CLAIMS

What is claimed is:

1. A diffractive optical element comprising: a substrate made of a transparent material; and an array of optical nanoantennas arranged on the substrate, the array of optical nanoantennas being spaced apart periodically in a lateral direction for supporting a plurality of diffraction orders at a predetermined wavelength, wherein each optical nanoantenna in the array of optical nanoantennas is configured to control distribution of electromagnetic energy from an incident light transmitted through the substrate and illuminated on a side of the array of optical nanoantennas that is arranged on the substrate, the incident light having the predetermined wavelength amongst the plurality of diffraction orders so as to promote scattering of the electromagnetic energy in at least a first direction and suppress scattering of the electromagnetic energy in at least a second direction, the first direction and the second direction corresponding to a first diffraction order and a second diffraction order of the plurality of diffraction orders, respectively, and wherein at least one optical nanoantenna in the array of optical nanoantennas comprises at least one of a semiconductor material and a dielectric material, and said at least one optical nanoantenna is configured on the substrate to support electric multipolar resonant modes and magnetic multipolar resonant modes.

2. The diffractive optical element according to claim 1, wherein said each optical nanoantenna is configured to promote scattering of the electromagnetic energy in at least the first direction and a third direction, and suppress scattering of the electromagnetic energy in at least the second direction and a fourth direction, the third direction and the fourth direction corresponding to a third diffraction order and a fourth diffraction order of the plurality of diffraction orders, respectively.

3. The diffractive optical element according to claim 1, wherein said each optical nanoantenna in the array of optical nanoantennas is configured to have substantially the same geometrical configuration.

4. The diffractive optical element according to claim 1, wherein said each optical nanoantenna is configured to exhibit constructive interference of the electromagnetic energy in the far-field in at least the first direction so as to enhance scattering efficiency of the electromagnetic energy in at least the first direction and to exhibit destructive interference of the electromagnetic energy in the far-field in at least the second direction so as to minimize scattering efficiency of the electromagnetic energy in at least the second direction.

5. The diffractive optical element according to claim 4, wherein said each optical nanoantenna is configured to have an asymmetrical shape, the asymmetrical shape being configured to facilitate the array of optical nanoantennas in exhibiting constructive interference of the electromagnetic energy in the far-field in at least the first direction and destructive interference of the electromagnetic energy in the far-field in at least the second direction.

6. The diffractive optical element according to claim 5, wherein said each optical nanoantenna is configured to comprise a first component having a ring shape and a second component having a cylinder shape, wherein the first and second components are configured to intersect each other.

7. The diffractive optical element according to claim 5, wherein said each optical nanoantenna is configured to comprise a first component having a cylinder shape and a second component having a cylinder shape spaced apart from the first component, wherein the first and second components are configured to have a different diameter.

8. The diffractive optical element according to claim 1, wherein the first direction has an angle with respect to a zero diffraction order in the range of about 30 to about 89 degrees.

9. The diffractive optical element according to claim 1, wherein the predetermined wavelength is selected from a visible range or an infrared range, and each optical nanoantenna has a dimension in said lateral direction that is less than the predetermined wavelength.

10. A method of forming a diffractive optical element, the method comprising: providing a substrate made of a transparent material; arranging an array of optical nanoantennas on the substrate, the array of optical nanoantennas being spaced apart periodically in a lateral direction for supporting a plurality of diffraction orders at a predetermined wavelength; and configuring each optical nanoantenna in the array of optical nanoantennas to control distribution of electromagnetic energy from an incident light transmitted through the substrate and illuminated on a side of the array of optical nanoantennas that is arranged on the substrate, the incident light having the predetermined wavelength amongst the plurality of diffraction orders so as to promote scattering of the electromagnetic energy in at least a first direction and suppress scattering of the electromagnetic energy in at least a second direction, the first direction and the second direction corresponding to a first diffraction order and a second diffraction order of the plurality of diffraction orders, respectively, wherein at least one optical nanoantenna in the array of optical nanoantennas comprises at least one of a semiconductor material and a dielectric material, and said at least one optical nanoantenna is configured on the substrate to support electric multipolar resonant modes and magnetic multipolar resonant modes.

11. The method according to claim 10, wherein said each optical nanoantenna is configured to promote scattering of the electromagnetic energy in at least the first direction and a third direction, and suppress scattering of the electromagnetic energy in at least the third direction and a fourth direction, the third direction and the fourth direction corresponding to a second diffraction order and a fourth diffraction order of the plurality of diffraction orders, respectively.

12. The method according to claim 10, wherein said each optical nanoantenna in the array of optical nanoantennas is configured to have substantially the same geometrical configuration.

13. The method according to claim 10, wherein said each optical nanoantenna is configured to exhibit constructive interference of the electromagnetic energy in the far-field in at least the first direction so as to enhance scattering efficiency of the electromagnetic energy in at least the first direction and to exhibit destructive interference of the electromagnetic energy

in the far-field in at least the second direction so as to minimize scattering efficiency of the electromagnetic energy in at least the second direction.

14. The method according to claim 13, wherein said each optical nanoantenna is configured to have an asymmetrical shape, the asymmetrical shape configured to facilitate the array of optical nanoantennas in exhibiting constructive interference of the electromagnetic energy in the far-field in at least the first direction and destructive interference of the electromagnetic energy in the far-field in at least the second direction.

15. The method according to claim 14, wherein said each optical nanoantenna is configured to comprise a first component having a ring shape and a second component having a cylinder shape, wherein the first and second components are configured to intersect each other.

16. The method according to claim 14, wherein said each optical nanoantenna is configured to comprise a first component having a cylinder shape and a second component having a cylinder shape spaced apart from the first component, wherein the first and second components are configured to have a different diameter.

17. The method according to claim 10, wherein the first direction has an angle with respect to a zero diffraction order in the range of about 30 to about 89 degrees.

18. A flat optical element comprising: a substrate made of a transparent material; and an array of optical nanoantennas arranged on the substrate to form a plurality of zones, each zone comprising a sub-array of optical nanoantennas spaced apart periodically in a lateral direction for supporting a corresponding plurality of diffraction orders at a predetermined wavelength, wherein, for each zone of the plurality of zones, each optical nanoantenna in the sub-array of optical nanoantennas of the respective zone is configured to control distribution of electromagnetic energy from an incident light transmitted through the substrate and illuminated on a side of the sub-array of optical nanoantennas that is arranged on the substrate, the incident light having the predetermined wavelength amongst the corresponding plurality of diffraction orders so as to promote scattering of the electromagnetic energy in at least a respective first direction and suppress scattering of the

electromagnetic energy in at least a respective second direction, the first respective direction and the second respective direction corresponding to a first diffraction order and a second diffraction order of the corresponding plurality of diffraction orders, respectively, and wherein at least one optical nanoantenna in the sub-array of optical nanoantennas of the respective zone comprises at least one of a semiconductor material and a dielectric material, and said at least one optical nanoantenna is configured on the substrate to support electric multipolar resonant modes and magnetic multipolar resonant modes.

19. The flat optical element according to claim 18, wherein: each optical nanoantenna in the sub-array of optical nanoantennas of the respective zone is configured to have substantially the same geometrical configuration; the first diffraction order and the second diffraction order belong to the same order level at opposing sides with respect to a zero diffraction order; and the plurality of zones are a plurality of angular zones, and the sub-array of optical nanoantennas of the respective zone is configured such that an angle which the respective first direction makes with an axis increases as the respective zone is further from the axis for focusing the incident light towards the axis.