Electronic Supplementary Material (ESI) for Lab on a Chip.

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Acoustofluidic Devices Controlled by Cell Phones

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1. RLC Resonant Circuit

In order to achieve sufficient voltages to power our acoustofluidic device, we implemented a RLC resonant circuit. The RLC circuit achieves resonance at the AC frequency where the inductor (L) and a capacitor's (C) impedances cancel each other (Fig. S1a, b). At this frequency, the impedance is a minimum, and the current flowing through the circuit reaches its maximum. At this point, even though the impedances across the capacitor and inductor cancel, the voltage across these elements is amplified. Conveniently, the disc style piezoelectric transducer used to power our pump acts as a capacitor, and thus only the correct inductor is necessary to complete the circuit. The physical equations governing this phenomena are as follows: $X_L = 2\pi f L$ and $X_C = \frac{1}{2\pi f C}$, where X_L and X_C are the inductive and capacitive reactances, L is the inductance (Henries) and C is the capacitance (Farads), respectively. The frequency at which these values negate each other is found by equating the magnitude of these equations and is given as: $f = 2\pi\sqrt{\frac{1}{LC}}$. At this frequency, the current through the circuit is represented by the following equation: $I = \frac{V}{R}$, where V is the supplied AC voltage and R is the resistance of the circuit. It follows that the voltage across the capacitor (equal in magnitude to that across the inductor) is given by: $V_C = I * X_C$. This voltage is greater than the voltage of the source, thus achieving amplification. The magnitude of amplification can be tuned by varying the value of the resistor, and the resonant frequency can be varied with different inductors (Fig. S1c-d). A variable inductor could also be used to provide tuning capabilities to the circuit.

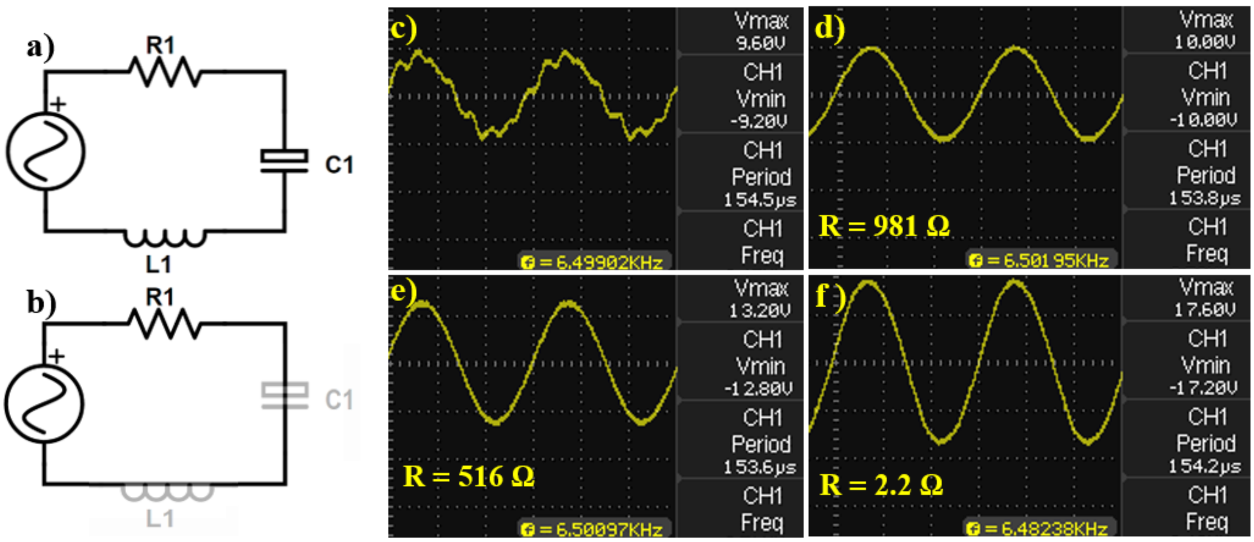

Figure S1 Schematic of the RLC circuit. (a) Actual circuit design. (b) Equivalent circuit at the resonance frequency. The impedance of the capacitor and inductor negate each other at resonance, acting like a short circuit (represented by gray elements). (c) Original signal directly from the Bluetooth speaker. (d-f) Various voltages achieved by tuning the series resistance. The sinewave signal shows improves clarity after passing through the RLC circuit.

2. Detailed Device Design

The following figures provide schematics and dimensions for each of the sharp-edge based devices used in experimentation. The channel depth for each of the devices is 100 µm, while the channel widths is 600 µm.

