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GOSNR MEASUREMENT DEVICE AND GOSNR MEASUREMENT METHOD

Abstract

An object of the present disclosure is to measure a GOSNR to which a nonlinear noise power is added from signal light. According to the present disclosure, there is provided a GOSNR measurement device including: a calculation processing unit (**14**) that calculates a total noise power (P.sub.total-noise), which is a sum of a nonlinear noise power (P.sub.nl) and an ASE noise power (P.sub.ase) in an optical fiber transmission line (**93**), by using Stokes parameters obtained by causing signal light to propagate through the optical fiber transmission line, and measures a generalized optical signal to noise ratio (GOSNR) by using the total noise power.

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Background/Summary

TECHNICAL FIELD

[0001] The present disclosure relates to a GOSNR measurement device and a GOSNR measurement method for an optical fiber.

BACKGROUND ART

[0002] In a case where high-power light is propagated through an optical fiber, nonlinear polarization occurs in glass, and various nonlinear optical phenomena occur. For example, in an optical fiber, a refractive index of the optical fiber changes in proportion to an optical power of incident light due to an optical Kerr effect. Therefore, self-phase modulation (SPM) and cross-phase modulation (XPM) occur. The SPM is a phenomenon in which the refractive index changes due to an optical Kerr effect caused by the optical signal power itself and thus phase modulation is caused. The XPM is a phenomenon in which the refractive index changes due to an optical Kerr effect caused by the optical power of another optical signal and thus phase modulation is caused. In addition, main nonlinear optical phenomena occurring in an optical fiber include four-wave mixing (FWM) in which, in a case where signal light beams having two or more wavelengths are input, a light beam having a new wavelength is generated between the signal light beams.

[0003] In a case where such a nonlinear optical phenomenon occurs in an optical fiber, waveform degradation due to loss of linearity in the optical response, a crosstalk deterioration due to generation of a wavelength other than the wavelengths of the incident light beams, and the like occur. These nonlinear noises deteriorate a quality of a signal propagating through the optical fiber. Therefore, it is required to measure a generalized optical signal to noise ratio (GOSNR) after a signal propagates through an optical fiber, by using a total noise obtained by adding a nonlinear noise to an amplified spontaneous emission (ASE) noise.

[0004] The GOSNR can be represented by the following equation in consideration of OSNR.sub.ASE due to an ASE noise and OSNR.sub.NL due to a nonlinear noise.

[00001]
$$\begin{aligned} 1/GOSNR &= 1/OSNR_{ASE} + 1/OSNR_{NL} \\ &= (\mathrm{ASEnoisepower} + \mathrm{nonlinearnoisepower}) / \mathrm{opticalsignalpower} \end{aligned}$$

[0005] An optical spectrum analyzer that includes a Stokes parameter measurement unit and can measure an optical spectrum and a polarized state of signal light has been proposed (for example, refer to Patent Document 1). However, in Patent Document 1, although an ASE noise power can be measured from the signal light, a GOSNR to which a nonlinear noise power is added cannot be measured.

