still only achieve up to about a bandwidth of 80%. As another example, single crystal materials have increasingly been used in an effort to improve performance of ultrasound probes but have lower Curie temperatures and are brittle. Another type of transducer material is silicon, which can be processed to build Capacitive Micromachined Ultrasound Transducer (CMUT) probes that can have increased bandwidth. However, CMUT probes are not very sensitive or reliable. Moreover, CMUT probes have several operational limitations. For example, CMUT probes are nonlinear transducers and, therefore, are not generally suitable for harmonic imaging. In addition, CMUT probes require an additional bias voltage to operate properly. Thus, there is a need for new and improved devices and methods for ultrasound sensing.

SUMMARY

[0005] Various examples and embodiments are described in relation to a mixed array probe. These illustrative examples are mentioned not to limit or define the scope of this disclosure, but rather to provide examples to aid understanding thereof. Illustrative examples are discussed in the Detailed Description. Advantages offered by various examples may be further understood by examining this specification.

[0005a] According to a first aspect of the present invention, there is provided an apparatus for use in imaging a target, comprising: a housing; and a distal portion coupled to the housing. The distal portion comprises an acoustic subarray on a first substrate configured to transmit acoustic signals toward the target; an optical subarray on a second substrate, configured to detect the acoustic signals from the target; and an input/output (I/O) region comprising one or more optical I/O channels configured to bend optical signals between the optical subarray and the one or more optical I/O channels, the one or more optical I/O channels comprising an optical fiber array in an axial direction.

[0005b] According to a second aspect of the present invention, there is provided an apparatus for use in imaging a target, comprising: an acoustic

subarray on a first substrate configured to transmit acoustic signals toward the target; an optical subarray on a second substrate, configured to detect the acoustic signals from the target; and an input/output (I/O) region comprising one or more optical I/O channels configured to bend optical signals between the optical subarray and the one or more optical I/O channels. The one or more optical I/O channels comprise an optical fiber array in an axial direction.

BRIEF DESCRIPTION OF DRAWINGS

[0006] The accompanying drawings, which are incorporated into and constitute a part of this specification, illustrate one or more certain examples and, together with the description of the example, serve to explain the principles and implementations of the certain examples.

[0007] Figure 1A shows a perspective drawing of an ultrasound imaging probe, according to this disclosure.

[0008] Figure 1B depicts an example internal mixed array in the example ultrasound imaging probe in Figure 1A.

[0009] Figure 1C is a block diagram illustrating one example of a mixed array in an ultrasound imaging probe.

[0010] Figure 1D depicts part of the mixed array support structure of the

CLAIMS

What is claimed is:

1. An apparatus for use in imaging a target, comprising:
   A housing; and
   a distal portion coupled to the housing, comprising:
      an acoustic subarray on a first substrate configured to transmit acoustic signals toward the target;
      an optical subarray on a second substrate, configured to detect the acoustic signals from the target; and
      an input/output (I/O) region comprising one or more optical I/O channels configured to bend optical signals between the optical subarray and the one or more optical I/O channels, the one or more optical I/O channels comprising an optical fiber array in an axial direction.

2. The apparatus of claim 1, wherein the acoustic subarray comprises acoustic energy generating (AEG) transducers, wherein the AEG transducers comprise one or more of a piezoelectric transducer, a lead zirconate titanate (PZT) transducer, a polymer thick film (PTF) transducer, a polyvinylidene fluoride (PVDF) transducer, a capacitive micromachined ultrasound transducer (CMUT), a piezoelectric micromachined ultrasound transducer (PMUT), a photoacoustic transducer, and a single-crystal transducer.

3. The apparatus of claim 1, wherein the optical subarray comprises one or more photonic integrated circuit (PIC) modules comprising interference-based optical sensors, optical resonators, or interferometers.

4. The apparatus of claim 1, wherein the first substrate comprises aluminum, wherein the acoustic subarray is attached to the first substrate via thermally conductive epoxy.

5. The apparatus of claim 1, wherein the first substrate comprises one or more integrated thermoelectric coolers or one or more thermistors or

thermocouples.

