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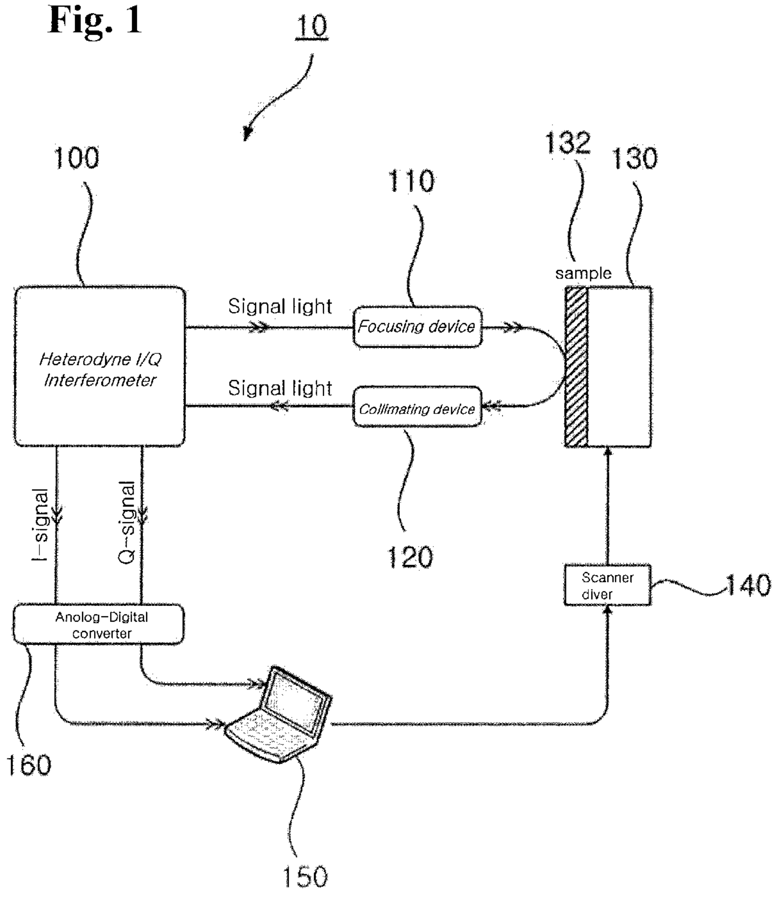
[Continued on next page]

(54) Title: SCANNING MICROMETER USING HETERODYNE INTERFEROMETER

Fig. 1



(57) Abstract: The present invention relates to a scanning micrometer using a heterodyne interferometer. A scanning micrometer using a heterodyne interferometer includes: a heterodyne interferometer providing a probe beam to a sample, and converting the probe beam and a reference beam focused and collimated with respect to the sample into an I signal and a Q signal and outputting the I and Q signals; an analogue to digital (A/D) converter converting the I signal and the Q signal outputted form the heterodyne interferometer into digital signals; and a computer receiving the digitalized I signal and Q signal provided from the A/D converter to extract information with respect to the surface of the sample. Therefore, it is possible to obtain and analyze physical and structural information with respect to surface or inside of the sample using a heterodyne interferometer having an I/Q demodulator.

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SCANNING MICROMETER USING HETERODYNE INTERFEROMETER

FIELD OF THE INVENTION

The present invention relates to a scanning micrometer using a heterodyne interferometer, and more particularly, to a scanning micrometer which is capable of obtaining and analyzing physical and structural information with respect to surface and inside of a sample using a heterodyne interferometer having an I/Q demodulator.

DESCRIPTION OF THE RELATED ART

An interferometric measuring system is a system that combines a probe beam and a reference beam together using a beam splitter (BS) and measures beam intensities outputted from two output terminals respectively with separate photodetectors. At this time, the electric signal outputted from each photodetector is referred to as a beam signal. The system is referred to as a homodyne interferometer in the case that the frequencies of the probe beam and the reference beam are identical, and the system is referred to as a heterodyne interferometer in the case that the frequencies of the probe beam and the reference beam are different.

In the case of the homodyne interferometer, the intensities of the beams outputted from the two output terminals vary as a phase difference between the probe beam and the reference beam. When a constructive interference occurs in the beam outputted from one output terminal, a destructive interference occurs in the beam outputted from the other output terminal. That is to say, the interference signals outputted from the respective terminals have a phase difference of 180 degrees. Therefore, by subtracting the two beam signals with a differential amplifier, correlated noises on the respective beam signals are removed and the beam signals are doubled thereby raising signal to noise ratio. This measuring method is called as a balanced detection method. The signal outputted from the differential amplifier is expressed by the mathematical formula 1.

【Mathematical Equation 1】

$$v_{diff} = R\sqrt{I_s}\sqrt{I_{LO}}\cos(\Phi_0 + \Phi_m)$$

wherein, IS and ILO represent, respectively, the intensities of the probe beam and reference beam, and Φm and Φo represent, respectively, a phase value derived in the probe beam due to partial structure or optical property of a sample to be measured and a phase difference due to difference between optical paths of the probe beam and the reference beam in the interferometer other than the phase value.

A scanning micrometer is the system which optimally measures a variation in the partial optical properties resulted from a structural change of the sample during scanning process and therefrom restores the shape of surface or inside structure of the sample, and it is thus necessary to optimally measure Φm while scanning the sample or the probe beam. Since the magnitude of Φm is very small in most cases, the mathematical equation 1 can be rewritten as the mathematical equation 2 by adjusting the path difference between the probe beam and the reference beam so that Φo is always π(2n+1)/2, wherein n=0, 1, 2, ···.

【Mathematical Equation 2】

$$v_{diff} = R\sqrt{I_S}\sqrt{I_{LO}}\sin\Phi_m = R\sqrt{I_S}\sqrt{I_{LO}}\Phi_m$$

Therefore, a magnitude of an interference signal comes to be proportional to Φm and it is thus possible to map the partial phase variation of the sample through scanning. However, in the case that intensity and phase of the probe beam vary at the same time, i.e. in the case that geometrical structure and material of the surface are changed at the same time, there is a disadvantage that it is impossible to identify them. Therefore, the homodyne interferometer is suitable to analyze a sample of the same material, but has a limitation in combined microscopic analysis for a general sample.

In the case of the heterodyne interferometer, the beam signal detected at each output terminal is given as the mathematical equation 3 since the frequencies of the probe beam and the reference beam are different.

【Mathematical Equation 3】

$$v_{diff} = R\sqrt{I_S}\sqrt{I_{LO}}cos(\triangle wt + \Phi_0 + \Phi_m)$$

wherein, Δω represents a frequency difference between the probe beam and the reference beam. In other words, the interference signal is a beat signal in RF or microwave band corresponding to frequency difference between the two beams, typical signal processing technology used in the field of RF can be used to measure phase variation or amplitude variation derived in the probe beam by the surface.

An interferometer capable of independently measuring the phase variation and the amplitude variation derived in the probe beam has been studied by the present inventor group. In the case of a homodyne I/Q-interferometer, two interferometers have a phase difference of 90 degrees between the interference signals while having the same probe beam path and reference beam path since it uses polarization of the probe beam and reference beam. Therefore, a signal of one interferometer is represented by the mathematical equation 4.

