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OPTICAL CIRCULATOR FOR FREE SPACE OPTICAL COMMUNICATION

ABSTRACT

A free space optical communication system transmits and receives optical signals in a colorless manner using an optical circulator. The system installs the optical circulator with a single mode (SM) fiber at port 1, a double clad (DC) fiber at port 2, and a multimode (MM) fiber at port 3. The system injects a first optical signal into a core of the SM fiber. The system then routes the first optical signal at port 1, using the optical circulator, into a SM core of the DC fiber via Port 2. Further, the system injects a second optical signal into a first cladding of the DC fiber. The system then routes the second optical signal at port 2, using the optical circulator, into the MM fiber via Port 3.

PROBLEM STATEMENT

Free space optical (FSO) communications are used to communicate information through free space between optical transmitters and receivers that are aligned to establish the line of sight connections for the data to be transmitted and received. Hence, optical alignment has to be established between two optical fiber tips at a distance. In FSO communication systems, transmitting an optical beam from a single mode (SM) fiber is required, so that the optical signal can propagate in Gaussian beam to ensure the focusability at the far end. However, it is desirable to receive the optical beam into a multimode (MM) fiber, having a larger diameter than a SM fiber, so that the pointing accuracy can be relaxed while the line of sight is still established. Furthermore, it is highly desirable that the transmitting and receiving optics are colorless, i.e., the transmitting and receiving wavelength(s) do not need to be predetermined, so that the network has the flexibility to reconfigure the wavelength assignments. Hence, it is desirable to have a simple photonic architecture that can support these features without the efforts to align optics in the free space. Accordingly, there are opportunities to create a method and system for transmitting an optical signal in a single mode fiber and receiving the optical signal in multimode fiber in a colorless manner.

DETAILED DESCRIPTION

The systems and techniques described in this disclosure relate to a free space optical (FSO) communication system having an optical circulator installed within a single mode (SM) fiber, a double clad (DC) fiber, and a multimode (MM) fiber. The system can be implemented for use in an Internet, an intranet, or another client and server environment. The system can be implemented locally on a client device or implemented across a client device and server environment. The client device can be any communication device such as an optical communication device, optical transmitters, optical receivers, or FSO base stations, etc.

Fig. 1 describes a system architecture of how to use the optical circulator in an FSO communications system. As shown in Fig. 1, this system installs the optical circulator pigtailed with a single mode (SM) fiber for a Port 1, a double clad (DC) fiber for a Port 2, and a multimode (MM) fiber for a Port 3.

In fiber optics, an optical signal is guided down the center of a fiber called the core. The core is surrounded by an optical material called the cladding that traps the light in the core using an optical technique called total internal reflection. The SM fiber has a small diametral core that allows only one mode of light to propagate and the MM fiber has a large diametral core that allows multiple modes of light to propagate. An optical circulator is a fiber optic component that can be used to direct the optical signal from one port to another port. The DC fiber has the SM core that is surrounded by a first cladding to support the SM optical guiding. The first cladding is surrounded by a second cladding, so that the first cladding itself is an MM optical waveguide, which ideally, matches with the MM fiber at Port 3 for low coupling loss.

As illustrated by purple arrow 110 in Fig. 1, a first optical signal is injected into the core of the SM fiber. The first optical signal from port 1 is routed by 120 the optical circulator to the SM core of port 2 which then exits the optical circulator as a transmitting signal 130. As illustrated by green arrow 140 in Fig. 1, the second optical signal is received into the first cladding of the DC fiber which acts as a MM waveguide. The second optical signal from port 2 is then routed 150 to port 3 which is pigtailed with a MM fiber.

Fig. 2 illustrates an example method 200 for transmitting and receiving an optical signal using an optical circulator in a colorless manner. Method 200 can be performed by the FSO communication system.

The system installs 210 an optical circulator with a single mode (SM) fiber at port 1, a double clad (DC) fiber at port 2, and a multimode (MM) fiber at port 3. The system then injects 220 a first optical signal into a core of the SM fiber. The system further routes (230) the first optical signal at port 1, using the optical circulator, into a SM core of the DC fiber via Port 2. Further, the system injects (240) a second optical signal into a first cladding of the DC fiber. The system then routes (250) the second optical signal at port 2, using the optical circulator, into the MM fiber via Port 3. Hence, the second optical signal acts as a received signal in the MM fiber.

The optical circulator is not wavelength sensitive, as a result, and promotes colorless transmitting from an SM fiber and receiving into an MM fiber.

