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An Encoder/Decoder Device Including a Single Reflective Element for Optical Code Division Multiple Access Systems

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Summary

In this paper, we present an encoding/decoding device for OCDMA communications. The device uses a single reflecting element to perform both the encoding of the outgoing signal and the decoding of the incoming signal. A directional optical setup allows differentiating the origin of the signals to forward the outgoing signals after encoding to the network and the incoming signals after decoding to a receiver.

1 Introduction

Systems based on optical communication could be a potential candidate for the access network. Indeed, the optical single mode fiber is a very attractive communication medium since it offers a large useful bandwidth (25THz) and low attenuation (0,2dB/Km) and can therefore facilitate demanding services such as high-quality video transmission. As the reach of optical fiber is being extended to the access network it is economically attractive to share fibers between different end-users without adding active components in the network. The most common multiple access method for such passive optical networks (PON) is time division multiple access (TDMA), but lately there has been an increased interest in using wavelength division multiple access (WDMA).

Optical code division multiple access (OCDMA) [1] constitutes an other potential candidate for the next generation of optical access network. It has several advantages compared to the TDMA and WDMA solutions. In fact, it is a random and simultaneous access protocol where there is no need for the strict timing synchronizations which are needed in the case of TDMA. This allows us to turn away from an expensive centralized network control furthermore to a strict wavelength control which is needed in the case of WDMA. In addition to the asynchronous access capability, OCDMA offers inherent security which represents a serious request for the end-users. Indeed, CDMA is a multiplexing scheme based on the principle of message encoding and decoding only by authorized receivers and in the presence of interfering signals from network co-users [1].

In this paper, we propose a new directional setup which allows reducing the cost of an encoder/decoder device for OCDMA users. Indeed both reflecting operations, the encoding and the decoding, could be done by the same reflective element, thereby eliminating the need for extra reflective elements and two optical circulators and a directional coupler at the Central Office and at the User Station.

2 Conventionnel encoder/decoder device

OCDMA (Optical Code Division Multiple Access) is a multiplexing technique whereby an optical signal is encoded. De-pending on the encoder used, the transmitter may for example be used in "slice and delay" schemes, also called Fast-Frequency Hopping (FFH) as in [2], or "spectrum slicing" schemes, also called Frequency Encoding (FE) [3,4]. A first reflective element is generally used for the encoder, and a second reflective element as a decoder having the same profile as the encoder except for the time-reversal property when time spreading is used. The favored reflective element for the en-coder and the decoder are fiber Bragg gratings (FBG) since they are readily fiber compatible.

Current networks require the provision of two identical reflective elements at each location where encoding and decoding operations are performed. Both operations are traditionally done separately. Fig. 1 shows the architecture of such a net-work, where the Central Office and every user are provided with both an encoder and a decoder.

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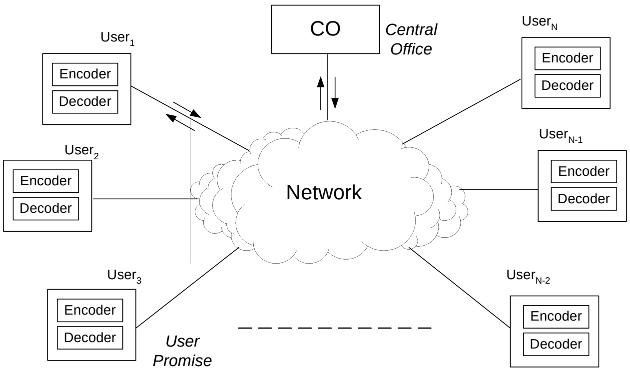
Fig. 1: Architecture of an OCDMA system with N end-users and a Central Office (CO).



The encoding and decoding of information is a symmetric process for the FFH-OCDMA as shown in Fig. 2. The same reflective element can be used from the first port to work as an encoder in the Central Office (or at a user station) and from the second port as a decoder at a User Station (or at the Central Office).

Fig. 2: The principle of an encoder and a decoder using fiber Bragg gratings in FFH-OCDMA system.