【Mathematical Equation 4】

$$v_I = \frac{R}{2}\sqrt{I_0}\sqrt{I_{LO}}cos(\Phi_0 + \Phi_m)$$

A signal of the other interferometer is represented by the mathematical equation 5 and it is thus possible to implement I/Q demodulation with respect to the beam signal. In other words, the phase derived in the probe beam can be obtained from the mathematical equation 6, and the magnitude variation of the probe beam is given by the mathematical equation 7.

【Mathematical Equation 5】

$$v_Q = \frac{R}{2}\sqrt{I_0}\sqrt{I_{LO}}sin(\Phi_0+\Phi_m)$$

【Mathematical Equation 6】

$$\Phi_0+\Phi_m = \tan^{-1}\frac{\sqrt{v_Q}}{\sqrt{v_I}}$$

【Mathematical Equation 7】

$$\sqrt{I_0}\sqrt{I_{LO}} = \sqrt{v_I^2+v_Q^2}$$

Accordingly, it is possible to independently measure the phase variation and the magnitude variation derived in the probe beam at the same time when using the I/Q-interferometer. Details of the interferometer and a surface micrometer using the same are disclosed in reference document 1 (Heseong Jeong, Jong-Hoi Kim, Kyumann Cho, "Complete mapping of complex reflection coefficient of a surface using a scanning homodyne multiport interferometer.", Optics communication, Vol. 204, pp.45-52 (2002)). Herein, the surface analysis was implemented in a reflection type, and it was possible to analyze the structural and material properties of the surface by mapping partial variations in phase and magnitude with respect to the probe beam while scanning the sample in x and y axial directions after focusing the probe beam onto one point on the surface. A function of a micrometer using the existing interferometer is significantly improved in this micrometer, and the present inventor group has shown in the reference document 1 that it is possible to find a material defect using this micrometer which could not be identified by the existing micrometer.

As can be appreciated from the aforementioned study, the homodyne interferometer includes three polarizing beam splitters and four photodetectors.

Therefore, the correct operation of the interferometer requires a very difficult and special arrangement process. The present inventor group has developed a technology of a heterodyne interferometer, which can effectively measure the phase derived in the probe beam while having the same function, using a simple optical structure, other than the balanced detection method, in which only two photo diodes (PD) are used to measure single probe beam and a high-pass filter or a band-pass filter is placed at a front end of a I/Q-demodulator. Since information with respect to amplitude and phase variations loaded on the probe beam are down converted to RF or microwave band range by interfering the probe beam and the reference beam having different frequencies from each other using a beam splitter as shown in Fig. 5 and converting the interfered result into an electric signal using a photodetector, it is possible to easily identify and measure the phase and magnitude variations derived in the probe beam when using the I/Q-demodulating method. The present inventor group have implemented a study for measuring a phase signal using an I/Q-demodulator and applying it into a highly sensitive displacement sensor, and the result is disclosed in reference document 2 (MOON Joon, "a hybrid type displacement sensor using a heterodyne I/Q interferometer", Seokang University, 2003).

Meanwhile, since the heterodyne interferometer has a simple optical structure compared to the homodyne interferometer, the heterodyne interferometer has low sensitivity to the phase measurement but can be easily integrated into a module type device with high reliability and has high applicability.

Throughout this application, several patents and publications are referenced and citations are provided in parentheses. The disclosure of these patents and publications is incorporated into this application in order to more fully describe this invention and the state of the art to which this invention pertains.

DETAILED DESCRIPTION OF THIS INVENTION

Therefore, an object of the present invention is to provide a scanning micrometer using a heterodyne interferometer which is capable of measuring phase and amplitude variations derived in a probe beam transmitted through or reflected from a sample.

The above objects, other features and advantages of the present invention will become more apparent by describing the preferred embodiment thereof with reference to the accompanying drawings.

To achieve the above and other objects, the present invention provides a scanning micrometer using a heterodyne interferometer, which includes: a heterodyne interferometer providing a probe beam to a sample, and converting the probe beam and a reference beam focused and collimated with respect to the sample into an I signal and a Q signal and outputting the I and Q signals; an XY scanner provided with a sample die on which the sample is disposed, and moving the sample die in two directions perpendicular to a moving direction of the probe beam; a scanner driver controlling the movement of the XY scanner; a focusing device focusing the probe beam provided from the heterodyne interferometer onto a surface of the sample; a collimating device collimating the probe beam reflected from or transmitted through the sample after focused onto the sample; an analogue to digital (A/D) converter converting the I signal and the Q signal outputted form the heterodyne interferometer into digital signals; and a computer receiving the digitalized I signal and Q signal provided from the A/D converter to extract information with respect to the surface of the sample, or transferring a movement control signal for controlling the movement of the XY scanner to the scanner driver.

Preferably, the heterodyne interferometer of the scanning micrometer is operated in such a manner that the probe beam is reflected on the surface of the sample, and the focusing device and the collimating device are integrated into a single objective lens. Alternatively, the heterodyne interferometer of the scanning micrometer is operated in such a manner that the probe beam is transmitted through the sample, and the focusing device and the collimating device are respectively disposed in front and rear of the sample.

Preferably, the heterodyne interferometer is provided with an I/Q-demodulator, and the I/Q-demodulator receives an electric signal with respect to the reference beam and an electric signal with respect to the probe beam and outputs the I signal and the Q signal with respect to the electric signals.

Preferably, the heterodyne interferometer uses a dual mode laser light source, a balanced detection manner, or an acousto-optic modulator and a balanced detection manner.

Since the scanning micrometer using a heterodyne interferometer measures phase and amplitude variations derived in a probe beam transmitted through or reflected from a sample at the same time, it is possible to analyze a structure or material of surface or inside of a sample. Therefore, the scanning micrometer using an I/Q interferometer according to the present invention can be utilized very usefully in a combined diagnosis for bio or semiconductor device or material. The present invention has improved the shortcomings of the various existing micrometers and is expected to contribute advance of high technology industry such as semiconductor or bio technology.

The scanning micrometer according to the present invention as described above has a function that can obtain complex information with respect to partial structure or the material of the surface or inside by independently and simultaneously measuring the phase and amplitude variations derived in the probe beam reflected from or transmitted through the surface or inside of the sample, and can perform a combined diagnosis with respect to a desired area by scanning the probe beam. Also, the scanning micrometer according to the present invention has an interferometer with very simple structure and thus it is possible to integrate the interferometer into a highly reliable and miniaturized module. Further, the scanning micrometer according to the present invention measures the phase and amplitude variations derived in the probe beam using an I/Q demodulation technology that is used in RF or microwave communication and thus a signal processing device thereof is low-priced and highly reliable.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an internal configuration of a scanning micrometer using a heterodyne interferometer according to a preferred embodiment of the present invention;

Fig. 2 is a view illustrating a path through which a probe beam is focused, reflected from the surface of the sample and then collimated by a focusing and collimating device, when the scanning micrometer according to the present invention is operated in a reflective manner;

Fig. 3 is a view illustrating a path of a probe beam in a polarizing beam splitter placed at a probe beam input/output terminal of the heterodyne interferometer in the scanning micrometer according to a preferred embodiment of the present invention;

Fig. 4 is a view illustrating a beam path in a focusing device, a collimating device and a sample when the heterodyne interferometer according to a preferred embodiment of the present invention is operated in a transmissive manner;

Fig. 5 is a view explaining a balanced detection method using two photodetectors and a differential amplifier;

Fig. 6 is a block diagram showing an internal structure of an I/Q-demodulator used in the heterodyne interferometer, wherein A denotes a low-pass filter, B denotes a 0 hybrid 3dB power splitter and C denotes a 90 hybrid 3dB power splitter;

Fig. 7 is a configurational view showing a first embodiment of a heterodyne interferometer in the scanning micrometer according to the present embodiment;

Fig. 8 is a configurational view showing a second embodiment of a heterodyne interferometer in the scanning micrometer according to the present embodiment; and

Fig. 9 is a configurational view showing a third embodiment of a heterodyne interferometer in the scanning micrometer according to the present embodiment.

