FIZEAU INTERFEROMETER AND INTERFEROMETRIC MEASUREMENT SYSTEM

Field of the Invention

The present invention relates to the field of laser coherence technology, and in particular to a Fizeau interferometer and an interferometric measurement system.

Background to the Invention

The principle of the Fizeau interferometry system for detecting planar optical elements is as follows: Light emitted from the laser source passes through an optical system such as collimating and beam expanders, and is incident parallel to the test mirror and the reference mirror respectively. Part of the light is reflected by the reference mirror to form a reference beam; the other part of the light passes through the reference mirror and is reflected by the test mirror to form a test beam. The interferogram formed by the reference wavefront and the test wavefront is finally imaged onto a CCD (Charge-Coupled Device) by the imaging system.

The interferometric measurement system detects the phase information of the optical element under test, that is, the height deviation of the optical element surface:

$$h = \frac{\lambda}{2} \bullet \frac{\varphi}{2\pi},$$

where h represents the measured surface height deviation of the optical element, ϕ is the phase, and λ is the test wavelength.

The phase difference between the reference mirror and the test mirror can produce interference fringes on the CCD camera, but the reflection from the glass surface can cause stray light on the image plane, affecting the detection results. Therefore, eliminating stray light on the image plane (i.e., the interferogram) is crucial.

Statement of Invention

The purpose of this invention is to provide a Fizeau interferometer and an interferometric measurement system to reduce the influence of stray lights.

In a first aspect, the present invention provides a Fizeau interferometer, comprising a laser, a polarizing beam splitter, a collimating mirror, a reference mirror, and a test mirror arranged sequentially along a direction of light propagation, and an imaging system, wherein a quarter-wave plate is disposed between the polarizing beam splitter and the reference mirror, and the quarter-wave plate is tilted.

Laser light emitted by the laser is converted into first polarized light after passing through a polarizing beam splitter. The first polarized light then passes through a collimating lens and a quarter-wave plate before being incident on a reference mirror. A portion of the polarized light incident on the reference mirror is reflected by the reference mirror, passes through the collimating lens and a quarter-wave plate again, and is reflected by the polarizing beam splitter into the imaging system to form a reference beam. The other portion of the polarized light incident on the reference mirror passes through the reference mirror and is incident on a test mirror. It is reflected by the test mirror, passes through the reference mirror, collimating lens and a quarter-wave plate again, and is reflected by the polarizing beam splitter into the imaging system to form a test beam.

Further, a quarter-wave plate is positioned between the collimating lens and the reference lens.

Furthermore, an optical axis of the quarter-wave plate forms a first predetermined angle with respect to the incident light, the first predetermined angle being within the range of 5° to 20°.

Furthermore, an optical axis of the quarter-wave plate coincides with the optical axis of the polarizing beam splitter.

Furthermore, the imaging system includes a linear polarizer, an aperture stop, and a detector arranged sequentially along the direction of light propagation, the linear polarizer being tilted.

Furthermore, the optical axis of the linear polarizer forms a second predetermined angle with respect to the incident light, the second predetermined angle being within the range of 5° to 20°.

Furthermore, an imaging lens group is disposed between the aperture stop and the detector.

Furthermore, the Fizeau interferometer also includes a tilt adjustment mechanism connected to a quarter-wave plate, the tilt adjustment mechanism being used to adjust the tilt degree of the quarter-wave plate.

Furthermore, the tilt adjustment mechanism includes a motor and a transmission assembly, the transmission assembly being connected to the motor and the quarter-wave plate respectively; the motor is used to drive the transmission assembly to move, thereby adjusting the tilt angle of the quarter-wave plate.

In a second aspect, the present invention also provides an interferometric measurement system, including the Fizeau interferometer of the first aspect.

