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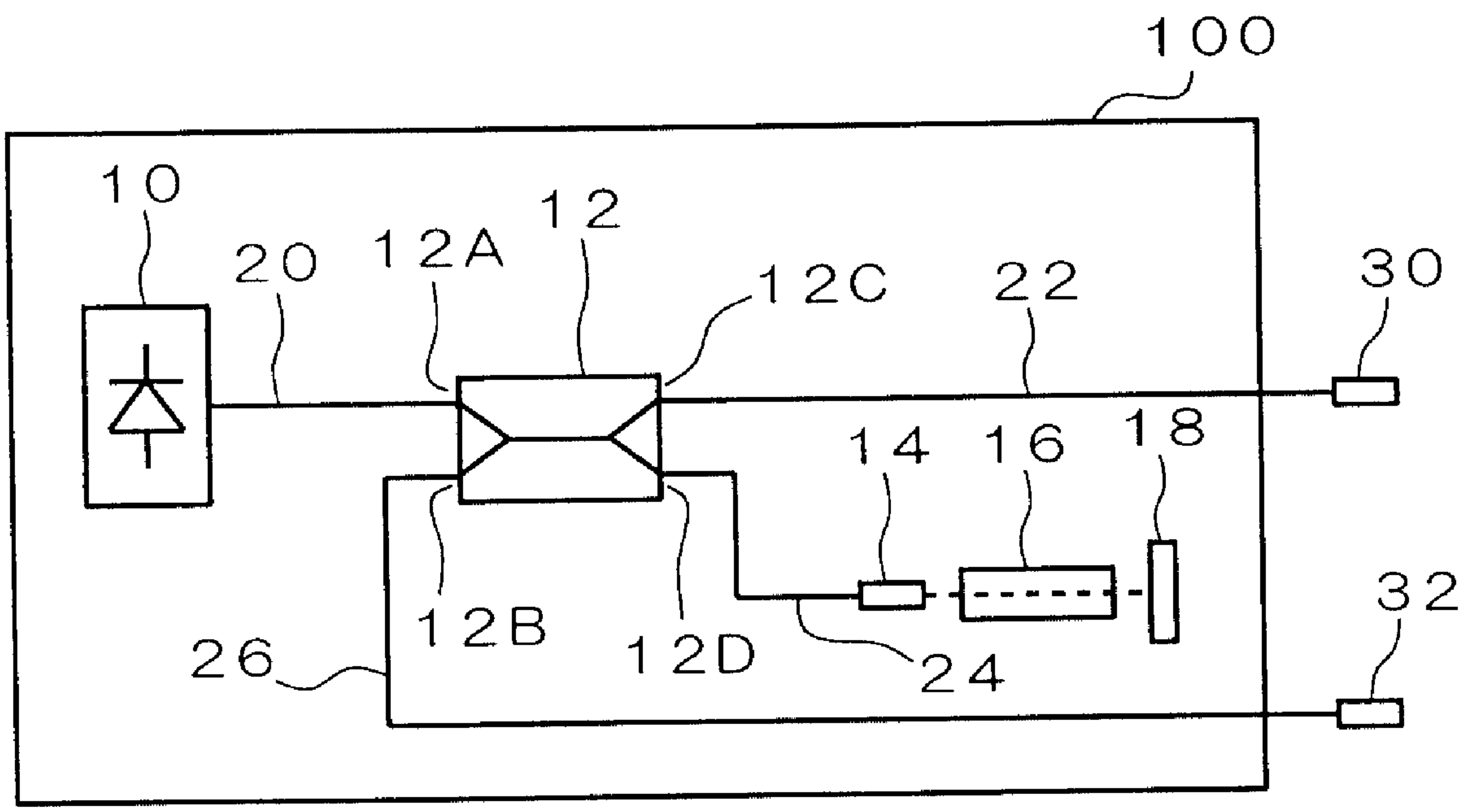
(54) Title: REFERENCE WAVELENGTH LIGHT GENERATING APPARATUS



(57) Abrégé/Abstract:
A reference wavelength light generating apparatus is disclosed in which light emitted by a light source is split into two beams by a beam splitter. One of the two beams is extracted as a measuring beam. The other beam is extracted as reference wavelength light after passage through a collimator and a band-stop filter and after being reflected back toward and through the beam splitter.

Abstract of the Disclosure

A reference wavelength light generating apparatus is disclosed in which light emitted by a light source is split into two beams by a beam splitter. One of the two beams is extracted as a measuring beam. The other beam is extracted as reference wavelength light after passage through a collimator and a band-stop filter and after being reflected back toward and through the beam splitter.

REFERENCE WAVELENGTH LIGHT GENERATING APPARATUS

Technical Field

This invention relates to apparatus for generating light of a predetermined reference wavelength for use in an optical spectrum analyzer, etc.

Background

Instruments such as optical spectrum analyzers which perform various measurements using a predetermined measuring beam often display measurement results in graphical form by plotting wavelength on a horizontal axis and plotting detection levels on a vertical axis. There are situations in which wavelength values plotted on the horizontal axis deviate over time, due to environmental factors such as temperature. For this reason, wavelength values are calibrated to the horizontal axis using reference wavelength light having wavelength corresponding to a known absorption spectrum. The apparatus for generating reference wavelength light used in such calibrations is called "reference wavelength light generating apparatus".

Figure 9 depicts the typical configuration of a prior art reference wavelength light generating apparatus as used in an optical spectrum analyzer, etc. Reference wavelength light generating apparatus 200 shown in Figure 9 simultaneously generates predetermined reference wavelength light used for calibration; and, a predetermined measuring beam used for measurement; and is comprised of two light sources 210, 240, two fiber collimators 212, 214 and an optical cell 216.

Light sources 210, 240 may be formed by using an edge emitting type LED for instance. Light source 210 produces a reference wavelength light beam which is emitted through optical fiber 220 into fiber collimator 212 for collimation into parallel light rays. Such parallel rays pass through optical cell 216 which functions as a band-stop filter by absorbing predetermined wavelength components. The remaining, non-absorbed light rays are output from optical cell 216 into fiber collimator 214, which re-collimates the light rays. The light rays are then emitted through optical fiber 222 to reference wavelength light optical output coupler 230. Light source 240 produces a measurement beam which is emitted through optical fiber 224 to measurement beam optical output coupler 252.

It is difficult to adjust the Figure 9 prior art apparatus with fiber collimators 212, 214 sandwiching optical cell 216. To ensure that the parallel light rays emitted by fiber collimator 212 are properly coupled into fiber collimator 214, one must adjust the horizontal and vertical positions of the two fiber collimators, as well as their respective angles of inclination. This involves many interdependent adjustments of angular, horizontal and vertical positions, which must be made simultaneously. It is difficult to perform the desired adjustments accurately.

