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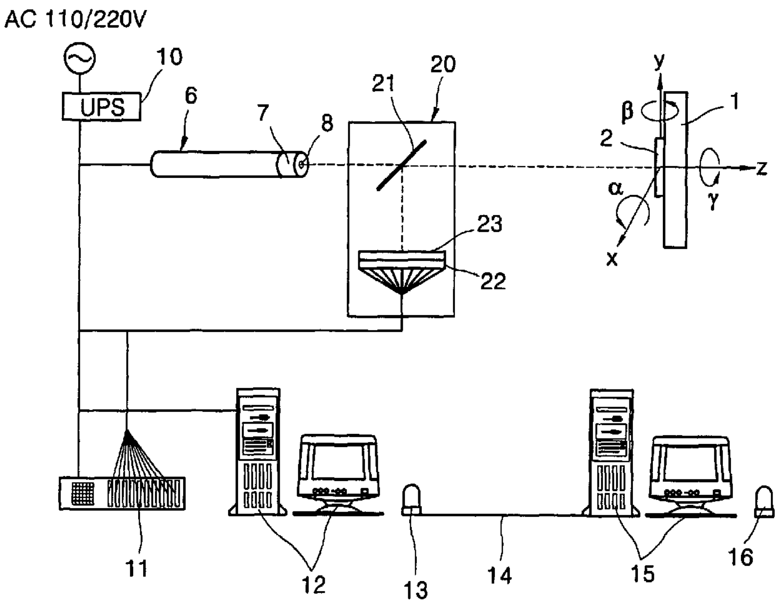

(57) Abstract: An optical structure safety monitoring system includes an optical system formed of a light emitting portion (6) and a light receiving portion (20) including a total reflection mirror (2) attached to a structure (1). A local monitoring system (12) and a first alarm 13 calculate a displacement of an optiocal path caused by vibration of the structure based on a signal detected by the light receiving portion of the optical system and give a first alarm when there is a change. A remote monitoring system 15 and a second alarm 16 establish database by collecting information through communications with the local monitoring system, diagnosing safety of the structure by analyzing inclination and vibration of the structure through the database, and giving a second alarm by analyzing the first alarm according to the result of diagnosis.

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APPARATUS FOR OPTICALLY MONITORING SAFETY STRUCTURE

Technical Field

The present invention relates to an optical structure safety monitoring system, and more particularly, to a system for optically monitoring a degree of inclination and vibration of a structure such as a building, bridge, tunnel, or steel tower by emitting a light beam from the outside of the structure to the structure so that safety of the structure is diagnosed in real time and anticipated danger is alarmed immediately.

Background Art

In general, safety of a structure, in particular, a large building or bridge, is verified from design to completion through thorough supervision and regular safety diagnoses after the completion. However, even a well built building passing the safety diagnosis may include a possibility of being collapsed by internal or external factors during use, causing a disastrous accident. Thus, to prevent any possible collapse and disastrous accident, a regular monitoring and alarming system enabling an appropriate action such as instant repair upon finding a change or evacuating people just in case is needed.

The safety of a structure can be accurately diagnosed by a non-destructive testing (NDT), such as radiation transmission or supersonic wave test, in addition to a fundamental appearance test. The NDT is necessary for the diagnosis of safety of a structure during construction thereof as well as at a regular or irregular time after construction. However, the NDT is not appropriate for a regular monitoring system. The NDT requires long-term preparation and diagnosis because it should be executed in a variety of manners according to features of structures and needs lots of experts in various fields. Furthermore, while an economical factor during operation should be taken into consideration for the regular monitoring system, the NDT needing manpower of a high quality and expensive equipments lacks the resolving factor.

In conventional technologies related to a regular monitoring of the safety of a structure, Korean Patent Publication No. 10-2000-0065832 discloses a detection sensor for monitoring internal cracks of a construction structure. The detection sensor is buried in the structure by making an optical fiber cable penetrate a body made of the same material (concrete) as that of the structure. The detection sensor is intended to make an error in an optical transmission function as being cut off or deformed when an internal crack occurs in the structure. That is, in the structure where the detection sensor is buried, by transmitting laser light into one end of the optical fiber cable and receiving the laser light emitted from the other end of the optical fiber cable, an internal crack of a structure can be monitored based on the presence of the laser light or a change in the quantity of light.

The monitoring by the detection sensor is limited. That is, regular monitoring is available only when the optical fiber cable is safely buried and well kept. If an error is generated in the buried optical fiber cable due to an internal crack in the structure, the detection sensor cannot be used again or repaired. When the buried optical fiber cable has a problem and does not work properly, the safety of the structure should be monitored or diagnosed in a different method thereafter. Also, the optical fiber cable is easily damaged during the steps of pouring and curing of concrete in the construction of a structure. Once the optical fiber cable is damaged, repair thereof is hardly possible. In addition, the optical fiber cable cannot be applied to existing structures and structures made of wood or steel frames, not concrete.

The present applicant has studied a way to optically monitor safety of a structure from the outside without burying an optical fiber cable in the structure. Based on the above studies, prior to the present invention, the present applicant has filed Korean Patent Application No. 10-1999-0061743 and Korean Utility Model Registration No. 185157 regarding a structure safety monitoring system and method using light which enables permanent monitoring, can be applied regardless of materials used for a structure. and enables accurate diagnosis and instant alarming for danger by analyzing a displacement of the structure in three dimensions.

According to the above inventions, a laser is used as a light emitting means and is fixed to a structure. A beam emitted from the laser is received at a stable place off from the structure. The received beam is converted to an electric signal. Information such as inclination or vibration of the structure included in the electric signal is analyzed so that the system gives an alarm for danger by diagnosing the safety of the structure.

Since the regular monitoring of the safety of a structure is very important, the installation of a system and maintenance thereof should be efficient. In the prior inventions, since the laser is directly fixed to the structure, in some cases, access to a structure is difficult and installation, maintenance, and repair of the system are difficult and inconvenient. Furthermore, although the laser requires a stable power supply, in some structures, no electric equipment is provided so that an addition electric equipment needs to be constructed or such a construction is not available.

To accurately diagnose a change in a structure, a smallest change such as inclination or vibration occurring in the structure can be sufficiently detected. That is, a high level optical resolving power is required and a sufficiently long optical path needs to be secured therefor. However, in some structure, it is difficult to secure an optical path due to a limit in installation such as a limited space and accordingly improvement of accuracy is restricted.

Since a laser apparatus is relatively expensive, considering an resolving point in operation, a mobile monitoring system has been suggested by reducing the number of lasers through an optimized installation and efficient management. Also, an apparatus such as a laser needs to be carried to a designated place for repair or check. However, in the above conventional inventions, since the laser is directly fixed to a structure, mobile monitoring becomes practically difficult. When the system is designed to be capable of detaching or moving, reliability in monitoring and diagnosis is lowered.

Disclosure of the Invention

To solve the above and other problems, it is an object of the present invention to provide an optical structure safety monitoring system which can be easily installed and maintained, can further improve optical resolving power, and can be easily moved.

To achieve the above object, an optical structure safety monitoring system comprising a target attached to a structure to be monitored and reflecting light, a light emitting portion projecting light toward the target, a light receiving portion detecting an electric signal including displacement information of the structure from the light reflected by the target, and a monitoring means for monitoring a displacement of the structure based on the electric signal detected by the light receiving portion.

A total reflection mirror such as a typical mirror, or a polarized patterned mirror selectively reflecting light according to the direction of polarization can be used as the target. To enable quantitative analysis of inclination and vibration of a structure, preferably, a goniometer which can adjust an angel by 0.1 ° is used as the means for adjusting an incident angle.

A laser is preferably used as the light emitting portion and a means for adjusting the diameter of a laser beam is added according to the light receiving method.

For the light receiving portion, two photoelectric sensors, an array in which the photoelectric sensors are arrayed in two dimensions, a CCD camera, and two CCD linear camera are used.

As the monitoring means, a computer system having a predetermined program is sued to process the detected signal from the light receiving portion and diagnose the safety of the structure. Preferably, computer systems for monitoring are installed at a site where the structure is located and a central management office at a remote place so that a plurality of structures located in different places can be integrally monitored and alarmed through networking.

Brief Description of the Drawings

FIG. 1A is a profile showing a change in an optical track due to inclination of a structure to explain the principle of an optical structure safely monitoring system according to the present invention;

FIG. 1B is a profile showing a change in an optical track due to vibration of a structure to explain the principle of an optical structure safely monitoring system according to the present invention;

FIG. 2 is a view showing an optical structure safety monitoring system according to a first preferred embodiment of the present invention, in which a reflection mirror is attached to a structure and a two-dimensional photoelectric sensor array is arranged at a light receiving portion;

FIG. 3A is a perspective view showing an example of installing a reflection mirror of FIG. 2 in which an angle can be adjusted by using a goniometer;

FIG. 3B is a perspective view showing an example of installing a reflection mirror of FIG. 2 in which an angle can be adjusted by using a goniometer and displacement of a structure can be amplified;

FIG. 4 is a flow chart showing a data process of a local monitoring system of FIG. 2;

FIG. 5 is a flow chart showing a data process of a remote monitoring system of FIG. 2;

FIG. 6 is a view showing an optical structure safety monitoring system according to a second preferred embodiment of the present invention, in which a total reflection mirror is attached to a structure and two CCD cameras are arranged at a light receiving portion;

FIG. 7 is a view showing an optical structure safety monitoring system according to a third preferred embodiment of the present invention, in which a total reflection mirror is attached to a structure and a CCD linear camera is arranged at a light receiving portion;

FIG. 8 is a view showing an optical structure safety monitoring system according to a fourth preferred embodiment of the present invention, in which a specially manufactured polarized patterned mirror is attached to a structure and a two-dimensional photoelectric sensor array is arranged at a light receiving portion;

FIG. 9 is a view showing an optical structure safety monitoring system according to a fifth preferred embodiment of the present invention, in which a specially manufactured polarized patterned mirror is attached to a structure and a spectroscope for splitting polarizing light only in a particular direction and two photoelectric sensors are arranged at a light receiving portion;

FIG. 10 is a view showing a pattern of the polarized patterned mirrors used in the fourth and fifth preferred embodiments;

FIG. 11A is a view showing a pattern obtained by observing a polarized patterned mirror used in the fourth and fifth preferred embodiments by a vertical polarizing spectroscope;

FIG. 11B is a view showing a pattern obtained by observing a polarized patterned mirror used in the fourth and fifth preferred embodiments by a horizontal polarizing spectroscope;

FIG. 12A is a graph showing a change in a detection signal corresponding to a vertical polarization component of a beam track shown in FIGS. 10 and 11A; and

FIG. 12B is a graph showing a change in a detection signal corresponding to a horizontal polarization component of a beam track shown in FIGS. 10 and 11B.

