Concert study of Four Wave Mixing optical fiber and its Application

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Abstract:
Four-wave mixing (FWM) is a occurrence that must be evade in DWDM transmission, but depending on the application it is the basis of significant second- generation optical devices and optical device extent technology. This paper converse the theory of FWM, and then introduces one of its applications --a broadband all-optical concurrent wavelength converter urbanized using a high nonlinearity dispersion fiber (HNL-DSF).
That competently produces FWM. The concurrent wavelength exchange of two different formats or bit-rate optical signals, with low input power, is established in a highly nonlinear optical fiber with a single strong continuous-wave pump. The effect of four-wave mixing at highly nonlinear optical fiber is analyzed at 1 km distances with its power.

Keywords: vector theory, conservation of fibre

I. INTRODUCTION

When a high-power optical signal is commence into a fiber, the linearity of the optical response is lost. One such nonlinear effect, which is due to the third-order exciting vulnerability, is called the optical Kerr effect. Four-wave Mixing (FWM) is a type of optical Kerr effect, and occurs when light of two or more diverse wavelengths is beginning into a fiber. Normally speaking FWM occurs when light of three dissimilar wavelengths is launched into a fiber, giving rise to a new wave (know as an idler), the wavelength of which does not coincide with any of the others. FWM is a kind of optical parametric oscillation.
In the broadcast of dense wavelength-division multiplexed (DWDM) signals, FWM is to be passing up, but for certain applications, it gives an effective technological basis for fiber-optic devices. FWM also provides the basic technology for measuring the nonlinearity and chromatic dispersion of optical fibers. This paper discusses those aspects of R & D into FWM applications that the authors have carried out recently in connection with broadband all-optical simultaneous wavelength conversion and a technique for measuring the nonlinear coefficient of optical fibers.

$$f\text{iddler} = f\text{p1} + f\text{p2} - p\text{robe}$$

Where: fp1 and fp2 are the pump light frequencies, and f-probe is the frequency of the probe light. This condition is called the frequency phase-matching condition. When the frequencies of the two pumping waves are identical, the more specific term "degenerated four-wave mixing" (DFWM) is used, and the equation for this case may be written where: fp is the frequency of the degenerated pumping wave.
Continuous-wave DFWM may be expressed by the following nonlinear coupled-mode equations

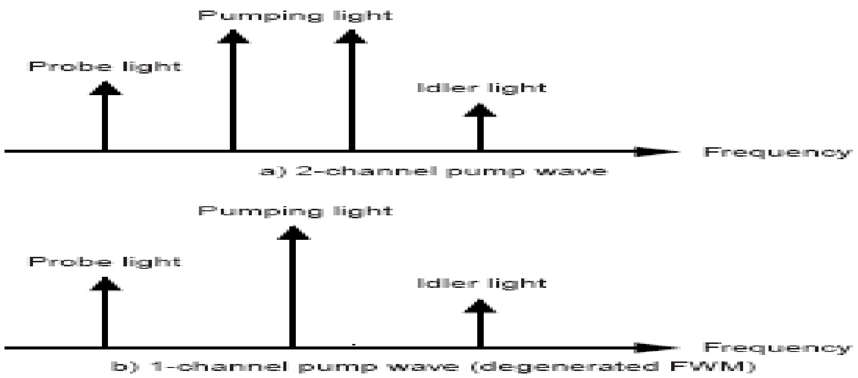

Figure 1 Schematic of four-wave mixing in the frequency domain

$$\frac{dE_{\rm p}}{dz}+\frac{1}{2}\alpha E_{\rm p}= {\rm i}\gamma\left(\left|E_{\rm p}\right|^2+2\left|E_{\rm probe}\right|^2+2\left|E_{\rm idler}\right|^2\right)E_{\rm p}+2{\rm i}\gamma\ E^*{}_{\rm p}E_{\rm probe}E_{\rm idler}\exp({\rm i}\Delta\beta\ z)$$

$$\frac{dE_{\rm probe}}{dz}+\frac{1}{2}\alpha E_{\rm probe}= {\rm i}\gamma\left(\left|E_{\rm probe}\right|^2+2\left|E_{\rm idler}\right|^2+2\left|E_{\rm p}\right|^2\right)E_{\rm probe}+2{\rm i}\gamma\ E^*{}_{\rm idler}E_{\rm p}{}^2\exp(-{\rm i}\Delta\beta\ z)$$

$$\frac{dE_{\rm idler}}{dz}+\frac{1}{2}\alpha E_{\rm idler}= {\rm i}\gamma\left(\left|E_{\rm idler}\right|^2+2\left|E_{\rm p}\right|^2+2\left|E_{\rm probe}\right|^2\right)E_{\rm idler}+2{\rm i}\gamma\ E^*{}_{\rm probe}E_{\rm p}{}^2\exp(-{\rm i}\Delta\beta\ z)$$

------------------------***EQ-1***

Where: z is the longitudinal coordinate of the fiber, a is the attenuation coefficient of the fiber, and Ep, Eprobe and Eidler are the electric field of the pumping, probe and idler waves. g is the nonlinear coefficient, and is obtained by 1) where: n2 is the nonlinear refractive index, Affiance is the effective area of the fiber and c is the speed of light in a vacuum.