The Fizeau interferometer and interferometric measurement system provided by the present invention includes a laser, a polarizing beam splitter, a collimating mirror, a reference mirror, and a test mirror arranged sequentially along a direction of light propagation, and also includes an imaging system; a quarter-wave plate is arranged between the polarizing beam splitter and the reference mirror, and the quarter-wave plate is tilted; the laser light emitted by the laser is converted into first polarized light after passing through the polarizing beam splitter, and the first polarized light is incident on the reference mirror after passing through the collimating mirror and the quarter-wave plate; a portion of the polarized light incident on the reference mirror is reflected by the reference mirror, and after passing through the collimating mirror and the quarter-wave plate, it is reflected by the polarizing beam splitter and enters the imaging system to form a reference light; another portion of the polarized light incident on the reference mirror passes through the reference mirror and is incident on the test mirror, is reflected by the test mirror, and after passing through the reference mirror, the collimating mirror, and the quarter-wave plate, it is reflected by the polarizing beam splitter and enters the imaging system to form a test light. The Fizeau interferometer employs a polarizing beam splitter prism and a quarter-wave plate. The polarizing beam splitter prism has the ability to cut off P-polarized/S-polarized light, which can eliminate stray light generated by the beam splitter prism itself. The tilting setting of the quarter-wave plate can reduce stray light generated by the quarter-wave plate itself. Therefore, the Fizeau interferometer reduces the influence of stray lights.

Brief Description of the Drawings

To more clearly illustrate the specific embodiments of the present invention or the technical solutions in the prior art, the drawings used in the description of the specific embodiments or the prior art will be briefly introduced below. Obviously, the drawings described below are some embodiments of the present invention. For those skilled in the art, other drawings can be obtained from these drawings without creative effort.

Figure 1 is a schematic diagram of a Fizeau interferometer.

Figure 2 is a stray light path corresponding to the Fizeau interferometer shown in Figure 1.

Figure 3 is a simulated image of the Fizeau interferometer shown in figure 1 without a reference mirror.

Figure 4 is a simulated image of the Fizeau interferometer shown in figure 1 with a reference mirror.

Figure 5 is a real photograph of the Fizeau interferometer shown in figure 1 without a reference mirror.

Figure 6 is a schematic diagram of a Fizeau interferometer provided in an embodiment of the present invention.

Figure 7 is a schematic diagram of stray light suppression analysis corresponding to a Fizeau interferometer provided in an embodiment of the present invention.

Figure 8 is a simulated image of a Fizeau interferometer provided in an embodiment of the present invention without a reference mirror.

Figure 9 is a simulated image of a Fizeau interferometer provided in an embodiment of the present invention with a reference mirror.

Figure 10 is a real photograph of a Fizeau interferometer provided in an embodiment of the present invention.

The markups in the drawings are indicated as follows:

101-first laser; 102-beam splitter prism; 1021-incident surface; 1022-first beam splitting surface; 1023-outgoing surface; 1024-top surface; 103-first collimating lens; 104-first reference lens; 105-first test lens; 106-first aperture; 107-first imaging lens group; 108-CCD; 201-laser; 202-polarizing beam splitter prism; 2021-first surface; 2022-beam splitting surface; 2023-second surface; 2024-third surface; 203-collimating lens; 204-quarter-wave plate; 205-reference lens; 206-test lens; 207-linear polarizer; 208-aperture; 209-Imaging lens group; and 210-detector.

Detailed Description

The technical solutiond of the present invention will be clearly and completely described below with reference to the embodiments. Obviously, the described embodiments are only some of the embodiments of the present invention, and not all of the embodiments. Based on the embodiments of the present invention, all other embodiments obtained by those skilled in the art without creative effort are within the scope of protection of the present invention.

As shown in figure 1, the Fizeau interferometer includes a first laser 101, a beam splitter 102, a first collimating lens 103, a first reference lens 104, and a first test lens 105 arranged sequentially along the direction of light propagation. It also includes an imaging system composed of a first aperture 106, a first imaging lens group 107, and a CCD 108. The laser light emitted from the first laser 101 passes through the beam splitter 102 and the first collimating lens 103. Part of the light is incident on the first reference lens 104, reflected back by the first reference lens 104, and then, after passing through the first collimating lens 103, reflected back by the beam splitter 102 into the imaging system, forming a reference beam. Another part of the light passes through the first reference lens 104, is reflected back by the first test lens 105, and then, after passing through the first reference lens 104 and the first collimating lens 103, is reflected back by the beam splitter 102 into the imaging system, forming a test beam.