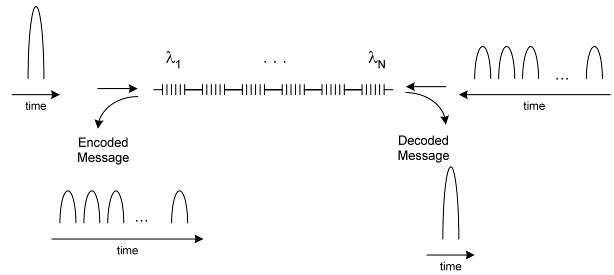
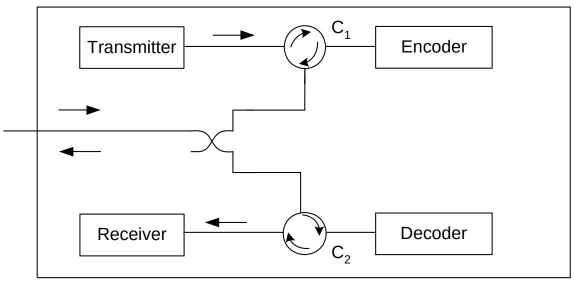


Fig.3 illustrates the data flow in a traditional bi-directional encoding/decoding device. In this system, a message sent from the user (via a transmitter) to the Central Office is directed towards the encoder by a three-port circulator C_1. The encoder reflects the signal modified in accordance with its particular code, and sends it back towards the circulator C_1. The signal is then redirected to the bi-directional link between the user and the network to be forwarded to the Central Office. Similarly, an encoded incoming signal from the Central Office will go to circulator C_2 which sends it to the decoder. Reflection by the decoder will decode the signal and send it back to circulator C_2, which redirects it to the receiver.

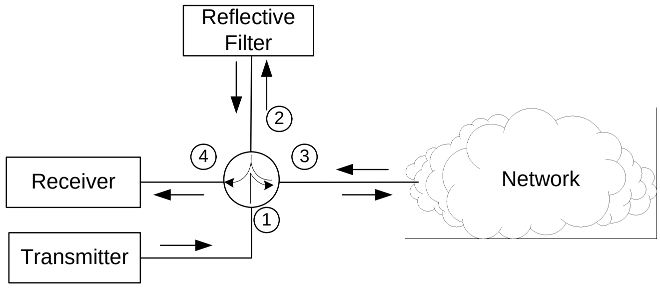
Fig. 3: The architecture of a traditional bi-directional encoder/decoder device.



3 Implementation of a new encoder/decoder for OCDMA with a single reflective element

It would however be advantageous to provide a device where both reflecting operations, the encoding and the decoding, could be done by the same element, thereby eliminating the need for extra reflective elements at each location, two optical circulators and a directional coupler. Of course, the user's reflective element should still be a mirror image of the Central Office's reflective element for the system to be operational. Such device should have a data flow as shown in Fig.4.

Fig. 4: A diagram illustrating the data flow between a network and a User Station in FFH-OCDMA system.



The reflective element includes at least one Bragg grating implemented in a length of optical fiber, but it could alternatively be replaced by other types of wavelength-dependent reflectors such as thin films reflectors or diffraction grating reflectors.

The encoding/decoding device further includes a directional optical setup. The directional optical setup is optically coupled to the transmitter (through the port 1), the receiver (through the port 4), the network (through the port 3) and the reflective element (through the port 2). Depending on the propagation direction of the optical signals, the setup enables differentiating their origin so that each signal is forwarded to the appropriate output. That is, even though all ports are interrelated, the origin of a signal sent to the reflective element will determine where it will be forwarded after reflection. The directional optical setup therefore receives:

- the uncoded outgoing signals from the transmitter, sends them to the reflective element to obtain the encoded out-going signals, and directs the encoded outgoing signals to the network; and
- the encoded incoming signals from the network, sends them to the reflective element to obtain the decoded in-coming signals, and directs the decoded incoming signals to the receiver.

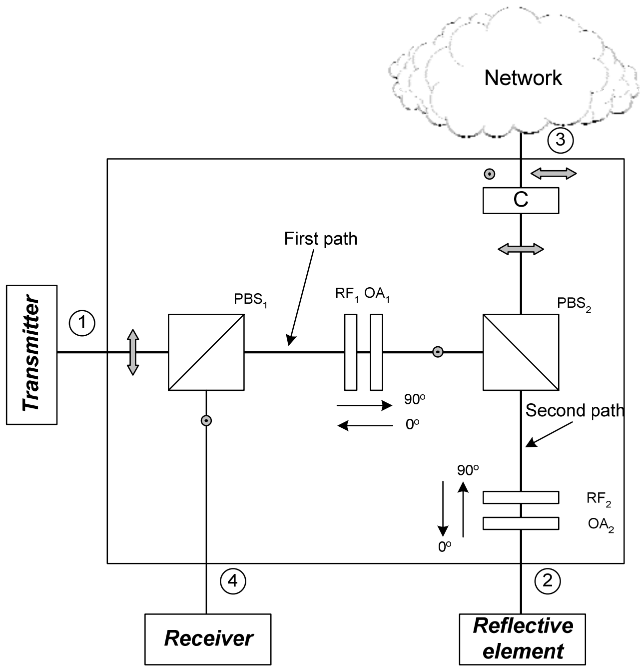
4 Description of a new directional setup

Fig. 5 shows the principle of the bi-directional network with four-port circulator.

