

(19) **DANMARK**

(10) **DK/EP 3926347 T3**



(12) **Oversættelse af
europæisk patentskrift**

Patent- og
Varemærkestyrelsen

-
- (51) Int.Cl.: **G 01 R 15/24 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2024-11-11**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2024-08-21**
- (86) Europæisk ansøgning nr.: **20382515.3**
- (86) Europæisk indleveringsdag: **2020-06-15**
- (87) Den europæiske ansøgnings publiceringsdag: **2021-12-22**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
- (73) Patenthaver: **Lumiker Aplicaciones Tecnologicas S.L., Parque Tecnológico de Bizkaia , Astondo Bidea, Edif. 612, 48160 Derio, Spanien**
- (72) Opfinder: **BENGOECHEA DE LA LLERA, Francisco Javier, , 48160 DERIO, Spanien**
BENGOECHEA GONZALEZ, David, , 48160 DERIO, Spanien
- (74) Fuldmægtig i Danmark: **Dennemeyer & Associates S.A, P.O. Box 700425, DE-81304 Munich, Tyskland**
- (54) Benævnelse: **OPTISK FIBERVIKLING TIL MÅLING AF STRØMMEN, DER CIRKULERER GENNEM EN LEDER OG STRØMMÅLEUDSTYR BASERET PÅ OPTISK FIBER**
- (56) Fremdragne publikationer:
EP-A1- 0 108 012
DE-A1- 3 115 433
GB-A- 2 190 744
JP-A- 2010 266 262

DESCRIPTION

Description

TECHNICAL FIELD

[0001] The present invention relates to an optical fiber winding and optical fiber-based current measuring equipment for measuring the current circulating through a conductor.

PRIOR ART

[0002] Measuring equipment based on optical fiber for measuring the current circulating through a conductor is known. Said equipment operates according to the Faraday effect, i.e., the magnetic field generated by the current circulating through the conductor causes a rotation in the polarization of the light circulating through the optical fiber winding arranged around the conductor. The operation of said measuring equipment consists of emitting light through optical fiber to the optical fiber winding in which the characteristics of the light are modified depending on the current circulating through the conductor, and analyzing the rotation caused in the polarization of light so as to determine the magnitude of the current circulating through the conductor.

[0003] Theoretically speaking, the polarization of light of a perfectly circular single-mode optical fiber in which said light is propagated in a longitudinal propagation direction remains unchanged if it receives no external actions of any type. That is, theoretically speaking, the polarization of light at the inlet of the optical fiber would be identical to the polarization of light at the outlet of the optical fiber. Therefore, in the event of the action of a magnetic field generated by the current circulating through a conductor, the rotation in the polarization of light would only be due to the current circulating through the conductor.

[0004] However, in the real world, the polarization of light within an optical fiber presents a fairly random behavior which hinders measuring current. There are various factors that can be attributed to the optical fiber itself, causing the polarization of light in the longitudinal propagation direction to be changed. For example, the core of the optical fiber is not perfectly circular; when the optical fiber is arranged around the conductor mechanical stresses which are not homogeneous along its longitudinal extension are created; optical fiber is an element with an elastic behavior which can be twisted and bent. All of this causes changes in the polarization of light.

[0005] To correct these problems relative to the random behavior of the polarization of light within the optical fiber, special optical fiber sensors or specific measurement methods minimizing the impact generated by said randomness are known to be used. For example, GB2190744A shows an apparatus for sensing magnetic fields by means of the Faraday effect which comprises two spun highly birefringent fibers which have a diminished birefringence produced by spinning during the drawing process. The two spun highly birefringent fibers are arranged in a helical manner around a central support core.

[0006] EP0108012A1 shows an apparatus for measuring electric intensity using the Faraday effect. DE3115433A1 shows a measuring device for magneto-optical current measurement. JP2010266262A shows an optical fiber structure that reduces complexity in the work for winding an optical fiber, and also shows a method of mounting the same.

[0007] EP3104183A1 or EP3598149A1, both belonging to the same applicant as the present invention, disclose optical fiber-based current measuring equipment for measuring the current circulating through a conductor, comprising an interrogator with light-emitting means and light-receiving means, a sensing portion close to the conductor, and an optical fiber transmission means arranged between the interrogator and the sensing portion.

DISCLOSURE OF THE INVENTION

[0008] The object of the invention is to provide an optical fiber winding and optical fiber-based current measuring equipment for measuring the current circulating through a conductor, as defined in the claims.

