AUSTRALIA

PATENTS ACT 1990

660069

NOTICE OF ENTITLEMENT

We, HONEYWELL INC., of Honeywell Plaza, Minneapolis, Minnesota 55408, United States of America, being the applicant in respect of an Application for an invention entitled:

"WAVELENGTH STABILIZATION"

state the following:-

1.   The person nominated for the grant of the patent has entitlement from the actual inventor/s by assignment.

2.   The person nominated for the grant of the patent has entitlement from the applicant/s of the application/s listed in the declaration under Article 8 of the PCT by assignment.

3.   The basic application/s listed in the declaration under Article 8 of the PCT is/are the first application/s made in a Convention country in respect of the invention.

For and on behalf of
HONEYWELL INC.

.......(Signature)   May 6, 1993
        (Signature)   (Date)

Name: ...John G. Shudy Jr.................

Title: ...Sr. Attorney...................

File: A42 13335 AU

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       WAVELENGTH STABILIZATION

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(56)   Prior Art Documents
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       EP C279603
       US 4485475

(57)   Claim

1.   An apparatus for providing a wavelength stabilized optical signal comprising:

       source means for providing a source optical signal, said source optical signal having a source optical signal power and a wavelength;

       splitting means for receiving said source optical signal and for splitting said source optical signal into a first optical signal having a first optical signal power and a second optical signal having a second optical signal power so that said source optical signal power is split by said splitting means between said first optical signal power and said second optical signal power, said split between said first optical signal power and said second optical signal power being dependent upon said wavelength of said source optical signal;

       a first light detecting diode having an anode and cathode for receiving said first optical signal and for providing a first detector signal indicative of said first optical signal power;

a second light detecting diode having an anode and a cathode for receiving said second optical signal and for providing a second detector signal indicative of said second optical signal power; and

control means comprising connecting means for connecting the anode of said first light detecting diode to said cathode of said second light detecting diode so that the first and second detector signals are subtracted from one another, said control means providing an output signal representing the difference between said first detector signal and said second detector signal which is transmitted to said source means for controlling said wavelength of said source optical signal in response to said first and second detector signals.

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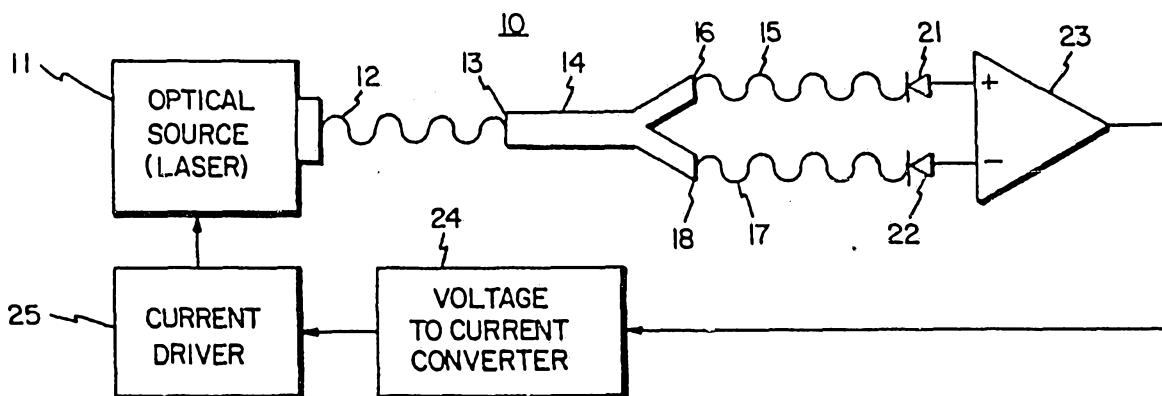
(57) Abstract

An optical source (11) emits a source optical signal (12) having a source optical signal power and a wavelength. A splitter (14) or other similar device splits the source optical signal into a first optical signal (15) having a first optical signal power and into a second optical signal (17) having a second optical signal power such that the source optical signal power is split between the first optical signal power and the second optical signal power. This split is dependent upon the wavelength of the source optical signal (11). A first detector (21) detects the first optical signal power and a second detector (22) detects the second optical signal power. A controller (25) responds to the first (21) and second (22) detectors in order to control the wavelength of the source optical signal (11).

