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MULTI-WAVELENGTH POLARIZATION DIVERSIFIED OPTICAL RECEIVER CONFIGURATION

Abstract

Examples herein describe optical receiver circuitry. The optical receiver circuitry includes a polarization diversifier and first and second waveguides. The polarization diversifier is configured to receive in input optical signal, output a first component of the input optical signal into a first end of an optical path, and output a second component of the input optical signal into a second end of the optical path. An add-drop ring resonator filter is disposed in the optical path. The first waveguide is configured to transmit the first optical component from the add-drop ring resonator filter to a photodetector circuit. The second waveguide is configured to transmit the second optical component from the add-drop ring resonator filter to the photodetector circuit. The first waveguide has a first length and the second waveguide has a second length that is greater than the first length.

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Background/Summary

TECHNICAL FIELD

[0001] Examples of the present disclosure generally relate to wavelength division multiplexing (WDM), and more specifically, to optical receiver circuitry.

BACKGROUND

[0002] Wavelength division multiplexing (WDM) is technique for simultaneously transmitting multiple different data streams using an optical fiber by dividing the optical spectrum into different wavelength channels. A transmitter of a WDM system multiplexes the data streams onto the wavelength channels which each operate at a particular wavelength. The multiplexed data streams are transmitted via the optical fiber to a receiver of the WDM system. The receiver includes a demultiplexer which separates the wavelength channels for detection based on the particular wavelengths.

[0003] For WDM systems implemented using silicon photonics (SiPh), polarization dependence is a significant challenge because of the relatively high index contrasts and non-symmetric cross-sections associated with these systems. Adverse effects of polarization dependence include mode dispersion where different polarization modes of light travel at different speeds which causes signal distortion. Successful efforts aimed at achieving efficient polarization-insensitive operation for SiPh-based WDM systems have been limited to systems operating at relatively low modulation rates (e.g., below 25 Gbps).

SUMMARY

[0004] Optical receiver circuitry is described in some embodiments. The optical receiver circuitry includes a polarization diversifier, an add-drop ring resonator filter, a photodetector circuit, a first waveguide, and a second waveguide. In various embodiments, the polarization diversifier is configured to receive an input optical signal, output a first component of the input optical signal into a first end of an optical path, and output a second component of the input optical signal into a second end of the optical path. For example, the add-drop ring resonator filter is disposed in the optical path, and the first waveguide is configured to transmit the first component from the add-drop ring resonator filter to the photodetector circuit. The second waveguide is configured to transmit the second component from the add-drop ring resonator filter to the photodetector circuit. In various embodiments, the first waveguide has a first length and the second waveguide has a second length that is greater than the first length.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0005] So that the manner in which the above recited features can be understood in detail, a more particular description, briefly summarized above, may be had by reference to example implementations, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical example implementations and are therefore not to be considered limiting of its scope.

[0006] FIG. **1** illustrates optical receiver circuitry in a first example configuration, according to some embodiments.

[0007] FIG. **2** illustrates optical receiver circuitry in a second example configuration, according to some embodiments.

[0008] FIG. **3** illustrates optical receiver circuitry in a third example configuration, according to some embodiments.

[0009] FIG. **4** is a flow diagram depicting a method for receiving an input optical signal by a