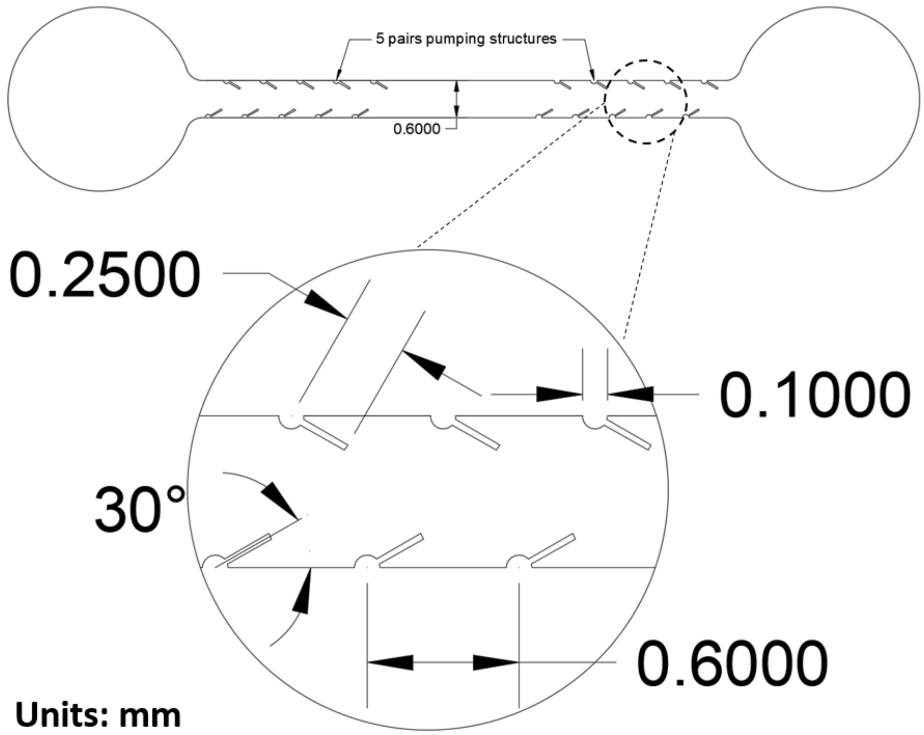

Figure S2. Channel schematic and dimensioning for the sharp-edge based pumping device. 30-degree tilted structures produce acoustic streaming that pumps fluid.