WAVELENGTH STABILIZATION

Field of the Invention

5   The present invention relates to the
stabilization of the wavelength of an optical signal
emitted by an optical source such as a laser.

Background of the Invention

Optical sources, particularly broadband optical
10   sources such as semiconductor light sources, are used in a
variety of applications in which a stable wavelength of the
emitted optical signal is important. For example, in ring
laser and fiber optic gyroscope systems, a light source
emits a light beam which is split. The resulting two light
15   beams are then supplied to respective ends of an optical
path. The two beams counterpropagate along the optical
path, are recombined at the beam splitter and are received
by a detection system for detecting the phase difference
between the two counterpropagating light beams. If the
20   gyroscope is at rest, the path length around the optical
path is ideally the same for both light beams so that no
phase difference between the two light beams will be
detected. However, as the gyroscope rotates, the time that
is required for one beam to travel the path is different
25   than the time that is required for the other beam to
traverse the path. In effect, one of the beams will travel
a longer path than the other beam. Since the phases of the
two beams are a function of the time required to travel
their respective paths, any difference in that time between
30   the two light beams will result in a phase difference.

Rotation of the gyroscope does not affect the frequency (i.e. wavelength) of the optical signal. However, environmental changes, such as temperature changes, can influence the wavelength of the signal

5 supplied to the gyroscope by the optical source. Since the phase difference (i.e. phase shift) between the counterpropagating light beams is dependent upon wavelength as well as rotation, a constant wavelength is necessary so that the relationship between rotation and

10 phase difference is repeatable from measurement to measurement. Therefore, it is important to minimize the effects of these environmental changes on the wavelength of the source optical signal so that any changes in phase of the output optical signals is due to rotation

15 and not to changes in environmental conditions.

Summary of the Invention

The present invention provides an apparatus for providing a wavelength stabilized optical signal

20 comprising:

source means for providing a source optical signal, said source optical signal having a source optical signal power and a wavelength;

splitting means for receiving said source optical

25 signal and for splitting said source optical signal into a first optical signal having a first optical signal power and a second optical signal having a second optical signal power so that said source optical signal power is split by said splitting means between said

30 first optical signal power and said second optical signal power, said split between said first optical signal power and said second optical signal power being dependent upon said wavelength of said source optical signal;

35 a first light detecting diode having an anode and cathode for receiving said first optical signal and for providing a first detector signal indicative of said first optical signal power;
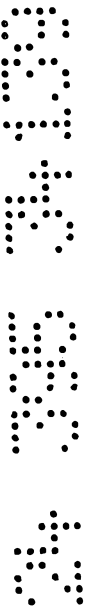
a second light detecting diode having a · anode
and a cathode for receiving said second optical signal
and for providing a second detector signal indicative of
said second optical signal power; and

5   control means comprising connecting means for
connecting the anode of said first light detecting diode
to said cathode of said second light detecting diode so
that the first and second detector signals are
subtracted from one another, said control means

10   providing an output signal representing the difference
between said first detector signal and said second
detector signal which is transmitted to said source
means for controlling said wavelength of said source
optical signal in response to said first and second

15   detector signals.

In one preferred form of the invention, the anode
of the first light detecting diode is connected to the
positive input of a differential amplifier and the anode
of the second light detecting diode may be connected to

20   the negative input of the differential amplifier.
(Alternatively, the cathodes of the first and second
light emitting diodes may be connected to the respective
positive and negative inputs of a differential
amplifier.) The differential amplifier provides an

25   output representative of the difference between the
first optical signal power and the second optical signal
power and is used for controlling the current supplied
to the optical source to in turn control the wavelength
of the source optical signal.