[Detailed Description of Main Elements]

10: scanning micrometer

100: heterodyne interferometer

110: focusing device

120: collimating device

130: XY scanner

140: scanner driver

150: computer

The present invention will now be described in further detail by examples. It would be obvious to those skilled in the art that these examples are intended to be more concretely illustrative and the scope of the present invention as set forth in the appended claims is not limited to or by the examples.

EXAMPLES

Reference will now be made in detail to a preferred embodiment of the present invention, examples of which are illustrated in the accompanying drawings.

Fig. 1 is an overall block diagram showing a scanning micrometer according to a preferred embodiment of the present invention. Referring to Fig. 1, the scanning micrometer 10 is provided with a heterodyne interferometer 100, a focusing device 110, a collimating device 120, an XY-scanner 130, an A/D converter 160, a computer 150 and scanner driver 140. By combining an interferometer and a scanning micrometer, the scanning micrometer 10 according to the present invention having the aforementioned configuration can analyze partial optical properties of surface or inside of a sample, which cannot be obtained by existing micrometer, and obtain structural and material information with respect to the sample. Hereinafter, components of the scanning micrometer according to the present invention will be described in detail.

The heterodyne interferometer 100 is also referred to as an I/Q interferometer, which can focus a probe beam onto a sample disposed on the scanner and independently and simultaneously measure a phase and an amplitude of the probe beam reflected from surface or inside of the sample or transmitted through the sample.

The focusing device 110 focuses the probe beam onto the sample and the collimating device 220 collimates the probe beam reflected from or transmitted through the sample. The scanning micrometer according to the present invention can be operated in a reflective manner or a transmissive manner. Fig. 2 is a view illustrating a path through which a probe beam is focused, reflected from the surface of the sample and then collimated by the focusing and collimating device when the scanning micrometer according to the present invention is operated in a reflective manner. As shown in fig. 2, the probe beam outputted from the heterodyne interferometer 100 is focused onto the surface of the sample 132 disposed on the scanner 130, and the beam reflected from the surface or inside of the sample is collimated through the same optical system and returns to the heterodyne interferometer 100.

Fig. 3 is a view illustrating a path of the probe beam in a polarizing beam splitter placed at a probe beam input/output terminal of the heterodyne interferometer. Referring to Fig. 3, the probe beam is transmitted or reflected at the polarizing beam splitter of the heterodyne interferometer and reciprocated through a quarter-wave plate (QWP) or a 45° faraday rotator. At this time, since a polarization direction of the probe beam is rotated by 90° as the probe beam is reciprocated through a quarter-wave plate (QWP) or 45° faraday rotator, the reciprocated probe beam is inputted again into the heterodyne interferometer after reflected or transmitted at the polarizing beam splitter. A phase variation and a magnitude variation are derived in the probe beam inputted into the heterodyne interferometer by partial structural and/or optical properties with respect to the surface of the sample, and the phase and amplitude variations of the probe beam can be independently measured by applying the heterodyne I/Q-demodulation method. And, while scanning the sample or the probe beam in XY directions, it is possible to obtain images with respect to the phase and amplitude which are partially varied, and perform a combined diagnosis for the surface from the obtained images.

Fig. 4 is a view illustrating exemplary the focusing device 400, the collimating device 402 and the sample in the case that the heterodyne interferometer according to the present invention is operated in a transmissive manner. Referring to Fig. 4, in the transmissive manner, the probe beam is focused into the inside of the sample using the focusing device 400, and the probe beam transmitted through the sample is collimated using the collimating device 402 and then inputted again into the heterodyne interferometer using a mirror, etc. Therefore, it is, like the reflective manner, possible to obtain images of phase and amplitude variations with respect to the scanning area and perform a combined diagnosis for the surface from the obtained images.

An object of the present invention is to configure an optical micrometer which is capable of performing a combined analysis for optical properties of the surface or inside of a sample by combining a heterodyne interferometer with a scanning micrometer. It is possible to independently and simultaneously measure the phase and amplitude variations of a probe beam reflected from the surface of the sample or transmitted through the sample using an I/Q-interferometer, and to map partial optical properties of a desired area through scanning.

During the scanning process, it is possible to found a structural shape of the surface from the phase variation of the probe beam reflected from the surface, and found a variation in physical property of the surface from the amplitude variation. This complements greatly shortcomings of an existing scanning micrometer, and may be applicable to particularly high resolution combined diagnosis for a bio device, a bio material and a semiconductor device, etc. Also, since the phase and amplitude of the probe beam transmitted through the sample is given by a refraction index and an absorption coefficient of a medium which consists the sample, it is possible to perform the combined diagnosis with respect to the structure and material of the inside of the sample by independently measuring the phase and amplitude variations of the transmitted beam using the I/Q interferometer. Therefore, it is possible to found much structural and physical information by performing the diagnosis in reflective and transmissive manners together in diagnosis for general semiconductor or bio sample.

The heterodyne interferometer 100 provides the probe beam, and the probe beam is focused and collimated to include the surface information of the sample and then inputted again into the interferometer 100. After that, the probe beam is converted into an I-probe beam and a Q-probe beam and provided to the A/D converter 160. The I-probe beam and the Q-probe beam outputted from the heterodyne interferometer are converted into digital signals at the A/D converter 160 and then provided to the computer 150.

Meanwhile, the computer 150 transfers a movement control signal to the scanner driver 140 for controlling the movement of the XY-scanner 130 on which the sample is placed, and the scanner driver 140 controls the movement of the scanner 130 according to the transferred movement control signal. The XY-scanner is configured so as to move a sample die in two directions perpendicular to the moving direction of the probe beam.

The heterodyne interferometer 100 has an optical system identical to that of the conventional heterodyne interferometer, but uses the I/Q-demodulator which is used as a signal processing device in a RF or microwave communication as shown in Fig. 6 to independently and simultaneously measure the phase and amplitude of the probe beam.

The scanning micrometer using a heterodyne interferometer according to the present invention as described above may be configured in various forms according to the type of the heterodyne interferometer. Hereinafter, embodiments of the heterodyne interferometer in the scanning micrometer according to the present invention will be described.