wavelength division multiplexing (WDM) receiver, according to some embodiments.
[0010] FIG. **5** illustrates a representation of electrical eye diagrams, according to some embodiments.
DETAILED DESCRIPTION
[0011] Various features are described hereinafter with reference to the figures. It should be noted that the figures may or may not be drawn to scale and that the elements of similar structures or functions are represented by like reference numerals throughout the figures. It should be noted that the figures are only intended to facilitate the description of the features. They are not intended as an exhaustive description or as a limitation on the scope of the claims. In addition, an illustrated example need not have all the aspects or advantages shown. An aspect or an advantage described in conjunction with a particular example is not necessarily limited to that example and can be practiced in any other examples even if not so illustrated, or if not so explicitly described.
[0012] Silicon photonics (SiPh) is a desirable candidate for use in wavelength division multiplexing (WDM) receiver applications due to its compatibility with CMOS, relatively low productions costs, and capacity for large-scale integration. However, SiPh devices are inherently polarization dependent because of relatively high index contrasts and non-symmetric cross-sections associated with these devices. The polarization dependence causes signal distortion which is particularly significant when operating at relatively high modulation rates (e.g., over 25 Gbps).
[0013] Examples herein describe optical receiver circuitry. In some embodiments, the optical receiver circuitry includes a polarization diversifier, an add-drop ring resonator filter, a photodetector circuit, a first waveguide, and a second waveguide. In various embodiments, the polarization diversifier is configured to receive an input optical signal (e.g., from a WDM transmitter), output a first component of the input optical signal (e.g., a quasi-transverse-electric mode) into a first end of an optical path, and output a second component of the input optical signal (e.g., a quasi-transverse-magnetic mode) into a second end of the optical path. For example, the polarization diversifier includes a polarization splitter and rotator, a polarization splitting grating coupler, etc.
[0014] In one or more embodiments, the add-drop ring resonator filter is disposed in the optical path and configured to receive light from the first and second components having a particular frequency from the optical path. In some examples, the first waveguide transmits the light from the first component having the particular frequency from the add-drop ring resonator filter to the photodetector circuit. In certain embodiments, the second waveguide transmits the light from the second component having the particular frequency from the add-drop ring resonator filter to the photodetector circuit.
[0015] In various embodiments, the first waveguide has a first length and the second waveguide has a second length that is greater than the first length. In one or more examples, the first and second lengths are configured for delay matching the first and second components such that the light from the first component having the particular frequency reaches the photodetector circuit at the same time that the light from the second component having the particular frequency reaches the photodetector circuit. By delay matching the first component and the second component of the input optical signal in this way, polarization-insensitive operation is achieved without signal distortion even when operating at relatively high modulation rates (e.g., over 25 Gbps). Moreover, in some examples, a substantial portion of the delay matching may be performed in the optical path such that a difference between the second length and the first length can be minimized to reduce a footprint of the optical receiver circuitry.
[0016] FIG. **1** illustrates optical receiver circuitry in a first example configuration **100**, according to some embodiments. In the first example configuration **100**, an input optical signal **102** is received, for example, from a transmitter of a wavelength division multiplexing (WDM) system. In various embodiments, an edge coupler **104** such as a nano-tapered edge coupler is utilized to efficiently couple a relatively small waveguide core used to transmit the input optical signal **102** to a larger

optical mode. In some examples, the input optical signal **102** generally includes horizontally polarized and vertically polarized components, and the edge coupler **104** couples the horizontally polarized and the vertically polarized components from the relatively small waveguide into quasi-transverse-electric (TE) and quasi-transverse-magnetic (TM) modes, respectively, e.g., in a larger waveguide.

[0017] In one or more embodiments, the TE mode and the TM mode are orthogonal, and a polarization diversifier **106** separates the TE mode into a first path **108** and the TM mode into a second path **110**. For example, the polarization diversifier **106** includes a polarization splitter and rotator, a polarization splitting grating coupler, etc. The TE mode passes through the first path **108** into a TE path **112**. In some embodiments, the polarization diversifier **106** rotates the TM mode by 90 degrees (e.g., into TE polarization) and the rotated TM mode passes through the second path **110** as a TE mode into a TM path **114**.

[0018] In one or more examples, the polarization diversifier **106** may be associated with an undesirable differential group delay (DGD) which causes light in the TM path **114** to travel faster than light in the TE path **112**. For example, the DGD may cause signal degradation. In order to compensate for the DGD, in some examples, a waveguide delay line **114**A is added after the polarization diversifier **106** in the TM path **114**.

[0019] In various embodiments, the waveguide delay line **114**A causes light in the TE path **112** to reach point **116** at the same time that light in the TM path **114** reaches point **118**. For example, by determining a difference in a velocity of light in the TE path **112** and a velocity of light in the TM path **114**, a length of the waveguide delay line **114**A is computed such that the light in the TE path **112** and the light in the TM path **114** simultaneously arrive at points the **116**, **118**, respectively. In some embodiments, the waveguide delay line **114**A may be included in the polarization diversifier **106** such that the point **116** is representative of a first end of a looped optical path **120** and the point **118** is representative of a second end of the looped optical path **120**.

[0020] The looped optical path **120** is illustrated to include points **122**, **124**, **126**, **128** which correspond to locations along the looped optical path **120** of channels associated with different wavelengths of the optical spectrum. In certain embodiments, the point **122** corresponds to a location of channel one **130** which is associated with a first wavelength; the point **124** corresponds to a location of channel two **132** which is associated with a second wavelength; the point **126** corresponds to a location of channel three **134** which is associated with a third wavelength; and the point **128** corresponds to a location of channel four **136** which is associated with a fourth wavelength. Although four channels are illustrated, it is to be appreciated that the first example configuration **100** can include any number of channels.

