CLAIMS

1. An apparatus comprising:

at least one optical waveguide;

a plurality of whispering gallery mode (WGM) resonators, each WGM resonator configured to propagate a first set of whispering gallery modes (WGMs); and

a polymer structure encapsulating the at least one optical waveguide and at least one WGM resonator of the plurality of WGM resonators,

wherein the at least one WGM resonator is optically coupled to the at least one optical waveguide such that the at least one WGM resonator is configured to communicate to the at least one optical waveguide a first set of signals corresponding to the first set of WGMs.

2. The apparatus of claim 1, wherein the polymer structure comprises at least one of:

a backing region configured to attenuate residual ultrasound echoes to prevent reverberation, and

a matching region configured to increase a bandwidth of a WGM frequency response of the plurality of WGM resonators.

3. The apparatus of claim 2, wherein the matching region is further configured to improve ultrasound transmission to the plurality of WGM resonators.

4. The apparatus of claim 3, wherein at least one of the backing region and the matching region has a first refractive index lower than a second refractive index of the at least one optical waveguide.

5. The apparatus of claim 2, wherein the at least one optical waveguide is embedded in the backing region of the polymer structure.

6. The apparatus of claim 2, wherein the at least one optical waveguide is embedded in the matching region of the polymer structure.

7. The apparatus of claim 2, wherein the at least one WGM resonator is embedded in the matching region of the polymer structure.

8. The apparatus of claim 1, wherein an effective refractive index of the polymer structure is lower than a refractive index of the at least one WGM resonator.

9. The apparatus of claim 1, wherein the polymer structure comprises an ultrasonic enhancement material.

10. The apparatus of claim 1, wherein an effective acoustic impedance of the polymer structure matches an acoustic impedance of the at least one WGM resonator.

11. The apparatus of claim 1, wherein the at least one WGM resonator comprises at least one of a microsphere and a microbubble.

12. The apparatus of claim 1, wherein the at least one WGM resonator is configured to:
receive a plurality of ultrasound echoes; and
in response to the plurality of ultrasound echoes, propagate a second set of WGMs.

13. The apparatus of claim 12, wherein the at least one WGM resonator is further configured to communicate to the at least one optical waveguide a second set of signals corresponding to the second set of WGMs.

14. The apparatus of claim 13, further comprising an optical detector communicably coupled to the at least one optical waveguide, wherein the at least one optical waveguide is configured to propagate the first set of signals and the second set of signals to the optical detector.

15. The apparatus of claim 1, wherein the at least one optical waveguide comprises an optical fiber or an integrated photonic waveguide.

16. The apparatus of claim 1, wherein the at least one optical waveguide is coupled to a light source.

17. The apparatus of claim 16, wherein the light source comprises a broadband light source or a tunable laser source.

18. The apparatus of claim 1, wherein the at least one WGM resonator comprises a hollow chamber.

19. The apparatus of claim 18, wherein the hollow chamber includes an ultrasonic enhancement material.

20. The apparatus of claim 1, each WGM resonator of the plurality of WGM resonators is optically coupled to the at least one optical waveguide.

21. The apparatus of claim 1, wherein the at least one optical waveguide comprises a plurality of optical waveguides, and each WGM resonator of the plurality of WGM resonators is optically coupled to a respective optical waveguide of the plurality of optical waveguides.

22. The apparatus of claim 1, wherein at least a portion of the WGM resonators are grouped in a linear arrangement.

23. The apparatus of claim 22, wherein the WGM resonators in the linear arrangement are equally spaced apart.

24. The apparatus of claim 22, wherein the WGM resonators in the linear arrangement are unequally spaced apart.

25. The apparatus of claim 1, wherein the plurality of WGM resonators are bundled in a circular arrangement.

26. The apparatus of claim 1, wherein at least a portion of the WGM resonators are equal sizes.

27. The apparatus of claim 1, wherein at least a portion of the WGM resonators are unequal sizes.

28. A system comprising the apparatus of claim 12 and a plurality of array elements configured to generate a set of ultrasound signals, wherein the plurality of ultrasound echoes correspond to the set of ultrasound signals.

29. The system of claim 28, wherein the array elements comprise at least array element selected from the group consisting of: a piezoelectric sensor, a single crystal material sensor, a piezoelectric micromachined ultrasound transducer (PMUT), and a capacitive micromachined ultrasound transducer sensor (CMUT).

30. A method of ultrasound imaging comprising:

receiving, from at least one optical waveguide, a first set of signals corresponding to a first set of whispering gallery modes (WGMs) propagating in a plurality of WGM resonators, wherein the at least one optical waveguide and the plurality of WGM resonators are in a polymer structure;

receiving, from the at least one optical waveguide, a second set of signals corresponding to a second set of WGMs propagating in the plurality of WGM resonators, the second set of WGMs propagating in response to the plurality of WGM resonators receiving a plurality of ultrasound echoes; and

detecting a set of differences between the first set of signals and the second set of signals.

~~31. The method of claim 30, wherein the polymer structure comprises at least one:~~

~~a backing region configured to attenuate residual ultrasound echoes to prevent reverberation, and~~

~~a matching region configured to increase a bandwidth of a WGM frequency response of the plurality of WGM resonators.~~

~~32. The method of claim 31, wherein the matching region is further configured to improve ultrasound transmission to the plurality of WGM resonators.~~

~~33. The method of claim 31, wherein at least one of the backing region and the matching region has a first refractive index lower than a second refractive index of the at least one optical waveguide.~~

34. The method of claim 33, wherein the at least one optical waveguide is in the backing region of the polymer structure.

