US 20080221488A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2008/0221488 A1
(43) Pub. Date: Sep. 11, 2008
KURONO et al.

(54) METHOD FOR MONITORING LIVING BODY ACTIVITIES, AND OPTICAL FIBER TYPE FLAT SHAPED BODY SENSOR, GARMENT STYLED OPTICAL FIBER TYPE FLAT SHAPED BODY SENSOR AND HUMAN BODY FITTED OPTICAL FIBER TYPE FLAT SHAPED BODY SENSOR USED FOR THE SAME

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(21) Appl. No.: **12/038,742**

(22) Filed: **Feb. 27, 2008**

Related U.S. Application Data

(63) Continuation-in-part of application No. PCT/JP2006/317297, filed on Aug. 25, 2006.

(30) **Foreign Application Priority Data**

Aug. 30, 2005 (JP) 2005-250154

Publication Classification

(51) **Int. Cl.**
A61B 5/103 (2006.01)

(52) **U.S. Cl.** **600/595**

(57) **ABSTRACT**

A living body monitoring activity system detects major activities, or feeble living body activities. In a method for monitoring existence of human movements or living body activities in living environments (e.g., sleeping activities involving a bed, a Futon-mat, a pad, or a Tatami-mat), an optical fiber type flat shaped body sensor including an optical fiber affixed or fitted to a flat shaped body is used, and light is emitted into the optical fiber from a light source, and changes of polarized wave conditions of light propagating in the optical fiber are brought about by changes in form of the optical fiber type flat shaped body sensor caused by human movements or living body activities and are detected by a measuring apparatus for polarized wave fluctuations so human activities or movements are discriminated based on the detected value of the polarized wave fluctuations.

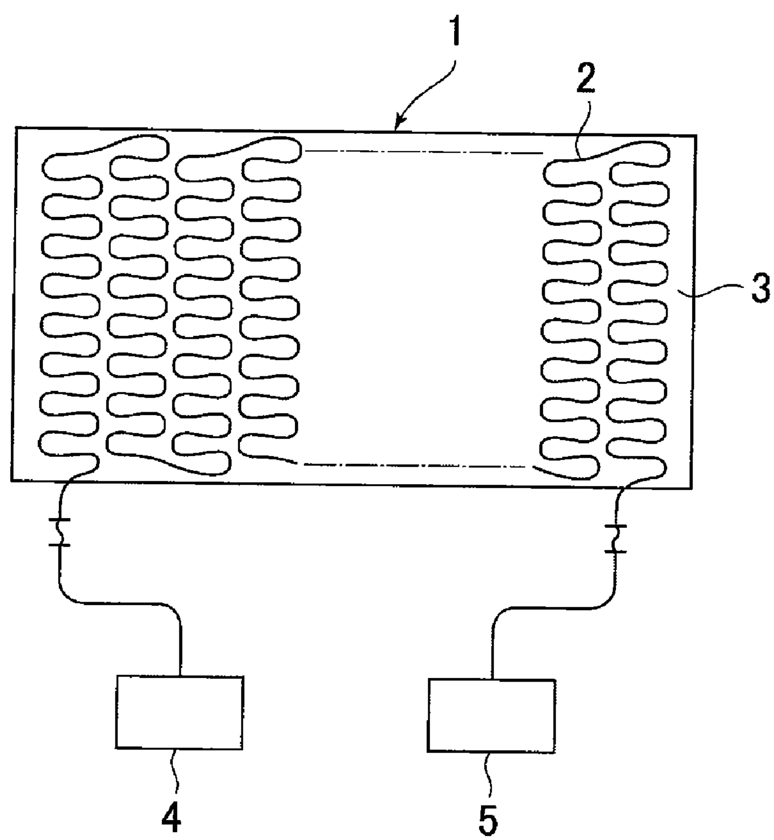


FIGURE 1

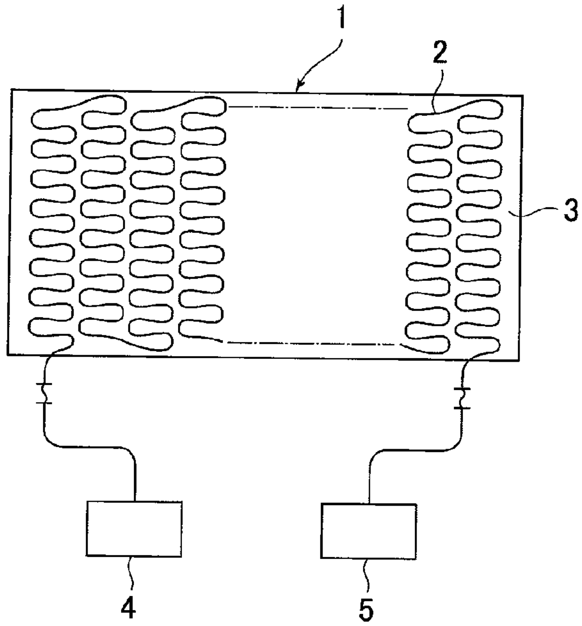


FIGURE 2

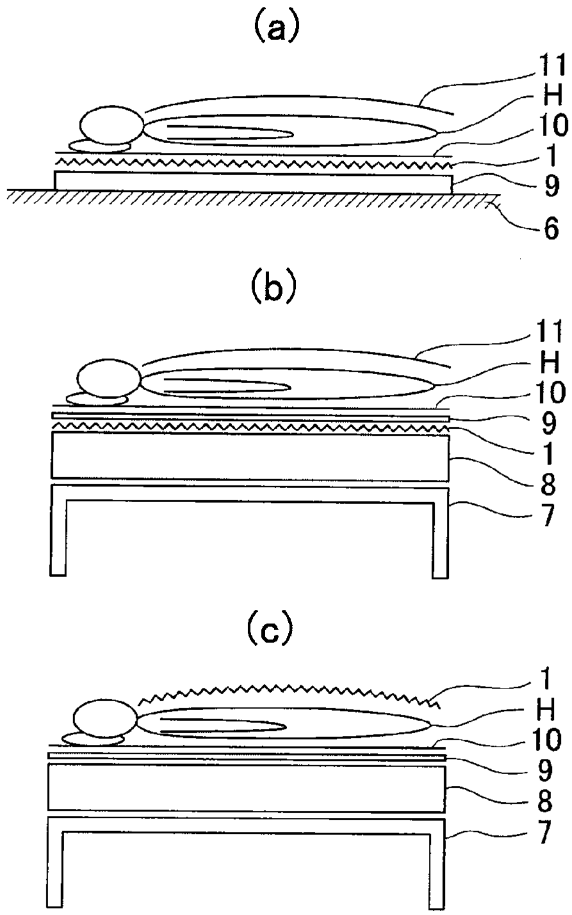
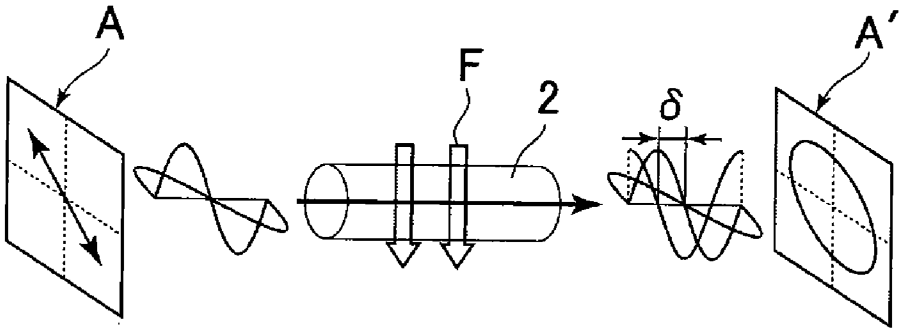
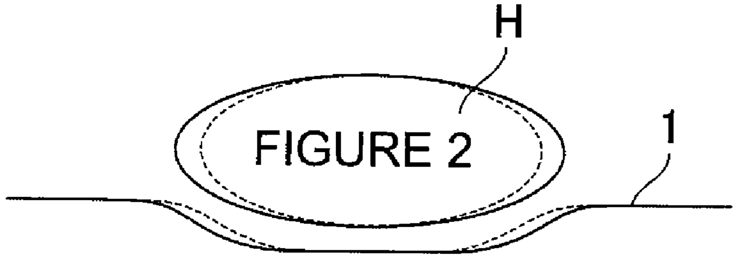


FIGURE 3

(a)



(b)



(c)

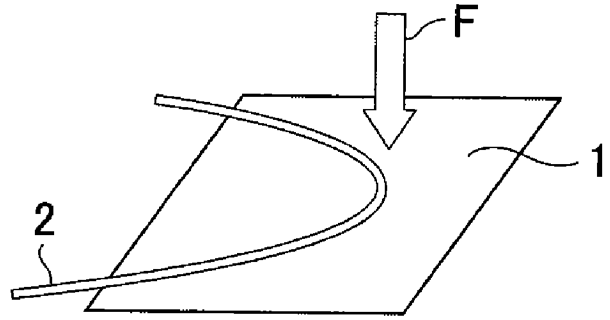
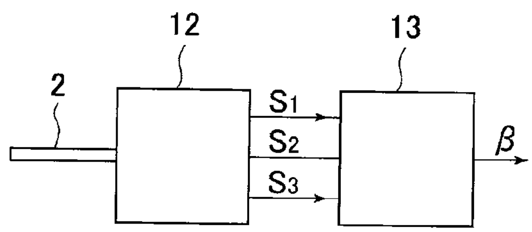
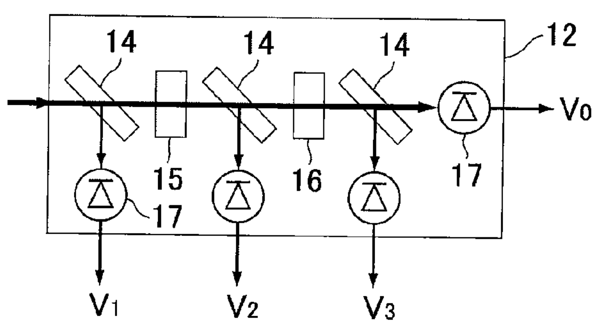


FIGURE 4

(a)



(b)



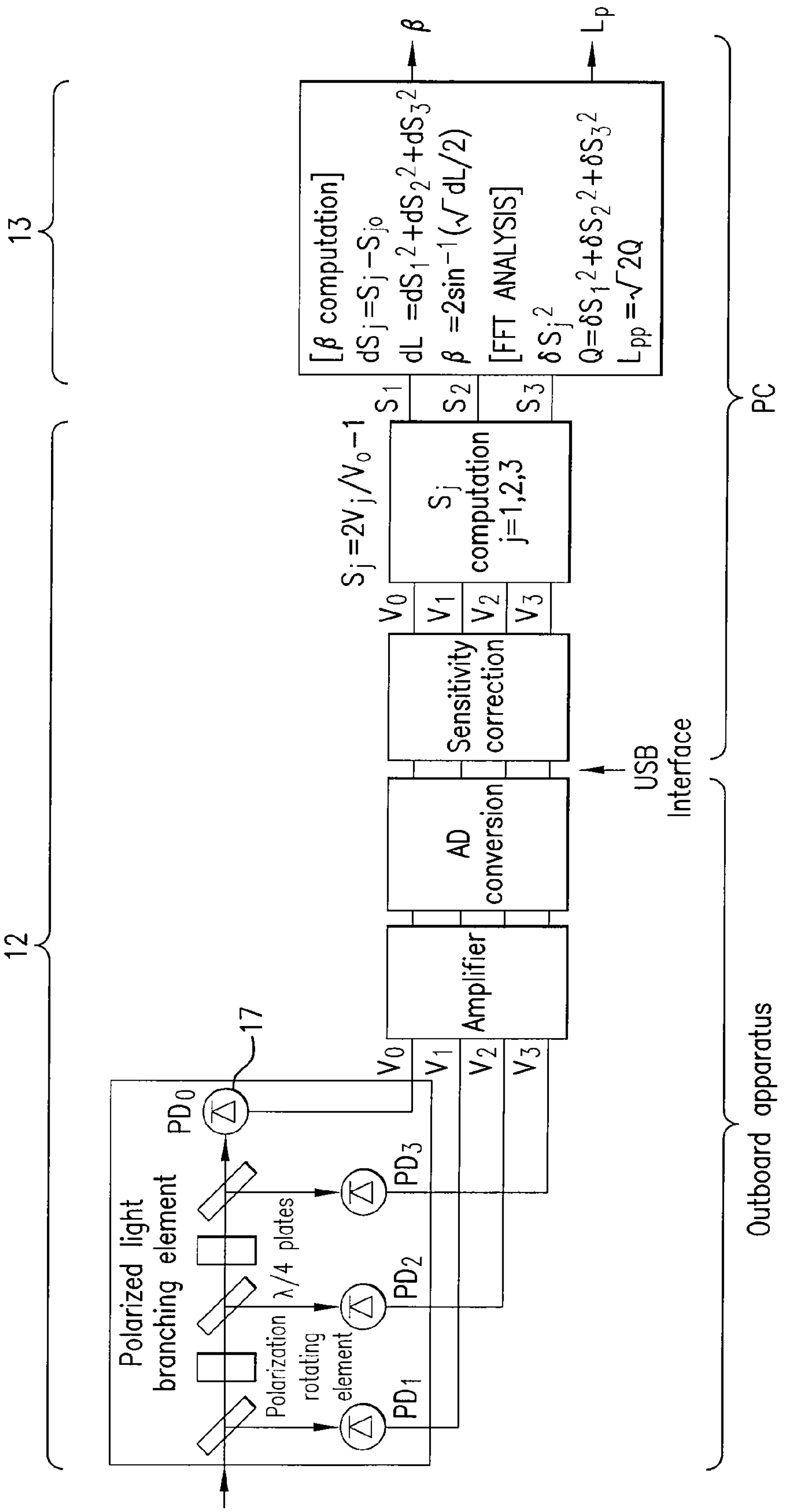

12
13
Polarized light branching element
Polarization rotating element
λ/4 plates
PD1
PD2
PD3
PD0
17
V0
V1
V2
V3
Amplifier
AD conversion
Sensitivity correction
USB Interface
Sj computation j=1,2,3
Sj=2Vj/V0−1
S1
S2
S3
[β computation]
dSj=Sj−Sjo
dL =dS1^2+dS2^2+dS3^2
β =2sin^-1(√dL/2)
[FFT ANALYSIS]
δSj^2
Q=δS1^2+δS2^2+δS3^2
Lpp=√2Q
β
Lp
Outboard apparatus
PC

