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Research on Fingerprint Extraction Method Based on Spiral Phase Contrast Imaging

Wu Xuan, Tian Shuangnan, Dong Rui

Taishan College School of Physics and Electronic Engineering, China

Abstract

Fingerprint extraction is of great significance in case detection. Usually, fingerprint lines formed by the natural secretion transfer of the body can not be clearly identified by naked eyes. Spiral phase contrast imaging method can transform transparent phase information into amplitude information, which is more suitable for this kind of fingerprint extraction. Based on the basic principle of spiral phase contrast imaging,Using the phase space light modulator, a 4f optical information processing system is built, and the fingerprint printed on the transparent glass plate is imaged and verified.

Keywords

Research , Fingerprint Extraction Method , Spiral Phase Contrast Imaging.

1. Introduction

People's fingerprints are unique, so they are of great significance in the detection of criminal investigation cases. However, there are some inconspicuous fingerprint traces, such as potential fingerprints. These fingerprints refer to fingerprint lines formed by the natural secretion transfer of the body, which cannot be clearly identified by naked eyes, and are the most common fingerprints in crime scenes. Therefore,How to reasonably and scientifically extract fingerprint traces from crime scenes, making fingerprint extraction technology more simple and accurate, is the work that needs further improvement at present. Fingerprint, as an almost transparent phase object, is suitable for detection by phase contrast imaging, especially the new spiral phase contrast imaging method.It provides a technical development direction for fingerprint extraction, especially potential fingerprint extraction. Using spiral phase contrast imaging method is expected to provide a scientific way with simple operation and accurate information for fingerprint extraction technology.

2. Basic principles

Optical microscope uses various phase and amplitude contrast enhancement techniques to enhance inherently low contrast samples. An interesting new technology is called "spiral phase contrast" (SPC) microscopy or Hilbert microscopy, which provides the possibility of producing edge enhancement independent of direction or displaying "phase fluctuation" of samples.The spiral phase profile is applied to the image wave in the Fourier plane of the optical path, which corresponds to the image and Laguerre-Gaussian point spread function (PSF) and leads to the strong isotropic edge enhancement of amplitude and phase samples.

The transmission function h of a typical spiral phase filter corresponds to the phase distribution of Laguerre-Gaussian beams with topological charge L of n = 1, and the transmittance function of the spiral phase filter can be expressed as:

$$H_n(r,\varphi) = circl\left(\frac{r}{R}\right)\exp(in\varphi)$$

Where r is the aperture of the spiral phase filter, n is the topological charge number of the spiral phase filter, that is, the order of radial Hilbert transform, and (r, φ) is the polar coordinate on the spatial filtering plane. Usually, we only use the topological charge n=1, as shown in Figure 1. Based on 4f system spectral filtering, the output result can be regarded as the convolution of the input image g(x,y) and the system point spread function, namely

$$\tilde{g}(x,y) = g(x,y) * h_1(\rho,\theta)$$

In which the point spread function $h_1(\rho,\theta)$ of the spiral phase filter is the Fourier transform of the transmittance function $H_p(r, \varphi)$. Based on the above theoretical analysis, the spiral phase filter can be used to realize theoretical simulation and experimental verification of fingerprint sample phase contrast imaging.

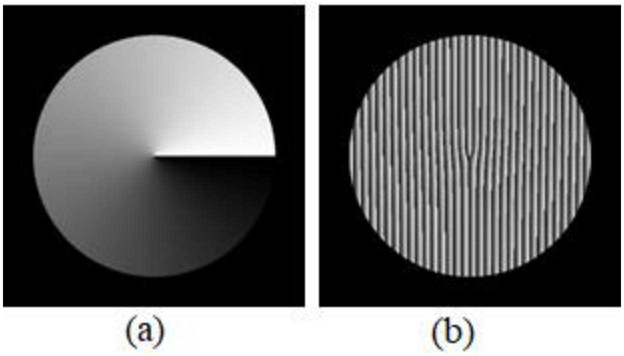

Fig. 1 Phase diagram of spiral phase filter and its hologram

Assuming that this sample object is illuminated by a plane wave, the wave transmitted by SPP is LG mode with topological charge of 1. Then, the wave is diffracted by the binary spiral phase hologram (Figure 1b). The diffraction of incident wave to two conjugate first-order and negative first-order diffraction orders results in the incident wave being convolved with two spiral phase Fourier filters with spiral indices of n= +1 and n= 1, respectively. In the image of the sample,The phase singularity in the center of local eddy current is represented as a focusing ring with dark center in one diffraction order, and as a focusing Gaussian spot with bright center in another diffraction order.