Fig. 7 is an overall structural view illustrating a complex function scanning micrometer using a heterodyne I/Q-interferometer using dual mode laser, which is a first embodiment of the heterodyne interferometer; Fig. 8 is an overall structural view illustrating a reflective type complex function scanning micrometer using a heterodyne I/Q-interferometer using a balanced detection manner, which is a second embodiment of the heterodyne interferometer; and Fig. 9 is an overall structural view illustrating a scanning micrometer using an acousto-optic modulator and a balanced detection manner, which is a third embodiment of the heterodyne interferometer.

The heterodyne interferometers according to the first and second embodiments use, as a light source, a dual mode/dual polarization laser which have two stabilized frequencies different from each other and are polarized so as to be perpendicular to each other. The heterodyne interferometer according to the third embodiment uses, as a light source, a single mode laser of which oscillation frequency is stabilized and further uses an acousto-optic modulator to generate two beams having different frequencies.

Hereinafter, an operation of a scanning micrometer using the heterodyne interferometer according to the first embodiment will be described with reference to Fig. 7.

In the heterodyne interferometer according to the first embodiment, the dual mode/dual polarization laser beam outputted from the laser is divided into two paths by using a beam splitter. One of them is transmitted through a polarization plate which is arranged in 45° with respect to the polarization direction and thus two polarization components of the beam perpendicular to each other are combined. A beat signal between the two modes having different frequencies is obtained from the beam transmitted through the polarization plate using a photodetector, and the obtained beat signal is used as a local oscillator signal of an I/Q-demodulator. The beam divided by the beam splitter is utilized to configure the interferometer as shown in the drawing, and a polarizing beam splitter divides each of the polarization components to configure a modified Michelson interferometer, which is largely used in an indirect measurement utilizing one polarization component, i.e. the component reflected from the PBS in the drawing, as a reference beam and the other polarization component, i.e. the component transmitted through the PBS, as a probe beam. The reference beam is converted into a circular polarized beam while passing through a quarter wave plate and reflected at a mirror, and the polarization direction of the reference beam is rotated by 90° with respect to the original polarization direction as the reference beam passes again through the quarter wave plate while returning along the same path by being reflected at a mirror. Now, the beam returned along the same path is transmitted through the PBS. Meanwhile, in the measurement in the reflective manner, the probe beam transmitted through the PBS is circularly polarized by the quarter wave plate and is focused onto the surface of the sample by the focusing device such as an objective lens of a microscope. The probe beam reflected from the surface is collimated by the focusing device and returns along the original path. At this time, the polarization direction of the probe beam is rotated by 90° with respect to the original polarization direction as the reflected probe beam passes again through the quarter wave plate, and thus the probe beam is reflected at the PBS and combined with the reference beam. Therefore, the two beams move along a single path. Since the probe beam and the reference beam are polarized perpendicularly to each other, they are not interfered with each other. Therefore, it is possible to obtain the beat signal between the probe beam and the reference beam using the photodetector by interfering them using a polarization plate arranged in 45° with respect to the polarization direction or a PBS. A balanced detection can be carried out using two photodetectors and a differential amplifier as shown in Fig. 5 when using the PBS, and a beat signal as represented by mathematical equation 3 can be obtained by removing DC component from the beat signal outputted from the photodetector using a high-pass filter or a band-pass filter when using the polarization plate as shown in Fig. 7. The beat signal obtained as described above is inputted into a RF input terminal of the I/Q-demodulator to obtain I signal and Q signal respectively given in the forms of mathematical equation 4 and mathematical equation 5. The obtained signals are digitalized by the A/D converter and then inputted into the computer. The computer carries out an operation with the input data by mathematical equation 6 and mathematical equation 7, thereby capable of independently and simultaneously measuring phase and amplitude signals derived in the probe beam.

In Mach-Zehnder interferometer such as the second embodiment of Fig. 8 and the third embodiment of Fig. 9, the interferometer is configured so that the probe beam and the reference beam having different frequencies are spatially separated. Though a reflective micrometer is shown in Fig. 8 and a transmissive micrometer is shown in Fig. 9, the reflective manner and the transmissive manner can be applicable to both cases.

By scanning an interesting area while accurately changing positions with the XY scanner connected to the computer, it is possible to obtain a map of the phase and amplitude variations with respect to the corresponding area and it is possible to perform, through the obtained map, a combined microscopic diagnosis for the structure and material of the surface or inside of the sample.

Hereinafter, an operation of a scanning micrometer using the heterodyne interferometer according to the second embodiment will be described with reference to Fig. 8.

The heterodyne interferometer of Fig. 8 is a transmissive interferometer using the balanced detection method. A dual mode He-Ne laser in which the frequency is stabilized through temperature control or a Zeeman laser which is oscillated in dual mode may be used as a light source. In this light source, the frequency in each mode is different from the frequency in other mode. The beam having the two modes that are linearly polarized perpendicular to each other is incident to BS1 and is divided into two beams through transmission and reflection. The beam in the reflected path passes through a polarizer which is rotated by 45° with respect to the optical axis, thereby combining the two modes, and the combined beam is detected by PD1. The detected electric signal is used as a local oscillation signal of the I/Q-demodulator. The beam transmitted through the BS1 is divided again into a transmissive path and a reflective path by PBS1. Due to its property, a PBS reflects the beam polarized in the direction perpendicular to an incident surface and transmits the beam polarized in the direction parallel to the incident surface. Therefore, the beam with a single polarization direction exists in each path. The beam reflected at the PBS1 is used as the reference beam with respect to entire interferometer. The beam transmitted through the PBS1 is used as a measuring beam in the present interferometer and this beam is converted from a linear polarization into a circular polarization while transmitting a quarter wave plate which is rotated by 45° with respect to the optical axis of the beam. This circularly polarized beam is focused onto the surface of the sample through the lens. The XY scanner which is movable on XY plane is used to measure the surface of the sample and this scanner is moved at a predetermined distances by the computer and the scanner driver. Therefore, as the sample is moved on the XY plane, surface information is represented by a value of phase variation in the beam focused by the lens. Also, the focused beam is reflected by the surface of the sample and is incident again into the focusing lens, thereby being converted to a parallel beam. Therefore, the lens used in the present interferometer act as both focusing lens and collimating lens. Such collimated beam is converted from the circular polarization into the linear polarization while passing again through the quarter wave plate. This linear polarizing direction is perpendicular to the direction when the beam is transmitted through the PBS1. In other words, the linear polarizing direction is perpendicular to the incident surface of the PBS1. Therefore, the beam is reflected while passing through the PBS1. The reference beam and the measuring beam of the interferometer are combined at the BS1 and detected in the balanced detection manner configured with PD2, PD4 and the differential amplifier. In the balanced detection manner, intensities of the two beams outputted through two output terminal of the BS, i.e. reflection and transmission are varied as phase difference between the reference beam and the probe beam. When the beam outputted from one output terminal is constructively interfered, the beam outputted from the other output terminal is destructively interfered. In other words, interference signals outputted from respective output terminal have a phase difference of 180°. Therefore, correlated noises loaded on the respective beam signals are removed and the beam signal is doubled by subtracting the two beam signals with the differential amplifier, thereby capable of raising a signal to noise ratio. And, this measuring method is referred as the balanced detection method. The electric signal detected in this manner is used as a radio frequency signal of the I/Q-demodulator. I and Q signals demodulated through the I/Q-demodulator are converted into digital signals through the A/D converter and sent to the computer. The computer carries out calculation for obtaining information with respect to the surface of the sample through phase and intensity values using the digital signals.

