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PHOTONIC CHIPS INCLUDING A STRUCTURE ENABLING MEASUREMENT OF THE GROUP VELOCITY OF LIGHT IN A PHOTONIC COMPONENT

Abstract

Structures for a photonic chip that enable the measurement of the group velocity of light in a photonic component and methods of forming such structures. The structure comprises a photonic component having an input and an output, a first waveguide core including a first section coupled to the input of the photonic component, and a second waveguide core including a second section coupled to the output of the photonic component. The structure further comprises a first reflector adjacent to the first section of the first waveguide core, and a second reflector adjacent to the second section of the second waveguide core.

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Background/Summary

BACKGROUND

[0001] This disclosure relates to photonic chips and, more specifically, to structures for a photonic chip that enable the measurement of the group velocity of light in a photonic component and methods of forming such structures.

[0002] Photonic chips are used in many applications and systems including, but not limited to, data communication systems and data computation systems. A photonic chip includes a photonic integrated circuit comprised of interconnected photonic components, such as modulators, polarizers, and couplers, that are used to manipulate light received from a light source, such as an optical fiber or a laser.

[0003] The group velocity is the velocity with which the envelope of a pulse of light propagates in a medium. The group index may be represented by a ratio of the group velocity in vacuum to the group velocity in the medium. Knowledge of the group velocity may be important when designing certain photonic integrated circuits or when performing diagnostics of certain photonic integrated circuits.

[0004] Improved structures for a photonic chip that enable the measurement of the group velocity of light in a photonic component and methods of forming such structures are needed.

SUMMARY

[0005] In an embodiment of the invention, a structure for a photonic chip is provided. The structure comprises a photonic component having an input and an output, a first waveguide core including a first section coupled to the input of the photonic component, and a second waveguide core including a second section coupled to the output of the photonic component. The structure further comprises a first reflector adjacent to the first section of the first waveguide core, and a second reflector adjacent to the second section of the second waveguide core.

[0006] In an embodiment of the invention, a method of forming a structure for a photonic chip is provided. The method comprises forming a photonic component, forming a first waveguide core including a first section coupled to an input of the photonic component, and forming a second waveguide core including a second section coupled to an output of the photonic component. The method further comprises forming a first reflector adjacent to the first section of the first waveguide core and forming a second reflector adjacent to the second section of the second waveguide core.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate various embodiments of the invention and, together with a general description of the invention given above and the detailed description of the embodiments given below, serve to explain the embodiments of the invention. In the drawings, like reference numerals refer to like features in the various views.

[0008] FIG. **1** is a top view of a structure at an initial fabrication stage of a processing method in accordance with embodiments of the invention.

[0009] FIG. **2** is a cross-sectional view taken generally along line **2-2** in FIG. **1**.

[0010] FIG. **2**A is a cross-sectional view taken generally along line **2**A-**2**A in FIG. **1**.

[0011] FIG. **3** is a top view of the structure at a fabrication stage of the processing method subsequent to FIGS. **1**, **2**, **2**A.

[0012] FIG. **4** is a cross-sectional view taken generally along line **4-4** in FIG. **3**.

[0013] FIG. **4**A is a cross-sectional view taken generally along line **4**A-**4**A in FIG. **3**.

[0014] FIGS. **5**, **5**A are cross-sectional views of the structure at a fabrication stage of the processing method subsequent to FIGS. **3**, **4**, **4**A.

[0015] FIG. **6** is a top view of a structure in accordance with alternative embodiments of the invention.

[0016] FIG. **7** is a top view of a structure in accordance with alternative embodiments of the invention.

[0017] FIG. **8** is a top view of a structure in accordance with alternative embodiments of the invention.

[0018] FIG. **9** is a top view of a structure in accordance with alternative embodiments of the invention.

[0019] FIG. **10** is a top view of a structure in accordance with alternative embodiments of the invention.

DETAILED DESCRIPTION

[0020] With reference to FIGS. **1**, **2**, **2**A and in accordance with embodiments of the invention, a structure **10** for a photonic chip includes a polarization splitter-rotator **12** and waveguide cores **14**, **16**, **18** that are positioned on, and above, a dielectric layer **11** and a semiconductor substrate **13**. In an embodiment, the dielectric layer **11** may be comprised of a dielectric material, such as silicon dioxide, and the semiconductor substrate **13** may be comprised of a semiconductor material, such as single-crystal silicon. In an embodiment, the dielectric layer **11** may be a buried oxide layer of a silicon-on-insulator substrate, and the dielectric layer **11** may provide low-index cladding that separates the waveguide cores **14**, **16**, **18** and the polarization splitter-rotator **12** from the semiconductor substrate **13**.