35. The method of claim 33, wherein the at least one optical waveguide is in the matching region of the polymer structure.

36. The method of claim 33, wherein the plurality of WGM resonators are in the matching region of the polymer structure.

37. The method of claim 30, wherein an effective refractive index of the polymer structure is lower than a refractive index of the plurality of WGM resonators.

38. The method of claim 30, wherein the polymer structure comprises an ultrasonic enhancement material.

39. The method of claim 30, wherein an effective acoustic impedance of the polymer structure matches an acoustic impedance of the plurality of WGM resonators.

40. The method of claim 30, wherein at least one WGM resonator of the plurality of WGM resonators comprises at least one of a microsphere and a microbubble.

41. The method of claim 30, wherein each of the plurality of WGM resonators is optically coupled to the at least one optical waveguide.

42. The method of claim 30, wherein the plurality of ultrasound echoes correspond to a plurality of ultrasound signals.

43. The method of claim 30, further comprising:

performing a synthetic aperture (SA) operation on the first set of signals and the second set of signals, and generating an image of an object based at least in part on the SA operation.

44. The method of claim 30, further comprising:

~~performing a compressed sensing (CS) operation on the first set of signals and the second set of signals, and generating an image of an object based at least in part on the CS operation.~~

3145. An apparatus comprising:

a whispering gallery mode (WGM) resonator configured to propagate a set of WGMs, wherein the WGM resonator comprises a curved surface,

wherein the curved surface comprises a first spherical segment corresponding to a first mode of the WGM resonator and a second spherical segment corresponding to a second mode of the WGM resonator, wherein the second mode is of higher frequency than the first mode, and

wherein the second spherical segment is covered with a polymer configured to attenuate the second mode.

~~46. The apparatus of claim 45, wherein the WGM resonator is a microsphere or a microbubble resonator.~~

~~47. The apparatus of claim 45, wherein the first spherical segment is not covered by the polymer.~~

~~48. The apparatus of claim 45, wherein the first mode is a fundamental mode of the WGM resonator.~~

~~49. The apparatus of claim 45, wherein the second spherical segment is a spherical cap of the WGM resonator.~~

~~50. The apparatus of claim 49, wherein a base of the spherical cap is between about 3 μm and 15 μm distance from an equatorial plane of the WGM resonator.~~

~~51. The apparatus of claim 49, wherein the WGM resonator comprises a stem side and a non-stem side that is polar opposite the stem side.~~

~~52. The apparatus of claim 51, wherein the spherical cap is on the stem side of the WGM resonator.~~

~~53. The apparatus of claim 51, wherein the spherical cap is on the non-stem side of the WGM resonator.~~

~~54. The apparatus of claim 45, wherein the second spherical segment is coated with the polymer.~~

~~55. The apparatus of claim 45, wherein the second spherical segment is encapsulated by the polymer.~~

~~56. The apparatus of claim 45, wherein the polymer has a refractive index higher than a refractive index of the WGM resonator.~~

~~57. The method of claim 45, wherein the polymer comprises an optical adhesive.~~

~~58. The apparatus of claim 45, further comprising an optical waveguide optically coupled to the WGM resonator.~~

~~59. A system comprising the apparatus of claim 58 and a plurality of array elements configured to generate a set of ultrasound signals, wherein the WGM resonator is configured to propagate the set of WGMs in response to receiving a plurality of ultrasound echoes corresponding to the set of ultrasound signals.~~

32~~60~~. A method for making a whispering gallery mode (WGM) resonator, the method comprising:

providing a WGM resonator comprising a curved surface, wherein the curved surface comprises a first spherical segment corresponding to a first mode of the WGM resonator and a second spherical segment corresponding to a second mode of the WGM resonator, wherein the second mode is of a frequency different from the first mode;

covering the second spherical segment with a polymer configured to attenuate the second mode.

~~61. The method of claim 60, wherein the WGM resonator is a microsphere or a microbubble resonator.~~

~~62. The method of claim 60, wherein the polymer does not cover the first spherical segment.~~

~~63. The method of claim 60, wherein the first mode is a fundamental mode of the WGM resonator.~~

~~64. The method of claim 60, wherein the second spherical segment is a spherical cap of the WGM resonator.~~

~~65. The method of claim 64, wherein the WGM resonator comprises a stem side and a non-stem side that is polar opposite the stem side.~~

~~66. The apparatus of claim 65, wherein the spherical cap is on the stem side of the WGM resonator.~~

~~67. The apparatus of claim 65, wherein the spherical cap is on the non-stem side of the WGM resonator.~~

~~68. The method of claim 64, wherein covering the second spherical segment with the polymer comprises coating the spherical cap with the polymer.~~

~~69. The method of claim 64, wherein covering the second spherical segment with the polymer comprises submerging the spherical cap into a solution comprising the polymer.~~

~~70. The method of claim 60, wherein the polymer has a refractive index higher than a refractive index of the WGM resonator.~~

~~71. The method of claim 60, wherein the polymer comprises an optical adhesive.~~