The uncoded outgoing signals received at port 1 of the directional optical setup encounter a first Polarization

Beam-Splitter PBS1. This component will maintaining the propagation of light polarized along the plane of incidence along the first path, but couple light polarized perpendicular to the same plane out of the first path. The uncoded outgoing signals may be already linearly polarized along the plane, depending on the type of transmitter used. In this case it will be unaffected by the PBS1 and continue its way. In the case where the signal is not polarized, its vertically polarized component will simply be coupled out of the first path through the un-connected port of the PBS1, and be lost to the system. This will result in a 3 dB loss of signal similar to what we have through the 3 dB directional coupler in the conventional bi-directional en-coder/decoder.

Fig. 5: A schematic view of an optical encoding/decoding device adapted for a bi-directional network.



After crossing the PBS1, the uncoded outgoing signal then reaches a first Faraday rotator RF1 and a first Optically Active element OA1 (such as an optically active quarter-wave plate). The optically active element rotates the polarization of the signal by ±45° depending on its propagation direction, whereas the Faraday rotator rotates it by +45° in all cases. The net effect is a 90° polarization rotation of signals traveling away from port 1, and polarization maintaining in the other direction. In this manner, the incoming signal from port 1 will have its polarization rotated to be perpendicular to its original orientation, and therefore becomes vertically polarized. As such, it will then be redirected on the second path towards port 2 by a second Polarization Beam Splitter PBS2, crossing on its way a second Faraday rotator RF2 and a second optical active element OA2 which do not influence signals propagating in this direction.

Port 2 is connected to the reflective element for encoding and decoding signals. It receives the uncoded outgoing signals and encoded incoming signals respectively. After reflection, the encoded outgoing signals and the decoded incoming signals are obtained respectively. In the present case, the uncoded outgoing signal will be encoded, and reflected along the second path as the encoded outgoing signal. It worth noting that, at this point, the signal is still vertically polarized. This time it will be affected by the second Faraday rotator RF2 and the second optical element OA2, which together rotate its polarization by 90° so that it becomes horizontally polarized. The signal will therefore be unaffected by the second Polarization Beam-Splitter PBS2, and reaches port 3 in order to be transmitted to the Central Office via the network.

The present system also serves as a signal decoder in the following manner. An encoded incoming signal is received from the network at port 3, and launched on the second path where an active polarization controller is provided to align the polarization components of the incoming signal to be in the plane (horizontally polarized). As such, the horizontally polarized signal goes through the second Beam Splitter PBS2 unaffected. In the alternative, the active polarization controller could be omitted, in which case the vertically polarized component of the incoming encoded signals will be redirected to the uncoupled port of the second beam splitter PBS2 and lost. The horizontally polarized signal is also unmodified by the second Faraday rotator and second optical element RF2 and OA2 in direction of port 2. It is then de-coded by reflection in the reflective element connected to port 2, becoming the decoded incoming signal. Returning on the second path through the second Faraday rotator and second optical element RF2 and OA2, it is this time rotated to be vertically polarized, and as such is deviated from the second path towards the first path by the second beam-splitter PBS2. It crosses the first Faraday rotator and first optical element RF1 and OA1 by maintaining its polarization state, which is vertical. It is therefore deviated by the first beam-splitter PBS1 towards port 4, connected to the receiver.

The present device could also be applied to other types of optical systems where the add and drop of one channel constitutes the "encoding" and "decoding" of the signal, and needs to be accomplished by a same reflector, such as, for example, in WDM (Wavelength Division Multiplexing systems) or in Spectrum-Sliced Wavelength Division Multiplexing (SS-WDM) for multi-wavelength or single-wavelength output spectra respectively as in [5,6,7].

5 Conclusion

We present for the first time a new directional assembly able to Add/Drop optical signal for incoherent optical communication systems with using a single reflective element as fiber Bragg grating for I-WDM or a series of FBG as code for FE- and FFH-OCDMA systems.

With this new directional assembly, we are able to reduce the cost of an encoder/decoder device for OCDMA users. In-deed both reflecting operations, the encoding and the decoding, will be done by the same reflective element, thereby eliminating the need for extra reflective elements and two optical circulators and a direc-

tional coupler at the Central Office and also at the User Station.

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