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(54) Benævnelse: **A pipe system, a gas sensing system for a pipe system, and a method of determing a gas component in a cavity of a pipe**

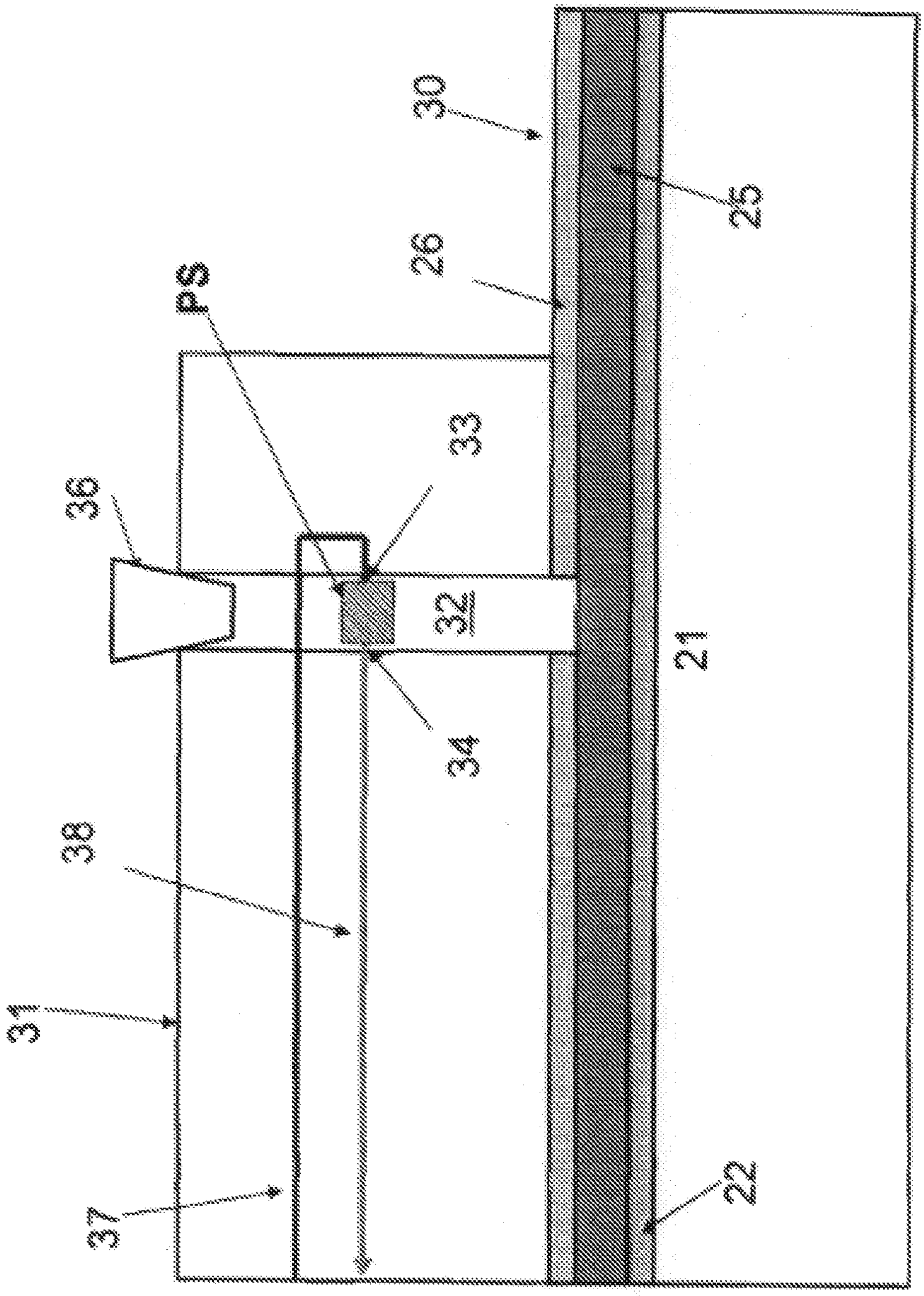
(57) Sammendrag:

The invention relates to a pipe system comprising a pipe, a gas sensing station and a remote output system. The pipe comprises a pipe gas cavity, such as an annulus, extending lengthwise in part or all of the length of the pipe; the gas sensing station comprises a sensing gas cavity which is in gas communication with the pipe gas cavity: The sensing gas cavity comprises a photoacoustic spectroscope. The pipe system comprises at least one optical feeding fiber for feeding light to the photoacoustic spectroscope and a transmission path for transferring a signal from the photoacoustic spectroscope to the remote output system, the transmission path from the gas sensing station to the remote output system is an optical transmission path.

The pipe may for example be a flexible pipe e.g. an umbilical or a pipe for the transportation of crude oil from a well to an off shore or on shore station , for example a ship or a platform.

The gas sensing station may be integrated in the pipe, e.g. in an end fitting or it may be an external gas sensing station.

According to a high security embodiment of the invention it is desired that all energy transported between the remote output system and the gas sensing station is in the form of optical energy e.g. transported in one or more optical fibers. This embodiment provides a very safe and simultaneously well functioning system, with reduced risk of igniting burnable fluids and simultaneously with a high signal-to-noise quality.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CLAIMS

1. A pipe system comprising a pipe, a gas sensing station and a remote output system, wherein the pipe is flexible pipe comprising from inside out an internal sheath, one or more armouring layers and an outer sheath, said internal sheath preferably forming a resistance or barrier against the outflow of liquid gas which is conveyed through the pipe through said flow channel, and said outer sheath preferably forming a barrier against ingress of liquid, the pipe comprises a pipe gas cavity extending lengthwise in part or all of the length of the pipe, the gas sensing station comprises a sensing gas cavity which is in gas communication with the pipe gas cavity, the sensing gas cavity comprises a photoacoustic spectroscope, the pipe system comprises at least one optical feeding fiber for feeding light to the photoacoustic spectroscope and a transmission path for transferring a signal from the photoacoustic spectroscope to the remote output system, the transmission path from the gas sensing station to the remote output system is an optical transmission path, wherein said gas sensing station is optionally separated from but in gas communication with said pipe gas cavity, such as the gas sensing station being external to the pipe or such as the gas sensing station being integrated in an end fitting.

2. A pipe system as claimed in claim 1 wherein said pipe gas cavity extends along the length of the pipe in a length of at least about 1 m, such as at least about 10 m, such as at least about 25 m, such as at least about 50 m, such as at least about 100 m, such as between about 50 and about 3000 m, the gas cavity optionally comprises one or more armouring layer of the pipe, and/or one or more optical fibers, such as an optical fiber for monitoring temperatures along the length of the pipe and or measuring mechanical properties along the length of the pipe.

3. A pipe system as claimed in any one of the preceding claims wherein the remote output system comprises a light source optically connected to said photoacoustic spectroscope via said feeding fiber for feeding pulsed and/or modulated light into said photoacoustic spectroscope, wherein the

light source preferably comprises at least one of a gas discharge lamp e.g. a xenon based light source, a laser, a light emitting diode (LED) and a semiconductor diode laser, preferably the light source being a laser such as a laser selected from supercontinuum lasers, said light source preferably being a broad spectered light source, and/or wherein the light source comprises at least one tunable laser.