FIG. 4c

FIGURE 5

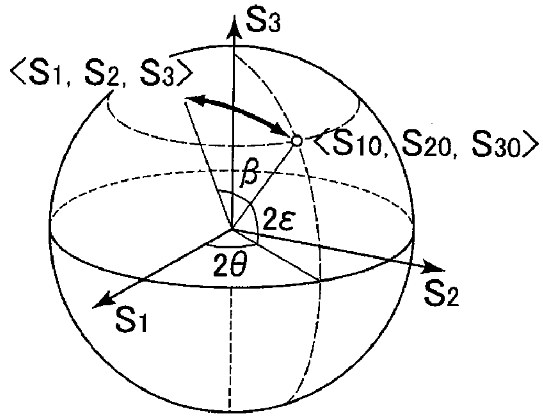


FIGURE 6

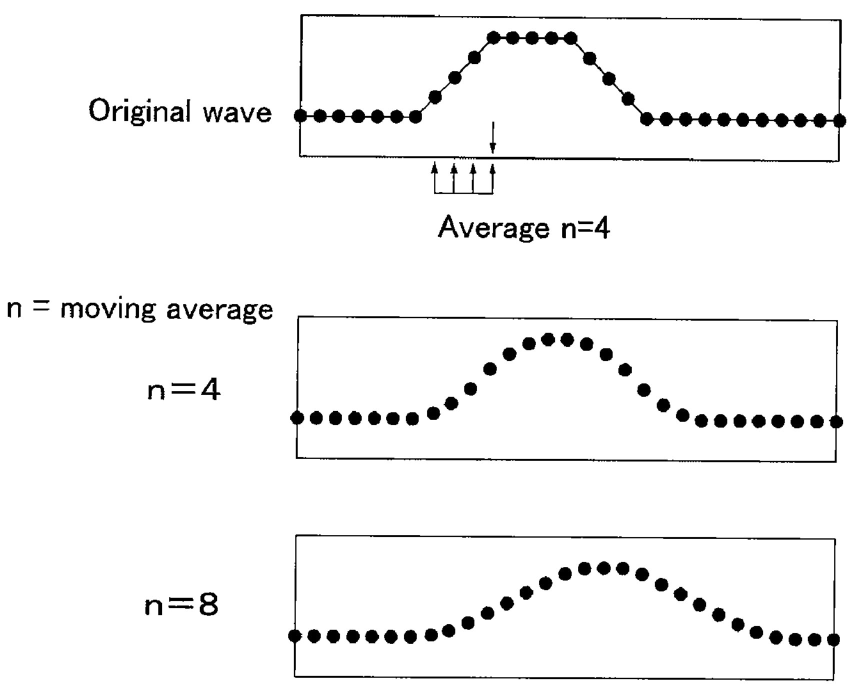
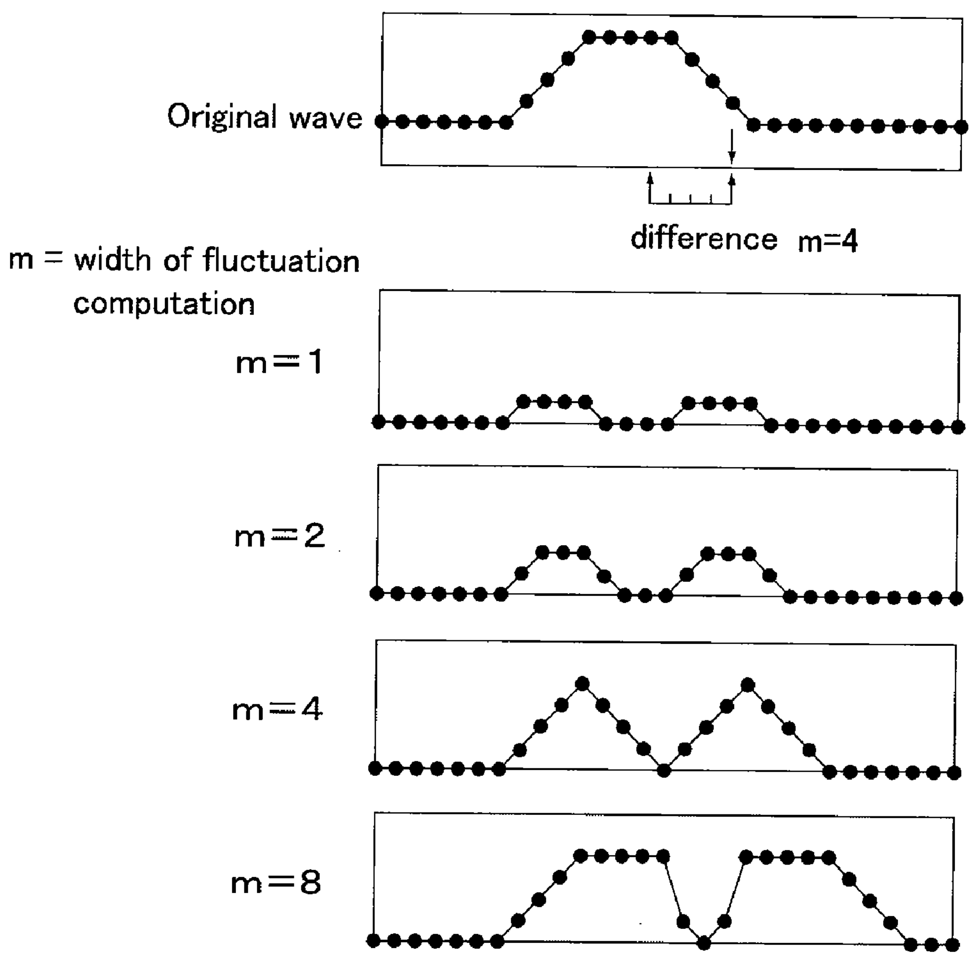


FIGURE 7



Original wave
difference m=4
m = width of fluctuation computation
m=1
m=2
m=4
m=8

FIGURE 8

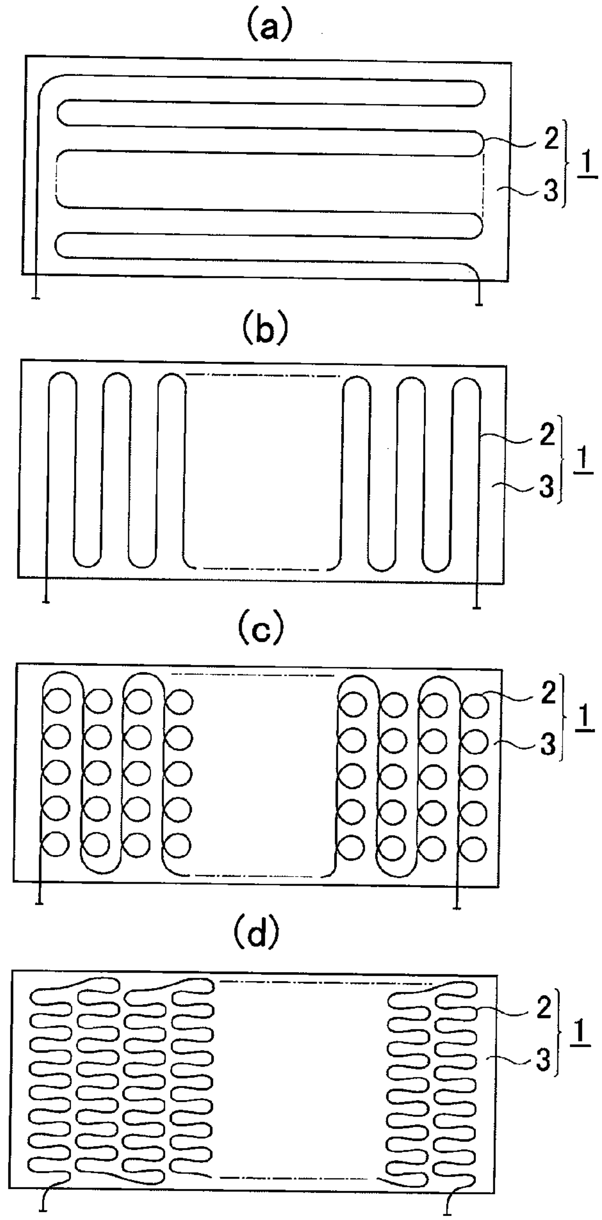


FIGURE 9

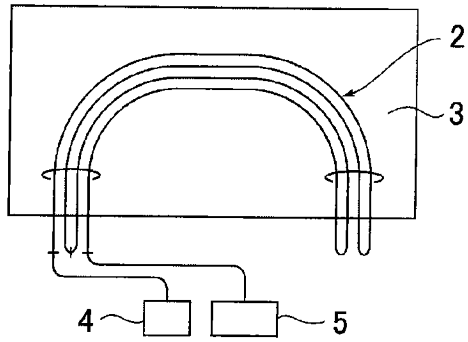


FIGURE 10

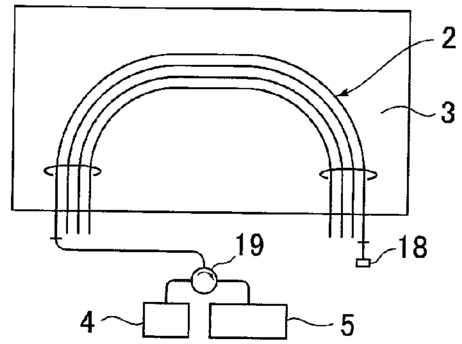


FIGURE 11

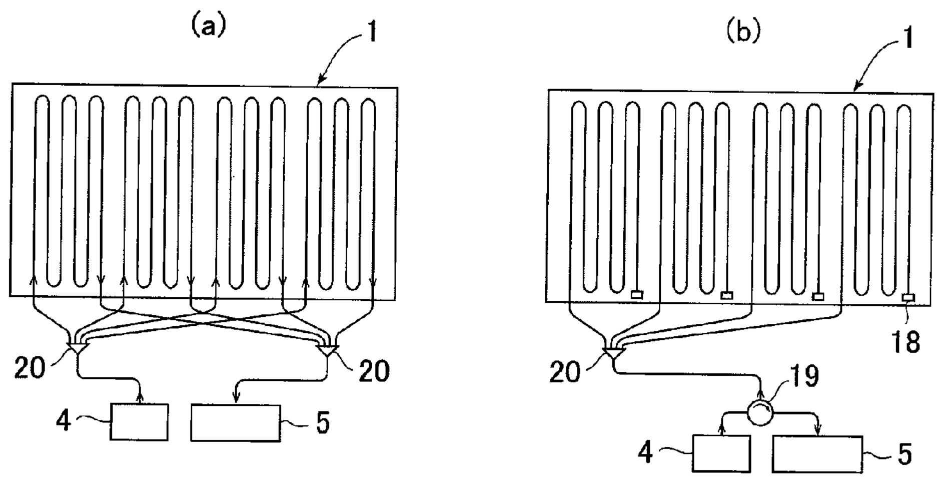


FIGURE 12

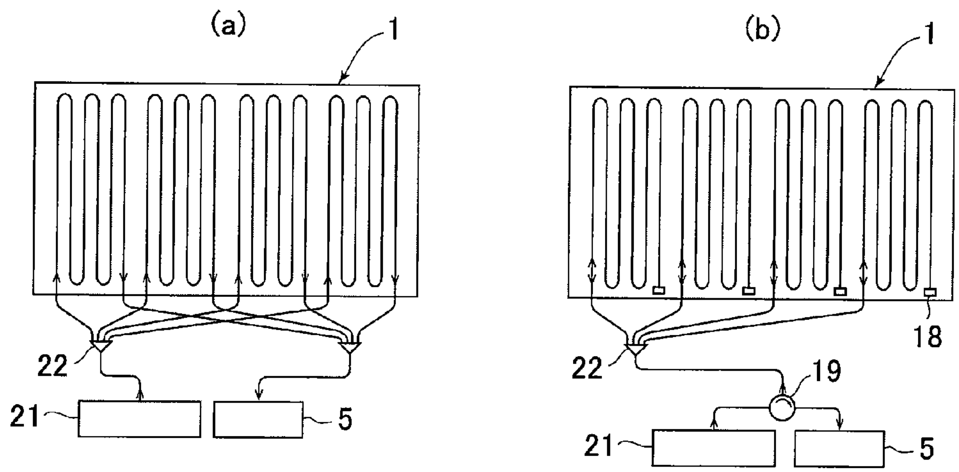


FIGURE 13

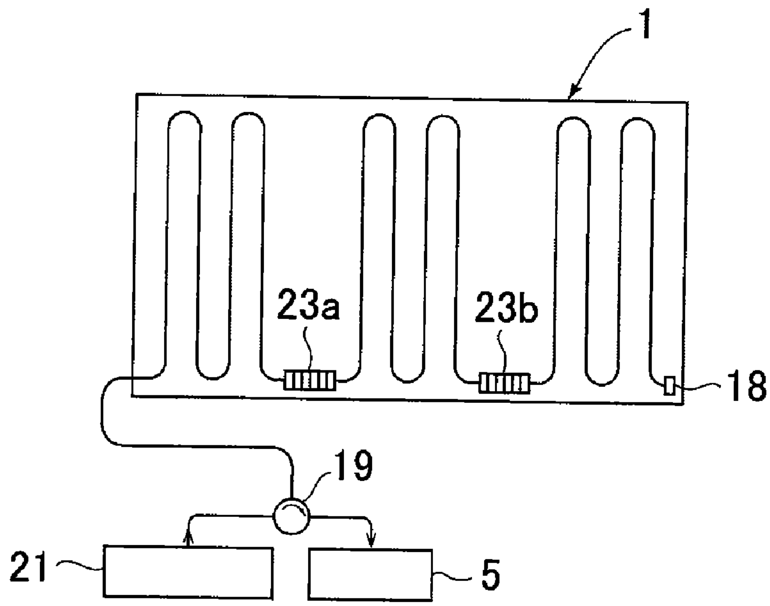
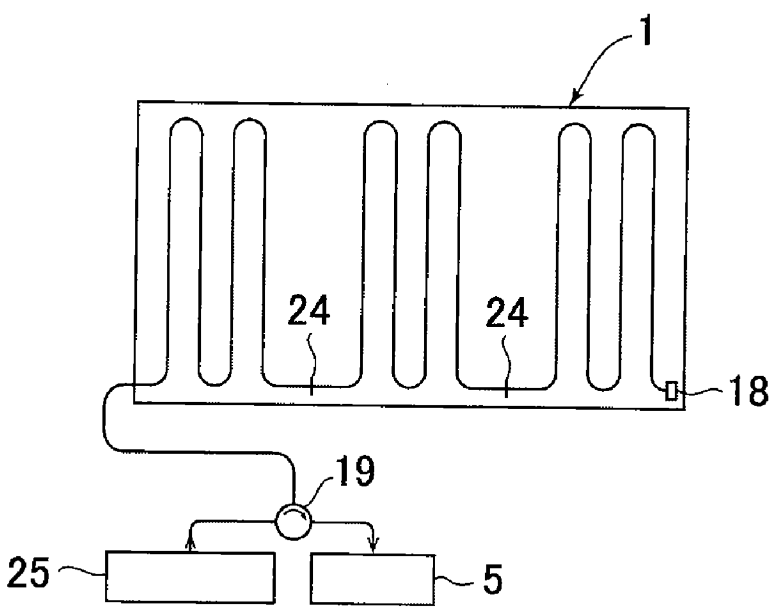