This model can be extended to the imaging of singular points of any phase, which can be mathematically described as the superposition of LG modes with different spiral indices. We can conclude that all chiral singularities will show differences when filtering with the spiral phase plate with the opposite spiral index. Subtract these two images, and get the graph of chiral singularity in the sample.The rotation direction can be extracted by analyzing the (positive or negative) sign of the central region of the structure in the difference image, that is, the position and rotation direction of screw dislocation, which can be used as a phase distribution diagram of the sample.

3. Experiment and data analysis

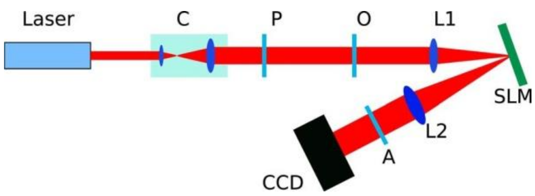

Fig. 2 Schematic diagram of experimental system

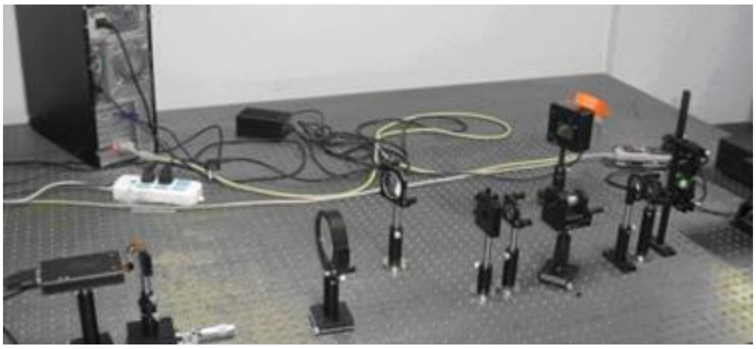

Fig. 3 Experimental system diagram

The experimental device of spiral contrast imaging system is shown in Figure 2 and Figure 3. The focal lengths of lenses L1 and L2 are f_1=300 mm and f_2=500mm, respectively. The wavelength of incident light is $\lambda = 532$ Nm, the collimated laser passes through the sample placed on the three-dimensional translation stage, the transmitted light with the fingerprint information of the sample (Figure 4a) passes through the objective lens, and the Fourier spectrum of the fingerprint sample image is projected onto the liquid crystal spatial light modulator through the telescopic system, and the modulated spiral phase filter (as shown in Figure 1b) is displayed on the liquid crystal spatial light modulator to spatially filter the Fourier spectrum of the sample.Then, the lens is connected to the objective lens to realize the inverse Fourier transform of the filtered light beam, and the fingerprint image imaged by spiral phase contrast is projected onto the CCD, and finally the image of Figure 4b is collected.

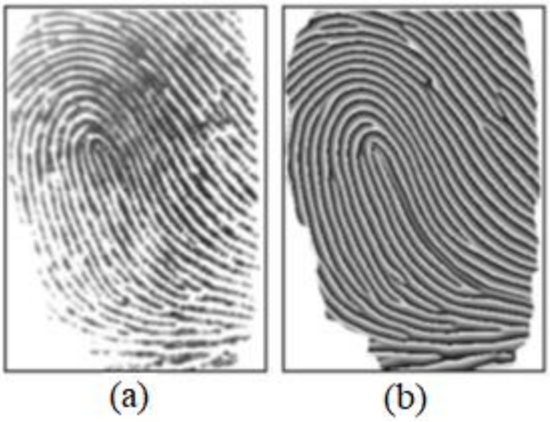

Fig. 4 Experimental results (a) fingerprint original image, (b) fingerprint contrast image

4. Conclusion

Experiments show that spatial filtering based on spiral phase filter has a strong contrast enhancement effect on both amplitude objects and phase objects. On the other hand, spiral filtering is not sensitive to the absolute phase of the object, but to the phase gradient of the object, that is, the phase change, and the energy of the incident light is redistributed to enhance these gradient changes.This experiment provides theoretical basis and experimental data for the application of spiral phase contrast imaging method in fingerprint extraction, and is of great practical significance for the continuous development and improvement of fingerprint trace inspection technology.

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About the author:

Wu Xuan (2000--), female, is currently studying in the physics major of Grade 2018 in the School of Physics and Electronic Engineering of Taishan University, and her research direction is optics.