4. A pipe system as claimed in claim 3 wherein the light comprises wavelengths which are at least partly absorbable by at least one of water vapour, methane (CH_4), hydrogen sulphide (H_2S), Carbon monoxide (CO), Carbon dioxide (CO_2), Oxygen (O_2) and hydrogen (H_2).

5. A pipe system as claimed in any one of the preceding claims wherein said photoacoustic spectroscope comprises a detection space, said detection space being a part of or the whole sensing gas cavity of the gas sensing station, said feeding fiber being arranged to feed light to said detection space, wherein said photoacoustic spectroscope comprises an acoustic detector arranged to detect gas pressure changes occurring as a result of stimulation of the gas in the photoacoustic spectroscope with light, and wherein said acoustic detector optionally comprises at least one amplifier, the amplifier preferably being in the form of a tuning fork comprising at least two prongs, the detection space comprises a space between said two prongs.

6. A pipe system as claimed in claim 5 wherein said acoustic detector comprises a microphone for detecting the gas pressure changes as sound waves, and wherein said microphone is preferably in electrical communication with a transducer for converting electrical signals from said microphone into optical signals, said optical signals being transmitted along said optical transmission path.

7. A pipe system as claimed in claim 5 wherein said acoustic detector comprises at least one piezoelectric crystal for detecting the gas pressure changes, wherein said piezoelectric crystal is preferably mounted on a tuning fork comprising at least two prongs, the detection space preferably

comprises a space between said two prongs, and wherein said piezoelectric crystal is in electrical communication with a transducer for converting electrical signals from said piezoelectric crystal into optical signals, said optical signals being transmitted along said optical transmission path.

8. A pipe system as claimed in any one of claims 5-7 comprising a transducer for converting electrical signals into optical signals, said transducer comprises an analogue-digital converter and an electromagnetic generator, and wherein said electromagnetic generator is a light emitter.

9. A pipe system as claimed in any one of claims 1-7 wherein said photoacoustic spectroscope comprises an acoustic detector comprising a piezoelectric crystal in electrical communication with an analogue-to digital transducer, which analogue-to digital transducer is connected to a light emitter, wherein the light emitter is preferably a laser preferably selected from a light-emitting diode (LED) and a semiconductor laser such as a Vertical cavity surface-emitting laser (VCSEL).

10. A pipe system as claimed in any one of the preceding claims wherein the pipe system comprises at least one amplifier for amplifying the signal from the photoacoustic spectroscope, said amplifier being arranged at the gas sensing station, wherein said photoacoustic spectroscope comprises an acoustic detector comprising a piezoelectric crystal in electrical communication with an analogue-to digital transducer, which analogue-to digital transducer is connected to a light emitter, said amplifier being applied to amplify the electrical signal prior to converting the signal in the analogue-to digital transducer or said amplifier being applied to amplify the optical signal.

11. A pipe system as claimed in any one of the preceding claims wherein said optical feeding fiber and/or at least one secondary optical feeding fiber is arranged to feed light to at least one energy consuming element in said gas sensing station to provide said at least one energy consuming element with energy, said at least one energy consuming element being selected from a laser, an amplifier and a transducer.

12. A pipe system as claimed in any one of the preceding claims wherein the remote output system comprises an analyzer, said analyzer preferably being optically connected to said photoacoustic spectroscope for receiving optical output from said photoacoustic spectroscope, wherein said analyzer is preferably capable of analyzing at least a fraction of light supplied from said photoacoustic spectroscope, said analyzer preferably comprises a computer, and wherein said analyzer is preferably capable of analyzing light from said photoacoustic spectroscope to detect the presence and preferably the amount of water vapour and/or one or more of the components selected from oxygen, hydrogen, methane, hydrogen sulphides and carbon dioxides.

13. A pipe system as claimed in any one of the preceding claims wherein at least one active element of the remote output system is placed at a distance from the gas sensing station which is at least about 2 m, wherein the active elements are selected from said light source and said analyzer and/or wherein the remote output system is placed at a distance from the gas sensing station which is at least about 2 m.

14. A pipe system as claimed in any of the preceding claims, wherein said end fitting comprises said sensing gas cavity which is in gas communication with the gas cavity, preferably a valve and/or a filter is arranged between said sensing gas cavity and said gas cavity, optionally, where said pipe is a riser pipe, said riser comprises the end fitting for connection to an offshore station, such as a platform or a ship, said gas sensing station being integrated in said end-fitting or being in gas communication with said gas cavity via said end-fitting and said remote output system being placed at said offshore station.

15. A pipe system as claimed in any of the preceding claims wherein the pipe comprises an access opening into said gas cavity through which said sensing gas cavity is in gas communication with said gas cavity, said access opening preferably being provided with a valve and/or a filter, said access opening into said gas cavity optionally being provided via said end fitting.

16. A pipe system as claimed in any one of the preceding claims wherein said pipe is an offshore pipe such as a riser pipe, preferably applied to transfer a gas from one offshore station, such as from the sea bed, to an onshore station or another offshore station, such as a platform or a ship.

17. A gas sensing system for sensing a gas in a cavity of a pipe, said gas sensing system comprises a gas sensing station and a remote output system, said gas sensing station comprises a sensing gas cavity comprising a photoacoustic spectroscope, said remote output system comprises at least one light source and an analyzer, said at least one light source being optically connected to said photoacoustic spectroscope for feeding said photoacoustic spectroscope, preferably by at least one optical feeding fiber, said photoacoustic spectroscope further being optically connected to said analyzer for analyzing signals from said photoacoustic spectroscope, said gas sensing station being arranged to be connected to a pipe with a gas cavity to provide a gas communication between said gas cavity and said sensing gas cavity.

18. A gas sensing system as claimed in claim 17 wherein said system comprises an optical transmission path for transferring a signal from the photoacoustic spectroscope to the remote output system, the transmission path from the gas sensing station to the remote output system preferably being provided by an optical fiber.

