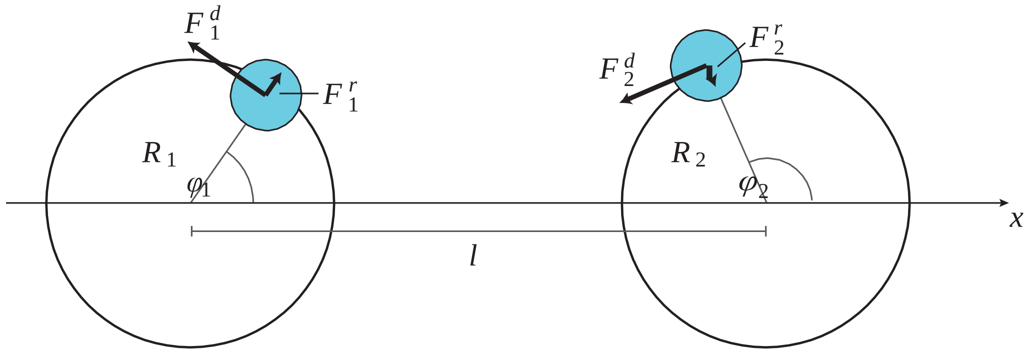
The Physics of Soft and Biological Matter

Hydrodynamic synchronisation of simple rotors

J Kotar[1], N Bruot[1], P Cicuta[1], L Debono[2], S Box[2], D Phillips[2], S Simpson[2] and S Hanna[2]

[1]Cavendish Laboratory, University of Cambridge, UK, [2]H. H. Wills Physics Laboratory, University of Bristol, UK

Hydrodynamic coupling is thought to play a role in the coordinated beating of cilia and flagella, and may inform the future design of artificial swimmers and pumps. In this study, holographic optical tweezers are used to investigate the hydrodynamic coupling between driven oscillators. In one study, the theoretical model of Lenz and Ryskin [1] is experimentally recreated, in which each oscillator consists of a sphere optically driven in a circular trajectory. The optical trap position is maintained ahead of the sphere to provide a tangential driving force. The trap is also moved radially to harmonically constrain the sphere to the circular trajectory.



Analytically, it has been shown that two oscillators of this type are able to synchronize or phase-lock under appropriate conditions [2, 3]. Here, the interplay between synchronization mechanisms is explored and good agreement is found between experiment, theory and Brownian dynamics simulations [4].

In a second study, a theoretical model is used to explore the hydrodynamic synchronisation between 2-dimensional lattices of simple rotors. In this case the rotors consist of rigid assemblies of spheres supported in an optical lattice of Laguerre-Gaussian beams. Different patterns of synchronisation are observed as the size of the lattice is varied. The symmetry of both the lattice and the rotors is also explored.

[1] P. Lenz and A. Ryskin, Physical Biology 3, 285–294 (2006)
[2] T. Niedermayer, B. Eckhardt, and P. Lenz, Chaos 18, 037128 (2008)
[3] N. Uchida and R. Golestanian, Physical Review Letters 106, 058104 (2011)
[4] J. Kotar et al, Physical Review Letters 111, 228103 (2013)