6. The apparatus of claim 1, wherein the second substrate comprises aluminum a backing block for the optical subarray.

7. The apparatus of claim 1, wherein the housing further comprises a tuning circuit electrically connected to the acoustic subarray, wherein the tuning circuit is configured to condition acoustic signals transmitted from the acoustic subarray.

8. The apparatus of claim 1, wherein the optical fiber array comprises an angled surface with a mirror coating for bending optical signals to and from the optical subarray, wherein the angled surface is about 45 degrees in reference to an elevational-lateral plane of the optical subarray, or the angled surface further comprises a reflective focusing right-angle optical fixture.

9. The apparatus of claim 1, wherein the one or more optical I/O channels further comprise a refractive focusing right-angle optical fixture with a lens plate, wherein the lens plate is bonded with the optical fiber array and/or an interposer chip via a flat surface or the one or more optical I/O channels further comprises a polymer waveguide bonding the optical fiber array with the optical subarray via one or more edge couplers on the optical subarray.

10. The apparatus of claim 1, wherein the optical fiber array is coupled to an interposer chip connecting with the optical subarray in an elevational direction via one or more surface couplers.

11. The apparatus of claim 1, wherein the optical fiber array is mated with an interposer chip in the axial direction comprising a mirror structure with about 45 degrees in reference to an elevational-lateral plane of the optical subarray.

12. The apparatus of claim 1, wherein the I/O region further comprises one or

more electrical I/O channels, wherein the one or more electrical I/O channels comprises a flexible printed circuit, wherein the distal portion further comprises an interposer board electrically connected to the optical subarray via the one or more electrical I/O channels, wherein the interposer board is configured to optimize coupling between the optical subarray and the one or more optical I/O channels.

13. The apparatus of claim 12, wherein the flexible printed circuit is connected to the optical subarray via one-dimensional pad array wire-bonding or a two-dimensional pad array flip-chip bonding.

14. The apparatus of claim 1, further comprising an acoustic front stack with a curved acoustic front facet, wherein the acoustic front stack comprises an interface layer configured to contact a surface of the target for imaging and transmit acoustic signals between the apparatus and the target.

15. The apparatus of claim 14, wherein the interface layer comprises a biocompatible material with minimal acoustic impedance, wherein the interface layer comprises at least one of an acoustic matching layer with an acoustic impedance matching with the target for imaging, one or more acoustic lenses configured to focus and steer the acoustic signals to the target, an acoustic window comprising materials with reduced acoustic attenuation and matching acoustic impedance, or an elastomer couplant with low attenuation and impedance.

16. The apparatus of claim 14, further comprising a first matching layer connecting the interface layer with the acoustic subarray and a second matching layer connecting the interface layer with the optical subarray.

17. The apparatus of claim 1, wherein the housing comprises a type III anodized aluminum housing with a combination of organic contours, dimples, textures, and over-molded silicone regions.

18. The apparatus of claim 1, further comprising a heat sink located in the housing, wherein the heat sink comprises a layer of thermal compound

interfacing with the housing.

19. The apparatus of claim 1, wherein the one or more optical I/O channels are realized in a fiber array unit (FAU) platform, a PIC platform, or a planar lightwave circuit (PLC) platform.

20. The apparatus of claim 1, wherein the optical subarray is a flip chip, wherein the optical fiber array is attached to the optical subarray via one or more surface couplers.

21. The apparatus of claim 1, wherein the acoustic subarray and the optical subarray are juxtaposed in an elevational direction in the distal portion.

22. The apparatus of claim 1, wherein the acoustic subarray is placed on a flat top surface on a non-sensing area of the optical subarray in the axial direction.

23. The apparatus of claim 1, wherein the optical subarray comprises a plurality of modularized optical subarrays arranged in a stair pattern in an elevational direction.

24. The apparatus of claim 1, wherein a coupling gap between a core of the optical fiber array and a waveguide mode of an interposer in an elevational direction is less than 10 μm.

25. An apparatus for use in imaging a target, comprising:

an acoustic subarray on a first substrate configured to transmit acoustic signals toward the target;

an optical subarray on a second substrate, configured to detect the acoustic signals from the target; and

an input/output (I/O) region comprising one or more optical I/O channels configured to bend optical signals between the optical subarray and the one or more optical I/O channels, the one or more optical I/O channels comprising an optical fiber array in an axial direction.