[0021] The waveguide core **14** includes a section **20** that is disposed adjacent to the polarization splitter-rotator **12**. The waveguide core **16** includes a section **22** that is disposed adjacent to the polarization splitter-rotator **12**. The waveguide core **18** includes a section **24** that is disposed adjacent to the polarization splitter-rotator **12**. The polarization splitter-rotator **12** is disposed in a space on the photonic chip between the section **20** of the waveguide core **14** and the sections **22**, **24** of the waveguide cores **16**, **18**.

[0022] The polarization splitter-rotator **12** has an input to which the section **20** of the waveguide core **14** is coupled. Specifically, the section **20** of the waveguide core **14** may be physically connected to an arm **26** of the polarization splitter-rotator **12** at the input to the polarization splitter-rotator **12**. In an embodiment, the section **20** of the waveguide core **14** may be directly connected to the arm **26** of the polarization splitter-rotator **12** at the input to the polarization splitter-rotator **12**.

[0023] The polarization splitter-rotator **12** has an output to which the section **22** of the waveguide core **16** is coupled. Specifically, the section **22** of the waveguide core **16** may be connected to the arm **26** of the polarization splitter-rotator **12** at the output from the polarization splitter-rotator **12**. In an embodiment, section **22** of the waveguide core **16** may be directly connected to the arm **26** of the polarization splitter-rotator **12** at the output from the polarization splitter-rotator **12**.

[0024] In an embodiment, the polarization splitter-rotator **12** may have another output to which the section **24** of the waveguide core **18** is coupled. Specifically, the section **24** of the waveguide core **18** may be connected to an arm **28** of the polarization splitter-rotator **12** at the output from the polarization splitter-rotator **12**. In an embodiment, the section **24** of the waveguide core **18** may be directly connected to the arm **28** of the polarization splitter-rotator **12** at the output from the polarization splitter-rotator **12**.

[0025] The section **20** of the waveguide core **14** may have a longitudinal axis **15** and a width W**1** in a direction that is transverse to the longitudinal axis **15**. The section **22** of the waveguide core **16** may have a longitudinal axis **17** and a width W**2** in a direction that is transverse to the longitudinal axis **17**. The section **24** of the waveguide core **18** may have a longitudinal axis **19** and a width W**3** in a direction that is transverse to the longitudinal axis **19**. In an embodiment, the width W**2** may differ from the width W**1**. In an embodiment, the width W**3** may differ from the width W**1**. In an embodiment, the width W**2** may differ from the width W**3**. In an embodiment, the widths W**1**, W**2**, and W**3** may all differ.

[0026] In an embodiment, the waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12** may be comprised of a material having a refractive index that is greater than the refractive index of silicon dioxide. In an embodiment, the waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12** may be comprised of a semiconductor material. In an embodiment, the waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12** may be comprised of single-crystal silicon. In an embodiment, the waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12** may be comprised of polysilicon or amorphous silicon. The waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12** may be formed by patterning a layer comprised of their constituent material with lithography and etching processes. In an embodiment, the waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12** may be formed by patterning the semiconductor material (e.g., single-crystal silicon) of the device layer of a silicon-on-insulator substrate. In an alternative embodiment, the waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12** may be comprised of a dielectric material, such as silicon nitride, silicon oxynitride, or aluminum nitride. In alternative embodiments, other materials, such as a III-V compound semiconductor, may be used to form the waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12**.

[0027] The polarization splitter-rotator **12** represents a photonic component that may have a relatively large footprint on the photonic chip. In alternative embodiments, the polarization splitter-rotator **12** may be replaced by a different type of photonic component, such as an edge coupler, a spot-size converter, an interlayer elevator, a multi-mode interferometer, etc., that may also have a relatively large footprint on the photonic chip The photonic component may have a different number of inputs and/or a different number of outputs than in the representative embodiment of the structure **10**. In an alternative embodiment, the semiconductor substrate **13** may include an undercut beneath all or part of the photonic component.