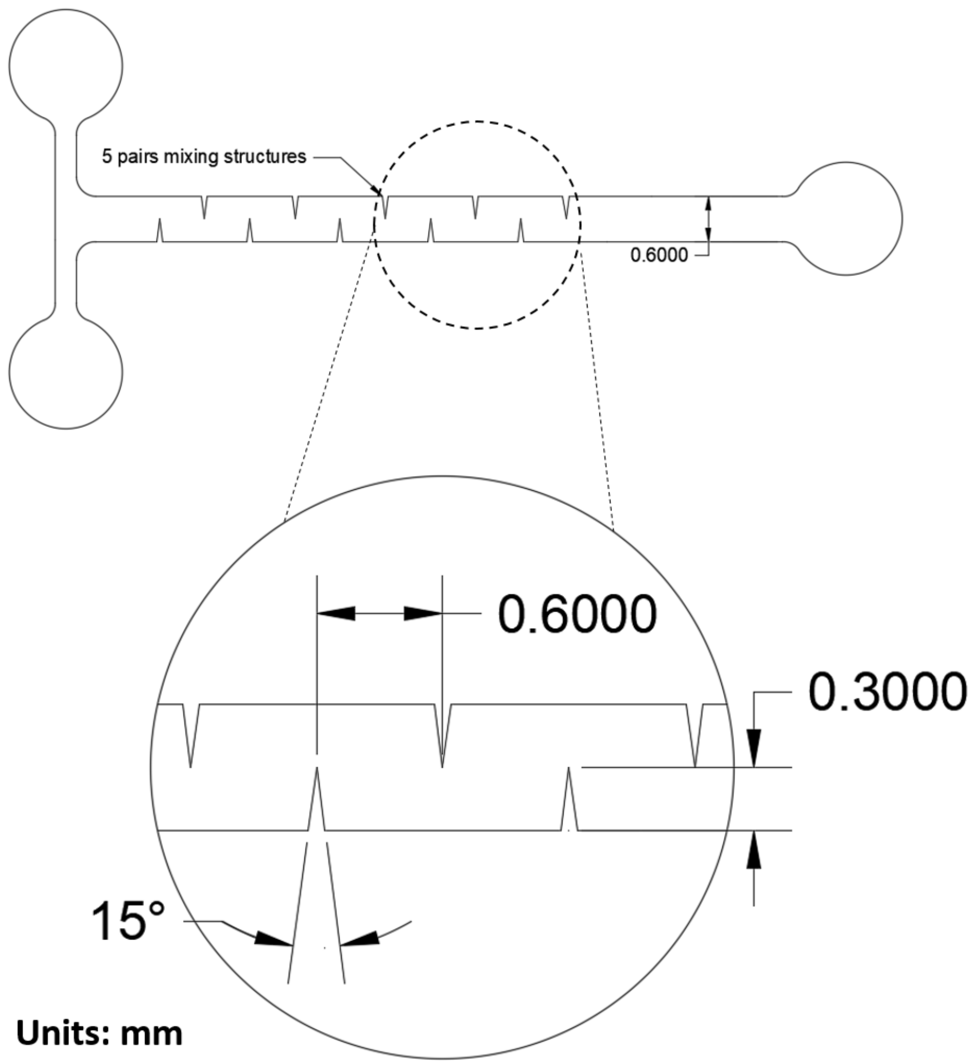

Figure S3. Channel schematic and dimensioning for the sharp-edge based mixing device. Vertical sharp-edge structures produce acoustic streaming that mixes fluid in the channel.

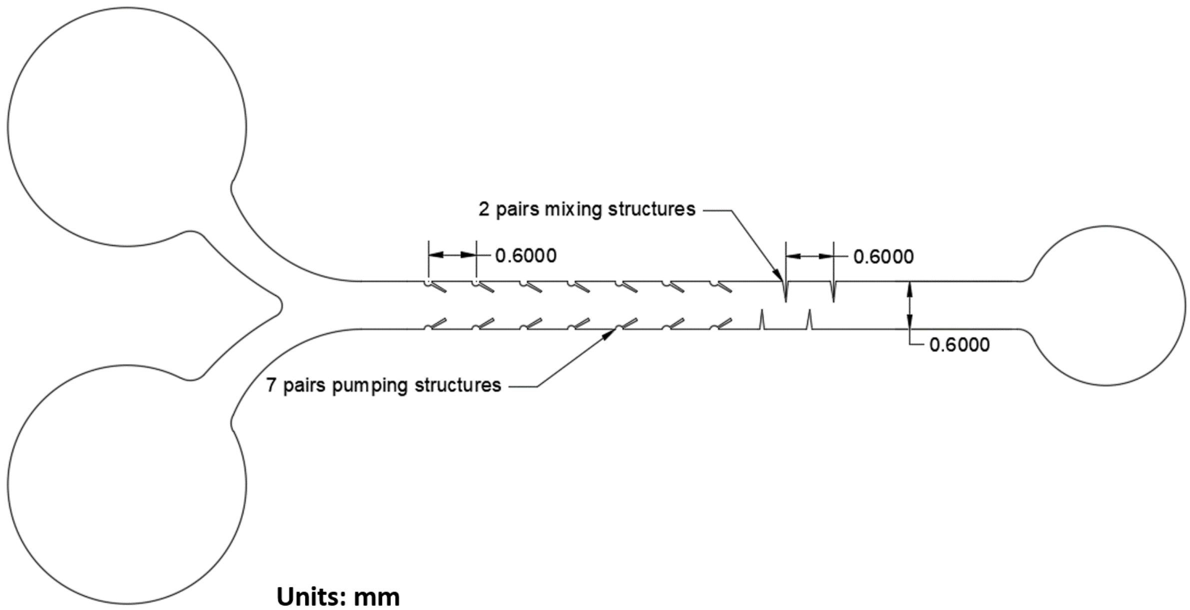

Figure S4. Channel schematic and dimensioning for the combined pumping and mixing device. Dimensions for the individual sharp-edge structure are consistent with those given in Fig. S2-3.

3. Portable microscope

The portable microscope used in experiments was based around a commercially available cell phone microscope (CML-60X-100X-BL-01,Efanr®). As displayed in Fig. S2, the cell phone microscope has a dial that allows for fine adjustment of the focus, which is needed to achieve a crisp image. Acrylic sheets were cut with a laser cutter (Epilog Zing, Epilog Laser). Large threaded bolts and nuts were used to secure the platforms at the correct height, and this also allows users to change the distance between platforms depending upon the sample. 3D printed components were used to hold and align components including the cell phone, filters, diffusers and LEDs.