[0009] A first aspect of the invention relates to an optical fiber winding for measuring the current circulating through a conductor, comprising:

- a central support core extending in a longitudinal direction,
- a first optical fiber cable arranged around the central support core, and
- a second optical fiber cable arranged around the central support core.

[0010] The optical fiber cables extend in a helical manner around the central support core. The optical fiber cables are standard single-mode optical fiber cables. The first optical fiber cable is twisted about its longitudinal axis in a first twist direction, and the second optical fiber cable is twisted about its longitudinal axis in a second twist direction, the first twist direction being opposite the second twist direction, so that, since the optical fiber cables are twisted in opposite directions, the efforts that said optical fiber cables make to recover their shape are counteracted.

[0011] A second aspect of the invention relates to optical fiber-based current measuring

equipment for measuring the current circulating through a conductor, comprising:

- an interrogator with light-emitting means and light-receiving means,
- a sensing portion close to the conductor, and
- an optical fiber transmission means arranged between the interrogator and the sensing portion, wherein the sensing portion comprises an optical fiber winding as disclosed above.

[0012] The twisting of the optical fiber allows single-mode optical fiber cables to be used for measuring the current circulating through the conductor. The twisting of the optical fiber is one of the factors changing the polarity of the light circulating through the optical fiber, such that by applying twisting on the longitudinal axis of the fiber, the remaining factors changing the polarity of light can be considered negligible with respect to the twisting factor. Therefore, by introducing controlled twisting in the optical fiber allows for the changes in the polarization of light basically being due to the magnetic field caused by the current circulating through the conductor, where the other factors can be considered irrelevant for the measurement of the current.

[0013] However, optical fiber is an elastic element which tends to recover its original shape when twisting is no longer applied. According to the invention, the two optical fiber cables twisted in opposite directions and arranged around the central support core allow obtaining a stable mechanical assembly which can be readily wound around the conductor the current of which is to be measured. The natural tendency of optical fiber cables is to return to their natural position, but since the cables are twisted in opposite directions, they will make efforts to recover their shape which will be counteracted.

[0014] A winding which is free of mechanical stresses and can be used as an optical fiber assembly for measuring the current of a conductor is thereby obtained. By means of a winding or wire drawing machine, the optical fiber winding can be arranged around the conductor, with the optical fibers of the winding remaining twisted around the central support core, without loops or bends arising which hinder the placement of the winding on the conductor.

[0015] These and other advantages and features of the invention will become apparent in view of the figures and detailed description of the invention.

DESCRIPTION OF THE DRAWINGS

[0016]

Figure 1 shows a first embodiment of an optical fiber winding for measuring the current circulating through a conductor.

Figure 2 shows a second embodiment of an optical fiber winding for measuring the current circulating through a conductor.

Figure 3 shows a third embodiment of an optical fiber winding for measuring the current circulating through a conductor.

Figure 4 shows a fourth embodiment of an optical fiber winding for measuring the current circulating through a conductor.

Figure 5 shows optical fiber-based current measuring equipment for measuring the current circulating through a conductor.

DETAILED DISCLOSURE OF THE INVENTION

[0017] The invention relates to an optical fiber winding 100 arranged around a conductor 5 for measuring the current I circulating through the conductor 5. The optical fiber winding 100 operates according to the Faraday effect. The magnetic field generated by the current I circulating through the conductor 5 causes a rotation in the polarization of the light circulating through the optical fiber winding 100 arranged around the conductor 5.

[0018] As shown in the embodiments of Figures 1 to 4, the optical fiber winding 100 comprises a central support core 110 extending in a longitudinal direction Z , a first optical fiber cable 120 arranged around the central support core 110, and a second optical fiber cable 130 arranged around the central support core 110.

[0019] The optical fiber cables 120 and 130 extend in a helical manner around the central support core 110 in the longitudinal direction Z . The first optical fiber cable 120 is twisted about its longitudinal axis $Z1$ in a first twist direction $T1$, and the second optical fiber cable 130 is twisted about its longitudinal axis $Z2$ in a second twist direction $T2$, the first twist direction $T1$ being opposite the second twist direction $T2$.

[0020] Twisting is understood as the optical fiber cables 120 and 130 being rotated about their longitudinal axes a certain number of turns.

[0021] The material with which the optical fiber cables are made has an elastic behavior, such that when a force is applied on the cable, the shape of the cable is modified, but when is removed said force, the elastic behavior of the cable tends to return it to its natural position. The configuration of the optical fiber winding 100 of the invention solves that problem. The central support core 110 keeps the optical fiber cables 120 and 130 extended in the longitudinal direction Z , impeding the natural tendency of the fiber to go back to its natural position. Furthermore, since the cables 120 and 130 are twisted in opposite directions, they make efforts to recover their shape that are counteracted. All this allows a mechanical stability

of the optical fiber winding 100 without the need to apply external forces to maintain said stability.