Fig. 1

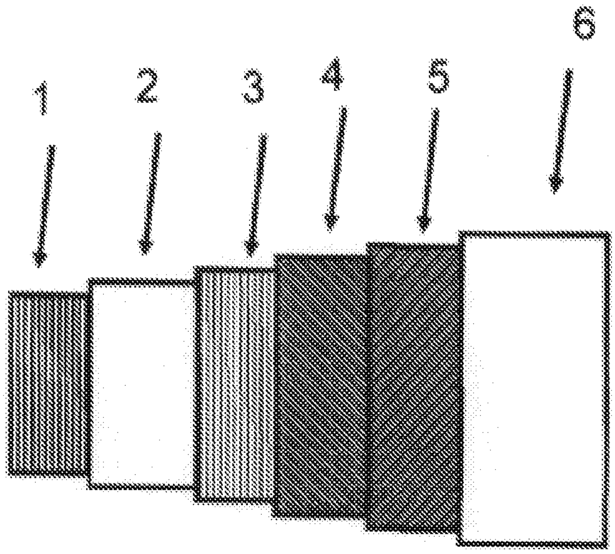


Fig. 2

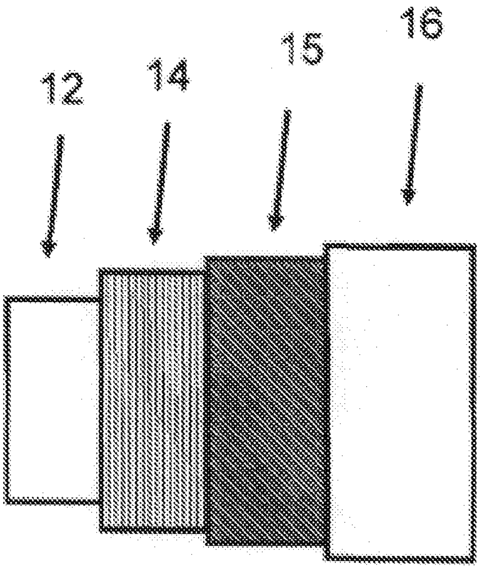


Fig. 3

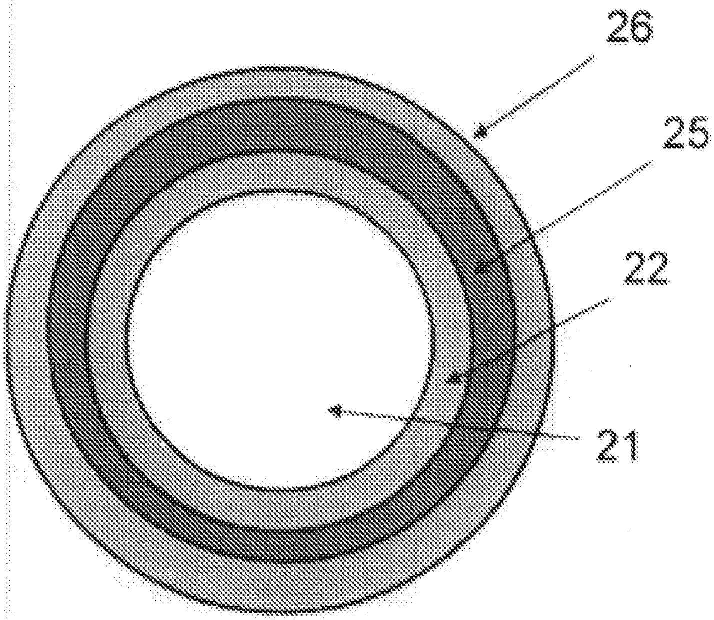
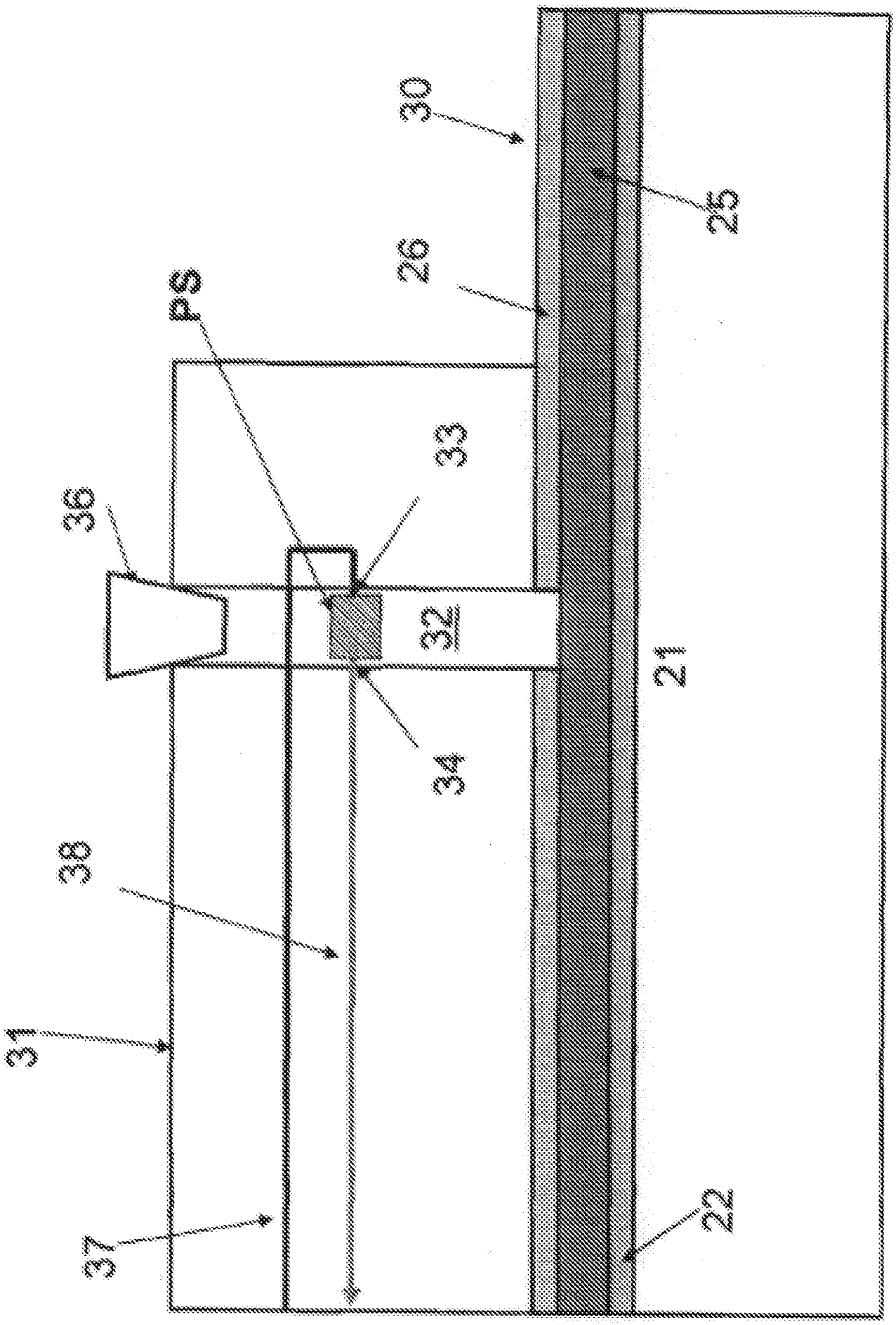