Best mode for carrying out the Invention

First, referring to FIGS. 1A and 1B, the principle of the present invention will be described.

In FIGS. 1A and 1B, reference 1 denotes a major portion of a structure, for example, a column or beam of a building, a pier or upper deck of a bridge, or a wall surface of tunnel to be monitored. A target, for example, a total reflection mirror 2, for reflecting a light beam is attached at a target position of the structure 1 to be monitored. An optical system is provided which includes a light emitting portion for projecting an incident beam 3 to the total reflection mirror 2 and a light receiving portion for detecting an electric signal by receiving reflected beams 4, 4a, and 4b. An information processing step is performed in which vibration of a structure is analyzed based on the electric signal detected by the light receiving portion of the optical system. If a change is determined to be dangerous in the above step, alarm is operated to notify the same to a manager so that the safety of a structure can be regularly monitored.

In a state in which the structure 1 is not inclined, assuming that a horizontal direction and a vertical direction on a plane where a surface of the total reflection mirror 2 which is a target are x axis and y axis , respectively, and that a direction perpendicular to the x-y plane is z axis, a displacement of a structure can be divided into a rotational vibration rotating with respect to each axis and/or an axial vibration moving along the respective axial directions. Thus, inclinations with respect to the respective axes are α, β, and χ and displacements of the respective axial directions according to the axial vibration are Δx, Δy, and Δz.

FIG. 1A shows a change in an optical track due to an inclination α with respect to the x axis of the structure 1. As shown in the drawing, assuming that the light emitting portion and the light receiving portion are arranged on an X-Y plane parallel to and separated a distance of l from the x-y plane at an interval of 2d, an incident angle and reflection angle θ is defined as follows.

$$\theta = \tan^{-1}\left(\frac{d}{l}\right) \quad \text{[Equation 1]}$$

The inclination θ can be expressed as follows.

$$\frac{d+\Delta Y}{l} = \tan(\theta + 2\alpha) \quad \text{[Equation 2]}$$

The following equations can be obtained from Equation 1 and Equation 2.

$$\frac{l\tan\theta + \Delta Y}{l} = \tan(\theta + 2\alpha), \text{ or}$$
$$\Delta Y = l\{\tan(\theta + 2\alpha) - \tan\theta\} \quad \text{[Equation 3]}$$

Here, ΔY is a vertical displacement of the reflection beam 4a moved on the X-Y plane due to α.

The steps according to Equations 1 through 3 are applied to the inclination β with respect to the y axis of the structure and to a horizontal displacement ΔX on the X-Y plane according thereto.

If an inclination within a range of $\alpha=\pm0.5°$ is to be measured by projecting a light beam under the conditions that l=50m and $\theta=0.1°$, from the result of Equation 3, d=25 cm and an array in which the photoelectric sensor is arranged in two dimensions with an interval of 17 cm in an area of 170 cm × 170 cm is used for the light receiving portion.

When $\theta=0°$, the right side of Equation 3 becomes $l\tan(2\alpha)$ and a two-dimensional photoelectric sensor array having the same interval and same area can be used to measure for a long distance, for example, 50 cm.

Next, FIG. 1B shows a change in an optical track of the reflected beam 4b when the structure 1 moves in a direction along the z axis. Here, the relationship of a vertical displacement $\Delta Y'$ by Δz can be expressed as follows.

$$\tan\theta=\frac{d+\frac{1}{2}\Delta Y'}{l+\Delta z}=\frac{\Delta Y}{2\Delta z},\ \text{or}$$
$$\Delta Y'=\frac{2d\Delta z}{l}$$
[Equation 4]

According to the result of Equation 4, for example, when a displacement within a range of ±5 mm is to be measured with an accuracy that Δz=1 mm and a distance that l =50 m, a two-dimensional photoelectric sensor array having a distance of 0.01 mm in an area of 0.1 mm×0.1 mm when d=25 cm is used. However, considering the present technology level, since a photoelectric sensor array is not capable, a CCD camera having a resolving power of 10 μm can be used instead of the photoelectric array.

In the meantime, in the case that d=0, that is, θ=0°, Δz cannot be measured. Thus, after information about α and β is obtained when d=0, for example, information of Δz only can be obtained from a condition that d=25 cm which includes α, β, and Δz. in other words, when a displacement ΔX when d=0 and displacements ΔX′ and ΔY′ when d≠0 are measured, the following equations are established.

$$\alpha=\frac{1}{2}\tan^{-1}\left(\frac{\Delta Y}{l}\right)$$
$$\beta=\frac{1}{2}\tan^{-1}\left(\frac{\Delta X}{l}\right)$$
$$\Delta z=\frac{l}{2d}\left[\Delta Y'+d-l\tan\left\{\tan^{-1}\left(\frac{d}{l}\right)+\tan^{-1}\left(\frac{\Delta Y}{l}\right)\right\}\right],\ \text{or}$$
$$\Delta z=\frac{l}{2d}\left[\Delta X'+d-l\tan\left\{\tan^{-1}\left(\frac{d}{l}\right)+\tan^{-1}\left(\frac{\Delta X}{l}\right)\right\}\right]$$

[Equation 5]

As a result, quantitative analysis of α, β, and Δz is possible by using Equation 5.

In the meantime, according to the method shown in FIGS. 1A and 1B, although α with respect to the x axis, β with respect to the y axis, and Δz in the z axis direction can be monitored, Δx, Δy, and γ with respect to the z axis cannot be monitored. In the following preferred embodiments of the present invention, a method for monitoring inclination and vibration in all directions is described.

In the following descriptions of preferred embodiments of an optical structure safety monitoring apparatus according to the present invention, the same reference numerals indicate the same elements having the same functions.

[Preferred Embodiment 1]

In the present preferred embodiment, as shown in FIG. 2, an optical structure safety monitoring apparatus includes a total reflection mirror 2 attached to the structure 1 as a target and a light emitting portion 6 and a light receiving portion 20. An optical system including a beam splitter 21 and a two-dimensional photoelectric sensor array 22 are arranged is provided at the light receiving portion 20. An electric power portion 10 for supplying electric power to the respective parts, and an analog to digital converter 11, a local monitoring system 12, and a first alarm 13, as a monitoring means, are installed at the site. The local monitoring system 12 is connected to a remote monitoring system 15 and a second alarm 16 at a remote place such as a central management center by using a communication network 14 such as a wireless optical communication, a dedicated line, or LAN.

Here, the remote monitoring system 15 may form a single network with the local monitoring systems 12 installed at a plurality of sites. Each local monitoring system 12 may be connected to a plurality of optical systems installed at a plurality of target positions in a single structure.

The total reflection mirror 2 that is a target can be replaced by a polarized patterned mirror to be described later. To adjust an incident angle of a light beam emitted from the light emitting portion 3, a goniometer capable of adjusting an angle at an accuracy of 0.1° can be attached at the structure 1 in two methods, as shown in FIGS. 3A and 3B. As shown in the drawings, two goniometers 30 and 30′ are used to adjust incident angles in two directions with respect to the x axis and the y axis. The two goniometers 30 and 30′ include main bodies 31 and 31′

and mobile bodies 32 and 32′ and adjustment screws 33 and 33′ are installed at the main bodies 31 and 31′. The main body 31 of one goniometer 30 is coupled to the structure 1 buy bolts. The main body 31′ of the other goniometer 30′ is disposed perpendicularly on the mobile body 32 of the one goniometer 30 by being coupled thereto using bolts. The total reflection mirror 2 is directly, or supported by an additional spring 34, attached to the mobile body 31′ of the other goniometer 30′. The main bodies 31 and 31′ and the mobile bodies 32 and 32′ of the goniometers 30 and 30′ are graduated to read a fine angle (here, a unit of an angle is omitted). By checking graduations and moving the mobile bodies 32 and 32′ using the adjustment screws 33 and 33′, the inclination of the total reflection mirror 2, that is, the incident angle θ, can be adjusted to a desired angle.

FIG. 3B shows that vibration of the total reflection mirror 2 is amplified b using an elasticity of the spring 34 with respect to vibrations of the structure 1. In this case, a response feature is superior due to an amplification effect with respect to fine vibrations of the structure 1. However, there is a problem in quantification of actual inclination or vibrations such as a spring constant, effect by wind, and remaining vibrations. Thus, this method is useful when a high frequency vibration is measured in a test room or a qualitative analysis at the site is needed.

