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## (54) OPTICAL FOURIER TRANSFORM DEVICE AND METHOD

VORRICHTUNG UND VERFAHREN ZUR OPTISCHEN FOURIER-TRANSFORMATION

DISPOSITIF ET PROCEDE DE TRANSFORMATION DE FOURIER OPTIQUE

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## Description

Field of the Invention

**[0001]** The present invention relates to an optical Fourier transform device and method, and particularly to an optical Fourier transform device and method which converts the temporal waveform of an optical pulse into the shape (envelope curve) of a frequency spectrum thereof and/or converts the shape of the frequency spectrum of the optical pulse into the temporal waveform thereof.

Background of the Invention

**[0002]** Various applications using an optical Fourier transform technique to convert the temporal waveform of an optical pulse into the shape of a frequency spectrum thereof or to convert the shape of the frequency spectrum of the optical pulse into the temporal waveform thereof have been proposed in the fields of ultrahigh-speed optical communication, ultra-short pulse mode-locked laser, optical signal processing and the like. For example, in the ultrahigh-speed optical communication, there have been proposed applications to the reduction of random fluctuation (timing jitter) of a time position of each pulse in a signal optical pulse train (see, for example, non-patent document 1), the compensation of polarization mode dispersion (see, for example, non-patent document 2), and the like. Besides , the optical Fourier transform technique is effective also in the suppression of timing jitter of an ultra-short pulse emitted from a mode-locked laser (for example, non-patent document 3). Besides, there is a document disclosing the generation of a quadratic function type optical pulse using an optical fiber amplifier having a normal dispersion (see, for example, non-patent document 4).

**[0003]** The present inventor has filed applications on waveform distortion-free transmission in which a time and a frequency are replaced with each other at the receiver side and transmission data is completely reproduced, since in general, even if any linear distortion effects exist in an optical fiber, the spectrum shape of a pulse is invariable (Japanese Patent Application No. 2003-23973 "Optical Transmission Method and Optical Transmission Device", Japanese Patent Application No. 2003-181964 "OTDM Transmission Method and Device"), optical pulse compression and optical function generation (Japanese Patent Application No. 2003-109708 "Optical pulse Compressor and Light Function Generator, Optical pulse Compression Method and Light Function Generation Method"). Besides, the inventor has filed an application on a method and device which generates an optical pulse expressed by a quadratic function type without using an optical fiber amplifier (Japanese Patent Application No. 2003-387563 "Optical pulse Generation Method and Optical pulse Compression Method, etc."). The contents of these applications can be incorporated in the present specification by reference.

**[0004]** Fig. 1 shows a structural example of a circuit conventionally used to perform optical Fourier transform. In the figure, this circuit includes a phase modulator (LN phase modulator) 2 using the Pockels effect in an electro-optic crystal such as $LiNbO_3$ crystal, and a dispersive medium 3 having a dispersion amount D. Incidentally, when the dispersion parameter of the dispersive medium 3 is $\beta_2$[$p^2$/km] and the length is L[km], the dispersion amount is given by D = $\beta_2$L[$ps^2$]. Besides, in the figure, a solid line indicates an optical pulse, and a dotted line indicates an electric signal. An optical fiber, a diffraction grating pair, a fiber Bragg grating or the like is used as the dispersive medium 3. The peak of a modulation characteristic of the phase modulator 2 is made to coincide with the center position of an optical pulse. The magnitude of a chirp (chirp rate K) applied to a pulse by the LN phase modulator 2 can be obtained in a manner as described below. When voltage $V(t) = V_0\cos(\omega_m t)$ is applied to the phase modulator 2, a light phase change amount $\Delta\phi(t)$ caused by a change in refractive index due to the electro-optic effect is given by
[Mathematical formula 1]

$$\Delta\phi(t) = M\cos(\omega_m t) \quad , \quad M = \frac{\pi V_0}{V_\pi} \qquad (1)$$

Where $V_\pi$ denotes a half-wavelength voltage (applied voltage necessary to rotate the phase of light by $\pi$), $\omega_m$ denotes the drive frequency of the phase modulator, and $V_0$ denotes the amplitude of the voltage. When expression (1) is expanded into Taylor series in the vicinity (t = 0) of the center of the pulse, it can be approximated by
[Mathematical formula 2]

$$\Delta\phi(t) = M\left(1 - \frac{\omega_m^2}{2}t^2\right) = \Delta\phi(0) + \frac{K}{2}t^2,\quad K = -M\omega_m^2 \qquad (2)$$

**[0005]** That is, by the LN phase modulator, a frequency chirp

**[Mathematical formula 3]**

$$\Delta\omega(t) = -\frac{\partial\Delta\phi}{\partial t} = -Kt$$

which has the chirp rate K and is approximately linear is applied to the optical pulse.

**[0006]** In Fig. 1, the optical pulse having a temporal waveform u(t) and a frequency spectrum U(ω) is first divided into two parts by an optical coupler 1, and the one part is launched to the LN phase modulator 2. The other part is launched to a clock extraction circuit 4, and a clock signal (sinusoidal signal) is extracted from the pulse train. The emitted signal is applied to the LN phase modulator 2 through a phase shifter 5 and an electrical amplifier 6, so that the LN phase modulator 2 is driven. The phase shifter 5 is inserted in order to apply phase modulation to the optical pulse optimally synchronously. The electric amplifier 6 is for driving the LN phase modulator 2.

**[0007]** The optical pulse launched to the LN phase modulator 2 is given the linear chirp $\Delta\omega(t) = -Kt$, and as a result, at each time position of the pulse waveform, it acquires a frequency shift with a magnitude proportional to the time. Further, the linearly chirped pulse is launched to the dispersive medium 3. In the dispersive medium 3, a time delay (group delay in the pulse) depending on frequency by a group-velocity dispersion is given to the temporal waveform of the optical pulse. Since the optical pulse is previously given the linear chirp in the LN phase modulator 2, the respective frequency components of the optical pulse are separated in the dispersive medium 3 to different positions in the time domain. As a result, when the dispersion amount D with respect to the chirp rate K is selected to be D = 1/K, the waveform in proportion to a spectrum shape U(ω) (where ω = t/D) of the optical pulse before optical Fourier transform is obtained in the time domain at the output of the dispersive medium 3.


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Disclosure of the Invention

Problems to be Solved

**[0008]** However, there is a case where an LN phase modulator used in conventional optical Fourier transform can not give a linear chirp uniformly over the entire pulse. Fig. 2 is a schematic view showing the magnitude of a phase modulation (a) applied to an optical pulse by the LN phase modulator and a phase shift (b). Dotted lines indicate a phase modulation characteristic expressed by a quadratic function and the magnitude of the frequency shift which is linear with respect to the time. As shown in Fig. 2, a range in which the sinusoidal modulation characteristic of the LN phase modulator can be approximated by a quadratic curve (range in which the chirp applied to the optical pulse by the LN phase modulator can be regarded as linear) is limited to the vicinity of the center of the pulse. Here, this will be called an allowable window width of optical Fourier transform. When this allowable window width is narrow as compared with the time width of the optical pulse, there has been a serious problem that the optical Fourier transform can not be accurately executed to the optical pulse component in a range outside the window width.

**[0009]** Besides, as described in the former section, the dispersion amount D of the dispersive medium constituting the optical Fourier transform device and the magnitude K of the chirp rate of the phase modulator are related by D = 1/K. Since the magnitude of the dispersion amount D which can be given by the dispersive medium is limited by the characteristic of a device, in order to reduce the required dispersion amount D, it is necessary to increase the chirp rate K of the phase modulator. On the other hand, the upper limit of the magnitude of the chirp rate K is determined by the length of the LN phase modulator, the thickness thereof in the direction of voltage application, the characteristic of an electrode, and the like. Thus, in the conventional optical Fourier transform device, there is a serious limitation to the available characteristic of the optical Fourier transform by the limitation in the characteristic of the dispersive medium and the characteristic of the LN phase modulator.

**[0010]** Further, in the LN phase modulator, since the processing speed by the electric circuit is limited to about 40 GHz, it has been difficult to perform the optical Fourier transform by the conventional method to the ultrahigh-speed optical pulse train whose transmission speed exceeds 40 Gbit/s.

**[0011]** The above problems are serious obstructions to the realization of various applications of the optical Fourier transform technique described in the former section. Therefore, in order to solve these problems, the invention has an object to provide an optical Fourier transform device and method in which a phase modulation characteristic is improved so that it is expressed by a quadratic function, and optical Fourier transform can be executed over a wide time range. Besides, one of objects of the invention is to provide an optical Fourier transform device and method in which the adjustment range of a chirp rate K of a chirp applied to a signal light is wide. Further, the invention has an object to provide an optical Fourier transform device and method in which optical Fourier transform can be performed on an ultrahigh-speed optical pulse train whose transmission speed exceeds the limitation of processing speed of an electric circuit.

Means to Solve the Problems

**[0012]** An optical Fourier transform device and method according to the invention are defined in claims 1, 5 and 15.

Advantage

**[0013]** In the optical Fourier transform device and method of the invention, the optical pulse whose shape is parabolic is used as the control light, and the linear chirp can be applied to the signal light by the cross phase modulation between itself and the signal light, and accordingly, more accurate optical Fourier transform can be realized. Besides, since the optical Fourier transform device and method of the invention does not require signal processing using an electric circuit, the optical Fourier transform can be performed also on the high-speed signal pulse train exceeding the limit of the processing speed by the electricity. Accordingly, various applications of the optical Fourier transform, which have been limited by the performance of the conventional optical Fourier transform device, can be realized by the optical Fourier transform device and method of the invention.

Brief Description of the Drawings

**[0014]**

Fig. 1 is a view showing a structure of a conventional optical Fourier transform device.

Fig. 2 is a schematic view showing the magnitude of a phase modulation applied to an optical pulse by an LN phase modulator and the magnitude of a frequency shift. Dotted lines indicate an ideal phase modulation characteristic and the magnitude of the frequency shift.

Fig. 3 is a view showing a structure of a first embodiment of an optical Fourier transform device of the invention.

Fig. 4 is a view showing a structure (first mode) of a parabolic optical pulse generator 7 in Fig. 3.

Fig. 5 is a view showing a structure (second mode) of the parabolic optical pulse generator 7 in Fig. 3.

Fig. 6 is a view showing a structure (third mode) of the parabolic optical pulse generator 7 in Fig. 3.

Fig. 7 is a schematic view showing a state in which a linear chirp is applied to signal light by the cross phase modulation between the control light and the signal light.

Fig. 8 is a view showing a change (a) of a dispersion value of a normal dispersion-decreasing fiber 16 of Fig. 5 in a longitudinal direction, and a temporal waveform (b) of a control optical pulse obtained at the output of the parabolic optical pulse generator 7 when the normal dispersion-decreasing fiber is used in Fig. 5.

Fig. 9 is a view showing the temporal waveform of signal light which is separated by an optical filter 11 after transmitting through an optical Kerr medium 10 in Fig. 3 and a frequency chirp. In the figure, a thin solid line indicates a theoretical value of the frequency chirp applied to the signal light, and a thin dotted line indicates the frequency chirp applied to the signal light by a conventional LN phase modulator.

Fig. 10 is a view showing a temporal waveform of signal light at the output of a dispersive medium 12 in Fig. 3. In the figure, a thin solid line indicates the result of optical Fourier transform when an ideal linear chirp is applied to the signal light in the optical Kerr medium 10, and a thin dotted line indicates the result of optical Fourier transform when a chirp is applied to the signal light by using a conventional LN type optical modulator.

Fig. 11 is a view showing a structure of a second embodiment of an optical Fourier transform device of the invention.

Fig. 12 is a view showing a structure of a third embodiment of an optical Fourier transform device of the invention.

Fig. 13 is a view showing a structure of a fourth embodiment of an optical Fourier transform device of the invention.

Embodiment of the Invention

**[0015]** Hereinafter, embodiments of the invention will be described in detail by use of the drawings.

A. First Embodiment

(Device Structure)

**[0016]** Fig. 3 is a structural view of an optical Fourier transform device of a first embodiment of the invention. The optical Fourier transform device includes an optical coupler 1, a clock extraction circuit 4, a parabolic optical pulse generator 7, an optical delay element 8, a coupler 9, an optical Kerr medium 10, an optical filter 11 and a dispersive medium 12.

**[0017]** The optical Kerr medium 10 is the medium having the third-order nonlinear refractive index, and for example, a single mode optical fiber, a photonic crystal fiber, a semiconductor optical amplifier, an erbium-doped optical fiber amplifier, an organic nonlinear material or the like is used.

**[0018]** As the dispersive medium 12, for example, a single mode optical fiber having a group-velocity dispersion characteristic in which a zero-dispersion region exists in the vicinity of a wavelength band of 1.3 $\mu$m, or a diffraction grating pair, a fiber Bragg grating or the like can be used. The clock extraction circuit 4 receives the signal optical pulse separated by the optical coupler 1, and extracts a clock signal based on the signal optical pulse. Incidentally, a solid line in the figure indicates an optical pulse (light signal), and a dotted line indicates an electric signal. The same applies to the following views showing the structure of a Fourier transform device and a parabolic optical pulse generator.

**[0019]** The parabolic optical pulse generator 7 generates the control optical pulse in accordance with the clock signal emitted from the clock extraction circuit. The optical delay element 8 gives an appropriate time delay so that the center time position of the control optical pulse is matched with the timing of the signal optical pulse. The optical filter 11 is the filter to separate the signal light from the control light.

(Parabolic optical pulse generator)

**[0020]** The parabolic optical pulse generator 7 is a device to generate a pulse having a parabolic waveform (hereinafter also referred to as a control optical pulse or a parabolic optical pulse), and can be realized in, for example, the following three modes.

**[0021]** The first mode uses an optical fiber amplifier having a normal dispersion (see, for example, non-patent document 4). Fig. 4 shows a structure of a parabolic optical pulse generator of the first mode. The parabolic optical pulse generator 7 of the first mode includes an optical pulse transmitter 13 and a normal dispersion optical fiber amplifier 14. The optical pulse transmitter 13 is fabricated by combination of, for example, a mode-locked laser driven by a clock extracted from the signal light by using the clock extraction circuit 4, an EA (Electro-Absorption) modulator, or an LN modulator. When the optical pulse emitted from the optical pulse transmitter 13 is launched to the normal dispersion optical fiber amplifier 14, the pulse is linearly chirped over the whole waveform by the normal dispersion and the nonlinear optical effect, and at the same time, the shape of the pulse is shaped into a parabola.

**[0022]** The second mode uses an optical fiber which has a normal dispersion and in which the magnitude of a dispersion value is gradually decreased in the longitudinal direction (see, for example, Japanese Patent Application No. 2003-387563 "Optical pulse Generation Method and Optical pulse Compression Method, etc."). Fig. 5 shows a structure of the parabolic optical pulse generator 7 of the second mode. When an optical pulse emitted from an optical pulse transmitter 13, which is driven by a clock signal similarly to the first mode, is amplified by an optical amplifier 15 and is launched to a normal dispersion-decreasing fiber 16, a parabolic pulse is obtained at the output thereof.

