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Doty

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(54) **NONMETALLIC INPUT DEVICE FOR MAGNETIC IMAGING AND OTHER MAGNETIC FIELD APPLICATIONS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 26 days.

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(51) **Int. Cl.**
G02B 6/26 (2006.01)

(52) **U.S. Cl.** **385/16**; 385/6; 385/13; 385/20

(58) **Field of Classification Search** 385/6, 385/13, 16, 18, 20, 24; 428/116
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,741,770 B1 * 5/2004 Dean et al. .... 385/16 X

OTHER PUBLICATIONS

"fORP: Fiber-Optic Response Pad", http://www.curdes.com/usbforp.htm, Current Designs, Inc., (Circa 2002), 1-4.

"fORP: Response Pads and Pointing Devices", http://www.curdes.com/handhelds.htm, Current Designs, Inc., (Circa 2002), 1-2.

"Lumina LP-400 Specifications", http://www.cedrus.com/lumina/specs.htm, (Circa 2002), 1-3.

"Lumina MRI Response Pad System", http://www.cedrus.com/lumina/index.htm, (Circa 2002), 1.

"Lumina Overview", http://www/cedrus.com/lumina/howitworks.htm, (Circa 2002), 1-2.

* cited by examiner

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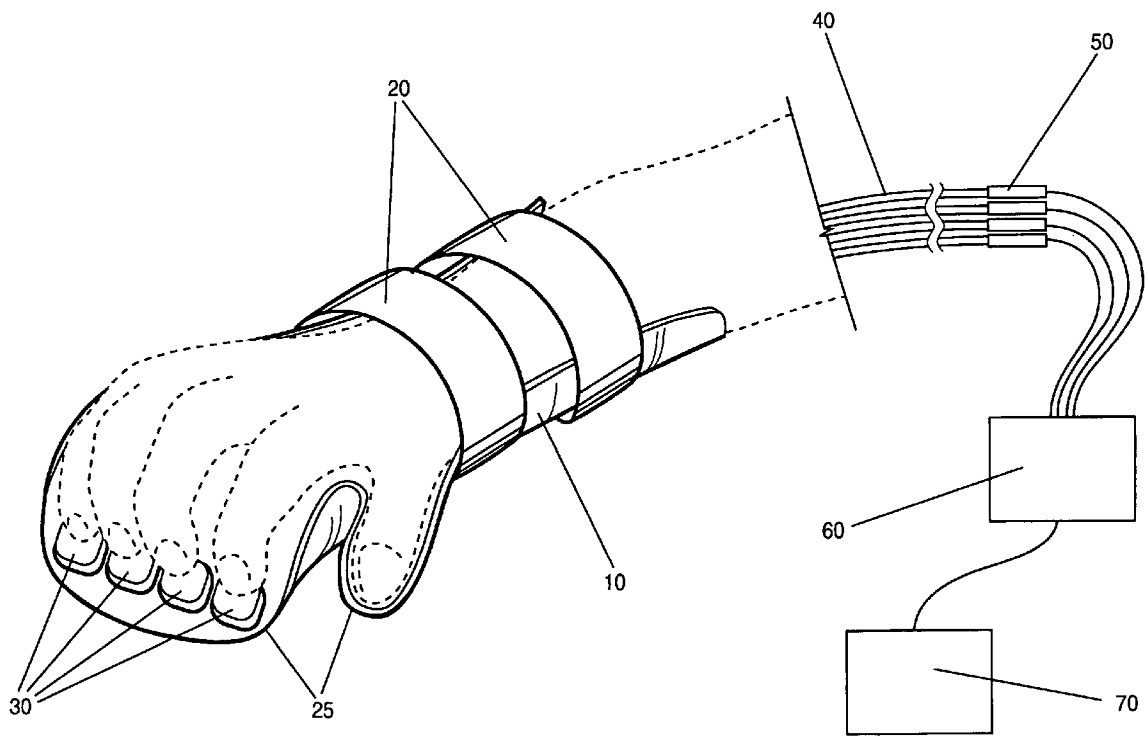
(57) **ABSTRACT**