[0028] With reference to FIGS. **3**, **4**, **4**A in which like reference numerals refer to like features in FIGS. **1**, **2**, **2**A and at a subsequent fabrication stage, a dielectric layer **32** may be formed over the polarization splitter-rotator **12** and waveguide cores **14**, **16**, **18**. The dielectric layer **32** may be comprised of a dielectric material, such as silicon dioxide, having a refractive index that is less than the refractive index of the material constituting the arms **26**, **28** of the polarization splitter-rotator **12** and the waveguide cores **14**, **16**, **18**.

[0029] The structure **10** further includes waveguide core regions **46**, **48**, **50** that are positioned on, and above, the dielectric layer **44** and that are respectively adjacent to the sections **20**, **22**, **24** of the waveguide cores **14**, **16**, **18**. The waveguide core region **46** is disposed over the section **20** of the waveguide core **14** and overlaps with the section **20**. The waveguide core region **48** is disposed over the section **22** of the waveguide core **16** and overlaps with the section **22**. The waveguide core region **50** is disposed over the section **24** of the waveguide core **18** and overlaps with the section **24**. The waveguide core regions **46**, **48**, **50** may be disposed outside of the footprint for the polarization splitter-rotator **12** with the waveguide core region **46** disposed adjacent to the input to the polarization splitter-rotator **12** and the waveguide core regions **48**, **50** respectively disposed adjacent to the outputs from the polarization splitter-rotator **12**.

[0030] In an embodiment, the waveguide core regions **46**, **48**, **50** may be comprised of a material having a refractive index that is greater than the refractive index of silicon dioxide. In an embodiment, the waveguide core regions **46**, **48**, **50** may be comprised of a different material from the waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12**. In an embodiment, the waveguide core regions **46**, **48**, **50** may be comprised of a material having a different refractive index from the waveguide cores **14**, **16**, **18** and the arms **26**, **28** of the polarization splitter-rotator **12**. In an embodiment, the waveguide core regions **46**, **48**, **50** may be comprised of a dielectric material, such as silicon nitride, silicon oxynitride, or aluminum nitride.

The waveguide core regions **46**, **48**, **50** may be formed by depositing a layer comprised of their constituent material and patterning the deposited layer with lithography and etching processes. In an alternative embodiment, the waveguide core regions **46**, **48**, **50** may be comprised of a semiconductor material, such as polysilicon or amorphous silicon. In an alternative embodiment, the waveguide core regions **46**, **48**, **50** may be comprised of germanium. In an alternative embodiment, the waveguide core regions **46**, **48**, **50** may be comprised of a metal, such as copper. In alternative embodiments, other materials, such as a III-V compound semiconductor, may be used to form the waveguide core regions **46**, **48**, **50**.

[0031] In an embodiment, the waveguide core region **46** may have a length L**1** that is less than about three times the width W**1** of the section **20** of the waveguide core **14**. In an embodiment, the length L**1** of the waveguide core region **46** may be greater than one-quarter of the width W**1** of the section **20** of the waveguide core **14** and less than about three times the width W**1** of the section **20** of the waveguide core **14**. The length L**1** may be measured in a direction parallel to the longitudinal axis **15** of the section **20** of the waveguide core **14** and transverse to the width W**1**.

[0032] In an embodiment, the waveguide core region **48** may have a length L**2** that is less than three times the width W**2** of the section **22** of the waveguide core **16**. In an embodiment, the length L**2** of the waveguide core region **48** may be greater than one-quarter of the width W**2** of the section **22** of the waveguide core **16** and less than about three times the width W**2** of the section **22** of the waveguide core **16**. The length L**2** may be measured in a direction parallel to the longitudinal axis **17** of the section **22** of the waveguide core **16** and transverse to the width W**2**.

[0033] In an embodiment, the waveguide core region **50** may have a length L**3** that is less than three times the width W**3** of the section **24** of the waveguide core **18**. In an embodiment, the length L**3** of the waveguide core region **50** may be greater than one-quarter of the width W**3** of the section **24** of the waveguide core **18** and less than about three times the width W**3** of the section **24** of the waveguide core **18**. The length L**3** may be measured in a direction parallel to the longitudinal axis **19** of the section **24** of the waveguide core **18** and transverse to the width W**3**.

