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(19)

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(54) OPTICAL TEST APPARATUS AND METHOD FOR EXAMINING AN OBJECT

(71) We, SIRA INSTITUTE LIMITED, a British Company of South Hill, Chislehurst, Kent BR7 5EH do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to optical test apparatus and method for examining an object.

According to one aspect, the invention comprises optical test apparatus for examining an object, the apparatus comprising a source of radiation; a pattern comprising a regular array of two different types of area which influence the radiation differently; means for passing the radiation from the radiation source to the object and then to the pattern including a focusing device for providing a beam of the radiation at the pattern and the object; scanner means for causing relative movement of the beam of radiation across both the object and the different types of area of the pattern; and collector means for collecting radiation influenced by both the pattern and the object.

As the beam is scanned across the pattern, a varying output signal is produced by the radiation collector. This varying signal varies in a predetermined manner depending on the pattern alone if the object is fault free. It will be understood that what might be considered to be faults in one application, may not be so considered in another but for the sake of clarity these differences from norm will be referred to hereinafter as faults. If the object includes faults, the radiation passing through the optical system will be deviated, scattered or otherwise differently influenced from a perfect object which will affect the position, disposition or intensity of that radiation at the pattern. To illustrate this by a simple example, a faut which causes the radiation to deviate may cause the radiation to fall on, for example, an opaque area of the pattern instead of a transparent area and the collector means will not collect any radiation. By analysing the radiation collected, it is possible to detect faults and in some circumstances to identify them.

By pattern, we mean a regular array of two different types of areas which influence the radiation differently. Examples of such areas may include reflective areas and absorbing areas: reflecting areas and transmitting areas: or transmitting areas and absorbing areas.

If the scanning means is arranged to scan the radiation linearly then a linear pattern would normally be used and if circularly then a radial pattern would be used so that in either case, the radiation traverses across the pattern from one type of area to another.

The object may comprise for example, a transparent or reflective material. Such optical test apparatus may be used in a manufacturing process to inspect the material and to reject, for example, faulty material.

The collector means may take various forms. If it is convenient, the radiation passing through the pattern may be collected from behind the pattern so that the beam is influenced by the pattern once only or alternatively, reflective, diffuse or retroreflective means may be provided behind the pattern to reflect radiation back through the pattern a second time in which case the reflected beam may be separated from the incident radiation by a suitable beam splitter.

We preferably arrange the pattern to be a regular grating of radiation absorbing and radiation transmitting or reflecting areas, and the focusing means is arranged so that thebeam width at the object is twice the width of the radiation transmitting or reflecting areas.

According to another aspect the invention provides a method of examining an object comprising focussing a beam of radiation, passing the beam of radiation to the object so as to be influenced by the object and from the object to a pattern comprising a regular array of two different types of area which influence the radiation differently, the beam of radiation being scanned across both the object and the pattern, and collecting and analysing the radiation influenced by both the pattern and the object.

The term "radiation" incorporates the visible wavelengths which will be referred to as light, as well as ultraviolet, infra red and other wavelengths.

Two embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

FIGURE 1 shows a front diagrammatic view of a first embodiment of the invention,

FIGURE 2 is a side view of the apparatus of FIGURE 1,

FIGURE 3 is a view corresponding to FIGURE 1 of a second form of the first embodiment of the invention,

FIGURE 4 is a side view of the apparatus of FIGURE 3,

FIGURE 5 is a view corresponding to FIGURE 1 of a third form of the first embodiment of the invention,

FIGURE 6 is a side view of the apparatus of FIGURE 5,

FIGURE 7 is a diagram illustrating the principle of the invention,

FIGURE 8 is a diagram of the output signal produced by the apparatus,

FIGURE 9 is a front diagrammatic view of an apparatus in accordance with a second embodiment of the invention, and,

FIGURE 10 is a side diagrammatic view of the apparatus of FIGURE 9.

The invention will be most readily understood by reference to FIGURE 7. In this, it will be appreciated that a beam 101 of radiation, in this case light from a laser, is being scanned across an object under examination in the form of a transparent sheet 102. Various faults may be present in the sheet 102 such as bubbles, surface damage and absorption defects, the faults being exaggerated in FIGURE 7 so as to be clear. Mounted below the sheet 102 is a pattern in the form of a grating 103. It will be understood that in this embodiment the grating 103 comprises a regular linear grating of alternate transmitting areas 104 and absorbing areas 105 of the same width.