The same arrangement illustrated in Fig. 2 can be used in a Lidar system while the first optical signal is the transmitted signal, typically consisting of optical pulses, and the second optical signal is the reflected signal from an object of interest.

Fig. 3 illustrates how an optical circulator 310 is used in the FSO communication system to transmit an optical signal from a SM fiber 320 and to receive the optical signal into a MM fiber 330. A system architecture has two terminals, a west terminal 350 and an east terminal 360. Each terminal has a transmitter (TX_{West} and TX_{East}, respectively) and each transmitter may include one or multiple optical channels. The output of the TX_{West} is connected to an optional optical amplifier 370. The output of the amplifier is connected to port 1 of the optical circulator and is routed to the SM core of a DC fiber 340 of Port 2. The signal is then propagated in the free space to the east terminal 360 and received into the first cladding of a DC fiber 345 which is a MM optical waveguide. This received signal is then routed to the Port 3 MM fiber 330 of the circulator and is received by the receiver. With this arrangement, transmitting from SM fiber 320 and receiving into MM fiber 330 is realized. Because the circulator is wavelength insensitive, the whole architecture is colorless in the sense that the east terminal 360 and the west terminal 350 can switch the transmitting and the receiving wavelengths without breaking the bidirectional optical link. Other wavelength management devices, such as wavelength division multiplexers and/or demultiplexers, as well as optical filters may be used to enhance the optical signal integrity or to increase the flexibility of the optical channel planning.

Fig. 4 illustrates an alternative architecture of Fig. 3. As illustrated in Fig. 4, a MM optical preamp 450 is used to increase the receiving sensitivity. Because the receiving path is in MM fibers 410 via the first clad of the DC fiber 420 and the MM fiber 410 of the Port 3 of the circulator 440, the preamp in the receiving path is illustrated as a MM optical preamp 450. Also as in Fig. 4, a tunable transmitter 430 can be used in both terminals. A tunable transmitter 430 can use one wavelength or multiple independently modulated laser wavelengths. Furthermore, a MM tunable bandpass filter 460 can be used to select certain wavelength band(s). The receiver (RX) may be a single photodiode or multiple spectrally separated photodiodes.

The subject matter described herein can be implemented in software and/or hardware (for example, computers, circuits, or processors). The subject matter can be implemented on a single device or across multiple devices (for example, a client device and a server device). Devices implementing the subject matter can be connected through a wired and/or wireless network. Specific examples disclosed are provided for illustrative purposes and do not limit the scope of the disclosure.