Fig. 4



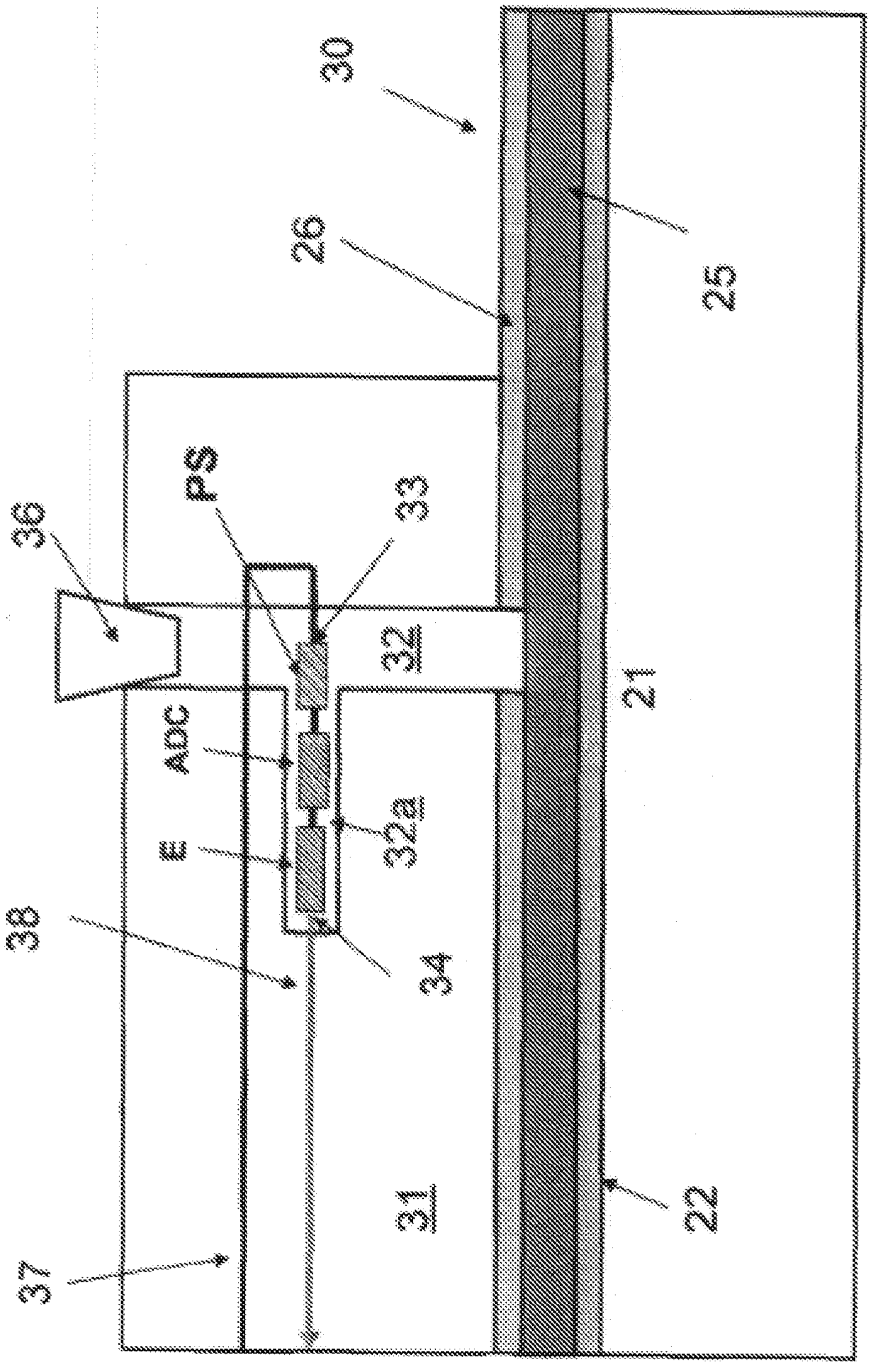


Fig. 5

Fig. 6

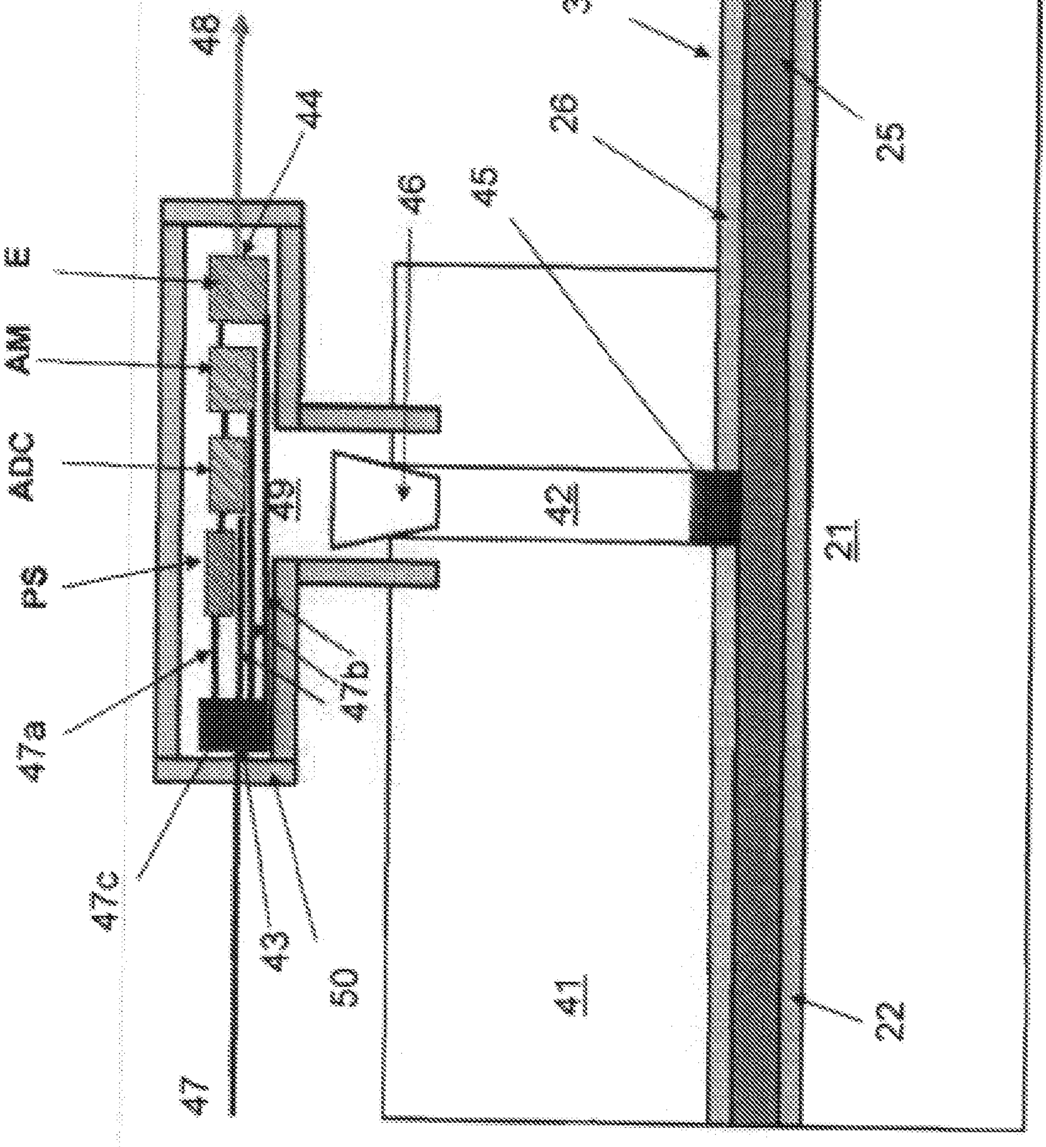
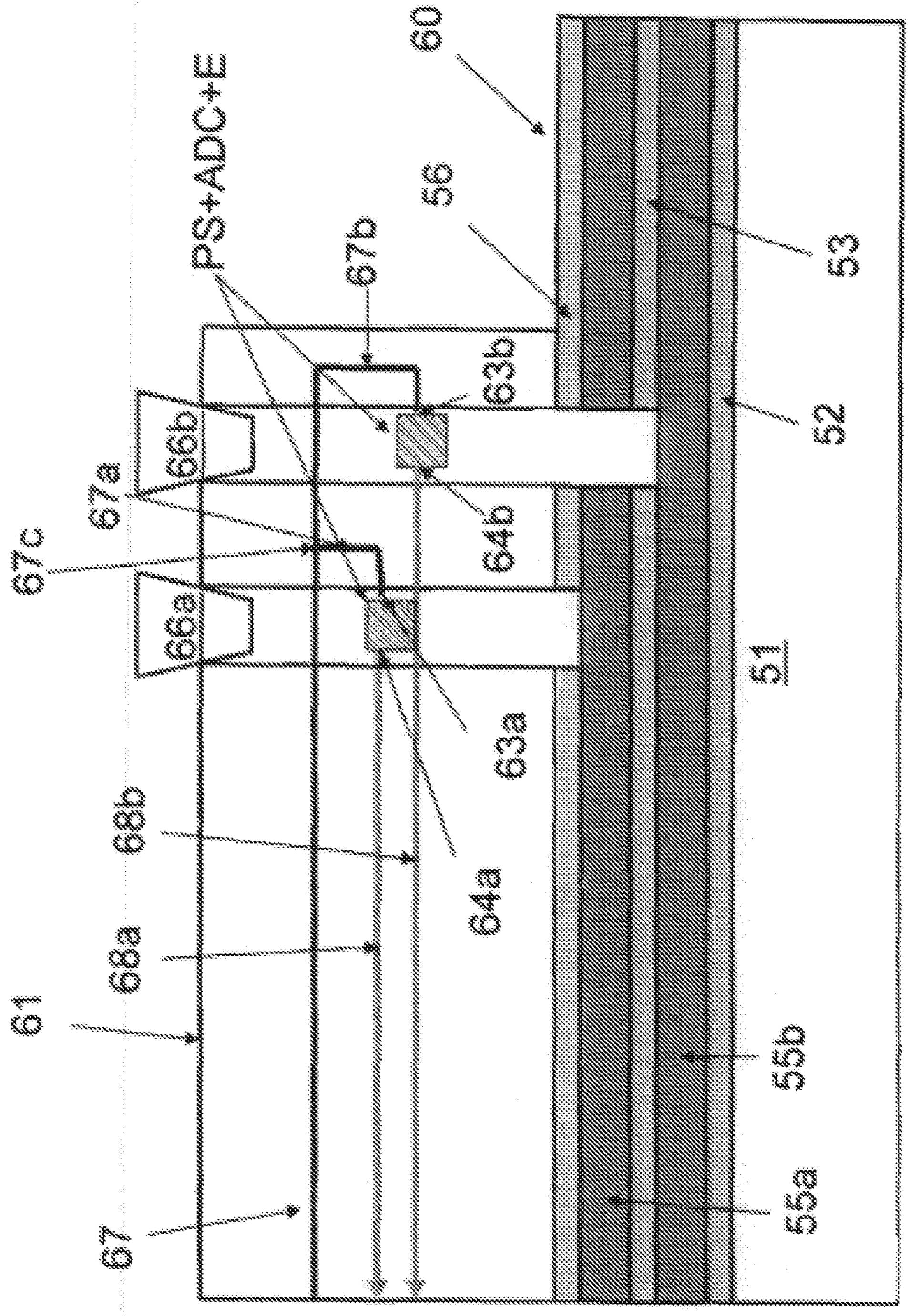