**[0023]** The parabolic optical pulse generator 7 includes the optical pulse transmitter 13, the optical amplifier 15, and the normal dispersion-decreasing fiber 16. As the optical pulse transmitter 13, for example, a mode locked fiber laser or a mode locked semiconductor laser can be used. When consideration is given to the use in an optical communication wavelength band, a 1.5 μm band can be mentioned as a particularly suitable wavelength. The wavelength, waveform or the like of the generated optical pulse is not limited to this, but may be arbitrary. The optical amplifier 15 is used to generate the nonlinear optical effect (self-phase modulation effect) in the normal dispersion-decreasing fiber 16. Incidentally, the output from the optical amplifier 15 is a nonlinear pulse. Here, the nonlinear optical pulse indicates an optical pulse having a power necessary to obtain the nonlinear optical effect in the normal dispersion-decreasing fiber 16.

**[0024]** The optical dispersion-decreasing fiber 16 is an optical fiber which has a normal dispersion value and in which the magnitude of the dispersion value is decreased in the longitudinal direction. For example, as the normal dispersion-decreasing fiber 16, one fiber in which the magnitude of the dispersion value is continuously changed can be used. Incidentally, in this embodiment and in general, "that the magnitude of the dispersion value is decreased" means that the absolute value of the dispersion value is decreased, and the normal dispersion fiber as stated above is called the normal dispersion-decreasing fiber. The normal dispersion-decreasing fiber 16 can be realized by, for example, continuously changing the core diameter of a normal optical fiber made of silica glass in the longitudinal direction. Specifically, this can be realized such that for example, in the process of drawing a fiber at the time of manufacture, the speed of drawing is changed to change the core diameter. Besides, as the normal dispersion-decreasing fiber 16, the continuous decrease of the dispersion value of the fiber may be discretely approximated by cascading some kinds of fibers in which the dispersion value is constant or is linearly changed in the longitudinal direction, or the dispersion value is continuously changed.

**[0025]** Here, a function D(z) to express the change of a dispersion value of the normal dispersion-decreasing fiber 16 in the longitudinal direction can be selected to be decreased with a distance (coordinate in the longitudinal direction) z as follows:

$$D(z) = D_0/(1 + D_0 \Gamma z).$$

Where $\Gamma$ denotes the ratio of decrease of the magnitude of the normal dispersion.

**[0026]** Fig. 5(b) shows an example of the change of the dispersion value of the normal dispersion-decreasing fiber 16. In the figure, a dotted line indicates the fiber 16 in which the dispersion value is continuously changed, and a solid line indicates an example in which approximation is made by cascading three kinds of fibers in which the dispersion values are linearly changed in the longitudinal direction. Incidentally, in this example, although the three kinds of fibers are used, limitation is not made to this, and a suitable number of fibers can be used. Besides, the function D(z) is all normalized by a value at z = 0 (for example, about - 4ps/nm/km in the example of the optical fiber shown in Fig. 5(b)), and may be expressed as $D_0 = 1$ or that the function value at the incident end (z = 0) is D(z) = 1.

**[0027]** The third mode is a mode in which the spectrum shape of an optical pulse is shaped into a parabola by a parabolic optical filter with an amplitude transmission characteristic expressed by a quadratic function, and the parabolic spectrum shape is converted into the parabolic optical pulse waveform by a conventional optical Fourier transform device (for example, the device shown in Fig. 1). Fig. 6 shows a structure of a parabolic optical pulse generator 7 according to the third mode. The parabolic optical pulse generator 7 of the third mode includes an optical pulse transmitter 13, a parabolic optical filter 17 and an optical Fourier transform circuit 18. An optical pulse emitted from the optical pulse transmitter 13, which is driven by a clock signal similarly to the first mode, is launched to the parabolic optical filter 17, the spectrum shape thereof is shaped into a parabola, and when it is launched to the conventional optical Fourier transform circuit 18, the parabolic optical pulse in which the temporal waveform is parabola is obtained at the output thereof.

**[0028]** Here, in the third mode, the optical Fourier transform circuit 18 similar to a conventional one is used. The characteristic of optical Fourier transform depends on a relation between the time width of a pulse having a parabolic spectrum shape and a characteristic of a phase modulator. Thus, in the phase modulator used in the conventional optical Fourier transform circuit 18, when there is a pulse having passed through the parabolic optical filter 17 in a time range in which the modulation characteristic can be approximated by a quadratic function, the quadratic function type control optical pulse can be obtained at the output.

(Detailed operation description)

**[0029]** Next, the operation of the optical Fourier transform device in this embodiment will be described. In Fig. 3, first, a signal optical pulse train is separated into two parts by the optical coupler 1, and one of them is connected to the clock extraction circuit 4 to extract a clock signal of the pulse train.

**[0030]** The signal optical pulse (wavelength $\lambda_s$) having a temporal waveform u(t) and a frequency spectrum U(ω) is coupled by the coupler 9 with the parabolic control optical pulse (wavelength $\lambda_c$) emitted from the parabolic optical pulse generator 7, and they are launched to the optical Kerr medium 10. At this time, a suitable time delay is given by the optical delay element 8 so that the center time position of the control optical pulse is matched with the timing of the signal optical pulse. Here, the temporal waveform u(t) of the signal optical pulse and the frequency spectrum U(ω) thereof are related by

[Mathematical formula 4]

$$U(\omega) = \int_{-\infty}^{\infty} u(t)\exp(i\omega t)\, dt \qquad (3)$$

**[0031]** In the optical Kerr medium 10, the instantaneous frequency of the signal light is modulated according to the time change of the control light intensity by the cross phase modulation between the signal light and the control light. Incidentally, it is assumed that the intensity of the signal light is sufficiently small as compared with the control light, and the self phase modulation by the intensity change of the signal light itself can be neglected. By differentiating a phase change $\delta\phi = (2\pi/\lambda)\ (2n_2 I)\ 1$ due to the cross phase modulation, a change (chirp) δω of the instantaneous frequency occurring in the signal light in the optical Kerr medium 10 having a length 1 becomes

[Mathematical formula 5]

$$\delta\omega(t) = -\frac{\partial\,\delta\phi}{\partial t} = -\frac{4\pi}{\lambda_s} n_2 l \frac{\partial I(t)}{\partial t} \qquad (4)$$

Where I(t) denotes the intensity of the control light per unit area, and $n_2$ denotes a constant called a Kerr coefficient.

**[0032]** The parabolic optical pulse as the control light has the temporal waveform $u_c(t)$ given by a following expression.

[Mathematical formula 6]

$$u_c(t) = \begin{cases} \sqrt{P_0}\left[1-(t/T_0)^2\right]^{1/2}, & |t| \le T_0 \\ 0, & |t| > T_0 \end{cases} \qquad (5)$$

Where $T_0$ denotes a time width from the center of the parabolic optical pulse to the edge. For example, $T_0$ denotes the width between the time when the intensity of the parabolic optical pulse becomes zero and the time of the center (peak) of the pulse. Incidentally, the expression (5) is an expression with respect to the amplitude of the pulse, and the power is expressed in the form of the square of time t. Accordingly, the chirp generated in the signal light by the cross phase modulation is given from expressions (4) and (5) by

[Mathematical formula 7]

$$\delta\omega(t) = \begin{cases} \dfrac{4\pi}{\lambda_s}\dfrac{n_2}{A_{eff}} l \cdot \dfrac{2P_0}{T_0^2} t, & |t| \le T_0 \\ 0, & |t| > T_0 \end{cases} \qquad (6)$$

Where $P_0$ denotes the peak power of the control light, $A_{eff}$ denotes the effective cross section, and I(t) is

$$I(t) = |u_c(t)|^2 / A_{eff}.$$

That is, although the phase modulation characteristic of the optical Kerr medium 10 depends on the waveform of the

control light as indicated in expression (4), when the intensity of the control light is parabolic as in this embodiment, the linear chirp $\delta\omega$ = -Kt (that is, the phase modulation $\delta\phi = \exp(iKt^2/2)$) is uniformly applied to the signal light over the time width $2T_0$. Where, from expression (6),
[Mathematical formula 8]

$$K = -\frac{8\pi n_2 P_0 l}{\lambda_s A_{\mathrm{eff}} T_0^2} = -\frac{4\gamma P_0 l}{T_0^2} \qquad (7)$$

($\gamma$ denotes a nonlinear constant).

**[0033]** Fig. 7 schematically shows a state in which a linear chirp is applied to each optical pulse constituting the signal optical pulse train by the cross phase modulation between itself and the parabolic optical pulse train. Here, the base repetition frequency of the signal light and the control optical pulse train is selected to be the inverse of a time width $2T_0$ of the parabolic optical pulse. The upper part of Fig. 7 indicates temporal waveforms of the signal light (solid line) and the control light (dotted line), and the lower part indicates the frequency shift applied to the signal light. As shown in the figure, when the time width from the center of the control light to the edge is made $T_0$, the linear chirp is applied to the signal light over the time width $2T_0$. Incidentally, the magnitude of the chirp rate K can be adjusted by changing the peak power $P_0$ of the control optical pulse, the length 1 of the optical Kerr medium 10, and the Kerr coefficient (nonlinear refractive index) $n_2$ of the optical Kerr medium 10 (see expression (7)).

**[0034]** Incidentally, in order to generate the cross phase modulation most efficiently, it is desirable that the walk-off caused by a group-velocity mismatch due to a wavelength difference $|\lambda_s - \lambda_c|$ between the signal light and the control light is small (in the above description, it is assumed that the walk-off is zero). Here, the walk-off indicates a group delay occurring between the control light and the signal light by the difference of the group-velocity in the wavelengths of both. For that purpose, for example, the optical Kerr medium 10 having a very small dispersion value is used, or $\lambda_s$ and/or $\lambda_c$ may be set so that $\lambda_s$ and $\lambda_c$ become wavelengths symmetrical to each other with respect to the zero-dispersion wavelength of the optical Kerr medium 10, and the signal light and the control light are subjected to the same time delay in the optical Kerr medium 10. For example, such $\lambda_c$ can be set by the optical pulse transmitter 13 of the parabolic optical pulse generator 7.

**[0035]** The temporal waveform $u_+(t)$ of the signal optical pulse after the linear chirp is applied in the optical Kerr medium 10 is expressed by
[Mathematical formula 9]

$$u_+(t) = u(t)\exp\left(\frac{iKt^2}{2}\right) \qquad (8)$$

**[0036]** At this time, different frequencies are assigned to the respective time positions by the frequency shift occurring in the temporal waveform of the signal optical pulse.

**[0037]** After passing through the optical Kerr medium 10, the signal light is separated from the control light by the optical filter 11, and is launched to the dispersive medium 12. The temporal waveform v(t) of the signal optical pulse after passing through the dispersive medium 12 becomes
[Mathematical formula 10]

$$\begin{aligned} v(t) &= \sqrt{\frac{i}{2\pi D}}\int_{-\infty}^{\infty} u_+(t')\exp\left(-\frac{i}{2D}(t-t')^2\right)dt' \\ &= \sqrt{\frac{i}{2\pi D}}\int_{-\infty}^{\infty} u(t')\exp\left(\frac{iKt'^2}{2}\right)\exp\left(-\frac{i}{2D}(t-t')^2\right)dt' \end{aligned} \qquad (9)$$

**[0038]** Here, when the dispersion amount of the dispersive medium 12 is selected to D = 1/K, expression (9) can be written as
[Mathematical formula 11]

$$v(t) = \sqrt{\frac{i}{2\pi D}} \exp\left(-iKt^2/2\right)\int_{-\infty}^{\infty} u(t')\exp\left(itt'/D\right)dt' = \sqrt{\frac{i}{2\pi D}} \exp\left(-iKt^2/2\right) U(t/D) \quad (10)$$

**[0039]** Accordingly, the temporal waveform v(t) of the optical pulse obtained at the output of the dispersive medium 12 is proportional to the spectrum shape U(ω) (where ω = t/D) of the optical pulse before the optical Fourier transform.

**[0040]** In other words, in the optical Kerr medium 10, the signal light in which the different frequencies are assigned to the respective time positions is given different time delays according to the frequencies by the group-velocity dispersion in the dispersive medium 12. As a result, the respective frequency components of the signal optical pulse are separated from each other in the time domain, and the temporal waveform in proportion to the Fourier transform image U(ω) of u(t), that is, U(t/D) is obtained by especially selecting the dispersion amount to D = 1/K.

(Example of numerical calculation)

**[0041]** Next, an example of numerical calculation relating to the optical Fourier transform device of the embodiment will be described. In this numerical calculation, a parabolic pulse obtained by the parabolic optical pulse generator 7 having the structure as shown in Fig. 5 is used as the control light. The energy of the control light is made 20 pJ, the dispersion value in the input of the normal dispersion-decreasing fiber 16 used for the generation of the parabolic optical pulse is made $D_0$ = -17.5 ps/nm/km, and the nonlinear coefficient is made $\gamma$ = 3.33 $W^{-1}km^{-1}$. Besides, the rate of decrease of the dispersion value of the normal dispersion-decreasing fiber 16 is made $\Gamma$ = 0.062 $m^{-1}$. A Gaussian pulse with a pulse width of 1.0 ps is incident on the normal dispersion-decreasing fiber 16.

**[0042]** Fig. 8 shows a change (a) of a dispersion value of the normal dispersion-decreasing fiber 16 in the longitudinal direction and a waveform (b) of the control optical pulse at the output. The peak power of the obtained control light is $P_0$ = 1.58 W, and the time width is $T_0$ = 12 ps. Incidentally, since the edge portion of the parabolic optical pulse shown in Fig. 8(b) is smoothly decreased, the strength becomes zero at about 12 ps.

**[0043]** Next, Fig. 9 is a view showing the temporal waveform of the signal light separated by the optical filter 11 after being transmitted through the optical Kerr medium 10 and the frequency chirp. In the figure, a thin solid line indicates the theoretical value of the frequency chirp applied to the signal light, and a thin dotted line indicates the frequency chirp applied to the signal light by a conventional LN phase modulator. Besides, thick solid lines indicate the power and chirp in this numerical calculation example. Arrows and an ellipse in the figure indicate a graph in which the left axis represents the power, and the right axis represents the chirp. The waveform and chirp shown in Fig. 9 indicate, in the system having the structure as shown in Fig. 3, the temporal waveform and frequency chirp of the signal light separated from the control light by the optical filter 11 after the signal light with a pulse width of 10 ps and having a Gaussian form and the control light obtained at the output of the normal dispersion-decreasing fiber 16 are coupled by the coupler 9 and are transmitted through the optical Kerr medium 10. Here, the wavelength interval of the signal light and the control light is made 20 nm. Besides, a dispersion-shifted fiber with a dispersion value of -0.2 ps/nm/km, a nonlinear coefficient of 3.33 $W^{-1}km^{-1}$, and a length of 1450 m is used as the optical Kerr medium 10. The theoretical value of the chirp rate obtained by substituting these values for expression (7) is K = -0.212 $ps^{-2}$. It turns out that the linear chirp (thin solid line in the figure) obtained from this theoretical value well coincides with the numerical calculation result. Besides, it turns out that as compared with the frequency chirp (thin dotted line in the figure) applied to the signal light by the LN phase modulator used for the conventional optical Fourier transform device, an range in which the chirp is linear is much expanded.

