CLAIMS

1. An apparatus for imaging a target, comprising:

an ultrasound transducer array comprising:

one or more array elements of a first type, wherein the first type is a transducer configured to transmit acoustic waves; and

one or more array elements of a second type different from the first type, wherein the second type is an optical sensor,

wherein the array elements of the first and second types are configured to detect acoustic echoes corresponding to the ~~transmitted~~ acoustic waves.

~~2. The apparatus of claim 1, wherein the ultrasound transducer array comprises one or more rows in an elevation dimension.~~

~~3. The apparatus of claim 2, wherein the ultrasound transducer array comprises an odd number of rows.~~

~~4. The apparatus of claim 2, wherein the ultrasound transducer array comprises an even number of rows.~~

~~5~~2. The apparatus of claim ~~2~~1, wherein the one or more array elements of the first type and the one or more array elements of the second type are in alternating rows.

~~6~~3. The apparatus of claim ~~5~~2, wherein at least a portion of the array elements of the first type is in a center row.

~~7~~4. The apparatus of claim ~~5~~2, wherein at least a portion of the array elements of the second type is in a center row.

~~8. The apparatus of claim 2, wherein the ultrasound transducer array comprises at least one row with a pitch that is larger than half of a wavelength of a center frequency of the transducer.~~

~~9. The apparatus of claim 2, wherein the ultrasound transducer array comprises at least one row with a pitch that is smaller than or equal to half of a wavelength of a center frequency of the transducer.~~

~~10. The apparatus of claim 2, wherein the rows have equal pitch in the lateral dimension.~~

~~11. The apparatus of claim 2, wherein the ultrasound transducer array comprises at least one row with a first pitch in the lateral dimension, and at least one row with a second pitch different than the first pitch in the lateral dimension.~~

~~12. The apparatus of claim 11, wherein the ultrasound transducer array comprises an inner row having the first pitch, and a row adjacent to the inner row having the second pitch, wherein the second pitch is larger than the first pitch.~~

~~13~~5. The apparatus of claim ~~12~~1, wherein the ultrasound transducer array includes an inner row and a row adjacent to the inner row, wherein the inner row comprises one or more array elements of the first type and the row adjacent to the inner row comprises one or more array elements of the second type.

~~14. The apparatus of claim 2, wherein the ultrasound array comprises at least one row with variable pitch in the lateral dimension.~~

~~15. The apparatus of claim 14, wherein the at least one row with variable pitch comprises a central region having a first pitch, and a lateral region adjacent to the central region having a second pitch larger than the first pitch.~~

~~16. The apparatus of claim 15, wherein the ultrasound transducer array comprises a first row with a first variable pitch pattern in the lateral dimension, and a second row with a second variable pitch pattern in the lateral dimension, wherein the second variable pitch pattern is different than the first variable pitch pattern.~~

~~17~~6. The apparatus of claim ~~16~~1, wherein the ultrasound transducer array comprises an inner row comprising one or more array elements of the first type, and a row adjacent to the inner row comprising one or more array elements of the second type.

~~18~~7. The apparatus of claim ~~2~~1, wherein the ultrasound transducer array comprises at least one row comprising at least one array element of the first type and at least one array element of the second type.

~~19~~8. The apparatus of claim ~~18~~7, wherein the at least one row comprising at least one array element of the first type and at least one array element of the second type is a center row.

~~20~~9. The apparatus of claim ~~19~~8, wherein the center row has a single array element of the second type.

~~21~~10. The apparatus of claim ~~20~~9, wherein the single array element of the second type is an optical sensor that is about equal to or smaller than a wavelength of the transmitted acoustic waves.

~~22~~11. The apparatus of claim ~~19~~8, wherein the center row comprises a plurality of array elements of the first type and a plurality of array elements of the second type.

~~23~~12. The apparatus of claim ~~22~~11, wherein the array elements of the second type are about equal to or smaller than a wavelength of the transmitted acoustic wave.

~~24~~13. The apparatus of claim ~~18~~7, wherein the ultrasound transducer array comprises two or more rows, each of the two or more rows comprising at least one array element of the first type and at least one array element of the second type.