[0021] In some embodiments, channel one **130** includes a first add-drop ring resonator filter disposed in the looped optical path **120**. For example, the first add-drop ring resonator filter is configured to selectively remove light having the first wavelength from the looped optical path **120** via one or more add ports, and then transmit the light having the first wavelength out from drop port **138**. Since light in the TM path **114** arrives at the point **122** before light from the TE path **112** arrives at the point **122**, light from the TE path **112** having the first wavelength is transmitted from the drop port **138** into a first waveguide **140** of channel one **130** and light from the TM path **114** having the first wavelength is transmitted from the drop port **138** into a second waveguide **142** of channel one **130**.

[0022] In various embodiments, the first waveguide **140** transmits the light from the TE path **112** having the first wavelength to a first photodetector circuit **144**. Similarly, in some embodiments, the second waveguide **142** transmits the light from the TM path **114** having the first wavelength to the first photodetector circuit **144**. Notably, the first waveguide **140** has a first length and the second waveguide **142** has a second length that is greater than the first length. In one or more examples, the first and second lengths are configured for delay matching the light from the TM path **114** and the light from the TE path **112**. For example, the second length is configured to delay the transmission of the light from the TM path **114** having the first wavelength such that the light from the TE path **112** having the first wavelength and the light from the TM path **114** having the first wavelength reach the first photodetector circuit **144** at the same time. In some embodiments, the second length is equal to a velocity of the light from the TM path **114** multiplied by a time required for the light from the TE path **112** to reach the first photodetector circuit **144**. In certain embodiments, the first photodetector circuit **144** includes a photodiode configured to detect light having the first wavelength.

[0023] In one or more embodiments, channel two **132** includes a second add-drop ring resonator filter disposed in the looped optical path **120**. In some examples, the second add-drop ring resonator filter is configured to selectively remove light having the second wavelength from the looped optical path **120** via one or more add ports, and then transmit the light having the second wavelength out from drop port **146**. As shown in FIG. **1**, light in the TM path **114** arrives at the point **124** before light from the TE path **112** arrives at the point **124**. To compensate for the different arrival times at the point **124**, light from the TE path **112** having the second wavelength is transmitted from the drop port **146** into a third waveguide **148** of channel two **132** and light from the TM path **114** having the second wavelength is transmitted from the drop port **146** into a fourth waveguide **150** of channel two **132**.

[0024] In certain embodiments, the third waveguide **148** transmits the light from the TE path **112** having the second wavelength to a second photodetector circuit **152**, and the fourth waveguide **150** transmits the light from the TM path **114** having the second wavelength to the second photodetector circuit **152**. The third waveguide **148** has a third length and the fourth waveguide **150** has a fourth length that is greater than the third length. In some examples, the third length of the third waveguide **148** may be equal to the first length of the first waveguide **140**. In other examples, the third length of the third waveguide **148** can be less than the first length of the first waveguide **140** or greater than the first length of the first waveguide **140**.

[0025] In various embodiments, the second length of the second waveguide **142** may be greater than the fourth length of the fourth waveguide **150**. In these embodiments, the second length is greater than the fourth length because light in the TM path **114** reaches the point **122** before reaching the point **124** and light in the TE path **112** reaches the point **124** before reaching the point **122**. In one or more examples, the third and fourth lengths are configured for delay matching the light from the TM path **114** and the light from the TE path **112**. In some examples, the fourth length is configured to delay the transmission of the light from the TM path **114** having the second wavelength such that the light from the TE path **112** having the second wavelength and the light from the TM path **114** having the second wavelength reach the second photodetector circuit **152** at the same time. In certain embodiments, the second photodetector circuit **152** includes a photodiode configured to detect light having the second wavelength.

[0026] For reasons similar to the reasons articulated with respect to channel one **130** and channel two **132**, channel three **134** may include a third add-drop ring resonator filter disposed in the looped optical path **120**. In various embodiments, the third add-drop ring resonator filter is configured to selectively remove light having the third wavelength from the looped optical path **120** via one or more add ports, and then transmit the light having the third wavelength out from drop port **154**. For example, light from the TE path **112** having the third wavelength is transmitted from the drop port **154** into a fifth waveguide **156** of channel three **134** and light from the TM path **114** having the third wavelength is transmitted from the drop port **154** into a sixth waveguide **158** of channel three **134**.