Referring to the beam 101 at the extreme left side of FIGURE 7, this beam 101 is passed through a normal part of the sheet 102 and then as it is scanned from left to right, the beam passes alternately through the light transmitting areas 104 and light absorbing areas 105 of the grating 103. It should be further noted that the beam is focussed so that its beam width is approximately the width of the light transmitting areas 104 at the grating 103 and is twice that width at the sheet 102. The light transmitted by the grating 103 is collected and the signal produced thereby will be in the form of a sine wave as the beam 101 traverses the light transmitting and absorbing areas 104 and 105 alternately. The portion to the left of Figure 8 shows that whilst scanning a normal part of the sheet 102, a sine wave is produced.

Considering now the distortion 106 shown in Figure 7, this fault will produce a distortion of the beam 101 passing through the sheet 102 and acts as a kind of lens which will tend to focus the light at a point above the grating 103 and will furthermore usually cause the light beam 101 to be displaced to one side from its normal position. The path which the beam 101 would follow below the sheet 102 if the fault 106 were not present is illustrated in dotted lines and as can be seen at that particular point in the scanning process the light should be passing through a light- transmitting area 104. However, by virtue of the fact that the beam 101 has been displaced the majority of the light is in fact striking a light absorbing area 105 and therefore the maximum signal which should otherwise be produced is not being produced by the light detector means. In practice not all of the light is absorbed by the light absorbing area 105 but some spills over into the next adjacent light transmitting area 104. The effect of this on the output signal of the detector means is seen from FIGURE 8. The signal never reaches its maximum value since the light beam has been spread so that at no time is all of the light able to pass through a single light transmitting area 104 and neither does the signal ever reach the minimum since at no time is all of the light absorbed by a light absorbing area 105. Furthermore, it will be understood that as the light beam is off axis, this provides a phase change X to Y in the signal since the light has been deflected away from its true position. This is generally indicated in the portion 108 of the signal of FIGURE 8. A similar but opposite phase change X′ to Y′ will occur when the beam 101 strikes the right hand side of fault 106.

Considering the fault 109 in FIGURE 7 which comprises a damaged surface which scatters the light generally randomly, it will be understood that the general effect of this is to reduce the maximum amplitude of signal produced since at no time is all of the light passing through light transmitting areas 104 and also increases the minimum signal since at no one time is all of the light being absorbed by light absorbing areas 105. The kind of signal output is indicated by reference numeral 110 in FIGURE 8.

In FIGURE 7, fault 111 absorbs the radiation passing through the sheet 102 and consequently no signal is detected. In this case, the output signal of the detector means will be as appears in FIGURE 8 at 112. In practice, of course, in some faults it may well be that less than complete absorption takes place owing to the absorption defect and so there will be low maxima at points corresponding to the absorption being passed through the light transmitting areas 104.

FIGURES 1 and 2 illustrate a first embodiment of apparatus of the invention. The apparatus is particularly adapted to examine a strip of transparent material being produced by a manufacturing process for faults.

The apparatus comprises a laser (not shown) for producing a beam of light 120 which beam is reflected from a mirror drum scanner 121 on to a cylindrical mirror/beam splitter 122. The cylindrical mirror 122 reflects the light from the mirror drum scanner 121 so as to scan the beam 120 transversely across the material 123 under inspection. In FIGURE 1 the length of the strip extends out of the plane of the paper and the strip moves in a direction along its length. The mirror drum scanner in 121 thus causes the light beam 120 to scan from one edge of the strip 123 to the other view in FIGURE 1. The strip 123 corresponds to the sheet 102 of FIGURE 7 already described.

The light transmitted by the strip 123 is passed through the linear grating 124 (corresponding to the grating 103 of FIGURE 7) onto a retroreflective layer 125 which extends behind the linear grating 124. The light incident on the retroreflective layer 125 is retroreflected (that is, reflected back along the incident path with slight scatter) and passes a second time through the grating 124 and inspected strip 123 to the cylindrical mirror/beam splitter 122 and thence through the beam splitter 122 through the cylindrical lens 126 to be focussed on the photomultiplier 127. With the scatter produced by the retroreflective layer 125, the light passes through many different light transmitting areas 104 and hence the total light intensity passed to the beam splitter 122 will not be varied during scanning.