Fig. 7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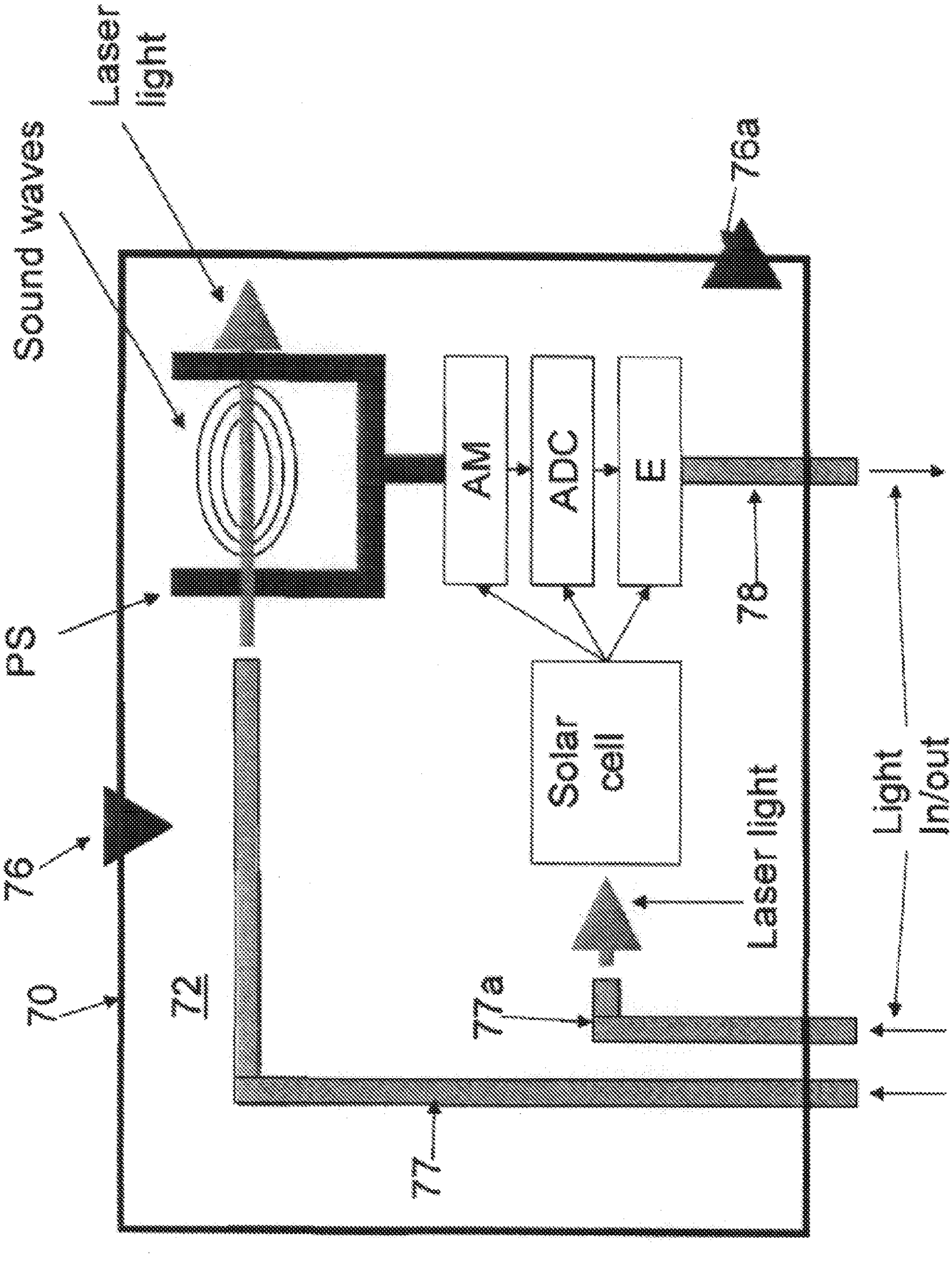
PS+ADC+E
56
53
67b
63b
52
66b
67a
64b
67c
66a
51
63a
68b
64a
68a
61
55b
55a
67