**[0044]** Fig. 10 shows the waveform (thick line) of signal light after the chirped signal light is further launched to the dispersive medium 12 and is transmitted. Here, the dispersion amount of the dispersive medium 12 is set to D = 1/K = -4.72 $ps^2$. A thin solid line indicates the waveform v(t) of signal light u(t) after optical Fourier transform calculated by using expression (10) on the assumption that the chirp is completely linear (linear chirp is applied to the signal light in the optical Kerr medium 10), and a thin dotted line indicates a result obtained when optical Fourier transform is performed by using the conventional LN phase modulator (when chirp is applied to the signal light by using the LN type optical modulator). When the LN phase modulator is used, a distortion occurs in the Fourier transform image, however, it turns out that by using the optical Fourier transform device of this embodiment, a distortion does not occur in the Fourier transform image, and the pulse width after the transform is equal to the pulse width obtained when the chirp is completely linear.

B. Second Embodiment

**[0045]** Fig. 11 is a structural view of an optical Fourier transform device of a second embodiment of the invention. A difference from the optical Fourier transform device of the first embodiment is that a dispersive medium 12 is positioned in front of a coupler 9 in this embodiment. Since the other structure is similar to the foregoing, its description will be omitted. Besides, a parabolic optical pulse generator 7 can have one of the structures of Figs. 4 to 6 similarly to the first embodiment.

**[0046]** Next, the operation of the optical Fourier transform device of this embodiment will be described. In Fig. 11, a signal optical pulse (wavelength $\lambda_s$) having a temporal waveform u(t) and a frequency spectrum U(ω) and separated by an optical coupler 1 is first launched to the dispersive medium 12. A frequency spectrum $U_+(\omega)$ of the signal optical pulse at the output of the dispersive medium 12 is given by
[Mathematical formula 12]

$$U_+(\omega) = U(\omega)\exp\left(\frac{iD\omega^2}{2}\right) \qquad (11)$$

**[0047]** Next, the signal optical pulse and a parabolic control optical pulse (wavelength $\lambda_c$) emitted from the parabolic optical pulse generator 7 are coupled by the coupler 9, and are launched to an optical Kerr medium 10. At this time, a suitable time delay is given to the control optical pulse by an optical delay element 8 so that the center time position of the control optical pulse is matched with the timing of the signal optical pulse. In the optical Kerr medium 10, similarly to the first embodiment, a linear chirp δω (expression (6)) is applied to the signal light by the cross phase modulation between itself and the control light. After passing through the optical Kerr medium 10, the signal light and the control light are separated by an optical filter 11. A frequency spectrum V(ω) of the signal light at the output of the optical filter 11 is given by the convolution integral to $U_+(\omega)$, and becomes
[Mathematical formula 13]

$$\begin{aligned} V(\omega) &= \sqrt{\frac{i}{2\pi K}}\int_{-\infty}^{\infty} U_+(\omega')\exp\left(-\frac{i}{2K}(\omega-\omega')^2\right)d\omega' \\ &= \sqrt{\frac{i}{2\pi K}}\int_{-\infty}^{\infty} U(\omega')\exp\left(\frac{iD\omega'^2}{2}\right)\exp\left(-\frac{i}{2K}(\omega-\omega')^2\right)d\omega' \end{aligned} \qquad (12)$$

**[0048]** Here, when setting is made so that the chirp rate K of the linear chirp applied by the optical Kerr medium 10 and the dispersion amount D of the dispersive medium 12 satisfy D = 1/K, expression (12) is written as
[Mathematical formula 14]

$$\begin{aligned} V(\omega) &= \sqrt{\frac{iD}{2\pi}}\exp\left(-iD\omega^2/2\right)\int_{-\infty}^{\infty} U(\omega')\exp\left(iD\omega\omega'\right)d\omega' \\ &= \sqrt{2\pi iD}\exp\left(-iD\omega^2/2\right)u(-D\omega) \end{aligned} \qquad (13)$$

**[0049]** Here,
[Mathematical formula 15]

$$u(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} U(\omega)\exp(-i\omega t)d\omega$$

is used. Accordingly, the frequency spectrum V(w) of the signal optical pulse separated by the optical filter 11 is in proportion to the temporal waveform u(t) (where t = -Dω) of the optical pulse before the optical Fourier transform.

C. Third Embodiment

**[0050]** Fig. 12 is a structural view of an optical Fourier transform device of a third embodiment. The optical Fourier transform device of the third embodiment includes an optical coupler 1, a clock extraction circuit 4, a parabolic optical pulse generator 7, an optical delay element 8, a coupler 9, an optical Kerr medium 10, an optical filter 11, a dispersive medium 12, and optical circulators 20 and 20'. Since what are denoted by the same reference numerals as those of the optical Fourier transform device shown in Fig. 3 are similar to the foregoing, their description will be omitted.

**[0051]** In the figure, signal light separated by the optical coupler 1 is first launched to a port 20a of the optical circulator 20. The port 20a is connected to a port 20'a through a port 20b, the dispersive medium 12, and a port 20'b of the optical circulator 20'. The port 20'a and the port 20'c of the optical circulator 20' are connected in a loop through the coupler 9, the optical Kerr medium 10 and the optical filter 11. The signal light separated by the optical filter 11 again passes through the dispersive medium 12 through the port 20'c and the port 20'b, and then is emitted from a port 20c through the port 20b of the optical circulator 20. The signal light is incident on the one input of the coupler 9 from the port 20'a of the optical circulator 20', and the control light generated by the parabolic optical pulse generator 7 and the optical delay element 8 is incident on the other input. The optical delay element 8 is used to give a suitable time delay to the control light so that the center time position of the control optical pulse is matched with the timing of the signal optical pulse in the optical Kerr medium 10.

**[0052]** Next, the operation of the optical Fourier transform device in this embodiment will be described. In Fig. 12, a temporal waveform $u_-(t)$ of the signal optical pulse at the output of the dispersive medium 12 is expressed by the convolution integral while using the temporal waveform u(t) of the input signal optical pulse and by a following expression.
[Mathematical formula 16]

$$u_-(t) = \sqrt{\frac{i}{2\pi D}} \int_{-\infty}^{\infty} u(t') \exp\left( -\frac{i}{2D}(t-t')^2 \right) dt' \qquad (14)$$

**[0053]** Next, the signal light is coupled with the control light, and then is launched to the optical Kerr medium 10, and the linear chirp $\delta\omega$ (expression (6)) is applied to the signal light by the cross phase modulation between itself and the control light. As a result, the temporal waveform $u_+(t)$ of the signal optical pulse at the output of the optical Kerr medium 10 is expressed by using $u_-(t)$ as follows:
[Mathematical formula 17]

$$u_+(t) = u_-(t) \exp(iKt^2/2) \qquad (15)$$

**[0054]** Further, the signal light is separated from the control light by the optical filter 11, and is again launched to the dispersive medium 12. As a result, the temporal waveform v(t) of the signal optical pulse is written by using $u_+(t)$ as follows:
[Mathematical formula 18]

$$v(t) = \sqrt{\frac{i}{2\pi D}} \int_{-\infty}^{\infty} u_+(t') \exp\left( -\frac{i}{2D}(t-t')^2 \right) dt' \qquad (16)$$

**[0055]** When the dispersion amount of the dispersive medium 12 is set to D = 1/K, from expressions (14) to (16), the signal optical pulse waveform finally emitted becomes
[Mathematical formula 19]

$$v(t)=\frac{i}{2\pi D}\int_{-\infty}^{\infty}\left[\int_{-\infty}^{\infty}u(t'')\exp\left(-\frac{i}{2D}(t'-t'')^2\right)dt''\right]\exp\left(\frac{iKt'^2}{2}\right)\exp\left(-\frac{i}{2D}(t-t')^2\right)dt'$$
$$=\frac{i}{2\pi D}\int_{-\infty}^{\infty}u(t'')\exp\left(-\frac{i}{2D}(t''^2+t^2)\right)\int_{-\infty}^{\infty}\exp\left(-\frac{i}{2D}\left[t'^2-2(t''+t)t'\right]\right)dt'dt''$$
$$=\sqrt{\frac{i}{2\pi D}}\int_{-\infty}^{\infty}u(t'')\exp\left(\frac{it}{D}t''\right)dt''$$
$$=\sqrt{\frac{i}{2\pi D}}U(t/D) \qquad (17)$$

**[0056]** Where U(ω) (ω = t/D) is Fourier transform (expression (1)) of u(t). That is, the output temporal waveform v(t) of the optical Fourier transform device is proportional to the spectrum shape U(ω) of the input waveform to the optical Fourier transform device. In this embodiment, the signal light passes through the dispersive medium 12 twice so that the chirp is completely compensated, and it is noted that differently from the first embodiment, the transform-limited waveform without chirp is obtained at the output.

**[0057]** Incidentally, the frequency spectrum of the emitted signal optical pulse becomes
[Mathematical formula 20]

$$V(\omega)=\int_{-\infty}^{\infty}v(t)\exp(i\omega t)dt$$
$$=\sqrt{\frac{i}{2\pi D}}\int_{-\infty}^{\infty}U(t/D)\exp(i\omega t)dt \qquad (18)$$
$$=\sqrt{2\pi iD}u(-D\omega)$$

and the spectrum shape V(ω) of the output waveform of the optical Fourier transform device is proportional to the temporal waveform u(t) of the input to the optical Fourier transform device.

D. Fourth Embodiment

**[0058]** Fig. 13 shows a structure of an optical Fourier transform device of a fourth embodiment. The optical Fourier transform device of the fourth embodiment includes an optical coupler 1, a clock extraction circuit 4, a parabolic optical pulse generator 7, optical delay element 8 and 8', couplers 9 and 9', an optical Kerr medium 10, an optical filter 11, a dispersive medium 12, an optical filter (a branching filter) 19, and optical circulators 20 and 20'. Since what are denoted by the same reference numerals as those of the optical Fourier transform device shown in Fig. 3 are similar to the foregoing, their description will be omitted.

**[0059]** In the figure, the signal light is first coupled by the coupler 9 with the control light generated by the parabolic optical pulse generator 7 and the optical delay element 8. The output of the coupler 9 is connected to the optical filter 19 to separate the control light from the signal light through a port 20a and a port 20b of the optical circulator 20, the optical Kerr medium 10, a port 20' b and a port 20' a of the optical circulator 20'. The optical filter 19 separates the control light from the signal light. The one output (signal light) of the optical filter 19 and the other output (control light) thereof are connected to the respective inputs of the coupler 9' through the dispersive medium 12 and the optical delay element 8', respectively. The control light and the signal light are again coupled in the coupler 9'. The output of the coupler 9' is connected to the optical filter 11 through a port 20'c and the port 20' b of the optical circulator 20' , the optical Kerr medium 10, the port 20b and a port 20c of the optical circulator 20. The signal light is separated from the control light by the optical filter 11. The optical delay elements 8 and 8' are used to give a suitable time delay to the control light so that the center time position of the control optical pulse is matched with the timing of the signal optical pulse in the optical Kerr medium 10.

**[0060]** Next, the operation of the optical Fourier transform device in this embodiment will be described. In Fig. 13, a temporal waveform $u_-(t)$ of the signal light, which has been coupled with the control light, has been launched to the optical Kerr medium 10 and has been linearly chirped in the optical Kerr medium 10, is expressed by using the temporal waveform u(t) of the original signal optical pulse and by a following expression.
[Mathematical formula 21]

$$u_-(t) = u(t)\exp(iKt^2/2) \qquad (19)$$

**[0061]** Next, a temporal waveform $u_+(t)$ of the signal light, which has been once separated from the control light by the optical filter 19 and has passed through the dispersive medium 12, is expressed by the convolution integral while using $u_-(t)$ and by a following expression.
[Mathematical formula 22]

$$u_+(t) = \sqrt{\frac{i}{2\pi D}}\int_{-\infty}^{\infty} u_-(t')\exp\left(-\frac{i}{2D}(t-t')^2\right)dt' \qquad (20)$$

**[0062]** The waveform v(t) of the signal light, which has been again coupled with the control light, has passed through the optical Kerr medium 10, and has been again given a linear chirp, is written by using $u_+(t)$ as follows:
[Mathematical formula 23]

$$v(t) = u_+(t)\exp(iKt^2/2) \qquad (21)$$

**[0063]** When the dispersion amount of the dispersive medium 12 is set to D = 1/K, by expressions (19) to (21), the waveform of the signal optical pulse finally separated by the optical filter 11 and emitted becomes
[Mathematical formula 24]

$$v(t) = \sqrt{\frac{i}{2\pi D}}U(t/D) \qquad (22)$$

**[0064]** Where $U(\omega)[\omega = t/D]$ indicates the Fourier transform (expression (1)) of the input temporal waveform u(t) to the optical Fourier transform device. In this embodiment, the signal light passes through the optical Kerr medium 10 twice so that the chirp is completely compensated, and as a result, it is noted that differently from the first embodiment, the transform-limited waveform without chirp is obtained at the output.

**[0065]** Incidentally, similarly to the foregoing expression (18), the frequency spectrum of the signal optical pulse emitted becomes
[Mathematical formula 25]

$$V(\omega) = \sqrt{2\pi iD}\,u(-D\omega) \qquad (23)$$

and the spectrum shape $V(\omega)$ of the output waveform of the optical Fourier transform device is proportional to the temporal waveform u(t) of the input to the optical Fourier transform device.

Industrial Applicability

**[0066]** Various applications using the optical Fourier transform technique are proposed in the fields of ultrahigh-speed optical communication, ultra-short pulse mode-locked laser, optical signal processing and the like, and use can be made in the industry relating to these.

## Claims

1. An optical Fourier transform device comprising:

   phase modulation means (10) adapted to linearly chirp a signal optical pulse at a rate K; and
   a dispersive medium (12) having a group-velocity dispersion and whose dispersion amount D is D=1/K,
   wherein the device is configured such that the chirped signal optical pulse emitted from the phase modulation means (10) is made to pass through the dispersive medium (12), such that the temporal waveform of the optical pulse obtained at the output of the dispersive medium (12) is proportional to the spectrum shape of the signal optical pulse;
   **characterized by**:

   an optical pulse generator (7) comprising an optical pulse transmitter (13), wherein the optical pulse transmitter (13) is adapted to be driven by a clock signal extracted from said signal optical pulse by a clock extraction circuit (4), and wherein said optical pulse generator (7) is adapted to generate a control optical pulse of a shape expressed by a quadratic function or a parabola from an optical pulse generated by the optical pulse transmitter (13), wherein the device is configured such that said control optical pulse is synchronized with said signal optical pulse; and
   a coupler (9) adapted to couple the signal optical pulse with the control optical pulse;
   wherein said phase modulation means (10) is adapted to receive the coupled signal optical pulse and control optical pulse, and comprises an optical Kerr medium (10) adapted to linearly chirp the signal optical pulse over the entire signal optical pulse by cross phase modulation between the signal optical pulse and the control optical pulse.