The linear grating 124 extends with alternate light transmitting areas and light absorbing areas 104 and 105 in a direction out of the plane of the paper in FIGURE 1 and parallel to the plane of FIGURE 2. Because it focuses in one plane only, the cylindrical mirror 122 allows the focussing in the plane of FIGURE 2 that the surface of the mirror drum scanner 121 and the surface of the inspected strap 123 are at conjugate points and separate focussing of the light beam in the plane of FIGURE 1 so that the width of the beam at the linear grating 124 is the same as the width of the light transmitting areas 104 and the width of the beam at the inspected strip 123 is approximately twice the width of the light transmitting areas 104.

The mode of operation of the apparatus of FIGURES 1 and 2 will be readily apparent particularly after consideration of FIGURES 7 and 8. By rotating the mirror drum scanner 121 the beam of light is traversed across the inspected strip 123 in the plane of FIGURE 1 whilst the inspected strip 123 moves at right angles to the plane of FIGURE 1 and the signal produced at the photomultiplier 127 by the light received retroreflected from the layer 125 and passing through the linear grating 124 is generally of the form shown in FIGURE 8.

The arrangement shown in FIGURES 3 and 4 is similar to that shown in FIGURES 1 and 2 except that in place of a planar retroreflective layer 125 and planar linear grating 124 there is provided a curved retroreflective layer 125′ and a curved linear grating 124′. The reason for this is that as the light beam is scanned across the linear grating and retroreflective layer in FIGURE 1, by virtue of the different angle of incidence, the frequency of output signals may vary. This is obviated in FIGURE 3. Furthermore, the beam is in focus accurately at all points along the scan and the signal frequency, as mentioned above, is constant. The distance between the inspected strip and the grating, however, varies and hence the sensitivity of the apparatus will vary across the width of the strip 123.

The arrangement shown in FIGURES 5 and 6 constitutes the third form of the first embodiment of the invention. In this instance, the grating 124′ is combined with a cylindrical mirror to reflect the light back in the incident direction. The cylindrical mirror 128 in this instance incorporates a grating of non-reflective material and may be constructed of a flexible material such as glass or a plastics which is reflected about two supports as disclosed in our Patent 1 441 386. As will be seen from FIGURE 6, the arrangement is such that the reflected light beam from the cylindrical mirror 128 is in a different plane from the incident light from the cylindrical mirror 122. The principle of operation is, however, the same as the previous embodiments. A greater light intensity is, of course, achieved but this arrangement is more difficult to set up.

With respect to the arrangement of FIGURES 1 and 3 by focussing the light at the photomultiplier, the effect of ambient light can be much reduced.

In place of a retroreflective material in the arrangement of FIGURE 1 and 3 a matt white surface can be used although of course not so much light is reflected.

The second embodiment of the invention will now be described with reference to the FIGURES 9 and 10. This embodiment is similar to the previously described embodiment except that the light which has passed through the grating 124 is not reflected back along the same path but is collected from the side of the grating 124 opposite the inspected strip 123. This is achieved by providing a cylindrical lens 130, the longitudinal axis of which is transverse the plane of the scanned light and the width of which enables all of the light from the grating 124 to be collected from one end of the scan to the other. The cylindrical lens 130 focuses the light via a second cylindrical lens 131 having a longitudinal axis at right angles to the cylindrical lens 130 onto a photomultiplier 127'.

In this second embodiment, the beam of light only passes through the grating 124 once. In this embodiment the cylindrical lens 130 could be replaced by a cylindrical mirror with suitable other modifications to the optical system.

Although in the embodiments so far described a linear scanning is described with a linear pattern, it is of course possible for a circular or spiral scan motion to be used in which case the pattern would normally be of a radial type. Other combinations of scan and grating may be envisaged.

The invention is not restricted to the details of the foregoing examples.

WHAT WE CLAIM IS:

1. Optical test apparatus for examining an object, the apparatus comprising a source of radiation; a pattern comprising a regular array of two different types of area which influence the radiation differently; means for passing the radiation from the radiation source to the object and then to the pattern including a focusing device for providing a beam of the radiation at the pattern and the object; scanner means for causing relative movement of the beam of radiation across both the object and the different types of area of the pattern; and collector means for collecting radiation influenced by both the pattern and the object.

2. Apparatus as claimed in claim 1 in which the scanning means is arranged to scan the beam in a linear manner and the pattern is in a linear form so that, in use, the beam traverses the pattern from one type of area to another.

3. Apparatus as claimed in claim 1 in which the scanning means is arranged to scan the beam in a generally circular manner and the pattern is a radial pattern so that the beam traverses the pattern from one type of area to another.

4. Apparatus as claimed in any of claim 1 to 3 in which, in use, the beam is influenced once by the pattern.

5. Apparatus as claimed in any of claims 1 to 3 in which a retroreflective or reflective means is provided to reflect the beam received from the pattern back through the pattern, a beam splitter being provided to separate the reflected beam from the incident beam.

