Serving Healthcare

Using acoustic vibrations to manipulate liquids for handheld diagnostic devices

Advanced diagnostic systems are required in both developed and developing countries to test patients outside the centralized facilities of hospital laboratories. In the developing world especially, diseases such as Malaria, sleeping sickness (Human African Trypanosomiasis or HAT), and tuberculosis, still take a significant toll on the population. Professor Jon Cooper's group at the University of Glasgow has developed a technology based on ultrasonics and the nanometer vibrations they generate at the surface of microchips, to manipulate liquid samples and integrate diagnostic tests onto disposable portable systems. Laser vibrometry critically enables us to characterize the vibrations on the surfaces with a high spatial resolution and on large scales, to validate our designs. ►

Only a handful of tests, such as glucose personal management for diabetes, have made the transition from centralized facilities to being performed right next to the patient. To do that more widely, we use ultrasound to perform all of the different functions required to run a complete diagnostic assay on low cost disposable devices. A range of ultrasonic transducers, largely used in consumer electronics, have already been developed, including those using Surface Acoustic Wave (SAW) devices for both sensing and microfluidic manipulations [Friend, J. & Yeo, L., Rev Mod Phys, 2011, 83, 647], as shown in Figure 1a.

We have developed a new platform, in which the ultrasonic waves are coupled into a phononic lattice, a miniaturized array of mechanical elements (Figure 1b-c). In a similar way that differences in refractive indices within the elements of a hologram can 'shape' light, the ultrasonic field is modulated by the elastic contrast between the elements in the phononic array and the matrix surrounding them. [R. Wilson et al. Lab Chip, 2011, 11, 323].

In one implementation of the platform, we have applied this technology to an integrated nucleic acid based test for the diagnosis of malaria. This assay is targeted at analyzing the genetic material of the parasite, located within red blood cells in the blood of infected patients. Figure 2 shows simulations and vibrometer measurements that illustrate the use of a phononic device to shape the waves to perform these specific functions.

VIBROMETRY MEASUREMENTS

The measurements were carried out using a Polytec UHF-120 system at 9.35 MHz excitation. The originality of these scans lie with the different scales involved in the measurements, which resulted in long scans to cover sufficient area (a liquid sample of a few mm) to obtain a valid result on vertical amplitudes below 1 nm, at resolutions below the wavelength (100 µm). In some instances, scans have taken as long as 10 days to cover cm-wide areas (see Figure 3).

CONCLUSIONS

Phononic surface acoustic wave devices have shown great potential for enabling integrated point-of-care diagnostics, using the mechanical energy carried by sound to manipulate liquid samples from patients on low-cost microchips. We have demonstrated the detection of malaria [Reboud J. et al., PNAS, 2012, 15162-7] from the volume of a fingerprick of blood using an acoustic filter. Laser vibrometry is an essential tool of the development process that permits us to visualize vibrations on the surface across the entire microchips, thus validating our designs. In the future, more complex assays will be integrated on the platform to detect diseases such as tuberculosis. ■

Polytec

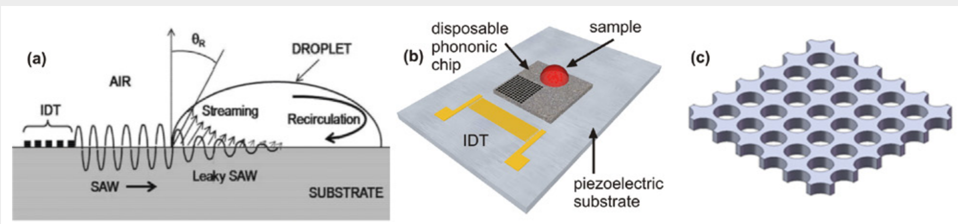
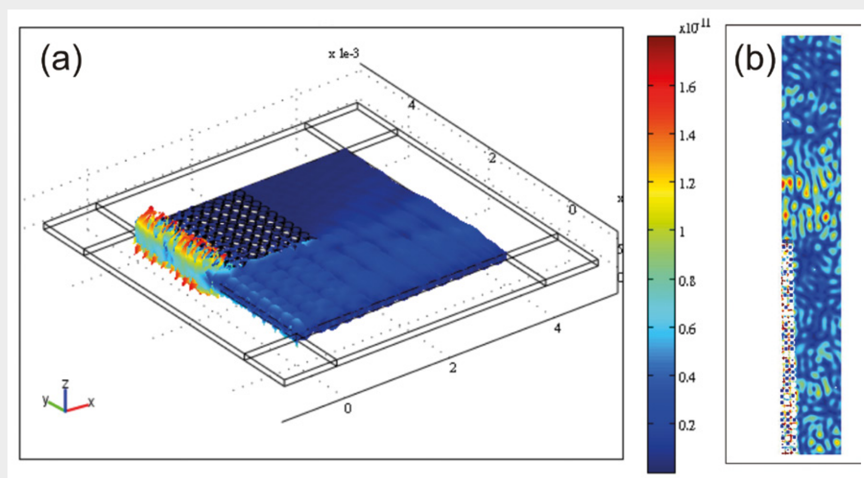


Figure 1: (a) SAW propagating on a piezoelectric substrate transferring mechanical energy into a liquid sample; (b) an alternative format where a phononic bandgap structure is patterned onto a disposable superstrate, which is placed on the piezoelectric substrate; (c) Example schematic of a phononic lattice (holes of 80 µm in diameter).

Figure 2: A phononic filter was (a) simulated (Comsol Multiphysics) and (b) measured using laser vibrometry (UHF, Polytec) at 9.35 MHz excitation. Results (vibration amplitude) show the attenuation of the waves within the structure (represented by the array of empty holes in the measurement (b)) while they propagate outside of it. The device is ca. 1.5 cm wide.



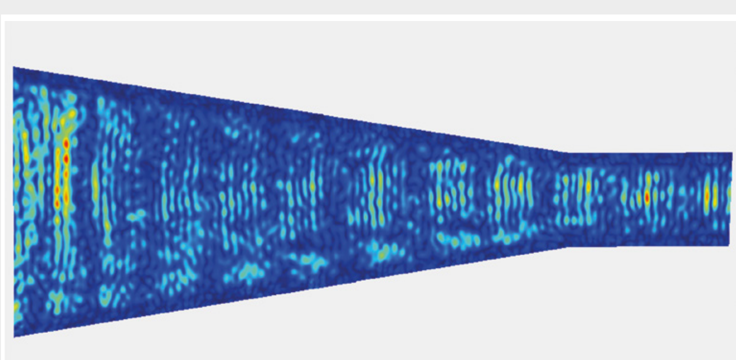


Figure 3: Vibrometer scan revealing the amplitude of vibrations in a phononic cone, able to focus the energy at specific locations. Scan of ca 190 000 points at 9.35 MHz. [Reboud J., et al, Lab Chip, 2012, 1268-73] – scale bar is 200 µm.

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