[0034] In an embodiment, the lengths L**1**, L**2**, and L**3** may be equal. In an embodiment, the lengths L**1**, L**2**, and L**3** may all differ from each other. In an embodiment, the length L**2** may differ from the length L**1**. In an embodiment, the length L**3** may differ from the length L**1**. In an embodiment, the length L**2** may differ from the length L**3**.

[0035] With reference to FIGS. **5**, **5**A, **5**B in which like reference numerals refer to like features in FIGS. **3**, **4**, **4**A, **4**B and at a subsequent fabrication stage, a dielectric layer **34** may be formed over the dielectric layer **32** and the waveguide core regions **46**, **48**, **50**. The dielectric layer **34** may be comprised of a dielectric material, such as silicon dioxide, having a refractive index that is less than the refractive index of the material constituting the waveguide core regions **46**, **48**, **50**.

[0036] In use, light (e.g., laser light) propagates in the waveguide core **14** toward the polarization splitter-rotator **12** and is directed into the arm **26** of the polarization splitter-rotator **12** by the section **20** of the waveguide core **14**. The waveguide core region **46** acts as a perturbation in the waveguide core **14** at the input to the polarization splitter-rotator **12** that reflects or redirects a fraction of the light in a reverse propagation direction. A portion of the light propagating in the arm **26** of the polarization splitter-rotator **12** is transferred to the arm **28** of the polarization splitter-rotator **12**. A non-transferred portion of the light is output from the arm **26** to the section **22** of the waveguide core **16**. The waveguide core region **48** acts as a perturbation in the waveguide core **16** at one of the outputs from the polarization splitter-rotator **12** that reflects or redirects a fraction of the light propagating in the section **22** in a reverse propagation direction. The transferred portion of the light is output from the arm **28** to the section **24** of the waveguide core **18**. The waveguide core region **50** acts as a perturbation in the waveguide core **18** at the other of the outputs from the polarization splitter-rotator **12** that reflects or redirects a fraction of the light propagating in the section **24** in a reverse propagation direction.

[0037] The waveguide core region **46** provides a reflector disposed at the input to the polarization splitter-rotator **12**. The waveguide core regions **48**, **50** provide reflectors disposed at the outputs from the polarization splitter-rotator **12**. The distance between the waveguide core region **46** and the waveguide core region **48** approximates the distance between the input and the associated output from the polarization splitter-rotator **12**. The distance between the waveguide core region **46** and the waveguide core region **50** may also approximate the distance between the input and the other associated output from the polarization splitter-rotator **12**. The distance between the waveguide core region **46** and each of the waveguide core regions **48**, **50** is a numerical quantity that may be known from the device layout for the polarization splitter-rotator **12**. A time differential exists between the light reflected from the waveguide core region **46** and the light reflected from the waveguide core region **48** and/or the waveguide core region **50**. The difference in the time of arrival, at a diagnostic device, between the light reflected from the waveguide core region **46** and the light reflected from the waveguide core region **48** and/or the waveguide core region **50** may be used to determine the group velocity and the group index of the polarization splitter-rotator **12**. The group velocity and the group index may be used for diagnostic purposes and/or for design purposes.

[0038] With reference to FIG. **6** and in accordance with alternative embodiments, the structure **10** may be modified such that the waveguide core regions **46**, **48**, **50** are formed before the polarization splitter-rotator **12** and waveguide cores **14**, **16**, **18**. The waveguide core regions **46**, **48**, **50** are positioned on, and above, the dielectric layer **11** and the semiconductor substrate **13**. The waveguide cores **14**, **16**, **18** are positioned on, and above, the dielectric layer **32** such that the waveguide core regions **46**, **48**, **50** are disposed between the respective sections **20**, **22**, **24** of the waveguide cores **14**, **16**, **18** and the semiconductor substrate **13**. The section **20** of the waveguide core **14** overlaps with the waveguide core region **46**, the section **22** of the waveguide core **16** overlaps with the waveguide core region **48**, and the section **24** of the waveguide core **18** overlaps with the waveguide core region **50**. The material used to form the waveguide core regions **46**, **48**, **50** may be swapped with the material used to form the waveguide cores **14**, **16**, **18**.