RELATED ART DOCUMENT
[Patent Document]
[0006] [Patent Document 1] JP-A-2010-002190
DISCLOSURE OF THE INVENTION
Problem that the Invention is to Solve
[0007] An object of the present disclosure is to measure a GOSNR to which a nonlinear noise power is added from signal light.
Means for Solving the Problem
[0008] Nonlinear polarization is represented by a sum of terms proportional to the square and the cube of the electric field of incident light. A coefficient of a second-order nonlinear optical term is referred to as a second-order nonlinear optical susceptibility, and a coefficient of a third-order nonlinear optical term is referred to as a third-order nonlinear optical susceptibility. A nonlinear optical phenomenon of an optical fiber is mainly caused by a third-order nonlinear optical susceptibility since the optical fiber has a point-symmetric structure with a central axis of a core as a center. Therefore, in the present disclosure, a nonlinear noise power is measured by using a third-order nonlinear optical term.
[0009] According to the present disclosure, there is provided a GOSNR measurement device including: a calculation processing unit (**14**) that calculates a total noise power (P.sub.total-noise), which is a sum of a nonlinear noise power (P.sub.nl) and an ASE noise power (P.sub.ase) in an optical fiber transmission line (**93**), by using Stokes parameters obtained by causing signal light to propagate through the optical fiber transmission line, and measures a generalized optical signal to noise ratio (GOSNR) by using the total noise power.
[0010] The calculation processing unit may calculate, based on a third-order nonlinear optical term for an optical signal power (P.sub.sig) that is input to the optical fiber transmission line, the nonlinear noise power (P.sub.nl) by applying, to the third-order nonlinear optical term, a coefficient (k.sub.PL) of polarized components and a coefficient (k.sub.NPL) of non-polarized components, the coefficients corresponding to the nonlinear noise power (P.sub.nl) in the optical fiber transmission line.
[0011] The calculation processing unit may calculate a non-polarized noise power (P.sub.NPLnoise) by using the Stokes parameters, calculate a polarized noise power (P.sub.PLnoise) by using the k.sub.PL and the P.sub.sig, and obtain the total noise power (P.sub.total-noise) by adding the non-polarized noise power and the polarized noise power.
[0012] The calculation processing unit may calculate a first measurement power P.sub.total(L.sub.1) and a first non-polarized noise power P.sub.NPLnoise(L.sub.1) by using Stokes parameters obtained by causing first signal light to propagate through the optical fiber transmission line, and calculates a second measurement power P.sub.total(L.sub.2) and a second non-polarized noise power P.sub.NPLnoise(L.sub.2) by using Stokes parameters obtained by causing second signal light, which has an optical signal power different from an optical signal power of the first signal light, to propagate through the optical fiber transmission line, and calculate an optical signal power P.sub.sig(L.sub.1) of the first signal light or an optical signal power P.sub.sig(L.sub.2) of the second signal light by using the first measurement power P.sub.total(L.sub.1), the first non-polarized noise power P.sub.NPLnoise(L.sub.1), the second measurement power P.sub.total(L.sub.2), and the second non-polarized noise power P.sub.NPLnoise(L.sub.2).
[0013] For example, a ratio α between the optical signal powers of the first signal light and the second signal light may be known, and the calculation processing unit may calculate the optical signal power P.sub.sig(L.sub.1) of the first signal light by using Equation (16) to be described.
[0014] According to the present disclosure, there is provided a GOSNR measurement method including: a first measurement procedure of measuring first Stokes parameters by causing first signal light to propagate through an optical fiber transmission line (**93**); and a second measurement procedure of measuring second Stokes parameters by causing second signal light, which has an optical signal power different from an optical signal power of the first signal light, to propagate through the optical fiber transmission line, in which a calculation processing unit (**14**) calculates a total noise power (P.sub.total-noise), which is a sum of a nonlinear noise power (P.sub.nl) and an ASE noise power (P.sub.ase) in the optical fiber transmission line, by using the first Stokes parameters and the second Stokes parameters, and calculates a generalized optical signal to noise ratio (GOSNR) by using the total noise power.
[0015] The above disclosures can be combined as much as possible.
Advantage of the Invention
[0016] According to the present disclosure, it is possible to measure a GOSNR to which a nonlinear noise power is added from signal light.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0017] FIG. **1** illustrates a configuration example of a GOSNR measurement device according to the present disclosure.
[0018] FIG. **2** illustrates a configuration example of a GOSNR measurement method according to the present disclosure.
BEST MODE FOR CARRYING OUT THE INVENTION
[0019] Hereinafter, an embodiment of the present disclosure will be described in detail with reference to the drawings. The present disclosure is not limited to the embodiment described below. These implementation examples are merely illustrative, and the present disclosure can be implemented in various modified and improved forms based on the knowledge of those skilled in the art. It is assumed that, in the present specification and the drawings, components having the same reference numerals are the same as each other.
First Embodiment
[0020] FIG. **1** illustrates a system configuration example according to the present disclosure. The system according to the present disclosure executes a GOSNR measurement method according to the present disclosure. Specifically, in a case where signal light is input from a signal light source unit **92** to an optical fiber transmission line **93**, the signal light propagates through the optical fiber transmission line **93**, and then polarization characteristics of the signal light are measured by a GOSNR measurement device **91**. The signal light source unit **92** sequentially outputs two or more signal light beams with a known optical signal power ratio to the optical fiber transmission line **93**. The signal light is, for example, WDM signal light.
[0021] The GOSNR measurement device **91** according to the present embodiment includes a spectroscopic unit **11**, a Stokes parameter measurement unit **12**, a calculation processing unit **14**, a light receiving unit **15**, and a spectral wavelength control unit **16**. The light receiving unit **15** receives the signal light propagating through the optical fiber transmission line **93**. The spectroscopic unit **11** spectroscopically splits the signal light that is input from the light receiving unit **15** according to wavelengths. Thereby, light beams having certain wavelength components are extracted by the spectroscopic unit **11**. In the present disclosure, the spectral wavelength control unit **16** that sweeps and controls the wavelengths which are spectroscopically split by the spectroscopic unit **11** may be included.
[0022] The Stokes parameter measurement unit **12** measures each of polarized components required for measuring Stokes parameters (S.sub.0, S.sub.1, S.sub.2, and S.sub.3), for each of the wavelengths that are spectroscopically split by the spectroscopic unit **11**. Various forms for the polarized components can be adopted. In the present embodiment, an example of measuring an optical power I.sub.0 of a linearly-polarized component at 0 degree, an optical power I.sub.90 of a linearly-polarized component at 90 degrees, an optical power I.sub.45 of a linearly-polarized component at 45 degrees, and an optical power I.sub.q45 of a circularly-polarized component will be described.
[0023] The calculation processing unit **14** calculates Stokes parameters by using each of the polarized components obtained by the Stokes parameter measurement unit **12**. For example, the calculation processing unit **14** calculates Stokes parameters (S.sub.0, S.sub.1, S.sub.2, and S.sub.3) by using the following equation.