6. Apparatus as claimed in any of claims 1 to 5 in which the pattern is a regular grating of radiation absorbing and radiation transmitting areas.

7. Apparatus as claimed in any of claims 1 to 5 in which the pattern is a regular grating of radiation absorbing and radiation reflecting areas.

8. Apparatus as claimed in claim 6 or 7 in which the focusing means is arranged so that the beam width at the object is substantially twice the width of the radiation transmitting or reflecting areas.

9. Apparatus as claimed in any of claims 1 to 8 in which the source of radiation comprises a laser.

10. Optical test apparatus as claimed in claim 1 substantially as hereinbefore described with reference to Figures 1 to 8 or Figures 9 and 10 of the accompanying drawings.

11. A method of examining an object comprising focussing a beam of radiation, passing the beam of radiation to the object so as to be influenced by the object and from the object to a pattern comprising a

regular array of two different types of area which influence the radiation differently, the beam of radiation being scanned across both the object and the pattern, and collecting and analysing the radiation influenced by both the pattern and the object.

12. A method as claimed in claim 11 substantially as hereinbefore described.

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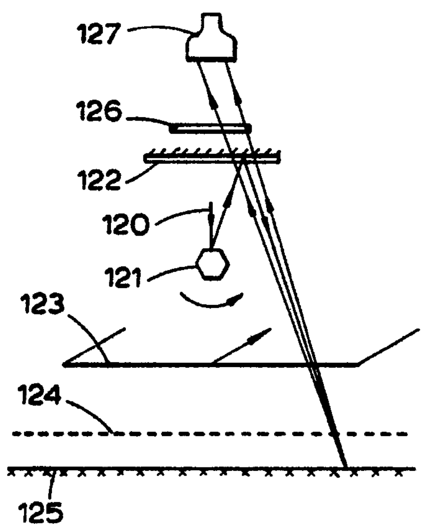