DRAWINGS

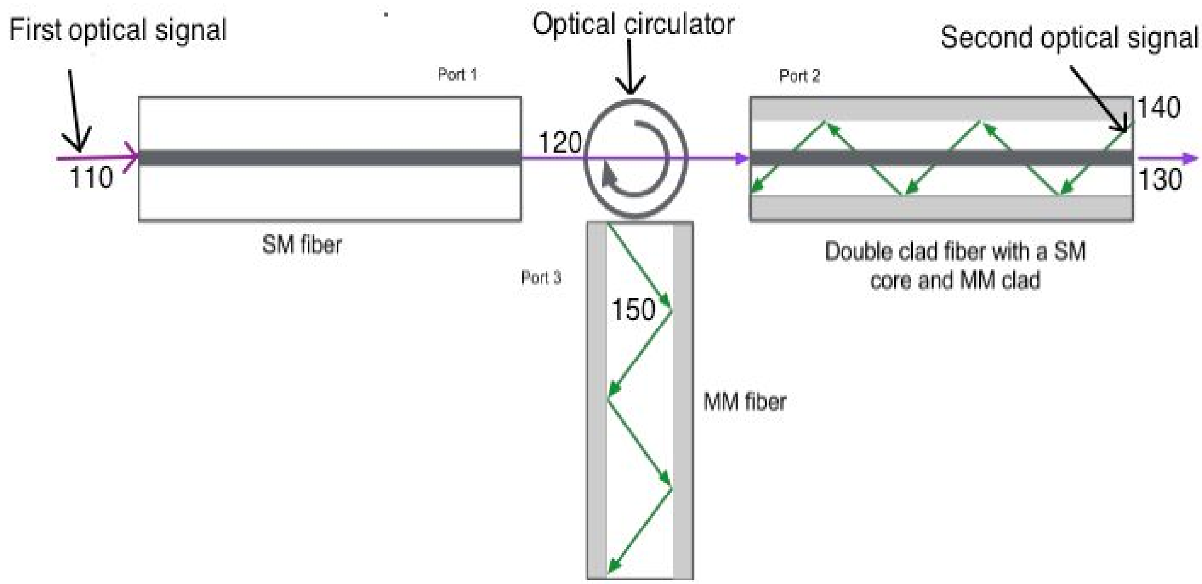

Fig. 1

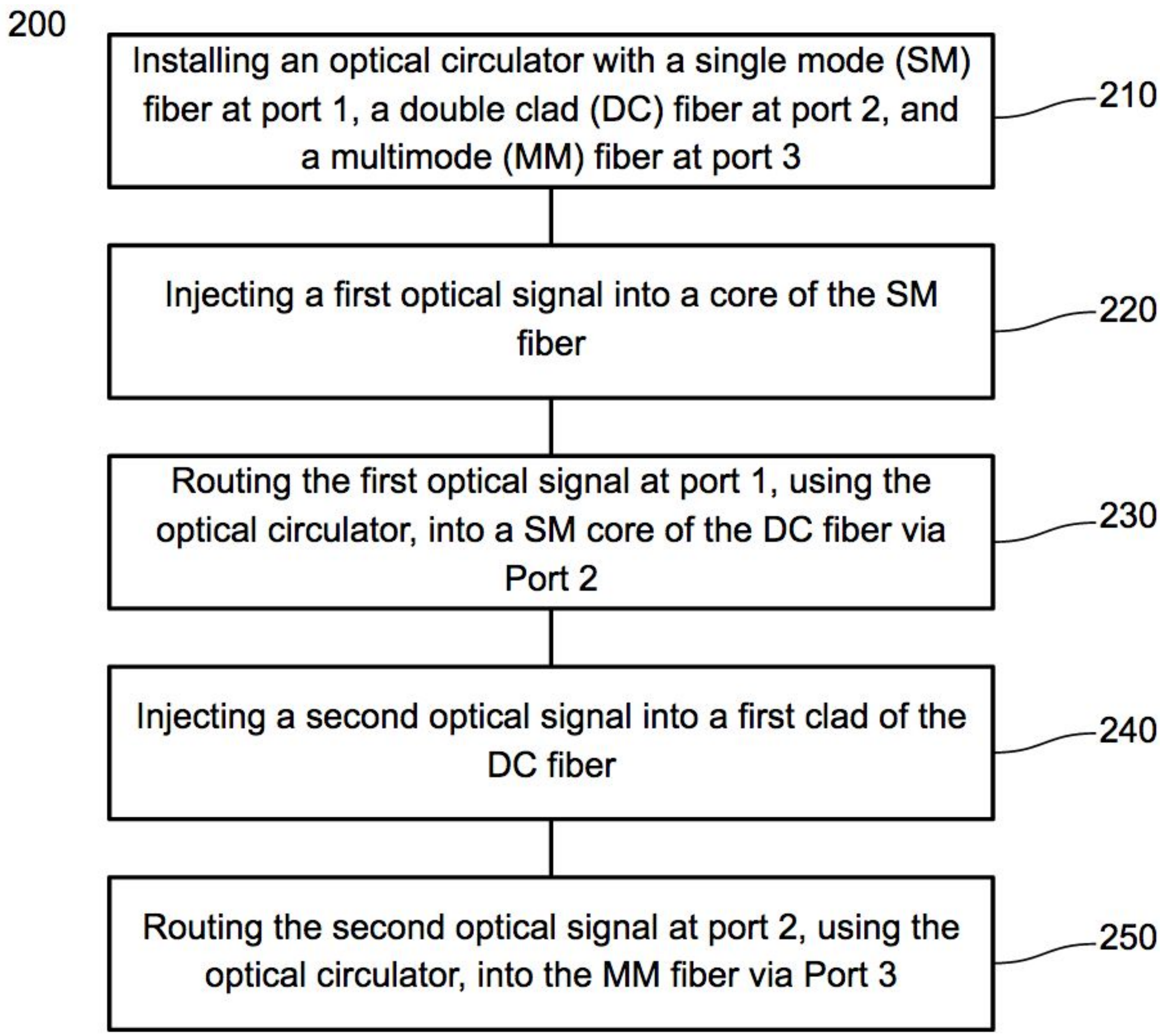
200
Installing an optical circulator with a single mode (SM) fiber at port 1, a double clad (DC) fiber at port 2, and a multimode (MM) fiber at port 3
210
Injecting a first optical signal into a core of the SM fiber
220
Routing the first optical signal at port 1, using the optical circulator, into a SM core of the DC fiber via Port 2
230
Injecting a second optical signal into a first clad of the DC fiber
240
Routing the second optical signal at port 2, using the optical circulator, into the MM fiber via Port 3
250