Referring back to FIG. 2, the light emitting portion 6 includes a He-Ne laser which continuously oscillating a beam having a wavelength of 635 nm, a rated output power of 17 mW, and a diameter of 1 mm. A beam expander 7 and a pinhole 8 for space filtering are installed on the He-Ne laser. The He-Ne laser is formed to emit a laser beam having a diameter of 10 mm corresponding to the size of a photoelectric sensor of the light receiving portion to be described later. A total of 100 photoelectric sensors, each having a size of 10 mm × 10 mm, are arrayed 10 by 10 along the x and y axes in the two-dimensional photoelectric sensor array 22 of the light receiving portion 20 and an optical filter 23 is attached thereon. If the diameter of a laser beam is less than 10 mm, a small inclination or vibration caused by a beam moving within an area of one photoelectric sensor forming the photoelectric sensor array 22 may not be monitored. If the diameter of a beam is greater than 10 mm, the beam is incident on neighboring 2 or 3 photoelectric sensors at the same time. Such a problem can be easily solved by comparing detection signals of the respective photoelectric sensors according to the Gaussian distribution of a laser beam spot using data process algorithm of a monitoring system to be described later and calculating the maximum value.

An uninterruptible power supply (UPS) using a commercial AC voltage AC110/220V is used as the electric power portion 10 so that power can be stably supplied even for blackouts, thus preventing interruption of the operation of an optical system and monitoring system.

The analog to digital converter 11 has 100 channels to parallel process an analog value of a signal detected from the respective photoelectric sensor device arranged on the two-dimensional photoelectric sensor array 22 of the light receiving portion 20 to digital data.

Each of the local monitoring system 12 and the remote monitoring system 15 includes a personal computer having an interface card installed for data compatibility and applications programs for performing the processing as shown in FIGS. 4 and 5. When a huge amount of information is processed and a great amount of data is to be stored in the local monitoring system 12, there may be a problem in information collecting speed and capacity. Thus, the local monitoring system 12 preferably performs only a simple calculation processing with respect to the displacements ΔX and ΔY of a beam received based on the detection signal of the respective photoelectric sensor devices while a detailed analysis work about inclination and vibration of a structure and management of a large scale of database are performed by the remote monitoring system 15.

In the operation of the present preferred embodiment, the beam emitted from the laser of the light emitting portion 6 is reflected by the total reflection mirror 2. Some (about 50%) of the amount of light is reflected by the beam splitter 21 and arrives at the two-dimensional photoelectric array 22, and electric signal is detected by the two-dimensional photoelectric array 22. The detected electric signal includes information indicating a degree of inclination or vibration of a structure corresponding to the positions of the respective photoelectric sensor devices arranged in the two-dimensional photoelectric sensor array 22.

The local monitoring system 12, as shown in FIG. 4, controls (S41) the two-dimensional photoelectric sensor array 22 of the light receiving portion in a trigger method to receive data through the analog-to-digital converter 11. Here, by determining whether the data is normally received (S42), if the data is normally input, the data is temporarily stored in a memory (S43). If the data is not input at all or determined to be abnormal, it can be through that the optical system does not work properly or the structure is inclined or vibrated greatly, which is very dangerous. Thus, for this case, the first alarm 13 is operated (S47) to have a manger check the situation and take action and then the information is stored (S48).

After the data is normally input and stored, the stored data is read by a calculation apparatus in the system and the maximum light amount value of each of the photoelectric sensor devices in the two-dimensional sensor arrays 22 is extracted to calculate the displacements ΔX and ΔY.

Also, visualized graphic display information by graphically processing the displacements is output to a monitor connected to the system. Thus, the manager can monitor in real time the present state of the structure through the monitor displaying graph information. Next, the processed displacement and graphic display information are stored (S45) and the displacement is compared with a set value to determine whether it is dangerous (S46). Here, if it is determined to be dangerous in the above step, the first alarm 16 is operated (S47) and alarm information is stored (S48).

Calculation result data including the stored input data and the graphic display information and alarm information are transmitted to the central monitoring system 15 at a remote place through the communications network 14.

The remote monitoring system 15, as shown in FIG. 5, collects information from the local monitoring system 15 provided at each site in a one-directional or bi-directional communications method to establish database (S52). The remote monitoring system 15 opens the established database to accurately analyze inclination and vibration (α, β, and Δz) of a structure based on Equation 5. After the first alarm information is analyzed (S53), it is determined from the result of the analysis whether the displacement of a structure is in a dangerous level (S54). If it is determined to be in a dangerous level, the manager is immediately notified of such information via the second alarm 16.

The second alarm operated by the remote monitoring system 15 is generated in the cases in which the first alarm is generated at a particular period so that a resonance phenomenon is expected, the first alarm continues so that plastic deformation of a structure is expected, or a malfunction or change is expected in an apparatus or structure from the accumulated database analysis result.

[Preferred embodiment 2]

In this preferred embodiment, as shown in FIG. 6, two CCD (charge coupled device) linear camera having a one-dimensional photographing deice are arranged at the light receiving portion 60, as shown in FIG. 6. The light receiving portion 60 includes a first beam splitter 61 splitting a light beam reflected by the total reflection mirror 2 from an incident path of a laser beam, a second beam splitter 62 splitting the amount of the light split by the first beam splitter 61 in a ratio of 50:50 to be separated into two reflected beams paths, and translucent sheets 63 and 63′, cylindrical lenses 64 and 64′, reflection mirrors 65 and 65′, and the CCD linear cameras 66 and 66′ which are arranged on each of the two reflected beam paths. Other configurations are the same as those of the preferred embodiment 1. However, a digital interface board, for example, Meteor2-DIG/4/L, 3CH of Matrox Inc., needs to be installed at the local monitoring system 12 for data input of the CCD linear camera.

An image of the reflected beam is projected onto the translucent sheets 63 and 63′. Each of the cylindrical lenses 64 and 64′ focuses an image in one direction of X axis or Y axis, and transmits in the other direction, to form an image. Two CCD linear cameras 66 and 66′ photograph an image of the reflected beam formed in any one direction and detect signals indicating information on displacements (ΔX and ΔY) of the reflected beam in each direction. Thus, the inclination and vibration of a structure can be quantitatively estimated based on the data input from the two CCD linear cameras 66 and 66′.

According to the present preferred embodiment, since the interval between pixels of a photographing device of the CCD linear camera is

14 μm, a resolving power having a high accuracy can be obtained. Also, since the number of pixels per camera is 512, a sufficient sampling speed can be obtained which is advantageous in detection of a high frequency vibration.

[Preferred embodiment 3]

In this present preferred embodiment, as shown in FIG. 7, a light receiving portion 70 includes a beam splitter 71, a translucent sheet 72, and a CCD camera 73. The reflected beam of the total reflection mirror 2 is separated by the beam splitter 71 and projected onto the translucent sheet 72. Since the CCD camera 73 has a two-dimensional photographing device, data including information on the position of the image is detected by photographing the image of the reflected beam projected on the translucent sheet 72. Typically, in a photographing device of the CCD camera, since the interval between pixels is 14 μm and the number of pixels is about 300,000, a space resolving power having a very high accuracy can be obtained. However, since the sampling speed of the CCD camera is mush slower than that of the CCD linear camera, the CCD camera is suitable for quantitatively measuring a lower frequency vibration. Also, according to the present preferred embodiment, since only one CCD camera is provided, the optical system including a lens can be simplified so that the structure becomes compact and economical and installation thereof is made easy.

In the above preferred embodiments, a common total reflection mirror is used as a target attached to a structure and an inclination angle is applied to the beam so that only the displacements α, β, and Δz of the displacements of a structure are monitored. Hereinafter, preferred embodiments in which not only the displacements α, β, and Δz but also displacements γ, Δx, and Δy can be detected will be described.

[Preferred embodiment 4]

In this preferred embodiment, as shown in FIG. 8, a polarized patterned mirror 5 having a special pattern is attached to the structure 1 instead of a total reflection mirror, and other structures are the same as those the preferred embodiment 1.

[Preferred embodiment 5]

In this preferred embodiment, as shown in FIG. 9, the polarized patterned mirror 5 of the preferred embodiment 4 is attached to the structure 1 instead of the total reflection mirror. A light receiving portion 90 includes a first beam splitter 91 splitting a reflected beam of the polarized patterned mirror 5 from an incident path of a laser beam, a second beam splitter 92 for splitting the amount of light of the reflected beam split by the first beam splitter 91 into a ratio of 50:50 to be separated into two reflected beam paths, and vertical and horizontal polarizing spectroscopes 93 and 93′, focusing lenses 94 and 94′, and photoelectric sensors 95 and 95′ arranged on the respective split optical paths of the reflected beams,

The polarized patterned mirror 5 in the above-described preferred embodiments 4 and 5 can be attached to a structure in two ways as shown in FIGS. 4A and 4B, by using the goniometer as in the case of the above-described total reflection mirror.

The pattern of the polarized patterned mirror 5, as shown in FIG. 10, has a vertical polarization pattern VP and a horizontal polarization pattern HP arranged at an interval of 1t, 2t, and 3t (t is a unit of length) so as to be horizontal and symmetrical with respect to the X axis and the Y axis, respectively. The remaining area is processed to be a non reflection area. Accordingly, the polarized patterned mirror 5 is divided into a non polarizing reflection area 5a where the vertical and horizontal polarization patterns VP and HP cross each other and light is reflected in all polarization directions, polarizing reflection areas 5b and 5c the vertical and horizontal polarization patterns VP and HP do not cross each other and light is reflected in the respective polarization directions, and a non reflection area 5d in the remaining area (please refer to FIGS. 11A and 11B).