A further disadvantage of the Figure 9 prior art apparatus is that light sources 210, 240 and fiber collimators 212, 214 are relatively expensive components, thereby increasing production costs. For example, SELFOC™ lenses, which are relatively expensive parts, are typically used, with one such lens being coupled to each end of optical fibers 220, 222 adjacent collimators 212, 214.

Summary of Invention

The invention provides a reference wavelength light generating apparatus which reduces adjustment time and effort and facilitates cost reduction by reducing the required number of expensive parts.

In accordance with a first embodiment, the invention provides a reference wavelength light generating apparatus incorporating a light source which produces a source light beam having a predetermined wavelength range, a band-stop filter which absorbs a predetermined wavelength component of incident light, a reflector which reflects light emitted from the band-stop filter back toward and through the band-stop filter, a beam splitter, and a collimator which is optically coupled between the beam splitter and the band-stop filter. The beam splitter splits the source light beam into first and second light beams, and directs the first light beam toward the band-stop filter. The beam splitter also splits the light which is reflected back toward and through the band-stop filter into third and fourth light beams, and directs the third light beam back toward the light source. The second light beam is emitted as a measuring beam and the fourth light beam is emitted as reference wavelength light.

In accordance with a second embodiment, the invention again provides a reference wavelength light generating apparatus incorporating a light source which produces a source light beam having a predetermined wavelength range, a band-stop filter which absorbs a predetermined wavelength component of incident light, a reflector which reflects light emitted from the band-stop filter back toward and through the band-stop filter, a beam splitter, and a collimator which is optically coupled between the beam splitter and the band-stop filter. In the second embodiment, the beam splitter emits the source light beam toward the band-stop filter as a first light beam. The beam splitter also splits the light which is reflected back toward and through the band-stop filter into second and third light beams, and directs the second light beam back toward the light source. The third light beam is emitted as reference wavelength light.

Advantageously, and in either embodiment, the light source is an edge emitting type LED and the collimator is a SELFOC™ lens.

Preferably, the beam splitter in the first embodiment has a light power splitting ratio whereby the second light beam has higher light power than the first light beam. In the second embodiment, the beam splitter's light power splitting ratio is preferably such that the remainder of the source light beam excepting the portion thereof constituting the first light beam has higher light power than the first light beam.

Brief Description of Drawings

Figure 1 is a block diagram depiction of a reference wavelength light generating apparatus in accordance with a first embodiment of the invention;

Figure 2 graphically depicts the characteristics of light emitted by the light source;

Figure 3 graphically depicts the characteristics of light emitted by the measurement beam optical output coupler;

Figure 4 graphically depicts the characteristics of light emitted by the reference wavelength light optical output coupler;

Figure 5 graphically depicts an absorption spectrum generated by light passing through the optical cell;

Figure 6 tabulates acetylene gas absorption spectrum values;

Figure 7 is a block diagram depiction of a reference wavelength light generating apparatus in accordance with a second embodiment of the invention;

Figure 8 tabulates cyanide gas absorption spectrum values; and

Figure 9 is a block diagram depiction of a prior art reference wavelength light generating apparatus.

Description

Throughout the following description specific details are set forth in order to provide a more thorough understanding of the invention. However, the invention may be practiced without these particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the present invention. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

Figure 1 depicts a first embodiment of the invention. Reference wavelength light generating apparatus 100 shown in Figure 1 can be included in various measuring apparatuses such as optical spectrum analyzers. Apparatus 100 simultaneously produces a predetermined reference wavelength light beam used for calibration; and, a predetermined measurement beam used for measurement. Apparatus 100 incorporates light source 10, light coupler (beam splitter) 12, fiber collimator 14, optical cell (band-stop filter) 16 and plane mirror 18.

Light source 10 may for example be formed by using an edge emitting type LED which emits a relatively wide wavelength range light band having a peak wavelength of about 1.55μm.

Beam splitter 12 has four input-output terminals 12A, 12B, 12C and 12D. Light emitted into either one of input-output terminals 12A or 12B is split in a predetermined ratio by beam splitter 12 and emitted through input-output terminals 12C and 12D. Similarly, light emitted into either one of input-output terminals 12C or 12D is split in a predetermined ratio by beam splitter 12 and emitted through input-output terminals 12A and 12B.

Light emitted by light source 10 passes through optical fiber 20 to input-output terminal 12A, and is partially emitted through input-output terminal 12C. Input-output terminal 12C is coupled through optical fiber 22 to measurement beam optical output coupler 30. Accordingly, light emitted from input-output terminal 12C is directly extracted as a measurement light beam from optical coupler 30. The remainder of the incident light applied to input-output terminal 12A is emitted through input-output terminal 12D. Input-output terminal 12D is coupled through optical fiber 24 to fiber collimator 14. Accordingly, light emitted from input-output terminal 12D coupled to fiber collimator

14; and, light emitted from fiber collimator 14 into optical fiber 24 is returned to and coupled to input-output terminal 12D.

The light thus returned to and coupled to input-output terminal 12D is partially emitted through input-output terminal 12B. Input-output terminal 12B is coupled through optical fiber 26 to reference wavelength light optical output coupler 32. Accordingly, light emitted from input-output terminal 12B is directly extracted as a reference wavelength light beam from optical coupler 32.

Fiber collimator 14 is affixed to one end of optical fiber 24, converts light emitted from this end into parallel rays and emits such rays into one side of band-stop filter 16. Fiber collimator 14 also gathers parallel light rays emitted from the aforementioned side of band-stop filter 16 and emits such rays them into the aforementioned end of optical fiber 24 for return to beam splitter 12. A SELFOC™ lens, for instance, can be used for fiber collimator 14.

Band-stop filter 16 may be an absorption cell in which acetylene gas is sealed. Band-stop filter 16 absorbs predetermined wavelength components of the light which passes through it.

Plane mirror (reflector) 18 is positioned opposite fiber collimator 14 with band-stop filter 16 sandwiched between them, to reflect parallel light rays which pass through band-stop filter 16 back toward and through band-stop filter 16. The reflection surface of mirror 18 constitutes a notional X-Y plane which can be oriented perpendicularly with respect to the direction of the incident parallel light rays. The mirror's rotation angles about the respective X and Y axes are independently adjustable, thus allowing the reflected light to be returned precisely in the direction of the incident light.

It can thus be seen that, in operation, light emitted by light source 10 is split into first and second light beams by beam splitter 12. The first light beam is coupled through optical fiber 24 to fiber collimator 14, which collimates the light. The light then passes through band-stop filter 16, which absorbs a predetermined wavelength component of the first light beam. The light is then reflected by mirror 18 back toward and through band-stop filter 16 and is returned through optical fiber 24 to beam splitter 12. The second light beam is coupled through optical fiber 24 to optical coupler 30 for extraction as a measurement light beam. The light which returns through optical fiber 24 to beam splitter 12 is split into third and fourth light beams by beam splitter 12. The third light beam is directed back toward light source 10. The fourth light beam is coupled through optical fiber 26 to optical coupler 32 for extraction as a reference wavelength light beam.

