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SHORT PULSE LASER GENERATION USING PHASE SHIFTED FIBER BRAGG GRATING

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Abstract

Short pulse laser generation using phase shifted fiber Bragg grating (FBG) is a theoretical demonstration and investigation in this paper. The specified refractive index can be photo- written in an optical fiber using UV laser with a standard phase mask scanning techniques. Two Bragg gratings were specially designed to spectrally filtering the edges of the input pulse. When the FBGs are fabricated in the core of the optical fiber, most of the power travels in the core with a smock part corresponding to the evanescent wave that travels outside near the core in the cladding. The results show the desired full width at half maximum (FWHM) of the pulse propagation in the core of the optical fiber is 5.025 nm, which corresponds to frequency FWHM equal to $6.27*10^{11}$. The duration bandwidth product of theoretical pulse using autocorrelation track was 0.65, and then the controllable pulse width generated using this method approximately equal to 1psec

توليد نبضات ليزرية قصيرة نظرياً باستخدام ازاحة الطور لمحزز براك للالياف البصرية

الخلاصة

في هذا البحث تم توضح وفحص توليد نبضات ليزرية قصيرة نظرياً باستخدام ازاحة الطور لمحزز براك للالياف البصرية. معامل الانكسار المميز طبع على الليف البصري باستخدام ليزر الأشعة فوق البنفسجية مع تقنية ماسك الطور. تم تصميم نوعين من محزز براك للالياف البصرية لترشيح حافات النبضة الليزرية. عند تصنيع محزز براك للألياف البصرية في قلب الليف البصري معظم الطاقة المنتقلة في القلب تكون على شكل موجات زائلة تنتقل في القشرة. أوضحت النتائج أن العرض الطيفي للنبضة المتبقية داخل القلب هي 5.025 nm والتي تعادل عرض نبضة ترددي مساوي إلى $67.2*10^{11}$ Hz حاصل ضرب زمن النبضة بعرض النبضة الترددي قيس نظرياً باستخدام Autocorrelation track ووجد انه مساوي إلى 0.65 وبالتالي فعرض النبضة المتولد باستخدام هذه الطريقة هي بحدود 1Psec.

Introduction

In recent years much work has been devoted to the development of convenient solid-state laser sources of ultrashort pulses [1]. Stable source of picosecond or femtosecond range optical pulses are required for a wide variety of applications including telecommunications, biological imaging, and direct laser inscription. π Shifted FBG shown in figure 1. Generation of subpecosecond to hundred femtoseconds in optical communication system is of particular interest. FBG is a device that creates a periodic perturbation in the refractive index of the fiber core, reflecting only the specific wavelength corresponding to the period [2]. The photosensitivity phenomenon, which is basis for the fabrication of fiber gratings, is commonly ascribed to two essential physical mechanisms: creation of color centers and structural transformations [3]. FGBs are proving to be one of the optical fiber technologies. They can effectively use for dispersion compensation in high bit rate, ultrahigh repetition-rate optical pulse generation, and long haul fiber communication Links, and short pulse generation and restoration. On the other hand, fiber Bragg gratings can be used for the implementation of high quality fiber laser of various geometries and semiconductor diode stabilization [4, 5, 6, 7, 8, 9]. The main advantage of the FBG include the immunity to optical signal intensity modulation due to spectral encoding, and excellent multiplexing, self referencing capabilities, low insertion loss, and the potential for low cost[10]. Ultrashort pulse generate at 1550 nm in polarization mainating dispersion shifted fiber is experimentally analyzed using cross correlated frequency resolved optical grating in 2001 by Nishizawa and Goto [11]. A 3.2 psec pulses at 10 GHz repetition rate is presented using Soliton-assisted time-lens compression in 2005 by Hanna at.el [12].

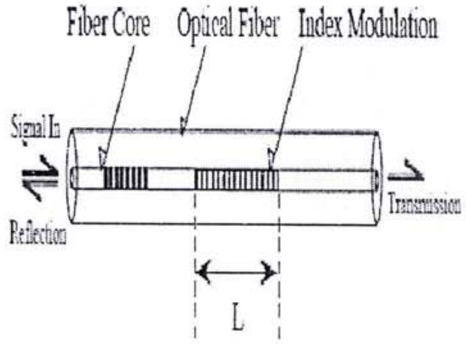

Figure (1): π Shifted fiber Bragg grating [4]

Long period grating fabricated to be used as transmission grating, the refractive index modulation periodicity is 100 times the operating wavelength (10-1000)μm. Long period grating couple the forward propagating core mode (LP_{01}) with the forward propagating cladding mode (LP_{11}). The Bragg wavelength (λ_B) of the long period grating is given by [13].

$$\lambda_B = (n_{core,eff} - n_{cladding,eff})\,\Lambda \qquad (1)$$

where $n_{core,eff}$ and $n_{cladding,eff}$ are the refractive index of the core and cladding respectively and Λ is the periodicity in μm.