[0022] For example, to maintain the twisting of the optical fiber cables 120 and 130, a force can be applied at each end of the cable and in the opposite direction, i.e., the optical fiber cables 120 and 130 can be longitudinally stressed from their ends to keep them twisted. However, applying that longitudinal tension causes the optical fiber cable to acquire an elliptical instead of circular shape, i.e., linear birefringence increases, which causes the measurement capacity to be reduced. The previously described arrangement of the winding 100 allows maintaining the twisting of the cables 120 and 130 without having to apply longitudinal tension in the cables.

[0023] Figure 5 shows an example of optical fiber-based current measuring equipment for measuring the current circulating through a conductor 5. The equipment comprises an interrogator 1 with light-emitting means 2 and light-receiving means 3, a sensing portion 4 close to the conductor 5, and optical fiber transmission means 6 arranged between the interrogator 1 and the sensing portion 4. The sensing portion 4 comprises an optical fiber winding 100 such as the one previously described, which is arranged around the conductor 5 for measuring the current I circulating through the conductor 5.

[0024] The operation of the measuring equipment consists of emitting light through the optical fiber transmission means 6 to the optical fiber winding 100 in which the features of the light are modified depending on the current I circulating through the conductor 5, and analyzing the rotation caused in the polarization of the light so as to determine the magnitude of the current I circulating through the conductor 5.

[0025] Pulses of light are sent from the light-emitting means 2 of the interrogator 1 to the optical fiber winding 100 of the sensing portion 4 through the optical fiber transmission means 6. The pulses are reflected in reflection means 7, such as a Faraday mirror, or a normal mirror, and return through the optical fiber winding 100, being directed towards the light-receiving means 3 of the interrogator 1 through the optical fiber transmission means 6.

[0026] The interrogator 1 is located away from the sensing portion 4 for measuring the current I remotely, and the optical fiber transmission means 6 allow connecting the interrogator 1 with the sensing portion 4 at large distances.

[0027] Figure 5 illustrates the optical fiber winding 100 arranged in a helical manner around the conductor 5. Alternatively, the optical fiber winding 100 can be arranged on an optical fiber reel. The winding 100 is therefore not arranged in a helical manner on the conductor 5, but rather the winding 100 is wound up a certain number of turns forming a loop inside the reel, and the conductor 5 is passed through the center of said reel. In that configuration, the reel is arranged transversely with respect to the longitudinal direction in which the conductor extends.

[0028] Figures 1 and 2 show first and second embodiments of the optical fiber winding 100.

The first optical fiber cable 120 extends in a helical manner around the central support core 110 according to a first rotation direction R1, and the second optical fiber cable 130 extends in a helical manner around the central support core 110 according to a second rotation direction R2, the first rotation direction R1 being opposite the second rotation direction R2, such that the optical fiber cables 120,130 are interlaced with one another around the central support core 110. Therefore, every time the cables 120 and 130 are interlaced, a contact area is created between both which favors the cables maintaining the twisting and their stability on the core central 110.

[0029] In the first embodiment of Figure 1, the first twist direction T1 of the first cable 120 is counterclockwise, the first rotation direction R1 of the first cable 120 is counterclockwise, the second twist direction T2 of the second cable 130 is clockwise, and the second rotation direction R2 of the second cable 130 is clockwise.

[0030] In the second embodiment of Figure 2, the first twist direction T1 of the first cable 120 is clockwise, the first rotation direction R1 of the first cable 120 is counterclockwise, the second twist direction T2 of the second cable 130 is counterclockwise, and the second rotation direction R2 of the second cable 130 is clockwise.

[0031] Figures 3 and 4 show third and fourth embodiments of the optical fiber winding 100. The first optical fiber cable 120 extends in a helical manner around the central support core 110 according to a first rotation direction R1, and the second optical fiber cable 130 extends in a helical manner around the central support core 110 according to a second rotation direction R2, the first rotation direction R1 being the same as the second rotation direction R2, and the optical fiber cables 120 and 130 being in contact with one another along their entire longitudinal extension around the central support core 110. Unlike the embodiments of Figure 1 and 2, in this case the cables 120 and 130 are not interlaced with one another, such that retaining points between them are not created; however, the cables 120 and 130 are at all times in contact with the central support core 110 and with one another.

