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# Compression of Secant and Gaussian Pulse Using Nonlinear Fiber Bragg Grating

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***Abstract*— The NFBGs with exponentially decreasing second-order dispersion allows nearly chirp free and pedestal free pulse compression in a short length, leading to novel all fiber compression device. It is based on the NLSE approximation that neglects the effect of higher order dispersion and the PBGs. NLSEs to have a complete study of self similar chirped optical pulse compression in the NFBGs. For the effect of higher order dispersion, to found that although the second-order dispersion is exponentially decreasing along the grating, the contributions of higher order dispersion can remain small throughout the compression process if the initial contribution of higher order dispersion is small. The compression of both the hyperbolic secant and Gaussian shaped pulses and the effect of variation in the initial pulse width on the optical pulse compression.**

**Index terms— *Index Terms*—Compression, Dispersion, Nonlinear fiber Bragg grating (NFBG), Photonic band gap (PBG)**

## I. Introduction

Generation of short pulses has always been of great scientific and technological interests. Ultra short pulses in the near infrared spectral region are required for various applications. For instance, in telecommunication applications, ultra short pulses are required in order to increase transmission capacity to 160 Gb/s and beyond. It is in general difficult to produce very short pulses even from the best available laser sources [1]. Hence, optical pulse compression techniques are important for the generation of ultra short optical pulses.

There are two widely used techniques to achieve pulse compression; namely soliton pulse compression and adiabatic pulse compression techniques. In soliton pulse compression technique, the compressed pulses suffer from significant pedestal generation, leading to nonlinear interactions between neighboring solitons. Adiabatic pulse compression technique has been used to generate a stable train of pedestal free and non-interacting solitons. However, this technique requires long length of fiber, on the order a few kilometers, since the fiber has relatively small group-velocity dispersion (GVD).

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It has been shown that the optical periodic structures or photonic band gap (PBG) materials such as fiber Bragg gratings (FBGs) have relatively large dispersion (six orders of magnitude larger) compared to silica fibers. Hence, the soliton dynamics could be studied on length scales of centimeters. It is suggested that chirped solitary waves can be compressed more efficiently if the dispersion decreases approximately exponentially. Recently, self-similar analysis has been utilized to study linearly chirped pulses in fiber amplifiers. The large dispersion in the spectral vicinity of the grating stop band leads to a very compact device that could be only centimeters long as compared to kilometers long if optical fibers are used.

## II. Gaussian and Secant Pulses

The two most widely used pulses in optical fiber communications is Gaussian pulse and hyperbolic secant pulse. These two pulses plays an important role in determining the effects namely nonlinear and dispersive effects which makes the pulses travel through the fiber in an efficient manner. The shape of gaussian and secant pulses are in a similar fashion. In optics we use these pulses on the basis of power level and time width of the pulse. Here, the power of Gaussian pulse is more compared to that of the secant pulse. Similarly the time period of the pulse also differs in the same manner. The peak power $P_0$ of the Gaussian and Secant pulses are given as *4857 W* and *3849 W* respectively. The time period of the Gaussian and Secant pulse are given as $T_0 = 10.586\ ps$ *and* $T_0 = 10\ ps$ [2]. The shape of the graph is important design for the NFBG. So we must include the shape of the graph in the analysis of the pulse compression. The graph of a Gaussian is a characteristic symmetric bell curve shape that quickly falls off towards zero when we introduce some dispersion in the fiber. The parameter is the height of the curve's peak, b is the position of the center of the peak, and c (the standard deviation) controls the width of the "bell".

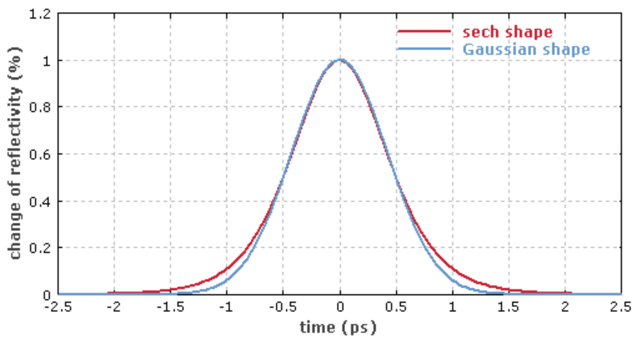


Fig.1: Graph of Secant and Gaussian shaped pulse

  