30   In another preferred form of the invention, the
anode of one light detecting diode and the cathode of
the other light detecting diode may be connected to a
common node. Since the currents flowing between the
node and the diodes will have opposite polarities, the

35   output current from the node represents the difference
of the currents of the two light detecting diodes and
thus represents the difference between the first optical
signal power and the ---------------------------------
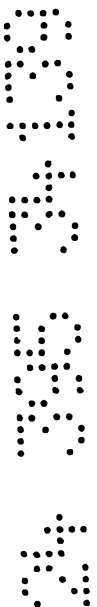
second optical signal power. The output current from the node is amplified if desired and used to control the current supplied to the optical source in order to control the wavelength of the source optical signal.

5   In yet another aspect of the invention, the first and second detectors may be used to control a temperature controller which in turn controls the temperature of the optical source. Since the wavelength of the optical source is temperature dependent, the control of the temperature of

10   the optical source will control the wavelength of the source optical signal.

Brief Description of the Drawings

These and other features and advantages will become more apparent from a detailed consideration of the

15   invention when taken in conjunction with the drawings in which:

Figure 1 shows a first embodiment of the wavelength stabilizing control system according to the present invention;

20   Figure 2 shows a second embodiment of a wavelength stabilization control system according to the present invention;

Figure 3 shows the current driver of Figures 1 and 2 in more detail; and,

25   Figure 4 shows a wavelength stabilization control system utilizing a temperature controller for controlling the wavelength of the source optical signal.

- 5 -

Detailed Description

Stabilization system 10, as shown in Figure 1,

comprises an optical source, such as later 11, for emitting

5   an optical signal 12, such as a light beam, having power

$P(\lambda)$. Optical signal 12 enters port 13 of an optical

component 14. Optical component 14 may be a WDM

(wavelength division multiplexer), a beam splitter, an

etalon, a grating, or the like. Optical component 14

10   splits the source optical signal 12 entering port 13 into a

first optical signal (or light beam) 15 exiting port 16 and

a second optical signal (or light beam) 17 exiting port 18.

The power contained in each of the optical signals 15 and

17 will be determined by the transmittance $T_1(\lambda)$ between

15   port 13 and port 16 and the transmittance $T_2(\lambda)$ between

port 13 and port 18 respectively. In the ideal case, $T_1(\lambda)$

and $T_2(\lambda)$ are complimentary and no transmission loss

occurs. Thus, $T_1(\lambda) + T_2(\lambda)$ is equal to 1. The

transmittance $T_1(\lambda)$ and $T_2(\lambda)$ of these devices are, as

20   indicated, dependent upon the wavelength λ. Accordingly,

the wavelength dependent output powers of .optical signals

15 and 17 are given by the following equations:

$$P_1(\lambda) = P_S(\lambda) \cdot T_1(\lambda) \tag{1}$$

and

25
$$P_2(\lambda) = P_S(\lambda) \cdot T_2(\lambda) \tag{2}$$

where $P_1(\lambda)$ represents the power of the source optical

signal 12 emitted from optical source 11, $P_1(\lambda)$ represents

the power of the first optical signal 15 exiting port 16 of

optical component 14, $P_2(\lambda)$ represents the power of the

second optical signal 17 exiting port 18 of optical

component 14, $T_1(\lambda)$ represents the transmittance of optical

component 14 between ports 13 and 16, $T_2(\lambda)$ represents the

transmittance of optical component 14 between ports 13 and

5   18, and the ⋆ symbol represents multiplication.

The total power of the first optical signal 15

which exits port 16 is given by the following equation:

$$P_1 = \int_\lambda P_1(\lambda)d\lambda \qquad (3)$$

The total power of the second optical signal 17

10   which exits port 18 is given by the following equation:

$$P_2 = \int_\lambda P_2(\lambda)d\lambda \qquad (4)$$

Ideally all light which enters the component 14 exits ports

16 and 18. Since the transmittance of the exit ports is a

function of wavelength of the source optical signal 12, a

15   greater or lesser portion of the source optical signal 12

will transmit through exit port 16 rather than exit port 18

dependent upon the wavelength of the source optical signal.

