CLAIMS

1. A tunable optical device comprising:

   a ferroelectric layer comprising a ferroelectric material;

   a plurality of first electrodes forming a metasurface on a first side of the ferroelectric layer; and

   one common second electrode on a second side of the ferroelectric layer opposite the first side;

   wherein a refractive index of the ferroelectric material is changeable in response to a potential difference applied between the plurality of first electrodes and the one common second electrode; and

   wherein the plurality of first electrodes and the one common second electrode are configured to allow visible light or infrared light to pass through.

2. The tunable optical device according to claim 1,

   wherein the ferroelectric material is barium strontium titanate (BST), barium titanate (BTO), lead lanthanum zirconate titanate (PLZT), lithium niobate ($LiNbO_3$), or potassium tantalate niobate (KTN).

3. The tunable optical device according to claim 1 or claim 2,

   wherein the plurality of first electrodes and the one common second electrode comprise a material selected from a group consisting of indium tin oxide (ITO), fluorine doped tin oxide (FTO), aluminum zinc oxide (AZO), barium titanate (BTO),

strontium vanadate ($SrVO_3$), calcium vanadate (CaV_2O_6), carbon nanotubes, and graphene.

4. The tunable optical device according to any one of claim 1 to claim 3, further comprising:

a bottom distributed Bragg reflector (DBR);

wherein the one common second electrode are over the bottom distributed Bragg reflector (DBR),

wherein the tunable optical device is configured to operate in a reflection mode.

5. The tunable optical device according to any one of claims 1 to 4, further comprising:

a top distributed Bragg reflector (DBR),

wherein the top distributed Bragg reflector (DBR) is over the ferroelectric layer, the plurality of first electrodes and the one common second electrode.

6. The tunable optical device according to any one of claim 1 to claim 3, further comprising:

a silicon oxide layer, disposed between the plurality of first electrodes and the ferroelectric layer.

7. The tunable optical device according to any one of claims 1 to 6,

a substrate;

wherein the one common second electrode is over the substrate,

wherein the substrate comprises magnesium oxide (MgO), sapphire (Al_2O_3), lanthanum aluminate - strontium aluminum tantalate (LSAT), strontium titanate (STO), magnesium fluoride (MgF_2), silicon, or quartz (SiO_2).

8. The tunable optical device according to any one of claim 1 to claim 3, further comprising:

a broadband metallic mirror;

wherein the one common second electrode is over the broadband metallic mirror.

9. The tunable optical device according to any one of claim 1 to claim 8,

wherein the plurality of first electrodes comprise a plurality of sub-wavelength structures forming the metasurface.

10. The tunable optical device according to any one of claim 1 to claim 8, further comprising:

a plurality of contacts located at corner regions of a circumscribed polygon, and/or an array of ring resonators on top of the plurality of first electrodes, wherein a diameter of the ring resonators tunes an operational wavelength of the tunable optical device.

11. The tunable optical device according to any one of claim 1 to claim 10,

wherein the tunable optical device is any one selected from a group consisting of a modulator, a tunable filter, a beam sweeper, a beam steering device, a tunable lens and a light router.

12. A method of forming a tunable optical device, the method comprising:

forming a ferroelectric layer comprising a ferroelectric material;

forming a plurality of first electrodes forming a metasurface on a first side of the ferroelectric layer; and

forming one common second electrode on a second side of the ferroelectric layer opposite the first side;

wherein a refractive index of the ferroelectric material is changeable in response to a potential difference applied between the plurality of first electrodes and the one common second electrode; and

wherein the plurality of first electrodes and the one common second electrode are configured to allow visible light or infrared light to pass through.

13. The method according to claim 12,

wherein the ferroelectric material is barium strontium titanate (BST), barium titanate (BTO), lead lanthanum zirconate titanate (PLZT), lithium niobate ($LiNbO_3$), or potassium tantalate niobate (KTN).

14. The method according to claim 12 or claim 13,

wherein the plurality of first electrodes and the one common second electrode comprise a material selected from a group consisting of indium tin oxide (ITO), fluorine doped tin oxide (FTO), aluminum zinc oxide (AZO), barium titanate (BTO), strontium vanadate ($SrVO_3$), calcium vanadate (CaV_2O_6), carbon nanotubes, and graphene.

15. The method according to any one of claim 12 to claim 14, further comprising:

forming a bottom distributed Bragg reflector (DBR);

wherein the one common second electrode is over the distributed Bragg reflector (DBR) ,

wherein the tunable optical device is configured to operate in a reflection mode.

16. The method according to any one of claims 12 to 15, further comprising:

forming a top distributed Bragg reflector (DBR),

wherein the top distributed Bragg reflector (DBR) is over the ferroelectric layer, the plurality of first electrodes and the one common second electrode.

17. The method according to any one of claim 12 to claim 14,

wherein the one common second electrode is formed over a substrate,

wherein the substrate comprises magnesium oxide (MgO), sapphire (Al_2O_3), lanthanum aluminate - strontium aluminum tantalate (LSAT), strontium titanate (STO), magnesium fluoride (MgF_2), silicon, or quartz (SiO_2).

18. The method according to any one of claims 12 to 17,

forming a silicon oxide layer between the plurality of first electrodes and the ferroelectric layer.

19. The method according to any one of claim 12 to claim 14,

wherein the one common second electrode is formed over a broadband metallic mirror.

20. The method according to any one of claim 12 to claim 19,

wherein the plurality of first electrodes comprise a plurality of sub-wavelength structures forming the metasurface.

21. The method according to any one of claim 12 to claim 19, further comprising:

forming a plurality of contacts located at corner regions of a circumscribed polygon.

22. The method according to any one of claim 12 to claim 21, further comprising:

forming an array of ring resonators on top of the plurality of first electrodes, wherein a diameter of the ring resonators tunes an operational wavelength of the tunable optical device.