2. The optical Fourier transform device according to claim 1, wherein
   the device is configured such that:

   the signal optical pulse having passed through the dispersive medium (12) and the control optical pulse are again coupled and are introduced into the optical Kerr medium (10),
   the signal optical pulse having passed through the dispersive medium (12) is again linearly chirped by the optical Kerr medium (10) by the cross phase modulation between the signal optical pulse and the control optical pulse, thereby, the temporal waveform of the optical pulse obtained at the output of the Kerr medium (10) is proportional to the spectrum shape of the signal optical pulse and the frequency spectrum of the optical pulse obtained at the output of the Kerr medium (10) is proportional to the temporal waveform of the signal optical pulse.

3. The optical Fourier transform device according to claim 1 or 2, wherein
   the device is configured such that the signal optical pulse is made to pass through the optical Kerr medium (10) twice so that chirp is completely compensated, and a transform-limited waveform without chirp is obtained at output.

4. The optical Fourier transform device according to claim 2, further comprising:

   an optical filter (11) adapted to separate the signal optical pulse having passed through the optical Kerr medium (10) from the control optical pulse and to introduce the separated signal optical pulse into the dispersive medium (12); and
   a coupler (9') adapted to again couple the signal optical pulse having passed through the dispersive medium and the separated control optical pulse and introduce them into the optical Kerr medium (10).

5. An optical Fourier transform device comprising:

   a dispersive medium (12) having a group-velocity dispersion, the device being configured such that a signal optical pulse is made to pass through the dispersive medium (12);
   an optical pulse generator (7) adapted to generate a control optical pulse;
   a coupler (9) adapted to couple the signal optical pulse emitted from the dispersive medium with the control optical pulse;
   an optical Kerr medium (10) adapted to receive the coupled signal optical pulse and control optical pulse and to linearly chirp the signal optical pulse at a rate K by cross phase modulation between the signal optical pulse and the control optical pulse; wherein the dispersive medium has a dispersion amount D = 1/K; and
   wherein the optical pulse generator comprises an optical pulse transmitter (13) adapted to generate an optical

pulse;
**characterized in that**:

the optical pulse transmitter (13) is adapted to be driven by a clock signal extracted from the signal optical pulse by a clock extraction circuit (4);
the optical pulse generator (7) further comprises a dispersion-decreasing fiber (16) adapted to decrease an absolute value of a normal dispersion in a longitudinal direction;
the optical pulse generator (7) is adapted to generate a control optical pulse of a shape expressed by a quadratic function or a parabola from the optical pulse generated by the optical pulse transmitter (13);
the device is configured such that the control optical pulse is synchronized with the signal optical pulse;
the optical Kerr medium (10) is adapted to linearly chirp the signal optical pulse over the entire signal optical pulse by the cross phase modulation between the signal optical pulse and the control optical pulse; and
the frequency spectrum of the optical pulse obtained at the output of the Kerr medium (10) is proportional to the temporal waveform of the signal optical pulse.

**6.** The optical Fourier transform device according to claim 5, wherein
the device is configured such that the signal optical pulse linearly chirped by the optical Kerr medium (10) is again made to pass through the dispersive medium (12), thereby, the temporal waveform of the optical pulse obtained at the output of the dispersive medium (12) is proportional to the spectrum shape of the signal optical pulse and the frequency spectrum of the optical pulse obtained at the output of the dispersive medium (12) is proportional to the temporal waveform of the signal optical pulse.

**7.** The optical Fourier transform device according to claim 5 or 6, wherein
the device is configured such that the signal optical pulse is made to pass through the dispersive medium (12) twice so that chirp is completely compensated, and a transform-limited waveform without chirp is obtained at output.

**8.** The optical Fourier transform device according to claim 1, wherein
the chirp rate K can be adjusted by changing one of or a plurality of a peak power of the control optical pulse, a length of the optical Kerr medium (10), and a nonlinear refractive index of the optical Kerr medium (10).

**9.** The optical Fourier transform device according to claim 1, wherein the optical pulse generator (7) further comprises an optical fiber amplifier (14) which has a normal dispersion and through which the optical pulse from the optical pulse transmitter (13) is transmitted.

**10.** The optical Fourier transform device according to claim 1, wherein
the optical pulse generator (7) further comprises:

a dispersion-decreasing fiber (16) in which an absolute value of a normal dispersion is decreased in a longitudinal direction.

**11.** The optical Fourier transform device according to claim 10, wherein
the dispersion-decreasing fiber (16) includes fibers in which a change in a dispersion value is discretely approximated in each section by cascading plural kinds of optical fibers in which a dispersion value is continuously changed, or a dispersion value is constant or is linearly changed in a longitudinal direction, or one fiber in which a dispersion value is continuously changed, and the change in the dispersion value is expressed by a following expression or is approximated by the following expression

$$D(z) = D_0/(1 + D_0\Gamma z)$$

expressing

where D(z) is a function expressing the change in the dispersion value, z is a coordinate of the fiber in the longitudinal direction, $D_0$ is a function value at the incident end of the fiber for z = 0, and $\Gamma$ is a rate of decrease of magnitude of the normal dispersion.

**12.** The optical Fourier transform device according to claim 1, wherein the optical pulse generator (7) comprises:

an optical pulse transmitter (13) adapted to generate an optical pulse;

an optical filter (17) whose amplitude transmission characteristic is expressed by a quadratic function or a parabola, adapted to change a frequency spectrum of the optical pulse from the optical pulse transmitter (13) into a quadratic function type or a parabola; and
an optical Fourier transform circuit (18) adapted such that the temporal waveform of the optical pulse obtained at the output thereof is proportional to the spectrum shape of the optical pulse having passed through the optical filter (17).

**13.** The optical Fourier transform device according to claim 1, wherein
a low dispersion optical Kerr medium (10) is used as the optical Kerr medium, or a wavelength of the signal light and/or the control light is set so that wavelengths of the signal light and the control light become wavelengths symmetrical to each other with respect to a zero-dispersion wavelength of the optical Kerr medium (10).

**14.** The optical Fourier transform device according to claim 1, further comprising:

a clock extraction circuit (4) adapted to extract the clock signal based on the signal optical pulse, and
an optical delay element (8) adapted to give an optical delay to the control optical pulse,
wherein the optical delay element (8) is adapted to give the optical delay to the control optical pulse such that the centre time position of the control optical pulse is matched with that of the signal optical pulse.

**15.** An optical Fourier transform method comprising:

linearly chirping a signal optical pulse at a chirp rate K; and
passing the chirped signal optical pulse through a dispersive medium (12) having a group-velocity dispersion whose dispersion amount D is D=1/K, such that the temporal waveform of the optical pulse obtained at the output of the dispersive medium is proportional to the spectrum shape of the signal optical pulse;
**characterized by**:

generating a control optical pulse, having a shape expressed by a quadratic function or a parabola, from an optical pulse generated by an optical pulse transmitter (13), the optical pulse transmitter (13) being driven by a clock signal extracted from the signal optical pulse by a clock extraction circuit (4),
synchronizing the control optical pulse with the signal optical pulse;
coupling the signal optical pulse and the control optical pulse;
introducing the signal optical pulse and the control optical pulse into an optical Kerr medium (10), linearly chirping the signal optical pulse at a chirp rate K over the entire signal optical pulse by the optical Kerr medium (10) by the cross phase modulation between the signal optical pulse and the control optical pulse, and making the signal optical pulse emitted from the optical Kerr medium (10) pass through the dispersive medium (12).

**16.** The optical Fourier transform method according to claim 15, wherein
the signal optical pulse having passed through the dispersive medium (12) and the control optical pulse are again coupled and are introduced into the optical Kerr medium (10), the signal optical pulse having passed through the dispersive medium (12) is again linearly chirped by the optical Kerr medium (10) by the cross phase modulation between the signal optical pulse and the control optical pulse, thereby, the temporal waveform of the optical pulse obtained at the output of the Kerr medium (10) is proportional to the spectrum shape of the signal optical pulse and the frequency spectrum of the optical pulse obtained at the output of the Kerr medium (10) is proportional to the temporal waveform of the signal optical pulse.

## Patentansprüche

**1.** Optische Fourier-Transformationsvorrichtung, die Folgendes umfasst:

Phasenmodulationsmittel (10) zum linearen Chirpen eines optischen Signalimpulses mit einer Rate K; und
ein dispersives Medium (12) mit einer Gruppengeschwindigkeitsdispersion, deren Dispersionsbetrag D D=1/K beträgt,
wobei die Vorrichtung so konfiguriert ist, dass der von dem Phasenmodulationsmittel (10) emittierte gechirpte optische Signalimpuls veranlasst wird, durch das dispersive Medium (12) zu passieren, sodass die zeitliche Wellenform des am Ausgang des dispersiven Mediums (12) erhaltenen optischen Impulses proportional zur

Spektralform des optischen Signalimpulses ist;
**gekennzeichnet durch**:

einen optischen Impulsgenerator (7), der einen optischen Impulssender (13) umfasst, wobei der optische Impulssender (13) so ausgelegt ist, dass er von einem Taktsignal angesteuert wird, das von dem genannten optischen Signalimpuls durch eine Taktextraktionsschaltung (4) extrahiert wird, und wobei der genannte optische Impulsgenerator (7) zum Erzeugen eines optischen Steuerimpulses mit einer Form ausgelegt ist, die **durch** eine quadratische Funktion oder eine Parabel von einer von dem optischen Impulssender (13) erzeugten optischen Impuls ausgedrückt wird, wobei die Vorrichtung so konfiguriert ist, dass der genannte optische Steuerimpuls mit dem genannten optischen Signalimpuls synchronisiert wird; und
einen Koppler (9) zum Koppeln des optischen Signalimpulses mit dem optischen Steuerimpuls;
wobei das genannte Phasenmodulationsmittel (10) zum Empfangen des gekoppelten optischen Signalimpulses und des optischen Steuerimpulses ausgelegt ist und ein optisches Kerr-Medium (10) zum linearen Chirpen des optischen Signalimpulses über den gesamten optischen Signalimpuls **durch** Kreuzphasenmodulation zwischen dem optischen Signalimpuls und dem optischen Steuerimpuls umfasst.

**2.** Optische Fourier-Transformationsvorrichtung nach Anspruch 1, wobei die Vorrichtung so konfiguriert ist, dass:

der optische Signalimpuls nach dem Passieren durch das dispersive Medium (12) und der optische Steuerimpuls wieder gekoppelt und in das optische Kerr-Medium (10) geleitet werden,
der optische Signalimpuls nach dem Passieren durch das dispersive Medium (12) von dem optischen Kerr-Medium (10) durch die Kreuzphasenmodulation zwischen dem optischen Signalimpuls wieder linear gechirpt wird,
sodass die zeitliche Wellenform des am Ausgang des Kerr-Mediums (10) erhaltenen optischen Impulses proportional zur Spektralform des optischen Signalimpulses ist und das Frequenzspektrum des am Ausgang des Kerr-Mediums (10) erhaltenen optischen Impulses proportional zur zeitlichen Wellenform des optischen Signalimpulses ist.

**3.** Optische Fourier-Transformationsvorrichtung nach Anspruch 1 oder 2, wobei
die Vorrichtung so konfiguriert ist, dass der optische Signalimpuls veranlasst wird, zweimal durch das optische Kerr-Medium (10) zu passieren, sodass Chirp vollständig kompensiert wird und eine transformationsbegrenzte Wellenform ohne Chirp am Ausgang erhalten wird.

**4.** Optische Fourier-Transformationsvorrichtung nach Anspruch 2, die ferner Folgendes umfasst:

einen optischen Filter (11) zum Trennen des optischen Signalimpulses nach dem Passieren durch das optische Kerr-Medium (10) von dem optischen Steuerimpuls und zum Leiten des getrennten optischen Signalimpulses in das dispersive Medium (12); und
einen Koppler (9') zum erneuen Koppeln des optischen Signalimpulses nach dem Passieren durch das dispersive Medium und des getrennten optischen Steuerimpulses und zum Leiten derselben in das optische Kerr-Medium (10).

**5.** Optische Fourier-Transformationsvorrichtung, die Folgendes umfasst:

ein dispersives Medium (12) mit einer Gruppengeschwindigkeitsdispersion, wobei die Vorrichtung so konfiguriert ist, dass ein optischer Signalimpuls veranlasst wird, durch das dispersive Medium (12) zu passieren;
einen optischen Impulsgenerator (7) zum Erzeugen eines optischen Steuerimpulses;
einen Koppler (9) zum Koppeln des von dem dispersiven Medium emittierten optischen Signalimpulses mit dem optischen Steuerimpuls;
ein optisches Kerr-Medium (10) zum Empfangen des gekoppelten optischen Signalimpulses und des optischen Steuerimpulses und zum linearen Chirpen des optischen Signalimpulses mit einer Rate K durch Kreuzphasenmodulation zwischen dem optischen Signalimpuls und dem optischen Steuerimpuls; wobei das dispersive Medium einen Dispersionsbetrag $D = 1/K$ hat; und
wobei der optische Impulsgenerator einen optischen Impulssender (13) zum Erzeugen eines optischen Impulses umfasst;
**dadurch gekennzeichnet, dass**:

der optische Impulssender (13) so ausgelegt ist, dass er von einem Taktsignal angesteuert wird, das von

einer Taktextraktionsschaltung (4) von dem optischen Signalimpuls extrahiert wird;
der optische Impulsgenerator (7) ferner eine Dispersionsverringerungsfaser (16) zum Verringern eines Absolutwerts einer normalen Dispersion in einer Längsrichtung umfasst;
der optische Impulsgenerator (7) zum Erzeugen eines optischen Steuerimpulses einer Form ausgelegt ist, die durch eine quadratische Funktion oder eine Parabel von dem durch den optischen Impulssender (13) erzeugten optischen Impuls ausgedrückt wird;
die Vorrichtung so konfiguriert ist, dass der optische Steuerimpuls mit dem optischen Signalimpuls synchronisiert wird;
das optische Kerr-Medium (10) zum linearen Chirpen des optischen Signalimpulses über den gesamten optischen Signalimpuls durch die Kreuzphasenmodulation zwischen dem optischen Signalimpuls und dem optischen Steuerimpuls ausgelegt ist; und
das Frequenzspektrum des am Ausgang des Kerr-Mediums (10) erhaltenen optischen Impulses proportional zur zeitlichen Wellenform des optischen Signalimpulses ist.

