

Study affects Pulse Parameters versus cavity length for both Dispersion Regimes in FM mode locked.

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Abstract:

To demonstrate the effect of changing cavity length for FM mode locked on pulse parameters and make comparison for both dispersion regime, a plot for each pulse parameter as Lr function are presented for normal and anomalous dispersion regimes.

The analysis is based on the theoretical study and the results of numerical simulation using MATLAB. The effect of both normal and anomalous dispersion regimes on output pulses is investigated. Fiber length effects on pulse parameters are investigated by driving the modulator into different values. A numerical solution for model equations using fourth-fifth order, Runge-Kutta method is performed through MATLAB 7.0 program. Fiber length effect on pulse parameters is investigated by driving the modulator into different values of lengths. Result shows that, the output pulse width equals to $\tau=501\text{ns}$ anomalous regime and $\tau=518\text{ns}$ in normal regime.

Key word: FM mode lock, Fiber laser, laser pulse parameter, Normal dispersion, Anomalous dispersion.

1-Introduction:

Ultrashort optical pulses have great applications in fields such as ultrafast optics, optical fibre communication, optical measurement, micro-mechanism processing, and medical treatments [1]. Compared with mode-locked solid-state lasers, ultrashort pulse fibre lasers have advantages of compactness, greater stability and so on. So far, researchers have proposed soliton fibre lasers, [2] stretched pulse fibre lasers [3] and self similar fibre laser. [4-5] But the evolution mechanisms of these pulse fibre lasers fail in output pulse energy or complexness (as dispersion compensation components, such as prism pairs, grating pairs, chirp mirrors, and micro construction fibres, are used). Recently, a novel all-normal-dispersion (ANDi) mode-locked fibre laser, in which all components are of normal dispersion,

has been proposed [6]. In this diagram, the energy of output pulses can be much higher, [7-10] and designs can be greatly simplified especially for Yb-doped mode-locked fibre lasers whose operating wavelength is in the normal dispersion domain of common fibers. Ultrashort fiber lasers offer additional benefits such as small physical dimensions, increased stability under environmental conditions, reduced thermal management and diffraction limited beam quality. In addition, fiber lasers can be easily engineered and are usually less expensive than their solid-state lasers counterparts. Particularly, Yb³⁺ doped fibers have a broad emission bandwidth, large saturation fluence and high optical to optical conversion efficiency. Therefore, they form an excellent gain medium for the generation and amplification of

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ultrashort optical pulses in the 1µm wavelength range [11].

2-Theoretical concept

Depending on master equation Eq.(1) , and using the assumed pulse

$$T_R \frac{\partial A}{\partial T} + \frac{1}{2}(\overline{\beta}_2 + i\overline{g}T_2^2)L_R \frac{\partial^2 A}{\partial t^2} - \frac{\overline{\beta}_3}{6}L \frac{\partial^3 A}{\partial t^3} = \overline{\gamma}L|A|^2 A + \frac{1}{2}(\overline{g} - \overline{\alpha})LA + M(A, t) \dots (1)$$

- 1st term describes the basic propagation of the optical field in z direction,
- 2nd term describes the effect of second order dispersion,
- 3rd term describes the effect of third order dispersion,
- 4th term describes the effect of nonlinearity,

shapes for both dispersion regimes after modifying Ginzburg–Landau Equation , GLE , by adding TOD and mode-locker effects, the extended solution will be as in the following relations [12,13, 14,15] .