FIGURE 14



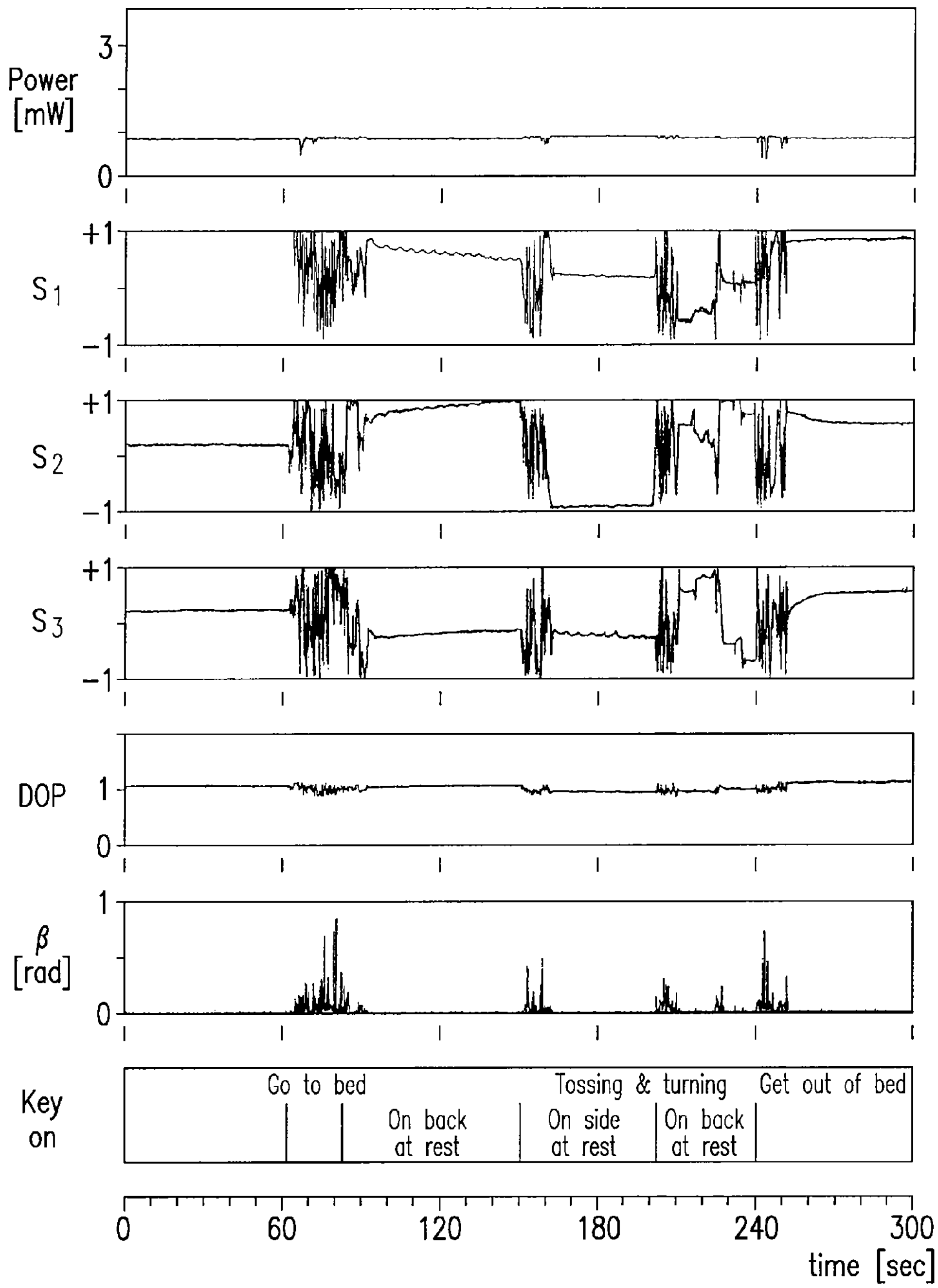

Power
[mW]
3
0
+1
S1
−1
+1
S2
−1
+1
S3
−1
DOP
1
0
1
β
[rad]
0
Key
on
Go to bed
Tossing & turning
Get out of bed
On back
at rest
On side
at rest
On back
at rest
0
60
120
180
240
300
time [sec]