## III. COMPRESSION GAUSSIAN AND SECANT PULSES

### *A. Flow diagram of pulse compression*

The flow diagram of Gaussian pulse and hyperbolic secant pulse compression is shown below. First we set the time period of the pulses and power levels which determines that the pulse is either of Gaussian pulse and hyperbolic secant pulse [3]. In the next step we set the values for Chirp parameter *(C)* and ratio of frequency detune to coupling coefficient *(b)*. The ratio of frequency detune to coupling coefficient *(b)* is an important parameter for compressing the pulse, so it must be carefully chosen for the compressing techniques. For effective compression of the pulse choose the value of *b* less than 3. If we choose the value of *b* greater than 3 the pulse may be distorted in the fiber or uncompressed.

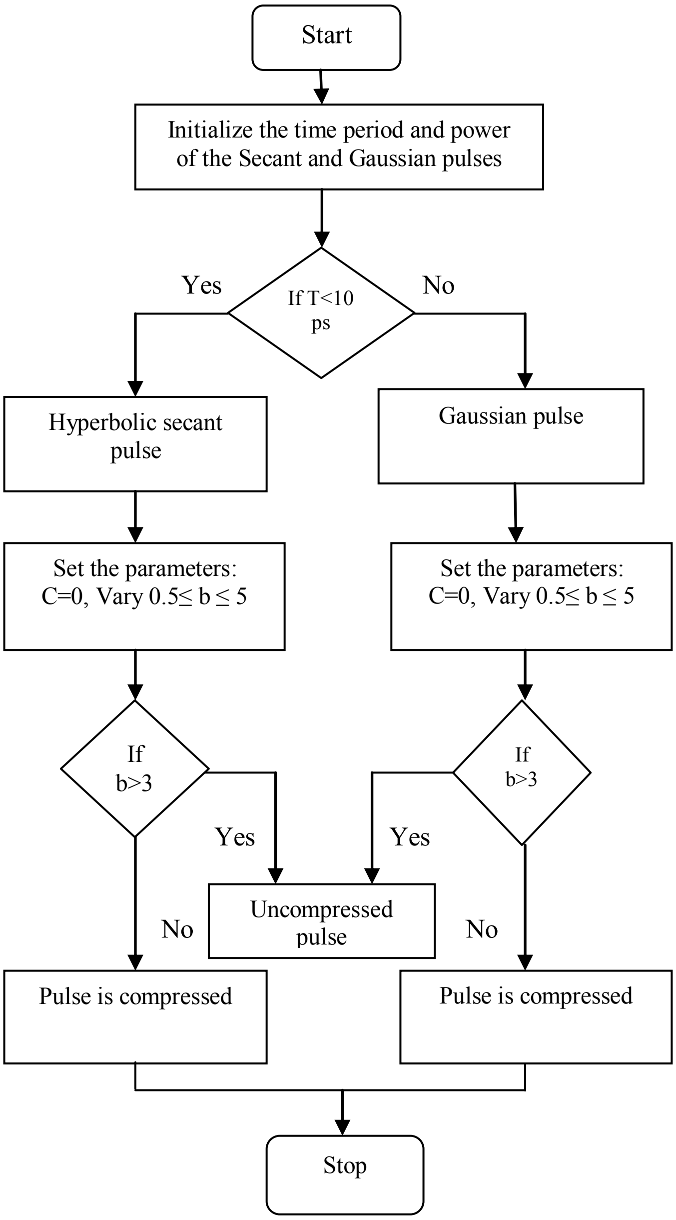


Fig.2: Flow diagram Representation

### *B. Methodology Used*

The compression of these pulses can be done with the analysis of Nonlinear Schrodinger Equation (NLSE) which is a partial differential equation of integrable form. There is numerous methods available for solving the NLSE, but here we are going to use Split Step Fourier Method [4]. This method is one of the simplest methods available for solving this type of partial differential equation. In this we are going to split the fiber into small parts, where we consider each small part as one unique fiber length and applying Fourier Transform for these small parts and also applying Inverse Fourier Transform makes the equation to solve in an efficient manner. Similarly the small part is split into three parts like two linear components and one nonlinear component for further analysis.

The Split Step Fourier Method can be demonstrated in easier manner with the help of block diagram representation as follows. Hence the numerical split step Fourier method is utilized, which breaks the entire length of the fiber into small step sizes of length "h" and then solves the nonlinear Schrödinger equation by splitting it into two halves , the linear part (dispersive part) and the nonlinear part over z to z + h.

