Michelson Interferometer Signal Processing Based on Wavelet Transformation

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Abstract—**Measurement signal of Michelson interferometer is considered as a cosine signal in low-frequency band limited. After that, we place our eyes on how to utilize wavelet transform to analyze and signal process the carrier signal and the interfering signal. In the low-frequency, the Continuous Wavelet Transformation time window automatically widened which depended on the different requirements and the different sampling module. The high-frequency can be adaptively narrowed in accordance with different sample modules. The characteristics of utilization Morlet wavelet transformation (a method of Gabor wavelet transform) owns huge computing capacity, slightly higher complexity .To the discrete signals, we take use of Mallat wavelet transformation to deal with the signal in the Discrete Continuous Transformation, to reduce computing complexity under without lowering the accuracy of measurement systems. At the same time, improve the response speed, and work out the best signal interference envelope fitting curve, to decrease the positioning error of zero-light-path difference.**

To achieve not to enhance the interfere measurement accuracy, as far as possibly, improve the measuring speed under different occasions.

Keywords-component; Michelson interferometry; Zero-Light-Path Difference; Continuous Wavelet Transformation;Discrete Wavelet Trabsformation; Morlet Wavelet Transformation; Matllat Wavelet Transformation

I. INTRODUCTION OF OPTICAL FIBER MICHELSON INTERFEROMETER

Two- light beam Interferometer was applied into a broad range, such as in the area of precision metrology and manufacturing. In these areas, the optical fiber Michelson interferometer was considered as high-precision displacement sensor and velocity measuring instruments in the lab or the factory, on the contrast, the existence of phase Random drift, such as the error of light path structure and light source problems etc make the most error in the measurement. In the precision measurement area, the Michelson interferometry can ensure the quality of manufacture. The optical fiber interferometer which based on the Michelson interferometer was proposed in measuring the increasing demands surface quality, like to achieve the sub-micro nano-meter measurement even through.

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A. The basis of Michelson interferometer

The optical fiber Michelson interferometer work on the basis of Michelson interferometry. From Figure 1.1, it shows the principle of Michelson interferometry. We can neglect the thickness of "A" film lies on G1 as well as the fixing error of G1 and G2,as a result, an ideal working condition were be setup, we can figure out the final d distance which lies in M1and M2 except Zero-light-path ,P is the position of observer.

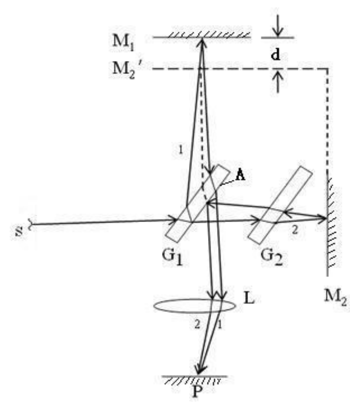

Figure1.1 Michelson interferometer scheme.

The principle of high-precision displacement sensors like optical fiber Michelson interferometer is shown in Figure 1.2. Measured in the surface scan on the peak and valley, causing interference fringe movement, the signals received by the optical receiver to deal with by the acquisition of computer terms Operator, has been detected on the surface of the original point measurement information Displacement. [1], optical interference signal is converted to electrical signals through Photo-electricity Detector (PD). PD in many occasions are CCD sensor. Etc.

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B. *The Sketch of Optical Fiber Michelson intrferometer*

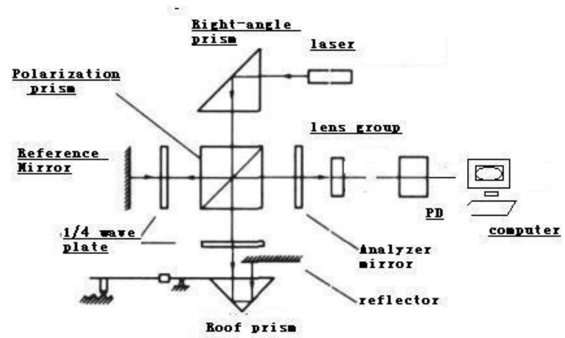

Figure 1.2 Sketch map of optical fiber Michelson interferometer

Of course, the optical fiber Michelson interferometer works on the basis of Michelson interferometry theory. As a result, we can draw the conclusion from the Michelson interference about its processing image, when the wavelet transform can enhance the measurement precision in the relative area.

