CLAIMS

1. An optical modulation device configured of a planar optical waveguide, comprising:

a light incidence unit which allows light to be incident on the planar optical waveguide;

a Mach-Zehnder interferometer which includes a first optical splitter section branching the light incident on the light incidence unit, two arm portions guiding the light branched by the first optical splitter section, a phase modulation unit linearly disposed on each of the two arm portions, and a first optical coupler section combining the light guided from the two arm portions;

a light launching unit which launches the light combined by the first optical coupler section from the planar optical waveguide; and

a traveling-wave electrode which includes an input unit and an output unit, and applies a voltage to the phase modulation unit,

wherein the planar optical waveguide has an outline including two sides each of which intersect with an extended line in a longitudinal direction of the phase modulation unit in a plan view,

the input unit is formed on one of the two sides, and

the light incidence unit and the light launching unit are positioned in a region different from a region in which the traveling-wave electrode is formed in a plan view.

2. The optical modulation device according to Claim 1,

wherein the longitudinal direction of the phase modulation unit is perpendicular to the two sides.

3. The optical modulation device according to Claim 1,

wherein the longitudinal direction of the phase modulation unit has an inclination at an angle of greater than 0° and less than 90° with respect to each of the two sides.

4. The optical modulation device according to any one of Claims 1 to 3,

wherein distances between each of the two phase modulation units and one side are identical to each other, and distances between the each of the two phase modulation unit and an other side are identical to each other.

5. The optical modulation device according to any one of Claims 1 to 4,

wherein the phase modulation units are arranged in parallel with each other.

6. The optical modulation device according to any one of Claims 1 to 5,

wherein the output unit is formed on the other side.

7. The optical modulation device according to any one of Claims 1 to 6,

wherein the traveling-wave electrode is linearly formed from the input unit to the output unit.

8. The optical modulation device according to any one of Claims 1 to 7,

wherein the planar optical waveguide is in a shape of a polygon configured of a plurality of sides including the two sides in a plan view, and

the light incidence unit and the light launching unit are arranged on a side

different from the two sides among the plurality of sides.

9. The optical modulation device according to any one of Claims 1 to 8,

wherein the planar optical waveguide is in a shape of a polygon configured of a plurality of sides including the two sides in plan view, and

the light incidence unit and the light launching unit are arranged on any one of the plurality of sides, and the side on which the light incidence unit is arranged and the side on which light launching unit is arranged are different from each other.

10. The optical modulation device according to any one of Claims 1 to 9,

wherein the planar optical waveguide is in a shape of a polygon configured of a plurality of sides including the two sides in a plan view, and

the light incidence unit and the light launching unit are arranged on any one of the plurality of sides, and the side on which the light incidence unit is arranged and the side on which light launching unit is arranged are identical to each other.

11. The optical modulation device according to any one of Claims 1 to 7, further comprising:

a groove portion which is configured to fix an optical fiber,

wherein one end of the groove portion is formed on the outline, and at least one of the light incidence unit and the light launching unit is formed on the other end of the groove portion.

12. The optical modulation device according to Claim 4,

wherein the light incidence unit and the light launching unit are positioned on an

outside of a region between two lines each of which extends in a direction in parallel with the two sides from both end portions of the phase modulation unit.

13. The optical modulation device according to Claim 4,

wherein the light incidence unit and the light launching unit are positioned in a region between two lines which respectively extend in a direction in parallel with the two sides from both end portions of the phase modulation unit.

14. The optical modulation device according to any one of Claims 1 to 13,

wherein a part of the optical waveguide configuring the Mach-Zehnder interferometer is positioned on an outside of a region between the extended lines of the two phase modulation units.

15. The optical modulation device according to Claim 14,

wherein at least one of the two arm portions further includes other element parts including at least one of a low speed phase modulation unit, a PD for a monitor, a polarization conversion element, a polarized wave separating and coupling element, and a variable optical attenuator, and

at least part of the other element parts is positioned on the outside of the region between the extended lines.

16. The optical modulation device according to Claim 14,

wherein at least one of the two arm portions further includes other element parts including at least one of a low speed phase modulation unit, a PD for a monitor, a polarization conversion element, a polarized wave separating and coupling element, and a

variable optical attenuator, and

at least part of the other element parts is positioned on the inside of the region between the extended lines.

17. The optical modulation device according to Claim 14 or 15,

wherein at least one of the first optical splitter section and the first optical coupler section is positioned on an outside of the region between the extended lines.

18. The optical modulation device according to any one of Claims 1 to 17,

wherein lengths of the two arm portions are identical to each other.

19. The optical modulation device according to any one of Claims 1 to 18,

wherein at least one of the first optical splitter section and the first optical coupler section is positioned in a region between two lines which respectively extend in a direction in parallel with the two sides from the both end portions of the phase modulation unit.