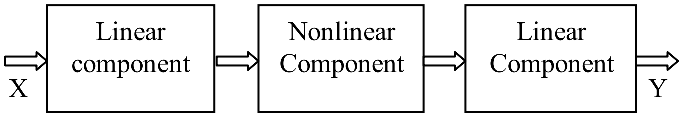


Fig.3 : Split Step Fourier Method

## IV. SIMULATION RESULTS

### *A. Compression of Gaussian Pulse*

Case I

$b$=1.0, $T_o$=10.586 ps, $C$=0,

$b$- ratio of frequency detune to coupling coefficient

$T_o$- Pulse width, $C$- initial chirp

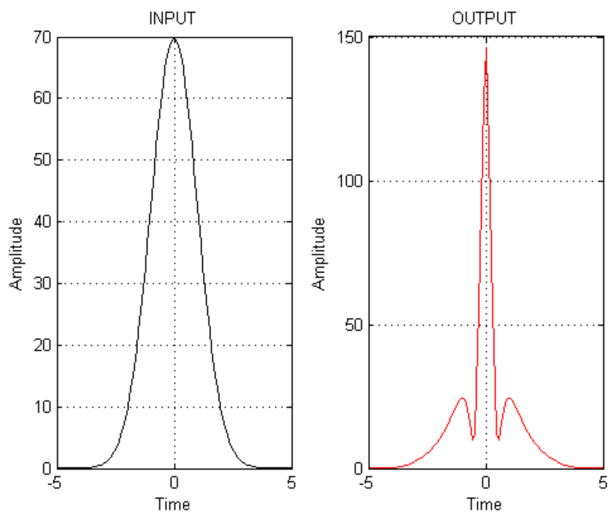


Fig.4 : Input pulse and Compressed output pulse

  

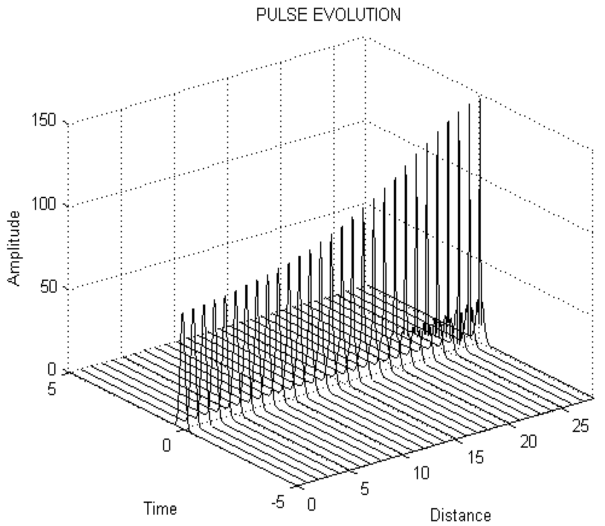


Fig.5: Pulse evolution profile

The Case I results shows that the Gaussian pulse is said to be compressed for minimum value of *b* which is an important design parameter of the proposed optical pulse compressor. In the output compressed Gaussian pulse form the width of the pulse is reduced when compared to the input pulse, similarly the amplitude of the pulse is increased which proves that the above Gaussian pulse is compressed.

Case II
$b$=5.0, $T_o$=10.586 ps, $C$=0,
$b$- ratio of frequency detune to coupling coefficient
$T_o$- Pulse width, $C$- initial chirp

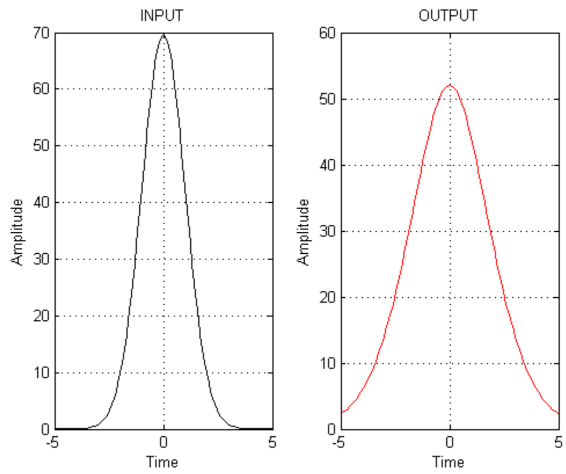


Fig.6 : Input pulse and Distorted output pulse

From the Case II results we can see that the Gaussian pulse is said to be uncompressed for almost maximum value of *b*. In the output pulse form the width of the pulse is not reduced when compared to the input pulse, similarly the amplitude of the Gaussian pulse is decreased which proves that the above pulse is not compressed. So as the value of *b* increases the compression of the pulse decreases. In other words we can say that Gaussian pulse is distorted when we increase the value of *b*.