FIG. 11A shows the vertical polarization pattern VP on the polarized patterned mirror 5 observed through the vertical polarizing spectroscope 93 in the preferred embodiment 5. FIG. 11B shows the horizontal polarization pattern HP on the polarized patterned mirror 5 observed through the horizontal polarizing spectroscope 93′ in the preferred embodiment 5. These spectroscopes 93 and 93′ have transmittances of 20% to the non polarizing reflection area 5a, 10% to each of the polarizing reflection areas 5b and 5c, and 0% to the non reflection area 5d.

That is, of the two-dimensional displacement of the laser beam reflected by the polarized patterned mirror 5, a displacement ΔY in the Y-axis direction is detected by the vertical polarizing spectroscope 93 and a displacement ΔX in the X-axis direction is detected by the horizontal polarizing spectroscope 93′. The amount of light of a beam passing through each of the respective spectroscopes 93 and 93′ regularly changes according to the pattern arrangement and the transmittance in each area along a movement path of the beam. Thus, a signal whose amplitude is changing regularly according to the change of the amount of light is detected by the photoelectric sensors 95 and 95′

so that inclination and vibration of a structure can be quantitatively analyzed based on the detected signal.

As an example, in FIGS. 10, 11A, and 11B, it is assumed that a beam is moved from the original position of P0(X0, Y0) to P2(X2, Y2) via P1(X1, Y1), due to inclination or vibration occurring in a structure in one direction. Here, the diameter of a laser beam input to the polarized patterned mirror 5 is less than the unit of length, t.

Part of the laser beam reflected by the polarized patterned mirror 5 is polarized. Changes of the signals detected by the photoelectric sensors 95 and 95′ through the spectroscopes 93 and 93′ are s shown in FIGS. 12A and 12B. That is, assuming that the initial amount of light of a beam incident on the polarized patterned mirror 5 is 1, a value corresponding to the non polarizing reflection area 5a having a 20% transmittance, values corresponding to the polarizing reflection areas 5b and 5c having 10% transmittances, and a value corresponding to the non reflection area 5d, in the X and Y axes from the original point P0, have a ratio of 0.2, 0.1, and 0. Of course, although the above result is from an ideal case, the ratio therebetween remains unchanged in most cases.

As can be seen from FIGS. 12A and 12B, the change in a signal value corresponding to the change in the amount of light is very regular. That is, the amount of light passing through the spectroscope change as in the sequence, $[\underline{0} \rightarrow \neq 0 \rightarrow \underline{00} \rightarrow \neq 0 \rightarrow \underline{000} \rightarrow \neq 0 \rightarrow \underline{0} \rightarrow \neq 0 \rightarrow \underline{00} \rightarrow \neq 0 \rightarrow \underline{000}]$, corresponding to the movement path thereof from the center. Here, when the case in which the amount of light is expressed by "0" and the case of not being 0 (≠0) is expressed by "U", and when light having a movement path, P0(X0, Y0)→P1(X1, Y1)→P2(X2, Y2), is detected by the photoelectric sensors 95 and 95′ via the spectroscopes 93 and 93′, a pattern of signal values is obtained as follows.

[0 U 00 U 000 U 0 U 0 U 000 U 00 U 0 U 00 U 000] and
[0 U 00 U 000 U 0 U 00]

The polarized patterned mirror 5 is manufactured such that a pattern of signal values, [0 U 00 U 000 U], is repeated while moving in one direction with respect to the center P0. However, the signal value pattern detected by the vertical polarizing spectroscope 93 is reversed from the 12^{th} signal which means the beam moves in the reverse direction after passing a peak of the 11^{th} signal. Also, it can be seen that the periodic signal value pattern is then repeated after the center of symmetry. The signal value pattern detected by the horizontal polarizing spectroscope 93′ means that the beam is moved only in one direction. From the above change of the signal value pattern, P0=(0, 0), P1=(11, 9), and P2=(-7, 4) can be extracted. Thus, it is possible to quantitatively measure the displacements, ΔX and ΔY, on the X and Y axes. In addition, from the above change of the signal value pattern, the inclination, γ, by the rotation with respect to the z axis, or the vibrations, Δx and Δy in the X axis and the Y axis, can be indicated. Here, the displacements ΔX and ΔY are caused by deformation of a structure, that is, rotation and vibration in the axial directions and are congruous with the scale of Δx and Δy. However, since the pattern on the polarized patterned mirror 5 is symmetrical to each axis, it is difficult to determine whether the direction of a displacement is positive (+) or negative (–). Such a problem can be solved by inputting the initial incident beam to a position deviated toward each axial direction, for example, to a position of P=(1, 1), not the center, P0=(0, 0). In this case, if the signal value pattern begins with [U 00], the direction is positive (+) whereas if the signal value pattern begins with [U 0], the direction is negative (–). As another method, the direction can be recognized by measuring the displacement only in the 1/4 quadrant section of the polarized patterned mirror 5.

When the polarized patterned mirror 5 and the two photoelectric sensors 95 and 95′ only are used as in the preferred embodiment 5, it is difficult to determine whether the measured displacements, ΔX and ΔY, are caused by the rotation with respect to the x axis and the y axis or the vibration in the z-axis direction. Such a problem can be solved by arranging a two-dimensional photoelectric array or a CCD linear camera at the light receiving portion, or adopting a variety of different polarization pattern, as in the above-described preferred embodiments. Further, it is possible to perform monitoring by attaching targets such as a total reflection mirror or polarized patterned mirror at a variety of positions on a structure.

Industrial Applicability

As described above, in the optical structure safety monitoring system according to the present invention, unlike the previous inventions by the subject applicant, a target is attached at a target position of a structure to be monitored and a light beam is emitted to the target. A light emitting portion and a light receiving portion to respectively project and detect a light beam to and from the target are installed at safe places remote from the structure. Thus, in spite of restriction of a structure, installation and maintenance thereof is very easy and convenient.

Furthermore, in the present invention, since a lengthy optical path including an incident path from the light emitting portion to the target and a reflection path from the target to the light receiving portion, resolving power for monitoring a fine vibration of a structure to be monitored is improved. Thus, the safety of a structure can be monitored with a sufficient resolving power in a narrow space in the structure.

Furthermore, in the present invention, since the light emitting portion and the light receiving portion of an optical system can be moved with respect to the target, a mobile monitoring is possible by attaching a target at many places on a structure and moving the optical system with respect to each target. That is, since the minimum number of an expensive equipment such as a laser is needed, the manufacturing costs can be reduced.

What is claimed is:

1. An optical structure safety monitoring system comprising:

a target attached to a structure to be monitored and reflecting light;

a light emitting portion projecting light toward the target;

a light receiving portion detecting an electric signal including displacement information of the structure from the light reflected by the target; and

an information processing portion processing information on displacement of the structure based on the electric signal detected by the light receiving portion.

2. The system of claim 1, wherein a total reflection mirror total-reflecting light is provided as the target, and a two-dimensional photoelectric sensor array in which photoelectric sensors are arrayed in two dimensions at the light receiving portion.

3. The system of claim 1, wherein a total reflection mirror total-reflecting light is provided as the target, and the light receiving portion comprises:

a beam splitter splitting a light beam reflected by the total reflection mirror into two light beams;

two translucent sheets respectively installed on optical paths of the two split reflected beams, onto which the reflected beams are projected;

two cylindrical lenses each focusing an image of one of the reflected beams projected onto the translucent sheets in one direction of two directions perpendicular to each other on each sheet and transmitting the image in the other direction; and

two CCD linear cameras each having a linear photographing device detecting a signal including information on a position of a light beam corresponding to each direction by photographing the image formed by the cylindrical lens.

4. The system of claim 1, wherein a total reflection mirror total-reflecting light is provided as the target, and the light receiving portion comprises:

a translucent sheet onto which a reflected beam of the total reflection mirror is projected; and

a CCD camera having a two-dimensional photographing device detecting a signal including information on a position of a light beam by photographing the image of the reflected beam projected onto the translucent sheet.

5. The system of claim 1, wherein a polarized patterned mirror reflecting light at different reflection rates according to the direction of polarization is provided as the target, and the light receiving portion comprises a two-dimensional photoelectric sensor array detecting an electric signal including information on a position of a reflected beam by receiving the reflected beam of the polarized patterned mirror.

6. The system of claim 1, wherein a polarized patterned mirror reflecting light at different reflection rates according to the direction of polarization is provided as the target, and the light receiving portion comprises:

a beam splitter splitting the reflected beam of the polarized patterned mirror into two optical paths;

two spectroscopes respectively installed on optical paths of the two split reflected beams and splitting vertical and horizontal polarizations of each reflected beam and transmitting the split polarization; and

two photoelectric sensors each detecting an electric signal including information on a position of each polarization direction by receiving the reflected beam transmitting each spectroscope.

7. The system of claim 1, further comprising a portion adjusting the diameter of the laser beam emitted from the light emitting portion.

8. The system of claim 1, wherein the information processing portion comprises:

a local monitoring system having a program which executes reading the detected signal from the light receiving portion, calculating and graphically processing an amount of a displacement of the reflected beam of the light receiving portion, and giving a command to alarm to the outside according to a state of the read signal and a result of the process;

a first alarm alarming by being operated according to the command of the local monitoring system;

a remote monitoring system connected to the local monitoring system to be capable of communicating, and having a program which executes establishing a database by receiving the processing information of the local monitoring system, processing inclination and vibration of the structure by analyzing the established database, and giving a command to alarm to the outside according to result of the process; and

a second alarm alarming by being operated according to the command of the remote monitoring system.

9. The system of any of claims 1 through 6, further comprising

an adjustment portion to adjust an angle of the target.

