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

Supplementary Information

Acoustic tweezers based on circular, slanted-finger interdigital transducers for dynamic manipulation of micro-objects

Putong Kang,[a,1] Zhenhua Tian,[b,1] Shujie Yang, [a,1] Wenzhuo Yu,[a] Haodong Zhu,[a] Hunter Bachman,[a] Shuaiguo Zhao,[a] Peiran Zhang,[a] Zeyu Wang,[a] Ruoyu Zhong,[a] and Tony Jun Huang[a,*]

a. Department of Mechanical Engineering and Materials Science, Duke University, Durham, NC 27708, USA.
b. Department of Aerospace Engineering, Mississippi State University, Starkville, MS 39762, USA.

[1] These authors contributed equally to this work.

*Corresponding author. Email: tony.huang@duke.edu

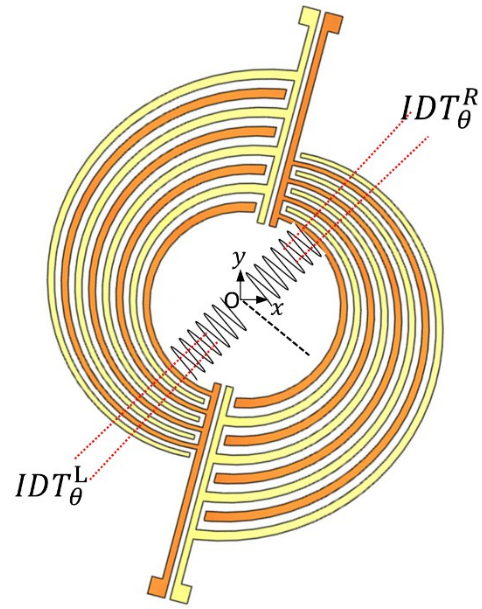

Figure S1. Schematic of acoustic tweezers composed of a pair of CSFITs for illustrating the case that angular sections in a pair are excited using an input signal with one frequency component.

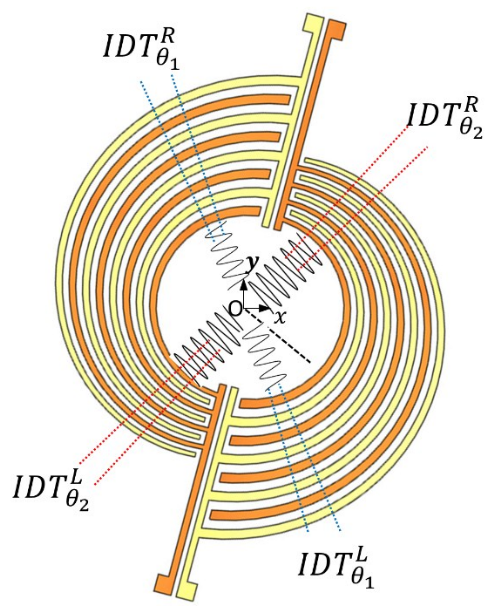

Figure S2. Schematic of acoustic tweezers composed of a pair of CSFITs for illustrating the case when angular sections in two pairs are excited using an input signal with two frequency components.

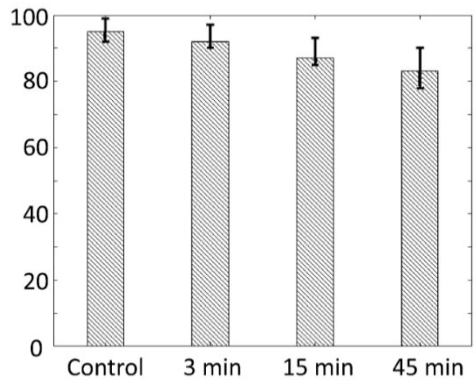

Figure S3. Viabilities of K562 cells for the control group without any SAWs and three test groups with different exposure durations (3, 15, and 45 mins) of SAWs.

Section S1. The configuration of acoustic tweezers based on CSFITs

Figure S1 shows a schematic of the acoustic tweezers based on circular slanted-finger interdigital transducers (CSFITs). The device is composed of a pair of CSFITs that are in a centrosymmetric distribution with respect to the origin O. We can define an infinitesimal element in the θ direction and its couple in the $\theta + \pi$ direction and denote them as the θ^{th} pair, as illustrated by the area between dotted lines in Figure S1. The two angular sections are denoted as IDT_θ^L and IDT_θ^R. These two sections have the same finger spacing d_θ and the same width d_θ of electrodes. Hence, they have the same resonate frequency $f_\theta = \frac{c_\theta}{4d_\theta}$, where c_θ is the phase velocity. Coordinates of tangent points on the inner edges of inner electrodes are denoted as x_θ^L and x_θ^R. Considering the centrosymmetric distribution of CSFITs, we can find that $x_\theta^L = -x_\theta^R$.

Section S2. Material properties

The material properties of $LiNbO_3$ wafers for simulations are

$$[\varepsilon] = \begin{bmatrix} 43.6 & 0 & 0 \\ & 43.6 & 0 \\ Sym & & 29.16 \end{bmatrix}$$

$$[e] = \begin{bmatrix} 0 & 0 & 0 & 0 & 3.69 & -2.53 \\ -2.54 & 2.54 & 0 & 3.69 & 0 & 0 \\ 0.19 & 0.19 & 1.31 & 0 & 0 & 0 \end{bmatrix} C/m^2$$

$$[c] = \begin{bmatrix} 202.90 & 52.92 & 74.91 & 9.00 & 0 & 0 \\ 52.92 & 202.90 & 74.91 & -9.00 & 0 & 0 \\ 74.91 & 74.91 & 243.08 & 0 & 0 & 0 \\ 9.00 & -9.00 & 0 & 59.90 & 0 & 0 \\ 0 & 0 & 0 & 0 & 59.90 & 8.99 \\ 0 & 0 & 0 & 0 & 8.99 & 74.88 \end{bmatrix} \times 10^9\ Pa$$

Where $[\varepsilon]$ is the relative permittivity matrix, $[e]$ is the piezoelectric coupling matrix, and $[c]$ is the elasticity matrix. The density of the $LiNbO_3$ substrate is 4700 kg/m^3.

Movie S1. Dynamic process of aligning K562 cells using CSFIT based acoustic tweezers.

Movie S2. Transformation of particle patterns by switching the excitation frequencies in CSFIT based acoustic tweezers.

Movie S3. Translation of particle patterns through phase modulation in CSFIT based acoustic tweezers.

Movie S4. Translation of single microparticles along complex paths in CSFIT based acoustic tweezers.