Thus, as the wavelength of the source optical signal 12

changes, the split between P_1 and P_2 will change.

20   The power in the first optical signal 15 is

sensed by detector 21 which may be a light detecting diode.

Similarly, the power in the second optical signal 17 is

sensed by detector 22 which also may be a light detecting

diode. The anode of light detecting diode 21 is connected

25   to the positive input of differential amplifier 23 and the

anode of light detecting diode of 22 is connected to the

negative input of differential amplifier 23. Light

detecting diode 21 produces an output current which is

converted to a voltage by the differential amplifier 23
according to the following equation:

$$V_1 = K_1 * P_1 \qquad (5)$$

where V_1 is the voltage produced by light detecting diode

5   21 and K_1 is a constant which incorporates light detector
efficiencies and electrical gairs. Similarly, light
detecting diode 22 produces an output current which is
converted to a voltage by the differential amplifier 23
according to the following equation:

10      $$V_2 = K_2 * P_2 \qquad (6)$$

where V_2 is the voltage produced by light detecting diode
22 and K_2 is a constant which incorporates light detector
efficiencies and electrical gain. Differential amplifier
23 will provide an output signal representing the

15 difference between V_1 and V_2. This output signal is
connected to voltage to current converter 24 which converts
the output voltage from differential amplifier 23 to a
current signal. This current signal is supplied to current
driver 25. Current driver 25 responds to the current from

20 voltage to current converter 24 so as to control the
current supplied to optical source 11 to in turn control
the wavelength of the source optical signal 12.

Light detecting diodes 21 and 22 may be selected
so that constants K_1 and K_2 are equal. If so, current

25 driver 25 is initially arranged to provide a current to
optical source 11 such that the power of source optical
signal 12 is evenly divided by optical component 14 between
the power of first optical signal 15 and the power of
second optical signal 17. When the power of the source

optical signal 12 is evenly divided between the powers of
first and second optical signals 15 and 16, light detecting
diodes 21 and 22 will supply equal voltages to the
respective positive and negative inputs of differential
5   amplifier 23. Thus, the output of differential amplifier
23 is 0 and no adjustment will be made to current driver
25. On the other hand, if optical source 11 experiences
fluctuations of either the injection current or the
environmental temperature, the wavelength of source optical
10   signal 12 will change. This change in wavelength of source
optical signal 12 will result in an unequal division of
power between first optical signal 15 and second optical
signal 17 which will result in unequal currents being
supplied by light detecting diodes 21 and 22 to the inputs
15   of differential amplifier 23. Accordingly, differential
amplifier 23 will supply a non-zero output to voltage to
current converter 24 which will convert that non-zero
voltage to a current output. Current driver 25 will
respond to this current from voltage to current converter
20   24 to adjust the injection current supplied to optical
source 11 to bring the wavelength of source optical signal
12 back to a value which produces a zero output from
differential amplifier 23.

Alternatively, if light detecting diodes 21 and
25   22 are not matched (i.e. constants K_1 and K_2 are not
equal), an injection current may be initially supplied to
optical source 11 so that, although the power of source
optical signal 12 is unevenly split between first optical
signal 15 and second optical signal 17, the light detecting

diodes 21 and 22 will supply equal voltages to differential

amplifier 23. In this case, as long as the wavelength of

the initial source optical signal 12 does not change, no

adjustment to the injection current of optical source 11

5   will be made. However, if the wavelength of the source

optical signal 12 changes for any reason, the output of

differential amplifier 23 will become non-zero which will

result in a current output from voltage to current

converter 24. This current output will be used by current

10   driver 25 to alter the injection current supplied to

optical source 11 to bring the wavelength back to its

initial value.