10. .The system of any of claims 1 through 6, further comprising a portion to amplify a displacement of the target caused by inclincation or vibration of the structure.

11. The system of claim 7, further comprising a portion to amplify a displacement of the target caused by inclincation or vibration of the structure.

12. The system of claim 7, wherein the adjustment portion comprises two goniometers each including a main body and a mobile body, in which the an angle of the mobile body can be adjusted with respect to the main body, the main body of one of the goniometers is fixed to the structure, the main body of the other goniometer is perpendicularly fixed on the mobile body of the one goniometer, and the target is attached to the mobile body of the other goniometer.

FIG. 1A

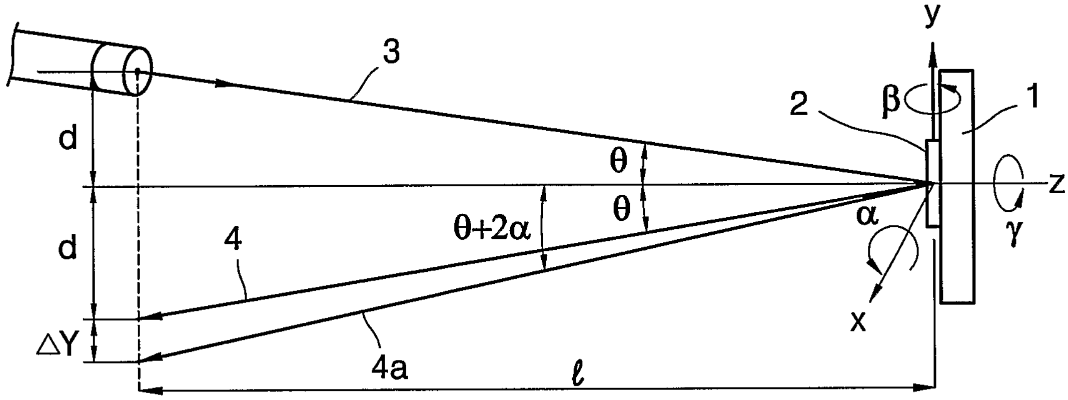


FIG. 1B

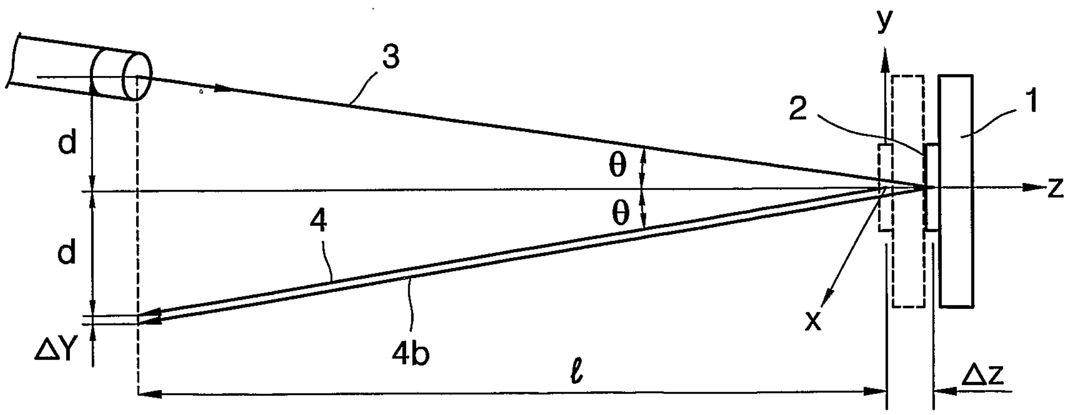


FIG. 2

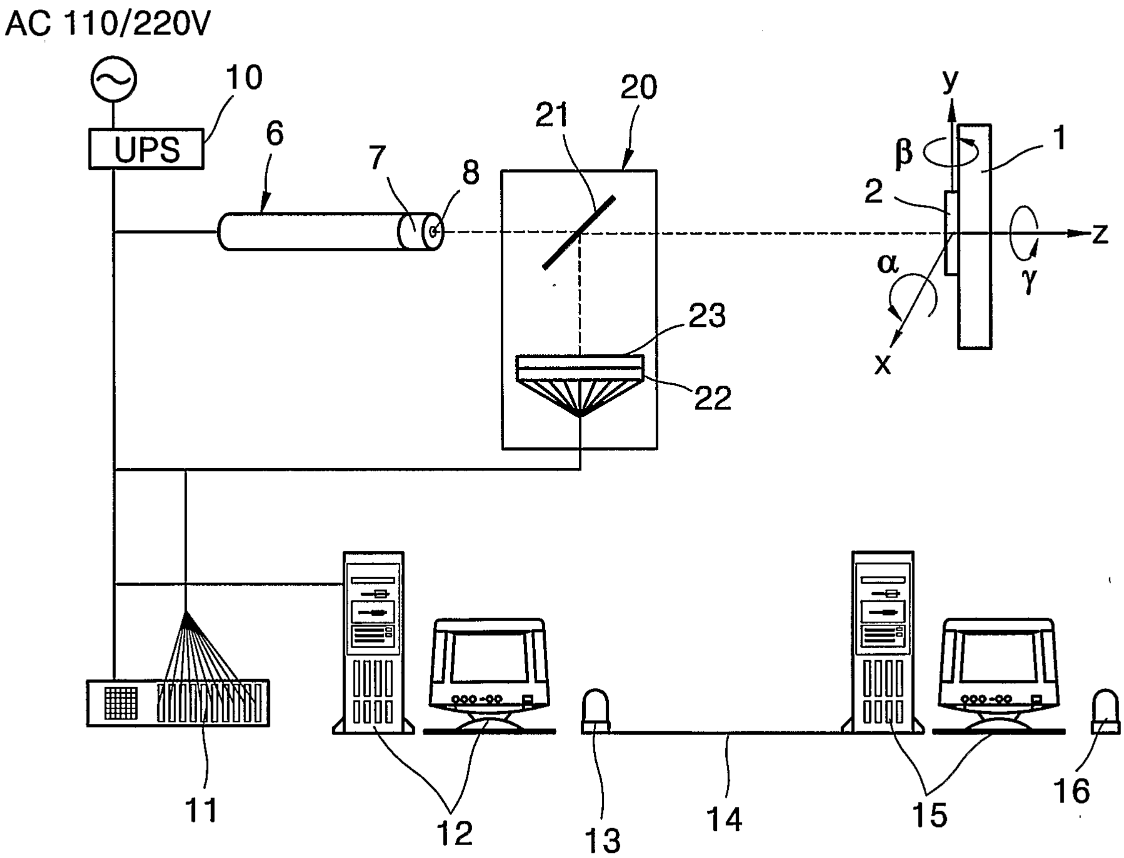


FIG. 3A

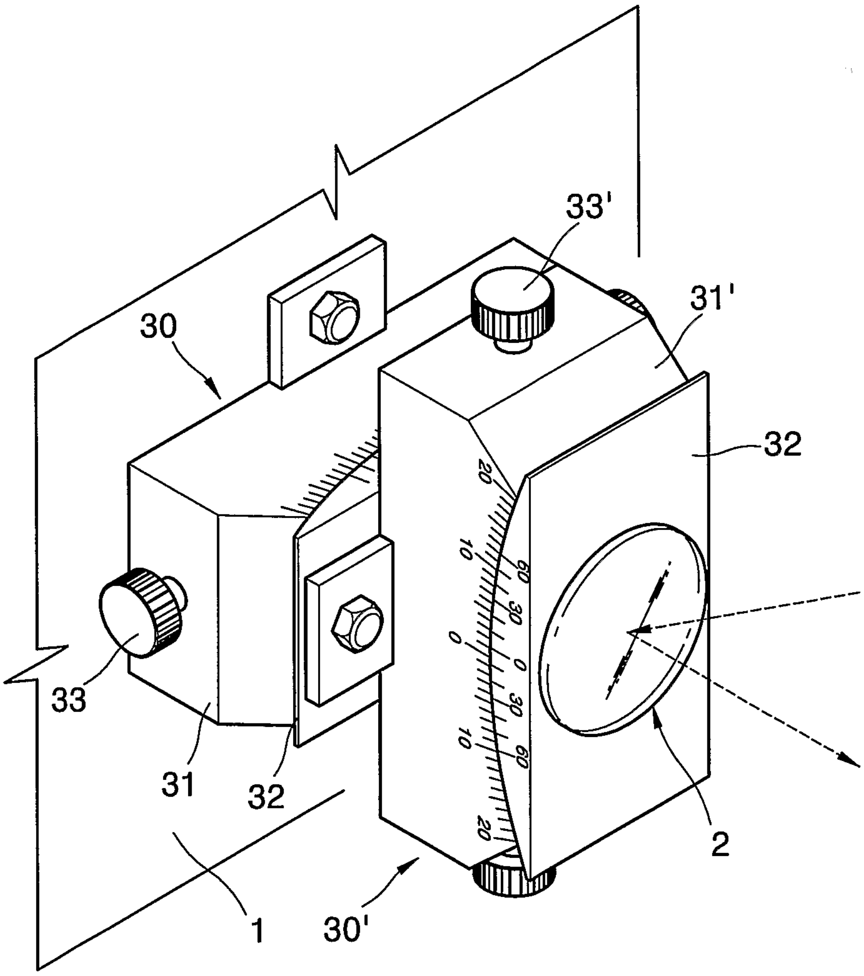


FIG. 3B

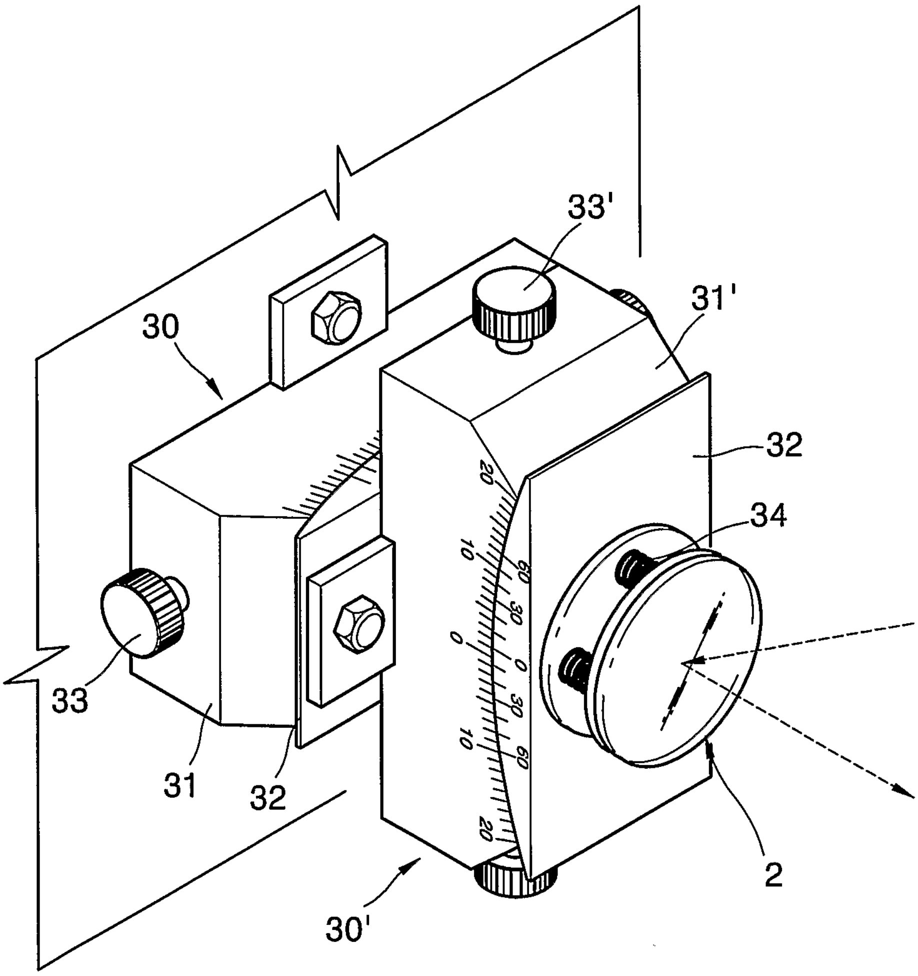


FIG. 4

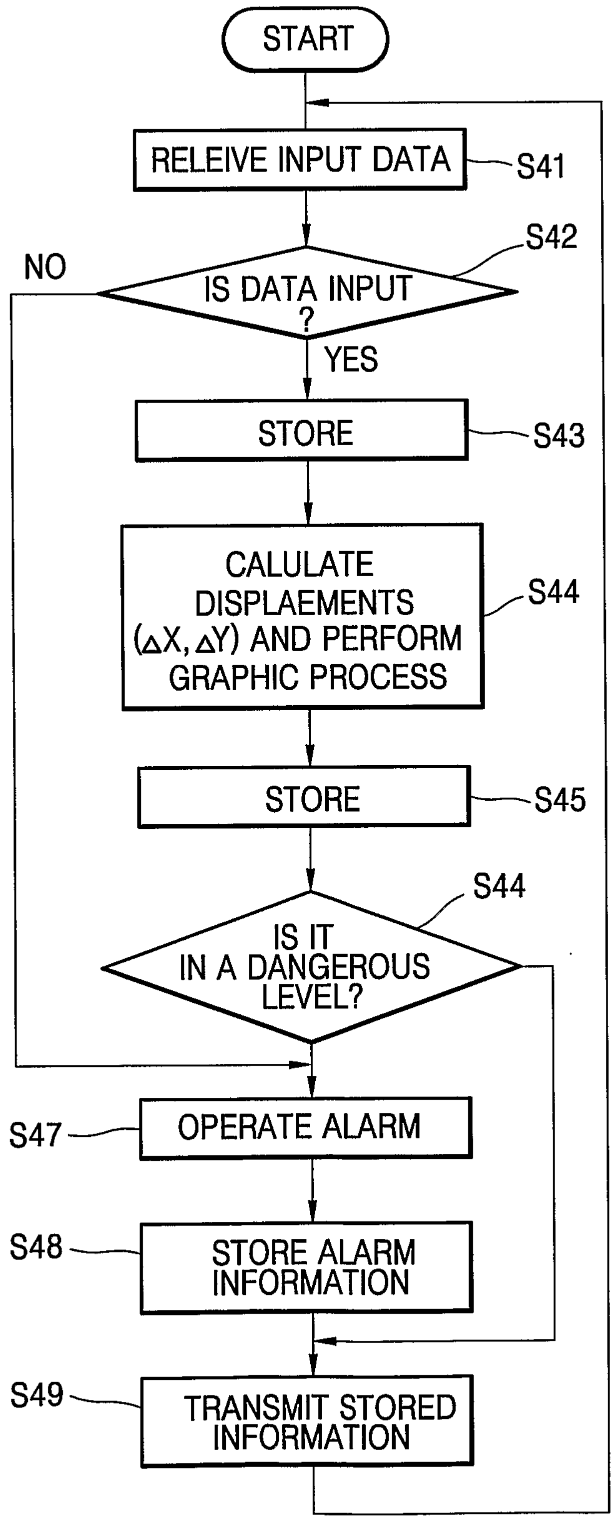

START
RELEIVE INPUT DATA
S41
S42
NO
IS DATA INPUT ?
YES
STORE
S43
CALULATE DISPLAEMENTS (△X, △Y) AND PERFORM GRAPHIC PROCESS
S44
STORE
S45
S44
IS IT IN A DANGEROUS LEVEL?
S47
OPERATE ALARM
S48
STORE ALARM INFORMATION
S49
TRANSMIT STORED INFORMATION

FIG. 5

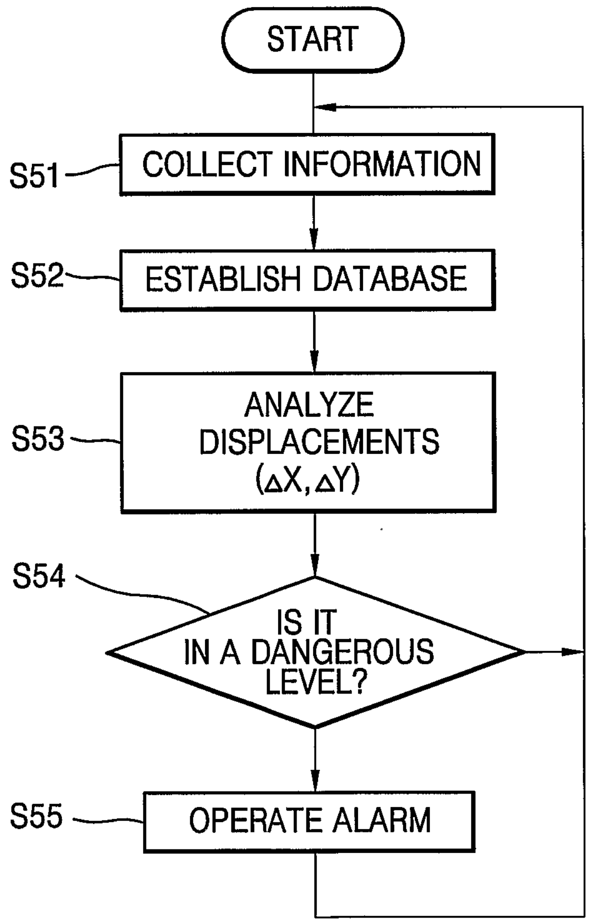

START
S51
COLLECT INFORMATION
S52
ESTABLISH DATABASE
S53
ANALYZE DISPLACEMENTS (ΔX, ΔY)
S54
IS IT IN A DANGEROUS LEVEL?
S55
OPERATE ALARM