**6.** Optische Fourier-Transformationsvorrichtung nach Anspruch 5, wobei
die Vorrichtung so konfiguriert ist, dass der von dem optischen Kerr-Medium (10) linear gechirpte optische Signalimpuls wieder veranlasst wird, durch das dispersive Medium (12) zu passieren, sodass die zeitliche Wellenform des am Ausgang des dispersiven Mediums (12) erhaltenen optischen Impulses proportional zur Spektralform des optischen Signalimpulses ist, und das Frequenzspektrum des am Ausgang des dispersiven Mediums (12) erhaltenen optischen Impulses proportional zur zeitlichen Wellenform des optischen Signalimpulses ist.

**7.** Optische Fourier-Transformationsvorrichtung nach Anspruch 5 oder 6, wobei
die Vorrichtung so konfiguriert ist, dass der optische Signalimpuls veranlasst wird, zweimal durch das dispersive Medium (12) zu passieren, sodass Chirp vollkommen kompensiert und eine transformationsbegrenzte Wellenform ohne Chirp am Ausgang erhalten wird.

**8.** Optische Fourier-Transformationsvorrichtung nach Anspruch 1, wobei
die Chirp-Rate K durch Ändern von einer oder mehreren aus Spitzenleistung des optischen Steuerimpulses, Länge des optischen Kerr-Mediums (10) und nichtlinearem Brechungsindex des optischen Kerr-Mediums (10) justiert werden kann.

**9.** Optische Fourier-Transformationsvorrichtung nach Anspruch 1, wobei der optische Impulsgenerator (7) ferner einen optischen Faserverstärker (14) umfasst, der eine normale Dispersion hat und durch den der optische Impuls vom optischen Impulssender (13) gesendet wird.

**10.** Optische Fourier-Transformationsvorrichtung nach Anspruch 1, wobei
der optische Impulsgenerator (7) ferner Folgendes umfasst:

eine Dispersionsverringerungsfaser (16), in der ein Absolutwert einer normalen Dispersion in einer Längsrichtung verringert wird.

**11.** Optische Fourier-Transformationsvorrichtung nach Anspruch 10, wobei
die Dispersionsverringerungsfaser (16) Fasern beinhaltet, in denen eine Änderung eines Dispersionswertes diskret in jedem Abschnitt durch Kaskadieren von mehreren Arten von
optischen Fasern approximiert wird, in denen ein Dispersionswert kontinuierlich verändert wird, oder ein Dispersionswert konstant ist oder sich linear in einer Längsrichtung ändert, oder eine Faser, in der sich ein Dispersionswert kontinuierlich ändert und die Änderung des Dispersionswertes durch einen folgenden Ausdruck ausgedrückt oder durch den folgenden Ausdruck approximiert wird:

$$D(z) = D_0/(1 + D_0\Gamma z)$$

wobei D(z) eine Funktion ist, die die Änderung des Dispersionswertes ausdrückt, z eine Koordinate der Faser in der Längsrichtung ist, $D_0$ ein Funktionswert am Einfallsende der Faser für z = 0 ist, und $\Gamma$ eine Größenabnahmerate der normalen Dispersion ist.

**12.** Optische Fourier-Transformationsvorrichtung nach Anspruch 1, wobei der optische Impulsgenerator (7) Folgendes umfasst:

einen optischen Impulssender (13) zum Erzeugen eines optischen Impulses;
ein optisches Filter (17), dessen Amplitudentransmissionscharakteristik durch eine quadratische Funktion oder eine Parabel ausgedrückt wird, ausgelegt zum Ändern eines Frequenzspektrums des optischen Impulses von dem optischen Impulssender (13) in einen quadratischen Funktionstyp oder eine Parabel; und
eine optische Fourier-Transformationsschaltung (18), so ausgelegt, dass die zeitliche Wellenform des am Ausgang davon erhaltenen optischen Impulses proportional zur Spektralform des optischen Impulses nach dem Passieren durch das optische Filter (17) ist.

**13.** Optische Fourier-Transformationsvorrichtung nach Anspruch 1, wobei
ein optisches Kerr-Medium (10) mit geringer Dispersion als optisches Kerr-Medium verwendet wird oder eine Wellenlänge des Signallichts und/oder des Steuerlichts so eingestellt wird, dass Wellenlängen des Signallichts und des Steuerlichts zu Wellenlängen werden, die miteinander in Bezug auf eine Null-Dispersion-Wellenlänge des optischen Kerr-Mediums (10) symmetrisch sind.

**14.** Optische Fourier-Transformationsvorrichtung nach Anspruch 1, die ferner Folgendes umfasst:

eine Taktextraktionsschaltung (4) zum Extrahieren des Taktsignals auf der Basis des optischen Signalimpulses, und
ein optisches Verzögerungselement (8), um dem optischen Steuerimpuls eine optische Verzögerung zu verleihen,
wobei das optische Verzögerungselement (8) so ausgelegt ist, dass es dem optischen Steuerimpuls die optische Verzögerung verleiht, sodass die Zentralzeitposition des optischen Steuerimpulses mit der des optischen Signalimpulses übereinstimmt.

**15.** Optisches Fourier-Transformationsverfahren, das Folgendes beinhaltet:

lineares Chirpen eines optischen Signalimpulses mit einer Chirp-Rate K; und
Leiten des gechirpten optischen Signalimpulses durch ein dispersives Medium (12) mit einer Gruppengeschwindigkeitsdispersion, deren Dispersionsbetrag D D=1/K beträgt, sodass die zeitliche Wellenform des am Ausgang des dispersiven Mediums erhaltenen optischen Impulses proportional zur Spektralform des optischen Signalimpulses ist;
**gekennzeichnet durch**:

Erzeugen eines optischen Steuerimpulses mit einer Form, die **durch** eine quadratische Funktion oder eine Parabel ausgedrückt wird, von einem **durch** einen optischen Impulssender (13) erzeugten optischen Impuls, wobei der optische Impulssender (13) von einem Taktsignal angesteuert wird, das von dem optischen Signalimpuls **durch** eine Taktextraktionsschaltung (4) extrahiert wird,
Synchronisieren des optischen Steuerimpulses mit dem optischen Signalimpuls;
Koppeln des optischen Signalimpulses und des optischen Steuerimpulses;
Leiten des optischen Signalimpulses und des optischen Steuerimpulses in ein optisches Kerr-Medium (10), lineares Chirpen des optischen Signalimpulses mit einer Chirp-Rate K über den gesamten optischen Signalimpuls **durch** das optische Kerr-Medium (10) **durch** die Kreuzphasenmodulation zwischen dem optischen Signalimpuls und dem optischen Steuerimpuls, und Bewirken, dass der von dem optischen Kerr-Medium (10) emittierte optische Signalimpuls **durch** das dispersive Medium (12) passiert.

**16.** Optisches Fourier-Transformationsverfahren nach Anspruch 15, wobei
der optische Signalimpuls nach dem Passieren durch das dispersive Medium (12) und der optische Steuerimpuls wieder gekoppelt und in das optische Kerr-Medium (10) geleitet werden, wobei der optische Signalimpuls nach dem Passieren durch das dispersive Medium (12) durch das optische Kerr-Medium (10) durch die Kreuzphasenmodulation zwischen dem optischen Signalimpuls und dem optischen Steuerimpuls wieder linear gechirpt wird, sodass die zeitliche Wellenform des am Ausgang des Kerr-Mediums (10) erhaltenen optischen Impulses proportional zur Spektralform des optischen Signalimpulses ist und das Frequenzspektrum des am Ausgang des Kerr-Mediums (10) erhaltenen optischen Impulses proportional zur zeitlichen Wellenform des optischen Signalimpulses ist.

## Revendications

1. Dispositif optique à transformée de Fourier comportant :

    un moyen de modulation de phase (10) conçu pour effectuer une compression d'impulsions linéaire d'une impulsion optique de signal selon un taux K ; et
    un support dispersif (12) possédant une dispersion de vitesse de groupe et dont la quantité de dispersion D est D=1/K,
    dans lequel le dispositif est configuré de telle sorte que l'impulsion optique de signal avec compression d'impulsions, émise par le moyen de modulation de phase (10), est amenée à traverser le support dispersif (12), de telle sorte que la forme d'onde temporelle de l'impulsion optique obtenue à la sortie du support dispersif (12) est proportionnelle à l'enveloppe de spectre de l'impulsion optique de signal ;
    **caractérisé par** :

        un générateur d'impulsions optiques (7) comportant un émetteur d'impulsions optiques (13), dans lequel l'émetteur d'impulsions optiques (13) est conçu pour être piloté par un signal d'horloge extrait de ladite impulsion optique de signal par un circuit d'extraction d'horloge (4), et dans lequel ledit générateur d'impulsions optiques (7) est conçu pour générer une impulsion optique de commande d'une enveloppe exprimée par une fonction quadratique ou une parabole à partir d'une impulsion optique générée par l'émetteur d'impulsions optiques (13), dans lequel le dispositif est configuré de telle sorte que ladite impulsion optique de commande est synchronisée avec ladite impulsion optique de signal ; et
        un coupleur (9) conçu pour coupler l'impulsion optique de signal avec l'impulsion optique de commande ;
        dans lequel ledit moyen de modulation de phase (10) est conçu pour recevoir l'impulsion optique de signal couplée et l'impulsion optique de commande, et comporte un support Kerr optique (10) conçu pour effectuer une compression d'impulsions linéaire de l'impulsion optique de signal sur l'intégralité de l'impulsion optique de signal par une modulation de phase croisée entre l'impulsion optique de signal et l'impulsion optique de commande.

2. Dispositif optique à transformée de Fourier selon la revendication 1, dans lequel le dispositif est configuré de telle sorte que :

    l'impulsion optique de signal ayant traversé le support dispersif (12) et l'impulsion optique de commande sont de nouveau couplées et sont introduites dans le support Kerr optique (10),
    l'impulsion optique de signal ayant traversé le support dispersif (12) est de nouveau soumise à une compression d'impulsions linéaire par le support Kerr optique (10) par la modulation de phase croisée entre l'impulsion optique de signal et l'impulsion optique de commande,
    ce par quoi la forme d'onde temporelle de l'impulsion optique obtenue à la sortie du support Kerr (10) est proportionnelle à l'enveloppe de spectre de l'impulsion optique de signal, et le spectre de fréquences de l'impulsion optique obtenue à la sortie du support Kerr (10) est proportionnel à la forme d'onde temporelle de l'impulsion optique de signal.

3. Dispositif optique à transformée de Fourier selon la revendication 1 ou 2, dans lequel le dispositif est configuré de telle sorte que l'impulsion optique de signal est amenée à traverser le support Kerr optique (10) deux fois de telle sorte que la compression d'impulsions est intégralement compensée, et une forme d'onde limitée par transformée de Fourier sans compression d'impulsions est obtenue en sortie.

4. Dispositif optique à transformée de Fourier selon la revendication 2, comportant en outre :

    un filtre optique (11) conçu pour séparer l'impulsion optique de signal ayant traversé le support Kerr optique (10) de l'impulsion optique de commande, et pour introduire l'impulsion optique de signal séparée dans le support dispersif (12) ; et
    un coupleur (9') conçu pour coupler de nouveau l'impulsion optique de signal ayant traversé le support dispersif et l'impulsion optique de commande séparée, et les introduire dans le support Kerr optique (10).

5. Dispositif optique à transformée de Fourier comportant :

    un support dispersif (12) possédant une dispersion de vitesse de groupe, le dispositif étant configuré de telle sorte qu'une impulsion optique de signal est amenée à traverser le support dispersif (12) ;

un générateur d'impulsions optiques (7) conçu pour générer une impulsion optique de commande ;
un coupleur (9) conçu pour coupler l'impulsion optique de signal émise par le support dispersif avec l'impulsion optique de commande ;
un support Kerr optique (10) conçu pour recevoir l'impulsion optique de signal couplée et l'impulsion optique de commande, et pour effectuer une compression d'impulsions linéaire, selon un taux K, par la modulation de phase croisée entre l'impulsion optique de signal et l'impulsion optique de commande ; dans lequel le support dispersif possède une quantité de dispersion D=1/K ; et
dans lequel le générateur d'impulsions optiques comporte un émetteur d'impulsions optiques (13) conçu pour générer une impulsion optique ;

**caractérisé en ce que** :

l'émetteur d'impulsions optiques (13) est conçu pour être piloté par un signal d'horloge extrait de l'impulsion optique de signal par un circuit d'extraction d'horloge (4) ;
le générateur d'impulsions optiques (7) comporte en outre une fibre à dispersion décroissante (16) conçue pour diminuer une valeur absolue de dispersion normale selon une direction longitudinale ;
le générateur d'impulsions optiques (7) est conçu pour générer une impulsion optique de commande d'une enveloppe exprimée par une fonction quadratique ou une parabole à partir de l'impulsion optique générée par l'émetteur d'impulsions optiques (13) ;
le dispositif est configuré de telle sorte que l'impulsion optique de commande est synchronisée avec l'impulsion optique de signal ;
le support Kerr optique (10) est conçu pour effectuer une compression d'impulsions linéaire de l'impulsion optique de signal sur l'intégralité de l'impulsion optique de signal par la modulation de phase croisée entre l'impulsion optique de signal et l'impulsion optique de commande ; et
le spectre de fréquences de l'impulsion optique obtenue à la sortie du support Kerr (10) est proportionnel à la forme d'onde temporelle de l'impulsion optique de signal.

**6.** Dispositif optique à transformée de Fourier selon la revendication 5, dans lequel
le dispositif est configuré de telle sorte que l'impulsion optique de signal soumise à une compression d'impulsions linéaire par le support Kerr optique (10) est de nouveau amenée à traverser le support dispersif (12), ce par quoi la forme d'onde temporelle de l'impulsion optique obtenue à la sortie du support dispersif (12) est proportionnelle à l'enveloppe de spectre de l'impulsion optique de signal, et le spectre de fréquences de l'impulsion optique obtenue à la sortie du support dispersif (12) est proportionnel à la forme d'onde temporelle de l'impulsion optique de signal.

**7.** Dispositif optique à transformée de Fourier selon la revendication 5 ou 6, dans lequel
le dispositif est configuré de telle sorte que l'impulsion optique de signal est amenée à traverser le support dispersif (12) deux fois de manière à compenser intégralement la compression d'impulsions, et une forme d'onde limitée par transformée de Fourier sans compression d'impulsions est obtenue à la sortie.

**8.** Dispositif optique à transformée de Fourier selon la revendication 1, dans lequel
le taux de compression d'impulsions K peut être ajusté en changeant une ou plusieurs caractéristiques parmi une puissance crête de l'impulsion optique de commande, une longueur du support Kerr optique (10) et un indice de réfraction non linéaire du support Kerr optique (10).

**9.** Dispositif optique à transformée de Fourier selon la revendication 1, dans lequel le générateur d'impulsions optiques (7) comporte en outre un amplificateur de fibre optique (14) qui possède une dispersion normale et au travers duquel est transmise l'impulsion optique provenant de l'émetteur d'impulsions (13).

**10.** Dispositif optique à transformée de Fourier selon la revendication 1, dans lequel
le générateur d'impulsions optiques (7) comporte en outre :

une fibre à dispersion décroissante (16) dans laquelle une valeur absolue d'une dispersion normale diminue selon une direction longitudinale.