[00002] $S_0 = I_0 + I_{90}$ (1) $S_1 = 2 \times I_0 - S_0$ (2) $S_2 = 2 \times I_{45} - S_0$ (3) $S_3 = 2 \times I_{q45} - S_0$ (4)

[0024] Here, S.sub.0 indicates a total optical power, S.sub.1 indicates an optical power difference between x polarization and y polarization, S.sub.2 indicates an optical power difference between 45-degree polarization and 135-degree polarization, and S.sub.3 indicates an optical power difference between right-handed circular polarization and left-handed circular polarization. The completely-polarized light is displayed as a polarized state on a Poincare sphere with S.sub.1, S.sub.2, and S.sub.3 as coordinate axes.

[0025] Assuming that the optical signal power is P.sub.sig, the nonlinear noise power is P.sub.nl, and the ASE noise power is P.sub.ase, a measurement power (P.sub.total=S.sub.0) obtained from the Stokes parameters is represented by the following equation.

[00003] $P_{\mathrm{total}} = P_{\mathrm{sig}} + P_{n1} + P_{\mathrm{ase}}$ (5)

[0026] In a case of a glass medium, atomic arrangement in the glass is random and effectively isotropic, and there is no second-order nonlinear optical term. Therefore, in a case where an optical fiber made of a glass medium is used for the optical fiber transmission line **93**, the nonlinear noise power P.sub.nl in the optical fiber transmission line **93** can be represented by a third-order nonlinear optical term as in the following equation.

[00004] $P_{n1} = k$ .Math. P_{sig}^3 (6)

[0027] Here, k is a proportionality constant.

[0028] In a case where the proportionality k is represented by a sum of a proportionality coefficient (k.sub.PL) of a nonlinear noise power of polarized components and a proportionality coefficient (k.sub.NPL) of a nonlinear noise power of non-polarized components, the proportionality k can be represented by the following equation.

[00005] $P_{n1} = (k_{\mathrm{PL}} + k_{\mathrm{NPL}})$ .Math. P_{sig}^3 (7)

[0029] In addition, from Equation (5) and Equation (7), the following equation is obtained.