- 5th term describes the effect of gain and intensity-dependent losses,
- 6th term represents the mode locker effect

In the following all the terms of Mode-Locking master equation will be identified.

a. Normal regime

$$A(T, t) = \alpha \left(\exp\left(-\frac{(\Phi - \xi)^2}{2\tau^2}\right) \right)^{1+iq} \times \exp(i\Omega(t - \xi) + iKT + i\varphi_Q) \dots (2)$$

b. Anomalous regime:

$$A(T, t) = \alpha \left(\operatorname{sech}\left(\frac{t - \xi}{\tau}\right) \right)^{1+iq} \times \exp(i\Omega(t - \xi) + iKT + i\varphi_Q) \dots (3)$$

Where pulse parameters for both profiles are:

- (α) represents pulse amplitude,
- (ξ) Temporal shift,
- (τ) pulse width,
- (q) Chirp,
- (Ω) frequency shift,

$iKT + i\varphi_Q$ Represent the phase and rarely is of physical interest in lasers producing picoseconds pulses, and will be ignored [12].

The relations of pulse parameters with temporal pulse profile are as following: [16,17]

$$E(T) = \int_{-\infty}^{+\infty} |A(T, t)|^2 dt \dots (4)$$

$$\xi(T) = \frac{1}{E} \int_{-\infty}^{+\infty} t |A(T, t)|^2 dt \dots (5)$$

$$\Omega(T) = \frac{t}{2E} \int_{-\infty}^{+\infty} \left[A \frac{dA}{dt} - A \frac{dA}{dt} \right]^2 dt \dots (6)$$

$$q(T) = \frac{t}{E} \int_{-\infty}^{+\infty} (t - \xi) \left[A \frac{dA}{dt} - A \frac{dA}{dt} \right]^2 dt \dots (7)$$

$$(T)^2 = \frac{2}{E} \int_{-\infty}^{+\infty} (t - \xi) |A(T, t)|^2 dt \dots (8)$$

3-Results and discussions:

To demonstrate the effect of changing cavity length on pulse parameters and make comparison for both dispersion regime , a plot for each pulse parameter as Lr function is drawn in Fig.(1) for normal and anomalous dispersion regimes . As shown in Fig.(1) almost same behavior for pulse energy is seen for variable Lr. Energy decreases exponentially as Lr increases .Then decreasing rate after certain value of cavity length (Lr = 5 m) and becomes so small for high values and almost constant straight line . Temporal shift plots in Fig. (1) for both regimes, are shown almost the same behavior in both regimes . Pulse

temporal shift is increases linearly as L_r increases. The main difference is that : in anomalous regime , the temporal shift is greater than normal regime by five times. Inspecting plots for pulse frequency shift in Fig.(2) the linear relation in anomalous and normal regime is seen. For normal regime, the frequency shift decrease linearly with L_r increases , while in anomalous regime , frequency shift increases with increase L_r .

For pulse chirp as function of cavity length, as shown in Fig. (2) the pulse chirp in normal regime suffers from positive linear relation for variable L_r increasing with increasing of L_r .In anomalous regime , the negative linear

relation chirp decreases with increasing L_r .This linear chirp enables us to compare the pulse outside the laser cavity without deforms in an anomalous dispersion regime until free chirp pulse is introduce [12]. Cavity Length has great effect on pulse width since it is responsible for mode-locking mechanism and producing pulses train. As shown in Fig.(2), pulse width increases exponentially with the increase of L_r , but for anomalous regime it is much faster increasing in magnitude and less in L_r values as compared with normal regime .Almost , for anomalous regime, the minimum pulse width is obtained .