[0032] In the third embodiment of Figure 3, the first twist direction T1 of the first cable 120 is counterclockwise, the second twist direction T2 of the second cable 130 is clockwise, and the first rotation direction R1 of the first cable 120 and the second rotation direction R2 of the second cable 130 are counterclockwise.

[0033] In the fourth embodiment of Figure 4, the first twist direction T1 of the first cable 120 is clockwise, the second twist direction T2 of the second cable 130 is counterclockwise, and the first rotation direction R1 of the first cable 120 and the second rotation direction R2 of the second cable 130 are clockwise.

[0034] Preferably, the first optical fiber cable 120 is twisted about its longitudinal axis Z1 a first number of turns, and the second optical fiber cable 130 is twisted about its longitudinal axis Z2 a second number of turns, the first and the second number of turns being the same. The twisting of both cables is therefore the same, and the behavior of the polarization of light in

both cables is therefore similar. This feature allows applying methods for measuring current in which it is necessary for both cables to emit optical signals in order to carry out the measurement.

[0035] Preferably, the optical fiber cables 120 and 130 are twisted

$$12 \times 2 \pi \frac{\text{rad}}{\text{m}}$$

, i.e., the cables are twisted 12 certain turns for each meter of cable.

[0036] The central support core 110 can be a mechanical element, such as a metal or plastic cable. Alternatively, the central support core 110 is made up of one or more optical fiber cables. This arrangement allows emitting an additional number of optical signals which can be used for applying different methods for measuring the current I circulating through the conductor 5.

[0037] The optical fiber cables 120 and 130 are standard single-mode optical fiber cables of the type normally used in the telecommunication sector. The twisting of the optical fiber cables 120 and 130 allows being able to use single-mode optical fiber cables to perform the measurement of the current of the conductor 5. Therefore, by using standard optical fiber cables a low-cost optical fiber winding 100 is obtained to perform current measurements, which is particularly relevant when the current in long cables for carrying electrical energy is to be measured. For example, the optical fiber winding 100 may be 100 meters long.

[0038] A single-mode optical fiber cable generally comprises a core, a cladding surrounding the core, a buffer surrounding the cladding, and a jacket surrounding the buffer. The core is the physical component that carries light and is generally made of glass fiber, the cladding protects the core and allows the propagation of the light. The buffer and the jacket are elements generally made of rigid plastic which provide protection and stiffness to the optical fiber cable.

[0039] As explained above, the polarization of light within an optical fiber presents a fairly random behavior which hinders measuring current. If an optical fiber is analyzed, from the point of view of propagation thereof, for purposes of polarization, and without contemplating the presence of magnetic fields due to the action exerted by an electrical conductor, the following behavior matrix is obtained:

$$\begin{bmatrix} E_{xo} \\ E_{yo} \end{bmatrix} = \begin{bmatrix} \cos(\sigma l) + j \frac{\delta_l}{2\sigma} \sin(\sigma l) & \frac{\left(\psi + \frac{\delta_c}{2}\right)}{\sigma} \sin(\sigma l) \\ -\frac{\left(\psi + \frac{\delta_c}{2}\right)}{\sigma} \sin(\sigma l) & \cos(\sigma l) - j \frac{\delta_l}{2\sigma} \sin(\sigma l) \end{bmatrix} \begin{bmatrix} E_{xi} \\ E_{yi} \end{bmatrix}$$

wherein:

$$\begin{bmatrix} E_{xo} \\ E_{yo} \end{bmatrix}$$

is the electric field at the outlet of the optical fiber.

$$\begin{bmatrix} E_{xi} \\ E_{yi} \end{bmatrix}$$

is the electric field at the inlet of the optical fiber.

δ_l is the linear birefringence of the optical fiber in rad/m.

δ_c is the circular birefringence of the optical fiber in rad/m.

ψ is the twisting of the optical fiber in rad/m.

l is the length of the optical fiber in m.

$$\sigma = \sqrt{\left(\frac{\delta_l}{2}\right)^2 + \left(\psi + \frac{\delta_c}{2}\right)^2}$$

[0040] In the presence of a magnetic field due to the action exerted by an electrical conductor, the behavior matrix would be:

$$\begin{bmatrix} E_{xo} \\ E_{yo} \end{bmatrix} = \begin{bmatrix} \cos(\sigma l) + j \frac{\delta_l}{2\sigma} \sin(\sigma l) & \frac{\left(\psi + \phi + \frac{\delta_c}{2}\right)}{\sigma} \sin(\sigma l) \\ -\frac{\left(\psi + \phi + \frac{\delta_c}{2}\right)}{\sigma} \sin(\sigma l) & \cos(\sigma l) - j \frac{\delta_l}{2\sigma} \sin(\sigma l) \end{bmatrix} \begin{bmatrix} E_{xi} \\ E_{yi} \end{bmatrix}$$

wherein $\phi = VBl$

ϕ is the angle of rotation of the polarization of light in radians.