Hereinafter, an operation of a scanning micrometer using the heterodyne interferometer according to the third embodiment will be described with reference to Fig. 9.

Fig. 9 is a configurational view illustrating a heterodyne interferometer using an acousto-optic modulator (AOM) and the balanced detection manner. A laser in which a beam polarized with a single frequency and a single mode is oscillated is used as a light source of this interferometer. This beam is incident to the AOM. The AOM acts to divide the path of the beam incident to the AOM into two paths with respect to the single mode and convert the beam into a beam having a frequency different from the initial oscillation frequency with respect to one path. This frequency can be adjusted through a frequency driver of the AOM and the adjusted frequency is used as a local oscillation signal of the I/Q-demodulator. A beam reflected by a mirror 1 of the two beams divided through the AOM is used as the reference beam with respect to the entire interferometer system. The beam moving along a straight linear path in AOM is focused onto the surface of the sample by the focusing lens. The sample is fixed to a transporting device of which movement is controlled at predetermined distances by the computer and the XY scanner. Therefore, the beam focused onto the surface of the sample has, as phase variation information, the surface information which varies as the movement of the sample. This beam is transmitted through the surface of the sample and converted into a parallel beam through the collimating lens. This parallel beam is incident to the BS through a proper arrangement of a mirror 3. This beam is combined with the reference beam incident to the BS by a mirror 2. The combined beam is detected in the balanced detection manner. The electric signal detected in this manner is used as a radio frequency signal of the I/Q-demodulator. I and Q signals demodulated through the I/Q-demodulator are converted into digital signals through the A/D converter and sent to the computer. The computer carries out calculation for obtaining information with respect to the surface of the sample through phase and intensity values using the digital signals.

Having described a preferred embodiment of the present invention, it is to be understood that variants and modifications thereof falling within the spirit of the invention may become apparent to those skilled in this art, and the scope of this invention is to be determined by appended claims and their equivalents.

What is claimed is:

1. A scanning micrometer using a heterodyne interferometer, comprising:

a heterodyne interferometer providing a probe beam to a sample, and converting the probe beam and a reference beam focused and collimated with respect to the sample into an I signal and a Q signal and outputting the I and Q signals;

an XY scanner provided with a sample die on which the sample is disposed, and moving the sample die in two directions perpendicular to a moving direction of the probe beam;

a scanner driver controlling the movement of the XY scanner;

a focusing device focusing the probe beam provided from the heterodyne interferometer onto a surface of the sample;

a collimating device collimating the probe beam reflected from or transmitted through the sample after focused onto the sample;

an analogue to digital (A/D) converter converting the I signal and the Q signal outputted form the heterodyne interferometer into digital signals; and

a computer receiving the digitalized I signal and Q signal provided from the A/D converter to extract information with respect to the surface of the sample, or transferring a movement control signal for controlling the movement of the XY scanner to the scanner driver.

2. The scanning micrometer using a heterodyne interferometer as set forth in claim 1, wherein the heterodyne interferometer of the scanning micrometer is operated in such a manner that the probe beam is reflected on the surface of the sample, and the focusing device and the collimating device are integrated into a single objective lens.

3. The scanning micrometer using a heterodyne interferometer as set forth in claim 1, wherein the heterodyne interferometer of the scanning micrometer is operated in such a manner that the probe beam is transmitted through the sample, and the focusing device and the collimating device are respectively disposed in front and rear of the sample.

4. The scanning micrometer using a heterodyne interferometer as set forth in claim 1, wherein the heterodyne interferometer is provided with an I/Q-demodulator, and the I/Q-demodulator receives an electric signal with respect to the reference beam and an electric signal with respect to the probe beam and outputs the I signal and the Q signal with respect to the electric signals.

5. The scanning micrometer using a heterodyne interferometer as set forth in claim 1, wherein the heterodyne interferometer uses a dual mode laser light source.

6. The scanning micrometer using a heterodyne interferometer as set forth in claim 1, wherein the heterodyne interferometer uses a balanced detection manner.

7. The scanning micrometer using a heterodyne interferometer as set forth in claim 1, wherein the heterodyne interferometer uses an acousto-optic modulator and a balanced detection manner.