Fig.1

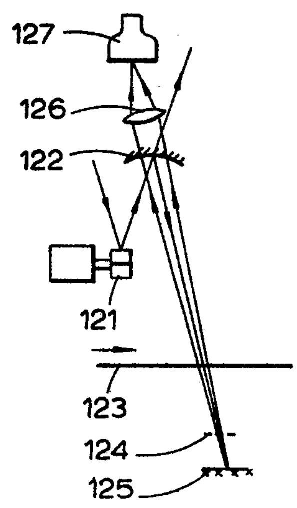

Fig.2

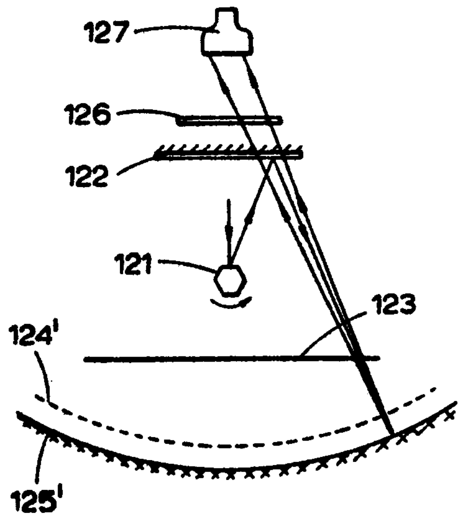

Fig.3

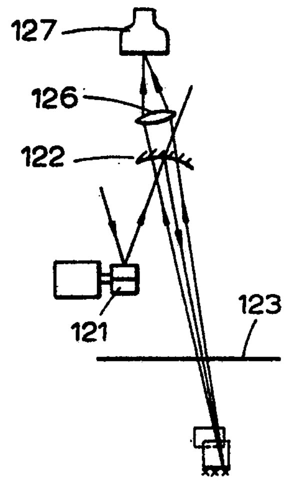

Fig.4

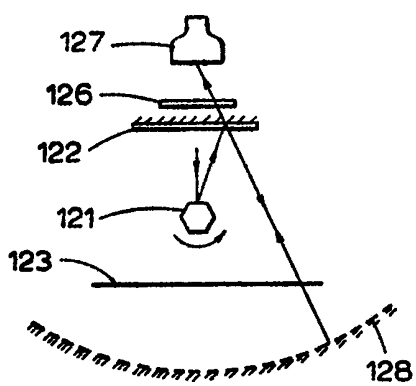

Fig.5

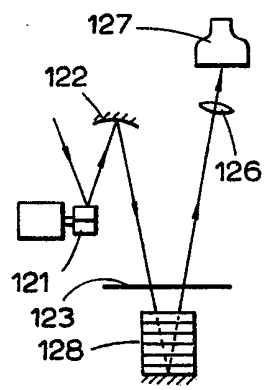

Fig.6

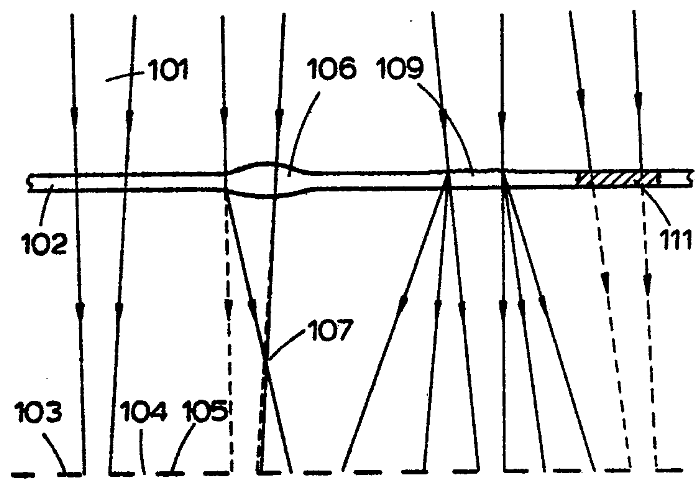

Fig. 7

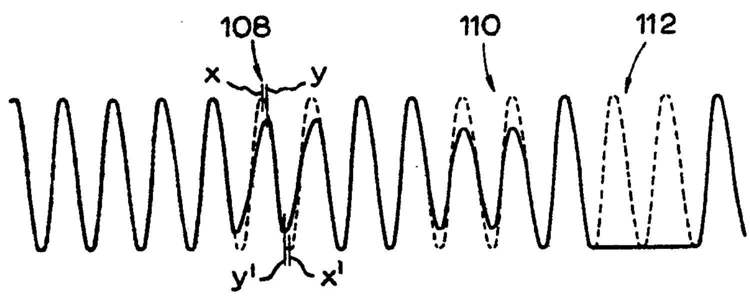

Fig. 8

1574423 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 4

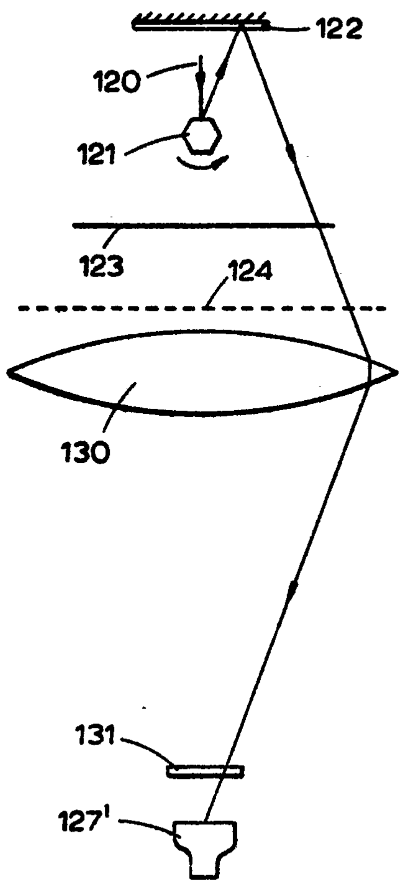

Fig. 9

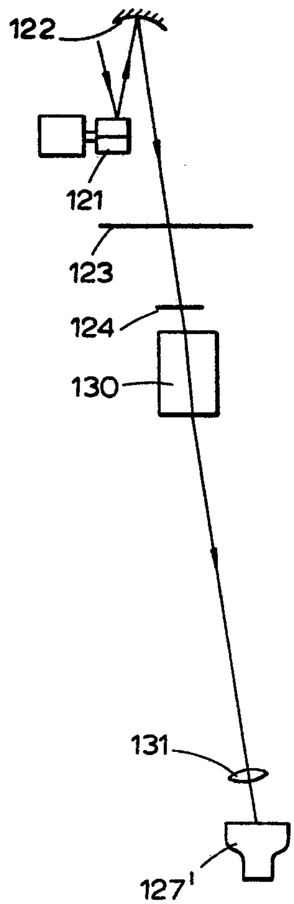

Fig. 10