A device and method for collecting subject responses, particularly during magnetic imaging experiments and testing using a method such as functional MRI. The device comprises a non-metallic input device which is coupled via fiber optic cables to a computer or other data collection device. One or more optical switches transmit the subject's responses. The input device keeps the subject's fingers comfortably aligned with the switches by partially immobilizing the forearm, wrist, and/or hand of the subject. Also a robust nonmetallic switch, particularly for use with the input device.

20 Claims, 2 Drawing Sheets



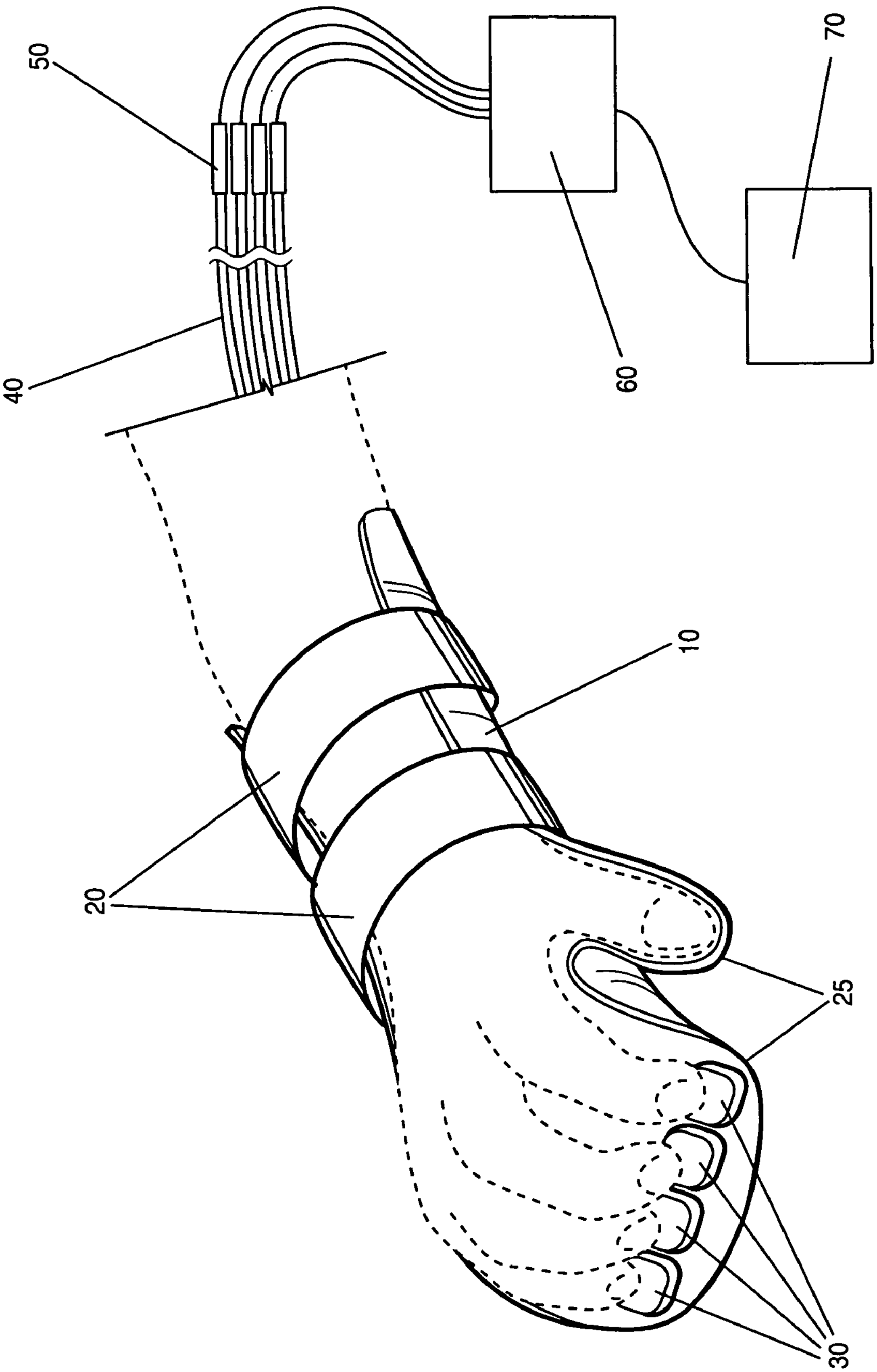


FIG-1

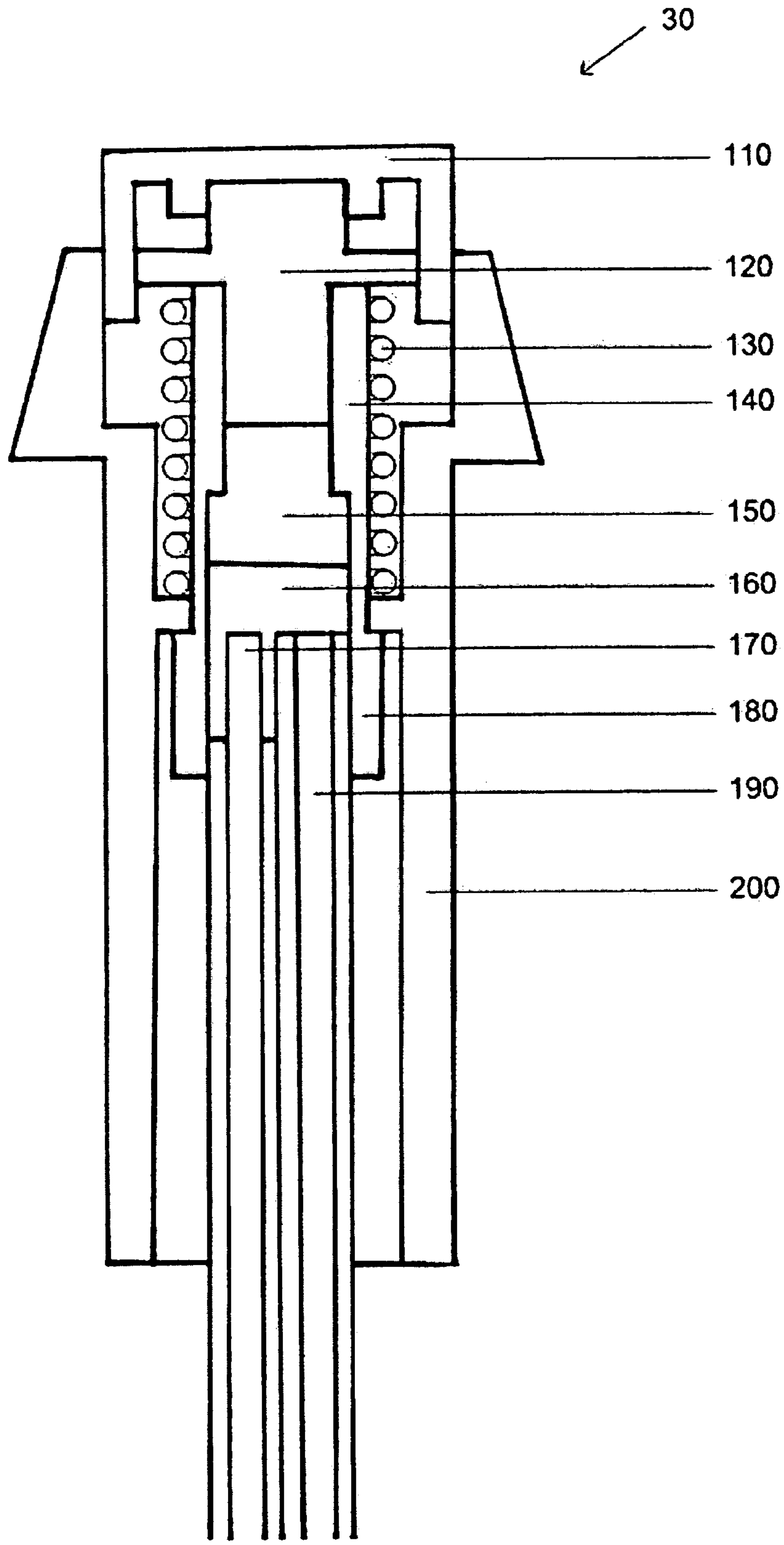


FIG. 2

NONMETALLIC INPUT DEVICE FOR MAGNETIC IMAGING AND OTHER MAGNETIC FIELD APPLICATIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention (Technical Field)

The present invention relates to a nonmetallic input device, and an optical switch therefor, for transmitting reactions from a subject being studied or tested using magnetic imaging, including but not limited to functional magnetic resonance imaging (MRI), or for other uses that require the switching and/or transmission of a signal in a magnetic field.

2. Background Art

Note that the following discussion refers to a number publications and references. Discussion of such publications herein is given for more complete background of the scientific principles and is not to be construed as an admission that such publications are prior art for patentability determination purposes.

