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(54) System for real-time monitoring of the state of occupation of railway lines

(57) Axle-count automatic-block system for monitoring the state of occupation of a section of railway line by means of sensors designed to count the number of axles of railway vehicles that enter the section of line, the system comprising two optical-fibre Bragg-grating sensors, which are mounted at a distance from one another in positions corresponding to end portions of a section of railway line to be monitored and identify a block section, connected by means of an optical fibre to a querying system, which is able to send a light radiation to the sensors and process the radiation back-reflected by each of the sensors in order to acquire the information on the direction of travel of the railway vehicles and on the state of occupation of the block section.

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Description

[0001] The present invention relates to a system for real-time monitoring of the state of occupation of railway lines.

[0002] One of the main methods for real-time monitoring of the state of occupation of railway lines is based upon the axle-count automatic-block system.

[0003] Said system is designed to detect the position of the railway vehicles moving with respect to sections of line, referred to as "block sections", identified on the rails of railway lines or stretches of line.

[0004] The automatic-block system produces information indispensable for operation of the signalling network that regulates the distance between trains and activation of switches, contributing to guaranteeing safe circulation.

[0005] In stretches of railway in which the axle-count automatic-block system is implemented, control of occupation of a block section is carried out by means of purposely provided equipment, actuated by the movement of the railway vehicles, which count the axles of a vehicle entering the block section and leaving the block section.

[0006] Axle-count equipment is provided with sensors set at the ends of the block section and designed to measure the number of the axles entering and leaving said section.

[0007] The axle-count equipment compares the number of axles measured at entry to the section with the one measured at exit in order to obtain the information on the occupation of the block section considered. In particular, the block section is free if the axles counted at entry to the section are equal in number to the axles counted at exit from the section.

[0008] In all other cases, irrespective of the value of count obtained, the block section is occupied.

[0009] In the current state of the art, the aforementioned sensor is built according to various technical solutions.

[0010] For example, in a first technical embodiment, the sensor comprises a solenoid, mounted on the inside of the rail and designed to generate a magnetic field, and a magnetic-field meter. The passage of each single axle is detected by analysing the perturbation of the magnetic field caused by the passage of the metal axle.

[0011] Another type of sensor comprises an electrical contact, set in the proximity of the internal edge of the rail and designed to behave as a switch actuated so that it closes upon passage of the axle of the vehicle.

[0012] A further type of sensor comprises a lever mechanism coupled to a switch, set on the internal edge of the rail, and actuated by the axle of the vehicle as the vehicle travels.

[0013] Finally, sensors have been devised comprising a fluid chamber set underneath the flange of the rail between two sleepers and having the function of detecting the deformations of the rail upon passage of the axle of the vehicle.

[0014] Axle-count block systems of a known type are subject to a series of drawbacks, such as wear (as regards the electromechanical systems) and electromagnetic incompatibility (as regards the systems based upon solenoids).

[0015] Consequently, axle-count block systems of a known type can make erroneous detections that seriously jeopardize circulation of railway vehicles.

[0016] The problems of axle-count block systems of a known type are overcome by the present invention, in so far as it regards a system for real-time monitoring of the state of occupation of railway lines of the type described in Claim 1.

[0017] The system forming the subject of the present invention envisages the use of optical-fibre Bragg gratings for dynamic or static detection of the passage or possible stoppage of railway vehicles on a railway line, simultaneously guaranteeing high reliability, low wear of the sensing components, electrical insulation and full electromagnetic compatibility, thus enabling the limitations described above to be overcome.

[0018] For a better understanding of the invention, a preferred embodiment is described in what follows, by way of nonlimiting example and with reference to the attached drawings, wherein:

- Figure 1 is a schematic illustration of a system for monitoring the state of occupation of railway lines, comprising two optical-fibre Bragg-grating sensors mounted on a rail; and
- Figure 2 shows a block diagram of a system for querying the optical-fibre Bragg-grating sensors.

[0019] With reference to Figure 1, represented as a whole is a system 1 for real-time monitoring of the state of occupation of railway lines according to the present invention, in which Bragg-grating sensors 4, 5, mounted on a rail 2, are connected to one another and to a querying system 10 by means of an optical fibre 3. The system 1 is designed to detect the static and/or dynamic deformations of the rail 2 caused by the passage of the axles of a railway vehicle (not illustrated).