II. VECTOR THEORY OF FOUR-WAVE MIXING:

A whole portrayal of dual-pump FOPAs should include all parametric processes invent from deteriorate+-- -as well as no worsen FWM.In most untried situations, the two pumps are positioned symmetrically 30–40 nm away from the zero-dispersion wavelength of the fiber.5–7 The resulting gain band exhibits a central flat region in which the leading donation comes from a single no degenerate FWM process corresponding to v1 1 v2! v*s.* 1 v*i*, where v1, v2, v*s.*, and v*i* are the optical frequencies of the two pumps, signal, and idler, respectively. Other FWM processes affect wings of the gain band but leave its flat portion unchanged. Since the flat part is used in practice, we focus only on the above no worsen process in the following analysis. Furthermore, we neglect pump .Assuming that the instantaneous electronic response dominates and neglecting the Raman contribution, we find that the third-order nonlinear polarization in a medium such as silica glass is given by

$$\mathbf{P}^{(3)}(\mathbf{r},\,t)\,=\,\epsilon_0\overleftrightarrow{\chi}^{(3)}\vdots\mathbf{E}(\mathbf{r},\,t)\mathbf{E}(\mathbf{r},\,t)\mathbf{E}(\mathbf{r},\,t),$$

III. THEORETICAL CONSIDERATIONS:

Dissemination of optical pulses in single-mode optical fibers is explain by the well-known nonlinear Schro ¨dinger equation

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$$\frac{\partial U}{\partial Z}+\frac{\beta^{(2)}}{T_0^2}\frac{\partial^2 U}{\partial \tau^2}=i\gamma P_0|U|^2U,$$

Where U is the complex electric field wrapper normalized to the absolute amplitude of the field $P0^2$, P0
is the total power in the fiber, t is time normalized to the pulse width and measured in a reference frame moving with the group velocity of the pulse $[\tau=(t-z/v_g)/T_0]$, T0 is the pulse width,
And b (2) is the group velocity spreading and is given by the second-order unoriginal of b, the axial wave vector, with respect to the angular frequency Wave The nonlinearity coefficient is given by the relationship

$$\gamma=\frac{\omega_{\text{ave}}n_2^1}{cA_{\text{eff}}},$$

IV. POLARIZATION-DEPENDENT ON NATURE OF FOUR-WAVE MIXING:

Here, we examine the polarization-dependent nature of FWM inside optical fibers. The vector FWM equations can be used in the general case in which the pumps and the signal are launched into the optical fiber with arbitrary SOPs. However, to examine the association between the FWM efficiency and the pump polarizations as simply as possible. Physically, the polarization-dependent nature of FWM inside optical fibers stems from the requirement of angular-momentum conservation among the four interacting photons in an isotropic medium. This requirement can be described most simply in a basis in which *"and denote* left and right circular polarization states and carry the intrinsic angular momentum respectively.

$$\frac{d\mathcal{U}_i}{dz}=i\beta_i\mathcal{U}_i+\frac{4i\gamma}{3}[\mathcal{U}_1\mathcal{U}_2\mathcal{U}_s^*+(\mathcal{U}_1\mathcal{D}_2+\mathcal{D}_1\mathcal{U}_2)\mathcal{D}_s^*],$$

(

$$\frac{d\mathcal{D}_i}{dz}=i\beta_i\mathcal{D}_i+\frac{4i\gamma}{3}[\mathcal{D}_1\mathcal{D}_2\mathcal{D}_s^*+(\mathcal{U}_1\mathcal{D}_2+\mathcal{D}_1\mathcal{U}_2)\mathcal{U}_s^*].$$

4.1 Consequence of Wavelength Converters:

Wavelength converter is simply a device for converting the injected signal light from one wavelength to another. It therefore is seen to have great promise in configuring the photonic networks of the future using optical cross connect. A number of methods of wavelength conversion have been proposed, of which parametric conversion using optical fiber FWM offers two major advantages: high conversion speed and the ability to effect simultaneous conversion of signals within a wavelength bandwidth.

4.2 Wavelength Conversion in the Fiber:

The most important characteristics desired of wavelength converters using parametric conversion are high conversion efficiency and broad bandwidth. To achieve this kind of wavelength conversion, the following conditions must be met:

(a) Pump wavelength must coincide with zero-dispersion wavelength;

(b) Chromatic dispersion variation in the longitudinal direction of the fiber should be minimized; and

(c) States of polarization of the pump and signals must coincide.