There are a number of techniques used to image brain function in a subject individual whose reactions or responses are studied. One such technique, Functional Magnetic Resonance Imaging (fMRI) consists of using a Magnetic Resonance (MR) scanner to image a subject's brain while the subject is presented with a functional task or paradigm. The functional task may comprise auditory and/or visual stimuli. It may be necessary and/or desirable to have the subject respond and make decisions based on the stimuli that are presented to them. The experimenter receives and records subject responses, preferably using the stimulus presentation software used to present the auditory and visual stimuli. Another such technique, Magnetoencephalography (MEG), is another form of magnetic imaging similar to MRI in that they both are imaging tools that use high magnetic fields.

For such applications the subject is situated within the magnet room or magnetic field of the imaging device. Therefore, devices to collect responses from the subject must also be located within the magnetic field. Such input devices must therefore be completely nonmagnetic. It is preferable that the device is entirely nonmetallic as well. Metallic components act as antennas and thus introduce noise, which must be filtered out using, for example, radio frequency (RF) filters.

Therefore, it is preferable that nonmetallic switches, such as optical switches, are used in such input devices. All-plastic input devices which use optical switching via optical cables are manufactured by numerous companies and are known in the art. However these devices have a number of disadvantages. They have a touchpad or keypad configuration, which requires that the subject either hold the device in one hand and operate the switches with the other hand, or that the device rest on a surface and the subject's fingers rest on the switches. This is disadvantageous because for numerous magnetic imaging applications, the subject is not able to operate the device with both hands, or comfortably or stably rest his or her hand on a horizontal surface. Further, with these devices, it is easy for the subject's fingers to move from the switches, for example but not limited to sliding laterally off one or more switches. The subject must frequently reposition his or her fingers, thus interfering with the magnetic imaging data collected. Also, these prior art devices do not immobilize the subject's wrist. This permits wrist movement at any time during the experiment, resulting in motor cortex activation which may be confused with activation that is desired to be recorded. In addition, many such existing devices require electronics, such as an opto-electric converter, to be situated within the magnet room, thus inducing noise in the system and requiring costly filters. Finally, these devices typically use plastic membrane-type switches, which are prone to failure.

Thus there is a need for a nonmetallic input device and nonmetallic switch for use particularly in magnetic imaging applications, or any other application which requires manual switching or signaling in the presence of a magnetic field, which is comfortable, robust, and which prevents the movement of fingers from the switches corresponding to each finger.