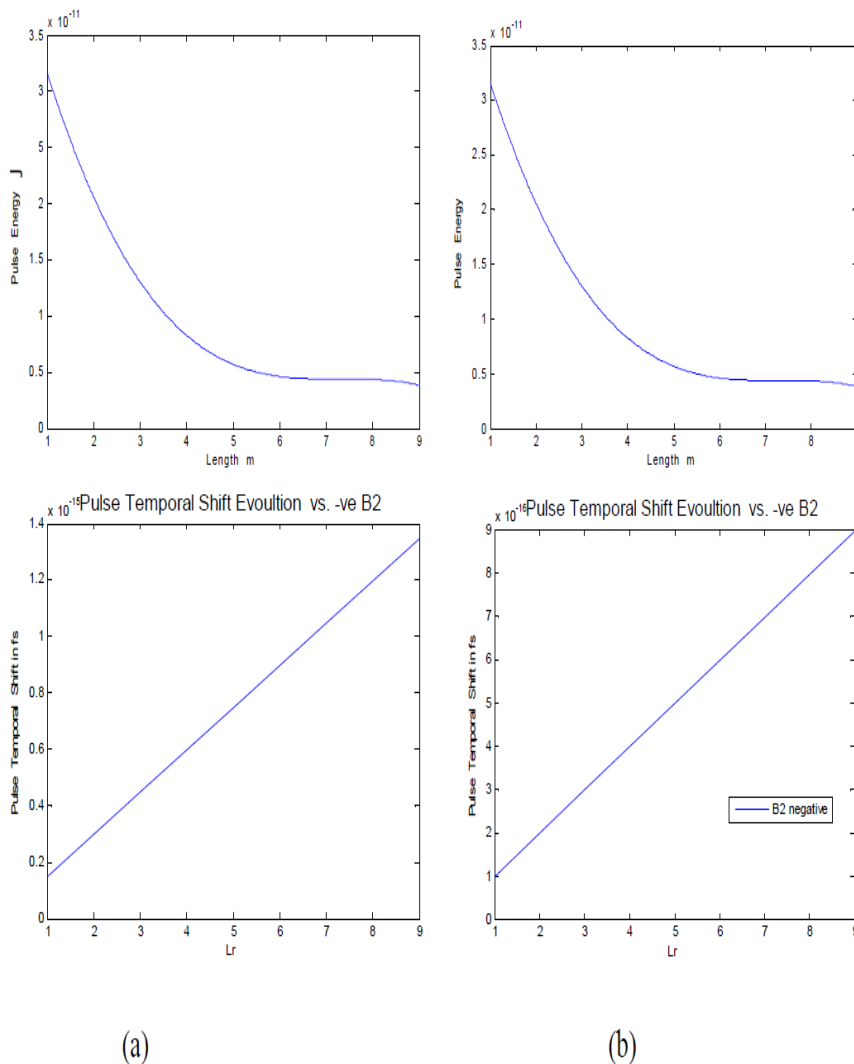


Fig. (1) Pulse energy, temporal shift versus cavity length in(a) Normal and (b) Anomalous dispersion .