FIG. 6

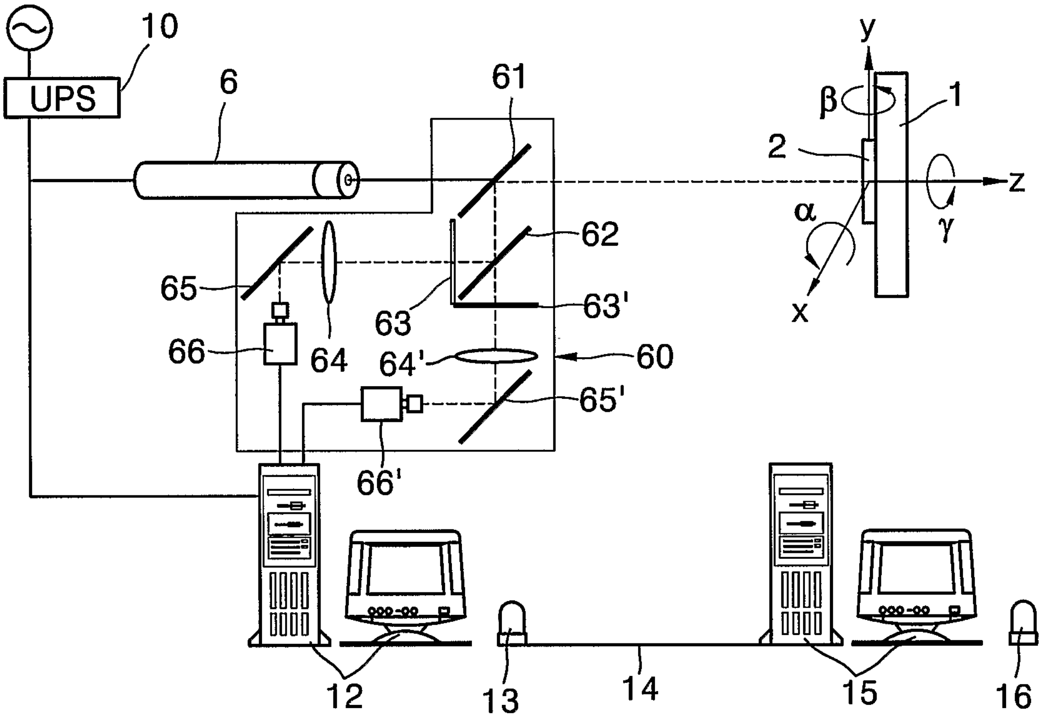

10
UPS
6
61
y
β
1
2
z
γ
α
x
62
65
63
63'
66
64
64'
60
65'
66'
12
13
14
15
16

FIG. 7

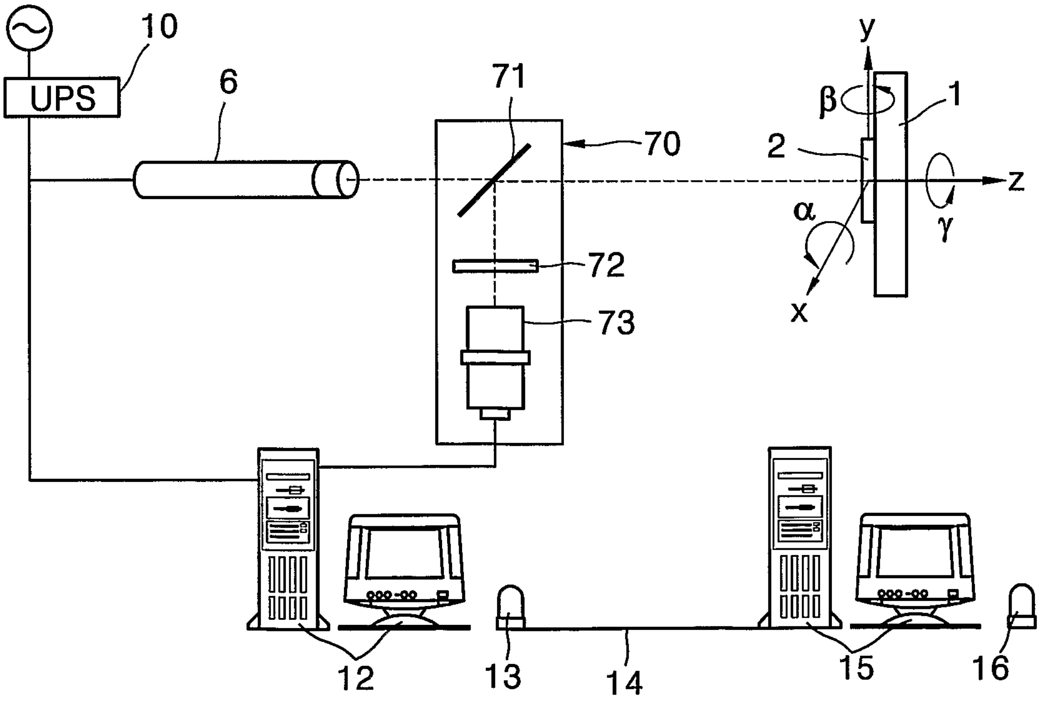
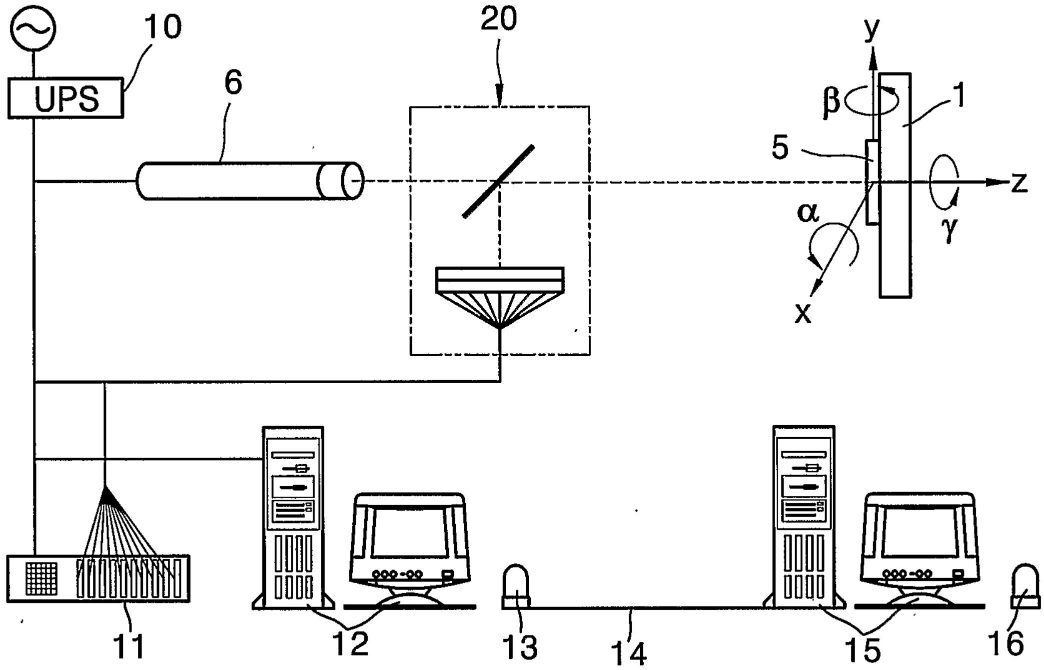

10
UPS
6
71
70
y
β
1
2
z
γ
α
x
72
73
12
13
14
15
16

FIG. 8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UPS
6
20
y
β
1
5
z
α
γ
x
11
12
13
14
15
16