20. The optical modulation device according to any one of Claims 1 to 19,

wherein the planar optical waveguide includes a plurality of Mach-Zehnder interferometers.

21. The optical modulation device according to Claim 18, further comprising:

at least one of a second optical splitter section which branches the light incident from the light incidence unit and launches the light to a plurality of Mach-Zehnder interferometers, and a second optical coupler section which combines the light launched

from the plurality of Mach-Zehnder interferometers.

22. The optical modulation device according to Claim 21,

wherein the second optical splitter section is included, and

at least a part of waveguides connecting the plurality of Mach-Zehnder interferometers to the second optical splitter section is positioned on the outside of a region between two extended lines in the longitudinal direction of each of the phase modulation units included in the plurality of Mach-Zehnder interferometers, which are furthest from each other.

23. The optical modulation device according to Claim 21,

wherein the second optical coupler section is included, and

at least a part of waveguides connecting the plurality of Mach-Zehnder interferometers to the second optical coupler section is positioned on the outside of a region between two extended lines in the longitudinal direction of each of the phase modulation units included in the plurality of Mach-Zehnder interferometers, which are furthest from each other.

24. The optical modulation device according to Claim 22 or 23,

wherein at least one of the second optical splitter section and the second optical coupler section is positioned on the outside of the region between the two lines which are furthest from each other.

25. The optical modulation device according to any one of Claims 21, 22, and 24,

wherein lengths of the waveguides connecting the plurality of Mach-Zehnder

interferometers to the second optical splitter section are identical to each other.

26. The optical modulation device according to any one of Claims 21, 23, and 24, wherein lengths of the waveguides connecting the plurality of Mach-Zehnder interferometers to the second optical coupler section are identical to each other.

27. The optical modulation device according to any one of Claims 20 to 26, wherein the planar optical waveguide has a QPSK structure or a DP-QPSK structure.

28. The optical modulation device according to any one of Claims 1 to 27, wherein at least one of the first light branching device and the first light combining device is formed of a multimode interferometer.

29. The optical modulation device according to any one of Claims 21 to 27, wherein at least one of the first optical splitter section, the first optical coupler section, and the second optical splitter section, and the second optical coupler section is formed of a multimode interferometer.

30. The optical modulation device according to any one of Claims 1 to 29, wherein the traveling-wave electrode has any one of (1) a GSG structure which includes a signal electrode between the two arm portions, and includes an earth electrode on the outside of each of the two arm portions, (2) a GSGSG structure which includes an earth electrode between the two arm portions, includes a signal electrode on the outside of each of the two arm portions, and further includes an earth electrode on the outside of

the signal electrode, and (3) a GS structure which includes an earth electrode and a signal electrode on the outside of each of the two arm portions.

31. The optical modulation device according to any one of Claims 1 to 30,

wherein at least one of a light source and a light receiver is disposed on the planar optical waveguide.

32. The optical modulation device according to any one of Claims 1 to 31,

wherein an optical waveguide configuring the phase modulation unit is formed of a rib waveguide which includes a rib portion, and a pair of slab portions connected to both sides of the rib portion.

33. The optical modulation device according to Claim 32,

wherein a rectangular waveguide is connected to at least one end of the rib waveguide, and

a transition region in which a width between the pair of slab portions is continuously changed to be optically coupled to the rectangular waveguide, is included in a connection portion between the rib waveguide and the rectangular waveguide.

34. The optical modulation device according to any one of Claims 1 to 33,

wherein a core configuring the planar optical waveguide is formed of silicon.

35. The optical modulation device according to any one of Claims 1 to 34,

wherein a substrate configuring the planar optical waveguide is formed of silicon.

36. The optical modulation device according to any one of Claims 1 to 35, wherein a clad formed of silica is disposed between an upper surface of a core configuring the planar optical waveguide and the traveling-wave electrode, and a thickness of the clad in a position in which the core and the traveling-wave electrode vertically intersect with each other in a portion other than the phase modulation unit, is greater than or equal to 1 μm.

37. An optical modulation device module, comprising:
the optical modulation device according to any one of Claims 1 to 36; and
a package containing the optical modulation device.

CLAIMS

1. An optical modulation device configured of a planar optical waveguide, comprising:

a light incidence unit which allows light to be incident on the planar optical waveguide;

a Mach-Zehnder interferometer which includes a first optical splitter section branching the light incident on the light incidence unit, two arm portions guiding the light branched by the first optical splitter section, a phase modulation unit linearly disposed on each of the two arm portions, and a first optical coupler section combining the light guided from the two arm portions;

a light emission unit which emits the light combined by the first optical coupler section from the planar optical waveguide; and

a traveling-wave electrode which includes an input unit and an output unit, and applies a voltage to the phase modulation unit,

wherein the planar optical waveguide has an outline including two sides each of which intersect with an extended line in a longitudinal direction of the phase modulation unit in a plan view,

the input unit is formed on one of the two sides, and

the light incidence unit and the light emission unit are positioned in a region different from a region in which the traveling-wave electrode is formed in a plan view.