[0027] In one or more examples, the fifth waveguide **156** transmits the light from the TE path **112** having the third wavelength to a third photodetector circuit **160** configured to detect light having the third wavelength. For example, the sixth waveguide **158** transmits the light from the TM path **114** having the third wavelength to the third photodetector circuit **160**. As shown, the fifth waveguide **156** has a fifth length and the sixth waveguide **158** has a sixth length that is greater than the fifth length. In certain embodiments, the fifth and sixth lengths are configured for delay matching the light from the TM path **114** and the light from the TE path **112** such that the light from the TE path **112** having the third wavelength and the light from the TM path **114** having the third wavelength reach the third photodetector circuit **160** at the same time.

[0028] For reasons similar to the reasons articulated with respect to channel one **130** and channel two **132**, channel four **136** can include a fourth add-drop ring resonator filter disposed in the looped optical path **120**. In one or more embodiments, the fourth add-drop ring resonator filter is configured to selectively remove light having the fourth wavelength from the looped optical path **120** via one or more add ports, and then transmit the light having the fourth wavelength out from drop port **162**. In some embodiments, light from the TE path **112** having the fourth wavelength is transmitted from the drop port **162** into a seventh waveguide **164** of channel four **136**, and light from the TM path **114** having the fourth wavelength is transmitted from the drop port **162** into an eighth waveguide **166** of channel four **136**.

[0029] In various embodiments, the seventh waveguide **164** transmits the light from the TE path **112** having the fourth wavelength to a fourth photodetector circuit **168** configured to detect light having the fourth wavelength. The eighth waveguide **166** may transmit the light from the TM path **114** having the fourth wavelength to the fourth photodetector circuit **168**. In some examples, the seventh waveguide **164** has a seventh length and the eighth waveguide **166** has an eighth length that is greater than the seventh length. In certain embodiments, the seventh and eighth lengths are configured for delay matching the light from the TM path **114** and the light from the TE path **112** such that the light from the TE path **112** having the fourth wavelength and the light from the TM path **114** having the fourth wavelength reach the fourth photodetector circuit **168** at the same time.

[0030] FIG. **2** illustrates optical receiver circuitry in a second example configuration **200**, according to some embodiments. In the second example configuration **200**, the looped optical path **120** is illustrated to include points **202**, **204**, **206**, **208** which correspond to locations along the looped optical path **120** of channels associated with different wavelengths of the optical spectrum. In some embodiments, the point **202** corresponds to a location of channel one **210** which is associated with a first wavelength; the point **204** corresponds to a location of channel two **212** which is associated with a second wavelength; the point **206** corresponds to a location of channel three **214** which is associated with a third wavelength; and the point **208** corresponds to a location of channel four **216** which is associated with a fourth wavelength. Although four channels are illustrated, it is to be appreciated that the second example configuration **200** can include any number of channels.

[0031] Unlike the first example configuration **100** in which the channels **130**, **132**, **134**, **136** are each disposed on the TM path **114** side of the looped optical path **120**, in the second example configuration **200** only channel one **210** and channel two **212** are disposed on the TM path **114** side of the looped optical path **120** while channel three **214** and channel four **216** are disposed on the TE path **112** side of the looped optical path **120** in some examples. In the first example configuration **100**, the TM path **114** is delayed in each of the channels **130**, **132**, **134**, **136**; however, in the second example configuration **200**, the TM path **114** is delayed in channel one **210** and in channel two **212** but the TE path **112** is delayed in channel three **214** and in channel four **216**.

[0032] In some embodiments, channel one **210** includes a first add-drop ring resonator filter disposed in the looped optical path **120**. In one or more examples, the first add-drop ring resonator filter is configured to selectively remove light having the first wavelength from the looped optical path **120** via one or more add ports, and then transmit the light having the first wavelength out from drop port **218**. Because light in the TM path **114** arrives at the point **202** before light from the TE path **112** arrives at the point **202**, light from the TE path **112** having the first wavelength is transmitted from the drop port **218** into a first waveguide **220** of channel one **210** and light from the TM path **114** having the first wavelength is transmitted from the drop port **218** into a second waveguide **222** of channel one **210**.

