CLAIMS

1. An apparatus for imaging a target, comprising:

an ultrasound transducer array comprising:

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

a second plurality of array elements of a second type different from the first type, wherein the second type is an optical sensor including an ultrasonic enhancement material,

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

further wherein the first plurality of array elements of the first type and the second plurality of array elements of the second type are arranged in two or more alternating rows in an elevation dimension, each of the alternating rows including either only the first type of array element or only the second type of array element.

2. The apparatus of claim 1, wherein at least a portion of the first plurality of array elements of the first type is in a center row.

3. The apparatus of claim 1, wherein at least a portion of the second plurality of array elements of the second type is in a center row.

4. The apparatus of claim 1, wherein the two or more alternating rows include an inner row and a row adjacent to the inner row, wherein the inner row comprises the first plurality of array elements of the first type and the row adjacent to the inner row comprises the second plurality of array elements of the second type.

5. The apparatus of claim 1, wherein the two or more alternating rows include an inner row comprising the first plurality of array elements of the first type, and a row adjacent to the inner row comprising the second plurality of array elements of the second type.

6. The apparatus of claim 1, wherein the ultrasound transducer array further 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.

7. The apparatus of claim 6, 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.

8. The apparatus of claim 7, wherein the center row has a single array element of the second type.

9. The apparatus of claim 8, 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.

10. The apparatus of claim 7, wherein the center row comprises a plurality of array elements of the first type and a plurality of array elements of the second type.

11. The apparatus of claim 10, wherein the array elements of the second type are about equal to or smaller than a wavelength of the transmitted acoustic wave.

12. The apparatus of claim 6, wherein the ultrasound transducer array further 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.

13. The apparatus of claim 12, wherein the array elements of the second type are spatially distributed in a regular pattern.

14. The apparatus of claim 12, wherein the array elements of the second type are spatially distributed in an irregular pattern.

15. The apparatus of claim 12, 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.

16. The apparatus of claim 1, wherein the ultrasound transducer array comprises a plurality of sub-apertures in the lateral dimension, each sub-aperture having a set of rows of the two or more alternating rows in the elevation dimension and having at least one array element of the first type and at least one array element of the second type.

17. The apparatus of claim 16, wherein a first set of rows of a first sub-aperture of the plurality of sub-apertures has a first pitch that differs from a second pitch of a second set of rows of a second sub-aperture of the plurality of sub-apertures.

18. The apparatus of claim 17, wherein the first sub-aperture is a central sub-aperture and the second sub-aperture is adjacent to the central sub-aperture.

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

20. The apparatus of claim 19, wherein the optical sensor comprises an optical resonator or an optical interferometer.

21. The apparatus of claim 1, wherein:

the first plurality of array elements of the first type are configured to permit generation of a first image from the acoustic echoes, and

the second plurality of array elements of the second type are configured to permit generation of a second image from the acoustic echoes.

22. The apparatus of claim 21, wherein the first plurality of array elements of the first type and the second plurality of array elements of the second type are configured to permit generation of a combination image of the first image and the second image.

23. The apparatus of claim 1, further comprising:

a transmit beamformer including transmit channels connected to the first plurality of array elements of the first type via a plurality of transmit channels routed through a multiplexer; and

a receive beamformer including receive channels connected to the second plurality of array elements of the second type via a plurality of optical waveguides.

24. A method of ultrasound transducing performed by a system comprising:

an ultrasound probe having an ultrasound transducer array including a first plurality of array elements of a first type configured to transmit acoustic waves and a second plurality of array elements of a second type different from the first type and configured as optical sensors including an ultrasonic enhancement material, wherein the first plurality of array elements of the first type and the second plurality of array elements of the second type are arranged in two or more alternating rows in an elevation dimension, each of the alternating rows including either only the first type of array element or only the second type of array element,

a transmit beamformer including transmit channels connected to the first plurality of array elements of the first type, and

a receive beamformer including receive channels connected to the second plurality of array elements of the second type, the method comprising:

transmitting acoustic waves using the transmit beamformer and the first plurality of array elements of a first type; and

receiving acoustic echoes in response to the acoustic waves, using the receive beamformer, the first plurality of array elements of the first type, and the second plurality of array elements of the second type.

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

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

27. The method of claim 24, wherein the two or more rows include an inner row and a row adjacent to the inner row and wherein the inner row comprises the first plurality of array elements of the first type and the row adjacent to the inner row comprises the second plurality of array elements of the second type.

28. The method of claim 24, wherein the two or more rows include an inner row comprising the first plurality of array elements of the first type, and a row adjacent to the inner row comprising the second plurality of array elements of the second type.

29. The method of claim 24, wherein the ultrasound transducer array further 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.

30. The method of claim 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.

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

32. The method of claim 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.

33. The method of claim 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.

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

35. The method of claim 29, wherein the ultrasound transducer array further 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.

36. The method of claim 24, wherein the array elements of the second type are spatially distributed in a regular pattern.

37. The method of claim 24, wherein the array elements of the second type are spatially distributed in an irregular pattern.

38. The method of claim 24, 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.

39. The method of claim 24, wherein the ultrasound transducer array comprises a plurality of sub-apertures in the lateral dimension, each sub-aperture having a set of rows of the two or more alternating rows in the elevation dimension and having at least one array element of the first type and at least one array element of the second type.

40. The method of claim 39, wherein a first set of rows of a first sub-aperture of the plurality of sub-apertures has a first pitch that differs from a second pitch of a second set of rows of a second sub-aperture of the plurality of sub-apertures.

41. The method of claim 40, wherein the first sub-aperture is a central sub-aperture and the second sub-aperture is adjacent to the central sub-aperture.

42. The method of claim 24, wherein the optical sensors are interference-based optical sensors.

43. The method of claim 42, wherein the optical sensors comprise at least one of an optical resonator and an optical interferometer.

44. The method of claim 43, 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.

45. The method of claim 24, further comprising:

generating a first image based on the acoustic echoes received by the first plurality of array elements of the first type, and

generating a second image based on the acoustic echoes received by the second plurality of array elements of the second type.

46. The method of claim 45, further comprising generating a combination image of the first image and the second image.

47. The method of claim 24, further comprising:

transmitting first signals via the transmit beamformer including transmit channels connected to the first plurality of array elements of the first type via a plurality of transmit channels routed through a multiplexer; and

transmitting second signals via the receive beamformer including receive channels connected to the second plurality of array elements of the second type via a plurality of optical waveguides.