Supplemental Information

Calculation of average flow rate and shear stress

Values for average flow rate and shear stress, given in the text, are derived via simulation from the steps and equations given below. These equations are based on a previous publication (Berthier and Beebe, *Lab Chip*, 2007, **7**, 1475–1478).

Step 1. To solve for the time, *t*, it takes a drop to collapse at the inlet, one uses:

$$t = -K_y\left[\frac{H^4 - H_0^4}{4} + R_w^2\left(H^2 - H_0^2\right) + R_w^4 ln\left(\frac{H}{H_0}\right)\right],$$

where H_0 is the original drop height, R_w is the wetted radius (assumed here to be equal to the inlet port), K_y is a function of the fluidic resistance and liquid properties and H is the drop height as it decreases during drop collapse.

The original drop height, H_0, is calculated using H_0 = (1-cos(θ))*r/sin(θ) where θ is the contact angle between the inlet drop and the inlet port. We assume a 135-degree contact angle, θ, based on observation. This results in an original drop volume of 3.8 μL, which is a close approximation to the drop volume of 5 μL used in experiments. Note that as soon at a drop comes in contact with the inlet port it begins collapsing, so this approximation is valid for practical purposes. The height during the drop collapse, H, ranges from $H = H_0$ to $H = zero$. The factor K_y is calculated using $K_y = \pi * K_w/(8*\Upsilon)$; where Υ is the liquid surface tension and K_w is the fluidic resistance of the microfluidic channel.

Step 2. The flow rate, *Q*, at each time step during drop collapse is found using:

$$Q = \left(-\frac{\pi}{2}\right)\frac{d(H)}{dt}\left(H^2 + r^2\right),$$

where

$$\frac{d(H)}{dt} = \left(-\frac{1}{K_y}\right)\frac{H}{\left(H^2 + r^2\right)^2}.$$

Step 3. The shear stresses, τ, are found using $\tau = (6*\mu*Q)/(w*h^2)$; where μ is the dynamic viscosity of water ($1.003*10^{-3}$ Pa·s), h is the channel height (280 μm) and w is the channel width (2 mm).