V is the Verdet constant of the optical fiber.

B is the density of the magnetic field.

l is the length of the optical fiber in m.

[0041] In the behavior matrix of an optical fiber with respect to polarization, it can be observed that if sufficient twisting is applied to the fiber, that term twisting ψ becomes dominant, such that the polarization matrix is simplified:

$$\begin{bmatrix} E_{xo} \\ E_{yo} \end{bmatrix} = \begin{bmatrix} \cos(\sigma l) & \sin(\sigma l) \\ -\sin(\sigma l) & \cos(\sigma l) \end{bmatrix} \begin{bmatrix} E_{xi} \\ E_{yi} \end{bmatrix}$$

[0042] The change in circular birefringence providing twisting to the fiber, which is about -0.075 of the amount of twisting performed, is disregarded.

[0043] In the presence of a magnetic field, the following holds:

$$\sigma \approx (\psi + \phi)$$

[0044] Given that the twisting may be unstable once certain levels of magnitude are reached, the light is required to pass through the turns of the winding 100, to be reflected in the mirror 7 and to go back through said turns of the winding 100, such that the effect of mechanical twisting is cancelled out, and given that the effect of the magnetic field is not symmetrical, the magnetic field measurement is doubled.

[0045] In this manner and by placing the mirror 7 at the end final of the optical fiber winding 100 (for example, a Faraday mirror, or a normal mirror, or another reflective element), the polarization matrix would be: This is the polarization matrix using a Faraday mirror:

$$\begin{bmatrix} E_{xo} \\ E_{yo} \end{bmatrix} = \begin{bmatrix} -\sin(2\phi) & \cos(2\phi) \\ \cos(2\phi) & \sin(2\phi) \end{bmatrix} \begin{bmatrix} E_{xi} \\ E_{yi} \end{bmatrix}$$

[0046] It can therefore be observed that with the fiber twisted, the change polarization, is due only to the presence of the magnetic field.

[0047] According to the foregoing, on one hand, the invention proposes twisting the optical fiber cables 120 and 130 to preferably be able to use standard single-mode optical fiber cables for measuring current. On the other hand, the manner in which the optical fiber winding 100 is performed allows maintaining the twisting of the optical fiber cables 120 and 130 without the need to use external forces or elements.

REFERENCES CITED IN THE DESCRIPTION

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- [GB2190744A \[0005\]](#)
- [EP0108012A1 \[0006\]](#)
- [DE3115433A1 \[0006\]](#)
- [JP2010266262A \[0006\]](#)

- EP3104183A1 [0007]
- EP3598149A1 [0007]

OPTISK FIBERVIKLING TIL MÅLING AF STRØMMEN, DER CIRKULERER GENNEM EN LEDER OG STRØMMÅLEUDSTYR BASERET PÅ OPTISK FIBER

PATENTKRAV

1. Optisk fibervikling til måling af strømmen, der cirkulerer gennem en leder, der omfatter:
 - en central støttekerne (110), der strækker sig i længderetningen (Z),
 - et første optisk fiberkabel (120) anbragt omkring den centrale støttekerne (110),og
 - et andet optisk fiberkabel (130) anbragt omkring den centrale støttekerne (110), hvor de optiske fiberkabler (120, 130) strækker sig på en spiralformet måde omkring den centrale støttekerne (110), **karakteriseret ved, at** de optiske fiberkabler (120, 130) er standard single-mode optiske fiberkabler, og det første optiske fiberkabel (120) er snoet om sin længdeakse (Z1) i en første snoningsretning (T1), og det andet optiske fiberkabel (130) er snoet om sin længdeakse (Z2) i en anden snoningsretning (T2), og den første snoningsretning (T1) er modsat den anden snoningsretning (T2), således at fordi de optiske fiberkabler er (120, 130) er snoet i modsatte retninger, modvirkes den kraft, som nævnte optiske fiberkabler (120, 130) udøver for at genvinde deres form.
2. Vikling i henhold til krav 1, hvor det første optiske fiberkabel (120) strækker sig på en spiralformet måde om den centrale støttekerne (110) i henhold til en første rotationsretning (R1), og det andet optiske fiberkabel (130) strækker sig på en spiralformet måde om den centrale støttekerne (110) i henhold til en anden rotationsretning (R2), og hvor den første rotationsretning (R1) er modsat den anden rotationsretning (R2), således at de optiske fiberkabler (120, 130) er sammenflettet med hinanden omkring den centrale støttekerne (110).
3. Vikling i henhold til krav 2, hvor den første snoningsretning (T1) af det første kabel (120) er mod uret, og den første rotationsretning (R1) af det første kabel (120) mod uret, den anden snoningsretning (T2) af det andet kabel (130) er med uret, og den anden rotationsretning (R2) af det andet kabel (130) er med uret.
4. Vikling i henhold til krav 2, hvor den første snoningsretning (T1) af det første kabel (120) er med uret, og den første rotationsretning (R1) af det første kabel (120) er mod