        Instead of selecting an initial injection current

(and, therefore, an initial source optical signal

15   wavelength) to produce a zero voltage output from

differential amplifier 23, voltage to current converter 24

can be initially arranged so that it supplies a zero output

current driver 25 at the desired wavelength of optical

signal 12 even though differential amplifier 23 supplies a

20   non-zero voltage output. If the wavelength of the source

optical signal 12 changes for any reason, the output of

voltage to current converter 24 will become non-zero which

will result in correction of the wavelength of source

optical signal 12 until that wavelength is again at the

25   desired value.

        Figure 2 shows an alternative which eliminates

the need for a differential amplifier. In this case, the

anode of light detecting diode 21 and the cathode of light

detecting diode 22 are connected to node 27. With this

arrangement, the current flowing between light detecting

diode 21 and node 27 will be of one polarity while the

current flowing through light detecting diode 22 and node

27 will be of an opposite polarity. Thus, the current in

5   line 28 represents the difference between these currents

and, therefore, the difference in power between optical

signals 15 and 17. This difference current may be

amplified by an amplifier 26, if desired, and the resulting

voltage supplied to voltage to current converter 24.

10   As shown in Figure 3, current driver 25 may

include a summing junction 25' which will receive a current

on input 29 equal to an initial injection current selected

to provide the desired wavelength for optical signal 12.

The output from voltage to current converter 24 is

15   connected to input 30 of summing junction 25'. Thus, any

signal on input 30 acts as an error signal indicating that

the wavelength of source optical signal 12 has drifted from

its desired value. In this case, the error on input 30

will adjust the injection current in line 31 being supplied

20   to optical source 11 to bring the wavelength of source

optical signal 12 back to its desired value.

Alternatively, a desired wavelength may be selected which

will produce an error signal at input 30 having a

predetermined non-zero value. Thus, when this

25   predetermined non-zero value is combined with the current

at input 29, optical signal 12 will have the desired

wavelength. However, any variation in wavelength of

optical signal 12 will change the error signal away from

its predetermined non-zero value, and thus change the

- 11 -

current at output 31, until optical signal 12 regains its
desired wavelength.

    As shown in Figure 4, instead of controlling the
injection current supplied to optical source 11, the

5   temperature of optical source 11 may be controlled in order
to in turn control the wavelength of source optical signal
12. In this case, voltage to current converter 24 and
current driver 25 shown in Figures 1 and 2 are replaced by
temperature controller 40. Temperature controller 40

10   receives the output from difference circuit 41 in order to
adjust the temperature of optical source 11 to control the
wavelength of source optical signal 12. Difference circuit
41 may represent either differential amplifier 23 of Figure
1, node 27 of Figure 2, or any other arrangement for

15   providing an output to temperature controller 40 based upon
the difference in power between first and second opt ʒal
signals 15 and 17.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1.   An apparatus for providing a wavelength stabilized optical signal comprising:

    source means for providing a source optical signal, said source optical signal having a source optical signal

5   power and a wavelength;

    splitting means for receiving said source optical signal and for splitting said source optical signal into a first optical signal having a first optical signal power and a second optical signal having a second optical signal

10   power so that said source optical signal power is split by said splitting means between said first optical signal power and said second optical signal power, said split between said first optical signal power and said second optical signal power being dependent upon said wavelength

15   of said source optical signal;

    a first light detecting diode having an anode and cathode for receiving said first optical signal and for providing a first detector signal indicative of said first optical signal power;

20   a second light detecting diode having an anode and a cathode for receiving said second optical signal and for providing a second detector signal indicative of said second optical signal power; and

    control means comprising connecting means for

25   connecting the anode of said first light detecting diode to said cathode of said second light detecting diode so that the first and second detector signals are subtracted from one another, said control means providing an output signal representing the difference between said first

30   detector signal and said second detector signal which is transmitted to said source means for controlling said wavelength of said source optical signal in response to said first and second detector signals.

2.   The apparatus of claim 1 wherein said control means

35   further comprises current control means connected to said connecting means and to said source means, said current control means being responsive to said output signal representing said difference between said first detector signal and said second detector signal for -----------

controlling current supplied to said source means in order to control said wavelength of said source optical signal.

