Visualisation of bacterial hydrodynamics

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Bacteria and other microorganisms live in an aqueous, low-Reynolds number environment where viscous forces dominate. The means by which many microorganisms propel themselves through such an environment are not well understood. Additionally, understanding the way in which fluid couples physical interactions between micro-scale objects and surfaces has received increasing attention in a number of biological and technological fields over recent years. The traditional approaches to investigating these problems are mathematical simulations and particle image velocimetry (PIV) experiments. While modeling can be done in three dimensions, the vast majority of experimental investigations have been restricted to only two. This is primarily due to the reduced depth of field available at the high magnifications required to see microorganisms.

I have used some novel approaches to investigating hydrodynamic interactions on the micro-scale, specifically in the context of the bacterial flagellar motor. I have adapted in-line holographic PIV techniques (Cheong *et al.*, 2009) for use in a biological environment under high magnification. Assays of motile *Escherichia coli* are seeded with microsphere tracer particles and illuminated with a collimated laser beam. The coherent light scattering off a microsphere interferes with non-scattered light and results in a characteristic interference pattern. From this pattern, microsphere positions in three dimensions can be determined. This technique allows for greater depth of field than other techniques, and, when combined with high-speed video microscopy, can generate a full three-dimensional map of a flow field in a dynamic micro-system.

Independently, microspheres can also be used as passive detectors of dynamic behaviour. In a separate experiment, a microsphere is held in an optical trap in close proximity to a second microsphere attached to the motor of an immobilised bacterium. The resulting hydrodynamic interactions are recorded through video microscopy. The ultimate aim of this approach is to develop a non-contact method of detecting the motion of dynamic systems which are invisible under normal microscopy.

These methods hold promise for exploring and visualising not only bacterial systems, but any dynamic, aqueous micro-scale environment.

Cheong, FC, Sun, B, Dreyfus, R, Amato-Grill, J, Xiao, K, Dixon, L & Grier, DG (2009). Flow visualization and flow cytometry with holographic video microscopy. *Optics Express*, **17**(15), 13071–13079.