~~25~~14. The apparatus of claim ~~24~~13, wherein the array elements of the second type are spatially distributed in a regular pattern.

~~26~~15. The apparatus of claim ~~24~~13, wherein the array elements of the second type are spatially distributed in an irregular pattern.

~~27~~16. The apparatus of claim ~~24~~13, wherein the ultrasound transducer array comprises at least 31 rows, at least some of the 31 rows comprising at least one array element of the first type and at least one array element of the second type.

~~28~~17. The apparatus of claim ~~1~~87, wherein the ultrasound transducer array comprises a single row, the single row comprising at least one array element of the first type and at least one array element of the second type.

~~29~~18. The apparatus of claim 1, wherein the ultrasound transducer array comprises a plurality of sub-apertures.

~~30. The apparatus of claim 29, wherein the plurality of sub-apertures comprises a first sub-aperture and a second sub-aperture, the first sub-aperture comprising a greater number of rows than the second sub-aperture.~~

~~31. The apparatus of claim 30, wherein the first sub-aperture is a central sub-aperture and the second sub-aperture is adjacent to the central sub-aperture.~~

~~32~~19. The apparatus of claim ~~29~~18, wherein each sub-aperture comprises at least one array element of the first type.

~~33~~20. The apparatus of claim ~~32~~19, wherein each sub-aperture further comprises at least one array element of the second type.

~~34. The apparatus of claim 1, wherein the ultrasound transducer array comprises a first plurality of array elements of the first type and a second plurality of elements of the second type, wherein the first plurality of array elements and the second plurality of array elements are each in a sparse array configuration.~~

~~35. The apparatus of claim 34, wherein the spatial distribution of the first plurality of array elements is different from the spatial distribution of the second plurality of array elements.~~

~~36. The apparatus of claim 1, wherein the ultrasound transducer array is on a planar surface.~~

~~37. The apparatus of claim 1, wherein the ultrasound transducer array is on a curved surface.~~

~~38. The apparatus of claim 37, wherein the curved surface comprises a quadratic curve.~~

~~39. The apparatus of claim 38, wherein the quadratic curve is a parabolic curve, a hyperbolic curve, or an elliptic curve.~~

~~40. The apparatus of claim 37, wherein the curved surface comprises a circular curve.~~

~~41. The apparatus of claim 1, wherein the ultrasound transducer array comprises at least one annular array element.~~

~~42. The apparatus of claim 41, wherein the ultrasound array comprises a circular array element of the second type concentric with the at least one annular array element.~~

~~43. The apparatus of claim 41, wherein the at least one annular array element is of the first type.~~

~~44. The apparatus of claim 1, wherein at least a portion of the array elements of the first type comprises at least one piezoelectric transducer, single crystal material transducer, piezoelectric micromachined ultrasound transducer (PMUT), or capacitive micromachined ultrasonic transducer (CMUT).~~

~~45. The apparatus of claim 1, wherein the ultrasound transducer array is a 1 dimensional (1D) array.~~

~~46. The apparatus of claim 1, wherein the ultrasound transducer array is a 1.25 dimensional (1.25D) array.~~

~~47. The apparatus of claim 1, wherein the ultrasound transducer array is a 1.5 dimensional (1.5D) array.~~

~~48. The apparatus of claim 1, wherein the ultrasound transducer array is a 1.75 dimensional (1.75D) array.~~

~~49. The apparatus of claim 1, wherein the ultrasound transducer array is a 2-dimensional (2D) array.~~

~~50. The apparatus of claim 1, wherein the one or more array elements are optical sensors embedded in a polymer structure.~~

~~51. The apparatus of claim 1, wherein the optical sensor is optically coupled to an optical fiber to transmit a set of optical signals to a photodetector.~~

~~52. The apparatus of claim 51, wherein the optical sensor is configured to transmit the set of optical signals in response to the acoustic echoes.~~

~~53~~21. The apparatus of claim 1, wherein the optical sensor is an interference-based optical sensor.

~~54~~22. The apparatus of claim ~~53~~21, wherein the optical sensor comprises an optical resonator or an optical interferometer.