FIG. 15

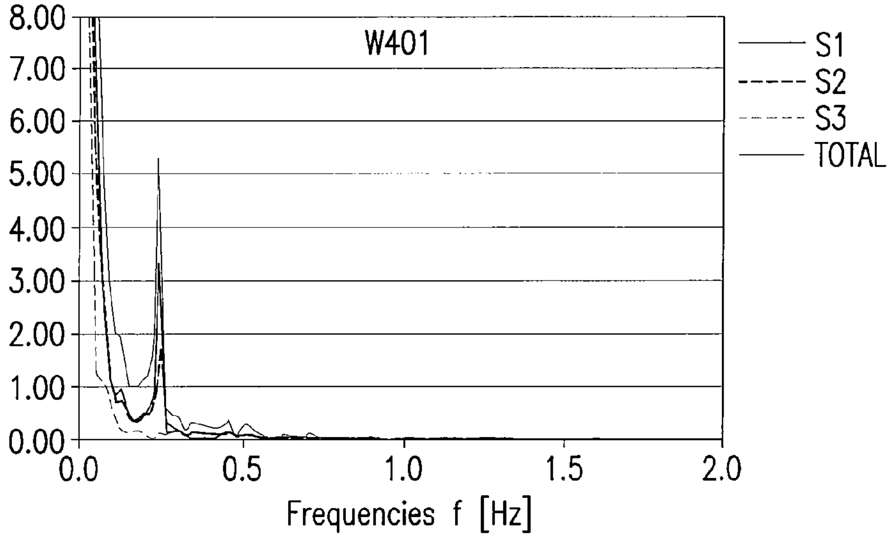


FIG.16a

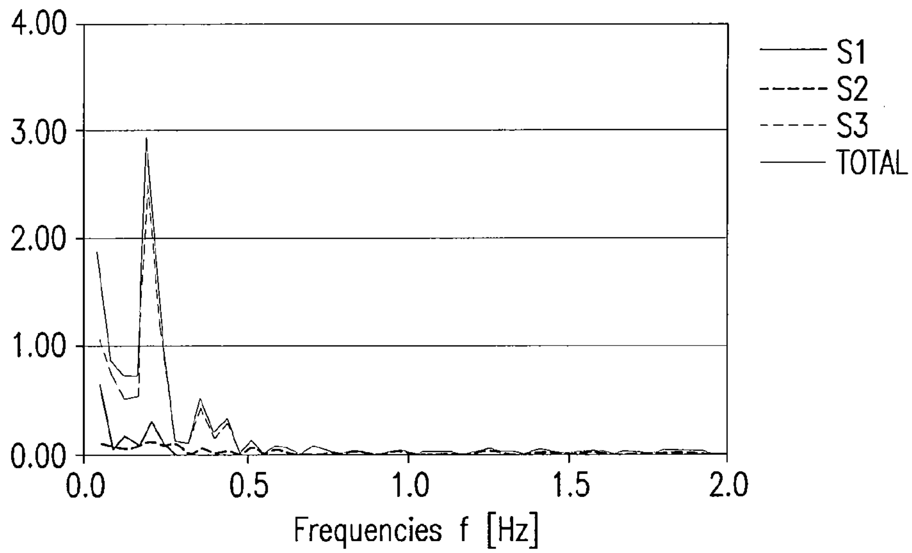


FIG.16b

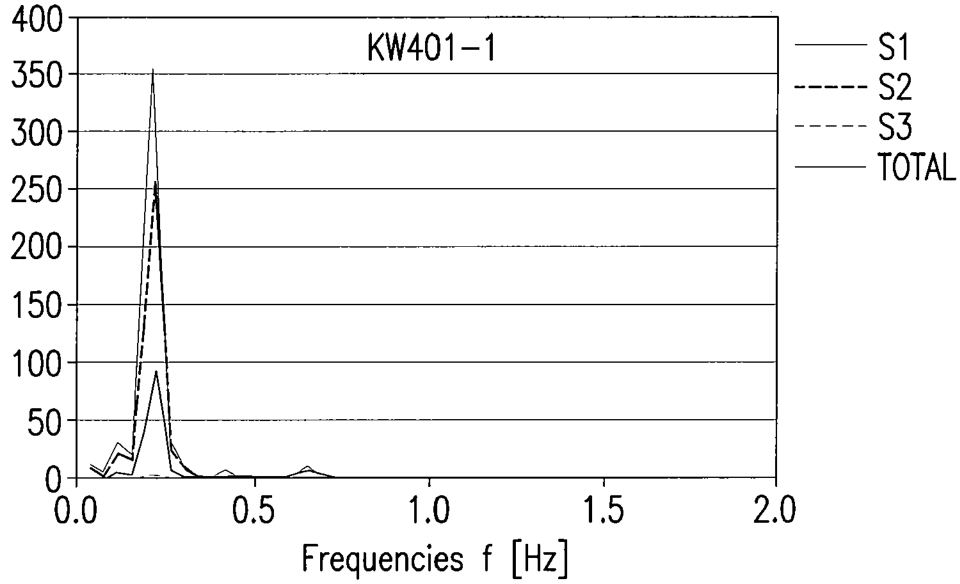


FIG.17a

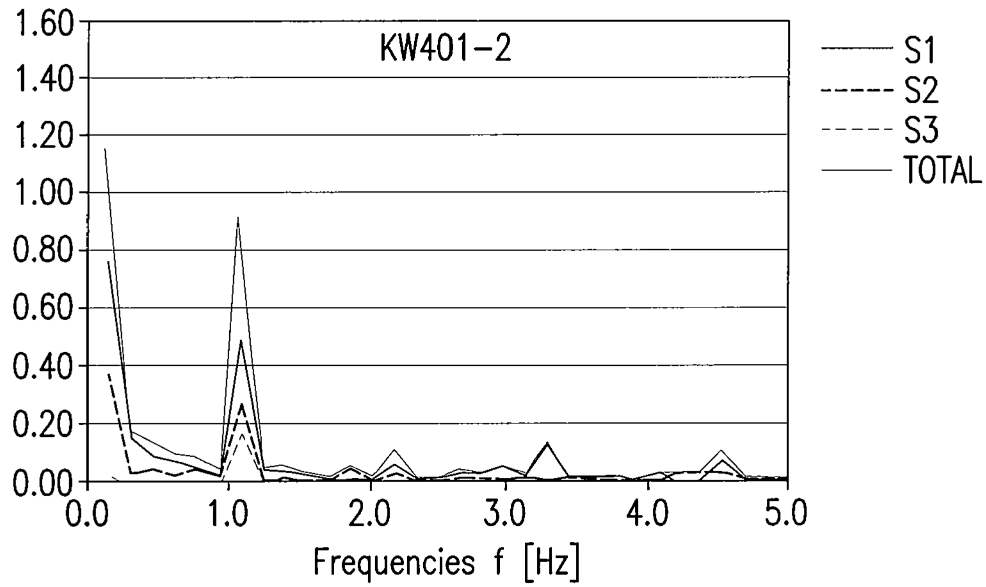


FIG.17b

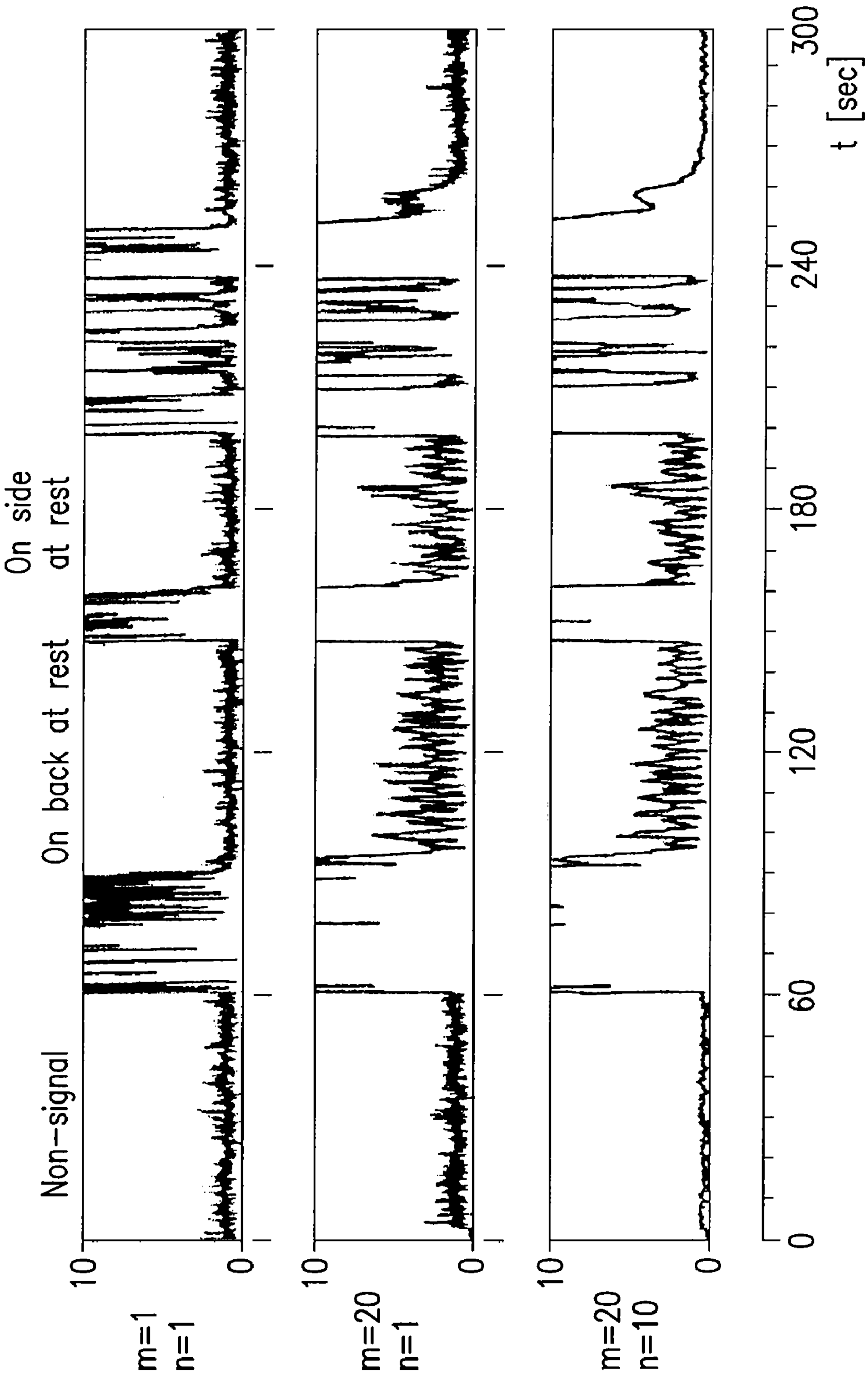

Non-signal
On back at rest
On side
at rest
m=1
n=1
m=20
n=1
m=20
n=10
10
0
10
0
10
0
0
60
120
180
240
300
t [sec]

FIG.18

FIGURE 19

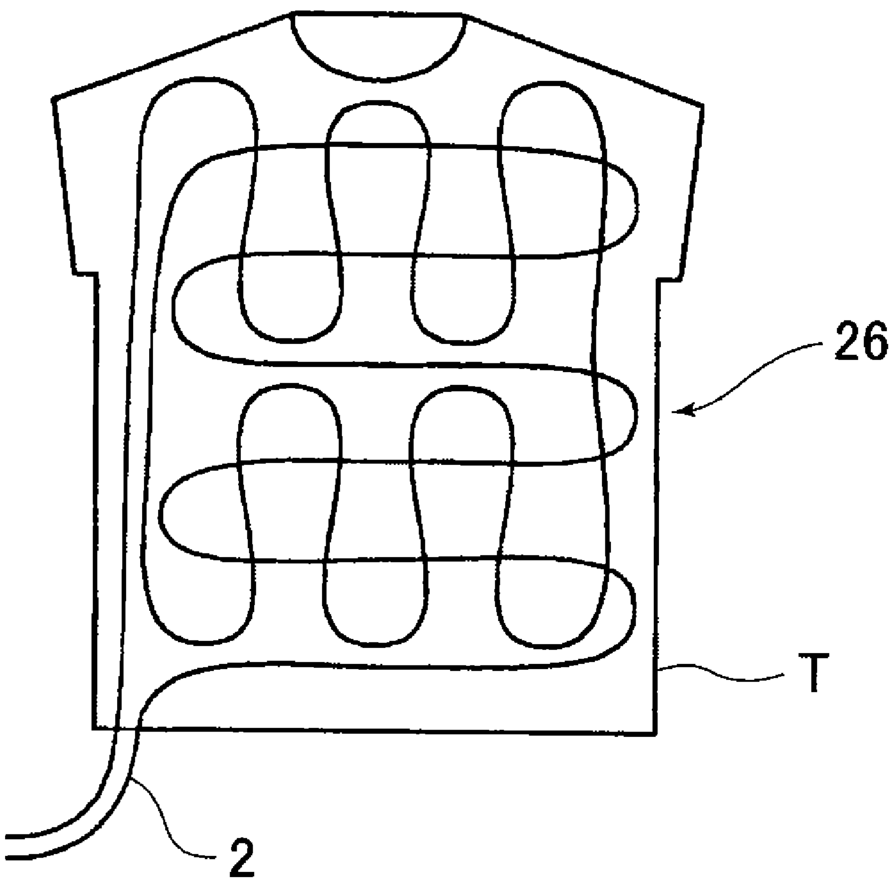
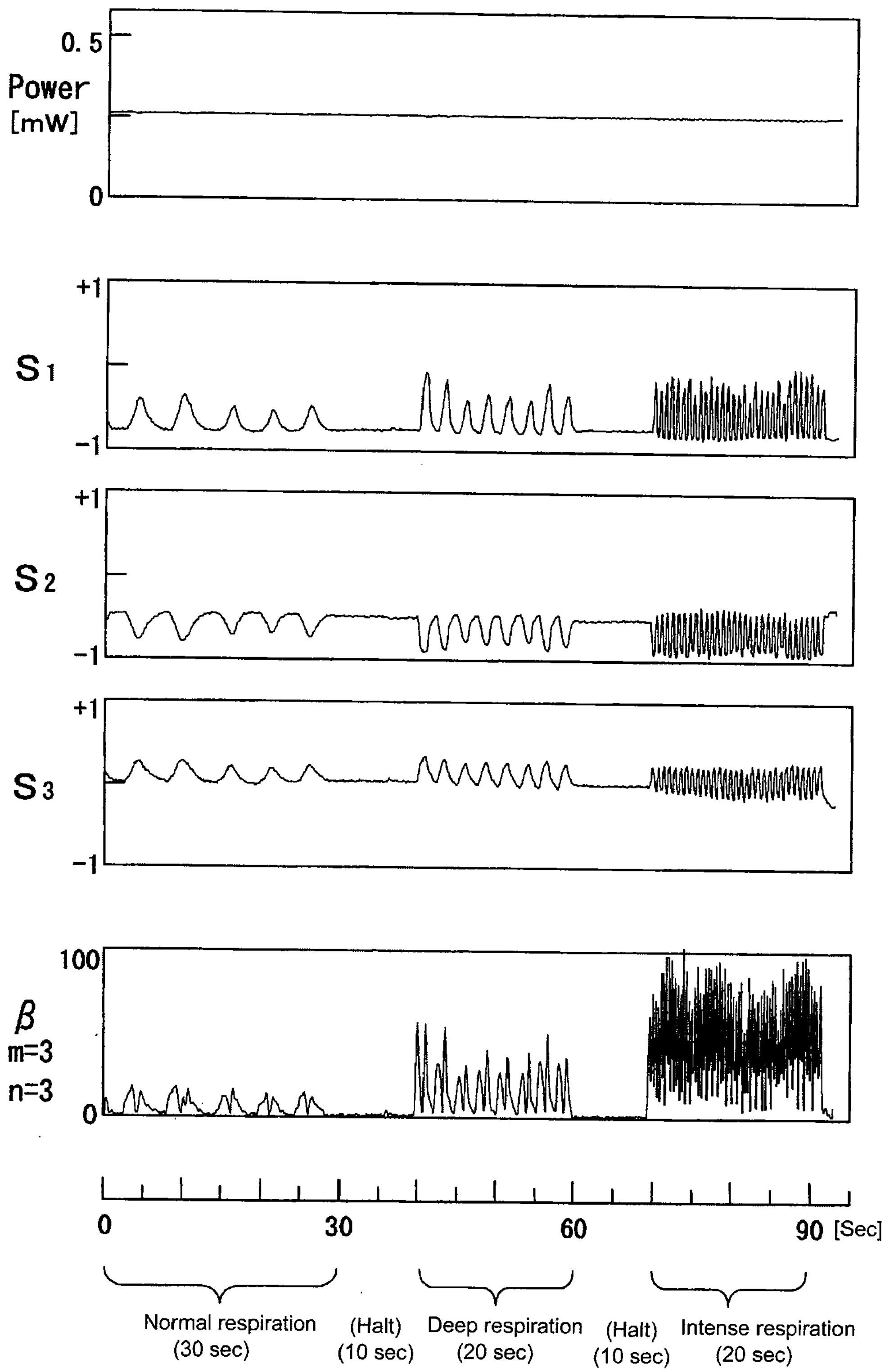


FIGURE 20


0.5
Power
[mW]
0
+1
S1
-1
+1
S2
-1
+1
S3
-1
100
β
m=3
n=3
0
0
30
60
90
[Sec]
Normal respiration
(30 sec)
(Halt)
(10 sec)
Deep respiration
(20 sec)
(Halt)
(10 sec)
Intense respiration
(20 sec)

METHOD FOR MONITORING LIVING BODY ACTIVITIES, AND OPTICAL FIBER TYPE FLAT SHAPED BODY SENSOR, GARMENT STYLED OPTICAL FIBER TYPE FLAT SHAPED BODY SENSOR AND HUMAN BODY FITTED OPTICAL FIBER TYPE FLAT SHAPED BODY SENSOR USED FOR THE SAME

TECHNICAL FIELD

[0001] The present invention is mainly utilized in the fields such as medical care or nursing care and the like, and relates to a method for monitoring living body activities or movements on a floor, a bed or a Tatami-mat and the like which makes it possible that human body activities or movements are sensed or monitored from a distance automatically and with high accuracy, and an optical fiber type flat shaped body sensor used for the same. More specifically, the present invention relates to a method for monitoring living body activities which makes it possible that all human body activities and movements including respiration, pulsation and the like are detected with high accuracy under exactly the same conditions as those of ordinary living environments without using a purpose-made bed, a special-made Futon-bed and the like by means of detecting fluctuations of the polarized wave of light inside an optical fiber brought about by human activities on a bed sheet, a mat, a pad, a Tatami-mat, a floor cover, a carpet and the like and underneath a quilt cover or a blanket by utilizing an optical fiber incorporated bed sheet, quilt, blanket, mat, pad, Tatami-mat, floor cover, carpet and the like (hereinafter called an optical fiber type flat shaped body sensor) with the aid of a highly sensitive polarized wave fluctuations measuring apparatus, and an optical fiber type flat shaped body sensor, a garment styled optical fiber type flat shaped body sensor, and a human body fitted optical fiber type flat shaped body sensor used for the same.

TECHNICAL BACKGROUND

[0002] Conventionally, in the field of medical care, nursing care and the like, a distance monitoring system for so-called nursing care and the like has been developed aiming at effective nursing with less staff by means of movements of a patient, the cared and the like in a hospital room being conveyed to a nurse station or a ward through a cable or cable-free system. Today, the development of this kind of a monitoring system is actively under way.

[0003] Among others, in recent years, a monitoring system for which an optical fiber is employed as a monitoring sensor for living body activities has received a widespread attention because of its excellent detection sensitivity and stability, while a conventional piezoelectric sensor or a vibration type sensor used for the similar living body activities is able to detect movements such as going to bed, rising from bed or tossing and turning in bed and the like of a human accurately to some extent, but it is found difficult to detect movements of a human including respiration and pulsation with high accuracy.

[0004] A monitoring system for living body activities for which an optical fiber is employed has been disclosed, for example, with Japanese Unexamined Patent Application No. 5-312966, Japanese Unexamined Patent Application No. 8-584 and the like.

[0005] The aforementioned technologies of a sensor are all based on a fact that "when an optical fiber is abruptly bent, a linearity of light surpasses a light enclosure effect of light of an optical fiber core, thus bringing about the loss of a light quantity due to the leakage of light". However, there remain several disadvantages such as the below mentioned a, b and c.

[0006] a. An optical fiber needs to be bent abruptly in order that a loss is brought about.

[0007] b. It becomes difficult to adjust a bending quantity due to a fact that a loss increases exponentially to the bend radius. This requires a specially designed tool to obtain an appropriate bend quantity.

[0008] c. It is feared that a wire is broken or deteriorated due to its fatigue when it is abruptly bent.

[0009] On the other hand, with an optical fiber, it has been well known since long ago that the polarized wave conditions of the propagated light changes along with the changes of the shape of its bending. And, detecting systems for crime prevention have been developed with this knowledge. For example, with Japanese Unexamined Patent Application Publication No. 2000-40187, Japanese Unexamined Patent Application Publication No. 2001-6055 and the like, it is so made that an optical fiber is fitted to a fence and the like to sense invaders and raise an alarm by means of detecting polarized wave fluctuations brought about by external forces applied to an optical fiber.

[0010] However, with Japanese Unexamined Patent Application Publication No. 2000-40187 and the like, it is so constituted that an optical fiber is simply fitted to a fence for the purpose of sensing invaders from outside. Therefore, it is found difficult to apply it immediately for monitoring living body activities of a human. In addition, since it is also so constituted that external forces of an invader is directly applied to an optical fiber, and no consideration is paid at all for enhancing the sensitivity of detecting fluctuations of polarized wave conditions due to changes of feeble pressure applied, thus making it difficult to immediately apply it to a monitoring system for human activities.