[0033] In certain embodiments, the first waveguide **220** transmits the light from the TE path **112** having the first wavelength to a first photodetector circuit **224**. Similarly, in some embodiments, the second waveguide **222** transmits the light from the TM path **114** having the first wavelength to the first photodetector circuit **224**. As shown in FIG. **2**, the first waveguide **220** has a first length and the second waveguide **222** has a second length that is greater than the first length. In some examples, the first and second lengths are configured for delay matching the light from the TM path **114** and the light from the TE path **112**. In one or more embodiments, the second length is configured to delay the transmission of the light from the TM path **114** having the first wavelength such that the light from the TE path **112** having the first wavelength and the light from the TM path **114** having the first wavelength reach the first photodetector circuit **224** at the same time. For example, the first photodetector circuit **224** includes a photodiode configured to detect light having the first wavelength.
[0034] For reasons similar to the reasons articulated with respect to channel one **210**, channel two **212** includes a second add-drop ring resonator filter disposed in the looped optical path **120**. The second add-drop ring resonator filter may be configured to selectively remove light having the second wavelength from the looped optical path **120** via one or more add ports, and then transmit the light having the second wavelength out from drop port **226**. In various embodiments, light from the TE path **112** having the second wavelength is transmitted from the drop port **226** into a third waveguide **228**, and light from the TM path **114** having the second wavelength is transmitted from the drop port **226** into a fourth waveguide **230**.
[0035] For example, the third waveguide **228** transmits the light from the TE path **112** having the second wavelength to a second photodetector circuit **232**, and the third waveguide **228** has a third length. In some embodiments, the fourth waveguide **230** transmits the light from the TM path **114** having the second wavelength to the second photodetector circuit **232**, and the fourth waveguide **230** has a fourth length that is greater than the third length. In one or more embodiments, the third and fourth lengths are configured for delay matching the light from the TM path **114** and the light from the TE path **112** such that the light from the TE path **112** having the second wavelength and the light from the TM path **114** having the second wavelength reach the second photodetector circuit **232** at the same time. In various examples, the second photodetector circuit **232** includes at least one photodiode configured to detect light having the second wavelength.
[0036] In certain embodiments, channel three **214** includes a third add-drop ring resonator filter disposed in the looped optical path **120**, e.g., on the TE path **112** side of the looped optical path **120**. In one or more examples, the third add-drop ring resonator filter is configured to selectively remove light having the third wavelength from the looped optical path **120** via one or more add ports, and then transmit the light having the third wavelength out from drop port **234**. In the example illustrated in FIG. **2**, light in the TE path **112** reaches the point **206** before light in the TM path **114** reaches the point **206**. In order to compensate for the different arrival times at the point **206** by the light in the TE path **112** and the light in the TM path **114**, light from the TM path **114** having the third wavelength is transmitted from the drop port **234** into a fifth waveguide **236** of channel three **214** and light from the TE path **112** having the third wavelength is transmitted from the drop port **234** into a sixth waveguide **238** of channel three **214**.
[0037] In some embodiments, the fifth waveguide **236** transmits the light from the TM path **114** having the third wavelength to a third photodetector circuit **240**. In these embodiments, the sixth waveguide **238** transmits the light from the TE path **112** having the third wavelength to the third photodetector circuit **240**. In various embodiments, the fifth waveguide **236** has a fifth length and the sixth waveguide **238** has a sixth length that is greater than the fifth length. In some embodiments, the sixth length of the sixth waveguide **238** may be the same as the second length of the second waveguide **222**. In other embodiments, the sixth length can be different from the second length.
[0038] For example, the fifth and sixth lengths are configured for delay matching the light from the

TM path **114** and the light from the TE path **112**. In one or more embodiments, the sixth length is configured to delay the transmission of the light from the TE path **112** having the third wavelength such that the light from the TM path **114** having the third wavelength and the light from the TE path **112** having the third wavelength reach the third photodetector circuit **240** at the same time. In various embodiments, the third photodetector circuit **240** includes a photodiode configured to detect light having the first wavelength.

[0039] For reasons similar to the reasons articulated with respect to channel three **214**, channel four **216** includes a fourth add-drop ring resonator filter disposed in the looped optical path **120**. For example, the fourth add-drop ring resonator filter may be configured to selectively remove light having the fourth wavelength from the looped optical path **120** via one or more add ports, and then transmit the light having the fourth wavelength out from drop port **242**. In various embodiments, light from the TM path **114** having the fourth wavelength is transmitted from the drop port **242** into a seventh waveguide **244**, and light from the TE path **112** having the fourth wavelength is transmitted from the drop port **242** into an eighth waveguide **246**.

[0040] In some embodiments, the seventh waveguide **244** transmits the light from the TM path **114** having the fourth wavelength to a fourth photodetector circuit **248**, and the seventh waveguide **244** has a seventh length. In various examples, the eighth waveguide **246** transmits the light from the TE path **112** having the fourth wavelength to the fourth photodetector circuit **248**, and the eighth waveguide **246** has an eighth length that is greater than the seventh length. In some embodiments, the eighth length of the eighth waveguide **246** may be the same as the fourth length of the fourth waveguide **230**. In other embodiments, the eighth length can be different from the fourth length.