Figure 2 graphically depicts the characteristics of light emitted by light source 10. The horizontal and vertical axes correspond to wavelength and light intensity respectively. As Figure 2 shows, the wavelength of the light emitted by light source 10 peaks at about 1550nm and gradually attenuates at wavelengths farther from the peak position.

Figure 3 graphically depicts the characteristics of the light extracted from optical coupler 30 as the measurement light beam. This is the light emitted by light source 10 after attenuation by passage through beam splitter 12, so its characteristics are basically the same as those shown in Figure 2.

Figure 4 graphically depicts the characteristics of the light extracted from optical coupler 32 as the reference wavelength light beam. This is the light emitted from light source 10 after attenuation by passage to and fro through beam splitter 12 and after selective wavelength absorption passage to and fro through band-stop filter 16.

Figure 5 graphically depicts, on an enlarged wavelength scale in comparison to the wavelength scales of Figures 2-4, the absorption spectrum of light passing through band-stop filter 16. Figure 6 tabulates the absorption spectrum values. The absorption spectrum shown in Figure 5 can be roughly divided into two groups, with the left hand group being called the "R branch" and the right hand group being called the "P branch". Figure 6 shows the absorption spectrum peaks for the P branch in increasing order of wavelength. Since the wavelengths of these peaks do not fluctuate substantially with changes in environmental factors such as temperature, apparatus 100 is suitable for use in an optical spectrum analyzer in order to calibrate the wavelength axes (horizontal axes) of various measurement results.

As previously explained, apparatus 100 uses mirror 18 to reflect parallel rays emitted from band-stop filter 16 back toward and through band-stop filter 16. Since it is only necessary to reflect the parallel light rays in the incident direction, it is sufficient to adjust the inclination of mirror 18. Such adjustments are easily made, in comparison to the difficult multiple adjustments which must be made to prior art apparatus 200 of Figure 9 as previously explained.

It will also be noted that apparatus 100 significantly reduces production costs by requiring only a single light source 10 and a single fiber collimator 16, whereas prior art apparatus 200 requires two light sources 210, 240 and two collimators 212, 214. Although apparatus 100 utilizes plane mirror 18 and beam splitter 12 which are not required by prior art apparatus 200, these are relatively low-cost components in comparison to edge emitting type LEDs (the typically used light source) and SELFOC lenses (the typically used collimator), so there is still a significant reduction in overall production cost.

A further advantage of the invention is that apparatus 100 passes the light through band-stop filter 16 twice (i.e. after reflection by mirror 18). This allows the length of band-stop filter 16 to be halved without reducing its attenuation capability, thereby facilitating an overall reduction in the size of apparatus 100. By contrast, the light passes only once through band-stop filter 216 of prior art apparatus 200, so there is no comparable opportunity for size reduction.

It is preferable to configure the light power splitting ratio of beam splitter 12 so that the second light beam (i.e. that emitted at input-output terminal 12C) has higher light power than the first light beam (i.e. that emitted at input-output terminal 12D), rather than having equal light power in both beams. In particular, if apparatus 100 is used in an optical spectrum analyzer, it is preferable to increase the power of the measuring beam emitted from optical coupler 30. It is according desirable to minimize attenuation losses in beam splitter 12. No inconvenience results if the reference wavelength light beam emitted from optical coupler 32 has low power, since that beam serves only as a wavelength reference. Considering these points, it is preferable to configure the light power splitting ratio of beam splitter 12 at about 90:10 (90% of the light power output in the second light beam and 10% in the first light beam); or 80:20.

If such preferred light power splitting ratios are employed, the light emitted at input-output terminal 12D in turn results in a reduction of the power of the light returned to light source 10 via input-output terminal 12A (i.e. it becomes 1/10 or 1/5 of the power of the light emitted at input-output terminal 12D). This in turn prevents light source 10 from becoming unstable and generating a ripple within a predetermined wavelength range (ideally light source 10 produces light having a flat, ripple-free spectrum).

The present invention is not limited to the above-described embodiment. For instance, while apparatus 100 simultaneously produces both a reference wavelength light beam and a measuring beam, the invention can alternatively be configured to produce only a reference wavelength light beam, as shown in Figure 7.

Figure 7 depicts apparatus 100A which produces only reference wavelength light. Apparatus 100A is equivalent to the Figure 1 apparatus 100, with optical fiber 22 and measurement light beam optical coupler 30 eliminated. Thus, even if only reference wavelength light is to be produced, the above-described advantages of ease of adjustment and reduced size of the apparatus due to use of a shorter band-stop filter 16 remain unchanged.

Instead of using a band-stop filter 16 containing acetylene gas, one may alternatively use a band-stop filter containing a different gas such as hydrogen cyanide (HCN).

Figure 8 tabulates cyanide gas absorption spectrum values. As in case of band-stop filter 16 containing acetylene gas, the absorption spectra obtained using cyanide gas can be roughly divided into two groups. Figure 8 shows absorption spectra peaks for the previously defined P branch.

As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the scope thereof. Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.

WHAT IS CLAIMED IS:

1. Reference wavelength light generating apparatus, comprising:
a light source for producing a source light beam having a predetermined wavelength range;
a band-stop filter for absorbing a predetermined wavelength component of light incident upon said band-stop filter;
a reflector for reflecting light emitted from said band-stop filter back toward and through said band-stop filter;
a beam splitter for:
(i) splitting said source light beam into first and second light beams and for directing said first light beam toward said band-stop filter;
(ii) splitting said light reflected back toward and through said band-stop filter into third and fourth light beams and for directing said third light beam back toward said light source; and,
a collimator optically coupled between said beam splitter and said band-stop filter;
wherein said second light beam is emitted as a measuring beam and said fourth light beam is emitted as reference wavelength light.

2. Reference wavelength light generating apparatus according to claim 1, wherein said light source is an edge emitting type LED and said collimator is a SELFOC lens.

3. Reference wavelength light generating apparatus according to claim 1, wherein said beam splitter has a light power splitting ratio whereby said second light beam has higher light power than said first light beam.

4. Reference wavelength light generating apparatus comprising:
a light source for producing a source light beam having a predetermined wavelength range;
a band-stop filter for absorbing a predetermined wavelength component of light incident upon said band-stop filter;
a reflector for reflecting light emitted from said band-stop filter back toward and through said band-stop filter;
a beam splitter for:
(i) emitting said source light beam toward said band-stop filter as a first light beam;
(ii) splitting said light reflected back toward and through said band-stop filter into second and third light beams and for directing said second light beam back toward said light source; and,
a collimator optically coupled between said beam splitter and said band-stop filter;
wherein said third light beam is emitted as reference wavelength light.