[0011] Furthermore, because polarized wave conditions of light in an optical fiber is generally random, a so-called polarized wave correction is required to use the polarized wave as a sensor. However, a polarized wave correction is found to be time-consuming and the manufacturing costs go up due to the reason that an apparatus for measuring polarized wave fluctuations is so complicated.

[0012] Applicants of the present invention developed and disclosed a system with which a polarized wave quantity is detected simply and with high sensitivity to solve problems pertaining to corrections of a polarized wave without requiring corrections of a polarized wave (Japanese Unexamined Patent Application Publication No. 2004-108918 and Japanese Unexamined Patent Application Publication No. 2004-184323). The present application allows that all human activities and movements including respiration and pulsation are detected (sensed) with high accuracy by means of applying the system for detecting said quantity of polarized wave fluctuations to a system for monitoring activities and movements of a human.

[0013] [Patent Document 1] Japanese Unexamined Patent Application Publication No. 5-312966

[0014] [Patent Document 2] Japanese Unexamined Patent Application Publication No. 8-584

[0015] [Patent Document 3] Japanese Unexamined Patent Application Publication No. 2000-40187

[0016] [Patent Document 4] Japanese Unexamined Patent Application Publication No. 2001-6055

[0017] [Patent Document 5] Japanese Unexamined Patent Application Publication No. 2004-108918

[0018] [Patent Document 6] Japanese Unexamined Patent Application Publication No. 2004-184223

OBJECTS OF THE INVENTION

[0019] It is the principal object of the present invention to provide a method for monitoring living body activities, and an optical fiber type flat shaped body sensor, a garment styled optical fiber type flat shaped body sensor and a human body fitted optical fiber type flat shaped body sensor used for the same to solve the aforementioned problems with the known monitoring system for living body activities such as:

a. with a system for which a piezoelectric sensor or a vibration type sensor is used, it is not possible to monitor respiration, pulsation and the like at low costs and with high accuracy,

b. with a system for which an optical fiber is used as a sensor, it is difficult to detect changes of feeble living body activities (such as, for example, respiration and pulsation) due to the reason that the loss of a light quantity brought about by abrupt bending of an optical fiber is made to be a detection element, and there exists a risk of a wire being broken or deteriorated, and

c. there exists a problem with low detection sensitivity because a monitoring system for which fluctuations of a polarized wave is made to be a detection element is mainly used for preventing invasion from outside, thus making it possible that they are used in the same way the conventional cloth made sheet is used, and a quantity of polarized wave fluctuations of propagated light in an optical fiber brought about by human activities such as respiration, pulsation and the like can be detected with high sensitivity by sensing human activities with high accuracy, and also making it possible that they are manufactured at low costs.

[0020] More specifically, it is the principal object of the present invention to provide:

a. an optical fiber type flat shaped body sensor which allows to monitor patients and the like without adversely affecting them while sleeping by integrating a flat shaped body such as a cloth made sheet with the aforementioned optical fiber by making use of features of a light and thin thread-like optical fiber, thus making it possible that the optical fiber is used in such a way the conventional cloth made sheet is used,

b. an optical fiber type flat shaped body sensor which can be adaptable to a variety of human activities under many possible circumstantial settings and forms (for example, a bed, a Tatami-mat, a bed sheet, a seat cover, a stretcher, a hammock, a carpet, a mat, clothes and the like along with human activities, and

c. a method for monitoring living body activities which makes it possible that various kinds of vibrations having a wide variety of vibration characteristics are detected with high accuracy by using a polarized wave fluctuation measuring apparatus and by treating signals thereof in a special way even though there exist the case of human activities or movements which bring about obvious changes in a flat shaped body like a sheet and the like, and the case of human activities or movements such as respiration or pulsation which conversely bring about little change in the form of a flat shaped body, also there are cases with which vibrations become feeble as when vibrations make a direct contact with a fiber, when changes of a flat shaped body lead to changes of changes of a fiber, or when changes of a flat shaped body and a fiber are brought about by way of a pad.

DISCLOSURE OF THE INVENTION

[0021] To overcome difficulty with the aforementioned inventions, the present invention as claimed in claim **1** is fundamentally so constituted that with a method for monitoring the existence of movements of a human or living body activities under living circumstances while sleeping on bed, Futon-bed, pad, Tatami-mat and the like, human activities or movements are discriminated with the detected value of polarized wave fluctuations in a manner that a flat shaped body is either spread or covered with an optical fiber type flat shaped body sensor in which an optical fiber is fitted to or mingled with, and light is emitted into the aforementioned optical fiber from a light source, thus changes of a polarized wave of light propagated in an optical fiber brought about by changes of a form of the aforementioned optical fiber type flat shaped body sensor along with living body activities or movements of a human being detected with a polarized wave fluctuations measuring apparatus.

[0022] The present invention as claimed in claim **2** according to claim **1** is so made that a flat shaped body is to be any of a sheet, a bed sheet, a blanket, a mat, a pad, a Tatami-mat, a floor cover or a carpet.

[0023] The present invention as claimed in claim **3** according to claim **1** is so made that periodic vibrations specific to respiration or pulsation are detected with the sum of the power spectrum by using a measuring apparatus for polarized wave fluctuations of light propagated in an optical fiber and by time wave forms of 3 stokes parameters that represent polarized wave conditions of light being transformed with Fourier Transform respectively.

[0024] The present invention as claimed in claim **4** according to claim **1** or claim **3** is so made that it becomes possible that by using a measuring apparatus for polarized wave fluctuations of light propagating in an optical fiber, living body activities or movements of a human are detected at high velocity and with high sensitivity in the manner that the difference between the present value of a polarized wave condition parameter expressed by 3 stokes parameters, a polarized wave ellipse or a phase difference between DC/AC polarized waves and the like and a polarized wave condition parameter found ¼-½ hours before the specific periodicity of vibration obtained with the aforementioned claim **3** is computed as a polarized wave fluctuation quantity.

[0025] The present invention as claimed in claim **5** according to claim **3** or claim **4** is so made that it becomes possible that highly sensitive living body activities or movements of a human are detected in the manner that, at a time of computing a polarized wave fluctuation quantity, a polarized wave condition parameter obtained from the sampling is processed for a moving average, and the width of the moving average is made to be ¼-½ the vibration periodicity obtained in claim **3** and the like, thus removing random noises in signals effectively.

[0026] The present invention as claimed in claim **6** according to claim **1** or claims **3** to **5** is so made that not only the existence of human activities but also the type of human activities is discriminated by utilizing the facts that in the event of body movements such as tossing and turning the polarized wave fluctuation signal is aperiodic but the fluctuation range is wide, while in the event of respiration at rest or pulsation during no respiring the fluctuation range is narrow but periodic.

[0027] The present invention as claimed in claim **7** according to claim **3** is so made that it becomes possible that signals are transmitted from a human to a measuring apparatus for polarized wave fluctuations with patterns made when a human kicks or knocks any given side of a flat shaped body intentionally.

[0028] The present invention as claimed in claim **8** according to claim **1** is so made that a plurality of optical fiber type flat shaped body sensors or a plurality of optical fibers in blocks are monitored in sequence with one set of a measuring apparatus for polarized wave fluctuations by means that a light source apparatus and a measuring apparatus are switched and connected to a plurality of optical fibers of optical fiber type flat shaped body sensors or to a plurality of optical fibers in blocks in an optical fiber type flat shaped body sensor.

[0029] The present invention as claimed in claim **9** according to claim **1** is so made that a plurality of optical fibers of a flat shaped body sensor or a plurality of blocks in an optical fiber type flat shaped body sensor are monitored in sequence with one set of a measuring apparatus for polarized wave fluctuations by means that light is emitted to a plurality of optical fibers of an optical fiber type flat shaped body sensors or a plurality of optical fibers in blocks in an optical fiber type flat shaped body sensor from a wavelength variable light source by switching optical fibers in sequence using a wavelength separation filter.

[0030] The present invention as claimed in claim **10** according to claim **1** is so made that a specific block of an optical fiber is discriminated for monitoring by means that a plurality of filters with which a specific wave length such as an optical fiber diffraction is reflected are incorporated at some midpoint of an optical fiber of an optical fiber type flat shaped body sensor, thus the wave length of a light source apparatus being changed.

[0031] The present invention as claimed in claim **11** according to claim **1** is so made that a specific block of an optical fiber is discriminated for monitoring with the delay time of light dispersed in the optical fiber by transmitting an optical pulse from one end of an optical fiber of an optical fiber type flat shaped body sensor.

[0032] The present invention as claimed in claim **12** according to claim **1** is so made that movements of a human are monitored from a distance by making an optical fiber of an optical fiber type flat shaped body sensor a communications optical fiber and by connecting said optical fiber to the communications optical fiber.

[0033] The present invention as claimed in claim **13** is fundamentally so constituted that shape changes of any part of the outer surface of a flat shaped body are reflected by means of making optical fibers affixed and run throughout the flat shaped body.

[0034] The present invention as claimed in claim **14** according to claim **13** is so made that the similar use-feelings as those obtained with cloth made sheets while in bed are secured in the manner that covered and extremely thin optical fibers are sewed up throughout a flat shaped body, thus weight, thickness and flexibility of an optical fiber incorporated flat shaped body remaining unchanged with those of an ordinary cloth made sheet.

[0035] The present invention as claimed in claim **15** according to claim **13** or claim **14** is so made that a flat shaped body is made to be any one of a sheet, a bed sheet, a quilt cover, a blanket, a mat, a pad, a Tatami-mat, a floor cover or a carpet.

[0036] The present invention as claimed in claim **16** according to claim **13** or claim **14** is so made that sensitivity brought about with polarized wave fluctuations is raised to changes in form of an optical fiber type flat shaped body sensor by means of making the form of affixing or sewing up of an optical fiber so complex like linear shaped, wave shaped or loop shaped.

[0037] The present invention as claimed in claim **17** according to claim **13** or claim **14** is so made that sensitivity brought about with polarized wave fluctuations is raised to changes in form of an optical fiber type flat shaped body sensor by means of the number of conductors of an optical fiber being multiplied.

[0038] The present invention as claimed in claim **18** according to claim **13** or claim **14** is so made that sensitivity brought about with polarized wave fluctuations is raised to changes in form of an optical fiber type flat shaped body sensor by means of a reflection mirror being placed on one side of an optical fiber so that light signals are transmitted in the optical fiber with to-and-from movements.

[0039] The present invention as claimed in claim **19** according to claim **13** or claim **14** is so made that an optical fiber type flat shaped body sensor is processed to make a cover for a Futon-bed, a quilt, a mat, a sofa and the like.

[0040] The present invention as claimed in claim **20** according to claim **19** is so made that a water tight process is conducted with a vinyl cover and the like.

[0041] The present invention as claimed in claim **21** is a garment styled optical fiber type flat shaped body sensor with which any changes in form of any part of a human body are reflected to changes in form of an optical fiber by means of making optical fibers sewed up in or affixed to clothes such as a pajama, a night wear, a patient dress, a garment worn by the monitored and the like which are all put on a human body while in bed, during a medical test being conducted, a human being monitored for activity conditions and the like.

[0042] The present invention as claimed in claim **22** is a human body fitted optical fiber type flat shaped body sensor with which any changes in form of any fitted part are reflected to changes in form of an optical fiber by means of an optical fiber being sewed up in or affixed to a human body fitted pad in the shape of a stomach band, a bandage or a sheet to be affixed.

EFFECT OF THE INVENTION

[0043] The present invention makes it possible that movements of a patient and the like is monitored under normal conditions in a daily life without giving the users of an optical fiber type flat shaped body sensor strange or abnormal feelings at all due to the reason that said optical fiber type flat shaped body sensor is formed with light weight optical fibers with a small diameter being integrated with and affixed to a flat shaped body such as a cloth made sheet and the like.

[0044] The present invention makes it possible that a wide range of vibration in intensity from human activities like bed going and bed leaving to respiration and pulsation is detected with high accuracy by using one measuring apparatus for polarized wave fluctuations, and the present invention is applicable to all flat shaped bodies such as a bed, a mat, a blanket, a bed sheet, a quilt cover and the like due to the reason that a fluctuation quantity of polarized wave conditions of light propagated in an optical fiber brought about by living body activities and respiration, pulsation and like of a human body can be detected in real time, and also sensitivity can be upgraded by raising the ratio of a detected value and noises.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] FIG. **1** is an explanatory drawing to show one of embodiments of a method for monitoring living body activities.

[0046] FIG. **2** is an explanatory drawing to show one example how an optical fiber type flat shaped body sensor is used wherein (a) designates when it is used on a floor top, (b) when it is used on a bed, and (c) when it used as a top cover.

[0047] FIG. **3** is an explanatory drawing to show polarized wave fluctuations of light passing through an optical fiber wherein (a) shows polarized wave conditions of the plane of emission (to be ellipse-shaped) by stress (F) being applied, (b) deformed conditions of an optical fiber **2** due to living body activities of a human, and (c) a relative relationship between the direction of vibration and stress F which bring about the maximum polarized wave fluctuations and the form of an optical fiber **2**, respectively.

[0048] FIG. **4** is an explanatory drawing of a measuring apparatus for polarized wave fluctuations **5** wherein (a) is an explanatory drawing of an entire basic constitution, (b) an explanatory drawing of the basic constitution of a polarized wave condition detection part and (c) an explanatory drawing to show how a polarized wave condition detection part and a polarized wave fluctuation quantity detection part are connected.

[0049] FIG. **5** shows definitions of the display of polarized wave fluctuations and a polarized wave fluctuation quantity with a stokes parameter detected by a polarized wave condition detection part of a measuring apparatus for polarized wave fluctuations respectively.

[0050] FIG. **6** is an explanatory drawing to show a concept of a moving average treatment of a polarized wave fluctuation quantity β.

[0051] FIG. **7** is an explanatory drawing to show a concept of a fluctuation computation width treatment of a polarized wave fluctuation quantity β.