The beam splitter 102 in the aforementioned Fizeau interferometer generates two types of stray light, as shown in Figure 2. When the laser light emitted by the first laser 101 enters the beam splitter 102 through the incident surface 1021, it will be incident on the first beam splitting surface 1022. Light within a specific wavelength range will be reflected, while light of other wavelengths will be transmitted. When the transmitted first light is incident on the exit surface 1023, part of the first light will be reflected back to the first beam splitting surface 1022 by the exit surface 1023, and then reflected into the imaging system by the first beam splitting surface 1022, forming stray light. When the reflected second light is incident on the top surface 1024, part of the second light will be reflected back to the first beam splitting surface 1022 by the top surface 1024, and then pass through the first beam splitting surface 1022 into the imaging system, forming stray light.

As shown in figure 3, without a reference mirror, the light intensity in the central circular region of the simulated image of the Fizeau interferometer is significantly higher than that in other regions. This indicates the presence of stray light in the central circular region, which mainly includes the two types of stray light mentioned above. As shown in Figure 4, it can be seen that when a reference mirror is added, the reference light and the test light interfere, forming interference fringes, which still causes central stray light. As shown in Figure 5, it can be seen that there is obvious stray light (bright spot) in the center of the actual image, consistent with the simulated image in Figure 3.

The stray light shown in figures 3 to 5 above is the stray light that has the greatest impact on the Fizeau interferometer. To solve this stray light problem, this embodiment of the invention provides a Fizeau interferometer and an interferometric measurement system.

To facilitate understanding of this embodiment, a detailed description of the Fizeau interferometer disclosed in this embodiment of the invention is provided first.

The embodiment of the invention provides a Fizeau interferometer, in which the above-mentioned beam splitter prism 102 is replaced with a polarizing beam splitter prism, and a quarter-wave plate (also known as a quarter-wave plate or QWP) is added. The laser light emitted by the laser passes through the polarizing beam splitter prism and then through the quarter-wave plate; the stray light is intercepted by the light-cutting capability of the polarizing beam splitter prism, thereby solving the above-mentioned stray light problem.

As shown in Figure 6, the Fizeau interferometer includes a laser 201, a polarizing beam splitter 202, a collimating mirror 203, a reference mirror 205, and a test mirror 206 arranged sequentially along the direction of light propagation, and also includes an imaging system; a quarter-wave plate 204 is disposed between the polarizing beam splitter 202 and the reference mirror 205, and the quarter-wave plate 204 is tilted.

The optical path of the above-mentioned Fizeau interferometer is as follows: The laser light emitted by the laser 201 is converted into first polarized light after passing through the polarizing beam splitter 202. The first polarized light passes through the collimating lens 203 and the quarter-wave plate 204 and is incident on the reference mirror 205. A portion of the polarized light incident on the reference mirror 205 is reflected by the reference mirror 205, and after passing through the collimating lens 203 and the quarter-wave plate 204, it is reflected by the polarizing beam splitter 202 and enters the imaging system to form a reference light. Another portion of the polarized light incident on the reference mirror passes through the reference mirror 205 and is incident on the test mirror 206. It is reflected by the test mirror 206 and then passes through the reference mirror 205 and the collimating lens 203. After passing through the quarter-wave plate 204, the light is reflected by the polarizing beam splitter 202 into the imaging system, forming test light.

The polarizing beam splitter 202 can reflect S-polarized light and transmit P-polarized light, or reflect P-polarized light and transmit S-polarized light. Taking the polarizing beam splitter 202 reflecting S-polarized light and transmitting P-polarized light as an example, the laser light emitted by the laser 201 becomes P-polarized light after passing through the polarizing beam splitter 202. The P-polarized light becomes left-handed circularly polarized light after passing through the quarter-wave plate 204. The left-handed circularly polarized light is reflected by the reference mirror 205 or the test mirror 206 and becomes right-handed circularly polarized light. The right-handed circularly polarized light then becomes S-polarized light after passing through the quarter-wave plate 204 again. The

S-polarized light is reflected by the polarizing beam splitter 202 into the imaging system.