~~55. The apparatus of claim 54, wherein the optical sensor comprises an optical resonator that is a whispering gallery mode (WGM) optical resonator, a microbubble optical resonator, a microsphere resonator, a micro-toroid resonator, micro-ring resonators, or a micro-disk optical resonator.~~

~~56~~23. A method of ultrasound transducing comprising:

transmitting acoustic waves using an ultrasound probe, the ultrasound probe comprising an ultrasound transducer array having one or more array elements of a first type and one or more array elements of a second type different from the first type; and

receiving acoustic echoes in response to the acoustic waves, using the one or more array elements of the first type and the one or more array elements of the second type,

wherein the one or more array elements of the second type are optical sensors.

~~57. The method of claim 56, wherein the ultrasound transducer array comprises one or more rows in an elevation dimension.~~

~~58. The method of claim 57, wherein the ultrasound transducer array comprises an odd number of rows.~~

~~59. The method of claim 57, wherein the ultrasound transducer array comprises an even number of rows.~~

~~60~~24. The method of claim ~~57~~23, wherein the one or more array elements of the first type and the one or more array elements of the second type are in alternating rows.

~~61~~25. The method of claim ~~60~~24, at least a portion of the array elements of the first type is in a center row.

~~62~~26. The method of claim ~~60~~24, wherein at least a portion of the array elements of the second type is in a center row.

~~63. The method of claim 57, wherein the ultrasound transducer array comprises at least one row with a pitch that is smaller than half of a wavelength of a center frequency of the transducer.~~

~~64. The method of claim 57, wherein the ultrasound transducer array comprises at least one row with a pitch that is smaller than or equal to half of a wavelength of a center frequency of the transducer.~~

~~65. The method of claim 57, wherein the rows have equal pitch in the lateral dimension.~~

~~66. The method of claim 57, wherein the ultrasound transducer array comprises at least one row with a first pitch in the lateral dimension, and at least one row with a second pitch different than the first pitch in the lateral dimension.~~

~~67. The method of claim 66, wherein the ultrasound transducer array comprises an inner row having the first pitch, and a row adjacent to the inner row having the second pitch, wherein the second pitch is larger than the first pitch.~~

~~68~~27. The method of claim ~~67~~23, wherein the ultrasound transducer array includes an inner row and a row adjacent to the inner row and wherein the inner row comprises one or more array elements of the first type and the row adjacent to the inner row comprises one or more array elements of the second type.

~~69. The method of claim 57, wherein the ultrasound array comprises at least one row with variable pitch in the lateral dimension.~~

~~70. The method of claim 69, wherein the at least one row with variable pitch comprises a central region having a first pitch, and a lateral region adjacent to the central region having a second pitch larger than the first pitch.~~

~~71. The method of claim 70, wherein the ultrasound transducer array comprises a first row with a first variable pitch pattern in the lateral dimension, and a second row with a second variable pitch pattern in the lateral dimension, wherein the second variable pitch pattern is different than the first variable pitch pattern.~~

~~72~~28. The method of claim ~~71~~23, wherein the ultrasound transducer array comprises an inner row comprising one or more array elements of the first type, and a row adjacent to the inner row comprising one or more array elements of the second type.

~~73~~29. The method of claim ~~57~~23, wherein the ultrasound transducer array comprises at least one row comprising at least one array element of the first type and at least one array element of the second type.

~~74~~30. The method of claim ~~73~~29, wherein the at least one row comprising at least one array element of the first type and at least one array element of the second type is a center row.

~~75~~31. The method of claim ~~73~~29, wherein the center row has a single array element of the second type.

~~76~~32. The method of claim ~~73~~29, wherein the single array element of the second type is an optical sensor that is about equal to or smaller than a wavelength of the transmitted acoustic waves.

~~77~~33. The method of claim ~~74~~30, wherein the center row comprises a plurality of array elements of the first type and a plurality of array elements of the second type.

~~78~~34. The method of claim ~~77~~33, wherein the array elements of the second type are about equal to or smaller than a wavelength of the transmitted acoustic wave.

~~79~~35. The method of claim ~~73~~29, wherein the ultrasound transducer array comprises two or more rows, each of the two or more rows comprising at least one array element of the first type and at least one array element of the second type.

