

CLAIMS

1. An optical waveguide for guiding light in a photonic circuit comprising a layer of phase change material for modulating the phase of the guided light,
5 wherein the phase change material is switchable between at least a stable crystalline state and a stable amorphous state each with different refractive indexes, and the phase change material exhibits an extinction coefficient of less than 0.1 in both states for wavelengths greater than 1000 nm
- 10 2. The waveguide of claim 1, wherein the phase change material exhibits an extinction coefficient of less than 0.05 or 0.01, or substantially zero, in both states for wavelengths greater than 1000 nm.
- 15 3. The waveguide of claim 1 or 2, wherein the phase change material exhibits an extinction coefficient of substantially zero in both states and a refractive index difference between the two states of at least 0.1 at a wavelength of 1550 nm.
4. The waveguide of claim 1, 2 or 3, wherein the phase change material is formed of or comprises a chalcogenide comprising antimony such as antimonide trisulphide
20 (Sb_2S_3) or antimonide triselenium (Sb_2Se_3).
5. The waveguide of any preceding claim, comprising a plurality of layers of phase change material distributed along the waveguide.
- 25 6. The waveguide of any preceding claim, wherein the layer of phase change material has a length in the direction of light propagation and defines the lateral width of the waveguide over its length.
7. The waveguide of claim 6, wherein the layer of phase change material is provided as a strip or ridge pattern, and wherein the width of the strip or ridge pattern defines the lateral width of the waveguide.
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8. The waveguide of claim 6 or 7, wherein the layer of phase change material has a length in the direction of light propagation of at least 10 μm .

9. The waveguide of any of claims 6 to 8, wherein the layer of phase change material defines a first waveguide portion with a first end and a second end, and the waveguide further comprises a second waveguide portion coupled to the first or second end of the first waveguide portion for routing light to or from the first waveguide portion, and wherein the second waveguide portion does not comprise a phase change material.

10. The waveguide of any of claims 6 to 9, wherein the waveguide comprises a first layer formed of a first material, and the layer of phase change material is provided on the first layer in a pattern to define the lateral width of the waveguide.

11. The waveguide of any of claims 1 to 5, wherein the waveguide comprises a first layer formed of a first material that defines the width of the waveguide, and the layer of phase change material is provided over the first layer and is evanescently coupled thereto.

12. The waveguide of claim 10 or 11, wherein refractive index of the phase change material is lower than the refractive index of the first material in at least one of the two states.

13. The waveguide of claim 10, 11, or 12, wherein the first layer is formed of or comprises a material selected from the group comprising: silicon, silicon nitride, indium phosphide, gallium phosphide, germanium, and lithium niobate.

14. The waveguide of claim 10, 11, or 12, wherein the first layer is formed of or comprises a silicon layer of a silicon-on-insulator substrate.

15. The waveguide of any preceding claim, further comprising a resistive heating element in thermal contact with at least a longitudinal portion of the layer of phase change material for switching the state of the phase change material at least at that longitudinal portion.

16. The waveguide of any of preceding claim, further comprising a plurality of resistive heating elements, each in thermal contact with separate longitudinal portion

of the layer of phase change material, for switching the state of the phase change material at least at the respective longitudinal portions.

17. The waveguide of any of claims 1 to 16, further comprising a pair of electrodes
5 coupled to the layer of phase change material for applying an electrical current through the phase change material to switch the state of the phase change material.

18. The waveguide of any preceding claim, wherein the layer of phase change material has a thickness in the range 50 nm to 200 nm.

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19. An optical device for a photonic circuit, comprising a first waveguide and a second waveguide as defined in any of claims 1 to 18, wherein:

the first and second waveguides are arranged substantially parallel and spaced apart by a lateral gap, over at least a coupling region thereof, such that light can
15 evanescently couple from the first to the second waveguide in the coupling region, and

the degree of optical coupling from the first to the second waveguide is dependent on the relative states of the phase change material of the first and second waveguides in the coupling region.

20. The device of claim 19, wherein the phase change material of the first and second waveguides in the coupling region is configurable to be in the same state or different states to selectively couple light from the first waveguide to the second waveguide.

21. The device of claim 20, wherein the length of the coupling region is equal to a critical coupling length for phase-matching to selectively couple substantially all light from the first waveguide to the second waveguide.

22. The device of claim 19, 20 or 21, further comprising a third waveguide as defined in any of claims 1 to 18 arranged substantially parallel to and spaced apart from the first or second waveguide by a lateral gap, over at least a respective coupling region thereof, such that light can evanescently couple from the first or second waveguide to the third waveguide in the respective coupling region, and wherein the degree of optical coupling from the first or second waveguide to the third waveguide

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is dependent on the relative states of the phase change material of the third waveguide and the first or second waveguide in the coupling region.

23. The device of claim 22, wherein the phase change material of the third
5 waveguide and the first or second waveguide in the coupling region is configurable to be in the same state or different states to selectively couple light from the first or second waveguide to the third waveguide.

24. The device of claim 23, wherein the length of the coupling region of the first
10 or second waveguide and the third waveguide is equal to a critical coupling length for phase-matching to selectively couple substantially all light from the first or second waveguide to the third waveguide.

25. The device of claim 19 or 22, wherein the length of the coupling region is
15 equal to a critical coupling length for phase-matching, and at least a longitudinal portion of the phase change material of each waveguide in the coupling region is in the same state and overlaps by an overlap length that is variable for varying the degree of optical coupling between respective waveguides.

26. A photonic field programmable coupler array comprising an array of
20 waveguides as defined in any of claims 1 to 18 arranged substantially parallel to and spaced apart from each by a lateral gap, over at least a respective coupling region thereof, such that light can evanescently couple from one waveguide to an adjacent waveguide in the respective coupling region,

25 wherein at least a longitudinal portion of the phase change material of each waveguide in the respective coupling region is configurable to be in the same state and overlap the corresponding longitudinal portion of an adjacent waveguide by an overlap length to selectively transfer light across two or more adjacent waveguides in the array.

30 27. The photonic field programmable coupler array of claim 26, wherein the overlap length of the respective longitudinal portions is equal to a critical coupling length for phase-matching to selectively transfer substantially all light across two or more adjacent waveguides in the array.

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28. A Mach-Zehnder interferometer for a photonic circuit comprising first and second parallel optical paths, wherein the first and/or second optical path comprises a waveguide as defined in any of claims 1 to 18.