Fig. 8a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Sound waves
76a
PS
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ADC
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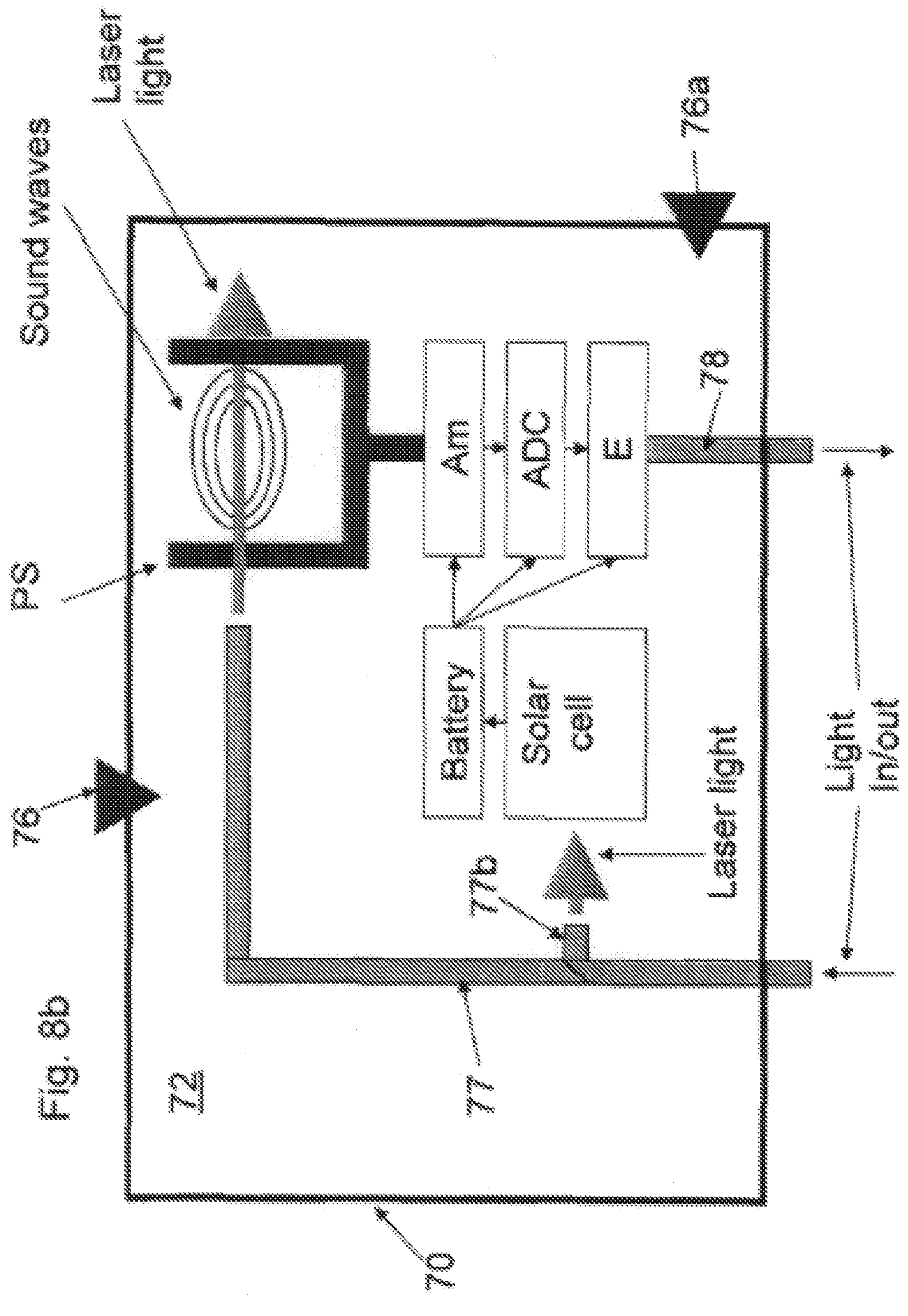
78
Solar cell
76
70
72
77a
Laser light
Light In/out
77


Laser light
Sound waves
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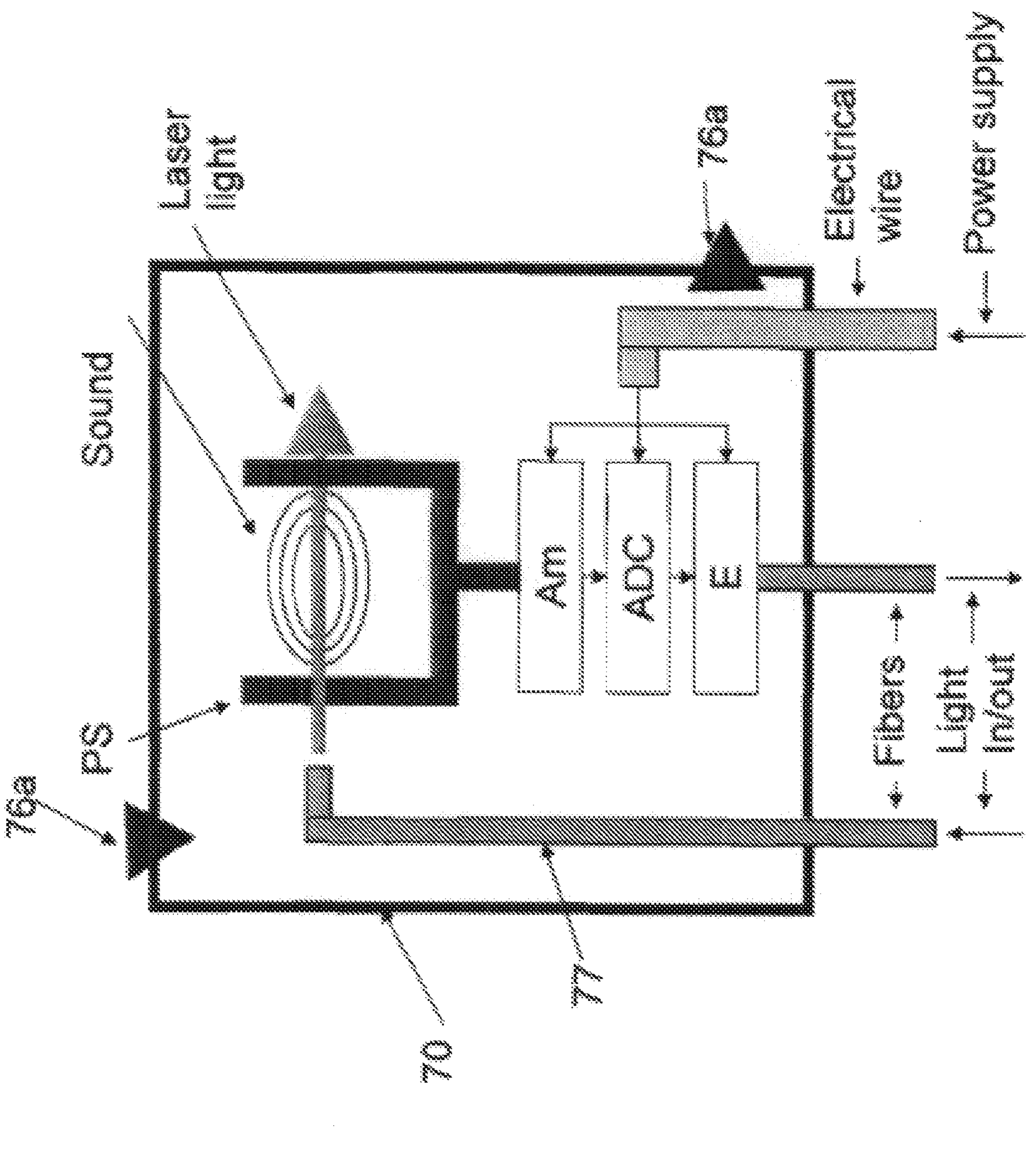
PS
Am
ADC
E
78
Battery
Solar cell
Laser light
Light In/out
76
77b
72
77
70