Fig. 2

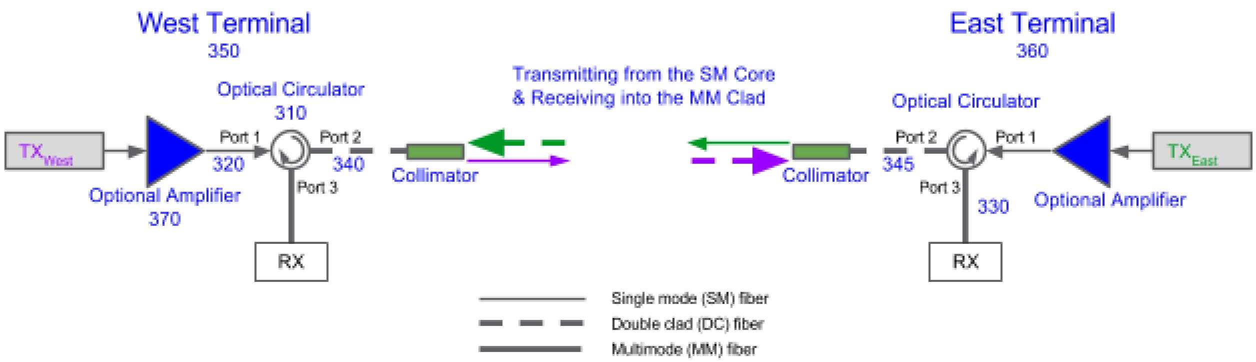
West Terminal
350
Optical Circulator
310
Transmitting from the SM Core
& Receiving into the MM Clad
East Terminal
360
Optical Circulator
TX West
Port 1
320
Port 2
340
Port 3
Collimator
Optional Amplifier
370
RX
Collimator
Port 2
345
Port 1
Port 3
330
Optional Amplifier
TX East
RX
Single mode (SM) fiber
Double clad (DC) fiber
Multimode (MM) fiber

Fig. 3

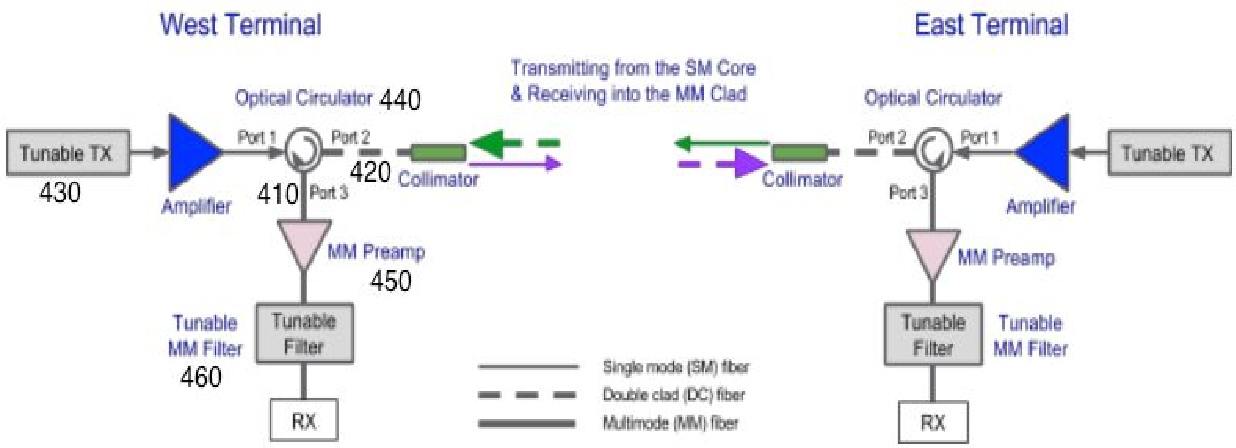
West Terminal
East Terminal
Transmitting from the SM Core
& Receiving into the MM Clad
Optical Circulator 440
Optical Circulator
Tunable TX
430
Amplifier
Port 1
Port 2
Port 3
410
420
Collimator
MM Preamp
450
Tunable MM Filter
460
Tunable Filter
RX
Single mode (SM) fiber
Double clad (DC) fiber
Multimode (MM) fiber

Fig. 4