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Analysis of the four wave mixing effect (FWM) in a dispersion decreasing fiber (DDF) for a WDM system

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Abstract

We did a numerical investigation of the propagation of short light pulses in the region of 1.55 µm and the conversion efficiency (CE) for the four wave mixing generation (FWM) of ordinary and dispersion decreasing fibers for use in wavelength division multiplexing (WDM) systems. Our simulations studies three different profiles, linear, hyperbolic, and constant. One conclude that for all the profiles there is decrease of the conversion efficiency with the increase in the channel separation. The hyperbolic profile present a higher efficiency of around 1000 above in magnitude compared with the others profiles at 0.2 nm of channel separation. We calculate the conversion efficiency versus the fiber length for the three profiles. The conversion efficiency for the hyperbolic profile is higher when compared to the constant and linear profiles. The other interesting point of the hyperbolic profile is that the increase of the CE in the beginning of the fiber does not show any oscillation in the CE

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value (log η), which was observed for the constant and linear profiles. For all the profiles there is an increase of the conversion efficiency with the increase of the pump power. The compression factor C_i for the generated FWM signal at ω_3 was measured along the DDF's and the constant profile fibers. One can conclude that with the use of decreasing dispersion profile (DDF) fibers one can have a control of the (CE) conversion efficiency and the compression factor of the four wave mixing (FWM) generation in WDM systems.

Keywords: Dispersion decreasing fibers; Four wave mixing; Special fibers

1. Introduction

As the capacity of fiber transmission systems increases, the spacing between wavelength division multiplexing (WDM) channels needs to decrease to make a better use of the limited optical amplifier bandwidth. The short pulse widths and increased optical lunch power used in ultra-high bit-rate systems lead to increased signal distortion due to the transmission fiber nonlinearity. In addition to interchannel nonlinear distortion, the short pulse widths lead to a large dispersive pulse broadening within each span resulting in inter channel effects, specifically cross phase modulation (XPM) and four wave mixing (WDM) which have been under study [1–5]. The XPM results in pulse timing jitter, while FWM results in the generation of new frequency components. The FWM effect can make channel signals distorted and channel energy lost, which induce crosstalk in dense WDM (DWDM). Many techniques were used to eliminate FWM in DWDM systems such as unequal spaced channels [6], polarization mode dispersion (PMD) [7], optical phase conjugation [8].

Several papers deals with the FWM effect in a CW configuration [9]. However the necessity to use short pulses (several ps) in a configuration where the decrease of frequency separation, to a better use of the optical amplifier bandwidth is getting more critical. Several papers were reported in the literature concerning the study of the ultra short pulse dynamics in the FWM effect [10–13]. The interaction between intrachannel pulses and the observation of ghost pulses were studied [14]. Recently a precompensation technique to reduce intrachannel nonlinear effects was presented [15].

Recently a special fiber was used to overcome optical fiber loss using the balance between group velocity dispersion (GVD) and self phase modulation (SPM) in a lossy fiber using by changing the dispersive properties of the fiber [16–18]. Such fibers are the dispersion decreasing fibers (DDF), because their GVD must decrease in a such a way that it compensates for the reduced SPM experienced by the optical pulse as its energy is reduced by the loss. Fibers with a nearly exponential GVD profile have been fabricated [16–18]. The technique used for making the DDF fiber consists of reducing the core diameter along the fiber length in a controlled manner during the fiber-drawing process. The use of these fibers in optical compressors [16–18], nonlinear couplers [19–21], and in fiber loop mirrors was studied [22].

A systematical study of the nonlinear effects that will be present in these special fibers on the transmission systems with ultra short pulses is demanded.