[0041] In one or more embodiments, the seventh and eighth lengths are configured for delay matching the light from the TM path **114** and the light from the TE path **112**. In some examples, by delay matching the light from the TM path **114** and the light from the TE path **112**, the light from the TM path **114** having the fourth wavelength and the light from the TE path **112** having the fourth wavelength reach the fourth photodetector circuit **248** at the same time. In various examples, the fourth photodetector circuit **248** includes at least one photodiode configured to detect light having the fourth wavelength.

[0042] FIG. **3** illustrates optical receiver circuitry in a third example configuration **300**, according to some embodiments. As shown, the third example configuration **300** includes an extended waveguide delay line **302** in place of the waveguide delay line **114**A illustrated in FIG. **1** and FIG. **2**. In some embodiments, the extended waveguide delay line **302** shifts a location in the looped optical path **120** where the light in the TE path **112** and the light in the TM path **114** arrive at the same time from the points **116**, **118** (illustrated in FIG. **1** and FIG. **2**) to points **304**, **306** depicted in FIG. **3**. In some examples, by including the extended waveguide delay line **302** and shifting the simultaneous arrival of the light in the TE path **112** and the light in the TM path **114** to the points **304**, **306** waveguide lengths for delay matching are substantially reduced relative to waveguide lengths for delay matching in the first example configuration **100**.

[0043] In the third example configuration **300**, the looped optical path **120** is illustrated to include points **308**, **310**, **312**, **314** which correspond to locations along the looped optical path **120** of channels associated with different wavelengths of the optical spectrum. In one or more embodiments, the point **308** corresponds to a location of channel one **316** which is associated with a first wavelength; the point **310** corresponds to a location of channel two **318** which is associated with a second wavelength; the point **312** corresponds to a location of channel three **320** which is associated with a third wavelength; and the point **314** corresponds to a location of channel four **322** which is associated with a fourth wavelength. Although four channels are illustrated, it is to be appreciated that the third example configuration **300** can include any number of channels.

[0044] In some embodiments, channel one **316** includes the first add-drop ring resonator filter and the first photodetector circuit **144** described with respect to the first example configuration **100**. In various embodiments, light from the TE path **112** having the first wavelength is transmitted from the drop port **138** to the first photodetector circuit **144** by a first waveguide **324** having a first length. In one or more embodiments, light from the TM path **114** having the first wavelength is transmitted from the drop port **138** to the first photodetector circuit **144** by a second waveguide **326** having a second length. For example, the second length is greater than the first length. In some examples, the first and second lengths are configured for delay matching the light from the TE path **112** and the light from the TM path **114** such that the light from the TE path **112** having the first wavelength and the light from the TM path **114** having the first wavelength reach the first photodetector circuit **144** at the same time.

[0045] In certain embodiments, channel two **318** includes the second add-drop ring resonator filter and the second photodetector circuit **152** described with respect to the first example configuration **100**. In some examples, light from the TE path **112** having the second wavelength is transmitted from the drop port **146** to the second photodetector circuit **152** by a third waveguide **328** having a third length. In one or more embodiments, light from the TM path **114** having the second wavelength is transmitted from the drop port **146** to the second photodetector circuit **152** by a fourth waveguide **330** having a fourth length. The fourth length may be greater than the third length. In various embodiments, the third and fourth lengths are configured for delay matching the light from the TE path **112** and the light from the TM path **114** such that the light from the TE path **112** having the second wavelength and the light from the TM path **114** having the second wavelength reach the second photodetector circuit **152** at the same time.

[0046] In one or more embodiments, channel three **320** includes the third add-drop ring resonator filter and the third photodetector circuit **160** described with respect to the first example configuration **100**. In various examples, light from the TM path **114** having the third wavelength is transmitted from the drop port **154** to the third photodetector circuit **160** by a fifth waveguide **332** having a fifth length. In certain embodiments, light from the TE path **112** having the third wavelength is transmitted from the drop port **154** to the third photodetector circuit **160** by a sixth waveguide **334** having a sixth length. For example, the sixth length is greater than the fifth length. In some embodiments, the sixth length of the sixth waveguide **334** is the same as the fourth length of the fourth waveguide **330**. In other embodiments, the sixth length is different from the fourth length. In some examples, the fifth and sixth lengths are configured for delay matching the light from the TM path **114** and the light from the TE path **112** such that the light from the TM path **114** having the third wavelength and the light from the TE path **112** having the third wavelength reach the third photodetector circuit **160** at the same time.