5. Reference wavelength light generating apparatus according to claim 4, wherein said light source is an edge emitting type LED and said collimator is a SELFOC lens.

6. Reference wavelength light generating apparatus according to claim 4, wherein said beam splitter has a light power splitting ratio whereby the remainder of said source light beam excepting the portion thereof constituting said first light beam has higher light power than said first light beam.

7. A method of producing reference wavelength light for a light source which produces a source light beam having a predetermined wavelength range, said method comprising:
   (a) splitting said source light beam into first and second light beams;
   (b) filtering said first light beam through a band-stop filter to absorb a predetermined wavelength component of said first light beam;
   (c) reflecting said filtered first light beam back toward and through said band-stop filter;
   (d) splitting said light reflected back toward and through said band-stop filter into third and fourth light beams;
   (e) emitting said second light beam as a measuring beam; and,
   (f) emitting said fourth light beam as reference wavelength light.

8. A method as defined in claim 7, further comprising directing said third light beam back to said light source.

9. A method as defined in claim 7, wherein said second light beam has higher light power than said first light beam.

10. A method of producing reference wavelength light for a light source which produces a source light beam having a predetermined wavelength range, said method comprising:
   (a) filtering a first light beam portion of said source light beam through a band-stop filter to absorb a predetermined wavelength component of said source light beam;
   (b) reflecting said filtered first light beam back toward and through said band-stop filter;

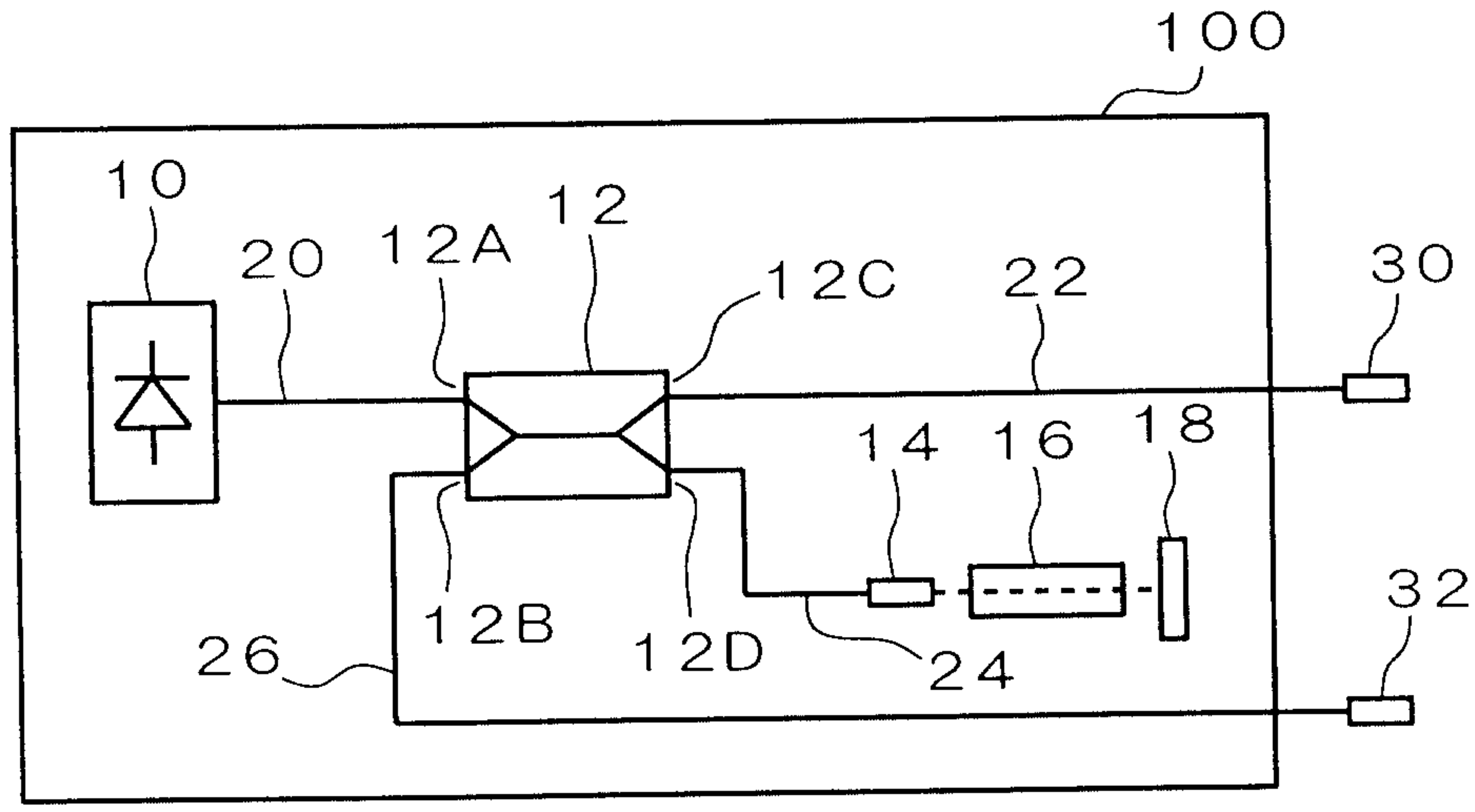
(c) splitting said light reflected back toward and through said band-stop filter into second and third light beams; and,

(d) emitting said third light beam as reference wavelength light.

11. A method as defined in claim 10, further comprising directing said second light beam back to said light source.

12. A method as defined in claim 10, wherein the remainder of said source light beam excepting the portion thereof constituting said first light beam has higher light power than said first light beam.