V. EXTENT OF NONLINEAR COEFFICIENT AND CHROMATIC DISPERSION:

5.1 Nonlinear Coefficients:

The explosive growth in long-haul telecommunications achieved in recent years has been largely attributable to DWDM technology and the role played by EDFAs, but the nonlinear effects of signals amplified by EDFAs have resulted in the degradation of system performance.

Attention has recently been focused on dispersion managed systems as a means of suppressing FWM. Reverse-dispersion fiber (RDF) is used in combination with conventional single-mode fiber (SMF). 16) At 1550 nm, RDF has a chromatic dispersion of the same magnitude as SMF but of opposite sign (normal dispersion), and the dispersion slope is reversed. Thus it can compensate for both dispersion and dispersion slope simultaneously.

A number of methods have been developed for measuring the nonlinear coefficient g, including the use of self phase modulation, cross-phase modulation and four waves mixing. In the present paper a technique was considered that was applicable to a comparatively wide normal dispersion domain, and yet measurements could be carried out by all-optical means. This was because it was realized that as dispersion-managed systems become more widely used and the demand for RDF and other fiber having normal dispersion increases, so will the need to evaluate it.

5.2 Principles of Extent:

Let us discuss measurement in terms of the pump undeleted approximation proposed by Stolen and Bornholm, which in the case of DFWM is accomplished by Equation. This is an approximation in which the attenuation coefficient of Equation is zero and the pumping power is taken to be so large as to be dominant. For this reason the pumping light is not subject to DFWM-induced reaction. The signal light and idler light are of about the same magnitude, and interact together through DFWM.

$$\frac{dE_{\mathrm{p}}}{dz} = \mathrm{i}\gamma \left|E_{\mathrm{p}}\right|^2 E_{\mathrm{p}}$$

$$\frac{dE_{\mathrm{probe}}}{dz} = 2\mathrm{i}\gamma \left|E_{\mathrm{p}}\right|^2 E_{\mathrm{probe}} + 2\mathrm{i}\gamma E^{*}{}_{\mathrm{idler}} E_{\mathrm{p}}{}^2 \exp(-\mathrm{i}\Delta\beta z)$$

$$\frac{dE_{\mathrm{idler}}}{dz} = 2\mathrm{i}\gamma \left|E_{\mathrm{p}}\right|^2 E_{\mathrm{idler}} + 2\mathrm{i}\gamma E^{*}{}_{\mathrm{idler}} E_{\mathrm{p}}{}^2 \exp(-\mathrm{i}\Delta\beta \mathrm{z})$$

Solving Equation analytically, conversion efficiency Gc in the normal dispersion domain of the fiber may be Represented 1) as

$$G_{\mathrm{c}} = \gamma^2 P_{\mathrm{p}}{}^2 L^2 \left[\frac{\sin(gL)}{gL}\right]^2$$

Where in g is termed parametric gain, and can be obtained by

$$g \equiv \sqrt{\frac{1}{4}\Delta\beta(\Delta\beta + 4\gamma P_{\mathrm{p}})}$$

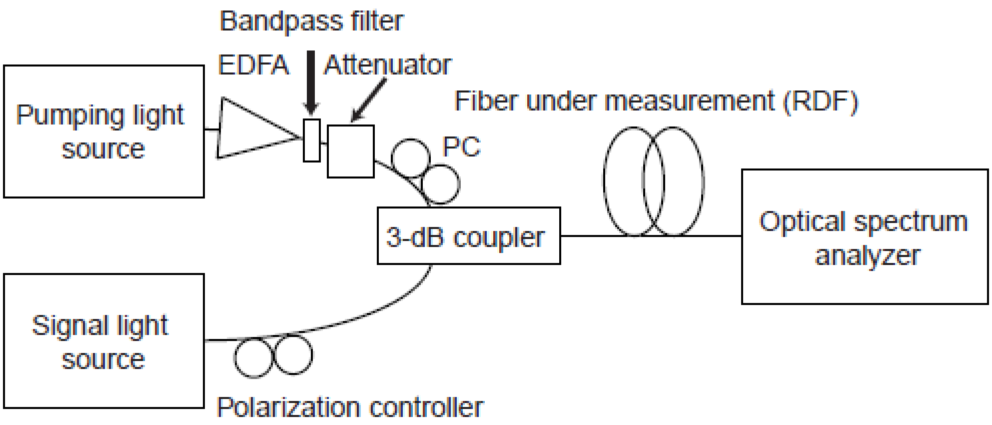

Figure2 Setup for simultaneous measurement of nonlinear coefficient and chromatic dispersion

CONCLUSION:

In this paper the we have discuss method for realize broadband all-optical simultaneous wavelength conversion by taking advantage of four-wave mixing (FWM) occurring in the fiber, together with techniques for the simultaneous measurement of the nonlinear coefficient and chromatic dispersion.

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