[0039] With reference to FIG. **7** and in accordance with alternative embodiments, the waveguide cores **14**, **16**, **18** may integrate respective waveguide core regions **36**, **38**, **40** that provide reflectors configured to replace the waveguide core regions **46**, **48**, **50**. The waveguide core region **36** extends across the waveguide core **14** and projects from both sidewalls of the waveguide core **14**. In an embodiment, the waveguide core region **36** may extend across the waveguide core **14** transverse to the longitudinal axis **15**. The waveguide core region **36** has a width W**4** that is greater than the width W**1** of adjacent regions of the waveguide core **14**. The waveguide core region **38** extends across the waveguide core **16** and projects from both sidewalls of the waveguide core **16**. In an embodiment, the waveguide core region **38** may extend across the waveguide core **16** transverse to the longitudinal axis **17**. The waveguide core region **38** has a width W**5** that is greater than the width W**2** of adjacent regions of the waveguide core **16**. The waveguide core region **40** extends across the waveguide core **18** and projects from both sidewalls of the waveguide core **18**. In an embodiment, the waveguide core region **40** may extend across the waveguide core **18** transverse to the longitudinal axis **19**. The waveguide core region **40** has a width W**6** that is greater than the width W**3** of adjacent regions of the waveguide core **16**. In an embodiment, waveguide core regions **36**, **38**, **40** may be comprised of the same material as the waveguide core regions **46**, **48**, **50**.

[0040] The enhanced widths of the waveguide core regions **36**, **38**, **40** provide respective perturbations at the input to the polarization splitter-rotator **12** and the outputs from the polarization splitter-rotator **12** that reflect or redirect light in a reverse direction and that may be used to determine group velocity.

[0041] With reference to FIG. **8** and in accordance with alternative embodiments, the waveguide cores **14**, **16**, **18** may integrate respective waveguide core regions **41**, **42**, **43** that provide reflectors configured to replace the waveguide core regions **46**, **48**, **50**. The waveguide core regions **41**, **42**,

43 provide perturbations at the input to the polarization splitter-rotator **12** and the outputs from the polarization splitter-rotator **12** that reflect or redirect light in a reverse direction and that may be used to determine group velocity.

[0042] The waveguide core region **41** extends as a slot across the width W**1** of the waveguide core **14** as a separator between adjacent solid waveguide core regions of the waveguide core **14**. In an embodiment, the waveguide core region **41** may extend as a slot across the full width W**1** of the waveguide core **14**. In an embodiment, the waveguide core region **41** may extend across the full width W**1** of the waveguide core **14** and through a full thickness of the waveguide core **14**. In an embodiment, the waveguide core region **41** may extend as a notched slot across the full width W**1** of the waveguide core **14** and through a partial thickness of the waveguide core **14**.

[0043] The waveguide core region **42** extends as a slot across the width W**2** of the waveguide core **16** as a separator between adjacent solid waveguide core regions of the waveguide core **16**. In an embodiment, the waveguide core region **42** may extend as a slot across the full width W**2** of the waveguide core **16**. In an embodiment, the waveguide core region **42** may extend across the full width W**2** of the waveguide core **16** and through a full thickness of the waveguide core **16**. In an embodiment, the waveguide core region **42** may extend as a notched slot across the full width W**2** of the waveguide core **16** and through a partial thickness of the waveguide core **16**.

[0044] The waveguide core region **43** extends as a slot across the width W**3** of the waveguide core **18** as a separator between adjacent solid waveguide core regions of the waveguide core **18**. In an embodiment, the waveguide core region **43** may extend as a slot across the full width W**3** of the waveguide core **18**. In an embodiment, the waveguide core region **43** may extend across the full width W**3** of the waveguide core **18** and through a full thickness of the waveguide core **18**. In an embodiment, the waveguide core region **43** may extend as a notched slot across the full width W**3** of the waveguide core **18** and through a partial thickness of the waveguide core **18**.

[0045] With reference to FIG. **9** and in accordance with alternative embodiments, the waveguide core region **41** of the waveguide core **14** may be a slot and may include a rib **52** that extends across the slot as a connector between the adjacent solid waveguide core regions of the waveguide core **14**. The rib **52** has a width that is less than the width W**1** of the section **20** of the waveguide core **14** such that the section **20** is characterized by multiple width dimensions. The waveguide core region **42** of the waveguide core **16** may be a slot and may include a rib **54** that extends across the slot as a connector between the adjacent solid waveguide core regions of the waveguide core **16**. The rib **54** has a width that is less than the width W**2** of the section **22** of the waveguide core **16** such that the section **22** is characterized by multiple width dimensions. The waveguide core region **43** of the waveguide core **18** may be a slot and may include a rib **56** that extends across the slot as a connector between the adjacent solid waveguide core regions of the waveguide core **18**. The rib **56** has a width that is less than the width W**3** of the section **24** of the waveguide core **18** such that the section **24** is characterized by multiple width dimensions.