3.   The apparatus of claim 2 wherein said output signal is a voltage signal and wherein said current control means comprises a voltage to current converter means for converting said voltage signal to a current signal, said control means being responsive to said current signal for controlling said current supplied to said source means in order to control said wavelength of said source optical signal.

4.   The apparatus of claim 2 wherein said current control means comprises a first input for receiving a current input, a second input for receiving an error input dependent upon said output signal, and an output for providing a source control signal dependent upon said current input and said error input, said output of said current control means being connected to said source means for controlling said wavelength of said source optical signal as a function of said source control signal.

5.   The apparatus of claim 4 wherein said output signal is a voltage signal and wherein said current control means further comprises a voltage to current converter connected to said connecting means and to said second input of said current control means for converting said voltage signal to a current which is connected to said current control means as said error input.
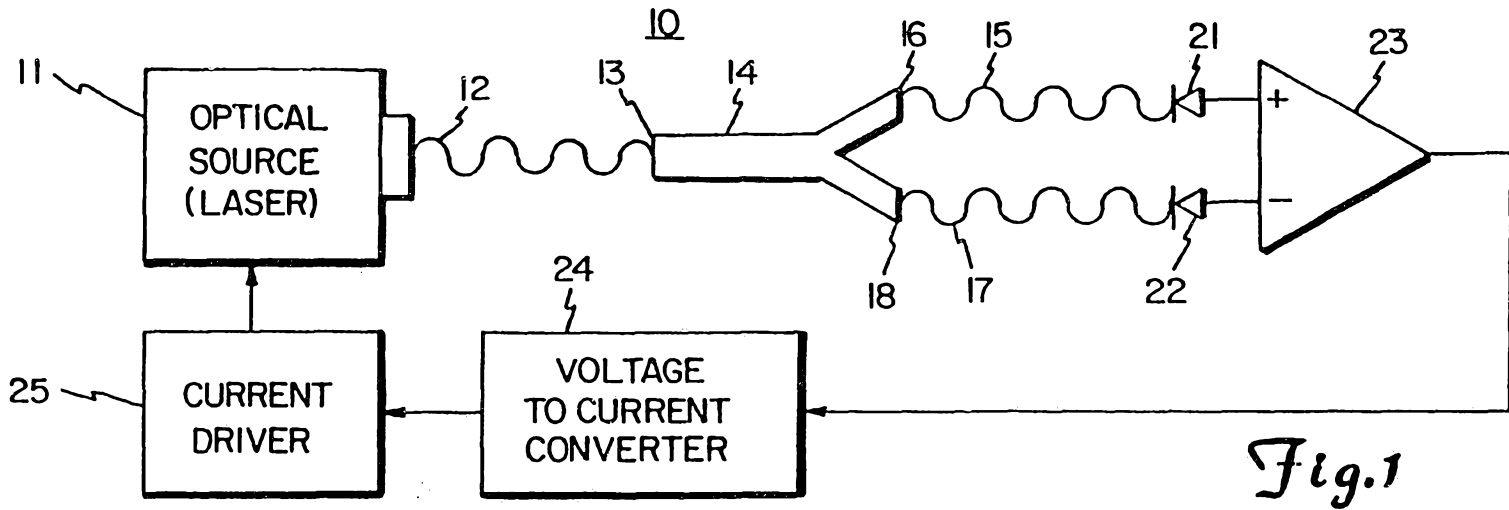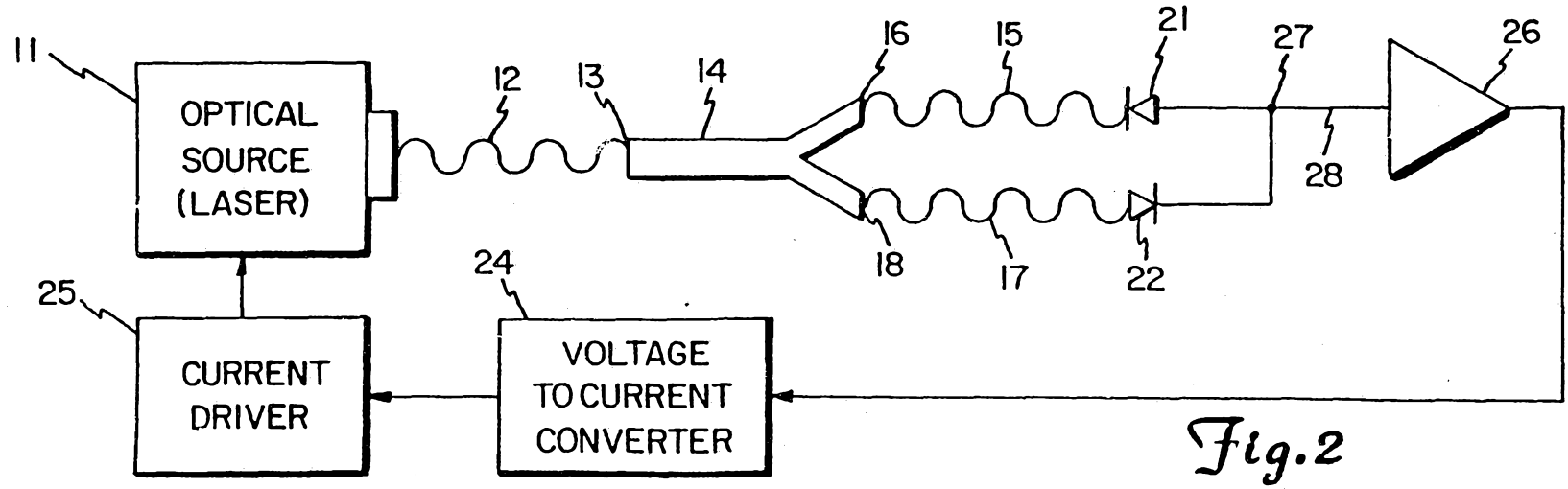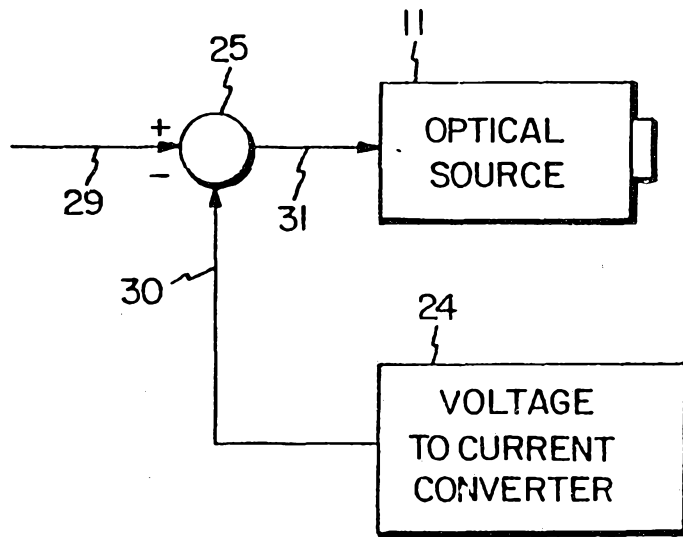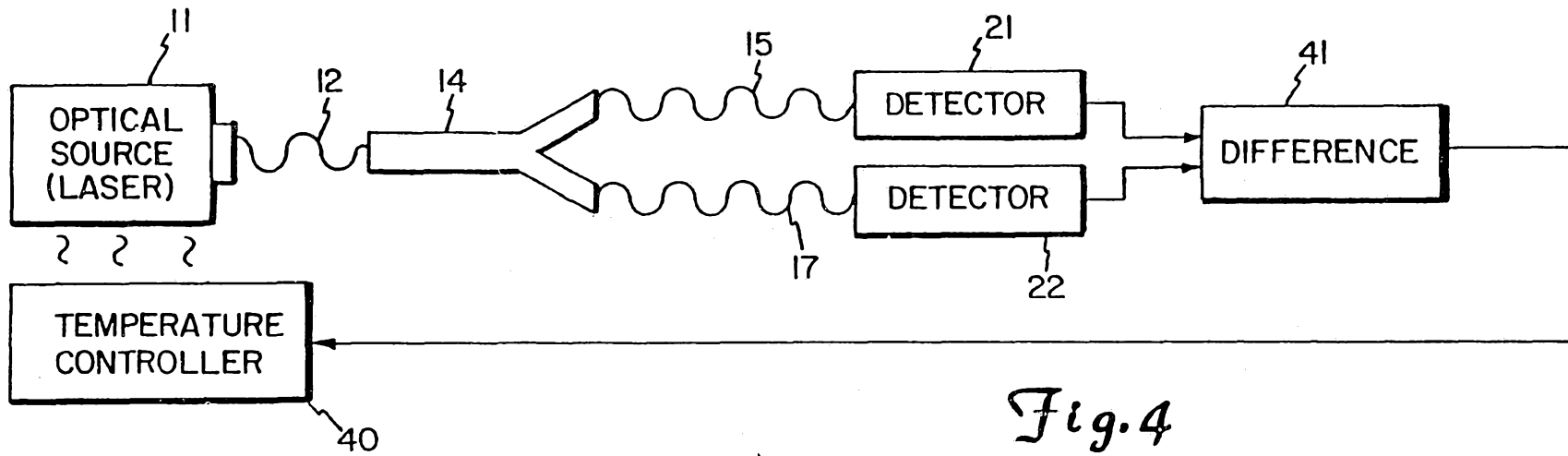
25