F/G. 1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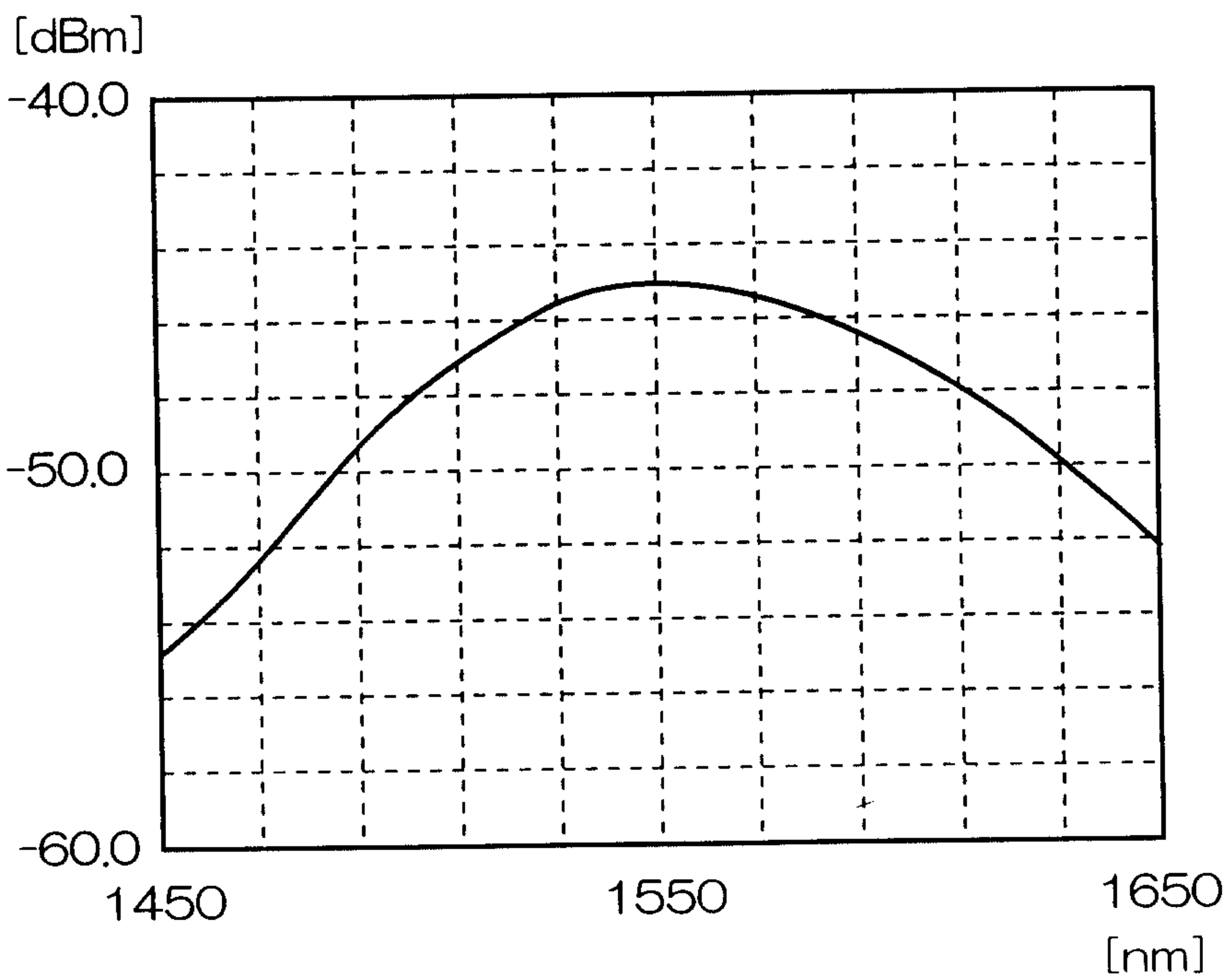
10
20
12A
12
12C
22
30
14
16
18
12B
12D
24
26
32

