On-demand sample injection: Combining acoustic actuation with a tear-drop shaped nozzle to generate droplets with precise spatial and temporal control

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Supplementary Information (SI)

LDV Measurements

The input substrate velocity to the model presented in the modelling section was taken from measurements of the substrate displacement as measured on a Laser Doppler Vibrometer (Polytec UHF-120) shown in Figure S1. Although the available signal generator was not capable of applying the same power as the amplifier used in the experiments, the $LiNbO_3$ linear relationship between applied voltage and displacement amplitude allowed it to be extrapolated. Based on an applied voltage of 7 V during ejection, the $LiNbO_3$ would be displaced 230 pm peak-to-peak.

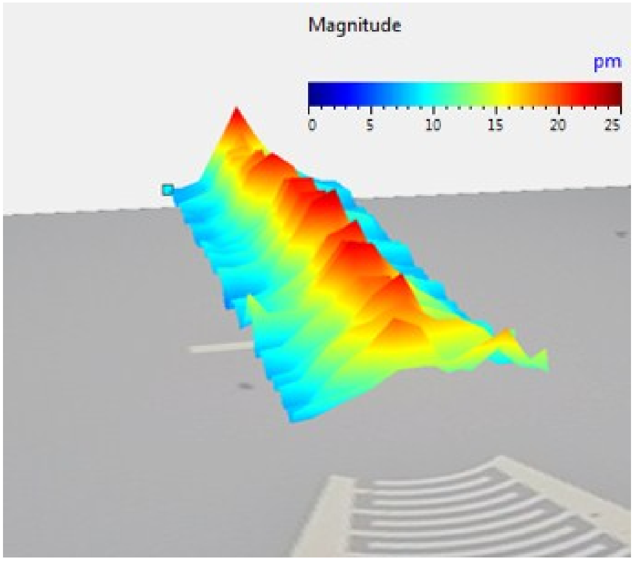

Figure S1: LDV measurements of substrate displacement due to traveling SAW emanating from focused IDTs

Measurement of Capillary Pressure

The capillary pressure at the nozzle was measured to validate the assumptions made in equation 4 discussed in the section on the driving mechanism. This was achieved by connecting an ejection device to a finely controlled pressure pump (Fuigent MFCS^{TM}-EZ) and recording the shape of the interface at the nozzle. The device was filled with water and positioned on a 3D printed inclined stage, again because of the location of the nozzle, under an upright microscope (Olympus BX43) as indicated in Fig. S2c. Its shape was recorded with a USB camera (Dino-Eye AM7025X) and the shape of the interface was identified by positioning lighting such that the centreline of the nozzle was highlighted. This curve was mapped and then transformed to account for the angle of the objective relative to the nozzle centreline using a custom MATLAB script.

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The measured profile was assumed to be in contact with the SiN_x at all points around the nozzle edge, given that the interface remained confined to the nozzle. Using this data, the measured spline was interpolated to produce surface plots for a range of pressures, one of which is shown in Fig. S2a. The mean curvature of these interfaces was then computed, and then subsequently plotted against applied pressure and compared to equation 4 in Fig. S2b.

Although there is some deviation from the Laplace-Young equation, given the indirect measurement of the curvature and the complex shape of the interface, the predicted pressures show reasonable agreement with those measurements. For the nozzle shown in Fig. S2d there was a sharp rise in the mean curvature above 3 kPa indicating the maximum capillary pressure of the nozzle had been exceeded and droplet ejection would occur at pressures above this value.

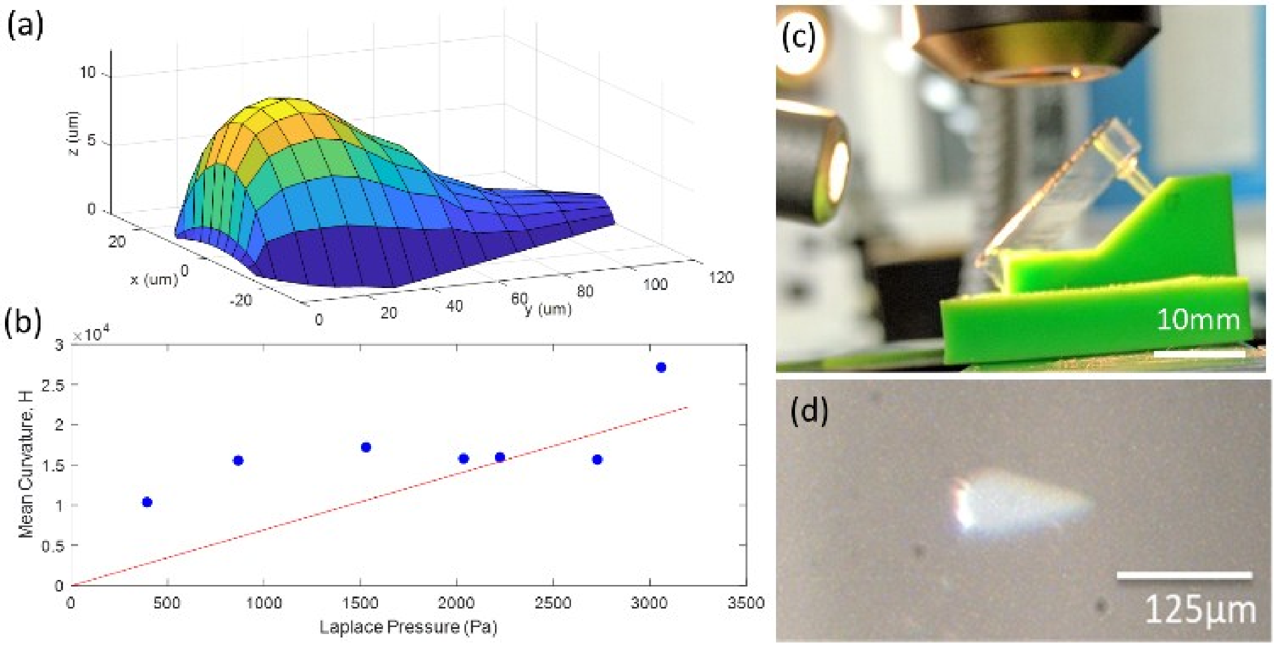

Figure S2: (a) Interpolated interface, measured at 3.06 kPa, used to calculate mean curvature (b) Measured mean curvature of interface at different applied pressures, blue circles, compared to predicted curvature based on equation 4, red line. (c) Photograph of device under microscope with directed illumination to highlight curvature (d) Optical image of nozzle shape where edges were defined by zero interface displacement.