Fig. 8b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PS
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76a
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Power supply
Am
ADC
E
Fibers
Light In/out
70
77

Fig. 8c

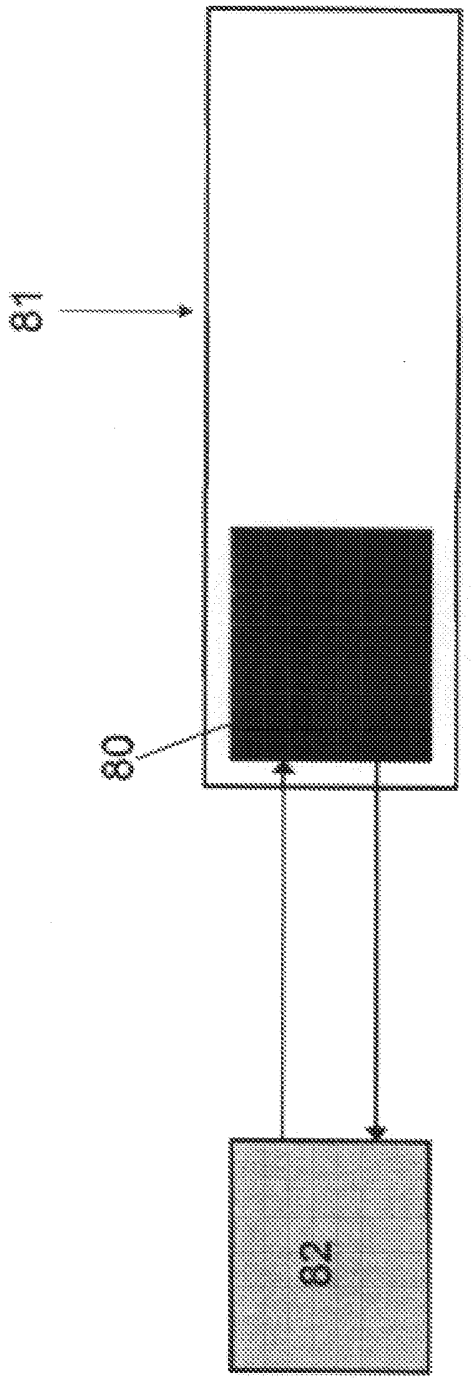


Fig. 9

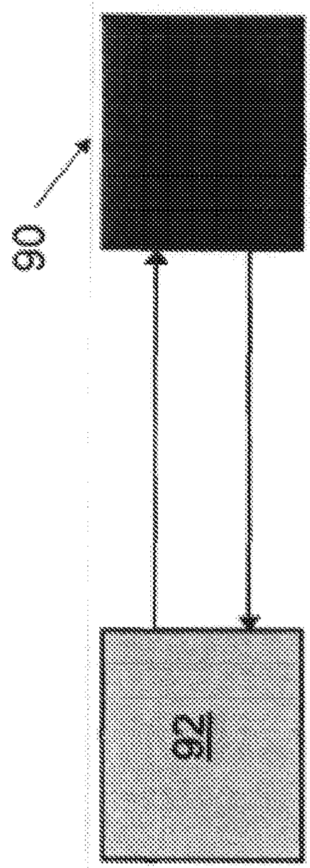


Fig. 10