[0047] In some embodiments, channel four **322** includes the fourth add-drop ring resonator filter and the fourth photodetector circuit **168** described with respect to the first example configuration **100**. In various examples, light from the TM path **114** having the fourth wavelength is transmitted from the drop port **162** to the fourth photodetector circuit **168** by a seventh waveguide **336** having a seventh length. In certain embodiments, light from the TE path **112** having the fourth wavelength is transmitted from the drop port **162** to the fourth photodetector circuit **168** by an eighth waveguide **338** having an eighth length. The eighth length can be greater than the seventh length. In some embodiments, the eighth length of the eighth waveguide **338** is the same as the second length of the second waveguide **326**. In other embodiments, the eighth length is different from the second length. In various embodiments, the seventh and eighth lengths are configured for delay matching the light from the TM path **114** and the light from the TE path **112** such that the light from the TM path **114** having the fourth wavelength and the light from the TE path **112** having the fourth wavelength reach the fourth photodetector circuit **168** at the same time.

[0048] FIG. **4** is a flow diagram depicting a method **400** for receiving an input optical signal by a wavelength division multiplexing (WDM) receiver, according to some embodiments. At **402**, an input optical signal is received. In one or more embodiments, the input optical signal **102** is received from a WDM transmitter. At **404**, the input optical signal is split into a first component and a second component. In some embodiments, the polarization diversifier **106** splits the quasi-transverse-electric (TE) mode of the input optical signal **102** into the first path **108** and the quasi-transverse-magnetic (TM) mode of the input optical signal **102** into the second path **110**.

[0049] At **406**, the first component is guided into a first end of an optical path. In various embodiments, the TE mode is guided into the TE path **112** of the looped optical path **120**. At **408**, the second component is guided into a second end of the optical path. In certain embodiments, the TM mode is guided into the TM path **114** of the looped optical path **120**. In some examples, in order to compensate for the differential group delay (DGD) which causes the light in the TM path **114** to travel faster than the light in the TE path **112**, the waveguide delay line **114**A may be included after the polarization diversifier **106** in the TM path **114**. In these examples, the waveguide delay line **114**A causes the light in the TM path **114** to reach the point **118** at the same time that the light in the TE path **112** reaches the point **116**.

[0050] At **410**, the first component is transmitted through an add-drop ring resonator filter disposed in the optical path and into a first waveguide having a first length. In some embodiments, light from the TE path **112** having the first frequency is transmitted into one or more add ports of the first add-drop ring resonator filter of channel one **130**, and the light from the TE path **112** having the first frequency is transmitted out from the drop port **138** into the first waveguide **140** having the first length. At **412**, the second component is transmitted through the add-drop ring resonator filter and into a second waveguide having a second length that is greater than the first length. In one or more embodiments, light from the TM path **114** having the first frequency is transmitted into one or more add ports of the first add-drop ring resonator filter of channel one **130**, and the light from the TM path **114** having the first frequency is transmitted out from the drop port **138** into the second waveguide **142** having the second length that is greater than the first length.

[0051] At **414**, the first component is transmitted through the first waveguide to a photodetector circuit. In various embodiments, the light from the TE path **112** having the first wavelength is transmitted through the first waveguide **140** to the first photodetector circuit **144**. At **416**, the second component is transmitted through the second waveguide to the photodetector circuit. In certain embodiments, the light from the TM path **114** having the first wavelength is transmitted through the second waveguide **142** to the first photodetector circuit **144**.

[0052] FIG. **5** illustrates a representation **500** of electrical eye diagrams, according to some embodiments. As shown, the representation **500** includes a baseline **502**. The representation **500** also includes a first eye diagram **504** for a wavelength division multiplexing (WDM) receiver that does not include delay matching for light from the TE path **112** and light from the TM path **114**. The representation **500** additionally includes a second eye diagram **506** for a WDM receiver that includes the described delay matching for light from the TE path **112** and light from the TM path **114**. As further shown, the first eye diagram **504** includes significant signal distortion, and the second eye diagram **506** does not include significant signal distortion.