[0052] FIG. **8** is a plan view to show the first embodiment of an optical fiber type flat shaped body sensor.

[0053] FIG. **9** is an explanatory drawing to show the second embodiment of an optical fiber type flat shaped body sensor.

[0054] FIG. **10** is an explanatory drawing to show the third embodiment of an optical fiber type flat shaped body sensor.

[0055] FIG. **11** is an explanatory drawing to show other embodiments of a method for monitoring living body activities.

[0056] FIG. **12** is an explanatory drawing to show further other embodiments of a method for monitoring living body activities.

[0057] FIG. **13** is an explanatory drawing to show another embodiment of a method for monitoring living body activities.

[0058] FIG. **14** is an explanatory drawing to show further another embodiment of a method for monitoring living body activities.

[0059] FIG. **15** is an embodiment to show a relationship between living body activities of a test subject and a polarized wave fluctuation quantity A, a degree of polarized light (DOP) and the like.

[0060] FIG. **16** shows the results of the FFT-analysis of a stokes parameter shown in FIG. **15** by using equation (5). FIG. **16**(*a*) shows the analytical results for 51.2 sec with a posture of being laid on one's back at rest, and (b) shows the analytical results for 25.6 sec with a posture of being laid on one's side at rest respectively.

[0061] FIG. **17** shows the results of the FFT-analysis of Test Case 19 (KW401) shown in Table 1 by using equation (5). FIG. **17**(*a*) shows the analytical results for 25.6 sec with a posture of being laid on one's back at rest under normal breathing conditions, and (b) shows the analytical results for 6.4 sec with a posture of being laid on one's side at rest under no breathing condition (no respiration).

[0062] FIG. **18** shows the difference in signals when values m and n are changed by expanding a longitudinal axis so that fluctuations during the still period can be clearly seen with regard to the wave forms of a polarized wave fluctuation quantity β in FIG. **15**.

[0063] FIG. **19** is a plan view to show an example of a garment styled optical fiber type flat shaped body sensor.

[0064] FIG. **20** is wave forms of an embodiment which show a relationship between respiration conditions of a human with a garment styled optical fiber type flat shaped body sensor and a polarized wave fluctuation quantity and a stokes parameter.

LIST OF REFERENCE NUMERALS AND CHARACTERS

[0065] H Human
[0066] **1** Optical fiber type flat shaped body sensor
[0067] **2** Optical fiber
[0068] **3** Cloth made sheet (flat shaped body)
[0069] **4** Light source apparatus
[0070] **5** Measuring apparatus for polarized wave fluctuations
[0071] **6** Floor
[0072] **7** Bed
[0073] **8** Mat
[0074] **9** Pad
[0075] **10** Cloth made sheet
[0076] **11** Blanket
[0077] **12** Polarized wave condition detection part
[0078] **13** Polarized wave fluctuation quantity detection part
[0079] S_1,S_2,S_3 Stokes parameters
[0080] β Polarized wave fluctuation quantity
[0081] **14** Polarized wave branching element
[0082] **15** Rotary polarization element
[0083] **16** λ/4 plate
[0084] **17** Photo receptor
[0085] **18** Reflection mirror
[0086] **19** Photo circulator
[0087] **20** Optical fiber selector switch
[0088] **21** Wavelength variable type light source
[0089] **22** Wavelength separation filter
[0090] **23** Filter
[0091] **24** Connector part or partial reflection element
[0092] **25** Pulse light source apparatus
[0093] **26** Garment styled optical fiber type flat shaped body sensor

BEST MODE FOR CARRYING OUT THE INVENTION

[0094] Preferred embodiments in accordance with the present invention are hereinafter described with reference to the drawings. FIG. **1** is an explanatory drawing to show one example of embodiments of a method for monitoring living body activities in accordance with the present invention. FIG. **2** is an explanatory drawing to show one example of uses of an optical fiber type flat shaped body sensor.

[0095] Referring to FIG. **1**, **1** designates an optical fiber type flat shaped body sensor, **2** an optical fiber, **3** a cloth made sheet (flat shaped body), **4** a light source apparatus, **5** a measuring apparatus for polarized wave fluctuations.

[0096] Referring to FIG. **2**, **6** designates a floor, **7** a bed, **8** a mat, **9** a pad, **10** a cloth made sheet, **11** a blanket and H a human.

[0097] The aforementioned optical fiber type flat shaped body sensor **1** is made with an optical fiber **2** being fixed to the entire surface of a cloth made sheet. As described later, there exist a variety of structures, forms and methods of fixing of an optical fiber to be used.

[0098] As shown in FIG. **2**, said optical type flat shaped body sensor **1** is used by fitting it on the top of a bed or a floor **6**, or in the form of covering a human H with it. Also, as described later, it is possible that said optical fiber type flat shaped body sensor **1** is not only used in the form of a sheet or a spread, but also used in the form of a pillow case or a cover sheet for a Futon-mat or in the form of a pajama, a night wear, an underwear and the like.

[0099] As shown in FIG. **1**, a method for monitoring living body activities is based on that the stress such as vibration, pressure or the like brought about by living body activities (bed-going, bed-leaving, respiration, pulsation and the like) of a human H is applied to an optical fiber **2** of an optical fiber type flat shaped body sensor **1**, thus polarized wave fluctuations brought about on light propagated in an optical fiber **2** being able to be detected by a measuring apparatus for polarized wave fluctuations **5**. FIG. **3** is an explanatory drawing to show the concept of the aforementioned polarized wave fluctuations, and FIG. **4** is an explanatory drawing to show the principal constitution of the aforementioned measuring apparatus for polarized wave fluctuations **5**.

[0100] Namely, when light propagating in an optical fiber **2** is applied by a magnetic field, pressure, vibration, temperature changes and the like, or, for example, an optical fiber **2** is applied by stress F as shown in FIG. **3**(*a*), an incident polarized wave plane A is made to be elliptic like an emitting polarized wave plane A'. A polarized wave plane mentioned here means a vibration plane of an electric field when light is taken as an electromagnetic wave.

[0101] Generally, polarized wave fluctuations are detected by means of a constituent only in the horizontal direction toward an emitting polarized wave plane A' being taken out normally by using a polarizer, and changes of a polarized wave are detected as changes of light-strength. However, polarized wave conditions change at random during propagation. Therefore, in order that the maximum degree of modulation (strength changes) can be obtained at the emission end, it is found necessary that a polarizer and a polarized wave adjuster are rotated and adjusted for detection. With the present invention, such adjustments are not needed, and it is so made, however, that stokes parameters are measured as described later.

[0102] The indication of polarized wave conditions of light wave signals is done normally with stokes parameters S_1, S_2, S_3. As described later, the indication is performed with values S_1, S_2, S_3 (stokes parameter S_1 is a linear polarized wave in a horizontal ⇔vertical direction, stokes parameter S_2 is a linear polarized wave in a +45 degree ⇔−45 degree direction, and S_3 is a circular polarized wave of a right turn ⇔a left turn) corresponding to each light strength constituent directly measured with three kinds of polarized filters on Poincare's spherical surface.

[0103] FIGS. **3**(*a*) and (*b*) show a relationship between the direction of stress F applied to an optical fiber **2** and the width of polarized wave fluctuations It has empirically found polarized wave fluctuations brought about by vibration or bend force F applied to an optical fiber **2** have been dependent largely on the form of an optical fiber, that is, polarized wave fluctuations are found to be relatively large when vibration is applied in a perpendicular to the original bent face of an optical fiber **2**.

[0104] FIG. **4** is an explanatory drawing to show a basic configuration of a measuring device for polarized wave fluctuations **5** in use with the present invention. Referring to FIG. **4**(*a*), **12** designates a polarized wave condition detection part, **13** a polarized wave fluctuation quantity detection part, and S a polarized wave fluctuation quantity detected.

[0105] FIG. **4**(*b*) is an example of a basic configuration of an element incorporated into a polarized wave condition detection part **12**, wherein **14** designates a polarized light branching element, **15** a rotary polarization element, **16** a λ/4 plate and **17** a photo receptor. The aforementioned polarized light branching element **14** is an element to take out a horizontal polarized light constituent at the branching ratio of approximately 1~5%. A rotary polarization element **15** is so made that the plane of a polarized light is rotated for 45 degree. Furthermore, a λ/4 plate is so made that a doubly refracting principal axis thereof is set at 45 degree from a horizontal face.

[0106] Generally, it is needed, as mentioned before, that a vibration-centered position on the sphere and the direction of vibration are adjusted to detect polarized wave fluctuations with high sensitivity. However, it is found not easy to make such adjustments in a short period of time.

[0107] Thus, with the present invention, it is so made that a polarized wave fluctuation quantity β is computed with three constituents of a polarized wave S_1, S_2, S_3.

[0108] Namely, output signals V_1, V_2, V_3, V_0 of each photo receptor **17** are corrected for sensitivity differences with a light branching element and the like (that is, correction is made so that V_1, V_2, V_3 become the values of $0 \sim V_0$ depending on polarized wave conditions), thus a polarized wave fluctuation quantity β being computed by using stokes parameters S_1, S_2, S_3 obtained as $Sj=2Vj/V_0-1$ (where j=1, 2, 3).

[0109] Concretely, as shown in FIG. **5**, standard conditions of polarized wave fluctuations are set as S_{10}, S_{20}, S_{30}, and assuming stokes parameters which show polarized wave conditions measured are S_1, S_2, S_3, a triangle with 2 vertices $[V_1, V_2, V_3]$ $[S_{10}, S_{20}, S_{30}]$ and an origin [0, 0, 0] becomes an isosceles triangle as in FIG. **5**, and its vertex angle β is expressed by the following equations:

$$\beta=2\sin^{-1}(dL/2) \quad (1)$$

$$dL=\sqrt{(dS_1^2+dS_2^2+dS_3^2)} \quad (2)$$

$$dSj=Sj-Sj_0 \quad (3)$$

[0110] (where j=1, 2, 3)

With the present invention, it is defined that the angle β is a polarized wave fluctuation quantity. Here, dsj is the change quantities of each coordinate, and dL is equivalent to a travel distance of a coordinate point. The distance from a coordinate original point to a coordinate point is the degree of polarized light ($DOP=S_1+S_2+S_3$). However, in the case that monochromatic light is used, it is that DOP=1.

[0111] Referring to FIG. **5**, θ is a so-called polarized wave principal axis azimuth, and ϵ is an elliptic rate angle.

[0112] A polarized wave fluctuation quantity β expressed by the above shown equation (1) is computed in real time with a polarized wave fluctuation quantity detection part **13** in FIG. **4**(*a*) without so-called polarized wave adjustments. Said polarized wave fluctuation quantity detection part **13** is constituted as a digital (or analogue) type computation apparatus.

[0113] Concretely, as shown in FIG. **4**(*c*), light is converted to electric signals with each photo receptor **17**, amplified with a log amplifier, AD-converted and transmitted to the PC the mediation of the USB interface. On the PC side, stokes parameters S_1, S_2, S_3, the degree of polarized light (DOP) and a polarized wave fluctuation quantity β are computed, and what are computed are stored in a hard disc together with the strength of light, time data, key events (key entry of condition changes and the like for a memo)

[0114] The range of a log amplifier is 30 dB, the resolving power of an AD converter is 12 bit (value of 1500 per a digit) and the velocity is 10 kHz. The transmission period of the USB is 0.01 sec. It is so constituted that an average is obtained for every 10 data, thus computation and storage being performed with the periodicity of 0.1 sec after making averaged for every 10 data.

[0115] With the aforementioned polarized wave fluctuation quantity detection part **13** in FIG. **4**, it is so constituted that a polarized wave fluctuation quantity β is computed with equations (1), (2), (3) by using stokes parameters S_1, S_2, S_3. However, as mentioned later, in the case that a survey on contents of feeble vibration (for example, feeble and periodic vibration wave forms such as those of respiration and pulsation of a human) is conducted, it is considered that feeble vibration can be easily discriminated with the wave forms of stokes parameters S_1, S_2, S_3 than a polarized wave fluctuation quantity β. So, the FFT (Fast Fourier Transform) analysis of the stokes parameters was conducted to determine the vibration detection limit, and based on what are found the improvements of detection sensitivity have been achieved by setting a standard of a polarized wave fluctuation quantity S and doing a moving average treatment.

[0116] As shown in FIG. **5** and the like, the aforementioned polarized wave fluctuations are expressed by vibration on the spherical surface of a radius **1** when stokes parameters S_1, S_2, S_3 are expressed with the 3-dimensional orthogonal coordinates of x, y, z, and a polarized wave fluctuation quantity B is expressed by the afore stated equations (1)~(3).

[0117] To obtain the fluctuation width (peak to peak) of periodic vibration, both ends of vibration can be replaced with S**1**, S**2**, S**3** and S**10**, S**20**, S**30** as shown in FIG. **5**. That is, in the case of feeble vibration, the afore shown equation (1) becomes as:

$$\beta p{\cdot}p = dL \text{ [rad]} \quad (4)$$

(in the case of [degree] unit, dL*180/π)

[0118] Now, with the vibration of single frequency F, assuming that the vibration widths of stokes parameters are dS_{1f}, dS_{2f}, dS_{3f} when there exists no phase difference with the vibration of stokes parameters, equation (2) can be written as:

$$dL_f^2 = dS_{1f}^2 + dS_{2f}^2 + dS_{3f}^2 \quad (5)$$

Here, ½ of dS (j=1, 2, 3) is equivalent to a vibration power with a frequency f of Sj.

[0119] Therefore, the power spectrum can be obtained with the aforementioned FFT on three wave forms of stokes parameters S**1**, S**2**, S**3** measured, thus making it possible that evaluation is achieved with the total value thereof.

[0120] Namely, the power spectrum can be obtained by treating three stokes parameters S_1, S_2, S_3 with the FFT, and its total Q is obtained as $Q=\zeta S_1+\zeta S_2+\zeta S_3$, thus an amplitude Lpp of a frequency constituent of a vibration peak being obtained as $Lpp=\sqrt{}(2Q)$. The concept of said analysis by the FFT is substantially same as that of an analysis of a polarized wave fluctuation quantity β shown in the afore stated equations (1)~(3).