FIG. 9

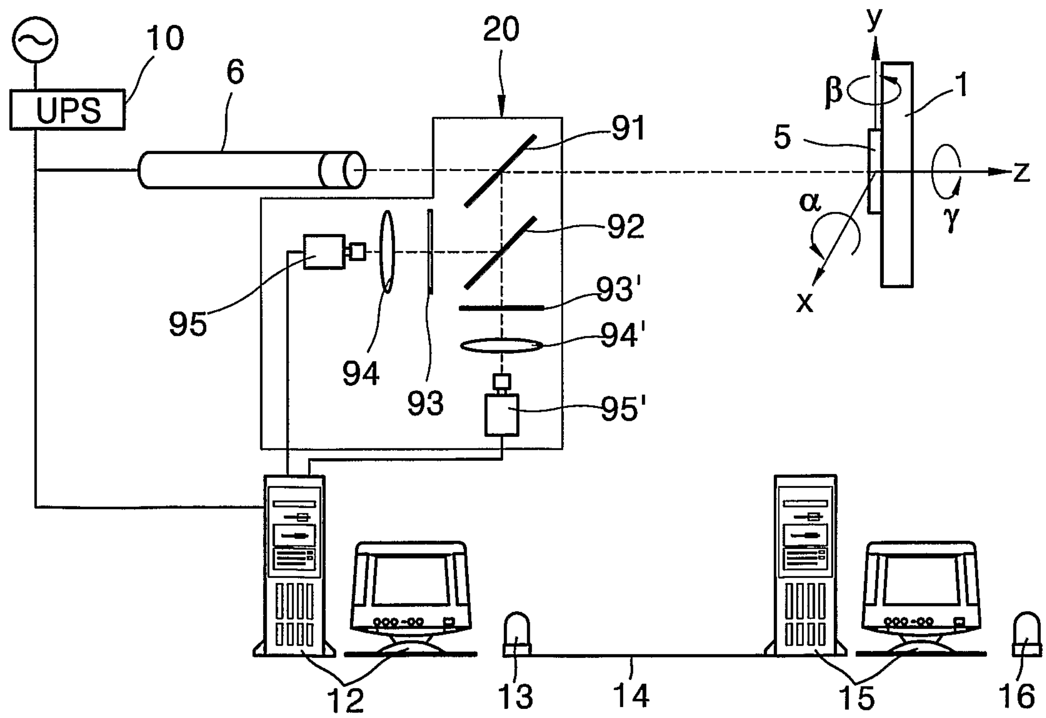

10
UPS
6
20
y
β
1
91
5
z
α
γ
92
x
95
93'
94'
94
93
95'
12
13
14
15
16

FIG. 10

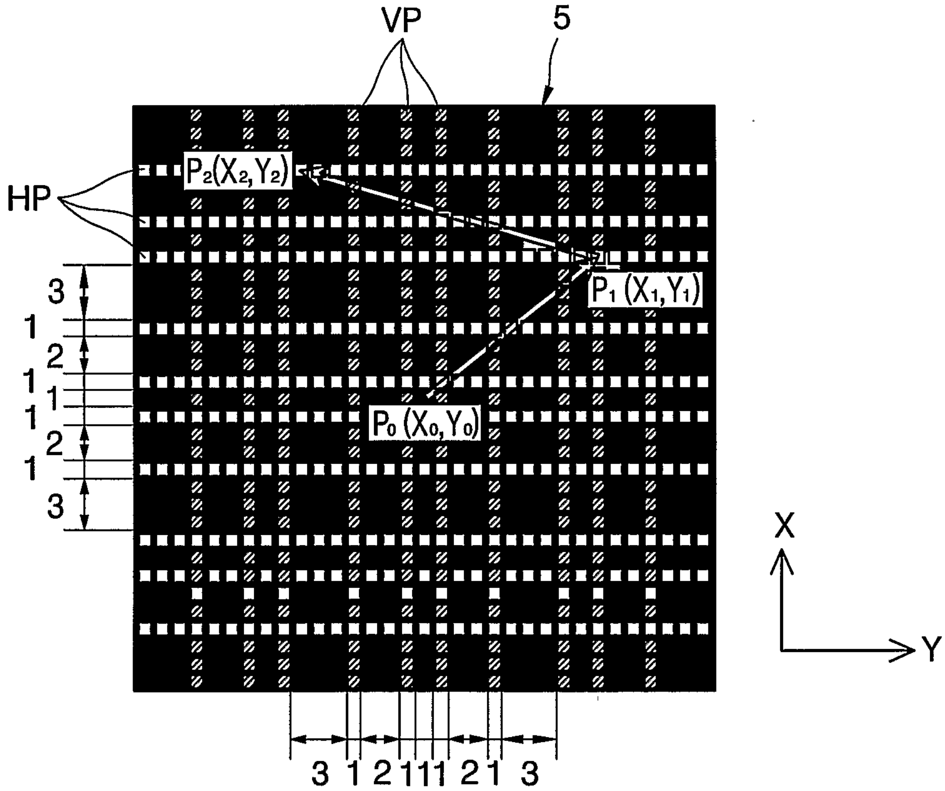


FIG. 11A

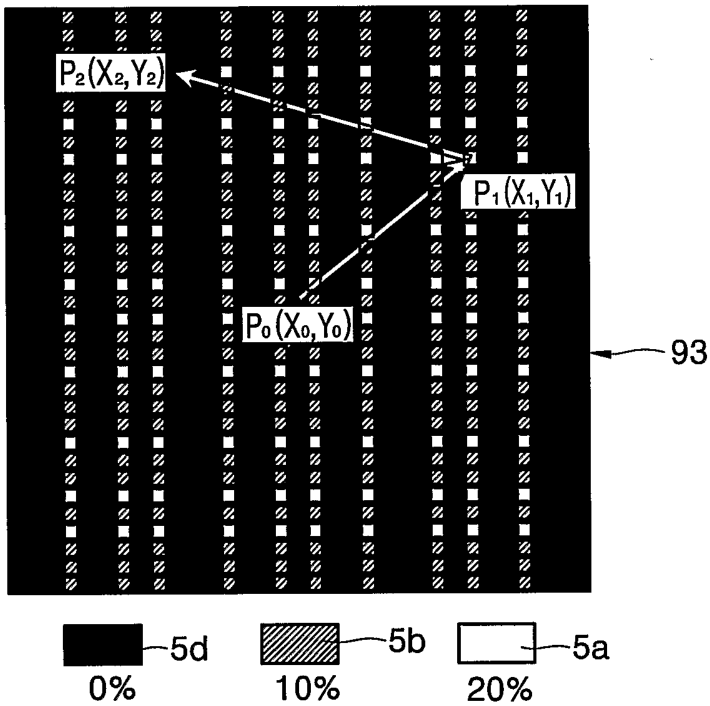


FIG. 11B

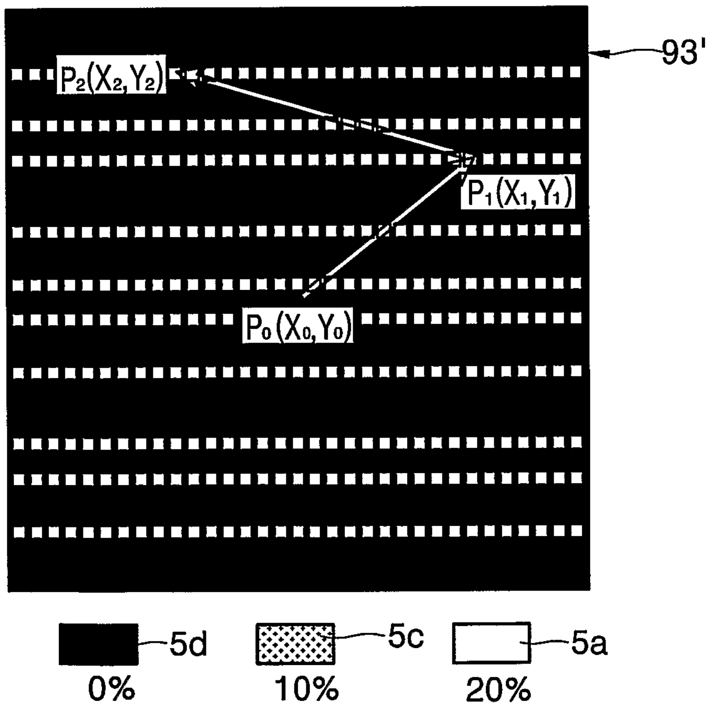


FIG. 12A

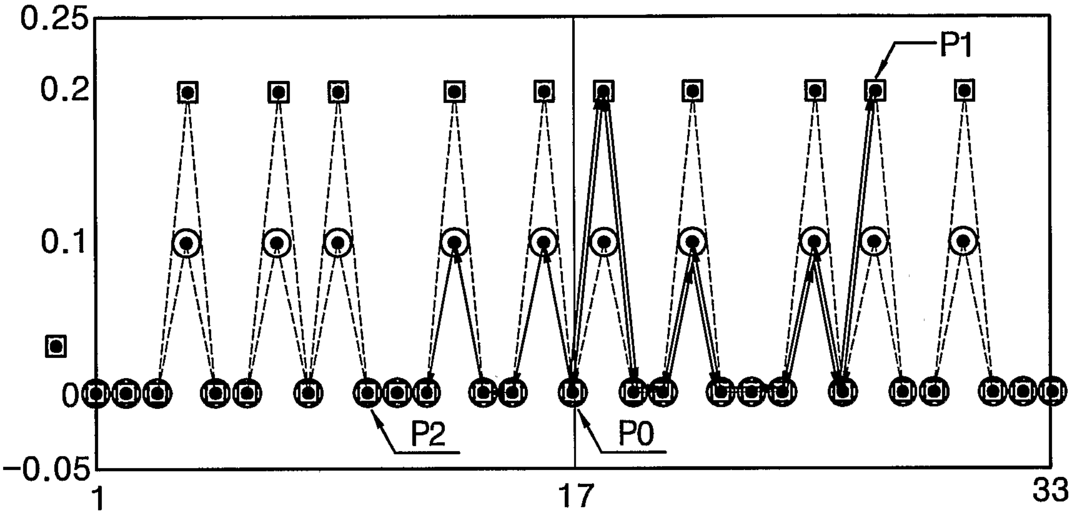
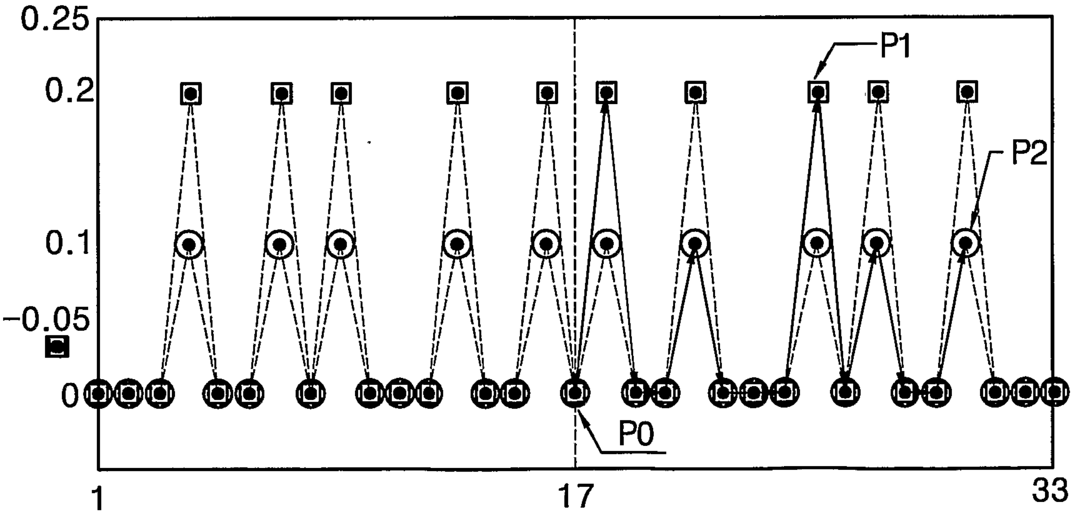


FIG. 12B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR01/01467

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 G01B 11/16

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)

IPC7 G01B 11/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

KOREAN PATENTS AND APPLICATIONS FOR INVENTIONS SINCE 1975, KOREAN UTILIY MODELS AND APPLICATIONS FOR UTILITY MODELS SINCE 1975, Japanese Utility models and application for Utility mokels since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,730928 (PATENT NUMBER) LASERCHECK LIMITED, BURNHAM, ENGLAND 15 MAR 1988 (DATE OF PATENT) see the whole documents	1 - 2
Y	GB 8614222 A (ASBURY ANTHONY JOHN) 11 JUNE 1986 see the whole documents	1 - 2
Y	US 3778167 DA (APPLIC GEN ELECTRICITE MECANIQ) 01 OCTOBER 1971 see the whole documents	1 - 2

☐ 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 relevence
"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 relevence; 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 relevence; 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	Date of mailing of the international search report
28 MAY 2002 (28.05.2002)	29 MAY 2002 (29.05.2002)

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