Supplementary

Simulations of acoustic valve with asymmetric parameters

Several simulations are carried out to analyze the acoustic valve under asymmetric parameters and different device design. Compared with Fig. 2(e), the higher voltage makes the acoustic pressure field generated by transducer 2 in Fig. S1(a) have a clearer and complete distribution. When the voltage of two transducers is the same, the interference of acoustic field will make the distribution of acoustic pressure field not as orderly as when only one transducer is turned on. The interference is more obvious when the two transducers are closer to each other. When transducer 1 remains unchanged, transducer 2 approaches transducer 1 by 90 μm along y direction, (Fig. S1(b)) the acoustic pressure field generated by transducer 2 has been greatly affected by the interference. (Fig. S1(c)) Although the voltage applied is the same as in Fig. 2(e), its pressure distribution has been largely disturbed. In addition, the interference also reduces the amplitude of the pressure field. In this case, the situation can be reversed by increasing the voltage on transducer 2 and decreasing the voltage on transducer 1. The acoustic pressure field generated by transducer 1 is almost completely disturbed by interference. (Fig. S1(d))

In Fig. S1(e), the geometric focus positions of the two transducers remain unchanged, the angle between the transducers and the main channel is changed, and the angle between the branch channels and the main channel is changed. Changing the transducer angle ε and the channel angle ε in this way will cause the intersection of the transducer geometric center lines (in short, called geometric intersection of the transducers) and the intersection of the extension line of the branch channel wall (in short, called branch channel center) not to coincide.

Two design of 25° (Fig. S1(f)) and 65° (Fig. S1(g)) are used in the simulations. It can be seen that all the acoustic pressure fields have orderly and clear distribution. In order to achieve droplet deflection in practice, the focused acoustic field needs to point to the branch channel to which the deflected droplet will go. For example, transducer 1 needs to point to branch channel 3. Although this does not mean that the center line of the transducer and the center line of the branch channel need to be parallel or