[0121] Due to the reason that polarized wave fluctuation quantity β is computed with the difference between stokes parameters at the present time and stokes parameters at the time antecedent to the specified time (a standard value), detection of fluctuations can be performed at ease, and an instantaneous response property (a real time property) is found excellent. However, when a time span of computation is made too short for comparatively slow vibration, a polarized wave fluctuation quantity β becomes hidden with noises for the reason that the width of changes of stokes parameters caused by the vibration becomes smaller than that with noises.

[0122] In the case of the waveform of, for example, pulsation as described later, the existence of the vibration can be identified when the entire waveform is found, but it will be difficult to see instantaneous changes with the difference between after- and before-samplings.

[0123] Furthermore, in order to raise the signal and noise ratio SNR of a polarized wave fluctuation quantity β, it is required that a. a moving average treatment of stokes parameters is optimized (n) and that b. the time width for computing β is optimized (m).

[0124] To do so, the following two treatments are conducted with the present invention.

[0125] a. For the optimization of a moving average treatment of stokes parameters, the k-th sampling dada, Sj(k)(j=1, 2, 3) of stokes parameters are transformed to the averaged Sj(k)a in the case of the number of a moving average=n as below:

$$Sj(k)a = (l/n) * \sum_{i=0}^{n-1} Sj(k-i) \quad (6)$$

[0126] Here, n=1 is for the case of (Sj(k)a=Sj(k)) without being averaged.

[0127] b. Next, for the optimization of the time width for a polarized wave fluctuation quantity β, in the case of the computation width of β, with equations (1)~(3), β(k) obtained by the k-th data Sj(k) is made to be a standard of stokes parameters antecedent to the m sample from the stokes parameters of the present time, and equation (3) is replaced as below:

$$dSj(k)=Sj(k)-Sj(k-m)$$

[0128] Here, Sj(k) can be Sj(k)a averaged with a.

[0129] FIG. **6** and FIG. **7** are explanatory drawings of the aforementioned a moving average treatment and a fluctuation quantity computation width. As apparent from FIG. **6** and FIG. **7**, with the moving average treatment, a rise time is delayed by the moving average number n, and a signal peak becomes smoothened, thus being small when a moving average number n is excessive, but a fluctuation quantity computation width m is not affected by this, thus there being no delay with a rise time and the peak not becoming small even when a fluctuation quantity computation width m is excessive. However, when an original waveform is observed as the periodic vibration, there is caused a delay by a fluctuation quantity computation width m, and the waveform is disrupted in the case that a fluctuation quantity computation width m is excessive. When a fluctuation quantity computation width m is small, the amplitude becomes smaller than the original waveform, thus a possibility of it being buried into the noise.

[0130] Accordingly, it is recommended that a moving average number n and an average computation width m are set shorter than ½ the assumed vibration periodicities. With the embodiment, a sampling periodicity is 0.1 sec/sample, and the effectiveness will be less than 25 sample if the vibration periodicity of respiration is approximately 5 sec.

EMBODIMENT 1

[0131] FIG. **8**(*a*)-FIG. **8**(*d*) show preferred embodiments of an optical fiber type flat shaped body sensor **1**. As shown in FIG. **3**(*b*) and FIG. **3**(*c*), polarized wave fluctuations caused by vibration and bend stress F applied to an optical fiber **2** become relatively large when vibration and the like are applied in the direction perpendicular to the original bend plane of an optical fiber **2**. Therefore, 4 different types of sensors **8**(*a*)~**8**(*d*) have been manufactured.

[0132] An optical fiber **2** has been affixed to a cloth made sheet **3**, and it is so constituted that, with this case, an single mode optical fiber **2** with a covered outer diameter of approximately 0.5 mm and a conductor clad which diameter is 0.125 mm ϕ is fixed with a synthetic resin made adhesive to a flat shaped body made of a blended cloth of a synthetic resin and a natural fabric.

[0133] Affixation of an optical fiber **2** to a flat shaped body (a cloth made sheet **3**) can be achieved with any method such as being sewed in a cloth made sheet or being caught between 2 thin cloth made sheets.

[0134] An optical fiber **2** can be used as bare. There is no need to say that the outer surface of an optical fiber **2** can be thinly covered.

[0135] Furthermore, affixation of an optical fiber **2** (flat shapes in a state of adhesion) can be of any form such as a loop shape (FIG. **8**(*c*)), a wave shaped (FIG. **8**(*d*)) or any other types.

EMBODIMENT 2

[0136] FIG. **9** shows a preferred embodiment in the event that the structure of an optical fiber **2** in FIG. **8** is made to be of a multi-conductor type (the number of conductors n) with which sensitivity brought about by polarized wave fluctuations to changes of shapes of a flat shaped body sensor **1** is improved. Here, a light source apparatus **4** and a measuring apparatus for polarized wave fluctuations are connected with the end part of one side of a multi-conductor type optical fiber **2**.

EMBODIMENT 3

[0137] FIG. **10** shows the method of sensitivity brought about by polarized wave fluctuations to changes of shapes of a flat shaped body sensor **1** being raised by means that a reflection mirror **18** is installed at the end part of one side of an optical fiber **2** in order that light wave signals are transmitted to and fro. In FIG. **10**, **19** designates an optical circulator. An optical coupler can be used as a substitute for an optical circulator **19**.

EMBODIMENT 4

[0138] With the afore shown embodiments 1~3, a flat shaped body sensor **1** is formed in a quadrangle shaped sheet (a flat shaped body). There is no need to say that a flat shaped body sensor **1** can be utilized by means of the sheet being integrally processed to make a cover for a Futon-bed, a quilt, a mat, a sofa and the like.

[0139] Also, there is no need to say that a flat shaped body sensor **1** with Embodiment 1~Embodiment 3 can be made watertight by using a vinyl cover.

[0140] Furthermore, by using a flat shaped body sensor **1** with Embodiment 1~Embodiment 3, clothes such as a pajama or a night wear can be formed, or an optical fiber **2** can be adhered to clothes separately prepared, to make a garment styled optical fiber type sensor with which any changes of a shape of a human body can be detected as changes of a shape of an optical fiber **2**.

[0141] In addition, by means of an optical fiber being sewed in a pad shaped body made in the manner that it is fitted directly to the outer surface of a human body, it becomes possible to make a human body fitted optical fiber type sensor which allows that any changes of a form of the part fitted to a human body can be reflected to the changes of a form of an optical fiber.

EMBODIMENT 5

[0142] FIG. **11** shows the case wherein, by using a measuring apparatus for polarized wave fluctuations **5**, a plurality of optical fiber type flat shaped body sensors or a plurality of blocks in an optical fiber type flat shaped body sensor can be monitored in sequence with an optical fiber selector switch **20**. FIG. **11**(*a*) and FIG. **11**(*b*) are formed as a transmittance type one and a reflectance type one respectively. Referring to FIG. **11**(*a*), **19** is an optical circulator.

EMBODIMENT 6

[0143] FIG. **12**(*a*) and FIG. **12**(*b*) are other preferred embodiments to show a method for monitoring living body activities, wherein a light source apparatus **4** is made to be a wavelength variable type light source **21**, and a wavelength separation filter **22** is used as a substitute for an optical fiber selector switch **20** so that by using one set of a measuring apparatus for polarized wave fluctuations **5**, polarized wave fluctuations of a plurality of optical fiber type flat shaped body sensors **1** can be detected in sequence, or a plurality of blocks of a flat shaped body sensor **1** can be detected individually in sequence. FIG. **12**(*a*) and FIG. **12**(*b*) are constituted as a transmittance type one and as a reflectance type one respectively.

EMBODIMENT 7

[0144] FIG. **13** shows a preferred embodiment of another method for monitoring living body activities, wherein a plurality of filters **23** allowing to reflect only a certain wavelength such as an optical fiber diffraction grating are incorporated at some midpoint in the optical fiber **2**, thus making it possible that a specific block of an optical fiber **2** is individually discriminated and monitored.

EMBODIMENT 8

[0145] Referring to FIG. **14**, it is so constituted that a plurality of connectors or partial reflection elements **24** are installed at some midpoint in an optical fiber, and photo pulse signals are transmitted from a pulse light source apparatus **25**, thus making it possible that a plurality of blocks of an optical fiber **2** are discriminated and monitored with the delay time of dispersed light in an optical fiber **2**.

[0146] With the aforementioned Embodiment 1~Embodiment 8, it is so constituted that a light source apparatus or a measuring apparatus for polarized wave fluctuations **5** is directly connected to an optical fiber type flat shaped body sensor **1**. However, in the case that a flat shaped body sensor **1** and a measuring apparatus **5** and the like are separated over a distance, it is possible that a flat shaped body sensor **1** is constituted by using an general communications purpose optical fiber so that a flat shaped body sensor **1** and a measuring apparatus for polarized wave fluctuations **5** an the like are directly connected through the mediation of a communications purpose optical fiber.

EMBODIMENT 9

[0147]

TABLE 1

Measurement Test Conditions of Polarized Wave Fluctuation Quantity

		Flat shaped body sensor (Sheet type)		Conditions for light transmission	
	Test case name	Type	Usage pattern	Number of conductors in use	Light direction
1	W401	FIG. 8 (d)	FIG. 2 (a)	4	1 way
2	W101	FIG. 8 (d)	"	1	1 way
3	L401	FIG. 8 (c)	"	4	1 way
4	L101	FIG. 8 (c)	"	1	1 way
5	L102	FIG. 8 (c)	"	1	Reflection
6	H401	FIG. 8 (b)	"	4	1 way
7	H101	FIG. 8 (b)	"	1	1 way
8	H102	FIG. 8 (b)	"	1	Reflection
9	V401	FIG. 8 (a)	"	4	1 way
10	V101	FIG. 8 (a)	"	1	1 way
11	V102	FIG. 8 (a)	"	1	Reflection
15	BV402	FIG. 8 (a)	FIG. 2 (b)	4	1 way
16	BV102	FIG. 8 (a)	"	1	1 way
17	BW401	FIG. 8 (d)	"	4	1 way
18	BW101	FIG. 8 (d)	"	1	1 way
19	KW401	FIG. 8 (d)	FIG. 2 (c)	4	1 way

As shown in Table 1, by using an optical fiber type flat shaped body sensor **1** in FIG. **8**(*a*), (*b*), (c), (d) in conditions as FIG. **2**(*a*), (*b*), (c), measurements were conducted for activities of a test subject with a measuring apparatus for polarized wave fluctuations. As described later, FIG. **15** shows measured data under the measurement test conditions of No. 1 in Table 1. With FIG. **15**, on the vertical axis, Power represents the strength of light, S_1, S_2, S_3 stokes parameters (3 constituents of a polarized wave), DOP a degree of polarized light, β a polarized wave fluctuation quantity, and key conditions of human activities respectively,

TABLE 2

Results of Assessment by Direct Visual Check on Measured Data

		Strength of	Actions							
	Test case name	photo reception [mW]	Go to bed	On back at rest	Tossing & Turning	On side at rest	Tossing & Turning	On back at rest	Get out of bed	Remarks
1	W401	0.838	◎	○	◎	○	◎	—	◎	
2	W101	2.436	◎	○	◎	Δ	◎	Δ	◎	
3	L401	0.117	◎	X	◎	Δ	◎	X	◎	Big loss
4	L101	1.538	◎	X	◎	Δ	◎	X	◎	
5	L102	1.259	◎	○	◎	○	◎	X	◎	
6	H401	0.206	◎	○	◎	X	◎	Δ	◎	Big loss
7	H101	3.112	◎	○	◎	X	◎	Δ	◎	
8	H102	1.613	◎	○	◎	X	◎	○	◎	
9	V401	1.772	◎	X	◎	Δ	◎	Δ	◎	
10	V101	2.674	◎	X	◎	X	◎	X	◎	
11	V102	1.529	◎	Δ	◎	X	◎	X	◎	
15	BV402	1.649	◎	Δ	◎	X	◎	Δ	◎	
16	BV102	2.551	◎	Δ	◎	X	◎	X	◎	

TABLE 2-continued

Results of Assessment by Direct Visual Check on Measured Data									
17 BW401	1.245	⊚	○	⊚	○	⊚	○	⊚	
18 BW101	2.903	⊚	○	⊚	○	⊚	○	⊚	
		Respiration							
		Respiration	Halt	Deep Respiration	Halt	Intense Respiration	Halt	—	Remarks
19 KW401	1.103	⊚	Δ	⊚	Δ	⊚	Δ	—	

* Existence of meaningful vibrations
⊚ Clearly seen
○ Slightly seen
Δ Difficult to judge
X Not seen

[0148] From the results of the aforementioned measurements, whether or not movements of a test object can be checked visually were judged on the data. The results were as shown in Table 2.

[0149] Specifically, with the test No. 19 (when an optical fiber type flat shaped body sensor **1** is used instead of a cover blanket), a clear judgment was possible on respiration or non-respiration of a test object directly from a so-called raw data.

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[0150] By using a wave styled optical fiber type flat shaped body sensor **1** shown in FIG. **1** in a form as shown in FIG. **2**(*a*), an analysis was conducted on a polarized wave fluctuation quantity β obtained from a variety of living body activities of a human H (a test object).

[0151] FIG. **15** shows the state of activities (key) of a test object (H) and stokes parameters S_1~S_3, a degree of polarized waves (DOP), a polarized wave fluctuation quantity β, the strength of light (Power) detected and computed by a measuring apparatus for polarized wave fluctuations **5**, with which it is learned that the strength of light (Power) remains same but stokes parameters S_1, S_2, S_3 and a polarized wave fluctuation quantity β are substantially changed. At the time of rest, there are seen periodic changes at some points of stokes parameters.

[0152] An optical fiber **2** of a flat shaped body sensor **1** is of 4-conductor type, and as shown in FIG. **9**, its constitution is of a 2 reciprocation type.