Some experiments indicate wave front retrieval by Gabor wavelets can improve the measurement effectively.[2]

II. THE ERROR OF OPTICAL FIBER MICHELSON INTERFEROMETER

To enhance the measuring precision, we try to decrease the error in any possible methods. First of all, error led by the structure of Michelson interferometer and the scan signal can be decreased with improving the interferometer structure. On the other hand, the positioning error of zero-light-path difference can be reduced with wavelet transformation. [3]

A. *Error from structure and environment influence*

Detecting changes in the electrical signal will show the phase-change optical interference signal.

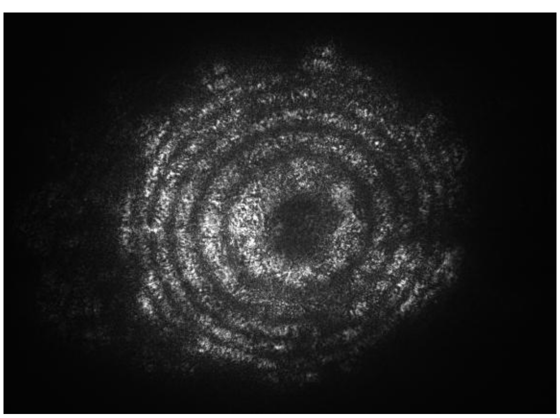

Figure 2.1 The image of Michelson interference

We can get the result form the Michelson interference experiment .Though the Michelson interferometer, we can get the Figure 2.1 Michelson interference image.

After that, we will transform the image into a new which owns a clearly border to get the first interference image.

The optical sensor is characterized by: two beams of the incident light. By the amount of polarization after the prism through reference mirror and mirrors, respectively, and two round-trip / 4 wave plate, the direction of their deflection by 90 °,then to return to mirror.

The light from the reference mirror to return to the light and reflection to all through the photoelectric detector, the analyzer allows the use of the last two beam interference occurred, on the other hand, the figure 1.2 tells us about the scheme of fiber optical interferometer. When interferometer working, (symmetric compensation, long arms, and so on), two-arm interference beams between the optical path difference for all wavelengths of light, only depends on the relative position of mirror M1 and M2, and has nothing to do with the wavelength . In other words, M1 and M2 on the G1 is the strict symmetry of the A side, and to make interferometer is made symmetrical compensation, should at least guarantee G1 and G2 in the material, the thickness of the installation of point of view on the line. Of course this has a bearing on the lens of the production process and the assembly process. We know well about the situation without including this paper.

- Given the ideal scale condition and the mirror right fitting, the measurement should be mainly made by the zero-Light-Path Difference which caused by the signal recognize and the information dealing etc. -Coherent issued by the laser light through optical isolator coupler and the latter split into two separate into 2 is basically the same as the length of the single. That is, fiber interferometer arms, one arm to signal the other reference arm, and the reflective film after reflection, in the coupler's output interference occurred. It is clear that this is a two-beam interferometer, to interfere with the range of light. The signal light and reference light of the range, and its phase to the phase of light arms make the measurement result worse, to interfere in the market for the distribution of light intensity

B. *Signal Analyzing*

In this part, we will discuss the signal including The interference intensity of double beam optical fiber Michelson interferometer can be figure out by the following formula:

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos(\Phi) = A + B\cos(\Phi) \qquad (1)$$

$$\Phi = 2n\pi\ell / \lambda \qquad (2)$$

Where I_1 refers to the distribution intensity of the reference light when it makes its effect alone in the optical paths; I2 denotes the distribution intensity of the signal light; λ shows the wavelength of the laser; where Φ shows the phase difference between the signal light and the reference light; where n is refraction index.