The polarizing beam splitter 202 can eliminate the two types of stray light generated by the beam splitter 102, as shown in Figure 7. When the laser light emitted by the laser 201 enters through the first surface 2021 of the polarizing beam splitter 202, it will be incident on the beam splitting surface 2022. P-polarized light will be transmitted, while S-polarized light will be reflected. When the transmitted P-polarized light is incident on the second surface 2023, part of the P-polarized light will be reflected back to the beam splitting surface 2022. At this time, this part of the P-polarized light is no longer reflected into the imaging system by the beam splitting surface 2022, but is transmitted by the beam splitting surface 2022, thus achieving the suppression of stray light from P-polarized light. When the reflected S-polarized light is incident on the third surface 2024, part of the S-polarized light will be reflected back to the beam splitting surface 2022. This portion of the light no longer passes through the beam-splitting surface 2022 into the imaging system, but is reflected by the beam-splitting surface 2022, thereby achieving stray light suppression of S-polarized light. In summary, the partially polarized light reflected by the second surface 2023 and the third surface 2024 cannot enter the imaging system, thus achieving stray light suppression.

The above-mentioned Fizeau interferometer uses a polarizing beam-splitting prism 202 and a quarter-wave plate 204. The polarizing beam-splitting prism 202 has the ability to cut off P-polarized/S-polarized light, which can eliminate stray light generated by the beam-splitting prism itself. The tilted setting of the quarter-wave plate 204 can reduce the stray light generated by the quarter-wave plate 204 itself. Therefore, this Fizeau interferometer reduces the influence of stray light.

Optionally, the laser wavelength generated by the above-mentioned laser can be, but is not limited to, 633nm.

Optionally, the quarter-wave plate 204 is located between the collimating lens 203 and the reference lens 205. This ensures that the light incident on the quarter-wave plate 204 is parallel, resulting in a smaller change in the incident angle and better consistency of the phase retardation, thus improving image uniformity and image quality.

Optionally, considering that the quarter-wave plate 204 is sensitive to the incident angle, the phase retardation may differ from the theoretical value at large incident angles. The optical axis of the quarter-wave plate 204 is positioned at a first preset angle relative to the incident light, within the range of 5° to 20°. This ensures the quarter-wave plate 204 effectively eliminates stray light while maintaining the required phase retardation.

Optionally, the optical axis of the quarter-wave plate 204 coincides with the optical axis of the polarizing beam splitter 202. This ensures that the first polarized light emitted from the polarizing beam splitter 202 becomes completely circularly polarized light after passing through the quarter-wave plate 204, thereby improving the imaging quality.

Optionally, the imaging system includes a linear polarizer 207, an aperture 208, and a detector 210 arranged sequentially along the direction of light propagation, with the linear polarizer 207 tilted. Considering the extinction ratio of the polarizing beam splitter 202, adding the linear polarizer 207 to the imaging system can further filter light and improve image quality. The tilted arrangement of the linear polarizer 207 can reduce stray light generated by the linear polarizer 207 itself.

Optionally, the optical axis of the linear polarizer 207 forms a second preset angle with respect to the incident light, the second preset angle being within the range of 5° to 20°. This ensures the linear polarizer 207's ability to eliminate stray light it generates.

Optionally, the detector 210 can be, but is not limited to, a CCD.

Optionally, an imaging lens group 209 is disposed between the aperture 208 and the detector 210. The imaging lens group 209 can be used to focus light from the aperture 208 onto the detector 210 to form a clear image; it can also be used to correct aberrations (such as spherical aberration, dispersion, etc.) to improve image quality; it can also be used to ensure that the detector 210 receives appropriate light intensity, neither overexposed nor underexposed; it can also be used to selectively transmit or block light of specific wavelengths to reduce background noise and enhance target signals.