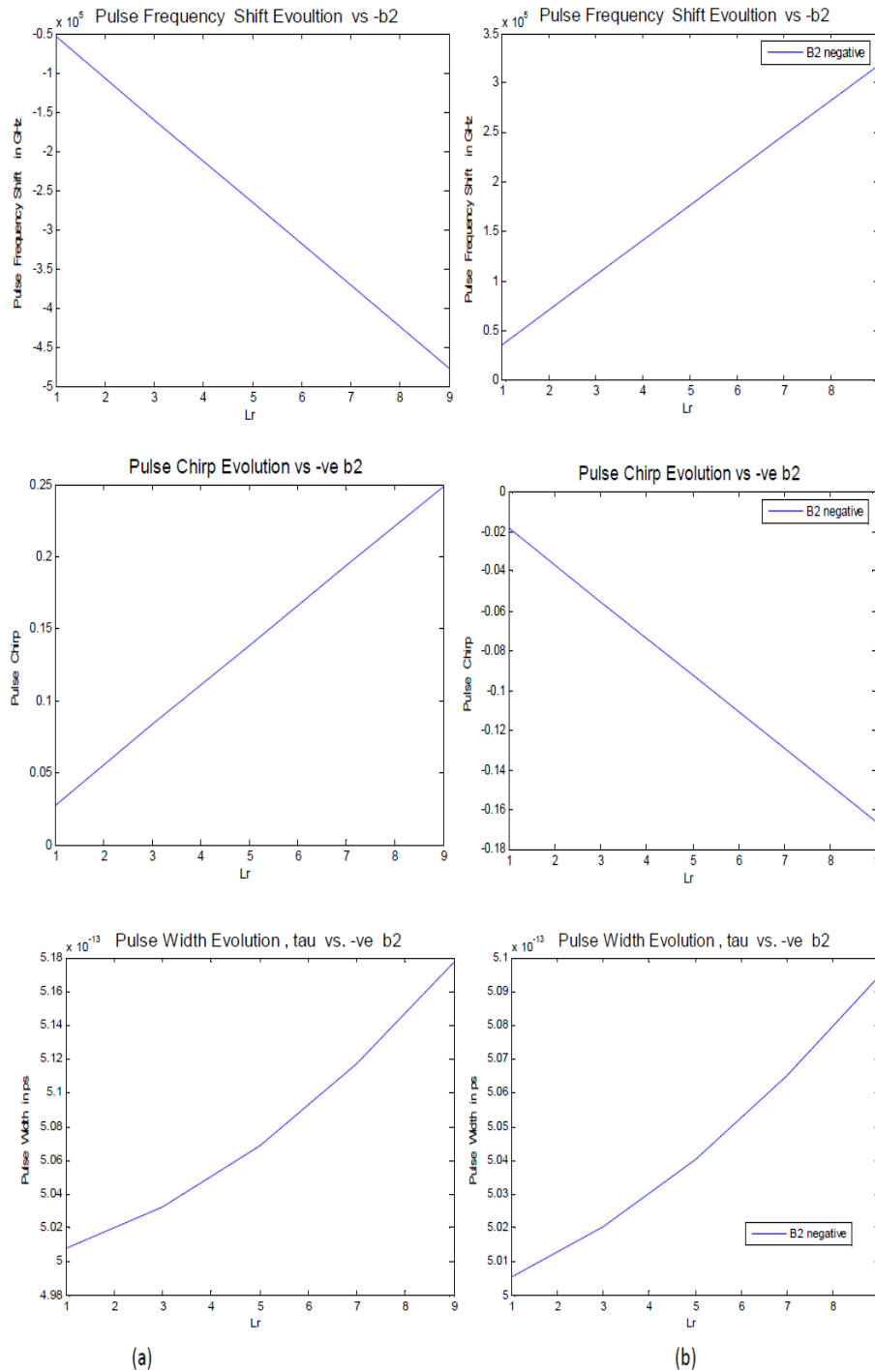


Fig. (2) Frequency shift, chirp and width versus cavity length in (a) Normal and(b) Anomalous dispersion .

4-Conclusions:

The length cavity varying of FM mode locking pulse parameter effect directly with varying L_r . The effective length in FM is equal 4m. Pulse width increases exponentially with the increase of L_r , but for

anomalous regime it is much faster increasing in magnitude and less in L_r values as compared with normal regime .Almost , for anomalous regime, the minimum pulse width is obtained .

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دراسة تأثير طول الحاوية على معلمات النبضة لكلا مناطق التشتت لقفل النمط الترددي

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الخلاصة:

تظهر النتائج تأثير طول الحاوية لقفل النمط الترددي لليزر الليف البصري وتوضيح المقارنة لكلا النظامين لمناطق التشتت وأظهرت معلمات النبضة كدالة لطول الحاوية للتشتت الطبيعي والشاذ. تم التحليل على أساس دراسة نظرية استخدام برنامج الماتلاب لاضهار نتائج التحليل العددي. تأثيرات طول الليف على معلمات النبضة يتحقق منها بواسطة إدخال الألياف بأطوال مختلفة القيم. الحل العددي لمعادلات الموديل باستخدام المرتبة الرابعة والخامسة لطريقة رانج كوتا من خلال استخدام برنامج الماتلاب. تأثيرات طول الليف على معلمات النبضة يتحقق منها بواسطة الألياف وباختلاف قيم الطول. النتيجة تبين ان عرض النبضة الخارجة من قفل النمط مساوي الى 501 نانوثانية في منطقة التشتت الشاذ و 518 نانوثانية في منطقة التشتت الطبيعي.