[0046] In an alternative embodiment, the waveguide core region **41** may be replicated to define multiple slots extending across the full width W**1** of the waveguide core **14** and the multiple slots may be optionally connected by the rib **52**. In an alternative embodiment, the waveguide core region **42** may be replicated to define multiple slots across the full width W**2** of the waveguide core **16** and the multiple slots may be optionally connected by the rib **54**. In an alternative embodiment, the waveguide core region **43** may be replicated to define multiple slots extending across the full width W**3** of the waveguide core **18** and the multiple slots may be optionally connected by the rib **56**.

[0047] With reference to FIG. **10** and in accordance with alternative embodiments, the structure **10** may include a grating coupler **62** that is coupled by a multimode interference region **64** to the waveguide core **14**, a waveguide core **66** that is coupled to the multimode interference region **64**, a grating coupler **68** that is coupled to the waveguide core **16**, and a grating coupler **70** that is coupled to the waveguide core **66**. In an alternative embodiment, the grating couplers **62**, **68**, **70** may be replaced by edge couplers. In addition to the waveguide core region **46** over the section **20** of the waveguide core **14** and the waveguide core region **48** over the section **22** of the waveguide core **16**, waveguide core regions **47**, **49** may be disposed over sections of the waveguide core **66** at opposite ends of the waveguide core **66** to define reflectors. In an alternative embodiment, the waveguide core regions **47**, **49** may disposed under the sections of the waveguide core **66** at opposite ends of the waveguide core **66** to define reflectors. The waveguide core **66** may define a reference path for light that can be used to de-embed the insertion loss arising from the waveguide core region **46**.

[0048] The methods as described above are used in the fabrication of integrated circuit chips. The resulting integrated circuit chips can be distributed by the fabricator in raw wafer form (e.g., as a single wafer that has multiple unpackaged chips), as a bare die, or in a packaged form. The chip may be integrated with other chips, discrete circuit elements, and/or other signal processing devices as part of either an intermediate product or an end product. The end product can be any product that includes integrated circuit chips, such as computer products having a central processor or smartphones.

[0049] References herein to terms modified by language of approximation, such as “about”, “approximately”, and “substantially”, are not to be limited to the precise value specified. The language of approximation may correspond to the precision of an instrument used to measure the value or, unless otherwise dependent on the precision of the instrument, may indicate a range of +/−10% of the stated value(s).

[0050] References herein to terms such as “vertical”, “horizontal”, etc. are made by way of example, and not by way of limitation, to establish a frame of reference. The term “horizontal” as used herein is defined as a plane parallel to a conventional plane of a semiconductor substrate, regardless of its actual three-dimensional spatial orientation. The terms “vertical” and “normal” refer to a direction in the frame of reference perpendicular to the horizontal, as just defined. The term “lateral” refers to a direction in the frame of reference within the horizontal plane.

[0051] A feature “connected” or “coupled” to or with another feature may be directly connected or coupled to or with the other feature or, instead, one or more intervening features may be present. A feature may be “directly connected” or “directly coupled” to or with another feature if intervening features are absent. A feature may be “indirectly connected” or “indirectly coupled” to or with another feature if at least one intervening feature is present. A feature “on” or “contacting” another feature may be directly on or in direct contact with the other feature or, instead, one or more intervening features may be present. A feature may be “directly on” or in “direct contact” with another feature if intervening features are absent. A feature may be “indirectly on” or in “indirect contact” with another feature if at least one intervening feature is present. Different features “overlap” if a feature extends over, and covers a part of, another feature.

[0052] The descriptions of the various embodiments of the present invention have been presented for purposes of illustration but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments. The terminology used herein was chosen to best explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments disclosed herein.