The coupled mode theory for transmission grating describes the co-propagation interaction between fundamental core mode and cladding modes, given by [11].

$$\frac{\partial A_{co}}{\partial z} = ik_{01-01}^{co-co} A^{co} + i\sum_{\upsilon} k_{0\upsilon-01}^{cl-co} A_{\upsilon}^{cl} \exp(-2i\delta_{0\upsilon-01}^{cl-co} z) \qquad (2)$$

$$\frac{\partial A_{\upsilon}}{\partial z} = ik_{1\upsilon-01}^{cl-co} A^{co} \exp(2i\delta_{1\upsilon-01}^{cl-co} z) \qquad (3)$$

where δ is detuning which is given by

$$\delta_{1\upsilon-01}^{cl-co} = \frac{1}{2}(\beta_{01}^{co} - \beta_{1\upsilon}^{cl} - \frac{2\pi}{\Lambda}) \qquad (4)$$

and A^{co} is the amplitude of the Lp_{01} forward core mode field, A_{υ}^{cl} is the amplitude of the $Lp_{1\nu}$ forward cladding mode field, $k_{1\upsilon-01}$ is the coupling coefficients between core and cladding modes, and $\delta_{1\upsilon-01}$ is the detuning parameter and β_{01}^{co} , $\beta_{1\nu}^{cl}$ are the wave number of core and cladding respectively.

The transmission coefficient t_g given as [14]

$$t_g = \frac{q}{q\cosh(qL) - i\delta\sinh(qL)} \qquad (5)$$

Whereas the transmission T_g is given as $T_g = |t_g|^2$

The FWHM of the evanescent waves from the core to the cladding is given by [12]

$$\Delta\lambda = \lambda_B\, S\, [(\Delta n/2n_0)^2 + (1/N)^2]^{1/2} \qquad (6)$$

where N is the number of the periods and S is parameter varying between 0.5 for weak grating to 1 for strong grating, Δn is the perturbation in the refractive index, and n_o is the core refractive index .

Results and Discussion

Frequency selective transmitted as evanescent waves as that travels outside near the core in the cladding by double fiber Bragg grating (phase shifted FBG) are designed to obtain the desired pulse shape. The specified refractive index may be photo-written in an optical fiber using standard phase mask scanning techniques. Two Bragg grating were specially designed to shape a train of Gaussian pulse. Since Δn=0.03 for Ge doped fiber, the two gratings have an exposure length is 5cm, then from equation 1, the periodicity (Λ) are equal to 51 μm and 52 μm to evanescent waves at 1545 nm and 1555 nm respectively as shown in figure 2. The optical power evanescent for both gratings from core to cladding is about 0.65 from the incident optical power, when the exposure length (L) is 5cm, by using the parameter values typical of Ge doped optical fiber, n_0=1.447, Δn=0.03, S= 0.5 and N=162 and 160 for 51 μm and 52 μm periodicity respectively. The FWHM evanescent to cladding are about 4.951 nm and 5.032 nm for 1545 nm and 1555 nm Bragg wavelengths respectively. From figure 2 the FWHM propagate inside the core which represent the laser pulse width is about 5.025 nm which corresponds to a frequency FWHM, Δν of $6.27*10^{11}$ Hz. The relation between the pulse duration and line width is Δν.Δt = k, where k is a factor of the spectrum shape. The calculated value of the time-bandwidth is equal to 0.65 using autocorrelation track, when assumed that the pulse shape was approximately Gaussian. The output pulse width was 1.036 psec.

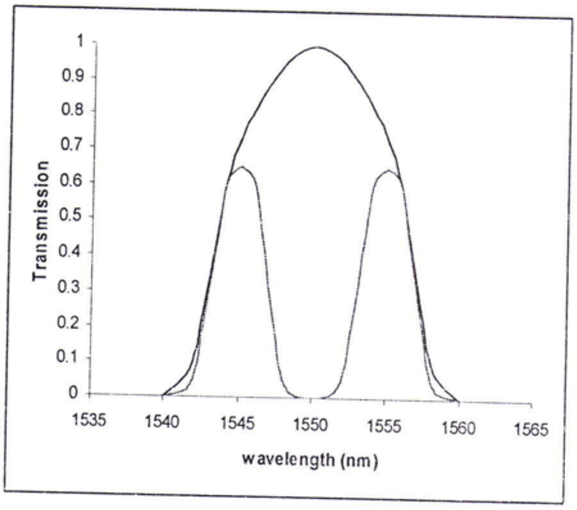

Figure (2): The power spectrum of the output pulse laser

Conclusion

Short pulse laser generation from 0.9 nsec to 1.03 psec using phase shifting FBG has been investigated and demonstrated theoretically. Pulse shaping was done by filtering incident pulses using phase-shifted FBG with an appropriately modulated refractive index and phase along its length. The method is simple because it is based on all fiber components. When the FBGs are fabricated in the core of the optical fiber, most of the power travels in the core with a small part corresponding to the evanescent wave that travels outside near the core in the cladding. In general, our theoretical results show the robustness of the proposed technique to imperfection in the grating structures as in the input pulses.

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