From the formula (1), we can know that the distribution intensity depends on Φ, I1, I2, on the other hand, it can be considered as a continuous cosine signal. After all, we can regard the measurement signal as a low-frequency band-limited and modulation swing cosine signal. The equations are an exception to the prescribed specifications of this template. You will need to determine whether or not your equation should be typed using either the Times New Roman or the Symbol font (please no other font). To create multileveled equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled.

Ⅲ. THE MALLAT WAVELET IN THE DISCRETE DOMAIN

When the sampling is not very often, you need not to catch the picture any time or record the video in a very high frequency, we can place our eyes on the Mallat wavelet to transform in discrete signal, under the some frequency, you can split the measurement signal into DWT or more to analyze. After that we can also get another Zero-light path difference which has been decrease as possible as we can. In the DWT, we can utilize the Mallat algorithm to improve the quality of the image.

In many occasion, we encode measurement in many positions firstly. Mallat wavelet will decrease the complexity of the operation in certain extent. With hierarchical tree collection and sorting division of the Law, we can use the different parameters of Mallat wavelet transformation. In this occasion, it can be express with L.

$$x_0 = l/2^L,\ x_1 = x_0 + (r-l)/2^L \quad (3)$$

$$y_0 = t/2^L,\ y_1 = y_0 + (b-t)/2^L \quad (4)$$

In formula (3) and (4), the coordinate ((r,l),(b,t)) of the relevant pixels (new coordination (x_1,y_1) and old coordination (x_0,y_0)), L means the series of Mallat Wavelet Transformation. After that we can get the re-encode signal to speed up our operation [5] , the relation between new coordination (x_1,y_1) and old coordination (x_0,y_0) like (3).

The He-Ne Laser is utilized as a light source in the experiment (Wavelength=632nm)

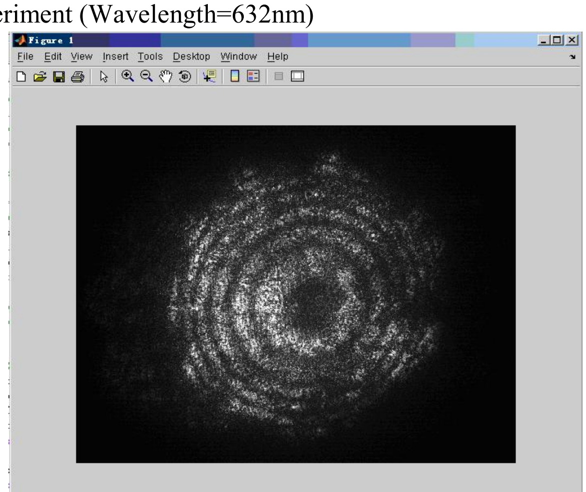

Figure 3.1 The processed image of Michelson interference with Mallat wavelet

With the Mallat wavelet, the picture edge more easily in Figure 3.1 can be found out. That is to say, the Michelson interference wave of procedure of altering can be searched.

The Mallat in DWT sharpen the edge and decompose the image without losing mass image information.

Ⅳ. CONTINUOUS MORLET WAVELET TRANSFORM THE TIME FREQUENCY DOMAIN

After the signal has been detected and transformed in the Discrete Domain**.** Morlet, one of Gabor wavelet transformation is ready for the continuous domain. As we know, the Gabor transformation owns its only benefits like the transformation between the time space and frequency domain. Meanwhile, the Morlet of wavelet means is utilized to achieve a more obvious split signal in the signal analyzing of the continuous domain. The analyzing can be regarded as follows:

A. The wavelet and Continuous Wavelet Transform

In the traditional signal analysis, methods of Fourier transform was usually used time-frequency analysis, after that, the signal can be split into various frequency components, it can not determine the frequency of a certain generation, as a result, it is applied to a long time relatively stable signals with the frequency analysis. For non-stationary signals, typically window Fourier method can overcome the Fourier transformation's shortcomings and analyze the specific frequency signal, being the fixed width of the window, whether for high-frequency or low frequency signal its resolving power is the same. From the 1980s, development of the wavelet theory overcome the shortcomings of the above, is a wavelet allowed to meet the conditions for a function with variable center frequency and the time window, that is, it Self-adaptive signal can be used to analyze the resolution of different signals at some point the frequency shift signal interference is a sharp change in non-stationary signals, the wavelet time-frequency signal is such a powerful tool for analysis.[8]

B. The Morlet wavelet transformation s

Under the allowance condition, the Morlet wavelet used in the time-frequency analysis can be expressed into a plural Gauss envelope function.[2]

$$\psi(t) = \exp[(-t^2/2\delta^2) + i\omega_0 t] \quad (5)$$

In the above Plural formula (5), the wavelet was applied to analyze in the time-frequency area. σ denotes the length of Gaussian window in time-domain, as ω0 denotes center frequency of 0. When σ= 1, $\omega_0 > 5$, the Morlet wavelet transform meets with the allowance conditions. Further more, while, as well as $\Psi(t)\in L_2(R)$, we can figure out that wavelet groups as following:

$$\psi(b,a)(t)=\psi((\tau-b)/a) \quad (6)$$

In the formula (6), letter a shows scale factor in according to the relevant length of wavelet time windows and ω_0 means the relevant center frequency [6]

In the Real domain, $f(t)\in L^2(R)$ means that ψ (b,a)(t) can change into the equation of

$\psi(b,a)(t)=\psi((\tau-b)/a)/$, $a,b\in R$ (7)

After those, the frequency resolution reduces along with the decrease of scale factor, on the contrast, the time resolution will reduce according to the increase of scale factor. Obviously, it shall reduce the complexity of operation according to the relevant domains. According to the speciality of Morlet wavelet, its envelope curve will smooth the signal among noise.

Then, we can get the relevant frequency from the biggest swing of wavelet transform. For its greatest change rate, it can achieve the proper scale factor to find out the relevant frequency, as a result, it can reduce the Zero-light path difference.

$$K_s(b,a)=\int_{\infty}^{-\infty} f(t)\exp[-\tau^2/\delta^2-i\omega_0(t)]dt \qquad (8)$$

After that, basing on the formula as following:

$$\omega(b)=\omega_0/a^{'}(b) \qquad (9)$$

In the formula (9), ω(b) shows the frequency of the b position, in the same time, a'(b) means the greatest swing, that is to say it will remain the lowest Zero-light path difference. Because we had get the lowest error of measurement when the center frequency lies on the scale factor is biggest, that is to say, the frequency resolution is the most notable under the condition of the greatest swing changing.[6],[7]

In other words, measurement factor in Morlet processing can be replaced by the frequency factor. After that, we can figure out the difference between measurement signal and reference signal from function (7),(8),(9).In according to the picture verified interference circle.

Ⅵ CONCLUSION

Although many of those theories base on the grown-up wavelet theory which was developed and founded in the 1980's, it is a pity I can't finish more experiments to test the theory. Given more time, we can draw the conclusion that the signal will be deal with vary situations. It would be cut off proceeding time as possible as we can, in other words, it should enhance the measurement efficient and not reduce the measurement precision.

Of course, most of them have been testified. We need do more experiment in the discrete signal domain. This may become my following task.

We can apply the technology to operate in many occasions, like laser medical operation, measurement etc.

After processing, the distance can be figured out according to the principle of Michelson interference. The counting error in time district can be decreased.

The optical fiber Michelson interferometer works on the same principle as well as the Michelson interferometer. We can get the same result of the processing image.

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