CLAIMS

1. A device for controlling an electromagnetic wave, the device comprising:

a first electrode layer;

a second electrode layer; and

a matrix layer between the first electrode layer and the second electrode layer, the matrix layer comprising:

a liquid crystal layer; and

a resonator element, the resonator element being a nanostructure consisting of a dielectric material, a Group IV semiconductor material, or a Group III Group V semiconductor material, the resonator element in contact with the liquid crystal layer;

wherein the liquid crystal layer is configured to switch, at least, from a first state to a second state in response to a voltage applied between the first electrode layer and the second electrode layer, the resonator element configured to act as an antenna and further configured to provide a phase accumulation, due to a magnetic dipole resonance and an electric dipole resonance excited within the resonator element, that adds to a phase accumulation due to the switching of the liquid crystal layer, thereby changing an optical property of the matrix layer to control the electromagnetic wave received by the matrix layer.

2. The device according to claim 1,

wherein the first electrode is transparent.

3. The device according to claim 1,

wherein the first electrode comprises indium tin oxide.

4. The device according to claim 1,

wherein the second electrode is configured to reflect the electromagnetic waves incident on the second electrode.

5. The device according to claim 1,

wherein the second electrode comprises a metal.

6. The device according to claim 1,

wherein the liquid crystal layer configured to switch from a first state to a second state comprises orientating liquid crystals comprised in the liquid crystal layer from a first direction to a second direction different from the first direction.

7. The device according to claim 1,

wherein the matrix layer further comprises further resonator elements to form an array of resonator elements.

8. The device according to claim 7,

wherein the array is an aperiodic array.

9. The device according to claim 7,

wherein the array is a periodic array.

10. The device according to claim 1,

wherein the resonator element is nearer to the first electrode compared to the second electrode.

11. The device according to claim 1,

wherein the resonator element is nearer to the second electrode compared to the first electrode.

12. The device according to claim 1,

wherein the resonator element is nearer to the first electrode compared to the second electrode, and

wherein the matrix layer further comprises a further resonator element nearer to the second electrode compared to the first electrode.

13. The device according to claim 1,

wherein the resonator element is a nanocylinder, a nanodisk, a nano-parallelepiped, a nano-prism, or a nano-ellipsoid.

14. The device according to claim 1,

wherein a refractive index of the dielectric material is greater than 2.

15. An arrangement comprising:

a device for controlling an electromagnetic wave, the device comprising:

a first electrode layer;

a second electrode layer; and

a matrix layer between the first electrode layer and the second electrode layer, the matrix layer comprising:

a liquid crystal layer; and

a resonator element, the resonator element being a nanostructure consisting of a dielectric material, a Group IV semiconductor material or a Group III Group V semiconductor material, the resonator element in contact with the liquid crystal layer;

wherein the liquid crystal layer is configured to switch from, at least, a first state to a second state in response to a voltage applied between the first electrode layer and the second electrode layer, the resonator element configured to act as an antenna and further configured to provide a phase accumulation, due to a magnetic dipole resonance and an electric dipole resonance excited within the resonator element, that adds to a phase accumulation due to the switching of the liquid crystal layer, thereby changing an optical

property of the matrix layer to control the electromagnetic wave received by the matrix layer; and

an electromagnetic wave source configured to emit the electromagnetic wave.

16. The arrangement according to claim 15,

wherein the resonator element is of subwavelength dimensions.

17. A method of operating a device to control an electromagnetic wave, the method comprising:

providing the electromagnetic wave to a device, the device comprising:

a first electrode layer;

a second electrode layer; and

a matrix layer between the first electrode layer and the second electrode layer, the matrix layer comprising:

a liquid crystal layer; and

a resonator element, the resonator element being a nanostructure consisting of a dielectric material, a Group IV semiconductor material or a Group III – Group V semiconductor material, the resonator element in contact with the liquid crystal layer; and

applying a voltage between the first electrode layer and the second electrode layer so that the liquid crystal layer switches from, at least, a first state to a second state in response to the voltage applied to control the electromagnetic wave received by the matrix layer;

wherein the resonator element is configured to act as an antenna and is further configured to provide a phase accumulation, due to a magnetic dipole resonance and an electric dipole resonance, that adds to a phase accumulation due to the switching of the liquid crystal layer.

18. The method according to claim 17,

wherein controlling the electromagnetic wave comprises inducing a phase shift of the electromagnetic wave of a value selected from a range of 0 radian to 2π radians.

19. The method according to claim 17,

wherein the liquid crystal layer comprise liquid crystals;

wherein the liquid crystals are oriented in a direction perpendicular to an electric field of the electromagnetic wave when the liquid crystal layer is in the first state; and

wherein the liquid crystals are oriented in a direction parallel to the electric field of the electromagnetic wave when the liquid crystal layer is in the second state.

20. The method according to claim 17,

wherein the magnetic dipole resonance and the electric dipole resonance of the at least one resonator element is changed by applying the voltage between the first electrode layer and the second electrode layer.