[0153] FIG. **16** shows the results of stokes parameters shown in FIG. **15** being FFT-analyzed by using the aforementioned equation (5). FIG. **16**(*a*) is what analyzed for 51.2 sec when laid on a back at rest, and (b) for 25.6 sec when laid on a side at rest. A lateral axis is for frequencies, while a longitudinal axis is for power spectrum which numeric values are made 10 times. For both there appeared strong spectrum in the vicinity of 0.2 Hz. Therefore, it can be judged that this is caused by respiration.

[0154] FIG. **17** shows the results of a test case 19 shown in Table 1 being FFT-analyzed by using the aforementioned equation (5). FIG. **17**(*a*) is what analyzed for 25.6 sec when laid on a back at rest while normally respiring, and (b) for 6.4 sec when laid on a back at rest while respiration being halted (non-respiration). With (a), there appeared extremely strong in the vicinity of 0.2 Hz, with which it was easily judged that this was caused by respiration, while with (b) it was confirmed that there existed a peak in the vicinity of 1.1 Hz, with which it was learned that this was caused by pulsation.

[0155] With visual assessments in Table 2, polarized wave fluctuations at the time of respiration being halted were too feeble to be recognized. However, it was confirmed with the analysis of the present invention that there existed signals.

[0156] In order to detect the existence of feeble vibration and its frequencies with the aforementioned FFT analysis, a time required for the analysis is approximately 5 times the periodicity of vibration of the object (6 sec for pulsation and 25.6 sec for respiration). Analysis of vibration frequencies and the like can not be performed with a polarized wave fluctuation quantity **3**, but the existence of polarized fluctuations can be instantaneously found because the time delay in computation become approximately a moving average n of stokes parameters and the β computation width m.

[0157] Polarized wave fluctuations in FIG. **18** are equivalent to the case of both a moving average n and a β computation width m being 1. The existence of prominent actions such as tossing and turning, bed-in, bed-out and the like can be instantaneously found from the results.

[0158] Furthermore, FIG. **18** shows a up-scaled longitudinal axis of the waveform of a polarized wave fluctuation quantity β in FIG. **15**.

[0159] Firstly, in the case of m=1 and n=1, it is difficult to identify the difference between the noises at the time of non-signals before a human goes to bed and the signals after being laid on a back at rest and being laid on a side at rest in bed.

[0160] Next, in the case of m=20 and n=1, there remain noises unchanged at the time of non-signals before a human goes to bed, and there appear fluctuation signals distinctly when laid on a back at rest and also laid on a side at rest.

[0161] Furthermore, in the case of m=20 and n=10, noises reduce remarkably at the time of non-signals, and signals at the time when laid on a back at rest and laid on a side at rest are clearly identified.

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[0162] FIG. **19** is a plan view of a garment styled optical fiber type flat shaped body sensor **16** in accordance with the present invention. Said garment styled optical fiber type flat shaped body sensor **26** is formed in the manner that the same optical fiber **2** as the one used for an optical fiber type flat shaped body sensor **1** shown in FIG. **1** is fitted to a T-shirt made from a so-called natural or synthetic fabric.

[0163] More specifically, an optical fiber **2** with 1 conductor or 4 conductors is affixed to the outer surface of a cotton made T-shirt. An optical fiber **2** is affixed in the shape of the combination of a wave (3-reciprocation and 2-tire) type and a horizontal (3-reciprocation) type as shown in FIG. **19**.

[0164] To conduct a test, conditions of respiration of a test object, a male adult who wore said garment styled fiber type flat shaped body sensor **26** were changed with 2 positions, sitting and lying using 2 garment styled optical fiber type flat shaped body sensor **26**, one with an optical fiber with 1 conductor and the other with an optical fiber with 4 conductors, thus making 4 different cases in total.

[0165] The pattern of respiration was made to be a certain one applicable to all cases, normal respiration (30 sec)→respiration halted (10 sec)→deep respiration (20 sec)→respiration halted (10 sec)→intense respiration (20 sec).

[0166] FIG. **20** is the measurement results of the time wave forms of the strength of light, stokes parameters S_1, S_2, S_3, and a polarized wave fluctuation quantity at the time of a lying position with a garment styled optical fiber type flat shaped body sensor equipped with an 4-conductor optical fiber.

[0167] Changes caused by respiration were distinctly detected with the waveforms of stokes parameters S**1**, S**2**, S**3** or a polarized wave fluctuation quantity.

[0168] Periodic changes were observed when respired. When normal respiration, deep respiration and intense respiration were compared, changes with the different velocities were also observed.

[0169] The magnitude of polarized wave fluctuations was found to be larger than that of a bed sheet (FIG. **18**), and slightly smaller than that of a quilt cover when compared with the test results in the case of being used as a bed sheet and a quilt cover with a 4-conductor and wave shaped optical fiber. Same analysis was conducted on the aforementioned other 3 cases, and it was learned that polarized wave fluctuations caused by respiration were able to be observed with any cases.

[0170] With the results in FIG. **20**, it is assumed that such movements as respiration and the like can be detected from polarized wave fluctuations with a human body fitted optical fiber type flat shaped body sensor. For example, in the case of a human body fitted optical fiber type flat shaped body sensor fitted to the chest area, it is understood that, because it can be fitted closely to the individual body shape when compared with the case of a garment styled one, polarized wave fluctuations equivalent to or better than those of FIG. **20**.

FEASIBILITY OF INDUSTRIAL USE

[0171] The present invention is mainly used for remote monitoring of patients, the cared and the like in nursing care facilities, hospitals and the like. Also, it can be widely used for monitoring living activities of animals, plants and the like other than humans. It also makes possible that patients and the like in hospitals or nursing care facilities over the wide area are intensively monitored by making use of a so-called communications network.

1. A method for monitoring living activities comprising a method for monitoring the existence of movements of human or living body activities under living circumstances while sleeping on a bed, Futon-bed, pad, or Tatami-mat, the method comprising the steps of:

disposing an optical fiber type flat shaped body sensor comprising a flat shaped body and an optical fiber fitted to or integrated with the flat shaped body so that living body activities or movements of a human being bring about chances in form of the optical fiber type flat shaped body sensor;

emitting light into the optical fiber from a light source;

producing fluctuations in a polarized wave of light propagated in the optical fiber when living body activities or movements of the human being bring about changes in form of the optical fiber type flat shaped body sensor;

detecting fluctuations in the polarized wave of light using a polarized wave fluctuations measurement apparatus; and

discriminating human activities or movements using the detected fluctuations in the polarized wave of light.

2. The method for monitoring living body activities according to claim **1**, wherein the flat shaped body is selected from the group consisting of a sheet, a bed sheet, a blanket, a mat, a pad, a Tatami-mat, a floor cover and a carpet.

3. The method for monitoring living body activities according to claim **1**, wherein periodic vibrations specific to respiration or heart pulsation are detected using a sum of a power spectrum detected by the polarized wave fluctuations measuring apparatus and by time wave forms of three stokes parameters that represent polarized wave conditions of light transformed using a Fourier Transform, respectively.

4. The method for monitoring living body activities according to claim **3**, wherein by using the polarized wave fluctuations measuring apparatus living body activities or movements of the human being are detected at high velocity and with high sensitivity so that a difference between a present value of a polarized wave condition parameter expressed by three stokes parameters, a polarized wave ellipse or a phase difference between DC/AC polarized waves and a polarized wave condition parameter found ¼ to ½ hours before the periodic vibrations specific to respiration or heart pulsation is computed as a polarized wave fluctuation quantity.

5. The method for monitoring living body activities according to claim **4**, wherein highly sensitive living activities or movements of the human being are detected so that, at a time of computing the polarized wave fluctuation quantity, the polarized wave condition parameter obtained from sampling is processed for a moving average, and the width of the moving average is made to be ¼ to ½ the periodic vibrations specific to respiration or heart pulsation thereby removing random noise in signals employed for discriminating human activities or movements.

6. The method for monitoring living body activities according to claim **1**, wherein both the existence of human activities and the type of human activities are discriminated by utilizing the fact that for body movements selected from the group consisting of tossing and turning, getting into bed and getting out of bed, polarized wave fluctuations are aperiodic and fluctuation range is wide while for respiration at rest, or heart pulsation during periods of no respiration, the fluctuation range is narrow and periodic.

7. The method for monitoring living body activities according to claim **3**, wherein when the human being intentionally kicks or knocks any given side of the flat shaped body, then signals are transmitted by the polarized wave fluctuations measuring apparatus.

8. The method for monitoring living body activities according to claim **1**, wherein a plurality of optical fiber type flat shaped body sensors or a plurality of optical fibers in blocks disposed in an optical fiber type flat shaped body sensor are monitored in sequence by one polarized wave fluctuations measuring apparatus, wherein monitoring in sequence is provided by a light source apparatus and the polarized wave fluctuations measuring apparatus connected together so as to switch and connect to the plurality of optical fiber type flat shaped body sensors or to the plurality of optical fibers in blocks.

9. The method for measuring living body activities according to claim **1**, wherein a plurality of optical fibers of the optical fiber type flat shaped body sensor or a plurality of blocks in the optical fiber type flat shaped body sensor are monitored in sequence by one polarized wave fluctuations measuring apparatus, wherein light is emitted to the plurality of optical fibers of the optical fiber type flat shaped body sensor or to the plurality of optical fibers in blocks in the optical fiber type flat shaped body sensor from a wavelength variable light source by switching optical fibers in sequence using a wavelength separation filter.

10. The method for monitoring living body activities according to claim **1**, wherein a specific block of the optical fiber is discriminated for monitoring by a plurality of filters, with which a specific wavelength is reflected, wherein the plurality of filters are incorporated at some midpoint of the optical fiber of the optical fiber type flat shaped body sensor so that, wavelength of the light source is changed.

11. The method for monitoring living body activities according to claim **1**, wherein a specific block of the optical fiber is discriminated for monitoring using a delay time of light dispersed in the optical fiber by transmitting an optical pulse from one end of the optical fiber of the optical fiber type flat shaped body sensor.

12. The method for monitoring living body activities according to claim **1**, wherein movements of the human being are monitored from a distance, wherein the optical fiber type flat shaped body sensor comprises a communication optical fiber and the optical fiber is connected to the communications optical fiber.

13. An optical fiber type flat shaped body sensor, comprising:

a flat shaped body; and

one or mole optical fibers affixed to and running throughout the flat shaped body so that shape changes of any part of an outer surface of the flat shaped body are reflected as a shape chance in form of one or more of the optical fibers.

14. The optical fiber type flat shaped body sensor according to claim **13**, wherein the sensor feels like, and is used in the same manner as, a cloth made sheet, and is deployable in bed as a cloth made sheet, wherein extremely thin optical fibers are sewed up throughout the flat shaped body, so that weight, thickness and flexibility of the optical fiber incorporated in the flat shaped body provides the sensor with essentially the same weight, thickness and flexibility as the cloth made sheet.

15. The optical fiber type flat shaped body sensor according to claim **13**, wherein the flat shaped body is selected from the group consisting of a sheet, a bed sheet, a quilt cover, a blanket, a mat, a pad, a Tatami-mat, a floor cover and a carpet.

16. The optical fiber type flat shaped body sensor according to claim **13**, wherein changes in form of the optical fiber type flat shaped body sensor reflected as the shape change in form of one or more of the optical fibers generates a fluctuation in polarized light propagated in the one or mole optical fibers, wherein sensor sensitivity brought about by polarized wave fluctuation is increased by affixing or sewing up of the one or more optical fibers with the flat shaped body so that the one or more optical fibers forms a complex linear shape, a complex wave shape or a complex loop shape.

17. The optical fiber type flat shaped body sensor according to claim **13**, wherein changes in form of the optical fiber type flat shaped body sensor reflected as the shape change in form of one or more of the optical fibers generates a fluctuation in polarized light propagated in the one or more optical fibers, wherein sensor sensitivity brought about by polarized wave fluctuation is increased due to the one or more optical fibers comprising a plurality of conductors.

18. The optical fiber type flat shaped body sensor according to claim **13**, wherein changes in form of the optical fiber type flat shaped body sensor reflected as the shape chance in form of one or more of the optical fibers generates a fluctuation in polarized light propagated in the one or more optical fibers, wherein sensor sensitivity brought about by polarized wave fluctuation is increased due to a reflection mirror placed on one side of the one or more optical fibers so that light signals are transmitted in the one or more optical fibers with to-and-from movements.

19. The optical fiber type flat shaped body sensor according to claim **13**, wherein the optical fiber type flat shaped body sensor is processed to make a cover for a Futon-bed, a quilt cover, a mat, or a sofa.

20. The optical fiber type flat shaped body sensor according to claim **19**, wherein the sensor is provided with a watertight vinyl cover.

21. A garment styled optical fiber type flat shaped body sensor comprising:

a flat shaped body, wherein the flat shaped body is a garment to be worn by a human being to be monitored; and

one or more optical fibers affixed to and running throughout the flat shaped body so that shape changes of a part of the flat shaped body are reflected as a shape change in form of one or more of the optical fibers, wherein changes in form of a part of the human body of the human being monitored are reflected as changes in form of one or more of the optical fibers, wherein the one or more optical fibers are sewed up in, or affixed to, the garment that is disposed on the body or the human being while in bed so that the human being is monitored for activity conditions.

22. A human body fitted optical fiber type flat shaped body sensor, comprising:

a flat shaped body, wherein the flat shaped body is a human body fitted pad in the shape of a stomach band, a bandage, or a sheet; and

an optical fiber affixed to and running throughout the flat shaped body so that shape changes or a part of the flat shaped body are reflected as a shape change in form of the optical fiber, wherein changes in form of any part of the human body fitted to the human body fitted pad are reflected as changes in form of the optical fiber, wherein the optical fiber is sewed up in, or affixed to, the human body fitted pad.

23. A method as recited by claim **10**, wherein the specific wavelength is reflected by optical fiber diffraction.

24. The garment styled optical fiber type flat shaped body sensor according to claim **21**, wherein the flat shaped body is a garment selected from the group consisting of pajamas, night wear, and a patient dress.

25. The garment styled optical fiber type flat shaped body sensor according to claim **21**, wherein the sensor operates to monitor the human being during a medical test.

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