F/G. 2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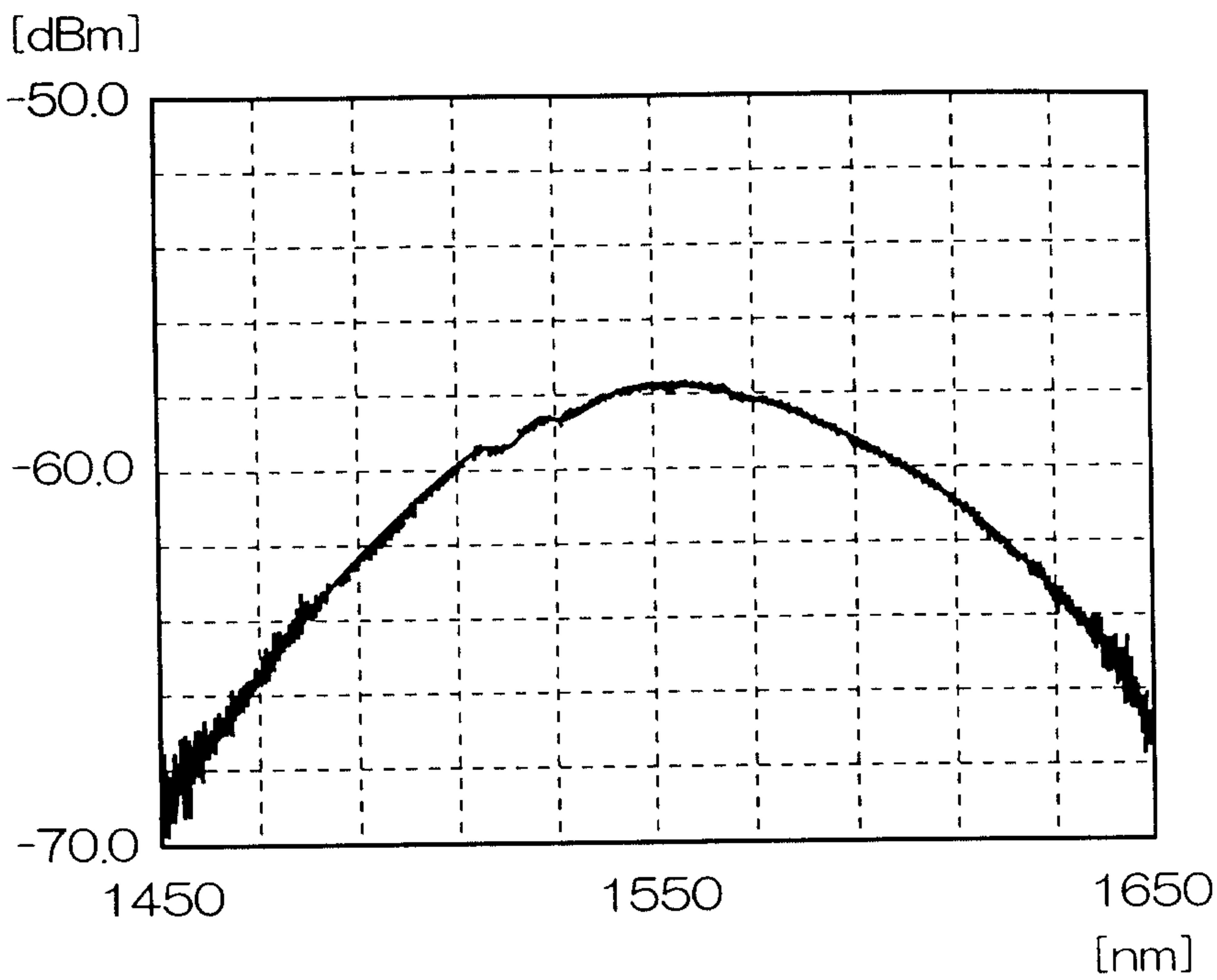
F/G. 3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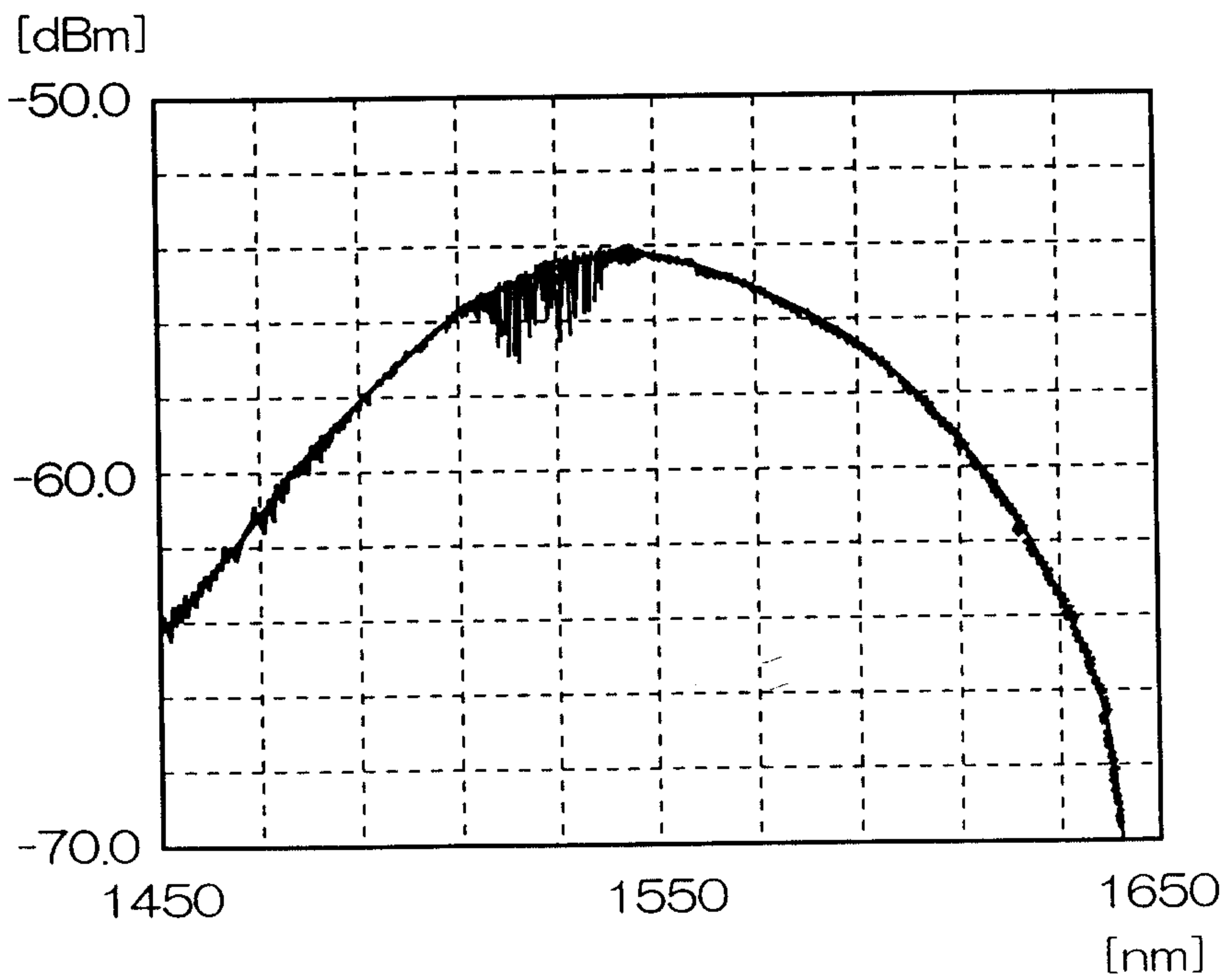
F/G. 4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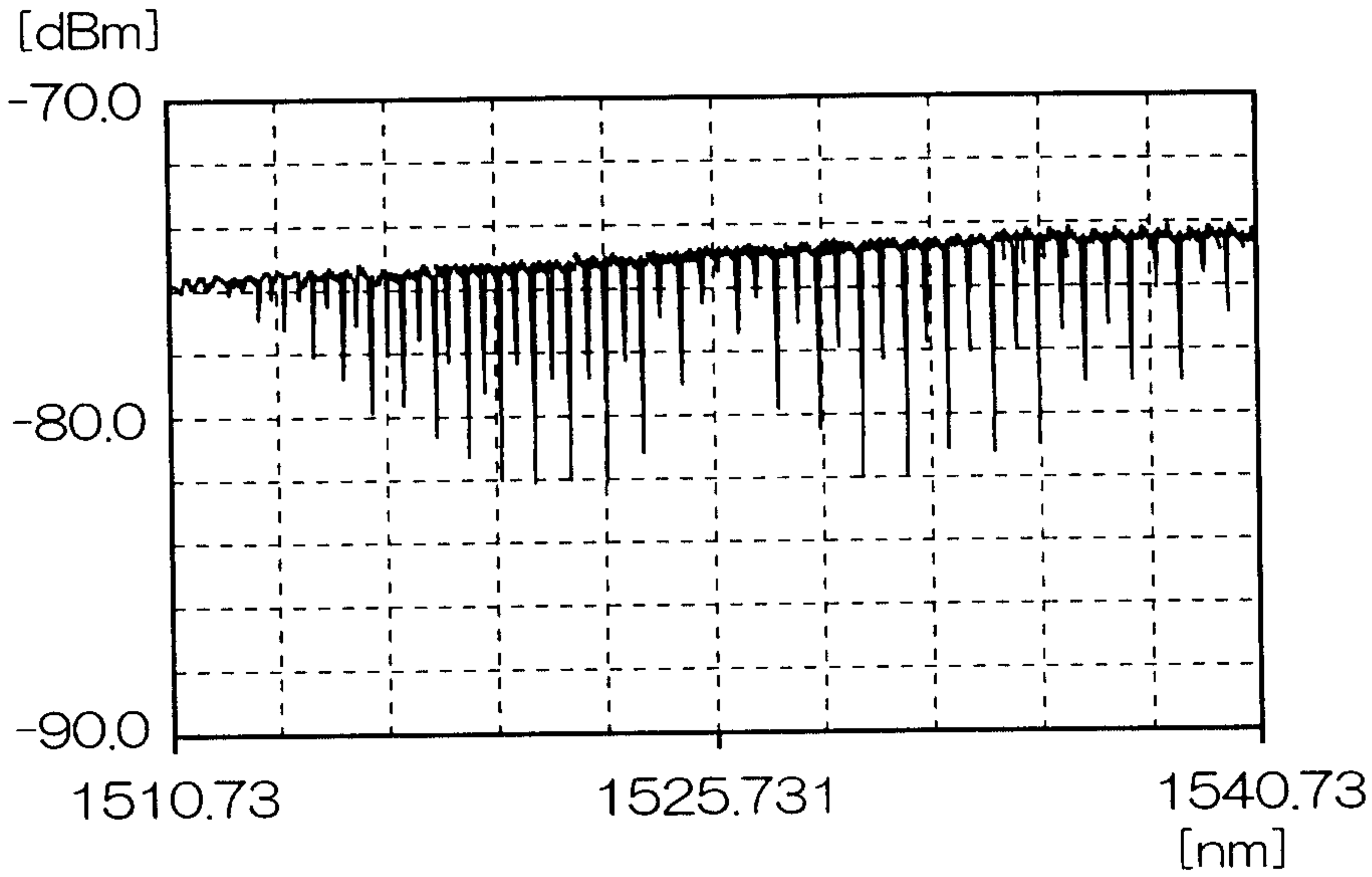
1650
[nm]