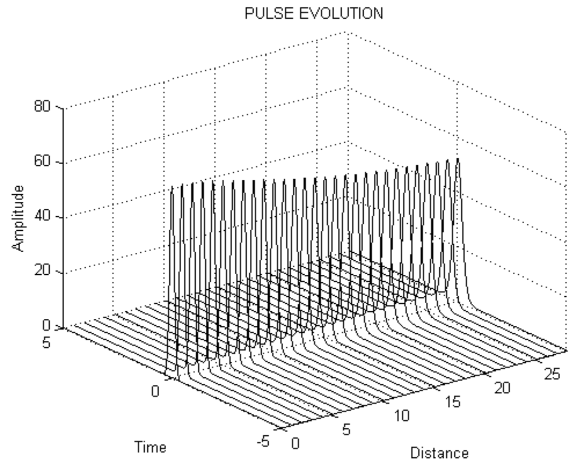


Fig.7: Pulse evolution profile

*B. Compression of Hyperbolic Secant pulse*

Case III
$b$=1.0, $T_o$=10 ps, $C$=0,
$b$- ratio of frequency detune to coupling coefficient
$T_o$- Pulse width, $C$- initial chirp

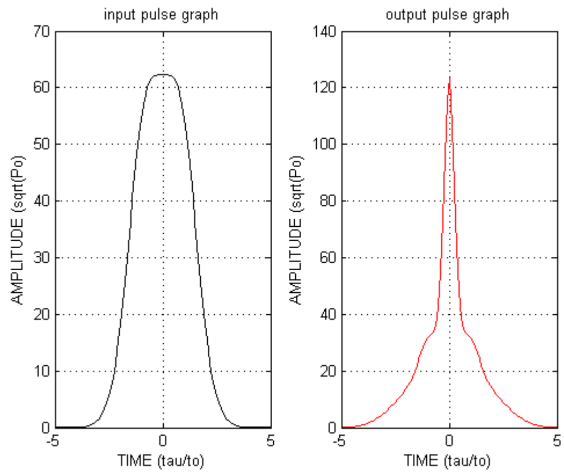


Fig.8 : Input pulse and Compressed output pulse

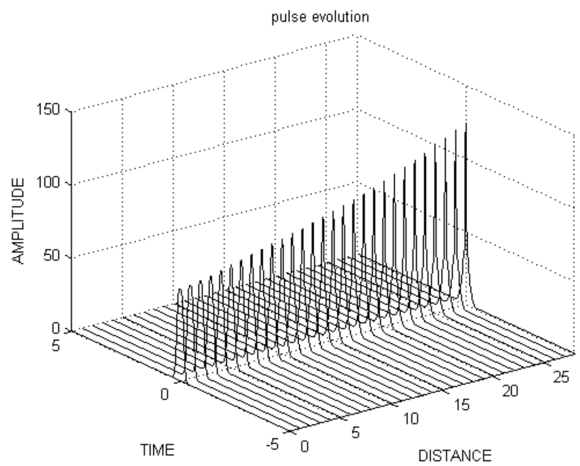


Fig.9: Pulse evolution profile

The Case III results shows that the Hyperbolic Secant pulse is said to be compressed for minimum value of *b* which is an

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important design parameter of the proposed optical pulse compressor. In the output compressed the Hyperbolic Secant pulse form the width of the pulse is reduced when compared to the input pulse, similarly the amplitude of the pulse is increased which proves that the above the Hyperbolic Secant pulse is compressed.