[00006]
$$\begin{aligned} P_{\mathrm{total}} &= P_{\mathrm{sig}} + (k_{\mathrm{PL}} + k_{\mathrm{NPL}}) \text{ .Math. } P_{\mathrm{sig}}^3 + P_{\mathrm{ase}} \\ &= P_{\mathrm{sig}} + k_{\mathrm{PL}} \text{ .Math. } P_{\mathrm{sig}}^3 + (k_{\mathrm{NPL}} \text{ .Math. } P_{\mathrm{sig}}^3 + P_{\mathrm{ase}}) \quad (8) \\ &= P_{\mathrm{sig}} + k_{\mathrm{PL}} \text{ .Math. } P_{\mathrm{sig}}^3 + P_{\mathrm{NPLnoise}} \end{aligned}$$

[0030] In Equation (8), a first term indicates an optical signal power, a second term indicates a nonlinear noise power of the polarized components, and a third term indicates a non-polarized noise power. Here, the non-polarized noise power P.sub.NPLnoise indicates a noise power of non-polarized components that includes a nonlinear noise power k.sub.NPL.Math.P.sub.sig.sup.3 of non-polarized components and an ASE noise power P.sub.ase.

[0031] In addition, the non-polarized noise power P.sub.NPLnoise can be represented by the following equation using the Stokes parameters (S.sub.0, S.sub.1, S.sub.2, and S.sub.3).

[00007] $P_{\mathrm{NPLnoise}} = S_0 - \sqrt{S_1^2 + S_2^2 + S_3^2}$ (9)

[0032] In the present disclosure, a plurality of signal light beams having different optical signal powers are input from the signal light source unit **92** to the optical fiber transmission line **93** at different timings, the Stokes parameters (S.sub.0, S.sub.1, S.sub.2, and S.sub.3) are measured in the GOSNR measurement device **91**, and the measurement power P.sub.total and the non-polarized noise power P.sub.NPLnoise are calculated. In the present embodiment, an example in which two signal light beams having optical signal powers P.sub.sig(L.sub.1) and P.sub.sig(L.sub.2) are input from the signal light source unit **92** to the optical fiber transmission line **93** at different timings will be described.

[0033] In a case where the optical signal powers are P.sub.sig(L.sub.1) and P.sub.sig(L.sub.2), Equation (8) can be represented as in Equation (10) and Equation (11).

[00008] $P_{\mathrm{total}}(L_1) = P_{\mathrm{sig}}(L_1) + k_{\mathrm{PL}}$ .Math. $P_{\mathrm{Psig}}(L_1)^3 + P_{\mathrm{NPLnoise}}(L_1)$ (10)

$P_{\mathrm{total}}(L_2) = P_{\mathrm{sig}}(L_2) + k_{\mathrm{PL}}$ .Math. $P_{\mathrm{sig}}(L_2)^3 + P_{\mathrm{NPLnoise}}(L_2)$ (11)

[0034] In the present embodiment, the following equation is satisfied between the optical signal powers P.sub.sig(L.sub.1) and P.sub.sig (L.sub.2).

[00009] $P_{\mathrm{sig}}(L_2) = \quad \times P_{\mathrm{sig}}(L_1)$

[0035] Therefore, from Equation (10) and Equation (11), Equation (12) and Equation (13) are obtained.

[00010] $P_{\mathrm{total}}(L_1) = P_{\mathrm{sig}}(L_1) + k_{\mathrm{PL}}$ .Math. $P_{\mathrm{sig}}(L_1)^3 + P_{\mathrm{NPLnoise}}(L_1)$ (12)

$P_{\mathrm{total}}(L_2) = $ .Math. $P_{\mathrm{sig}}(L_1) + k_{\mathrm{PL}}$ .Math. ^{3} .Math. $P_{\mathrm{sig}}(L_1)^3 + P_{\mathrm{NPLnoise}}(L_2)$ (13)

[0036] From Equation (12), the following equation is obtained.

[00011] k_{PL} .Math. $P_{\mathrm{sig}}(L_1)^3 = P_{\mathrm{total}}(L_1) - P_{\mathrm{NPLnoise}}(L_1) - P_{\mathrm{sig}}(L_1)$ (14)

[0037] In a case where Equation (14) is substituted into Equation (13), Equation (15) is obtained, and Equation (16) is obtained.