uret, og den anden snoningsretning (T2) af det andet kabel (130) er mod uret, og den anden rotationsretning (R2) af det andet kabel (130) er med uret.

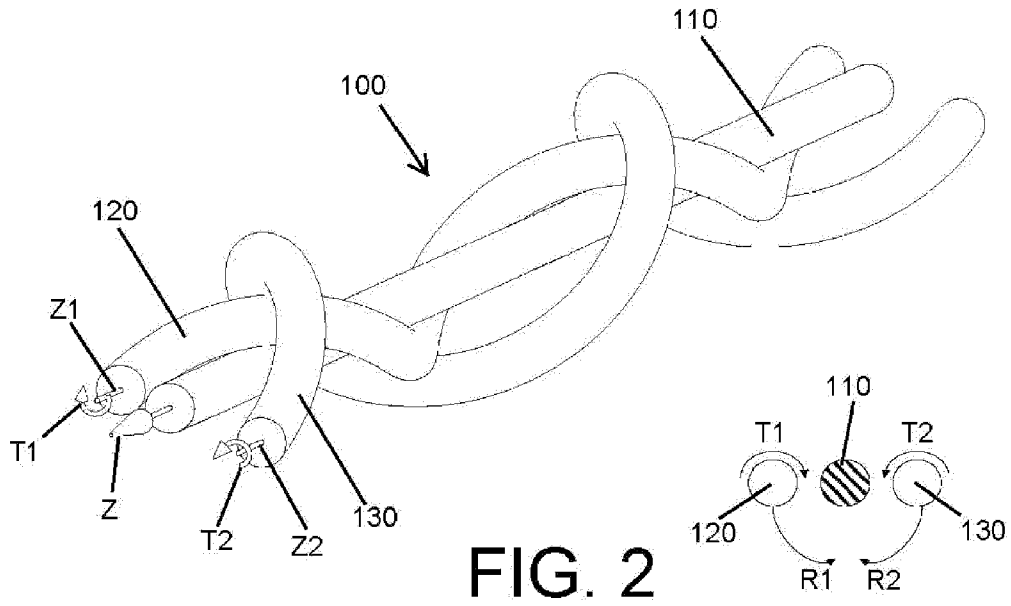
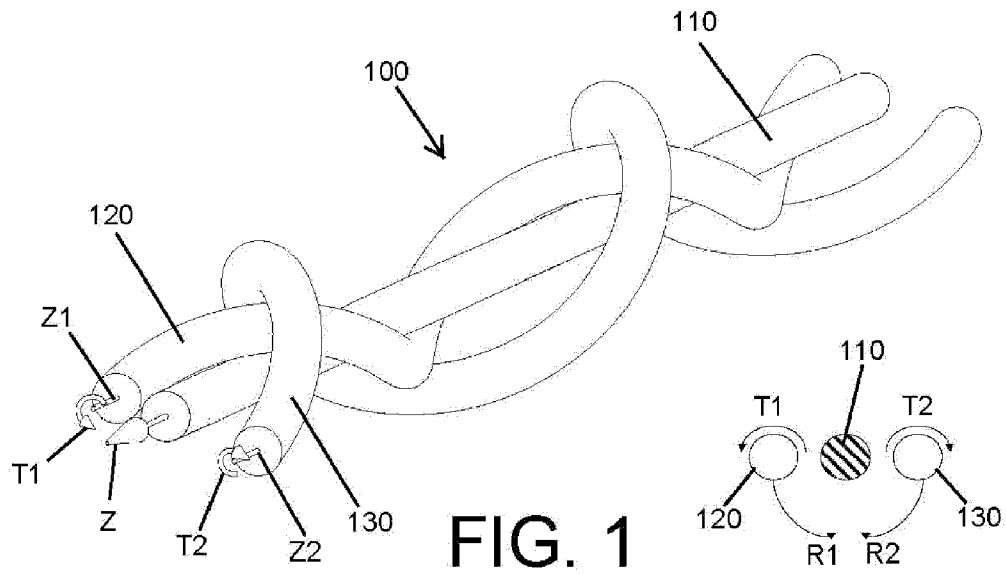
5. Vikling i henhold til krav 1, hvor det første optiske fiberkabel (120) strækker sig på en spiralformet måde om den centrale støttekerne (110) i henhold til en første rotationsretning (R1), og det andet optiske fiberkabel (130) strækker sig på en spiralformet måde om den centrale støttekerne (110) i henhold til en anden rotationsretning (R2), og hvor den første rotationsretning (R1) er den samme som den anden rotationsretning (R2), de optiske fiberkabler (120,130) er i kontakt med hinanden langs hele deres langsgående strækning omkring den centrale støttekerne (110).
6. Vikling i henhold til krav 5, hvor den første snoningsretning (T1) af det første kabel (120) er mod uret, og den anden snoningsretning (T2) af det andet kabel (120) er med uret, og det første rotationsretning (R1) af det første kabel (130) og den anden rotationsretning (R2) af det andet kabel (130) er mod uret.
7. Vikling i henhold til krav 5, hvor den første snoningsretning (T1) af det første kabel (120) er med uret, og den anden snoningsretning (T2) af det andet kabel (130) er mod uret, og den første rotationsretning (R1) af det første kabel (120) og den anden rotationsretning (R2) af det andet kabel (130) er med uret.
8. Vikling i henhold til et af de foregående krav, hvor det første optiske kabel (120) er snoet omkring sin længdeakse (Z1) et første antal omdrejninger, og det andet optiske fiberkabel (130) er snoet omkring sin længdeakse (Z2) et andet antal omdrejninger, og hvor det første og andet antal omdrejninger er det samme.
9. Vikling i henhold til det foregående krav, hvor de optiske fiberkabler (120,130) er snoede $12 \times 2 \pi \frac{rad}{m}$.
10. Vikling i henhold til et af de foregående krav, hvor den centrale støttekerne (110) består af et eller flere optiske fiberkabler.
11. Strømmåleudstyr baseret på optisk fiber til måling af den strøm, der cirkulerer gennem en leder, der omfatter:

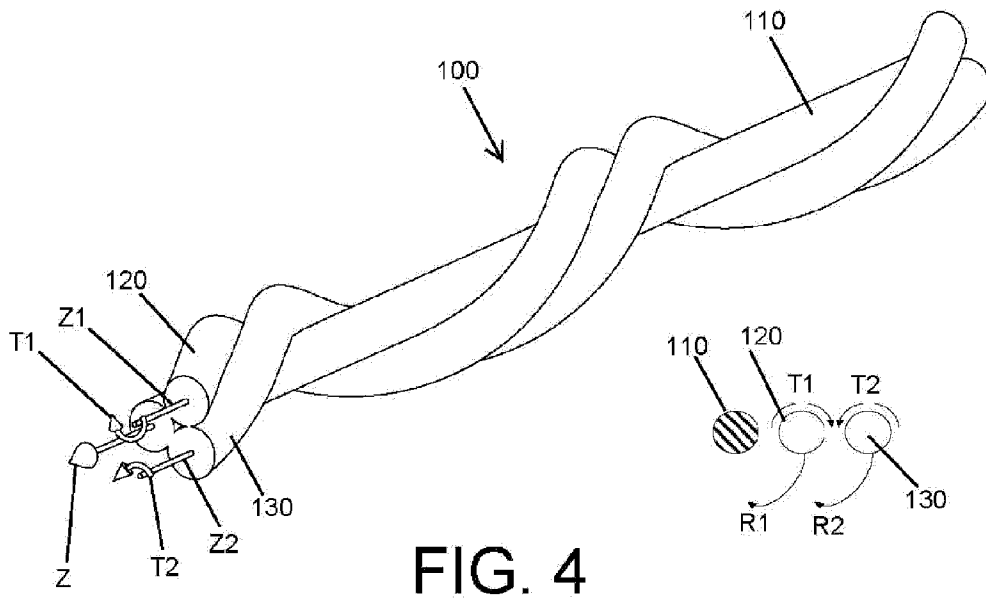
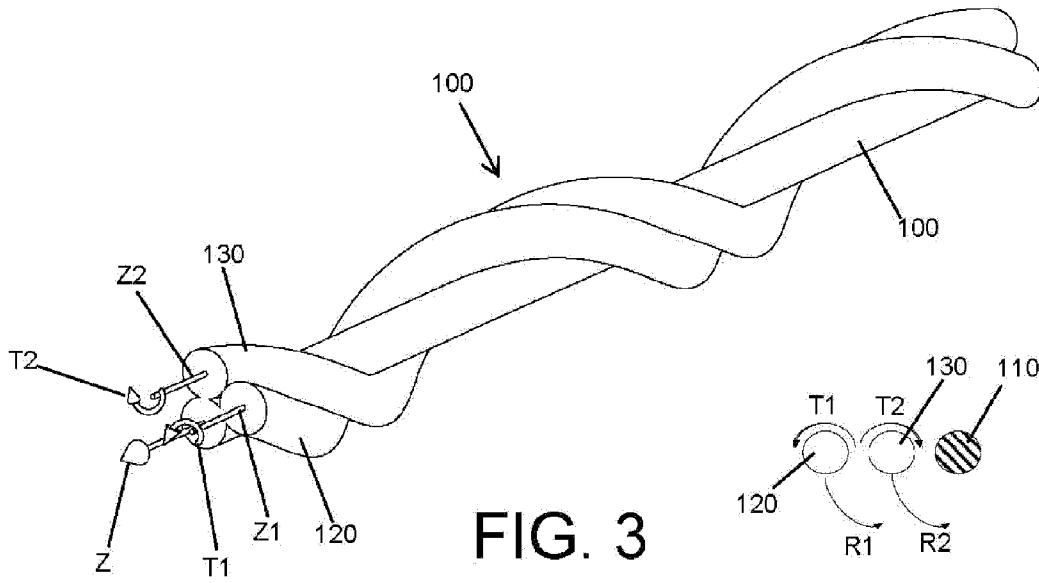
- en interrogator (1) med lysemitterende anordning (2) og lysmodtagende anordning (3),
- en sensordel (4) tæt på lederen (5), og
- en optisk fibertransmissionsanordning (6), der er anbragt mellem interrogatoren (1) og sensordelen (4)

