Título Phase and amplitude measurements for high bandwidth optical signals

Tipo de Producto Publicación científica

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Código del Proyecto y Título del Proyecto

P14T02 - Desarrollo de sensores por fibra óptica: Análisis de esquemas de multiplexación e implementación de dispositivos para diversas aplicaciones metrológicas

Responsable del Proyecto

Esteban Sicre

Línea

Aplicaciones especiales de Fibra óptica

Área Temática

TIC

Fecha

Agosto 2014

INTEC
Instituto de Tecnología

UADE

FUNDACIÓN UADE

Optical Fiber Technology 20 (2014) 403–408

Contents lists available at ScienceDirect

Optical Fiber Technology

www.elsevier.com/locate/yofte

Phase and amplitude measurements for high bandwidth optical signals

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ARTICLE INFO

Article history:
Received 10 December 2013
Revised 10 April 2014
Available online 2 June 2014

Keywords:
Phase measurements
Transport-of-intensity equation
Fiber optic device

ABSTRACT

In this paper a novel technique for obtaining the amplitude and phase of optical pulses with time extents as short as tens of ps is presented. The method which is based on the transport-of-intensity equation only requires, for a practical realization, of passive fiber optic devices. It employs as the main component a dispersive element with a known second order dispersion coefficient. Two different setup implementations are considered, for which simulations are carried out in order to test the method performance taking into account both, realizable models of the involved devices and typical pulses found in optical transmission systems. The characterization of optical pulses affected by dispersion and nonlinear effects, such as self-phase modulation, is used to evaluate the performance of the method and show the practical feasibility of the future implementation.

1. Introduction

All-optical signal processing techniques have taken the attention of the photonics and optical communications scientific community because of its potential advantages regarding aspects such as high processing bandwidth and immunity to electromagnetic interference [1]. The use of passive optical devices translates into simpler and more economic systems than the active optoelectronic counterpart, and obviously but worth mentioning, there is no energy consumption in the process. In recent years, many optical devices have been proposed for switching, filtering and coding signals typically found in optical communication and microwave-photonics scenarios [2,3].

In fiber optic applications, there is much interest in the characterization of optical pulses since the deployment of high bit rate transmission systems which use coherent detection methods that require to estimate the phase value in the demodulation process, e.g. optical pulses present in advanced modulation formats such as QPSK or 16 QAM. Another important use of optical phase recovery methods is in sensing applications, to increase the sensitivity and range of operation fiber optic sensors.

During the 90’s, several methods have been proposed to measure the phase of an ultrashort optical pulse and some of them were even converted into commercial devices (Chilla y Martínez [4], Kane y Trebino [5], O’Shea y Trebino [6], Iaconis y Walmsley [7]). Along this development process, also emerged techniques that due to the procedure and/or the technology used for their implementation, they are only capable of measuring the amplitude and phase of pulses with durations in the order of picoseconds. In 1993 it was presented a method called chronocyclic tomography [8] which determines the phase of a pulse from the reconstruction of its associated Wigner Distribution Function (WDF) employing tomographic measurements of the spectrum. In the year 2003, from the base of the latter technique, Dorrer and Kang [9] presented a method which allows to obtain the phase from spectrum measurements of the pulse after being passed through a phase modulator in the temporal domain. That same year, Alieva et al. [10,11], introduced a way to reconstruct the amplitude and the phase of a signal, utilizing measurements of the squared modulus of the fractional Fourier transform with close fractional orders.

In this paper, we present a technique for pulse characterization based on the transport-of-intensity equation and propose a scheme for its photonic implementation which uses only passive fiber optic devices.

2. Signal recovery method

The method here presented is derived from the relationship between the first order WDF moment of a given signal and the

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http://dx.doi.org/10.1016/j.yofte.2014.05.001
1068-5200/