Claims

1. A structure for a photonic chip, the structure comprising: a photonic component having an input and a first output; a first waveguide core including a first section coupled to the input of the photonic component; a second waveguide core including a second section coupled to the first output of the photonic component; a first reflector adjacent to the first section of the first waveguide core; and a second reflector adjacent to the second section of the second waveguide core.

2. The structure of claim 1 wherein the photonic component is a polarization splitter-rotator.

3. The structure of claim 1 wherein the photonic component has a second output, and further comprising: a third waveguide core including a third section coupled to the second output of the photonic component; and a third reflector adjacent to the third section of the third waveguide core.

4. The structure of claim 1 further comprising: a semiconductor substrate, wherein the first section of the first waveguide core is disposed between the first reflector and the semiconductor substrate, and the second section of the second waveguide core is disposed between the second reflector and the semiconductor substrate.

5. The structure of claim 4 wherein the first reflector comprises a first waveguide core region, and the second reflector comprises a second waveguide core region.

6. The structure of claim 5 wherein the first waveguide core region overlaps with the first section of the first waveguide core, and the second waveguide core region overlaps with the second section of the second waveguide core.

7. The structure of claim 5 wherein the first waveguide core and the second waveguide core comprise a first material, and the first waveguide core region and the second waveguide core region comprise a second material that differs from the first material.

8. The structure of claim 5 wherein the first waveguide core has a first longitudinal axis and a first width transverse to the first longitudinal axis, the first waveguide core region has a first length parallel to the first longitudinal axis, and the first length ranges from less than three times the first width to one-quarter of the first width.

9. The structure of claim 8 wherein the second waveguide core has a second longitudinal axis and a second width transverse to the second longitudinal axis, the second waveguide core region has a second length parallel to the second longitudinal axis, and the second length ranges from less than three times the second width to one-quarter of the second width.

10. The structure of claim 1 further comprising: a semiconductor substrate, wherein the first reflector is disposed between the first section of the first waveguide core and the semiconductor substrate, and the second reflector is disposed between the second section of the second waveguide core and the semiconductor substrate.

11. The structure of claim 10 wherein the first reflector comprises a first waveguide core region, and the second reflector comprises a second waveguide core region.

12. The structure of claim 11 wherein the first section of the first waveguide core overlaps with the first waveguide core region, and the second section of the second waveguide core overlaps with the second waveguide core region.

13. The structure of claim 11 wherein the first waveguide core and the second waveguide core comprise a first material, and the first waveguide core region and the second waveguide core region comprise a second material that differs from the first material.

14. The structure of claim 11 wherein the first waveguide core has a first longitudinal axis and a first width transverse to the first longitudinal axis, the first waveguide core region has a first length parallel to the first longitudinal axis, and the first length ranges from less than three times the first width to one-quarter of the first width.

15. The structure of claim 14 wherein the second waveguide core has a second longitudinal axis and a second width transverse to the second longitudinal axis, the second waveguide core region has a second length parallel to the second longitudinal axis, and the second length ranges from less than three times the second width to one-quarter of the second width.

16. The structure of claim 1 wherein the first reflector is a first slot in the first section of the first waveguide core, and the second reflector is a second slot in the second section of the second waveguide core.

17. The structure of claim 16 wherein the first section of the first waveguide core has a first width, the second section of the second waveguide core has a second width, the first slot extends fully across the first width of the first section of the first waveguide core, and the second slot extends fully across the second width of the second section of the second waveguide core.

18. The structure of claim 1 wherein the first section of the first waveguide core has a first width, the second section of the second waveguide core has a second width, the first reflector is a region of the first section having a third width that is greater than the first width of the first section of the first waveguide core, and the second reflector is a region of the second section having a fourth width that is greater than the second width of the second section of the second waveguide core.

19. The structure of claim 1 wherein the first section of the first waveguide core has a first waveguide core region, a second waveguide core region, and a third waveguide core region connected by the first waveguide core region to the second waveguide core region, the first waveguide core region has a first width, the second waveguide core region and the third waveguide core region have a second width, and the first width is less than the second width.

20. A method of forming a structure for a photonic chip, the method comprising: forming a photonic component having an input and an output; forming a first waveguide core including a first section coupled to the input of the photonic component; forming a second waveguide core including a second section coupled to the output of the photonic component; forming a first reflector adjacent to the first section of the first waveguide core; and forming a second reflector adjacent to the second section of the second waveguide core.