Fig. 1

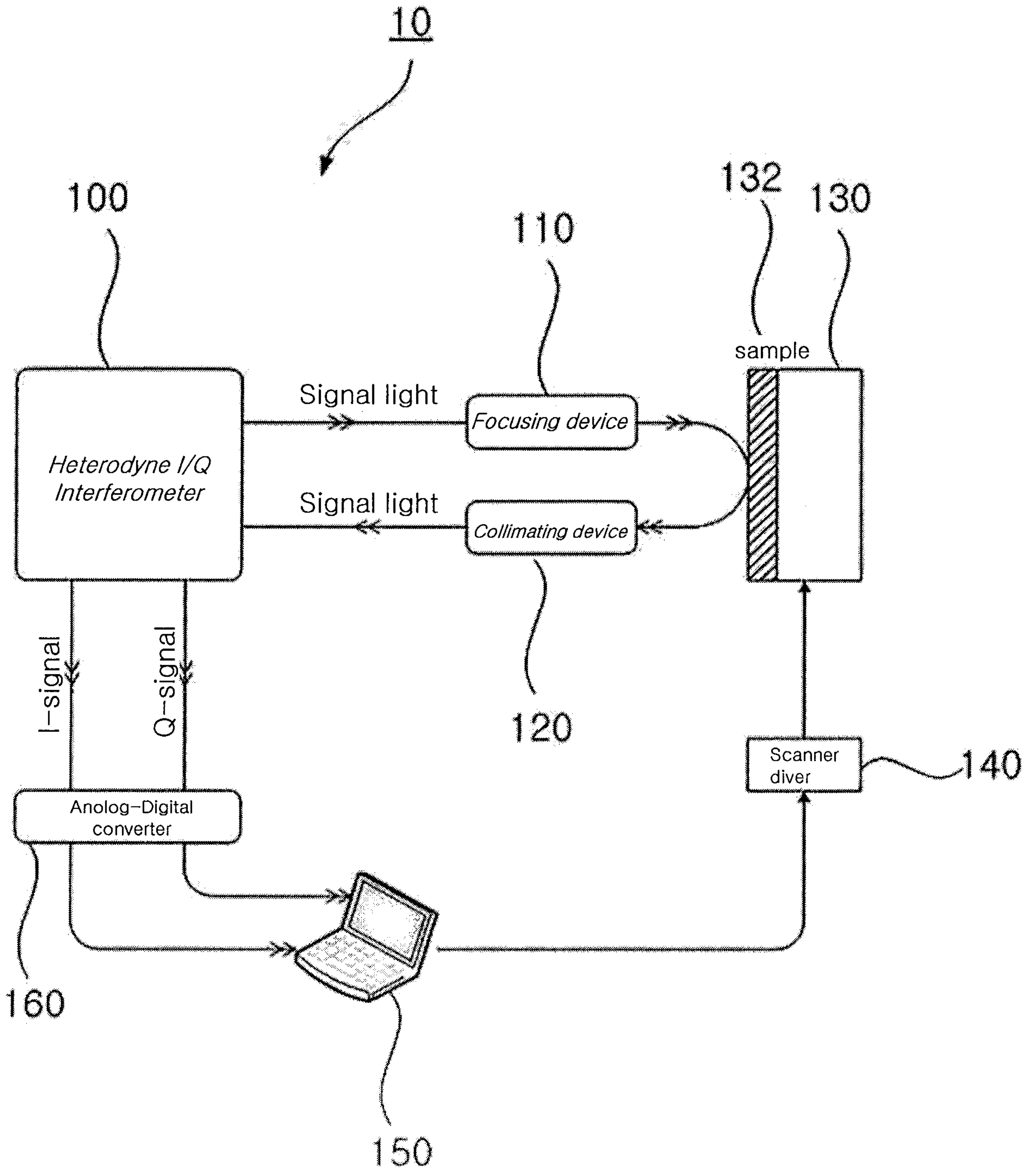

10
100
110
132
130
sample
Signal light
Focusing device
Heterodyne I/Q Interferometer
Signal light
Collimating device
120
I-signal
Q-signal
Scanner diver
140
Anolog-Digital converter
160
150