**11.** Dispositif optique à transformée de Fourier selon la revendication 10, dans lequel
la fibre à dispersion décroissante (16) comporte des fibres dans lesquelles une modification d'une valeur de dispersion est approchée de manière discrète dans chaque section en superposant plusieurs types de fibres optiques dans lesquelles une valeur de dispersion est modifiée de manière continue, ou une valeur de dispersion est constante

ou est modifiée de manière linéaire selon une direction longitudinale, ou une fibre dans laquelle une valeur de dispersion est modifiée de manière continue, et la modification de la valeur de dispersion est exprimée par une expression suivante, ou est approchée par l'expression suivante :

$$D(z) = D_0/(1 + D_0\Gamma z)$$

dans laquelle D(z) est une fonction exprimant la modification de la valeur de dispersion, z est une coordonnée de la fibre selon la direction longitudinale, $D_0$ est une valeur de fonction de l'extrémité incidente de la fibre pour z = 0, et $\Gamma z$ est un taux de diminution de l'amplitude de la dispersion normale.

**12.** Dispositif optique à transformée de Fourier selon la revendication 1, dans lequel le générateur d'impulsions optiques (7) comporte :

un émetteur d'impulsions optiques (13) conçu pour générer une impulsion optique ;
un filtre optique (17) dont la caractéristique d'émission d'amplitude est exprimée par une fonction quadratique ou une parabole, conçue pour modifier un spectre de fréquences de l'impulsion optique provenant de l'émetteur d'impulsions optiques (13) en un type de fonction quadratique ou une parabole ; et
un circuit optique de transformation de Fourier (18) conçu de telle sorte que la forme d'onde temporelle de l'impulsion optique obtenue à sa sortie est proportionnelle à l'enveloppe de spectre de l'impulsion optique ayant traversé le filtre optique (17).

**13.** Dispositif optique à transformée de Fourier selon la revendication 1, dans lequel
un support Kerr optique à faible dispersion (10) est utilisé pour former ledit support Kerr optique, ou une longueur d'onde de la lumière du signal et/ou de la lumière de commande est fixée de telle sorte que les longueurs d'onde de la lumière de signal et de la lumière de commande deviennent des longueurs d'ondes mutuellement symétriques par rapport à une longueur d'onde de dispersion nulle du support Kerr optique (10).

**14.** Dispositif optique à transformée de Fourier selon la revendication 1, comportant en outre :

un circuit d'extraction d'horloge (4) conçu pour extraire le signal d'horloge en fonction de l'impulsion optique de signal, et
un élément de retardement optique (8) conçu pour appliquer un retard optique à l'impulsion optique de commande,
dans lequel l'élément de retardement (8) est conçu pour appliquer le retard optique à l'impulsion optique de commande de telle sorte que la position temporelle centrale de l'impulsion optique de commande est en correspondance avec celle de l'impulsion optique de signal.

**15.** Procédé optique de transformation de Fourier comportant :

la compression d'impulsions linéaire d'une impulsion optique de signal avec un taux de compression K ; et
le passage de l'impulsion optique de signal compressée dans un support dispersif (12) possédant une dispersion de vitesse du groupe dont la quantité de dispersion D est D=1/K, de telle sorte que la forme d'onde temporelle de l'impulsion optique obtenue à la sortie du support dispersif est proportionnelle à l'enveloppe de spectre de l'impulsion optique de signal ;
la génération d'une impulsion optique de commande, possédant une enveloppe exprimée par une fonction quadratique ou une parabole, à partir d'une impulsion optique générée par un émetteur d'impulsions optiques (13), l'émetteur d'impulsions optiques (13) étant piloté par un signal d'horloge extrait de l'impulsion optique de signal par un circuit d'extraction d'horloge (4),
le couplage de l'impulsion optique de signal et de l'impulsion optique de commande ;
l'introduction de l'impulsion optique de signal et de l'impulsion optique de commande dans un support Kerr optique (10), la compression d'impulsions linéaire de l'impulsion optique de signal selon un taux de compression K sur l'intégralité de l'impulsion de signal par le support Kerr optique (10) par la modulation de phase croisée entre l'impulsion optique de signal et l'impulsion optique de commande, et le passage de l'impulsion optique de signal émise par le support Kerr optique (10) au travers du support dispersif (12).

**16.** Dispositif optique à transformée de Fourier selon la revendication 15, dans lequel l'impulsion optique de signal ayant traversé le support dispersif (12) et l'impulsion optique de commande sont de nouveau couplées et sont introduites dans le support Kerr optique (10), l'impulsion optique de signal ayant traversé le support dispersif (12) est de nouveau soumise à une compression d'impulsions linéaire par le support Kerr optique (10) par la modulation de phase croisée entre l'impulsion optique de signal et l'impulsion optique de commande, ce par quoi la forme d'onde temporelle de l'impulsion optique obtenue à la sortie du support Kerr (10) est proportionnelle à l'enveloppe de spectre de l'impulsion optique de signal, et le spectre de fréquences de l'impulsion optique obtenue à la sortie du support Kerr (10) est proportionnel à la forme d'onde temporelle de l'impulsion optique de signal.

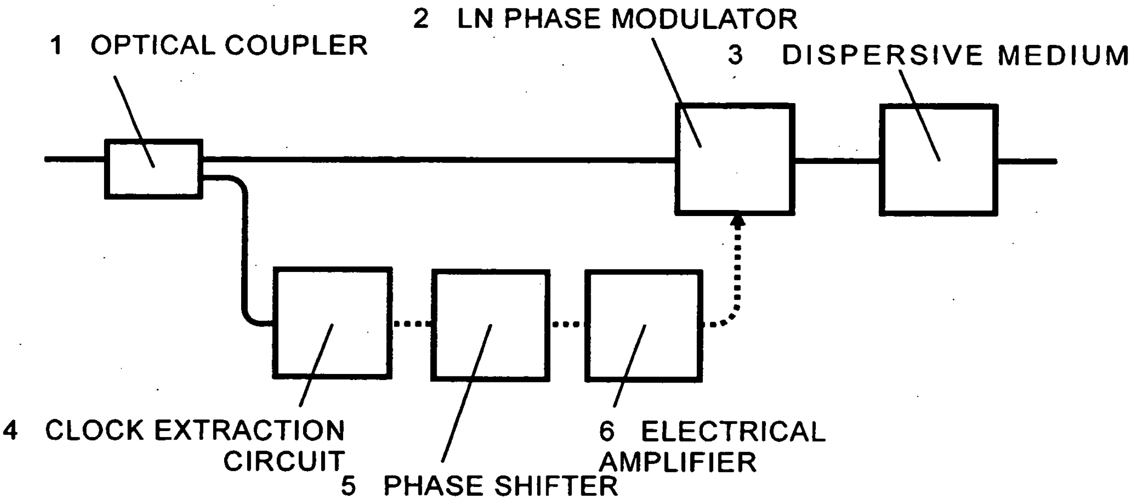

2 LN PHASE MODULATOR
1 OPTICAL COUPLER
3 DISPERSIVE MEDIUM
4 CLOCK EXTRACTION CIRCUIT
5 PHASE SHIFTER
6 ELECTRICAL AMPLIFIER

FIG. 1

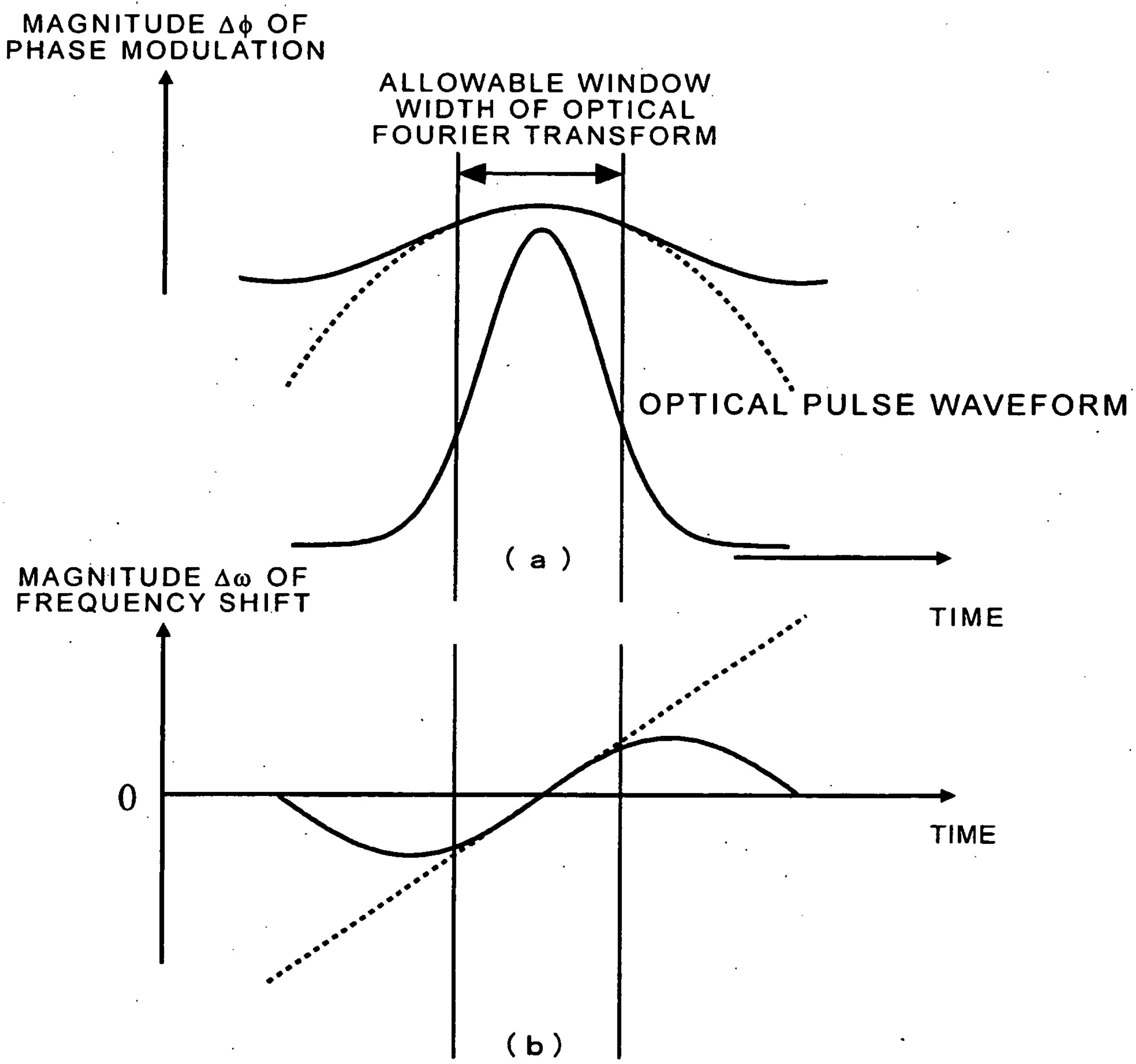

MAGNITUDE Δφ OF
PHASE MODULATION
ALLOWABLE WINDOW
WIDTH OF OPTICAL
FOURIER TRANSFORM
OPTICAL PULSE WAVEFORM
(a)
TIME
MAGNITUDE Δω OF
FREQUENCY SHIFT
0
TIME
(b)

FIG. 2

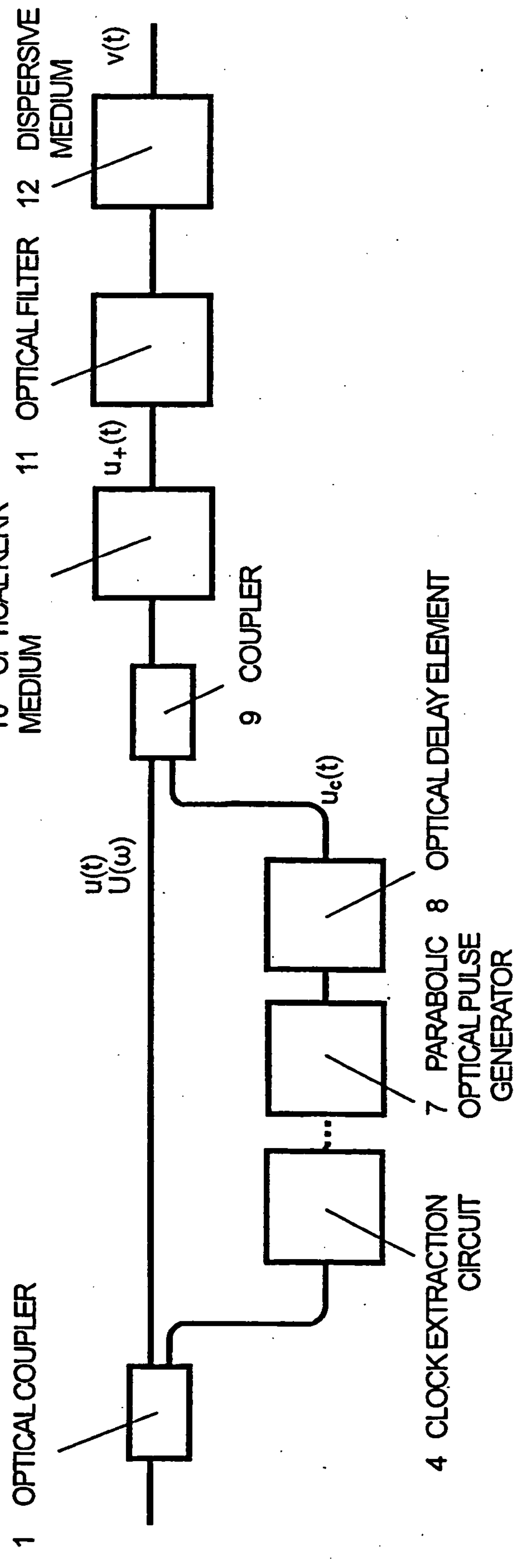

1 OPTICAL COUPLER
4 CLOCK EXTRACTION CIRCUIT
7 PARABOLIC OPTICAL PULSE GENERATOR
8 OPTICAL DELAY ELEMENT
9 COUPLER
10 OPTICAL KERR MEDIUM
11 OPTICAL FILTER
12 DISPERSIVE MEDIUM
u(t)
U(ω)
$u_c(t)$
$u_+(t)$
v(t)

