Supplementary Information

A simple microfluidic dispenser for single-microparticle and cell samples.

A. Kasukurti, C.D. Eggleton, S.A.Desai, D.I. Disharoon, D.W.M. Marr*

Section 1

Derivation of probability of doublets

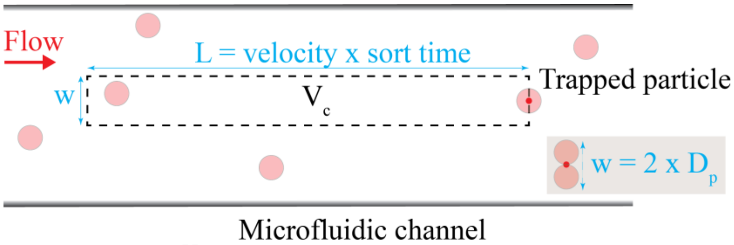

Figure S1: Schematic identifying the unit volume V_c encapsulating fluid volume flowing past the optical trap during the sorting. Here, width of the control volume w is the capture range of the optical trap and is approximately twice the particle diameter (inset image) and L, length of the control volume is the length of the column of fluid that will flow past the optical trap during the sorting. Marked in red is the optical trap and the pink circles represent microparticles or cells.

Doublets arise primarily due to optical trapping and isolation of multiple particles at once, which happens when a second particle flows into the trap after it has already trapped a sorting target. To identify the appropriate system parameters that influence doublet formation, we quantify the probability of a second particle in the fluid plug flowing into the optical trap during the time the detection system requires to identify and translate a trapped particle away from the particle streamlines. This fluid plug has unit volume V_c, of length L, width w and height h as illustrated in Figure S1. The total time the optical trap requires to detect and translate a particle or cell out of the path of this fluid plug is defined as τ and with the average flow velocity υ, $L = \upsilon\tau$. We define a normalized concentration φ as the number of particles per defined unit volume V_c in the bulk sample at particle concentration C µm^{-3} and $\varphi = CV_c = CLwh = C\upsilon\tau wh$. The probability of a unit volume having x number of particles is governed by a Poisson distribution $P(x) = e^{-\lambda}(\varphi^x/x!)$[1]. With this, the doublet probability becomes,

$$P_{doublet}(\varphi) = P(x > 0) = 1 - P(x = 0) = 1 - e^{-\varphi}$$

For our microparticle system, C = 3x10^{-5} µm^{-3}, υ = 60 µm s^{-1}, τ = 1.2 s, w = 10 µm, h = 10 µm, $\varphi = C\upsilon\tau wh$ = 0.216 and $P_{doublet}(\varphi)$ = 19.42%.

Section 2

Derivation of back force oscillation

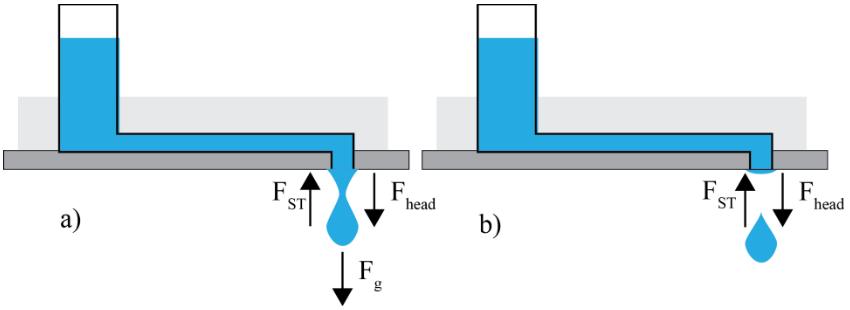

Figure S2: Illustration of the forces involved in droplet formation. F_{ST} is the force caused by surface tension, F_g is the gravitational force and F_{head} is due to the pressure head a) During droplet formation, surface tension forces pull the fluid up while pressure head and droplet mass pull the droplet down. b) Immediately after a droplet falls, there is no gravitational force due to the mass of the droplet opposing the surface tension force causing a sudden change in the force balance at the exit induces a back pressure wave proportional to the falling droplet weight.

The net force on the droplet while it is forming is,

$$F_b = force\ due\ to\ pressure\ head + gravitational\ force - surface\ tension\ force$$

, where surface tension forces arise due to the water-air hydrophobic glass interface and gravitational force due to the mass of the droplet being formed. Assuming pressure head and surface tension force are constant the droplet formation, oscillations is back force are approximately $\Delta F_b = \Delta(gravitational\ force) = \Delta mg$. With the droplet mass m of ~55 mg, we expect oscillations in back force of ~550mN oscillations.

Section 3

Final Design parameters

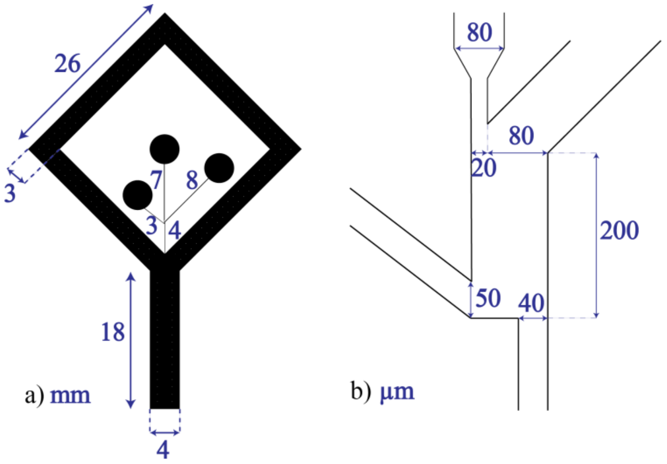

Figure S3: Device dimensions. a) Supply channels (mm). b) Particle isolation section (µm). (see Figure 2 for location of each)

References

S1. L. Mazutis, J. Gilbert, W. L. Ung, D. A. Weitz, A. D. Griffiths, and J. A. Heyman, *Nat. Protoc.*, 2013, **8**, 870–891.