SUMMARY OF THE INVENTION (DISCLOSURE OF THE INVENTION)

The present invention is of a nonmetallic optical switch comprising a manually operated switching mechanism, a nonmetallic spring, an input optical fiber cable, an output optical fiber cable, and a material configured to block light transmission from the input optical fiber cable to the output optical fiber cable when the switching mechanism is operated. The material, preferably comprising foam, more preferably closed cell foam, is preferably at least partially conformable to the end of the output optical fiber cable, and more preferably is sufficiently conformable to the end to provide a light-tight seal over the end. The material preferably blocks light from entering the output optical fiber cable, and/or preferably blocks light from exiting the input optical fiber cable. The end of the input optical fiber cable preferably comprises an exposed core, preferably wherein insulation has been stripped off the end. The switch preferably further comprises a fiber sensor, preferably which detects a change in the intensity of light transmitted through the output optical fiber cable. The fiber sensor preferably produces a signal when the intensity of light drops below a threshold value. The switch preferably comprises a processor, preferably a computer, for recording the signal.

The present invention is also of a method for blocking light, the method comprising the steps of manually engaging a switching mechanism, reversibly disposing an opaque material on an end of an optical fiber cable, at least partially blocking the light from entering the end, and detecting a change in an intensity of light being transmitted through the optical fiber cable. The method preferably further comprises the step of conforming the material to the end of the optical fiber cable, wherein the material preferably comprises foam. The method preferably further comprises the step of establishing a light intensity threshold value, and preferably further comprises the step of generating a signal when the intensity of light drops below the light intensity threshold. The method preferably further comprises the step of recording the signal.

The present invention is additionally of a nonmetallic input device for collecting responses of a subject, the device comprising a splint removably attachable to the subject, at least one manually operated optical switch aligned with at least one finger of the subject, at least one fiber sensor for detecting optical signals; and one or more fiber optic cables connecting the at least one switch and the at least one fiber sensor, wherein the splint at least partially restricts lateral movement of the at least one finger with respect to the at least one switch; and preferably wherein the splint at least partially immobilizes the wrist of the subject. The input device preferably comprises a processor, preferably a computer, for recording the subject's responses.

The present invention is further of a method of collecting responses of a subject, the method comprising the steps of at least partially restricting lateral movement of at least one finger of the subject, activating at least one nonmetallic optical switch aligned with the at least one finger, detecting a change in an optical signal, and producing a signal in response to the change. The method preferably further comprises the step of immobilizing the wrist of the subject. The method preferably further comprises the step of recording the signal.

An object of the present invention is to provide a nonmetallic input device suitable for use with magnetic imaging systems, or any magnetic field system where switching or response detection within the magnetic field is required.

An object of the present invention is to provide a robust nonmetallic optical switch for use with the input device of the present invention.

An advantage of the device of the present invention is that the subject's fingers are comfortably prevented from moving laterally away from the switches corresponding to each finger.

Another advantage of the device of the present invention is that the wrist is substantially immobilized, thus reducing motor cortex activation, thereby improving the accuracy of the experimental results.

A further advantage of the present invention is that no metal parts are required to be in the magnet room, thus greatly reducing signal noise and eliminating the need for filters.

Other objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the specification, illustrate several embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating a preferred embodiment of the invention and are not to be construed as limiting the invention. In the drawings:

FIG. **1** depicts a preferred embodiment of the present invention; and

FIG. **2** is a cross section of a preferred embodiment of the nonmetallic switch of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS (BEST MODES FOR CARRYING OUT THE INVENTION)

The present invention is a nonmetallic input device for use in magnetic imaging applications, or any magnetic field system where switching or response detection within the magnetic field is required, which keeps a subject's fingers aligned with the switches of the device. The present invention is further a robust nonmetallic optical switch for use with the input device.

