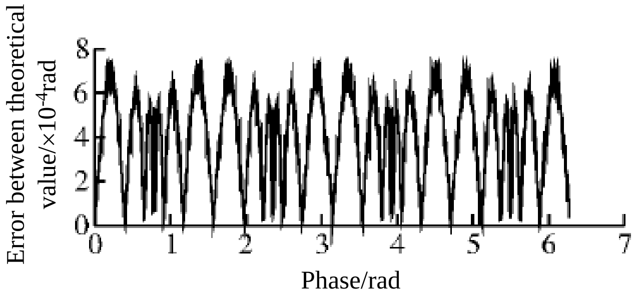

Fig. 4. simulation of measurement error

Conclusion

Through the experimental simulation, we can find that the improved laser phase distance measurement method is less than the consumption system resources, the high precision measurement, and the measurement range of error control in the lower range, that is, when the measurement length is 0.1m, the accuracy can be 1000m, the measurement range of different levels will be more accurate results.

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