[0020] The system 1 uses an optical fibre 3, comprising at least two Bragg-grating sensors 4, 5 and, in general, N Bragg-grating sensors, set at a distance from one another in positions corresponding to end portions of one or more stretches of line, each stretch constituting a block section 6 to be monitored.

[0021] An optical-fibre Bragg-grating sensor is obtained by means of a spatial modulation of the index of refraction of the "core" of an optical fibre in order to bestow upon the latter the characteristics of an optical reflector that is selective for a particularly narrow range of wavelengths (tenths of a nanometre).

[0022] As is known, optical-fibre Bragg-grating sensors are readily available on the market and are used, for example, in the telecommunications sector on optical fibres as filters for selecting a channel in a WDM ("Wavelength Division Multiplexing") or DWDM ("Dense Wavelength Division Multiplexing") coding.

[0023] The optical fibre 3 is positioned along the rail 2 in such a way that each sensor 4, 5 will be stably fixed in contact with the rail 2 (for example, positioned under the head 2a or in contact with the stem 2b of the rail) in the point in which it is desired to make the detection.

[0024] The installation of the optical fibre 3 and of the sensors 4, 5 can occur by direct bonding of the optical fibre 3 and/or of the sensors 4, 5 on the external wall of the rail 2 or else by setting the optical fibre 3 and/or the sensors 4, 5 inside a metal package (not illustrated) and welding said package to the rail 2.

[0025] In this way, the deformations/vibrations transmitted to the rail by the passage of an axle of a railway vehicle are detected by the sensor 4 or by the reference sensor 5 (according to whether the passage of the axle occurs at entry to or at exit from the block section 6), which modifies its own optical characteristics.

[0026] In fact, a peculiarity of optical-fibre Bragg gratings lies in the fact that local variations, due for example to vibrations, of the physical state of the stretch of optical fibre in which the Bragg grating has been made are the cause of a translation of the central wavelength of the reflection spectrum of the optical signal back-reflected by the Bragg grating with respect to the case of absence of alterations of said stretch of optical fibre.

[0027] The sensors 4, 5 have wavelengths of maximum reflectivity that are different from one another. In fact, in the case where more than one sensor is used, each sensor must operate at a wavelength of maximum reflectivity that is different from that of all the other sensors.

[0028] The sensor 4, 5 provides an axle-passage detection point and can be used in both directions of travel, rendering possible not only the control of occupation of the block section 6, but also the direction of movement of the railway vehicles in both directions. Said sensors 4, 5, in fact, detect transit of the axle of a railway vehicle each at a location of their own and are characterized by a reflection wavelength of their own. For example, the sensor 4 can have a wavelength of maximum reflectivity lower than 1550 nm (referred to hereinafter as "low wavelength"), whilst the sensor 5 can have a wavelength of maximum reflectivity higher than 1550 nm (referred to hereinafter as "high wavelength").

[0029] The optical fibre 3 communicates, through at least one end thereof, with the querying system 10 designed to supply at input to the optical fibre 3 to which it is connected an appropriate light radiation and designed to acquire the radiation of low and high wavelength back-reflected by the sensors 4, 5.

[0030] The optical fibre 3 and, consequently, the Bragg-grating sensors 4, 5 are mounted along the railway line, whilst the querying system 10 can be mounted in a remote location, for example in the railway station (not illustrated).

[0031] In particular, a single optical fibre 3 comprising Bragg-grating sensors 4, 5 can be used for monitoring several tens of kilometres of railway lines, and a single querying system 10 can query simultaneously a number of optical fibres 3 and corresponding sensors 4, 5.

[0032] Figure 2 shows in greater detail the system 10 for querying the sensors 4, 5.

[0033] The querying system 10 comprises a wide-band optical source 11 (for example, obtained by means of a LED) designed to illuminate the optical fibre 3, which can be, for example, of the type used for phone and/or data communications, and in which the sensors 4, 5 are present, set at an appropriate distance from one another.