As used throughout the specification and claims, "attach" means any method for removably attaching two objects, including but not limited to using a strap, tie, belt, adhesive, adhesive pad, adhesive patch, cuff, clamp, and the like.

As used throughout the specification and claims, "splint" means any device for at least partially immobilizing, or at least partially restricting the movement of, a portion of the body, including but not limited to cast, board, bracer, truss, wrap, and the like.

As used throughout the specification and claims, "opaque" means impenetrable by light at an operational frequency or frequencies of light being utilized by a device comprising the opaque element.

As used throughout the specification and claims, a "spring" refers to any device that operates according to Hooke's law, including coil springs, flat flexures, and like devices. Hooke's law is that for small Δx,

$$F_x = -k(x - x_0) = -k\Delta x,$$

where the empirically determined constant k is known as the force constant of the spring, x is the coordinate of the free end of the spring, x_0 is the value of x when the spring is not stretched or compressed from its equilibrium condition, and F_x is the force applied on or exerted by the spring.

Referring to FIG. **1**, a preferred embodiment of the present invention comprises splint **10**. Splint **10** preferably comprises a thermoplastic material and may optionally be modifiable or replaceable for a custom fit. Splint **10** is preferably designed to at least partially immobilize one or more of the subject's forearm, wrist, hand, and fingers. One object of the splint is to at least partially restrict lateral movement of the fingers, whether by restricting movement of individual fingers or by preventing movement of the hand, wrist, and/or forearm. It is preferred that finger lift action is not restrained by the device; since it is typically desirable to measure motor cortex activation directly related to finger movement, a higher finger lift will produce more such desired activation. A preferred splint for use with the present invention is the Preformed Resting Pan Mitt Splint available from Sammons Preston Rolyan; however, any splint or cast may be used. Splint **10** is preferably formed so that all of the subject's fingers, including the thumb, can rest comfortably in the curved position. Splint **10** may be formed for the left or right hands.

Splint **10** is preferably formed to accept the hand, wrist, at least a portion of the forearm, and at least one finger of the subject, and is removably attached thereto, preferably by one or more straps **20**. Straps **20** are preferably fastened by a hook and loop-type fastener. Additional straps may optionally be used across the subject's hand, and even across one or more fingers. Optionally, splint **10** may be attached to the subject as desired via adhesive pads. Splint **10** may optionally comprise two halves which separate to insert the subject's arm and then which close to form a cast-type device which substantially encloses the entirety of the subject's forearm, wrist, and optionally the subject's hand and/or fingers. Although splint **10** depicted in FIG. **1** comprises two projections **25**, one to receive the subject's thumb and a wide one to receive the subject's other four fingers, splint **10** may alternatively comprise separate projections for each finger, or the projections may instead comprise one or more dividers to separate the fingers.

One or more nonmetallic pushbutton optical switches **30** are preferably attached to splint **10** in positions under each finger, including the thumb. The fingers then operate the switches, thereby providing a response during an experiment or test. Because switches **30** are preferably located under each finger, and because splint **10** at least partially restricts the fingers from moving laterally away from each button **30**, the fingers of the subject are always located directly above each corresponding switch. For the purposes herein, lateral movement means movement of a finger which is in a direction substantially parallel to the plane of the surface of splint **10** at the button location. One switch for each finger is preferably provided; however, multiple switches for each finger may be employed. Alternatively, not every finger may have a corresponding switch. Each switch **30** preferably comprises a threaded housing and is preferably secured to splint **10** by being screwed into a hole drilled into splint **10**. Although pushbutton switches are preferred, any type of switch may be utilized.

Each switch **30** is preferably connected via two nonmetallic fiber optic cables **40** to a fiber sensor **50**. Cables **40** are preferably long enough so that fiber sensors **50** may be located outside the magnet room. Cable **40** preferably has an outer diameter of 2.2 mm with a 1.0 mm diameter solid plastic core; however, any fiber cable may be used. Fiber sensor **50** is a device which emits and senses light. The FX-301 Digital Fiber Sensor, available from Sunx Sensors USA, is preferably used for fiber sensor **50**.

