Research of chromatic spectral peak location on confocal point sensors

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Abstract. Chromatic confocal point sensors are used to measure the high-precision surface distance, and it's based on the theory of chromatic dispersion and encodes the distance between the measure surface and chromatic lens. By accurately measuring the wavelength value, it indirectly calculates the distance to object surface. The accuracy of the sensor depends on the chromatic range of the lens and the resolution of the spectrograph. In this paper, the algorithm of spectral peak positioning can effectively filter kinds of noise, such as spectrometer and light source. The spectral data signal peak is extracted by Gaussian fitting method. In practice, the wavelength position can be stably detected effectively.

1. Introduction
The spectral confocal displacement sensor is built on the confocal principle, and uses the polychromatic light as the light source[1][2]. Accuracy of the confocal sensor be can up to the nanometer level, and usually can use to the measurement of objects with diffuse reflection or mirror reflection on the surface. In addition, the spectral confocal sensor can also measure the thickness of transparent objects in one direction[3-4]. Due to its high precision in the measurement of displacement, for single-layer and multi-layer transparent objects, it can accurately measuring the displacement of the object, and the thickness can also be measured in a single direction, such as transparent materials optical elements and biological films, metal films, thin glass sheets, parallel plate[5-8].

In the paper, the spectral confocal displacement sensor is applied to the displacement measurement, and the experiment verifies that the spectral confocal measurement system can meet the requirements of high-precision displacement measurement, and it can extract the chromatic spectral peak location to accurately calculate the displacement of the object. It has great significance for the miniaturization and productization of the whole measurement system in the future.

2. Measuring principle
Chromatic confocal point sensors is developed from laser confocal microscopy. This configuration is shown in Fig 1, where the white light point source W is obtained by the chromatic lens L on the object point M. Back-scattered light passes back through objective lens L. The pinhole P plays an important role in this configuration, and it stops light coming from all points except M, in particular points located on the optical axis,above or below M. Due to the confocal configuration, only the wavelength \( \lambda_M \) will pass through the filter with high efficiency, all other wavelengths will be out of focus.
To extract the information about the z-coordinate of the point M, it is need to decode of the collected light. Spectral analysis is applied, a diffraction grating used deviates each wavelength at a different direction, and a line CCD obtains the light from the diffraction grating. The position of the intensity maximum on the CCD is the position of point M. In the measurement range, the distance is coded spectrally using the axial chromatic of the objective lens. The image of a point M emits white light, and it produces a continuum of monochromatic image points distributed along the optical axis, as shown in Fig 2.

3. Testing apparatus
The test device, as shown in Figure 3, is composed of white LED MWWHF2, T-Cube LED driver LEDD1B, multi-mode fiber coupler FCMIH2-SMA, fiber optic spectrometer FX2000, adjusted dispersion lens, vertical displacement platform, micrometer heads, fixture and so on.
4. Data processing of spectral data

The spectral signal obtained by the spectrometer is analyzed, the peak wavelength is extracted accurately, and the displacement value corresponding to the wavelength is calculated. The light beam from the white LED light source passes through the optical fiber, and enters the dispersion lens to the object surface, then the light is reflected back to the dispersion lens and transmitted back to the spectrometer along the optical fiber through the optical fiber coupler, and the peak value of the wavelength is measured. The acquisition of spectral data signal introduces noise, such as spectrometer and light source, as well as the defects of each element in confocal measurement system. It affects the spectral signal shape and the accuracy of peak wavelength extraction. If these noise is not filtered, it will affect the peak extraction of spectral data, and even if the high-precision extraction algorithm is employed, the peak value cannot also be accurately and stably obtained. Therefore, it is very necessary to process the spectral data.

Gaussian fitting method was used to extract the peak value of spectral data. The form of Gaussian distribution is as follows:

\[ I(x) = e^{-\frac{(x-b)^2}{2\sigma^2}} \]  \hspace{1cm} (1)

The peak value of the Gaussian function is at the position of the mean value of the function, and the Gaussian fitting is the find position according to the spectral discrete data. The peak position of gaussian function is the zero of its first derivative, the zero of the first derivative of Gaussian function is the spectral peak position of Gaussian function. In the actual calculation, the spectral peak position is calculated by differential operation of spectral data and zero-crossing intersection point, as shown in the calculation shown below.

\[ \frac{dI(x)}{dx} = \frac{e^{-\frac{(x+b)^2}{2\sigma^2}}}{\sigma^2} (x-b) \]  \hspace{1cm} (2)

Labview was used to extract the gaussian fitting spectral peak, and the processing process was shown in Figure 4.

![Figure 4 Extract the spectral peak](image-url)
5. Conclusion
In this paper, the algorithm of spectral peak positioning is examined in the aspect of the spectral confocal measuring system. Utilising the filter algorithm, the signal process of spectral data can effectively kinds of noise, such as spectrometer and light source. The spectral data signal peak is extracted by gaussian fitting method. In practice, the wavelength position can be stably detected effectively.

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