karakteriseret ved, at sensordelen (4) omfatter en optisk fibervikling (100) i henhold til et hvilket som helst af de foregående krav.

DRAWINGS

Drawing





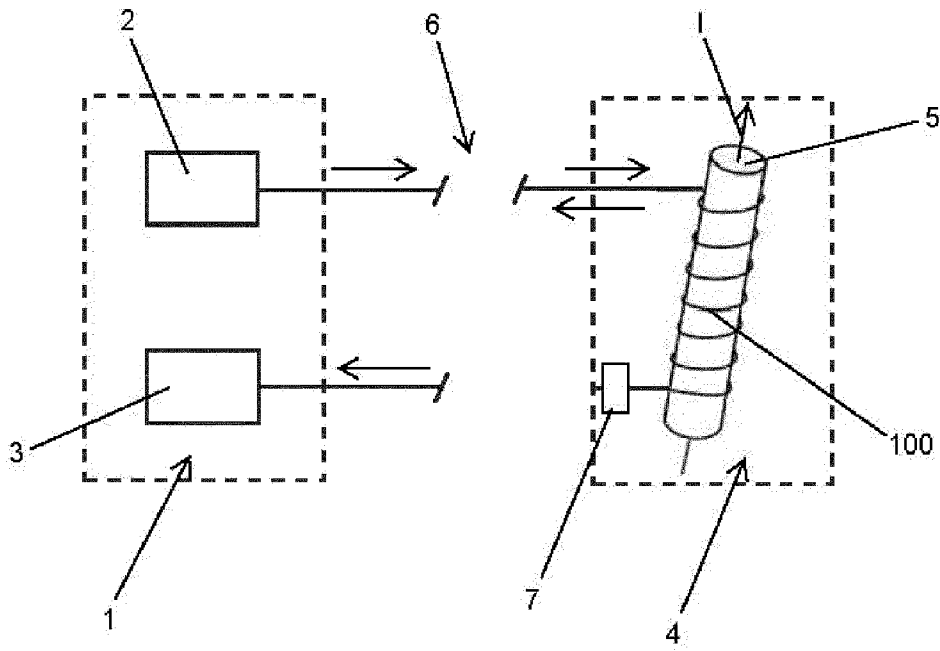


FIG. 5