[0034] The signal at output from the optical source 11 is supplied to a first three-way connector 12, having at least three ports, and in particular:

- a first port 12a has the function of input for the optical signal coming from the optical source 11;
- a second port 12b is connected to one end of the optical fibre 3 and is used for routing the light coming from the optical source 11 onto the optical fibre 3 and for receiving the components of light back-reflected by the sensors 4, 5; and
- a third port 12c is connected to a wavelength multiplexer 14.

[0035] The multiplexer 14 has the function of separating the components of light back-reflected by the sensors 4, 5 and routing them each on a different output. For example, the component of light of low wavelength can be routed on a multiplexer output 14a and supplied to a first channel 15, whilst the component of light of high wavelength can be routed on a multiplexer output 14b and supplied to a second channel 15'.

[0036] The first and second channels 15 and 15' are each made up of an optoelectronic system, the optoelectronic systems being separate from one another but equivalent as regards the operating function performed. Consequently, in the following description, reference will be made just to the first channel 15.

[0037] The first channel 15 comprises:

- a second three-way connector 20 connected on a first output of its own to a first filter 21 with linear optical transmissivity and reflectivity; and
- a first optical detector 22, the input of which is connected to an output of the first filter 21 and the output of which is connected to a first adapter port 25a of a first electrical adapter 25.

[0038] In this way, the second connector 20, the first filter 21, the first detector 22, and the first electrical adapter 25 are cascaded to one another.

[0039] The first channel 15 further comprises a second optical detector 26, connected at input to a second output of the second connector 20 and at output to a second adapter port 25b of the first electrical adapter 25.

[0040] The outputs of the second detector 26 and of the first electrical adapter 25 are moreover connected respectively to a first acquisition port 30a and to a second acquisition port 30b of an acquisition system 30.

[0041] In use, the optical component of low wavelength reflected, for example, by the sensor 4, after being routed by the multiplexer 14 on the first channel 15, reaches the second connector 20, which transfers it to the first filter 21.

[0042] The first filter 21 has a spectral response of the transmissivity/reflectivity coefficient having a linear law as a function of the wavelength, so that variations in the wavelength of the light that illuminates it result in variations in the transmitted/reflected intensity.

[0043] The signal reflected by the first filter 21 reaches, through the second connector 20, the second detector 26, which converts the variations of amplitude of the light signal that it receives at input from the second connector 20 into a voltage signal Ssens_2(t).

[0044] The signal transmitted by the first filter 21 reaches the first detector 22 and from this is converted into a voltage signal Ssens_1(t).

[0045] Both of the voltage signals Ssens_1(t) and Ssens_2(t) are supplied at input to the first electrical adapter 25, respectively on the port 25a and 25b of the first electrical adapter 25, which processes them by means of an algorithm of ratiometric compensation, of a type known in the literature. Processing by means of the ratiometric-compensation algorithm becomes necessary in so far as the amplitude of the signals Ssens_1(t) and Ssens_2(t) can depend, not only upon the variation, due to the physical quantities to be monitored, of the wavelength of the component of light reflected by the sensors 4, 5, but also upon fluctuations of power of the optical source 11 or upon the variation in the losses in any point of the querying system 10 and/or of the optical fibre 3.

[0046] By means of the ratiometric compensation, made by the first electrical adapter 25 by processing Ssens_1(t) and Ssens_2(t), at output on a third adapter port 25c, there is a single signal Ssens_3(t), the amplitude variations of which are due exclusively to the variations in the tensional/vibrational state to which the corresponding sensor 4 is subject during passage of the axles of a railway vehicle in the point in which the sensor 4 is mounted. In this way, the variation in amplitude of the signal Ssens_3(t) actually represents the variation in the quantity measured by the single sensor 4.

[0047] The second channel 15' is made and operates in a way similar to the first channel 15. In the same way as the first channel 15, also the second channel 15' generates, at output from a second electrical adapter 25', a voltage signal Ssens_3' (t), the amplitude variations of which are due exclusively to the passage of the axle of a railway vehicle at the end of the block section 6 where the corresponding sensor 5 is mounted.

[0048] The voltage signals Ssens_3(t), Ssens_3'(t) are then supplied at input, respectively, to the ports 30b and 30b', of the acquisition system 30, which has the function of acquiring said signals and processing them so as to obtain the information that is to define the number of axles of a railway vehicle that has entered and left the block section 6, at the end of which the sensors 4, 5 are installed.