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34139/93

11 — OPTICAL SOURCE (LASER)

12

13

14

10

16

15

21

23

+

−

18

17

22

25 — CURRENT DRIVER

24 — VOLTAGE TO CURRENT CONVERTER

Fig.1

11 — OPTICAL SOURCE (LASER)

12

13

14

16

15

21

27

26

18

17

22

28

25 — CURRENT DRIVER

24 — VOLTAGE TO CURRENT CONVERTER

Fig.2

Fig. 3

Fig. 4

I. CLASSIFICATION OF SUBJECT MATTER   (if several classification symbols apply, indicate all)⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H01S3/133

II. FIELDS SEARCHED

Minimum Documentation Searched⁷

Classification System	Classification Symbols
Int.Cl. 5	H01S

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category°	Citation of Document,¹¹ with indication, where appropriate, of the relevant passages¹²	Relevant to Claim No.¹³
X	EP,A,0 415 407 (NEC) 6 March 1991 see abstract; claims 1-10; figures 1-4 ---	1-4,6,8, 9,11-15, 17-19
X	PATENT ABSTRACTS OF JAPAN vol. 8, no. 190 (E-263)(1627) 31 August 1984 & JP,A,59 078 587 (TOSHIBA) 7 May 1984 see abstract ---	1,2,5, 10,13, 16,19
X	EP,A,0 279 603 (LITTON SYSTEMS) 24 August 1988 see abstract; figures 1,2 ---	1-4,6,8, 9,11, 13-15, 17,19
	-/--	

° Special categories of cited documents :¹⁰

"A" document defining the general state of the art which is not considered to be of particular relevance

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
25 MARCH 1993	2 2. 04. 93

International Searching Authority	Signature of Authorized Officer
EUROPEAN PATENT OFFICE	MALIC K.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	US,A,4 485 475 (S.C.LARGE ET AL.) 27 November 1984 see abstract; figure 1 -----	1,12,13, 18,19

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0415407	06-03-91	JP-A-	3089575	15-04-91
		US-A-	5107512	21-04-92
EP-A-0279603	24-08-88	US-A-	4842358	27-06-89
		CA-A-	1301510	26-05-92
		JP-A-	63233582	29-09-88
US-A-4485475	27-11-84	None		

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82