Untraditional All-Optical Chromatic Dispersion Compensating Elements - Experimental Verification

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Abstract

This contribution deals with experimental investigation of usability of untraditional all-optical chromatic dispersion elements. Results are compared with traditional dispersion compensating fibres; emphasis was also given to tuneability and broadband characteristics of elements.

Introduction

Standard single mode fibres (SSMF) according ITU-T specification G.652 represent the majority of already installed fibres. SSMFs were original designed for operation in O band and thus their wavelength of zero chromatic dispersion (CD) is about 1310 nm. Their low loss in C band and the availability of reliable and relatively cheap erbium doped fibre amplifiers (EDFAs) makes the 1550 nm window attractive for multi channel high speed transmission. Unfortunately within this window SSMF shows relatively large CD, about +16.8 ps/(nm*km), severely limiting transmission distance unless compensated. In the past fibre vendors tried to overcome CD issue by introducing non-zero dispersion shifted fibres (NZDF). Nevertheless these fibres represent a minority of installed fibre base and their usage under high channels counts (induces high powers in fibre) is considered as controversial. At transmission rates 10 Gb/s and higher the effect of CD can be mitigated by various means. These range from electrical to all-optical ones. As electrical processing is performed per wavelength and therefore unsuitable for wavelength division multiplex (WDM) systems, we will focus all optical methods.

Very typical approach represents application of dispersion compensating fibres (DCF) [1], showing negative CD typically of between -90 and -100 ps/(nm*km). Unfortunately they also have higher insertion loss (IL) compared with SSMF. To compensate 80km of SSMF it is necessary about 13km of DCF having IL about 13 dB. Although DCF is a broadband element, dispersion slope of SSMF and DCF are not exactly balanced so in WDM systems only one channel can be compensated exactly.

Next quite often used element is a chirped fibre Bragg grating (FBG) [2]. At first channelized FBGs becomes available, compensating CD only in 100 GHz or 50 GHz spaced channels – typically of ITU-T grid. Nevertheless broadband FBG are now also available. Main advantages of FBG CD compensating modules are low IL (about 3 dB for device compensating 80km of SSMF) and possibility of designing the DC modules to exactly match dispersion slope of compensated fibre. The disadvantage is that fixed FGB module must be tailored to compensate certain distance.

Tuneability of CD compensation becomes crucial with increasing transmission bit rate because the tolerance of receivers to accumulated CD decreases with square of transmission rate. For example existing 40 Gb/s NRZ receivers can tolerate residual CD of about 100 ps/nm, only. Furthermore in reconfigurable networks accumulated CD can change due to rerouting of optical path.

There are several possibilities how to achieve tuneable CD compensation, including: differential thermal tuning of nonlinearly chirped FBG [3, 4], thermal tuning of free space or FBG coupled-cavities Gires-Tournois etalons (GTE's) [5, 6] and virtually-imaged phase-array (PA's) [7, 8].

Experimental setup

In the area of research and educational networking REN (typically based on leased dark fibres) it is sometimes uneconomical or even impossible to deploy inline amplification and CD compensation.

Our experimental setup takes into account this fact - using so called nothing in line (NIL) approach, where transmission equipment is placed in terminal nodes, only [9,10]. In our experiment signals from eight 10 GE DWDM XFP transceivers were combined in a multiplexer (MUX), amplified in a high-power C-band EDFA and launched into the test fibre link. The test link consisted of 225 km of SSMF on spools with granularity 50 km and 25 km. The chromatic dispersion of the link was about +3780 ps/nm. At the receiver side signals were first amplified in a low noise preamplifier EDFA. Accumulated CD was compensated and signals were finally de-multiplexed. Bit-error rate tests were performed by Packet Blazer 10GigE FTB-5810G module.

Experimental results

In the reference experiment CD was compensated by DCF modules. It was necessary to use additional EDFAs after DCFs to overcome their high IL of up to 18 dB. Transmission tolerance to total input power is shown in Fig 1 with the amount of compensated CD as parameter.