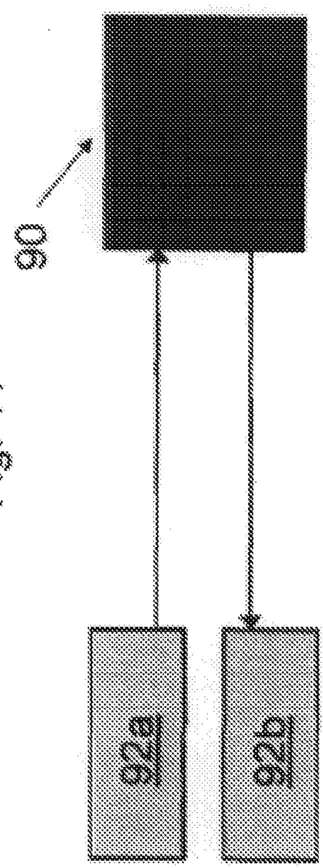


Fig. 11

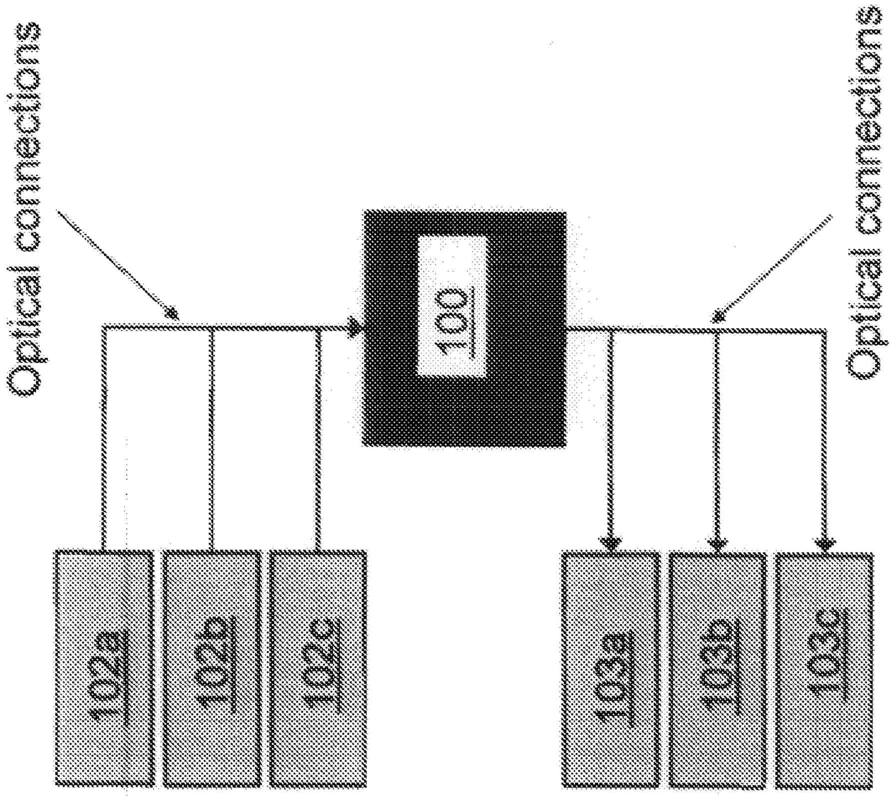
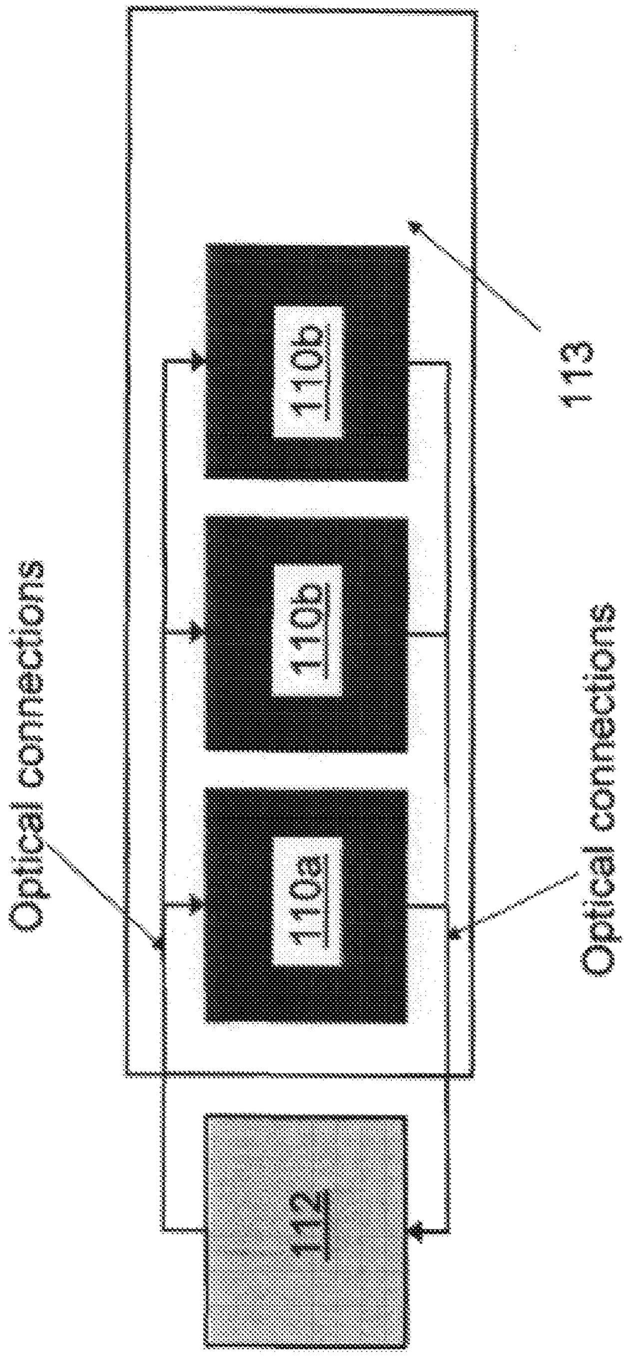

Optical connections
100
Optical connections
102a
102b
102c
103a
103b
103c

Fig. 12

Fig. 13


Optical connections
110a
110b
110b
113
Optical connections
112

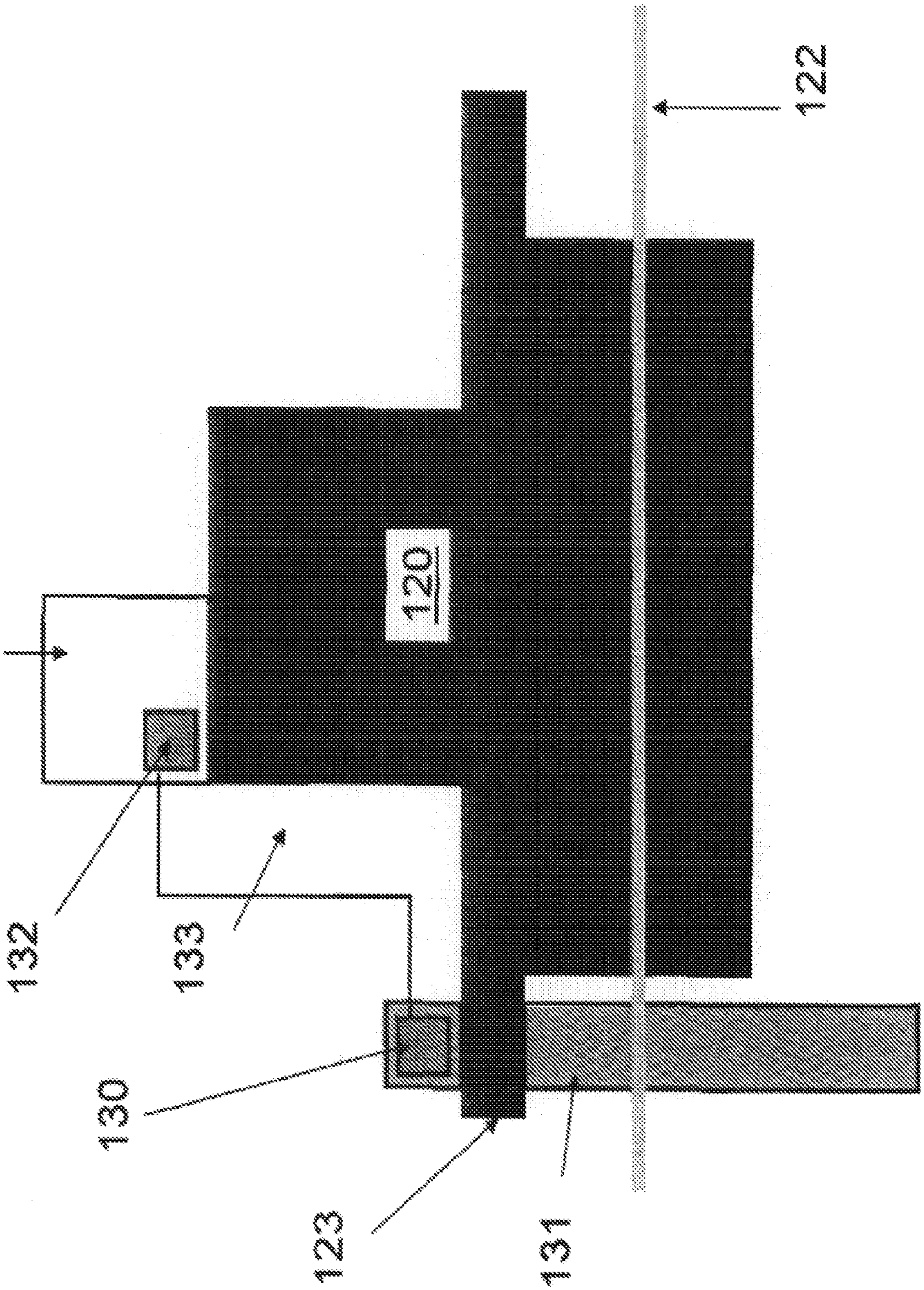


Fig. 14