Acoustofluidic clump formation: Experiments on the location and development stages

Jeremy Hawkes visiting and working with Tatsuki Fushimi, Luke Cox, Jenna Shapiro and Liangfei Tian in Bruce Drinkwater's laboratory, University of Bristol, 1-5 April 2019

The week involved conversations and experiments with members from the lab and associated labs of Bruce Drinkwater. The theme of these was: where do particles form clumps in acoustofluidics systems?

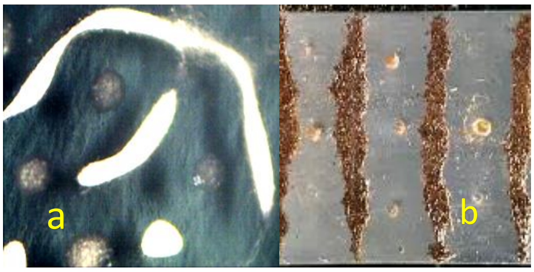

Figure 1 *a) In water, 5µm diameter silicon, 1.3MHz: sausage shapes near lower surface, discs suspended in fluid. b) In air, tea leaves, 40 kHz: sausage shapes on surface, discs levitated.*

Figure 1 shows the clumps formed by two systems I took to Bristol: these form clumps of particles in water above a microscope slide and in air above an aluminium plate.

I learned: 1/ In air large and small particles move to the pressure and velocity nodes, respectively. I believed that solid and liquid droplets move to different nodes since in my previous experiments droplets of liquid aerosols (4-100 µm diameter) moved to pressure nodes, while suspensions of solid particles (2-10 µm diameter) moved to velocity nodes. An experiment with Luke Cox convinced me that large liquids droplets and solid particles of expanded polystyrene (both ~ 1mm diameter) moved to the same location in his levitation system. Also Jenna Shapiro had previously observed that big and small solid particles move to different locations with a crossover probably in the region of 50 µm diameter. I had some theoretical papers predicting this phenomenon which I gave to Jenna (before seeing the results from Jenna and Luke I was unconvinced by these papers).

2/ Tatsuki Fushimi showed in a system that levitated particles on a single axis: Particles form clumps where two waves are 180° out of phase. This concept was also 180° different from what I previously thought. In my levitation system (Fig. 1b) clumps never form in the region of the 180° phase change. However, this is also a minimum sound amplitude region. Tatsuki's results indicate that in my system it is the low sound amplitude not the phase change which is determining the location of the clumps.

Experiments showed: the orientation of clumps above the microscope slide depends on the meniscus orientation, i.e. the very thin edge, while the large surfaces of the reflector and driving plate seem less significant.

Figure 2 *Suspension below a plastic film window 0.75 mm above a microscope slide vibrating at 1 MHz. Window is at an angle to the slide, to show that the thin lines of clumps form parallel to the meniscus and not the slide. The pattern of larger clumps also visible was influenced more by the orientation of the microscope slide.*

Summary

- Larger particles move to pressure nodes smaller ones to the antinodes.
- Particles gather in clumps where the sound is a minimum; this effect overrides the drive for clumps to form where the phase changes.
- Lateral forces determining the location of clump formation can arise from the walls or meniscus edge of the fluid even when the wall is very thin (< 1/10 of the chamber width).