~~80~~36. The method of claim ~~71~~23, wherein the array elements of the second type are spatially distributed in a regular pattern.

~~81~~37. The method of claim ~~71~~23, wherein the array elements of the second type are spatially distributed in an irregular pattern.

~~82~~38. The method of claim ~~71~~23, wherein the ultrasound transducer array comprises at least 31 rows, at least some of the 31 rows comprising at least one array element of the first type and at least one array element of the second type.

~~83~~39. The method of claim ~~56~~23, wherein the ultrasound transducer array comprises a single row, the single row comprising at least one array element of the first type and at least one array element of the second type.

~~84~~40. The method of claim ~~56~~23, wherein the ultrasound transducer array comprises a plurality of sub-apertures.

~~85~~41. The method of claim ~~84~~40, wherein the plurality of sub-apertures comprises a first sub-aperture and a second sub-aperture, the first sub-aperture comprising a greater number of rows than the second sub-aperture.

~~86~~42. The method of claim ~~85~~41, wherein the first sub-aperture is a central sub-aperture and the second sub-aperture is adjacent to the central sub-aperture.

87. The method of claim 84, wherein each sub-aperture comprises at least one array element of the first type.

88. The method of claim 87, wherein each sub-aperture further comprises at least one array element of the second type.

89. The method of claim 56, wherein the ultrasound transducer array comprises a first plurality of array elements of the first type and a second plurality of elements of the second type, wherein the first plurality of array elements and the second plurality of array elements are each in a sparse array configuration.

90. The method of claim 89, wherein the spatial distribution of the first plurality of array elements is different from the spatial distribution of the second plurality of array elements.

91. The method of claim 56, wherein the ultrasound transducer array is on a planar surface.

92. The method of claim 56, wherein the ultrasound transducer array is on a curved surface.

93. The method of claim 92, wherein the curved surface comprises a quadratic curve.

94. The method of claim 93, wherein the quadratic curve is a parabolic curve, a hyperbolic curve, or an elliptic curve.

95. The method of claim 92, wherein the curved surface comprises a circular curve.

96. The method of claim 56, wherein the ultrasound transducer array comprises at least one annular array element.

97. The method of claim 96, wherein the ultrasound array comprises a circular array element of the second type concentric with the at least one annular array element.

98. The method of claim 97, wherein the at least one annular array element is of the first type.

~~99. The method of claim 56, wherein at least a portion of the array elements of the first type comprises at least one piezoelectric transducer, single crystal material transducer, piezoelectric micromachined ultrasound transducer (PMUT), or capacitive micromachined ultrasonic transducer (CMUT) .~~

~~100. The method of claim 56, wherein the ultrasound transducer array is a 1 dimensional (1D) array.~~

~~101. The method of claim 56, wherein the ultrasound transducer array is a 1.25 dimensional (1.25D) array.~~

~~102. The method of claim 56, wherein the ultrasound transducer array is a 1.5 dimensional (1.5D) array.~~

~~103. The method of claim 56, wherein the ultrasound transducer array is a 1.75 dimensional (1.75D) array.~~

~~104. The method of claim 56, wherein the ultrasound transducer array is a 2 dimensional (2D) array.~~

~~105. The method of claim 56, wherein the one or more array elements of the second type are optical sensors embedded in a polymer structure.~~

~~106. The method of claim 56, wherein the optical sensors are optically coupled to an optical fiber to transmit a set of optical signals to a photodetector.~~

~~107. The method of claim 106, wherein the optical sensors are configured to transmit the set of optical signals in response to the acoustic echoes.~~

~~1084~~3. The method of claim ~~56~~23, wherein the optical sensors are interference-based optical sensors.

~~109~~44. The method of claim ~~108~~43, wherein the optical sensors comprise at least one of an optical resonator and an optical interferometer.

~~110~~45. The method of claim ~~109~~44, wherein the optical sensors comprise an optical resonator that is a whispering gallery mode (WGM) optical resonator, a microbubble optical resonator, a microsphere resonator, a micro-toroid resonator, micro-ring resonators, or a micro-disk optical resonator.