2. The optical modulation device according to claim 1,

at least one of the light incidence unit and the light emission unit is arranged on the same side on which the output unit is arranged.

3. The optical modulation device according to claim 2,

the light emission unit is arranged on the same side on which the output unit is arranged.

4. The optical modulation device according to claim 1,

wherein an optical waveguide configuring the phase modulation unit is formed of a rib waveguide which includes a rib portion, and a pair of slab portions connected to both sides of the rib portion,

a rectangular waveguide is connected to at least one end of the rib waveguide, and

a transition region in which a width between the pair of slab portions is continuously changed to be optically coupled to the rectangular waveguide, is included in a connection portion between the rib waveguide and the rectangular waveguide.

5. The optical modulation device according to claim 1,

wherein distances between each of the two phase modulation units and one side are identical to each other, and distances between the each of the two phase modulation unit and an other side are identical to each other, and

the light incidence unit and the light emission unit are positioned in a region between two lines which respectively extend in a direction in parallel with the two sides from both end portions of the phase modulation unit.

6. The optical modulation device according to claim 1,

wherein the longitudinal direction of the phase modulation unit has an inclination at an angle of greater than 0° and less than 90° with respect to each of the two sides, and

distances between each of the two phase modulation units and one side are identical to each other, and distances between the each of the two phase modulation unit and an other side are identical to each other.

7. The optical modulation device according to any one of claims 1 to 5,

wherein the longitudinal direction of the phase modulation unit is perpendicular to the two sides.

8. The optical modulation device according to any one of claims 1 to 5,

wherein the longitudinal direction of the phase modulation unit has an inclination at an angle of greater than 0° and less than 90° with respect to each of the two sides.

9. The optical modulation device according to any one of claims 1 to 8,

wherein distances between each of the two phase modulation units and one side are identical to each other, and distances between the each of the two phase modulation unit and an other side are identical to each other.

10. The optical modulation device according to any one of claims 1 to 9,

wherein the phase modulation units are arranged in parallel with each other.

11. The optical modulation device according to any one of claims 1 to 10,

wherein the output unit is formed on the other side.

12. The optical modulation device according to any one of claims 1 to 11,

wherein the traveling-wave electrode is linearly formed from the input unit to the output unit.

13. The optical modulation device according to any one of claims 1 to 12,

wherein the planar optical waveguide is in a shape of a polygon configured of a plurality of sides including the two sides in a plan view, and

the light incidence unit and the light emission unit are arranged on a side different from the two sides among the plurality of sides.

14. The optical modulation device according to any one of claims 1 to 13,

wherein the planar optical waveguide is in a shape of a polygon configured of a plurality of sides including the two sides in plan view, and

the light incidence unit and the light emission unit are arranged on any one of the plurality of sides, and the side on which the light incidence unit is arranged and the side on which light emission unit is arranged are different from each other.

15. The optical modulation device according to any one of claims 1 to 13,

wherein the planar optical waveguide is in a shape of a polygon configured of a plurality of sides including the two sides in a plan view, and

the light incidence unit and the light emission unit are arranged on any one of the plurality of sides, and the side on which the light incidence unit is arranged and the side on which light emission unit is arranged are identical to each other.

16. The optical modulation device according to any one of claims 1 to 12, further comprising:

a groove portion which is configured to fix an optical fiber,

wherein one end of the groove portion is formed on the outline, and at least one of the light incidence unit and the light emission unit is formed on the other end of the groove portion.

17. The optical modulation device according to any one of claims 5, 6, and 9,

wherein the light incidence unit and the light emission unit are positioned on an outside of a region between two lines each of which extends in a direction in parallel with the two sides from both end portions of the phase modulation unit.

18. The optical modulation device according to any one of claims 5, 6, and 9,

wherein the light incidence unit and the light emission unit are positioned in a region between two lines which respectively extend in a direction in parallel with the two sides from both end portions of the phase modulation unit.

19. The optical modulation device according to any one of claims 1 to 18,

wherein a part of the optical waveguide configuring the Mach-Zehnder interferometer is positioned on an outside of a region between the extended lines of the two phase modulation units.

20. The optical modulation device according to claim 19,

wherein at least one of the two arm portions further includes other element parts including at least one of a low speed phase modulation unit, a PD for a monitor, a

polarization conversion element, a polarized wave separating and coupling element, and a variable optical attenuator, and

at least part of the other element parts is positioned on the outside of the region between the extended lines.