Optionally, to facilitate adjustment of the tilt angle of the quarter-wave plate 204, the aforementioned Fizeau interferometer further includes a tilt adjustment mechanism connected to the quarter-wave plate 204. This tilt adjustment mechanism is used to adjust the tilt angle of the quarter-wave plate 204.

Further, the aforementioned tilt adjustment mechanism can also be connected to the linear polarizer 207 and used to adjust the tilt angle of the linear polarizer 207.

Optionally, the aforementioned tilt adjustment mechanism includes a motor and a transmission assembly. The transmission assembly is connected to both the motor and the quarter-wave plate 204. The motor drives the transmission assembly to move, thereby adjusting the tilt angle of the quarter-wave plate 204. This motor can be, but is not limited to, a motor.

Further, the aforementioned motor and transmission assembly can be two sets, corresponding to the quarter-wave plate 204 and the linear polarizer 207 respectively, to respectively adjust the tilt angles of the quarter-wave plate 204 and the linear polarizer 207. [0057] In one possible implementation, the motor rotates to tilt the quarter-wave plate 204/linear polarizer 207. When there is a bright spot reflected by the quarter-wave plate 204/linear polarizer 207 in the image generated by the imaging system, the motor can be rotated until the bright spot is deflected out of the image.

To verify the effect of the Fizeau interferometer provided in this embodiment of the invention, as shown in Figure 8, when no reference mirror is added, the center of the simulated image of the Fizeau interferometer does not have stray light, and the central stray light disappears compared to Figure 3; as shown in Figure 9, it can be seen that the reference light and the test light interfere, forming interference fringes, and the polarizing beam splitter 202 does not cause central stray light; as shown in Figure 10, it can be seen that the central bright spot in Figure 5 disappears, which is the same as the simulation result in Figure 9.

The embodiment of the invention also provides an interferometric measurement system, which includes the aforementioned Fizeau interferometer and a data processing device connected to the imaging system of the Fizeau interferometer. The data processing device is used to acquire the interferogram output by the imaging system and perform corresponding data processing on the interferogram to obtain the measurement result.

The interferometric measurement system provided in this embodiment has the same implementation principle and technical effect as the aforementioned Fizeau interferometer embodiment. For the sake of brevity, any parts not mentioned in the interferometric measurement system embodiment can be referred to the corresponding content in the aforementioned Fizeau interferometer embodiment.

Furthermore, in the description of the embodiments of the present invention, unless otherwise explicitly specified and limited, the terms "installation," "connection," and "linking" should be interpreted broadly. For example, they can refer to a fixed connection, a detachable connection, or an integral connection; they can refer to a mechanical connection or an electrical connection; they can refer to a direct connection or an indirect connection through an intermediate medium; and they can refer to the internal connection of two components. Those skilled in the art can understand the specific meaning of the above terms in the present invention based on the specific circumstances.

In the description of the present invention, it should be noted that the terms "center," "upper," "lower," "left," "right," "vertical," "horizontal," "inner," and "outer," etc., indicate the orientation or positional relationship based on the orientation or positional relationship shown in the accompanying drawings. They are only for the convenience of describing the present invention and simplifying the description, and do not indicate or imply that the device or component referred to must have a specific orientation, or be constructed and operated in a specific orientation. Therefore, they should not be construed as limitations on the present invention. In addition, the terms "first," "second," and "third" are used for descriptive purposes only and should not be construed as indicating or implying relative importance.

Finally, it should be noted that the above embodiments are only used to illustrate the technical solutions of the present invention, and not to limit them; although the present invention has been described in detail with reference to the foregoing embodiments, those skilled in the art should understand that modifications can still be made to the technical solutions described in the foregoing embodiments, or equivalent substitutions can be made to some or all of the technical features therein; and these modifications or substitutions do not cause the essence of the corresponding technical solutions to deviate from the scope of the technical solutions of the embodiments of the present invention.