[00012] $P_{\mathrm{total}}(L_2) - P_{\mathrm{NPLnoise}}(L_2) = $ .Math. $P_{\mathrm{sig}}(L_1) + {}^3$ .Math. $\{P_{\mathrm{total}}(L_1) - P_{\mathrm{NPLnoise}}(L_1) - P_{\mathrm{sig}}(L_1)\}$ (15)

$P_{\mathrm{sig}}(L_1) = \frac{P_{\mathrm{total}}(L_2) - P_{\mathrm{NPLnoise}}(L_2) - {}^3\{P_{\mathrm{total}}(L_1) - P_{\mathrm{NPLnoise}}(L_1)\}}{- \quad {}^3}$ (16)

[0038] P.sub.total is the total optical power S.sub.0 represented by Equation (1). Therefore, P.sub.total(L.sub.2) can be calculated by using I.sub.0 and I.sub.90 measured in a case where the signal light having the optical signal power P.sub.sig(L.sub.2) is propagated through the optical fiber transmission line **93**. In addition, P.sub.total(L.sub.1) can also be calculated by using I.sub.0 and I.sub.90 measured in a case where the signal light having the optical signal power P.sub.sig(L.sub.1) is propagated through the optical fiber transmission line **93**.

[0039] In a case where the obtained P.sub.sig(L.sub.1) is substituted into Equation (12), k.sub.PL (proportionality constant), which is a ratio of the nonlinear noise power of the generated polarized components to the optical signal power, can be specified. For example, the calculation processing unit **14** calculates k.sub.PL (proportionality constant) by using the following equation.

[00013] $k_{\mathrm{PL}} = \{P_{\mathrm{total}}(L_1) - P_{\mathrm{NPLnoise}}(L_1) - P_{\mathrm{sig}}(L_1)\} / P_{\mathrm{sig}}(L_1)^3$ (17)

[0040] In addition, the calculation processing unit **14** can obtain a polarized noise power P.sub.PLnoise(L.sub.1), which is a nonlinear noise power of the polarized components, by using Equation (18).

[00014] $P_{\mathrm{PLnoise}}(L_1) = k_{\mathrm{PL}}$ .Math. $P_{\mathrm{sig}}(L_1)^3$ (18)

[0041] Further, a total noise power P.sub.total-noise(L.sub.1), which is a sum of the nonlinear noise power P.sub.nl(L.sub.1) and the ASE noise power P.sub.ase(L.sub.1), can be obtained by adding the polarized noise power P.sub.PLnoise(L.sub.1) and the non-polarized noise power P.sub.NPLnoise(L.sub.1).

[00015] $P_{\mathrm{total-noise}}(L_1) = P_{n1}(L_1) + P_{\mathrm{ase}}(L_1) = P_{\mathrm{PLnoise}}(L_1) + P_{\mathrm{NPLnoise}}(L_1)$ (19)

[0042] The GOSNR can be obtained from the optical signal power P.sub.sig(L.sub.1) and the total noise power P.sub.total-noise(L.sub.1) by using Equation (20).

[00016] $\mathrm{GOSNR}(L_1) = 10$ .Math. $\mathrm{LOG}_{10}\{P_{\mathrm{sig}}(L_1)/P_{\mathrm{total-noise}}(L_1)\} + 10$ .Math. $\mathrm{LOG}_{10}(B_m / B_{\mathrm{ref}})$ (20)

[0043] Here, B.sub.m indicates a measurement light bandwidth, and B.sub.ref indicates a reference light bandwidth (typically, 0.1 nm)

[0044] FIG. **2** illustrates an example of a GOSNR measurement method according to the present disclosure. The GOSNR measurement method according to the present disclosure includes a first measurement procedure S**11**, a second measurement procedure S**12**, and a calculation procedure S**13**.

[0045] In the first measurement procedure S**11**, first signal light is propagated through the optical fiber transmission line **93**, and first Stokes parameters are measured. Thereby, the calculation processing unit **14** can calculate P.sub.total(L.sub.1) and P.sub.NPLnoise(L.sub.1) by using Equation (1) to Equation (4), and Equation (9).

[0046] In the second measurement procedure S**12**, second signal light is propagated through the optical fiber transmission line **93**, and second Stokes parameters are measured. Thereby, the calculation processing unit **14** can calculate P.sub.total(L.sub.2) and P.sub.NPLnoise(L.sub.2) by using Equation (1) to Equation (4), and Equation (9).

[0047] In the calculation procedure S**13**, the calculation processing unit **14** can calculate a polarized noise power P.sub.PLnoise(L.sub.1) of the first signal light by using Equation (17) and Equation (18).