Fig. 2

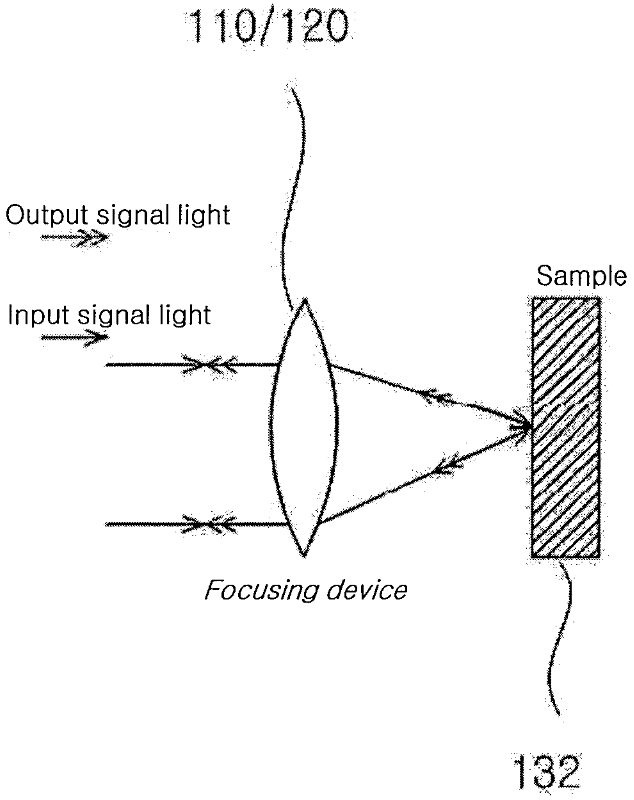

110/120
Output signal light
Input signal light
Sample
Focusing device
132

Fig. 3

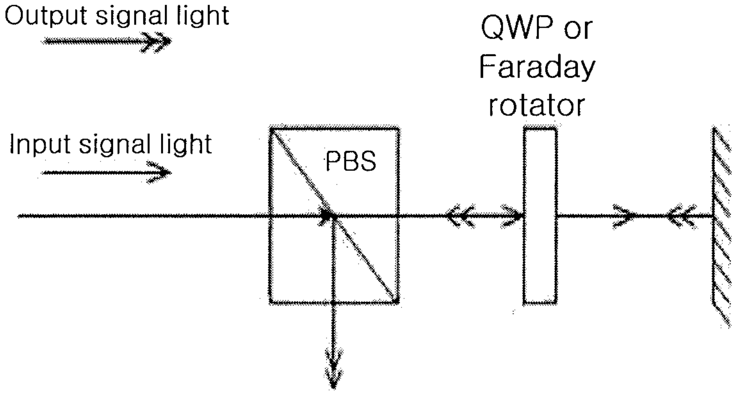

Output signal light
QWP or
Faraday
rotator
Input signal light
PBS

Fig. 4

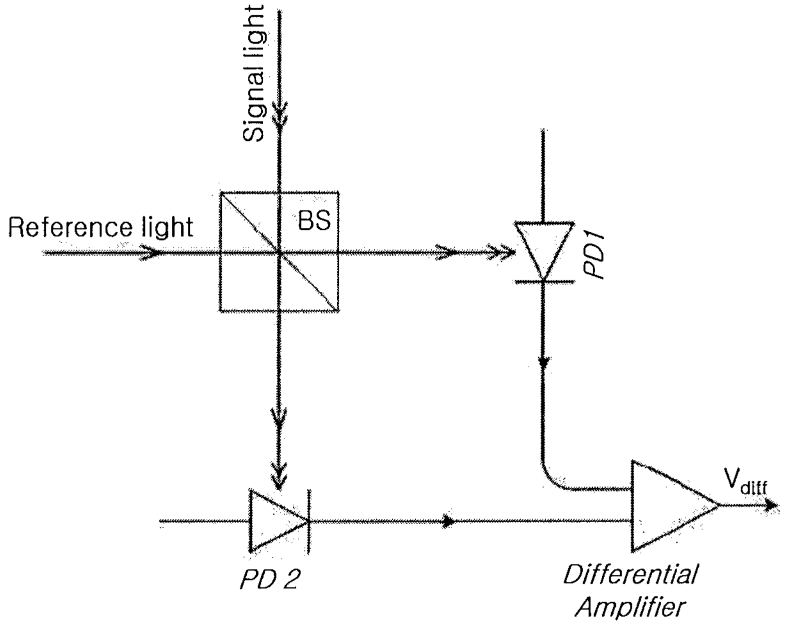

Signal light
Reference light
BS
PD1
PD 2
V_{diff}
Differential Amplifier

Fig. 5

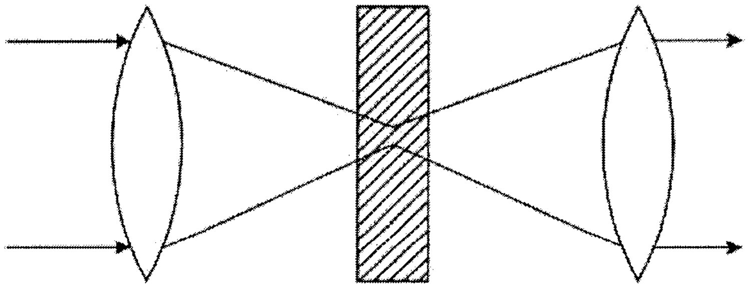


Fig. 6

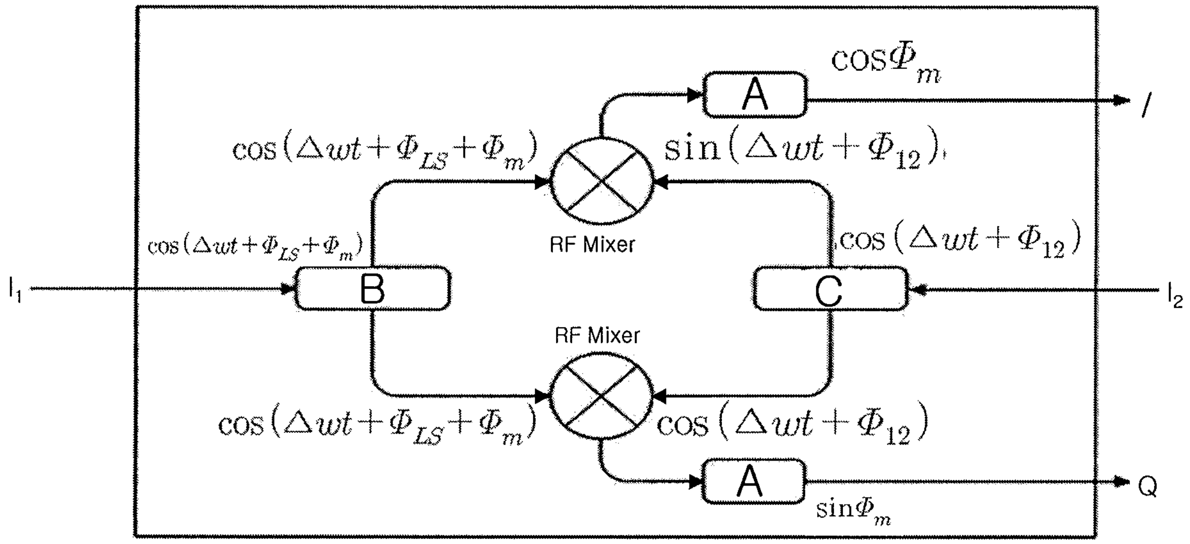

$\cos\Phi_m$
A
I
$\cos(\Delta wt+\Phi_{LS}+\Phi_m)$
$\sin(\Delta wt+\Phi_{12})$
RF Mixer
$\cos(\Delta wt+\Phi_{LS}+\Phi_m)$
$\cos(\Delta wt+\Phi_{12})$
I_1
B
C
I_2
RF Mixer
$\cos(\Delta wt+\Phi_{LS}+\Phi_m)$
$\cos(\Delta wt+\Phi_{12})$
A
Q
$\sin\Phi_m$

Fig. 7

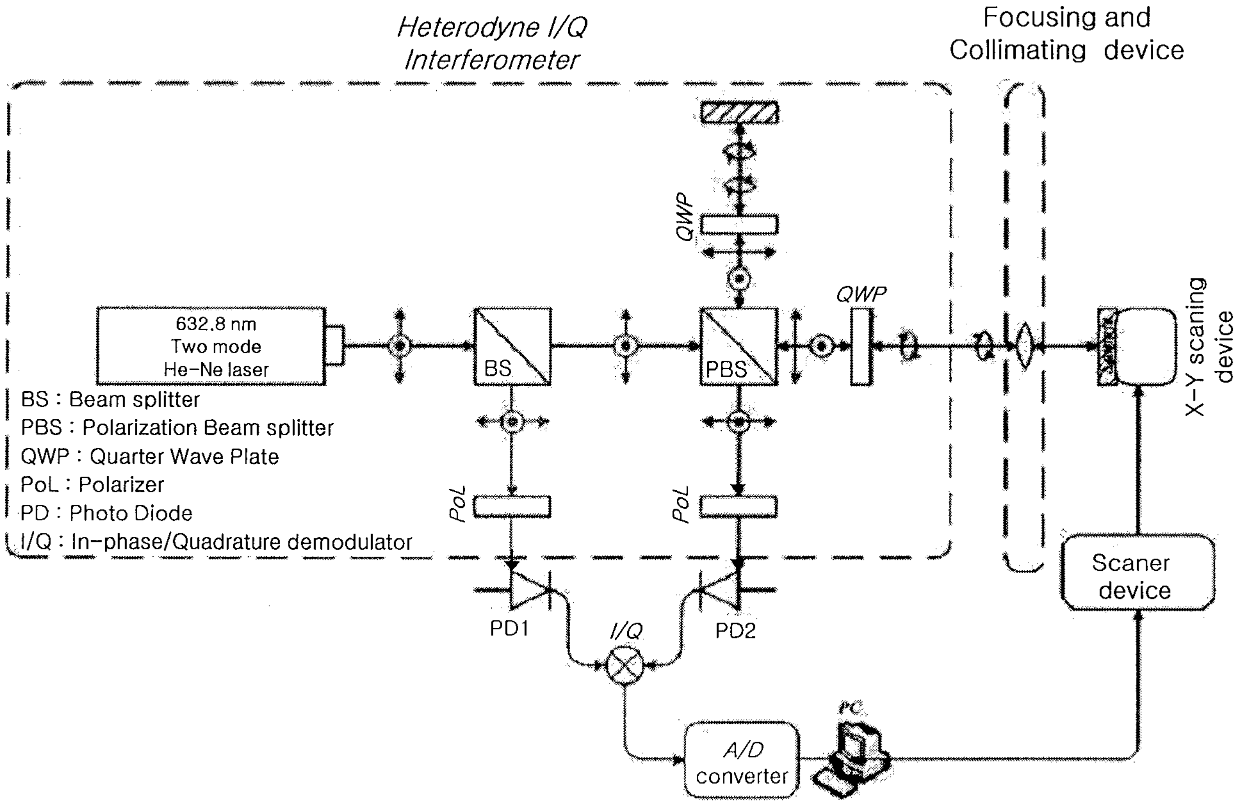

Heterodyne I/Q Interferometer
Focusing and Collimating device
QWP
632.8 nm Two mode He-Ne laser
BS
PBS
QWP
X-Y scaning device
BS : Beam splitter
PBS : Polarization Beam splitter
QWP : Quarter Wave Plate
PoL : Polarizer
PD : Photo Diode
I/Q : In-phase/Quadrature demodulator
PoL
PoL
PD1
I/Q
PD2
Scaner device
A/D converter
PC