Filters purchased were designed for use with Alexa Fluor 488™, which has an excitation and emission center frequency of 498nm and 520nm, respectively. Using this, a band pass excitation filter (AT480/30x, Chroma) was placed in between the blue LEDs and the sample with a center frequency of 480nm and a Full width at half maximum (FWHM) value of 30nm. This will allow enough excitation light to reach the sample, but not crossover into the frequency range of the emission filter (part no. 86-939, Edmonds Optics); the frequency data of the emission filter was 525nm for the center frequency, with a FWHM value of 50nm.

While these filters work well with Alexa Fluor 488™, the 3D printed components used to hold the filters allows for easy modification when using other fluorochromes with varying excitation and emission frequencies. A diffuser (part no. 43-723, Edmonds Optics) was placed in between the light source and the sample to ensure an even light field within the cell phone camera image.

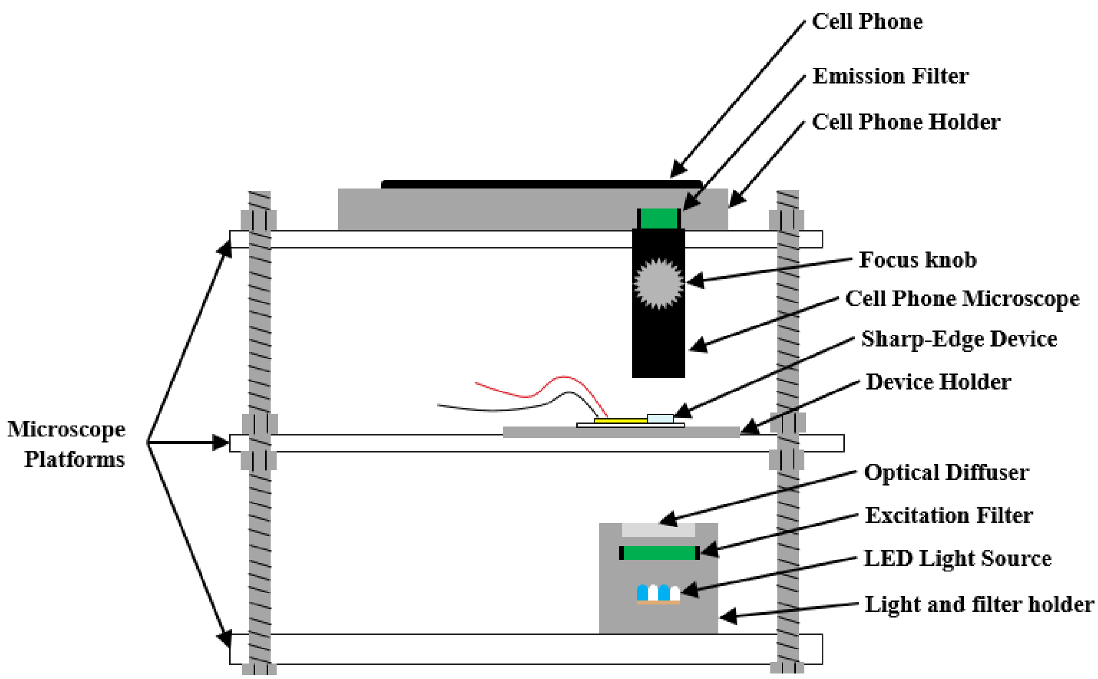

Figure S5 Schematic of the portable microscope. The nuts and bolts used to connect the different stages of the microscope allow for course focusing, and the commercial cell phone microscope has dials for a finer focus.

4. Video Captions

Video 1: Operating the Device

First, the sharp-edge based pump was connected to the power source; then, the device was power supply was turned on and the Bluetooth® connection was established with the phone. Next, the specific sound file was chosen to operate the sharp edge pumping device. Playing the sound file through the Bluetooth® speaker starts pumping the fluid in the channel. Pausing the sound file will deactivate the pump.

A custom sound file was chosen which plays for two seconds then has four seconds of silence. The pumping in the channel mimics the pulsing sound file, demonstrating custom pumping performance. After this demonstration, the frequency of the signal passed to the device was modulated. Frequencies farther away from the resonance of the device do not create as strong of a flow. Lastly, the volume on the cell phone was varied to show how the flow rate of the pump could be changed on demand.

Video 2: Portable microscope pumping

5µm particles in isopropanol were pumped using a sharp edge pump and the Bluetooth® speaker. The portable microscope was used to record the particles.