[0048] In this way, by inputting the signal light of which the ratio α between the optical signal powers is known and detecting each of the Stokes parameters, it is possible to obtain the optical signal power P.sub.sig(L.sub.1), the polarized noise power P.sub.PLnoise(L.sub.1) which is the nonlinear noise power of the polarized components, and the non-polarized noise power P.sub.NPLnoise(L.sub.1) which includes the nonlinear noise power of the non-polarized components and the ASE noise power. In the present embodiment, an example in which the polarized noise power P.sub.PLnoise(L.sub.1) and the non-polarized noise power P.sub.NPLnoise(L.sub.1) are obtained has been described. On the other hand, the polarized noise power P.sub.PLnoise(L.sub.2) and the non-polarized noise power P.sub.NPLnoise(L.sub.2) may be obtained. The same applies to the following embodiments.

Second Embodiment

[0049] The present method can also be applied to a case where a second-order nonlinear optical term and a third-order nonlinear optical term are included. For example, the measurement power P.sub.total=S.sub.0 obtained from the Stokes parameters can be obtained by using the following equation.

[00017] $P_{\mathrm{total}} = P_{\mathrm{sig}} + P_{n1} + P_{\mathrm{ase}} \quad (21)$

[0050] Here, P.sub.sig is the optical signal power, P.sub.nl is the nonlinear noise power, and P.sub.ase is the ASE noise power.

[0051] The nonlinear noise power P.sub.nl can be obtained by using the following equation.

[00018] $P_{n1} = k_2 \ \mathrm{.Math.}\ P_{\mathrm{sig}}{}^2 + k_3 \ \mathrm{.Math.}\ P_{\mathrm{sig}}{}^3 \quad (22)$

[0052] Here, k.sub.2 is a proportionality constant of the second-order nonlinear optical term, and k.sub.3 is a proportionality constant of the third-order nonlinear optical term.

[0053] In a case where the proportionality k.sub.2 and the proportionality k.sub.3 are represented by a sum of a proportionality coefficient (k.sub.PL2 and k.sub.PL3) of the nonlinear noise power of the polarized components and a proportionality coefficient (k.sub.NPL2 and k.sub.NPL3) of the nonlinear noise power of the non-polarized components, Equation (22) is represented by Equation (23).

[00019] $P_{n1} = (k_{\mathrm{PL2}} + k_{\mathrm{NPL2}}) \ \mathrm{.Math.}\ P_{\mathrm{sig}}{}^2 + (k_{\mathrm{PL3}} + k_{\mathrm{NPL3}}) \ \mathrm{.Math.}\ P_{\mathrm{sig}}{}^3 \quad (23)$

[0054] Here, k.sub.PL2 is a proportionality coefficient of the second-order nonlinear noise of the polarized components, k.sub.NPL2 is a proportionality coefficient of the second-order nonlinear noise of the non-polarized components, k.sub.PL3 is a proportionality coefficient of the third-order nonlinear noise of the polarized components, and k.sub.NPL3 is a proportionality coefficient of the third-order nonlinear noise of the non-polarized components.

[0055] Therefore, Equation (21) can be represented by Equation (24).

[00020]

$P_{\mathrm{total}} = P_{\mathrm{sig}} + (k_{\mathrm{PL2}} + k_{\mathrm{NPL2}}) \ \mathrm{.Math.}\ P_{\mathrm{sig}}{}^2 + (k_{\mathrm{PL3}} + k_{\mathrm{NPL3}}) \ \mathrm{.Math.}\ P_{\mathrm{sig}}{}^3 + P_{\mathrm{ase}} = P_{\mathrm{sig}} + (k_{\mathrm{PL2}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}{}^2 + k_{\mathrm{PL3}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}{}^3) + (k_{\mathrm{NPL2}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}{}^2 + k$

[0056] In Equation (24), the first term indicates the optical signal power, the second term indicates the nonlinear noise power of the polarized components, and the third term indicates the non-polarized noise power (P.sub.NPLnoise=k.sub.NPL2.Math.P.sub.sig.sup.2+k.sub.NPL3.Math.P.sub.sig.sup.3+P.sub.ase) including the nonlinear noise power of the non-polarized components and the ASE noise power.