FIG. **2** depicts a cross-section of a preferred embodiment of switch **30**. Housing **200** of switch **30** is preferably substantially plastic, nylon, or otherwise nonmetallic; any commonly available pushbutton-based switch may be used. Alternatively, a switch based on a different switching mechanism, including but not limited to a rocker switch or a toggle switch, may be utilized. Typical pushbutton switches with plastic housings comprise metallic contacts and springs. Thus in the switch of the present invention the metallic contacts and other metallic parts are preferably removed and the metallic spring is preferably replaced with a nonmetallic, preferably plastic, spring. A preferred plastic spring is part number J001 available from Kato Spring Inc. The spring is preferably chosen not only to fit into the housing **200** of switch **30** but also for an optimal value of the spring tension. Housing **200** may require further modification to receive input cable **170** and output cable **190**, both of which preferably comprise fiber optic cables.

Operation of the preferred embodiment of the invention depicted in FIGS. **1** and **2** is as follows. Fiber sensor **50** sends light through input cable **170** to switch **30**. Normally spring **130** holds pushbutton **110** in the open position via linkage **120**. Guide **140** preferably comprises one or more protrusions **180**, optionally configured as a ring having a larger diameter than the top portion of guide **140**, which contact a portion of housing **200**, preventing pushbutton **110** from popping out of housing **200**. However, other means for preventing the pushbutton from traveling too far may optionally be used, including but not limited to a nonmetallic locking ring. In the open position, light enters switch **30** through input cable **170** and illuminates chamber **160**. Insulation at the end of input cable **170** is preferably stripped off to expose the fiber core, thereby increasing the intensity of the light entering chamber **160**. Light from chamber **160** travels through output cable **190** out of switch **30** to fiber sensor **50**.

When pushbutton **110** is pressed, foam **150** is pushed against the end of output cable **190**, thereby blocking the light from entering output cable **190** and thus from reaching fiber sensor **50**. The amount of light blocked is preferably sufficient to drop the light intensity detected by fiber sensor **50** below a predetermined threshold level, as discussed below. Foam **150** preferably at least partially conforms to the end of output cable **190**, and is preferably sufficiently conformable to provide a substantially light-tight seal over end of output cable **190**. Foam **150** preferably comprises a dark-colored high memory closed cell foam. The preferable high memory property of foam **150** means that foam **150** quickly returns to its original shape once pushbutton **110** is released. Any nonmetallic material with similar conformability and/or compressibility characteristics may be substituted for foam **150**. Alternatively, any nonmetallic opaque material, including nonconformable or noncompressible materials, may be used in place of foam **150**.

In the preferred embodiment, when pushbutton **110** is pressed, foam **150** also partially blocks light from exiting input cable **170** by covering, and preferably at least partially conforming to, the end of input cable **170**; however, the stripped fiber core of input cable **170** is left partially exposed. Alternatively, foam **150** and input cable **170** may optionally be configured so that the light is completely blocked from exiting input cable **170** instead of, or in addition to, blocking the light from entering output cable **190**. In this alternative, a highly compressible foam may be utilized so that it both covers the end of, and substantially completely surrounds the stripped fiber core portion of, input cable **170** when pushbutton **110** is pressed.

Thus, unlike a typical switch, in this embodiment the optical "circuit" is closed (i.e. light flows) when switch **30** is open. Depressing pushbutton **110** blocks the light, thereby opening the optical circuit. A switch with momentary ON action is preferably used, which in this embodiment means that the light is blocked for as long as the subject holds the pushbutton down. As soon as the subject releases the pushbutton, the optical signal is restored.