FIG. 3

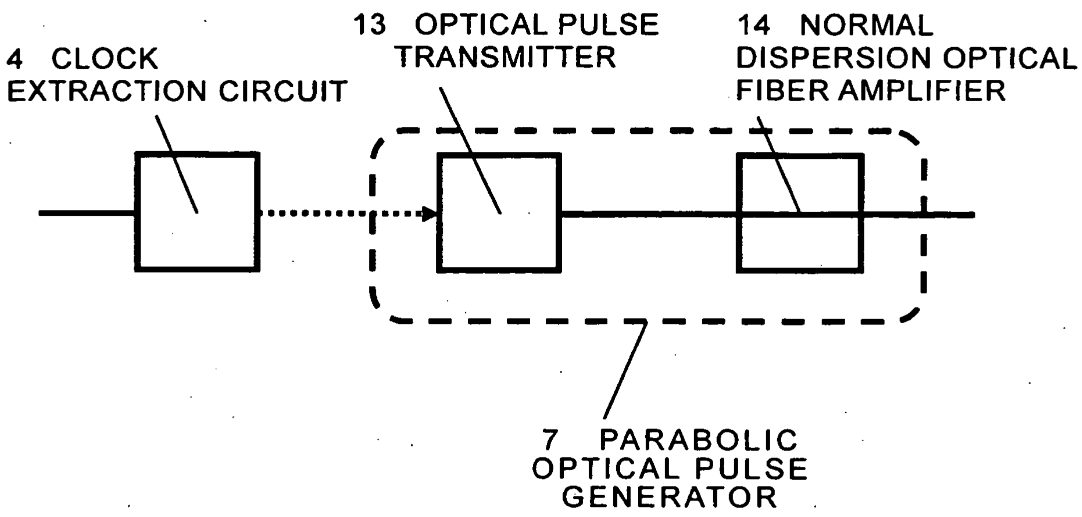
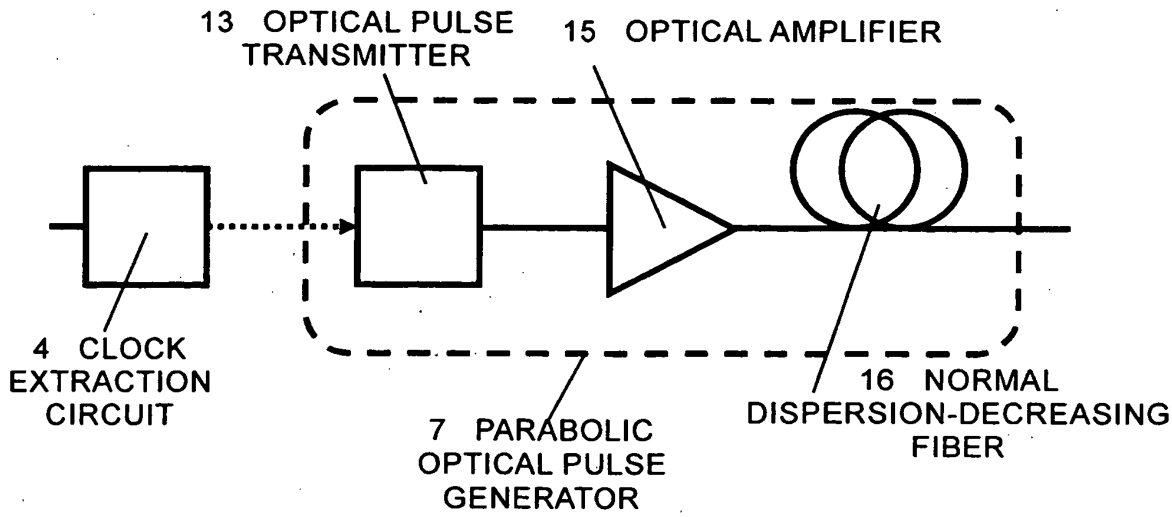
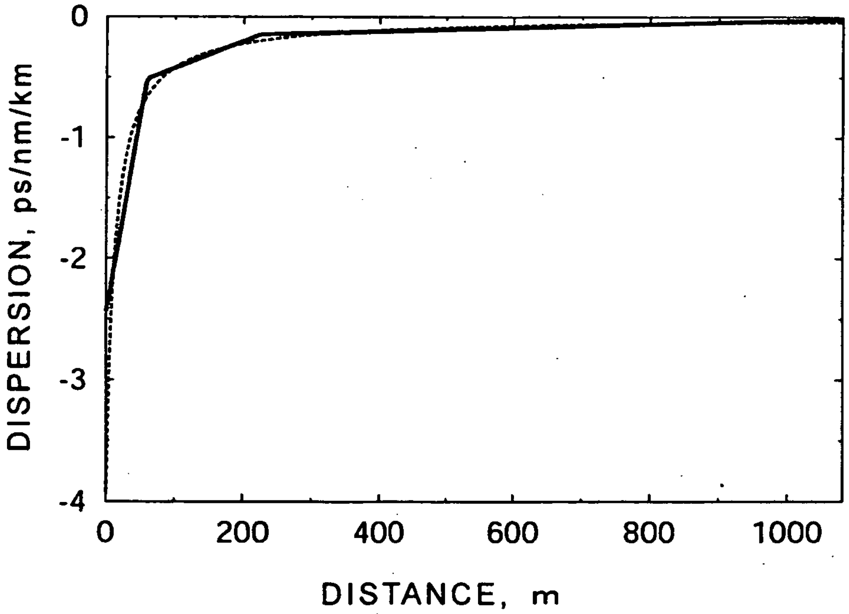

4 CLOCK EXTRACTION CIRCUIT
13 OPTICAL PULSE TRANSMITTER
14 NORMAL DISPERSION OPTICAL FIBER AMPLIFIER
7 PARABOLIC OPTICAL PULSE GENERATOR

FIG. 4


13 OPTICAL PULSE TRANSMITTER
15 OPTICAL AMPLIFIER
4 CLOCK EXTRACTION CIRCUIT
7 PARABOLIC OPTICAL PULSE GENERATOR
16 NORMAL DISPERSION-DECREASING FIBER

( a )


0
-1
-2
-3
-4
DISPERSION, ps/nm/km
0
200
400
600
800
1000
DISTANCE, m

( b )

FIG. 5

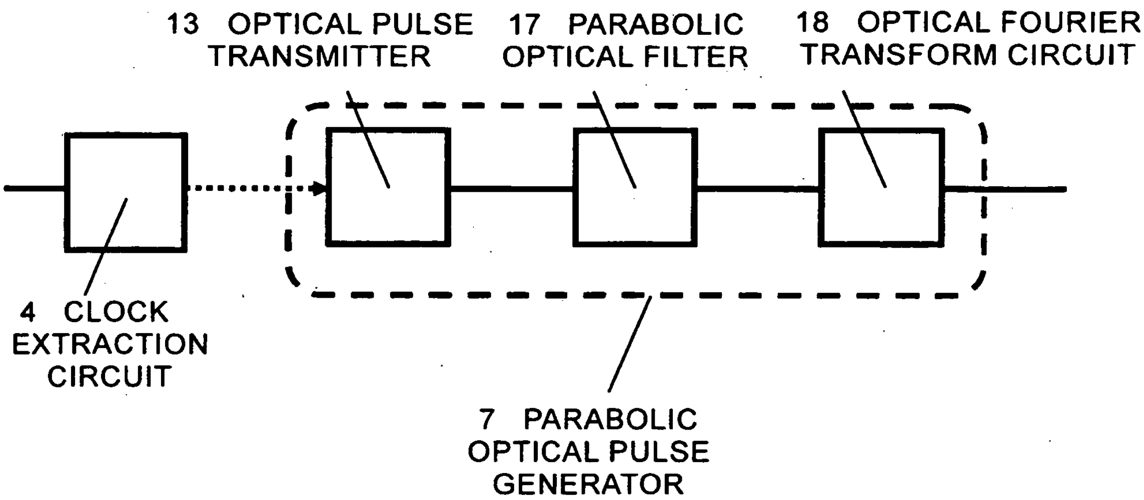

13 OPTICAL PULSE TRANSMITTER
17 PARABOLIC OPTICAL FILTER
18 OPTICAL FOURIER TRANSFORM CIRCUIT
4 CLOCK EXTRACTION CIRCUIT
7 PARABOLIC OPTICAL PULSE GENERATOR

FIG. 6

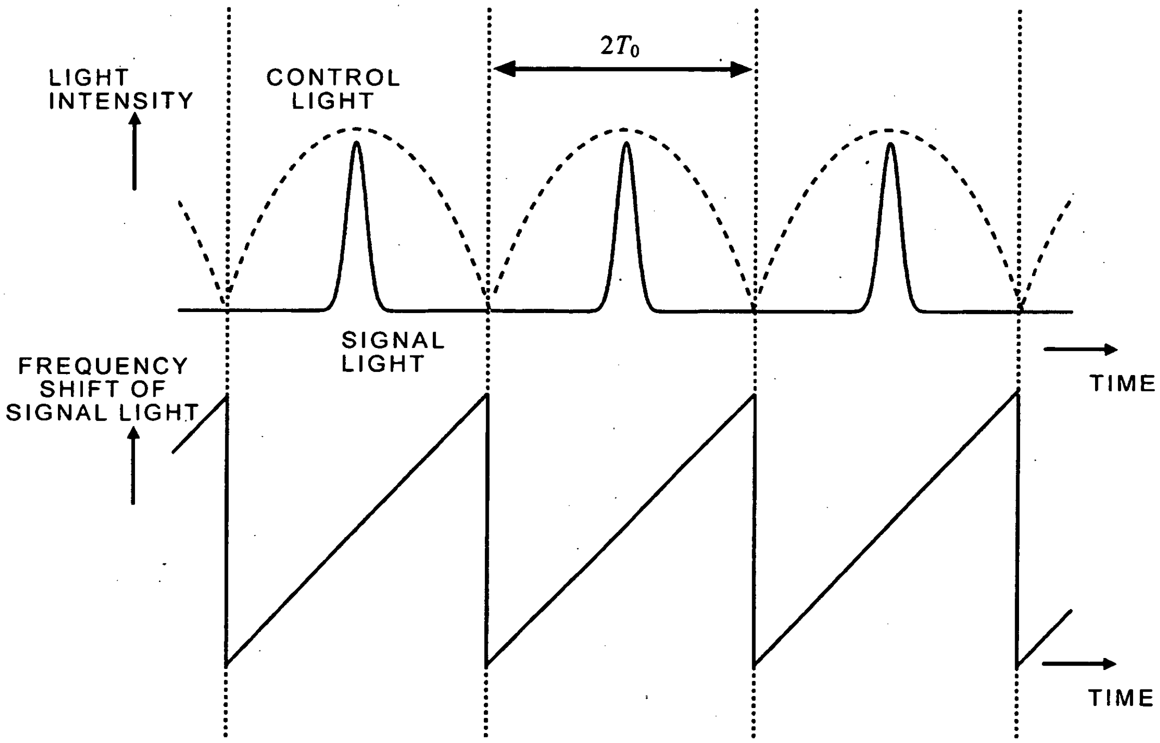

2$T_0$
LIGHT INTENSITY
CONTROL LIGHT
SIGNAL LIGHT
FREQUENCY SHIFT OF SIGNAL LIGHT
TIME
TIME

FIG. 7

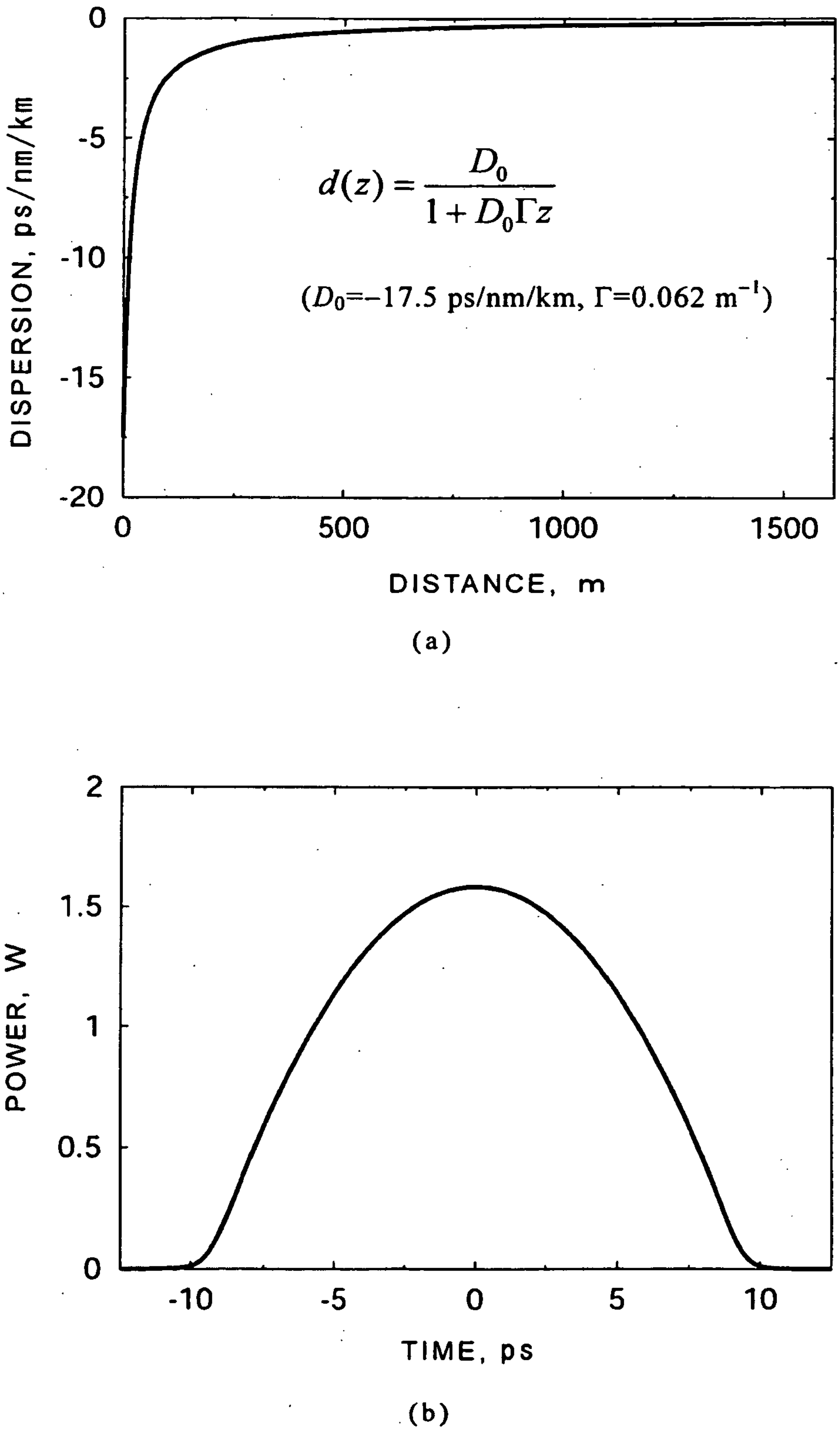

0
-5
-10
-15
-20
DISPERSION, ps/nm/km
$d(z) = \frac{D_0}{1 + D_0 \Gamma z}$
($D_0$=−17.5 ps/nm/km, Γ=0.062 $m^{-1}$)
0
500
1000
1500
DISTANCE, m
(a)
2
1.5
1
0.5
0
POWER, W
-10
-5
0
5
10
TIME, ps
(b)