Fig. 8

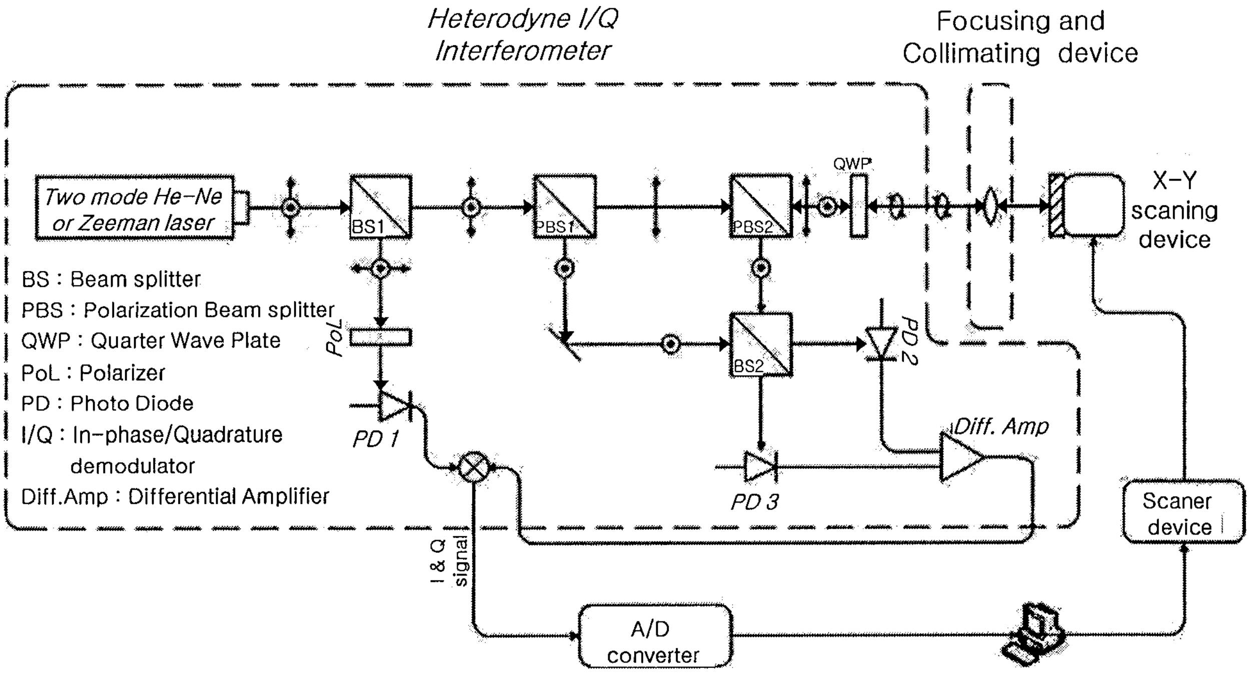
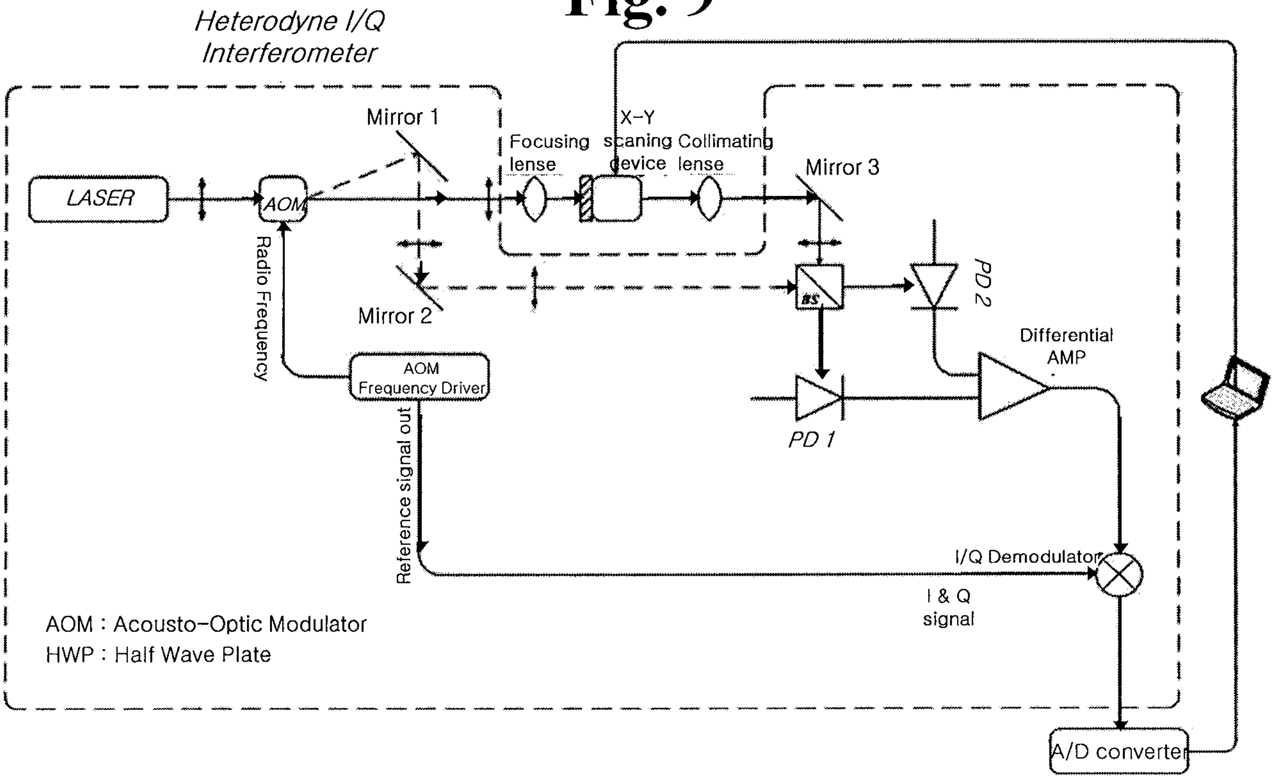

Heterodyne I/Q Interferometer
Focusing and Collimating device
Two mode He-Ne or Zeeman laser
BS1
PBS1
PBS2
QWP
X-Y scaning device
BS : Beam splitter
PBS : Polarization Beam splitter
QWP : Quarter Wave Plate
PoL : Polarizer
PD : Photo Diode
I/Q : In-phase/Quadrature demodulator
Diff.Amp : Differential Amplifier
PoL
PD 1
BS2
PD 2
Diff. Amp
PD 3
Scaner device
I & Q signal
A/D converter

Fig. 9


Heterodyne I/Q Interferometer
Mirror 1
Focusing lense
X-Y scaning device
Collimating lense
LASER
AOM
Mirror 3
Radio Frequency
Mirror 2
BS
PD 2
Differential AMP
AOM Frequency Driver
PD 1
Reference signal out
I/Q Demodulator
I & Q signal
AOM : Acousto-Optic Modulator
HWP : Half Wave Plate
A/D converter

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2008/000671

A. CLASSIFICATION OF SUBJECT MATTER

H01J 37/26(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC8: H01J, G01B, G02B, G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKIPASS(KIPO internal) "Keywords: heterodyne interferometer, polarizing beam splitter, correlated noise, balanced detection, photo diode, acousto-optic modulator"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 06324268 A (NEC CORP.) 25 November 1994 see abstract, claims 1, page 3, figure 1.	1-7
A	US 05371588 A (DAVIS et al.) 06 December 1994 see abstract, claims 1, col.5-col.6, figure 1.	1-7
A	JP 10293019 A (CITIZEN WATCH CO., LTD.) 04 November 1998 see abstract, page 3-4, figure 2.	1-7

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
29 MAY 2008 (29.05.2008)

Date of mailing of the international search report
29 MAY 2008 (29.05.2008)

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Facsimile No. 82-42-472-7140

Authorized officer
KIM, Sung Hoon
Telephone No. 82-42-481-8505

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 06324268 A	25.11.1994	JP2536718B2	18.09.1996
US 05371588 A	06.12.1994	NONE	
JP 10293019 A	04.11.1998	NONE	