Fiber sensor **50** outputs an electrical signal depending on the light intensity it receives. For a preferred embodiment of the present invention, the output electrical signal changes once the intensity of the light received by fiber sensor **50** drops below a threshold value, and changes back again once the intensity increases back above the threshold value. The threshold value is preferably set to be approximately halfway between the light intensity detected by fiber sensor **50** when switch **30** is open (i.e. when pushbutton **110** is released) and the light intensity detected when switch **30** is closed (i.e. when pushbutton **110** is pressed). The electrical signal generated by fiber sensor **50** is preferably passed to interface box **60** and is then passed to a computer or other processor **70** by means known in the art, where the response of the subject is preferably recorded, preferably by recording the time that processor **70** received the electrical signal. Interface box **60** preferably scales and/or otherwise modifies said signals by means known in the art, in accordance with the input requirements of computer or other processor **70**.

Although the invention has been described in detail with particular reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover all such modifications and equivalents. The entire disclosures of all patents and publications cited above are hereby incorporated by reference.

What is claimed is:

1. A nonmetallic optical switch comprising:

a manually operated switching mechanism;

a nonmetallic spring;

an input optical fiber cable;

an output optical fiber cable; and

a material configured to block light transmission from said input optical fiber cable to said output optical fiber cable when said switching mechanism is operated.

2. The switch of claim **1** further comprising a fiber sensor.

3. The switch of claim **2** wherein said fiber sensor detects a change in an intensity of light transmitted through said output optical fiber cable.

4. The switch of claim **3** wherein said fiber sensor produces a signal when said intensity of light drops below a threshold value.

5. The switch of claim **4** further comprising a processor for recording said signal.

6. The switch of claim **5** wherein said processor comprises a computer.

7. The switch of claim **1** wherein said material is at least partially conformable to an end of said output optical fiber cable.

8. The switch of claim **7** wherein said material comprises foam.

9. The switch of claim **8** wherein said foam comprises closed cell foam.

10. The switch of claim **7** wherein said material is sufficiently conformable to said end to provide a light-tight seal over said end.

11. The switch of claim **1** wherein an end of said input optical fiber cable comprises an exposed core.

12. The switch of claim **11** wherein insulation has been stripped off said end.

13. The switch of claim **1** wherein said material blocks light from entering said output optical fiber cable.

14. The switch of claim **1** wherein said material blocks light from exiting said input optical fiber cable.

15. A method for blocking light, the method comprising the steps of:

manually engaging a switching mechanism;

reversibly disposing an opaque material on an end of an optical fiber cable;

at least partially blocking the light from entering the end; and

detecting a change in an intensity of light being transmitted through the optical fiber cable.

16. The method of claim **15** further comprising the step of establishing a light intensity threshold value.

17. The method of claim **16** further comprising the step of generating a signal when the intensity of light drops below the light intensity threshold.

18. The method of claim **17** further comprising the step of recording the signal.

19. The method of claim **15** further comprising the step of conforming the material to the end of the optical fiber cable.

20. The method of claim **19** wherein the material comprises foam.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,039,266 B1
APPLICATION NO. : 10/933644
DATED : May 2, 2006
INVENTOR(S) : Michael Doty

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 1 Line 2 - 5

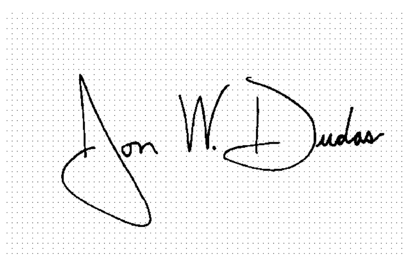
the TITLE and before the BACKGROUND OF THE INVENTION paragraph:

GOVERNMENT RIGHTS

The U.S. Government has a paid-up license in this invention and the right in limited circumstances to require the patent owner to license others on reasonable terms as provided for by terms of Contract No. DE-FG02-99ER62764 awarded by the Department of Energy.

Signed and Sealed this

Fifteenth Day of August, 2006



JON W. DUDAS

Director of the United States Patent and Trademark Office