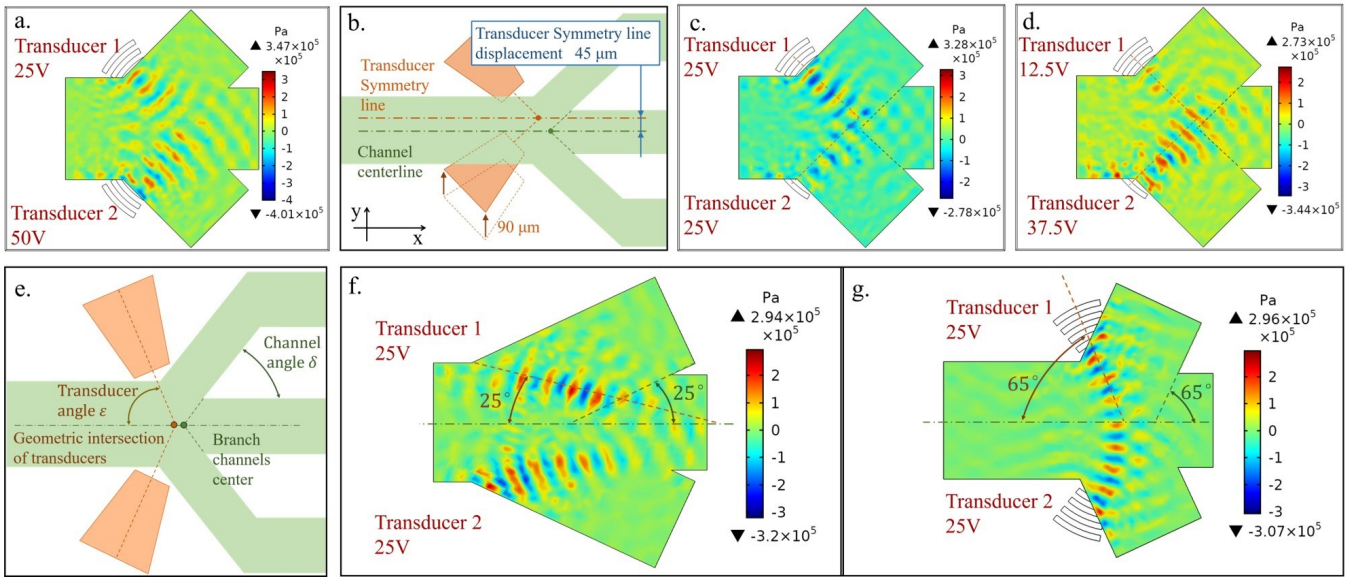

Figure S1: Acoustic pressure field simulation under asymmetric parameters and different device design. (a) The acoustic pressure field when two transducers applied with different voltages. (b) Transducer 1 remains unchanged, and the symmetrical lines of the two transducers move 45 μm in y direction. That is, the transducer 2 moves 90 μm in y direction. When the symmetry line moves in y direction, the intersection of the geometric center lines of the two transducers will move along the geometric center line of transducer 1, not y direction. The design of asymmetric distribution of electrodes and channels is applied to the simulations in (c) and (d). (e) When the transducer angle and branch channels angle are changed, the position of the valve center will also be changed. Two design of 25° (f) and 65° (g) are used in the simulations. All dashed lines and dot dash lines in the figure are only schematic diagrams, roughly marking the positions of some center lines and extension lines.