21. The optical modulation device according to claim 19,

wherein at least one of the two arm portions further includes other element parts including at least one of a low speed phase modulation unit, a PD for a monitor, a polarization conversion element, a polarized wave separating and coupling element, and a variable optical attenuator, and

at least part of the other element parts is positioned on the inside of the region between the extended lines.

22. The optical modulation device according to claim 19 or 20,

wherein at least one of the first optical splitter section and the first optical coupler section is positioned on an outside of the region between the extended lines.

23. The optical modulation device according to any one of claims 1 to 22,

wherein lengths of the two arm portions are identical to each other.

24. The optical modulation device according to any one of claims 1 to 23,

wherein at least one of the first optical splitter section and the first optical coupler section is positioned in a region between two lines which respectively extend in a direction in parallel with the two sides from the both end portions of the phase modulation unit.

25. The optical modulation device according to any one of claims 1 to 24, wherein the planar optical waveguide includes a plurality of Mach-Zehnder interferometers.

26. The optical modulation device according to claim 25, further comprising: at least one of a second optical splitter section which branches the light incident from the light incidence unit and emits the light to a plurality of Mach-Zehnder interferometers, and a second optical coupler section which combines the light emitted from the plurality of Mach-Zehnder interferometers.

27. The optical modulation device according to claim 26, wherein the second optical splitter section is included, and at least a part of waveguides connecting the plurality of Mach-Zehnder interferometers to the second optical splitter section is positioned on the outside of a region between two extended lines in the longitudinal direction of each of the phase modulation units included in the plurality of Mach-Zehnder interferometers, which are furthest from each other.

28. The optical modulation device according to claim 26, wherein the second optical coupler section is included, and at least a part of waveguides connecting the plurality of Mach-Zehnder interferometers to the second optical coupler section is positioned on the outside of a region between two extended lines in the longitudinal direction of each of the phase

modulation units included in the plurality of Mach-Zehnder interferometers, which are furthest from each other.

29. The optical modulation device according to claim 27 or 28,

wherein at least one of the second optical splitter section and the second optical coupler section is positioned on the outside of the region between the two lines which are furthest from each other.

30. The optical modulation device according to any one of claims 26, 27, and 29,

wherein lengths of the waveguides connecting the plurality of Mach-Zehnder interferometers to the second optical splitter section are identical to each other.

31. The optical modulation device according to any one of claims 26, 28, and 29,

wherein lengths of the waveguides connecting the plurality of Mach-Zehnder interferometers to the second optical coupler section are identical to each other.

32. The optical modulation device according to any one of Claims 25 to 31,

wherein the planar optical waveguide has a QPSK structure or a DP-QPSK structure.

33. The optical modulation device according to any one of claims 1 to 32,

wherein at least one of the first light branching device and the first light combining device is formed of a multimode interferometer.

34. The optical modulation device according to any one of claims 26 to 32,

wherein at least one of the first optical splitter section, the first optical coupler section, and the second optical splitter section, and the second optical coupler section is formed of a multimode interferometer.

35. The optical modulation device according to any one of claims 1 to 34,

wherein the traveling-wave electrode has any one of (1) a GSG structure which includes a signal electrode between the two arm portions, and includes an earth electrode on the outside of each of the two arm portions, (2) a GSGSG structure which includes an earth electrode between the two arm portions, includes a signal electrode on the outside of each of the two arm portions, and further includes an earth electrode on the outside of the signal electrode, and (3) a GS structure which includes an earth electrode and a signal electrode on the outside of each of the two arm portions.

36. The optical modulation device according to any one of claims 1 to 35,

wherein at least one of a light source and a light receiver is disposed on the planar optical waveguide.

37. The optical modulation device according to any one of Claims 1 to 36,

wherein an optical waveguide configuring the phase modulation unit is formed of a rib waveguide which includes a rib portion, and a pair of slab portions connected to both sides of the rib portion.

38. The optical modulation device according to claim 37,

wherein a rectangular waveguide is connected to at least one end of the rib waveguide, and

a transition region in which a width between the pair of slab portions is continuously changed to be optically coupled to the rectangular waveguide, is included in a connection portion between the rib waveguide and the rectangular waveguide.

39. The optical modulation device according to any one of claims 1 to 38, wherein a core configuring the planar optical waveguide is formed of silicon.

40. The optical modulation device according to any one of claims 1 to 39, wherein a substrate configuring the planar optical waveguide is formed of silicon.

41. The optical modulation device according to any one of claims 1 to 40, wherein a clad formed of silica is disposed between an upper surface of a core configuring the planar optical waveguide and the traveling-wave electrode, and a thickness of the clad in a position in which the core and the traveling-wave electrode vertically intersect with each other in a portion other than the phase modulation unit, is greater than or equal to 1 μm.

42. An optical modulation device module, comprising:
the optical modulation device according to any one of claims 1 to 41; and
a package containing the optical modulation device.