F I G. 5



F I G. 6

P BRANCH No.	WAVELENGTH (nm)
1	1525. 7607
2	1526. 3147
3	1526. 8751
4	1527. 4419
5	1528. 0151
6	1528. 5946
7	1529. 1806
8	1529. 7730
9	1530. 3718
10	1530. 9770
⋮	⋮

FIG. 7

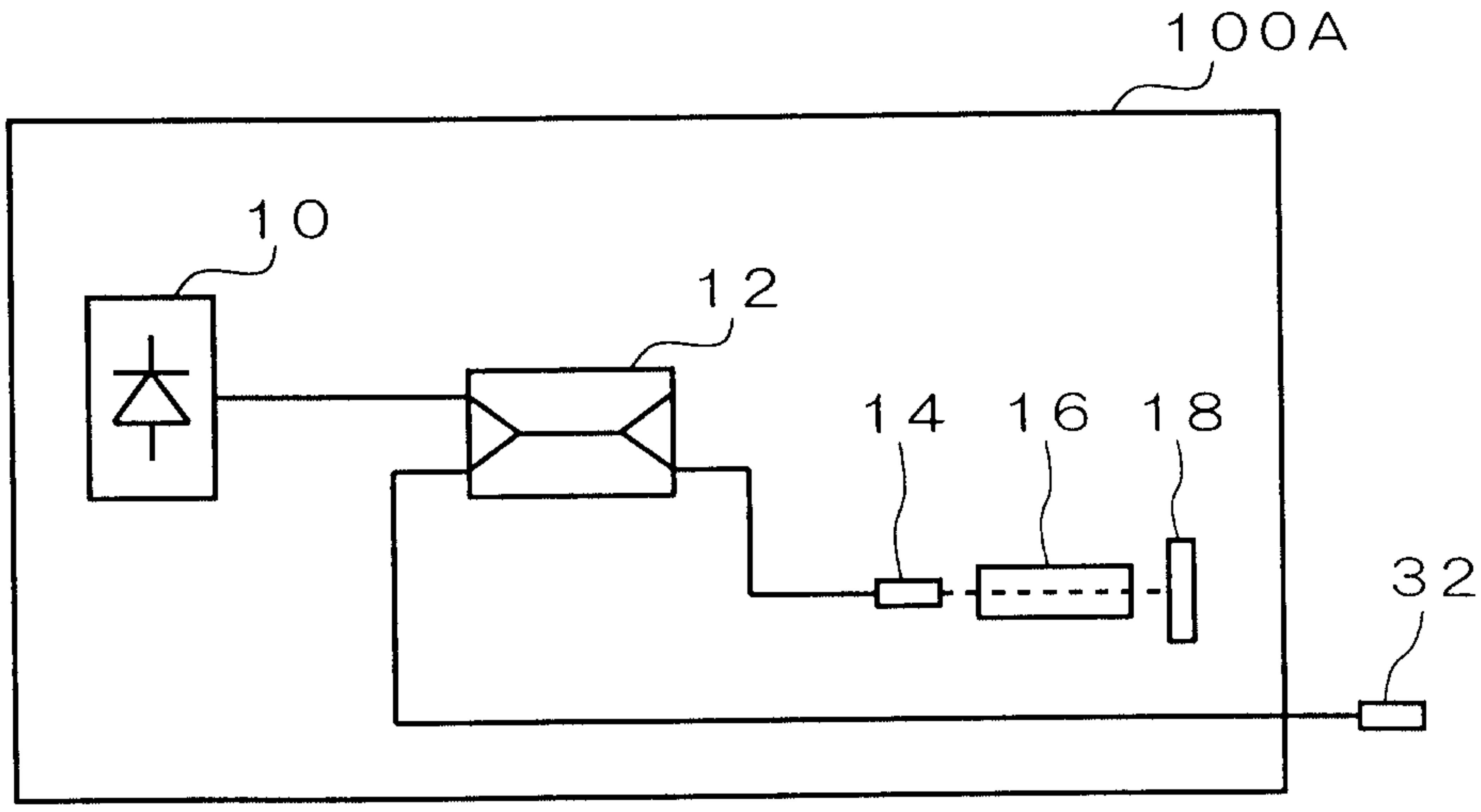
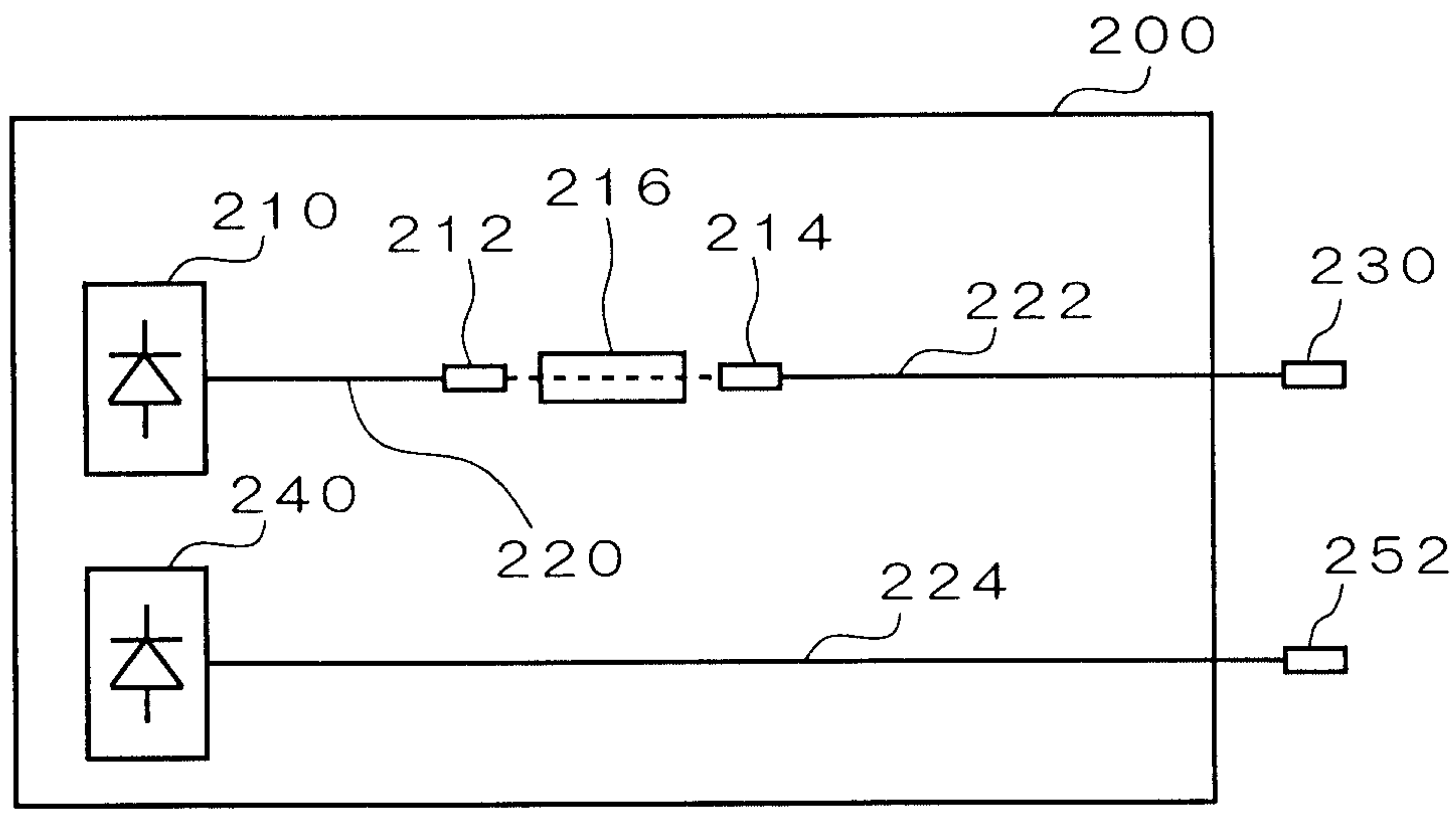