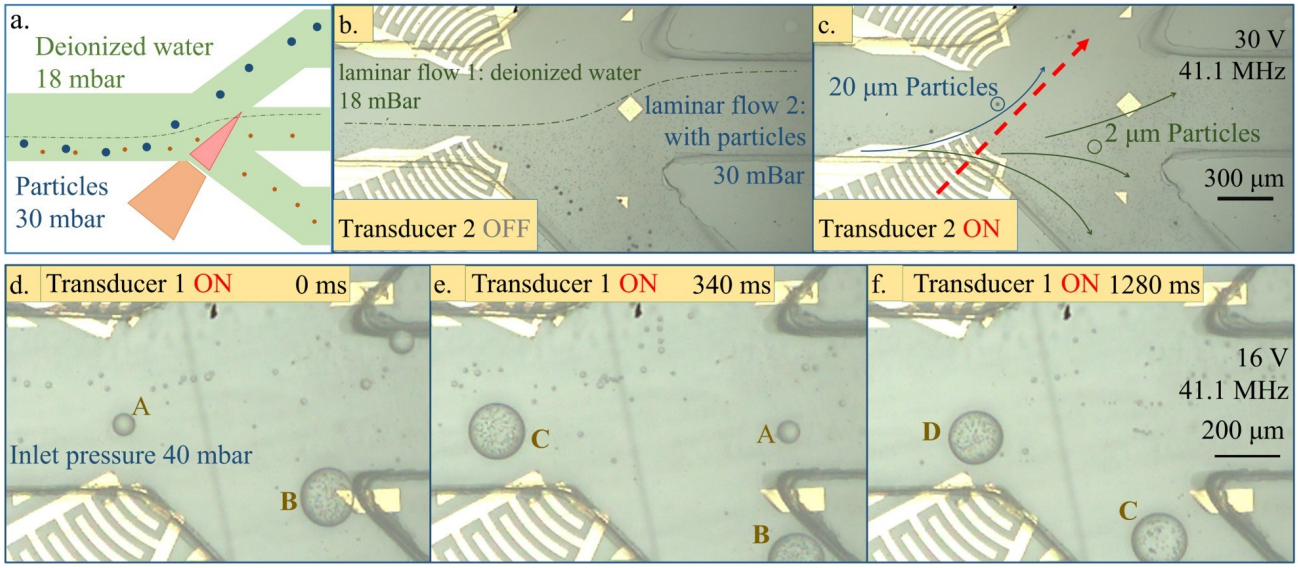

Figure S2: Particle and biological cell experiments. (a) Keep the transducer turned on, and targets of different sizes will be sorted to different branch channels. (b) The interface between the two laminar flows is very clear. The green curve refers to the approximate boundary of two laminar flows. (c) The sizes of the two kinds of particles are 2 and 20 μm. The red dotted line refers to the approximate position of the acoustic field and the direction of SAW propagation. The d_o in (b, c) is 100 μm. The blue and green curvilinear arrows are the approximate trajectories of 20 μm particles and 2 μm particles, respectively. (d, e, f) Droplets of different sizes can also be sorted by acoustic field that remains ON. The d_o in (d, e, f) is 100 μm. Multiple droplets are marked to locate their positions in different images, so as to display their trajectories.

even collinear, in this simulation, the two angles are set to be the same, so that the transducer can roughly point to the branch channel.

In Fig. S1(f), the acoustic pressure fields on both sides failed to close the main channel completely, and also failed to point to the branch channels. The transducers should be shifted to the left along the x-axis to optimize the acoustic pressure distribution. As a contrast, when transducer angle ε and channel angle ε are both 65° , the two acoustic pressure fields can close the whole channel, and each of them point to different branch channels.

Particle and biological cell experiments

In the experiment of Fig. S2(a, b, c), the phosphate buffer solution (PBS) flows with suspended particles through the inlet of the main channel, while the PBS without particles flows through the inlet of the T-shaped channel, which is originally used to generate droplets. All particles enter branch channel 2 and 3 by controlling the inlet pressure of the T-shaped channel, that is, using PBS as sheath fluid. Afterward, 20 μm particles will go to branch channel 1 when transducer 2 is turned on. The pressure of main channel and T-shaped channel inlets is 30 mbar and 18 mbar, respectively. The average velocity of the 20 μm particles in main channel is about 8351 μm/s, which is an average of three measurements, and measured when the acoustic field is OFF.

To consolidate the valve functioning for sorting applications, droplets encapsulated with biological cells are used for passive sorting. (Fig. S2(d, e, f)) Three kinds of droplets were used in the experiment. The larger droplets are physiological saline with porcine red blood cells, about 180 μm. The medium droplets are deionized water droplets, about 50μm. The smallest droplet is deionized water droplet, about 10μm. The 180 μm physiological saline droplets with porcine red blood cells are generated through T-shaped channel, the inlet pressure is 5 mbar. The 50μm deionized water droplets and the 10μm deionized water droplet are generated in advance, and injected into main channel with continues phase. The continues phase FC-40 is biocompatible, [1] causing no damage to pig red blood cells in the droplets.
When transducer 1 remains on, the pig blood droplets are deflected by the acoustic field and enter the branch channel 3, like droplet B and C. In contrast, 50μm droplets can pass through the acoustic valve and enter the branch channel 2, like droplet A.

This sorting method will not damage the cells in the droplet. In Fig. S2(f), the blood cells in droplet C aggregate, which is a normal phenomenon in acoustic cell manipulation. SAWs can induce cell aggregation without damage to cells, [2] and can be used for separation of plasma and blood cells [3].

In the experiments shown in Fig. S2, 2 and 20 μm particles are polystyrene microspheres (Rainbow, Tianjin BaseLine Chromtech Research Center, China). Two kinds of particles are suspended in PBS (SS6235, Biofount, CN). A total of 1% sodium dodecyl sulfate (SS0013, Biofount, CN) is added to PBS to prevent particle aggregation. Pig blood (Sodium citrate pig blood, Shanghai YuDuo biological science and Technology Corporation, CN) was diluted 20 times by normal saline.

Notes and references

1 Prastowo, A., Feuerborn, A., Cook, P. R., & Walsh, E. J., *Biomedical Microdevices,* 2016, **18**, 114.
2 Li H, Friend J R, Yeo L Y. *Biomedical microdevices,* 2007, **9**, 647-656.
3 Sudeepthi A, Sen A K, Yeo L. *Microfluidics and Nanofluidics,* 2019, **23**, 1-11.