[0053] In the preceding, reference is made to embodiments presented in this disclosure. However, the scope of the present disclosure is not limited to specific described embodiments. Instead, any combination of the described features and elements, whether related to different embodiments or not, is contemplated to implement and practice contemplated embodiments. Furthermore, although embodiments disclosed herein may achieve advantages over other possible solutions or over the prior art, whether or not a particular advantage is achieved by a given embodiment is not limiting of the scope of the present disclosure. Thus, the preceding aspects, features, embodiments and advantages are merely illustrative and are not considered elements or limitations of the appended claims except where explicitly recited in a claim(s).

[0054] While the foregoing is directed to specific examples, other and further examples may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims

1. Optical receiver circuitry comprising: a polarization diversifier configured to: receive an input optical signal; output a first component of the input optical signal into a first end of an optical path; and output a second component of the input optical signal into a second end of the optical path; a first add-drop ring resonator filter disposed in the optical path; a first photodetector circuit; a first waveguide configured to transmit the first component from the first add-drop ring resonator filter to the first photodetector circuit, the first waveguide having a first length; and a second waveguide configured to transmit the second component from the first add-drop ring resonator filter to the first photodetector circuit, the second waveguide having a second length that is greater than the first length.
2. The optical receiver circuitry of claim 1, wherein the first component includes a quasi-transverse-electric mode and the second component includes a quasi-transverse-magnetic mode.
3. The optical receiver circuitry of claim 1, wherein the polarization diversifier includes at least one of a polarization splitter and rotator or a polarization splitting grating coupler.
4. The optical receiver circuitry of claim 1, further comprising a waveguide delay line in the optical path.
5. The optical receiver circuitry of claim 1, further comprising: a second add-drop ring resonator filter disposed in the optical path; a second photodetector circuit; a third waveguide configured to transmit the first component from the second add-drop ring resonator filter to the second photodetector circuit; and a fourth waveguide configured to transmit the second component from the second add-drop ring resonator filter to the second photodetector circuit.
6. The optical receiver circuitry of claim 5, wherein the third waveguide has a third length that is equal to the first length.
7. The optical receiver circuitry of claim 6, wherein the fourth waveguide has a length that is greater than the first length and less than the second length.
8. The optical receiver circuitry of claim 5, wherein the third waveguide has a third length that is equal to the second length.
9. The optical receiver circuitry of claim 8, further comprising a waveguide delay line in the optical path.
10. A wavelength division multiplexing (WDM) receiver comprising: a polarization diversifier configured to: receive an input optical signal; output a first component of the input optical signal into a first end of a looped optical path; and output a second component of the input optical signal into a second end of the looped optical path; a first channel extending out from the looped optical path, the first channel comprising: a first waveguide configured to transmit the first component through the first channel to a first photodetector circuit; and a second waveguide configured to transmit the second component through the first channel to the first photodetector circuit, the second waveguide including a waveguide delay line; and a second channel extending out from the looped optical path, the second channel comprising: a third waveguide configured to transmit the first component through the second channel to a second photodetector circuit; and a fourth waveguide configured to transmit the second component through the second channel to the second photodetector circuit.
11. The WDM receiver of claim 10, further comprising an add-drop ring resonator filter of the first channel, the first waveguide and the second waveguide coupled to the add-drop ring resonator filter.
12. The WDM receiver of claim 10, wherein the first component includes a quasi-transverse-electric mode and the second component includes a quasi-transverse-magnetic mode.
13. The WDM receiver of claim 10, wherein the polarization diversifier includes at least one of a polarization splitter and rotator or a polarization splitting grating coupler.

14. The WDM receiver of claim 10, further comprising an additional a waveguide delay line included in the looped optical path.

15. The WDM receiver of claim 10, further comprising an additional a waveguide delay line included in the third waveguide.

16. The WDM receiver of claim 10, further comprising an additional a waveguide delay line included in the fourth waveguide.

17. A method comprising: receiving an input optical signal; splitting the input optical signal into a first component and a second component; guiding the first component into a first end of an optical path; guiding the second component into a second end of the optical path; transmitting the first component through an add-drop ring resonator filter disposed in the optical path and into a first waveguide having a first length; transmitting the second component through the add-drop ring resonator filter and into a second waveguide having a second length that is greater than the first length; transmitting the first component through the first waveguide to a photodetector circuit; and transmitting the second component through the second waveguide to the photodetector circuit.

18. The method of claim 17, wherein the first component includes a quasi-transverse-electric mode and the second component includes a quasi-transverse-magnetic mode.

19. The method of claim 17, wherein the input optical signal is split into the first component and the second component using a polarization diversifier.

20. The method of claim 17, further comprising delaying transmission of the second component through the optical path.
