Optofluidic size estimation

Before we begin testing the flow cytometer on cells, it is important to test the working of the optofluidic counter. One easy way to do this is by studying the flow of air bubbles in a micro-channel. The channel is fabricated using lithographic techniques and printed onto a PDMS device. The micro-channel being used in this study has a width of 500 μm and height of 150 μm. Figure 1 is a microscopic image of the PDMS device. Visible in the image are fluid inlet channels, used as a sheath, around the central sample channel. For the purposes of this study, we do not flow any fluid in the sample channel. Instead we control the flow rates of the sheath fluid, and generate air bubbles in the fluid stream. These bubbles then propagate down the channel to the interrogation point, where there are two fibre channels, almost perpendicular to the fluid channel, threaded with optical fibres. One fibre is excited by a laser source, and the transmiited light is collected by the second fibre and delivered to a photodetector.

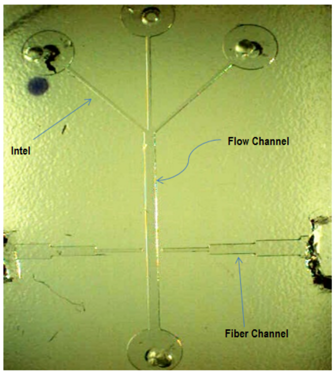

Figure 1: PDMS Device

Imagine a continuous beam of light, that gets interrupted when a bubble crosses its path. The output of the detector remains high, and goes low for the duration of time taken by the bubble to cross light beam. The photodetector output is continuously monitored by a micro-controller, with an internal analog-to-digital convertor (ADC) that converts the analog output signal from the photodetector to a digital signal. By measuring the time when the bubble occludes the laser beam, and knowing the flow rates of the fluid, we can estimate the size of the bubble. Now, we don't necessarily need to use a continuous beam of light. We could save power by using a series of laser pulses. As long as the time period between the pulses is shorter than the time it takes for a bubble to cross the optical beam, we can still estimate the size of the bubble. We must however ensure that the ADC has a sampling rate faster than the pulse width of our laser. In our experiments, the laser driver modulates the optical signal every 1 ms, with a duty cycle of 1%, and we sample the ADC every 2.5 μs., i.e., we get 4 samples for every optical pulse. The 1% duty cycle allows us to use high power laser diodes, with a peak output power of 7.94 dBm. For the detector, we use InGaAs p-i-n photodiode, followed by a low-noise amplifier (LNA) with gain of 10 kΩ. Without any bubbles, we observed a peak input power of -14.26 dBm at the detector. This is the light that is coupled from one bare fiber to another. The waveform of the detector's output is shown in Figure 2. A further increase in detected power is possible by adjusting the optical alignment of the two fibres in the fibre channels.

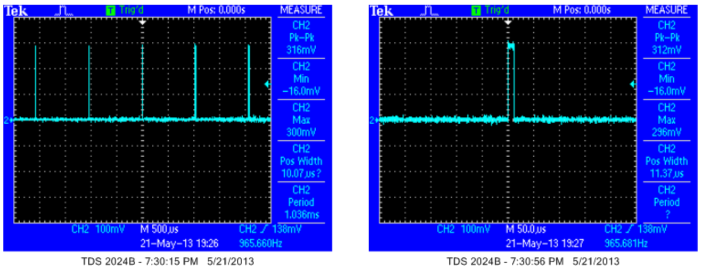

Figure 2: Detector Output Waveform

Imagine that we run this experiment for 15 minutes, and collect data on different sizes of bubbles. Each of them would give me a different occlusion time, and we could create a histogram of the observed times for different flow rates. We can also do this as we vary the flow rates, and plot them all together, as shown in Figure 3.

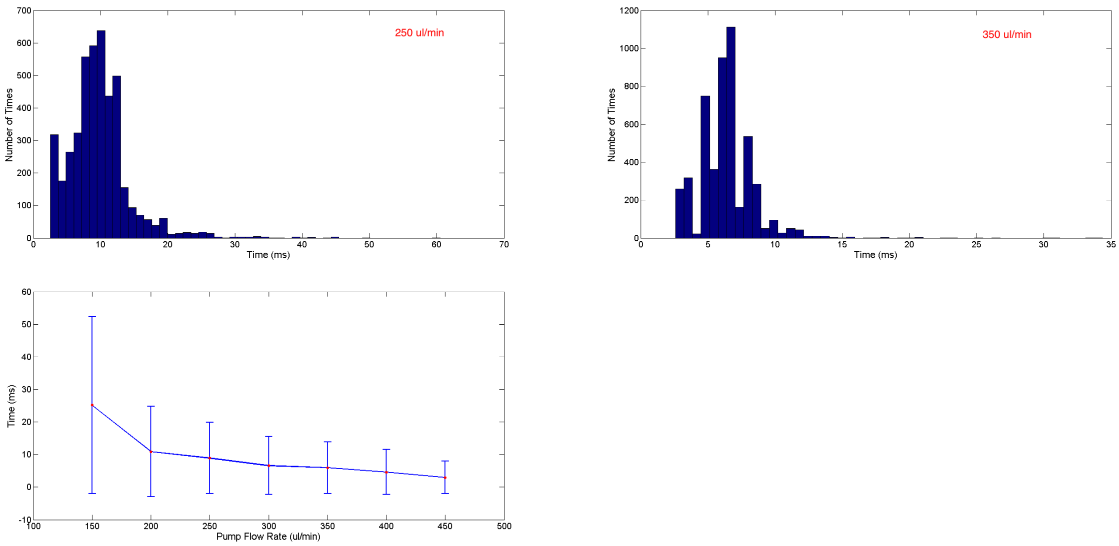

Figure 3: Occlusion time due to bubbles for different flow rates.