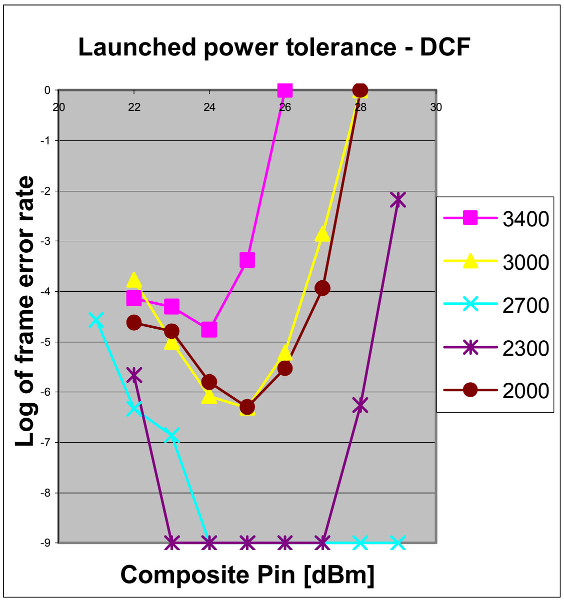

Fig 1: Transmission tolerance to launched input power – DCF

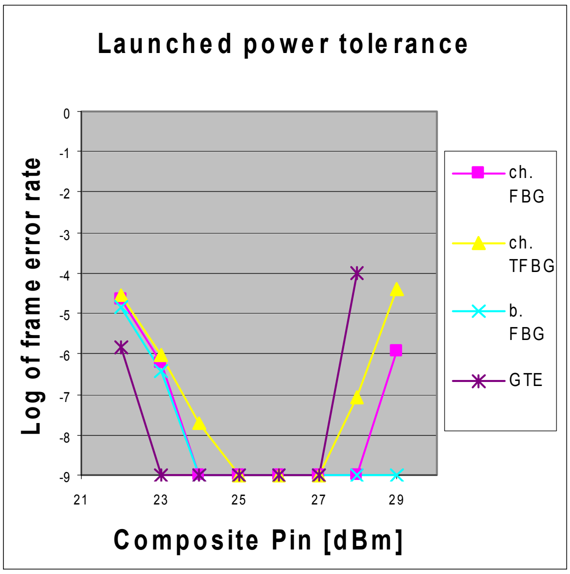

Fig 2: Transmission tolerance to launched input power – untraditional elements

In following experiments CD was compensated by one of following all optical methods: channelized FBGs, channelized tuneable FBGs (TFBG), broadband FBGs and tuneable GTEs. Fig 2 demonstrates the tolerance to input power for different compensating methods, when the value of compensated CD was fixed at 3400 ps/nm.

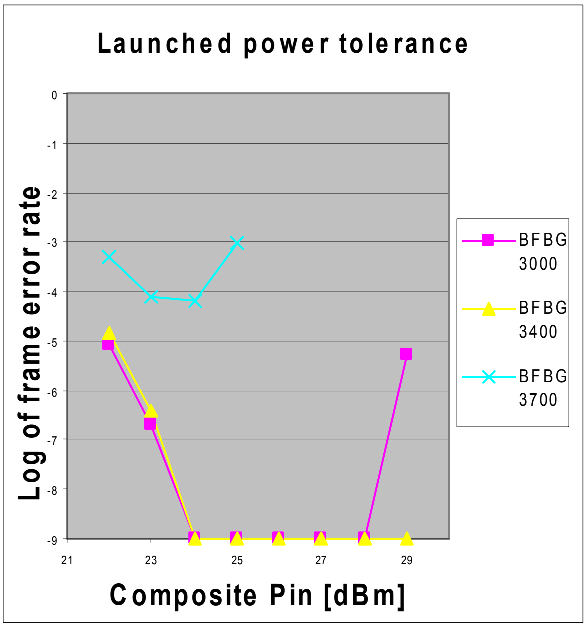

Fig 3: Transmission tolerance to launched input power – broadband FBGs

Next, tolerance to input power for different values of compensated CD using tuneable elements (channelized TFBGs, GTEs) and broadband FBGs (different modules were available) was examined. For example in Fig 3 power tolerance for broadband FBGs is shown. For tuneable compensators launched power was fixed to +25 dBm and operational range over compensated CD was experimentally investigated too.

Conclusions

We experimentally investigated different CD compensation techniques in NIL setup. Under test were traditional DCFs, fixed channelized and broadband FBGs, tuneable FBGs and tuneable GTEs. Tests were performed by transmitting 8x10 GE channels over 225 km of SSMF, signals were amplified at transmitter and receiver sides by standard C-band EDFAs only. Experiments confirmed that unconventional elements allow implementation of simpler setups due to lower IL compared with DCFs. Furthermore we can summarize that for error-free transmission the GTEs allow launching of lower signal powers in contrast to broadband FBGs, which can tolerate higher launch powers. When comparing tuneable devices we can state that FBGs allow error free operation over broader ranges of input power and compensated CD, comaped with GTEs. However, GTEs offer tuneable CD compensation with very low IL at reasonable prices. Experimental setups based on partial CD pre-compensation proved that small CD (≈-340 ps/nm) pre-compensation can dramatically increase transmission CD tolerance range (2 times), we believe due to suppression of self-phase modulation in the link. On other hand higher CD pre-compensation prevented error-free transmission completely. In the future we would like to experimentally verify applicability of virtually-imaged phase-array CD compensators, both fixed and tuneable.

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