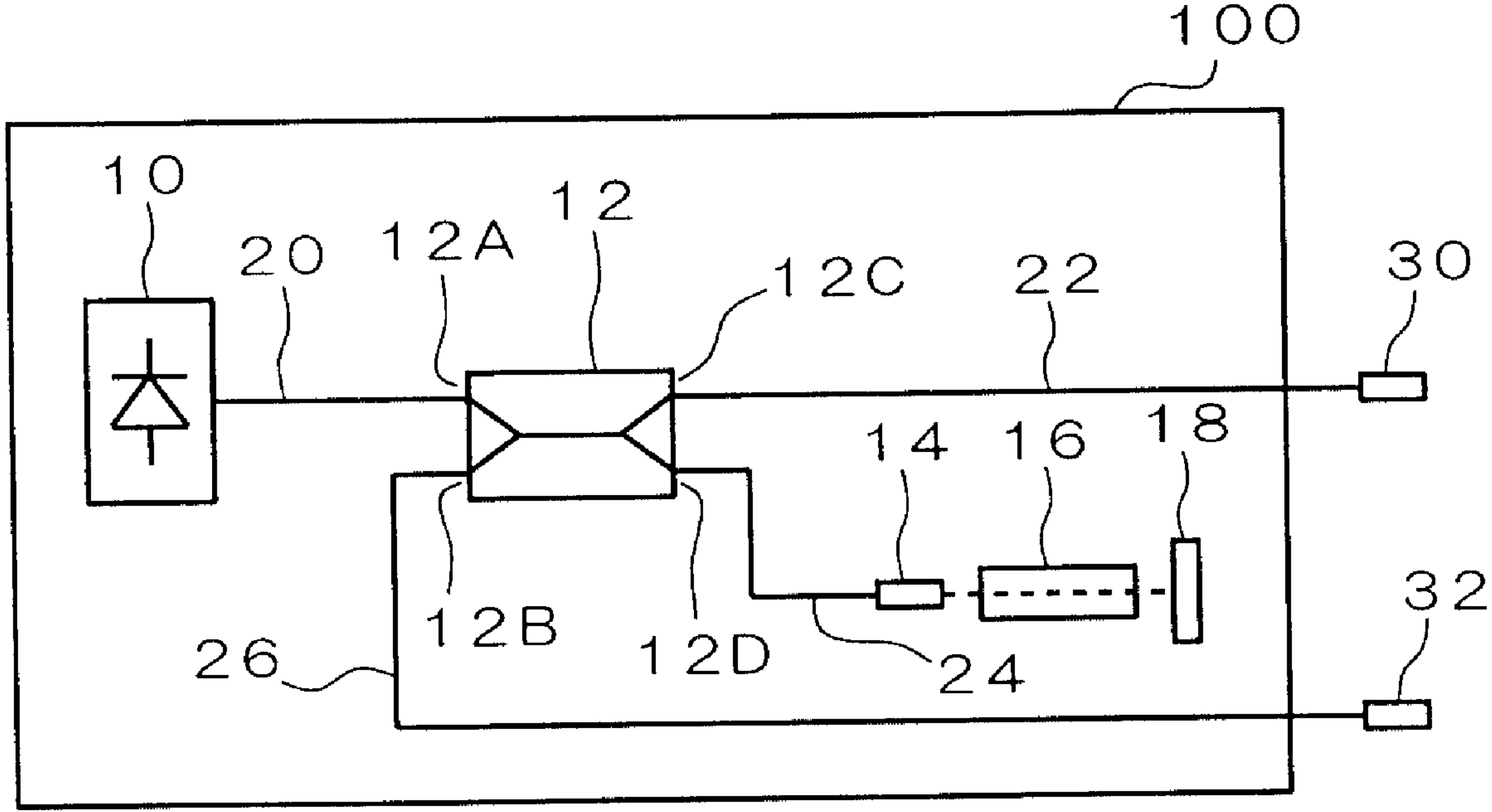
FIG. 8

P BRANCH No.	WAVELENGTH (nm)
1	1543. 1148
2	1543. 8094
3	1544. 5147
4	1545. 2314
5	1545. 9563
6	1546. 6902
7	1547. 4354
8	1548. 1904
9	1548. 9554
10	1549. 7302
⋮	⋮

FIG. 9

PRIOR ART

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