[0049] For example, the passage of an axle of the railway vehicle is detected when the signal Ssens_3(t) assumes a pre-set relationship with respect to (for example is higher than) a threshold value Slim.

[0050] Following upon detection of said event, a first counter (not shown) is activated, which detects the passage of the axle in a position corresponding to one between the sensor 4 and the sensor 5, for example the sensor 4. Similar operations can be performed for the sensor 5 by activating a second counter, which detects the passage of an axle on the sensor 5. The contents of said counters can be compared, according to a known technique, in order to detect the state of occupation of the block section 6.

[0051] It is moreover possible to acquire further information, such as, for example, the direction of travel of the railway vehicle and/or the speed of travel.

[0052] Finally, it is possible to connect, between a third acquisition output 30c of the acquisition system 30 and an input of the optical source 11, a testing element 31. The testing element 31 performs functions of alarm and control of operation of the querying system 10, of the optical fibre 3 and of the sensors 4, 5 and can be activated, for example, by a remote location at a railway station (not illustrated) for a time interval in which passage of a railway vehicle is not expected.

[0053] When the testing element 31 is active, it interacts with the optical source 11 in such a way as to generate a variation in the characteristic of emission of the optical source 11, for example modulating the amplitude of the output optical signal in a known way according to a pre-set law.

[0054] In particular, if the law of modulation of the optical signal is known, by analysing the signal Ssens_2(t) at output from the second optical detector 26 and the signal Ssens_2'(t) at output from the fourth optical detector 26', it is possible to assess the integrity of the optical-fibre connections of the monitoring system 1 and proper operation of the sensors 4, 5, at the same time verifying that also the optical signal received presents an evolution that follows the pre-set law.

[0055] Any possible difformity of the signals Ssens_2 (t), Ssens_2'(t) with respect to the expected response enables generation of an appropriate request for troubleshooting and/or an alarm for improper operation. The analysis of the signals Ssens_2(t) and Ssens_2' (t) and sending of the request for troubleshooting or of alarm for improper operation are carried out by the acquisition system 30.

[0056] The system described can be integrated with systems that use spectral properties, tuning qualities and time profiles of the radiation emitted that are different from the ones explicitly considered and chosen appropriately according to the specific application.

[0057] The use of appropriate frequency multiplexing techniques finally enables use of the optical fibre with the corresponding Bragg-grating sensors both for the sensor applications described and for the normal data and/or voice transmission, without the various activities interfering with one another.

Claims

1. A system for real-time monitoring of the state of occupation of railway lines, comprising at least a first sensitive element (4) and a second sensitive element (5) arranged at end portions of a block section (6) to be monitored and designed to detect the passage of an axle of a railway vehicle that enters/leaves the block section, said system being **characterized in that** said sensitive elements are of an optical type and each comprise at least one Bragg-grating sensor (4, 5).

2. The system according to Claim 1, in which said sensors (4, 5) are connected to one another by means of a single optical fibre (3).

3. The system according to Claim 2, in which means are provided for querying (10) said sensors (4, 5), said means comprising:

   - an optical source (11) designed to supply a light signal to said sensors (4, 5);
   - deviator means (12) designed to receive on an input (12b) part of the light radiation reflected by said sensors (4, 5) to supply it to a multiplexer (14) of an optical type; said multiplexer (14) being designed to route on at least one first output and one second output (14a, 14b) the reflected light radiation associated to the first and second sensors, respectively; said first and second outputs communicating with respective first and second processing channels (15; 15').

4. The system according to Claim 3, in which said each channel (15, 15') comprises:

   - filter means (21, 21'), receiving at least part of the light radiation supplied to said channel;
   - first optical-detector means (22, 22'), receiving at input the radiation transmitted through said filter and generating at output a first signal;
   - second optical-detector means (26, 26'), receiving at input the radiation reflected by said filter and generating at output a second signal; and
   - means for processing said first and said second signals.

5. The system according to Claim 4, in which said means (25, 25') for processing said first and second signals are designed to generate at output a global signal Ssens_3(t), Ssens_3' (t), the amplitude variations of which express the physical state of the respective sensor (4, 5).

6. The system according to Claim 5, in which threshold-comparator means are provided, designed to detect the passage of said axle of a railway vehicle in the case where said global signal assumes a pre-set relationship with respect to at least one threshold value.