Case IV
*b*=5.0, $T_o$=10 ps, *C*=0,
*b*- ratio of frequency detune to coupling coefficient
$T_o$- Pulse width, *C*- initial chirp

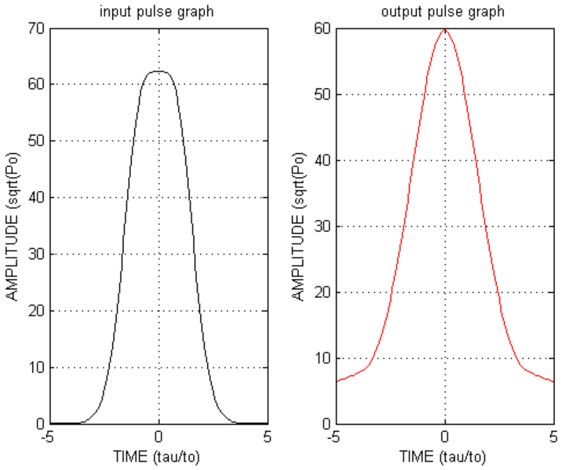


Fig.10 : Input pulse and Distorted output pulse

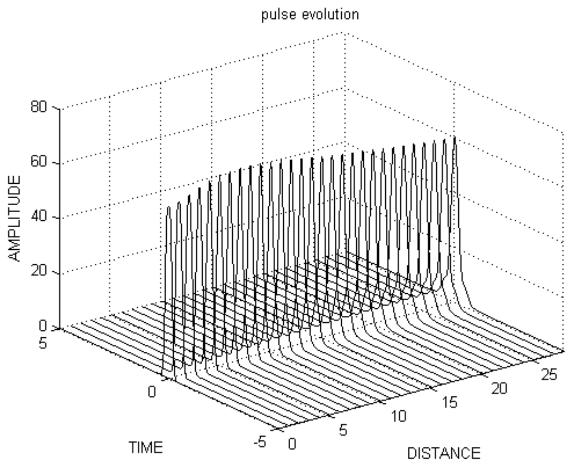


Fig.11: Pulse evolution profile

From the Case IV results we can see that the Hyperbolic Secant pulse is said to be uncompressed for almost maximum value of *b*. In the output pulse form the width of the pulse is not reduced when compared to the input pulse, similarly the amplitude of the Hyperbolic Secant pulse is decreased which proves that the above pulse is not compressed. So as the value of *b* increases the compression of the pulse decreases. In other words we can say that Hyperbolic Secant pulse is distorted when we increase the value of *b*.

### *C. FWHM Tabulation Results*

The compression of Gaussian and Hyperbolic Secant pulses can be found out by can be found by comparing the width of the input pulse as well as the output pulse with the parameter called *FWHM* which measures the width of the pulse at its half maximum value. From the tabulation results we can able to find out whether the pulse is compressed or not. If the *FWHM* of the output pulse is lesser than the *FWHM* of the input pulse then it is said to be compressed, if it is not then it is said to be uncompressed or distorted.

TABLE I. Compression of Gaussian pulse
(b vs FWHM(ps))

| S. No | Value of b | FWHM (ps) |
|---|---|---|
| 1 | 0.5 | 3 |
| 2 | 1.0 | 5 |
| 3 | 1.5 | 7 |
| 4 | 2.0 | 15 |
| 5 | 2.5 | 23 |
| 6 | 3.0 | 29 |
| 7 | 3.5 | 35 |
| 8 | 4.0 | 39 |
| 9 | 4.5 | 43 |
| 10 | 5.0 | 45 |

Note: FWHM of input pulse = 25 ps

TABLE II. Compression of Hyperbolic Secant pulse
(b vs FWHM(ps))

| S. No | Value of b | FWHM (ps) |
|---|---|---|
| 1 | 0.5 | 1 |
| 2 | 1.0 | 5 |
| 3 | 1.5 | 13 |
| 4 | 2.0 | 23 |
| 5 | 2.5 | 29 |
| 6 | 3.0 | 35 |
| 7 | 3.5 | 39 |
| 8 | 4.0 | 41 |
| 9 | 4.5 | 45 |
| 10 | 5.0 | 47 |

Note: FWHM of input pulse = 23 ps

## V. CONCLUSION

Thus the Hyperbolic secant and Gaussian shaped pulses can be compressed by using split step method by solving the Nonlinear Schrodinger Equation. Here second order dispersion plays an important role in determining the compression of the pulse. Higher order dispersion increase when the second order dispersion increases along the fiber, so the pulse is uncompressed in the fiber. The Gaussian pulse and Secant pulse are two most widely used pulses in optical fiber communication, so it is necessary to compress the pulse in an efficient manner. Since of value of b decides the compression of the pulse it is important to maintain the b value in the compressor, so that the pulse can be compressed in a efficient manner. FWHM also used to know whether the pulse is compressed or not. So for the pulse to be compressed the FWHM should be minimum.

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