International Journal of Current Science Research and Review

ISSN: 2581-8341

Volume 06 Issue 05 May 2023

DOI: 10.47191/ijcsrr/V6-i5-08, Impact Factor: 6.789

IJCSRR @ 2023

www.ijcsrr.org

Optical Pulse Compression in Fibre

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ABSTRACT: Optical pulse compression using similariton propagation in an optical fibre with decreasing dispersion has been demonstrated for the first time. This compression scheme is a practical application of the sech-similariton solution to the generalized nonlinear schrodinger equation(NLSE) with distributed coefficients recently found using the self similarity technique. The fibre with a decreasing dispersion profile is constructed using the comb-profile approximation technique and different variations of the technique have been developed to improve the accuracy of the approximation.

INTRODUCTION

Optical pulse compression using similariton propagation in an optical fibre with decreasing dispersion has been demonstrated for the first time. This compression scheme is a practical application of the sech-similariton solution to the generalized nonlinear schrodinger equation(NLSE) with distributed coefficients recently found using the self similarity technique. The sech-similariton exhibits a characteristicreases in positive linear frequeny chirp, which increases in slope as the pulse compresses. The solution does not develop any side pedestals or deformation in pulse shape as it propagates, making it a promising candidate for a new compression technique. Unlike the adiabatic compression technique, rapid compression can be achieved in a fibre with a specially designed decreasing group velocity dispersion profile since the sech-similariton is an exact solution to the NLSE.

SIMILARITON COMPRESSION

The sech-similariton compresses in temporal width and increases in peak power and pulse energy during propagation in the dispersion tailored fibre.Thus the secxperimentally measured CDDF-2 output pulse with the numerically propagated and the theorh-similariton solution can be used as the basis of a new compression technique appropriately named as the similariton compression. Taking the practical considerations into account ,similariton compression realized in a fibre with decreasing dispersion and constant nonlinearity have been studied mathematically, physically and numerically.

In some cases, the necessary GVD profile may be approximated in a step-like DDF, where different types of fibre with different β2 values are spliced together in a sequence to yield a variation in GVD. however it is difficult to accurately approximate the varying GVD using this technique, as it requires many different fibre types with different β2 values. Another method of constructing a DDF in a laboratory environment is to build a comb-like types of fibre consists of two different types of fibre spliced in an alternating sequence to achieve a given dispersion profile by exploiting the different characteristics of the two fibre types .The name comb-like is given to reflect the shape of the GVD profile consisting of alternatively high and low values ,which resembles like a comb when plotted on a graph. Previously, such comb-like arrangements have been used with the highly dispersive fibre and highly nonlinear fibre to apply the effects of dispersion and nonlinearity separately at different spatial points along the fibre. The comb-like arrangement can also be used to create a nonlinearity decreasing fibre, by using two fibre types with similar β2 values and different γ values.

Comb-like DDF β2 profile:

In a CDDF, the total fibre length is divided into many segments. Each segment consists of a piece of high β2 fibre and a piece of low- β2 fibre. since the GVD is a linear process, the total amount of GVD Experienced by a pulse in a segment is the weighted average of the two β_2 values of the pair of fibre used in the segment. Hence the desired GVD profile can be approximated by varying the proportion of each of type of fibre within a segment to make the weighted average of β2 equate to the desired value for that segment. The accuracy of the comb-profile approximation depends on the number of steps used for a given length of CDDF. Using more steps will increase the accuracy of the comb-profile approximation, but it will come at the expense of increased attenuation due to a greater number of splice losses. This increase in loss affects the gain profile g(z) and results in a decrease in the comprehensive performance.

ACCURACY OF THE COMB-PROFILE APPROXIMATION:

The number of steps used in a CDDF should be determined to keep the error resulting from the comb-profile approximation within an acceptable range. To demonstrate the relationship between the accuracy of the comb-profile approximation and the number of steps used in a CDDF, an ideal input pulse has been numerically propagated through CDDF's designed with the number of steps varying from 3 to 13. The pulse propagating in a CDDF has been compared against the pulse propagating in a theoretical profile to give a quantitative measure of the accuracy of the comb-profile approximation. The difference between the two pulses presented in terms of the normalized RMS error of the temporal intensity, weighted RMS, error of the frequency chirp, the final pulse width and the final chirp parameter.

DDF WITH EXPERIMENTAL β2 BOUNDARIES:

The comb-like DDF manufacturing techniques place a restriction on the range of β_2 values that the GVD profile can span across. The upper and lower limits of the range determined by the two β2 values of the fibre types used in the CDDF. This experimental constraint reduces the degrees of freedom associated with the calculation of the GVD profile that maximises the compression for an input pulse with a given value of the chirp parameter.

Raman Pumping Configuration:

The expression for the distributed optical gain represents the Raman gain achieved by a co-propagating (forward) pump wave for a loss-less DDF, the Raman walk-off effect results in a near-constant distributed gain along the fibre. In such cases, the direction of the Raman pump wave doesn't influence the similariton pump wave experiences a significant loss due to the splices and the pumping direction does influence the compressive performance of the similariton compressor. In this section the compressive performance achieved by forward and backward Raman pumping configurations in a CDDF designed with limited step sizes are compared.

CONCLUSION

In the present study, the techniques and methods employed in the experimental realisation of the similariton compression and the optimisation of the compressor have been presented . Since the advent of optical fibres, there has been an endless desire to make ultra short pulses consisting of only a few optical cycles using the special properties of silica fibre. Indeed, there have been many reported incidences where pulses were compressed below 20 *fs.* But these pulses are often very distorted in shape and are usually marred by the presence of side pedestals that render them unsuitable for many applications such as optical telecommunication. Hence there is still a lot of effort being put into the field of pulse compression to achieve distortion- free, transform limited femtosecond pulses. The four pulse compression techniques that form the basis of pulse compression in optical fibres will be introduced, followed by a brief introduction of pulse re-shaping techniques used to improve the quality of compressed pulses. Two-stage similariton compressor system has successfully compressed an 11ps linearly chirped input pulse to 418fs, yielding a total compression factor greater than 25. As the amount of compression achievable by a CDDF is limited by the experimental β2 restraints resulting from the use of the comb-profile approximation .the source of error of this ally approximation has been physically explained by considering the difference in the amounts of dispersive and non-linear effects arising from the use of this design. The physical analysis of the error has led to the development of the improved CDDF step-size distribution scheme, where the step-sizes are determined such that the pulse accumulates the same amount of the maximum non-linear phase shift in each step.

Following the experimental realization and optimisation of the DDF the experimental realisation of a linearly chirped sech input pulse was presented. The relationship between the performance of the similariton compressor and the DDF length was numerically investigated. The outcome of this investigation was used to decide the length of DCF used for the experimental similariton input generation.

To achieve a high accuracy in the experimental results, the values of the fibre parameters have been measured experimentally.quick overviews of the techniques used for the measurements were presented along with the experimentally measured values. In order to achieve further compression a second-stage CDDF was constructed and added to the compressor system in a cascaded structure. The experimental set-up of the two-stage similariton compressor was presented with its experimental results and analysis.

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