7. The system according to Claim 5, in which said processing means (25, 25') implement a ratiometric algorithm on the first and second signals for generating at output said global signal Ssens_3 (t), Ssens_3' (t).

8. The system according to any one of Claims 3 to 7, in which testing means (31) are provided, configured for supplying a modulation of the output intensity of said optical source (11) according to a pre-set law; said testing means co-operating with optical-detector means, receiving at least part of the signal reflected by said Bragg-gratings sensors for generating a test signal Ssens_2(t);
said testing means (31) detecting the integrity of said system in the case where said test signal follows said pre-set law.

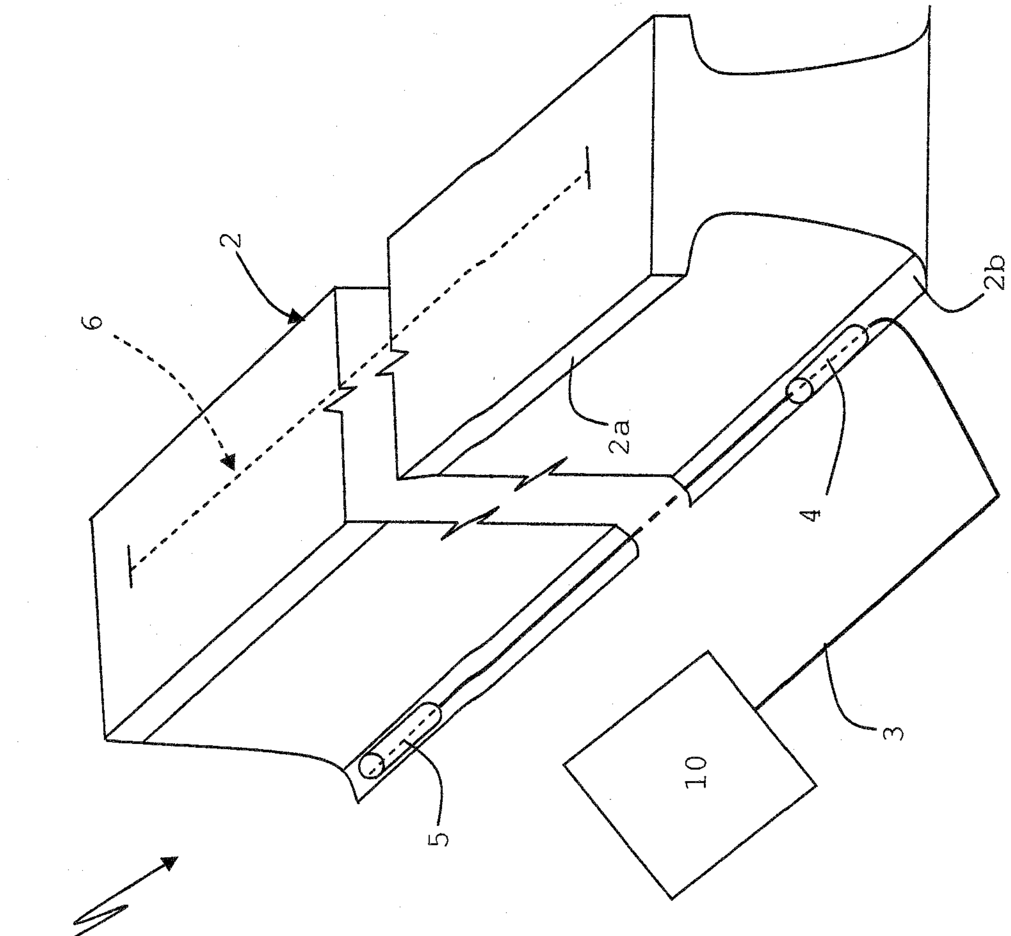

Fig. 1

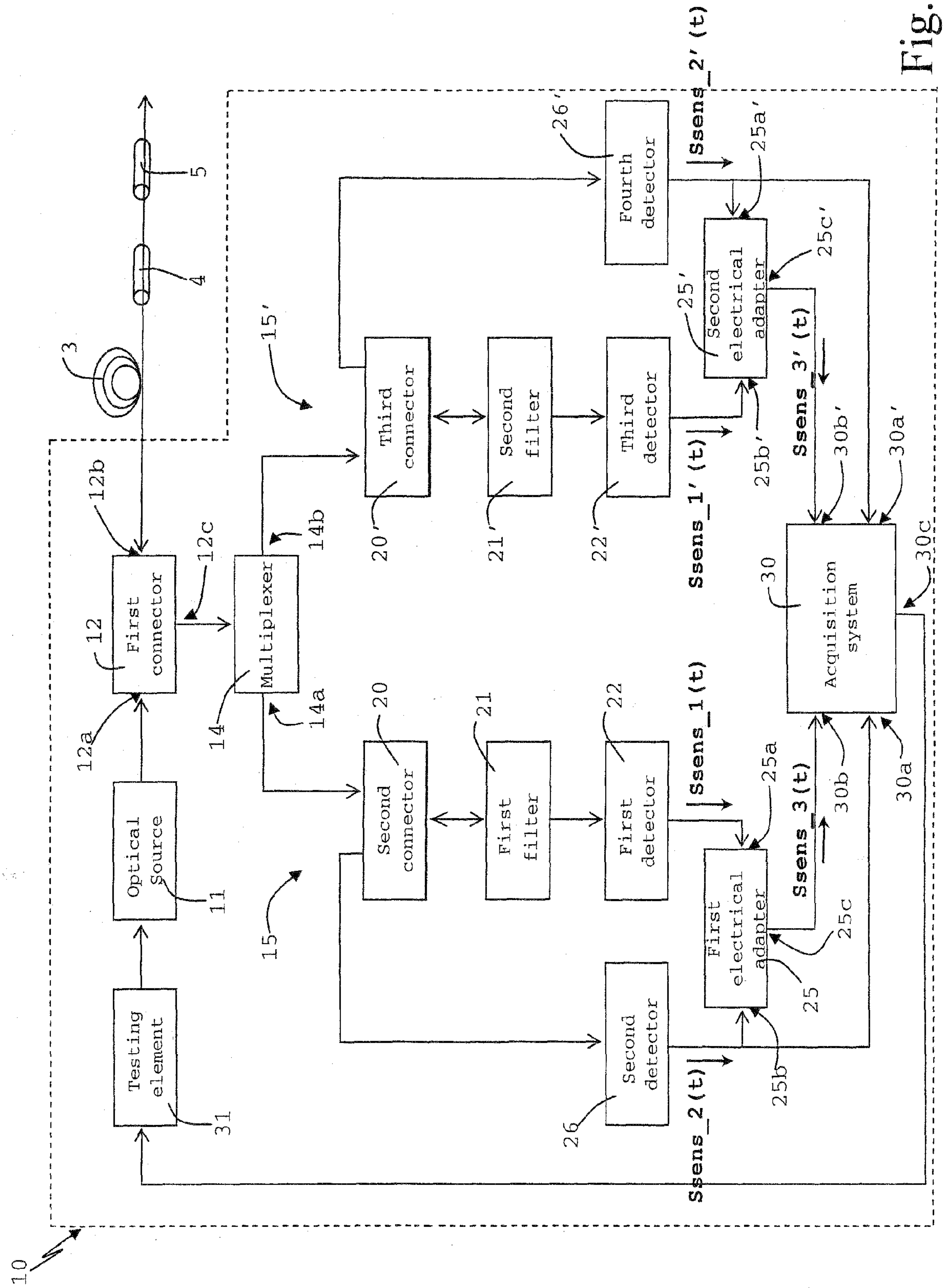
Testing element
Optical Source
First connector
Multiplexer
Second connector
Third connector
First filter
Second filter
First detector
Second detector
Third detector
Fourth detector
First electrical adapter
Second electrical adapter
Acquisition system
Ssens_1(t)
Ssens_2(t)
Ssens_3(t)
Ssens_1'(t)
Ssens_2'(t)
Ssens_3'(t)
3
4
5
10
11
12
12a
12b
12c
14
14a
14b
15
15'
20
21
22
20'
21'
22'
25
25a
25b
25c
25'
25a'
25b'
25c'
26
26'
30
30a
30b
30c
30a'
30b'
31

Fig. 2