FIG. 8

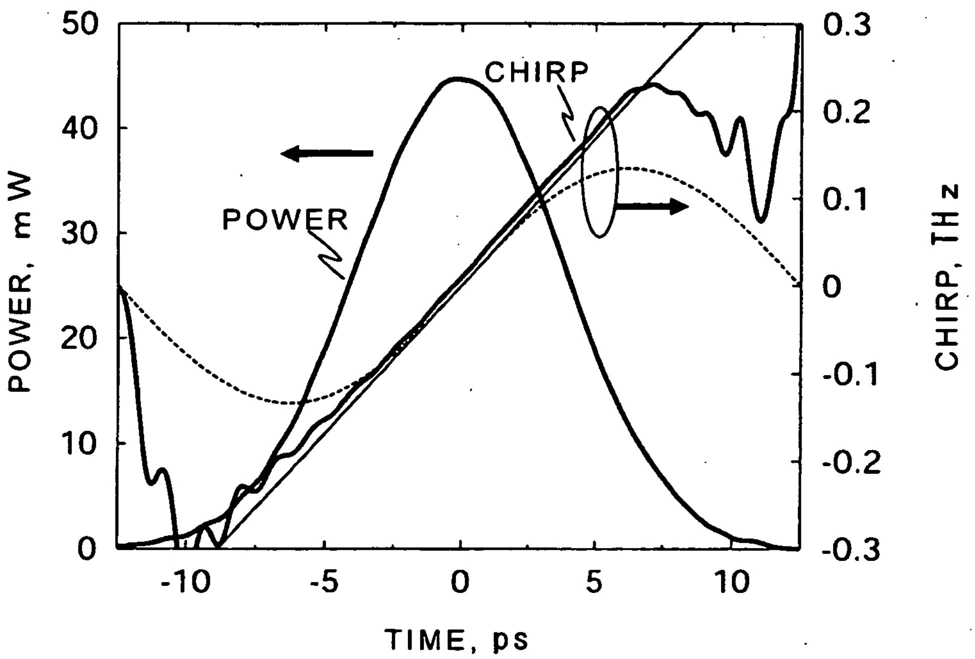

50
40
30
20
10
0
POWER, mW
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
CHIRP, THz
CHIRP
POWER
-10
-5
0
5
10
TIME, ps

FIG. 9

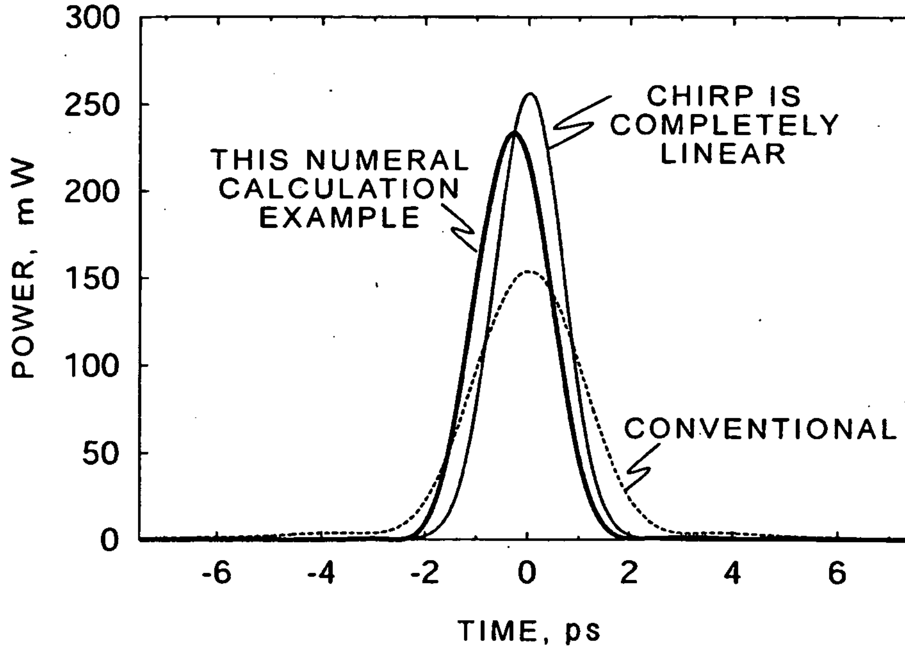

300
250
200
150
100
50
0
POWER, mW
THIS NUMERAL
CALCULATION
EXAMPLE
CHIRP IS
COMPLETELY
LINEAR
CONVENTIONAL
-6
-4
-2
0
2
4
6
TIME, ps

FIG. 10

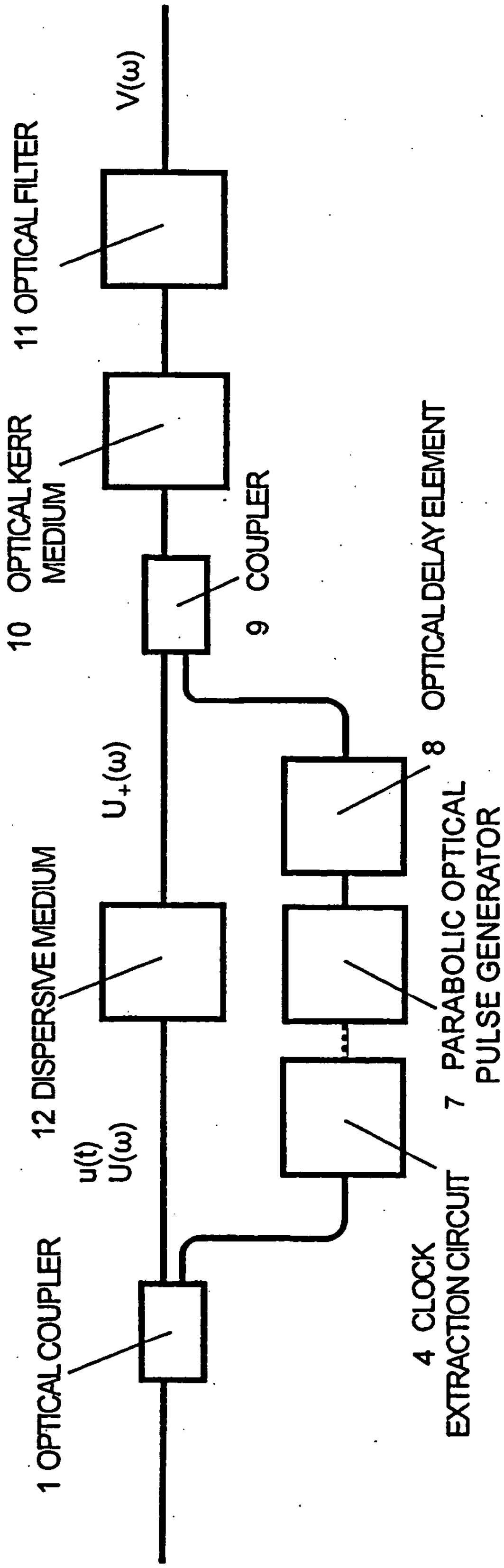

V(ω)
11 OPTICAL FILTER
10 OPTICAL KERR MEDIUM
9 COUPLER
8 OPTICAL DELAY ELEMENT
U+(ω)
12 DISPERSIVE MEDIUM
7 PARABOLIC OPTICAL PULSE GENERATOR
u(t)
U(ω)
1 OPTICAL COUPLER
4 CLOCK EXTRACTION CIRCUIT

FIG. 11

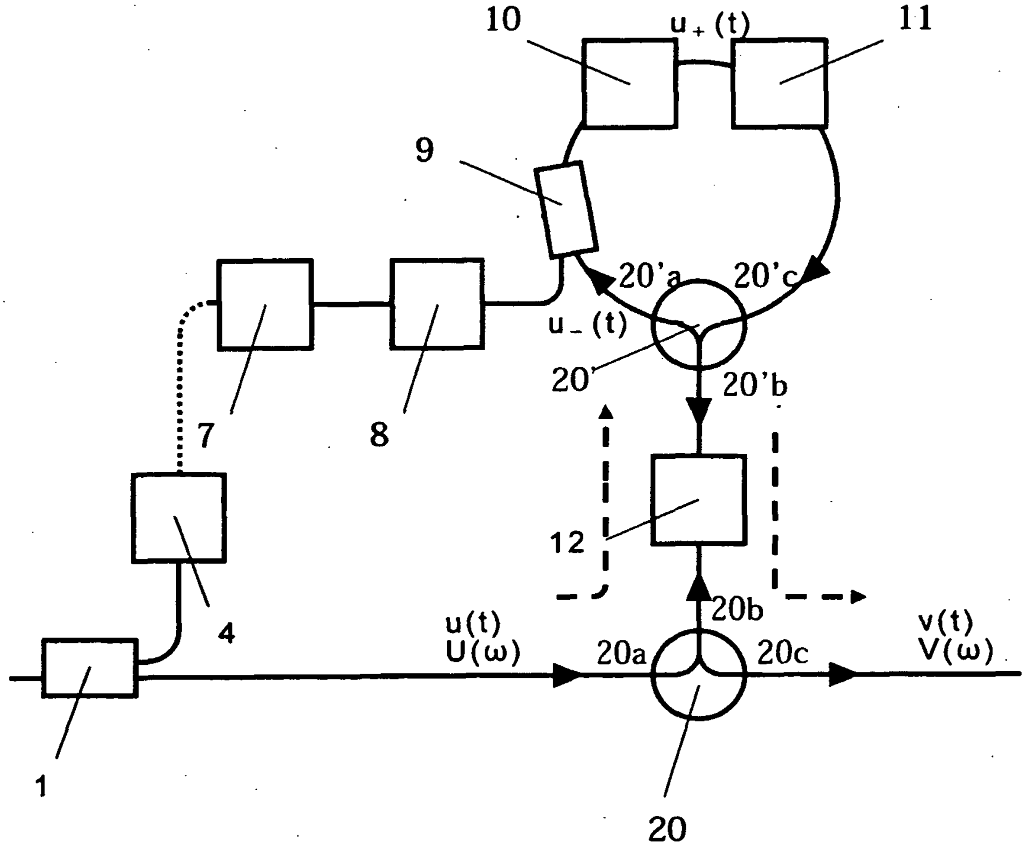



FIG. 12

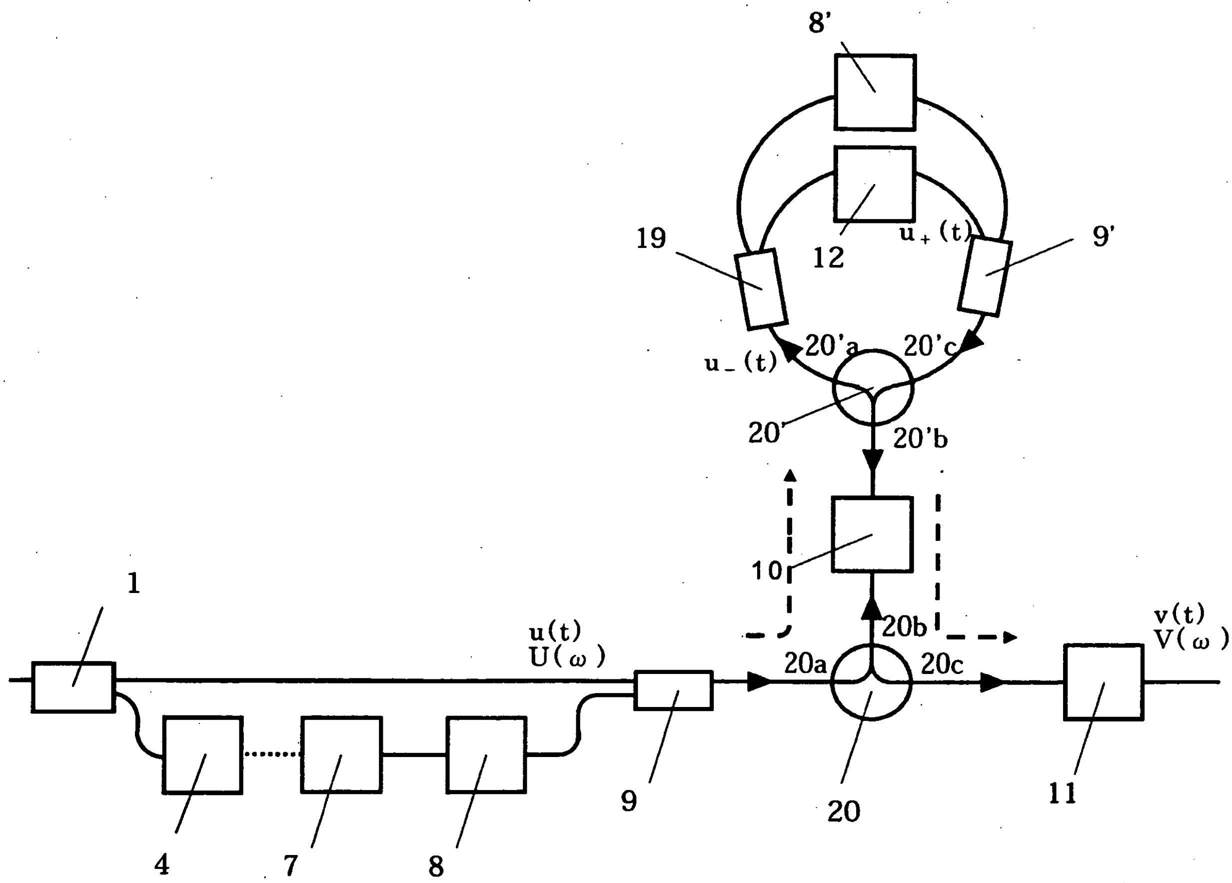



FIG. 13

## REFERENCES CITED IN THE DESCRIPTION

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- **M.ROMAGNOLI ; P.FRANCO ; R. CORSINI ; A.SCHIFFINI ; M.MIDRIO.** Time-domain Fourier Optics for polarization-mode dispersion compensation. *Optics Letters,* 1999, vol. 24 (17), 1197-1199 **[0007]**
- **L.A.JIANG ; M.E.GREIN ; H.A.HAUS ; E.P.IPPEN ; H.YOKOYAMA.** Timing jitter eater for optical pulse trains. *Optics Letters,* 2003, vol. 28 (2), 78-80 **[0007]**
- **M.E.FERMANN ; V.I.KRUGLOV ; B.C.THOMSEN ; J.M.DUDLEY ; J.D.HARVEY.** Self-simiar propagation and amplification of parabolic pulses in optical fibers. *Phys.Rev.Lett.,* 2000, vol. 84, 6010-6013 **[0007]**
- **MOURADIAN L. et al.** Characterization of optical signals in fiber-optic Fourier converter. *Proceedings of the SPIE,* 1998, vol. 3418, 78-85 **[0007]**
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- **KRUGLOVV. I. et al.** Self-similar propagation of high-power parabolic pulses in optical fiber amplifiers. *Optics Letters,* vol. 25 (24), 1753-1755 **[0007]**
- **HARVEY J. D. et al.** Analytical solutions of the nonlinear Schrodinger equation with gain. *LEOS,* 2002, vol. 1, 319-320 **[0007]**