[0057] In the present embodiment, three signal light beams of which the ratios (α and β) between the optical signal powers are known are used. The three signal light beams P.sub.sig(L.sub.1), P.sub.sig(L.sub.2), and P.sub.sig(L.sub.3) are represented by the following equations.

[00021]
$$P_{\mathrm{sig}}(L_1)$$
$$P_{\mathrm{sig}}(L_2) = \quad \times P_{\mathrm{sig}}(L_1)$$
$$P_{\mathrm{sig}}(L_3) = \quad \times P_{\mathrm{sig}}(L_1)$$

[0058] From the above relationship, the following equation is satisfied.

[00022] $P_{\mathrm{total}}(L_1) = P_{\mathrm{sig}}(L_1) + k_{\mathrm{PL2}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_1)^2 + k_{\mathrm{PL3}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_1)^3 + P_{\mathrm{NPLnoise}}(L_1) \quad (25)$

$P_{\mathrm{total}}(L_2) = P_{\mathrm{sig}}(L_2) + k_{\mathrm{PL2}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_2)^2 + k_{\mathrm{PL3}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_2)^3 + P_{\mathrm{NPLnoise}}(L_2) = P_{\mathrm{sig}}(L_1) + k_{\mathrm{PL2}} \ \mathrm{.Math.}\ {}^2 \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_1)^2 + k_{\mathrm{PL3}} \ \mathrm{.Math.}\ {}^3 \ \mathrm{.M}$

$P_{\mathrm{total}}(L_3) = P_{\mathrm{sig}}(L_3) + k_{\mathrm{PL2}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_3)^2 + k_{\mathrm{PL3}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_3)^3 + P_{\mathrm{NPLnoise}}(L_3) = P_{\mathrm{sig}}(L_1) + k_{\mathrm{PL2}} \ \mathrm{.Math.}\ {}^2 \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_1)^2 + k_{\mathrm{PL3}} \ \mathrm{.Math.}\ {}^3 \ \mathrm{.M}$

[0059] P.sub.total(L.sub.3), P.sub.NPLnoise(L.sub.3), P.sub.total(L.sub.2), P.sub.NPLnoise(L.sub.2), P.sub.total(L.sub.1), and P.sub.NPLnoise(L.sub.1) are determined from the Stokes parameters. In addition, since α and β are known values, P.sub.sig(L.sub.1), k.sub.PL2, and k.sub.PL3 can be obtained from Equation (25), Equation (26), and Equation (27). Therefore, the calculation processing unit **14** can obtain the nonlinear noise power P.sub.PLnoise(L.sub.1) of the polarized components by using Equation (28).

[00023] $P_{\mathrm{PLnoise}}(L_1) = k_{\mathrm{PL2}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_1)^2 + k_{\mathrm{PL3}} \ \mathrm{.Math.}\ P_{\mathrm{sig}}(L_1)^3 \quad (28)$

[0060] Further, a total noise power P.sub.total-noise(L.sub.1), which is a sum of the nonlinear noise power P.sub.nl(L.sub.1) and the ASE noise power P.sub.ase(L.sub.1), can be obtained by adding the polarized noise power P.sub.PLnoise(L.sub.1) and the non-polarized noise power P.sub.NPLnoise(L.sub.1)

[00024] $P_{\mathrm{total\text{-}noise}}(L_1) = P_{n1}(L_1) + P_{\mathrm{ase}}(L_1) = P_{\mathrm{PLnoise}}(L_1) + P_{\mathrm{NPLnoise}}(L_1) \quad (29)$

[0061] The GOSNR can be obtained from the optical signal power P.sub.sig(L.sub.1) and the total noise power P.sub.total-noise(L.sub.1) by using Equation (30).

[00025] $\mathrm{GOSNR}(L_1) = 10 \ \mathrm{.Math.}\ \mathrm{LOG}_{10}\{P_{\mathrm{sig}}(L_1) / P_{\mathrm{total\text{-}noise}}(L_1)\} + 10 \ \mathrm{.Math.}\ \mathrm{LOG}_{10}(B_m / B_{\mathrm{ref}}) \quad (30)$

[0062] Here, B.sub.m indicates a measurement optical bandwidth, and B.sub.ref indicates a reference optical bandwidth (typically, 0.1 nm)

Other Embodiments

[0063] The GOSNR measurement device according to the present invention can also be realized by a computer and a program, and the program can be recorded on a recording medium or provided through a network.

DESCRIPTION OF REFERENCE NUMERALS AND SIGNS

[0064] **11**: Spectroscopic unit [0065] **12**: Stokes parameter measurement unit [0066] **14**: Calculation processing unit [0067] **15**: Light receiving unit [0068] **16**: Spectral wavelength control unit [0069] **91**: GOSNR measurement device [0070] **92**: Signal light source unit [0071] **93**: Optical fiber transmission line

Claims

1. A GOSNR measurement device comprising: a calculation processing unit that calculates a total noise power (P.sub.total-noise), which is a sum of a nonlinear noise power (P.sub.nl) and an ASE noise power (P.sub.ase) in an optical fiber transmission line, by using Stokes parameters obtained by causing signal light to propagate through the optical fiber transmission line, and measures a generalized optical signal to noise ratio (GOSNR) by using the total noise power.

2. The GOSNR measurement device according to claim 1, wherein the calculation processing unit calculates, based on a third-order nonlinear optical term for an optical signal power (P.sub.sig) that is input to the optical fiber transmission line, the nonlinear noise power (P.sub.nl) by applying, to the third-order nonlinear optical term, a coefficient (k.sub.PL) of polarized components and a coefficient (k.sub.NPL) of non-polarized components, the coefficients corresponding to the nonlinear noise power (P.sub.nl) in the optical fiber transmission line.

3. The GOSNR measurement device according to claim 2, wherein the calculation processing unit calculates a non-polarized noise power (P.sub.NPLnoise) by using the Stokes parameters, calculates a polarized noise power (P.sub.PLnoise) by using the k.sub.PL and the P.sub.sig, and obtains the total noise power (P.sub.total-noise) by adding the non-polarized noise power and the polarized noise power.

4. The GOSNR measurement device according to claim 2, wherein the calculation processing unit calculates a first measurement power P.sub.total(L.sub.1) and a first non-polarized noise power P.sub.NPLnoise(L.sub.1) by using Stokes parameters obtained by causing first signal light to propagate through the optical fiber transmission line, and calculates a second measurement power P.sub.total(L.sub.2) and a second non-polarized noise power P.sub.NPLnoise(L.sub.2) by using Stokes parameters obtained by causing second signal light, which has an optical signal power different from an optical signal power of the first signal light, to propagate through the optical fiber transmission line, and calculates an optical signal power P.sub.sig(L.sub.1) of the first signal light or an optical signal power P.sub.sig(L.sub.2) of the second signal light by using the first measurement power P.sub.total(L.sub.1), the first non-polarized noise power P.sub.NPLnoise(L.sub.1), the second measurement power P.sub.total(L.sub.2), and the second non-polarized noise power P.sub.NPLnoise(L.sub.2).

5. The GOSNR measurement device according to claim 4, wherein a ratio α between the optical signal powers of the first signal light and the second signal light is known, and the calculation processing unit calculates the optical signal power P.sub.sig(L.sub.1) of the first signal light by using the following equation: $P_{\mathrm{sig}}(L_1) = \frac{P_{\mathrm{total}}(L_2) - P_{\mathrm{NPLnoise}}(L_2) - {}^{3}\{P_{\mathrm{total}}(L_1) - P_{\mathrm{NPLnoise}}(L_1)\}}{-\,{}^{3}}$.

6. A GOSNR measurement method comprising: a first measurement procedure of measuring first Stokes parameters by causing first signal light to propagate through an optical fiber transmission line; and a second measurement procedure of measuring second Stokes parameters by causing second signal light, which has an optical signal power different from an optical signal power of the first signal light, to propagate through the optical fiber transmission line, wherein a calculation processing unit calculates a total noise power (P.sub.total-noise), which is a sum of a nonlinear noise power (P.sub.nl) and an ASE noise power (P.sub.ase) in the optical fiber transmission line, by using the first Stokes parameters and the second Stokes parameters, and calculates a generalized optical signal to noise ratio (GOSNR) by using the total noise power.