The Interaction of Two Droplets Confined within Corrals

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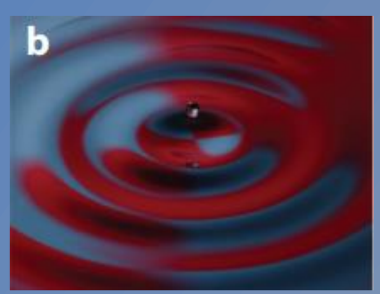
Introduction

The oil droplets can bounce and walk on the oil surface under a specified condition by interacting with the pilot waves they produced. Only when the amplitude of the pilot wave is large enough will the droplet move. The amplitude of the pilot wave is depth-dependent; the deeper the water is, the larger the amplitude is. With the property, the motion of the droplets can be confined to a region, a corral, if the water depth is different in space. We design a two-corral system to analogize it to a system with two interacting bound atoms. The interacting range between these two droplets is studied.

Regime Diagram

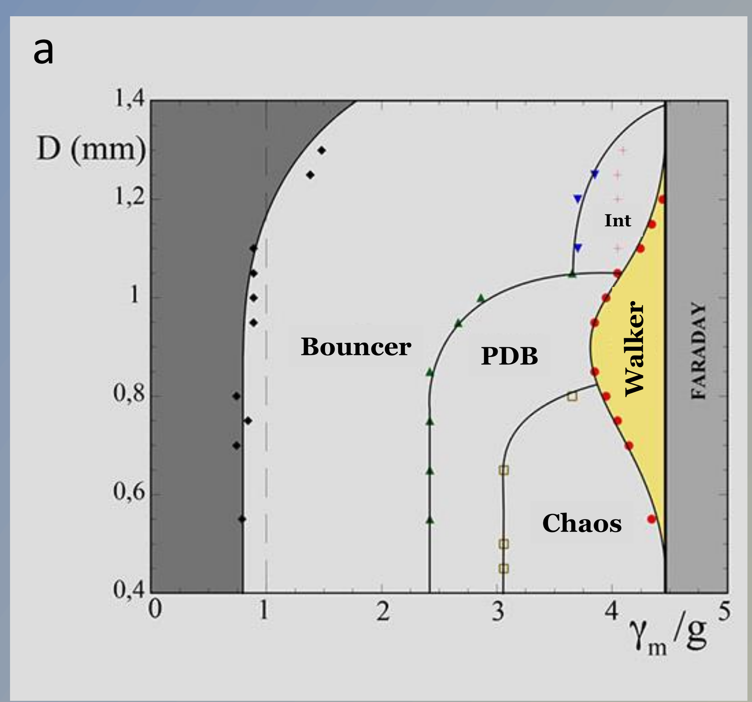
The droplet has different motion mode depending on several parameters:

1. $\gamma_m^F = 2^{4/3}(\rho/\sigma)^{1/3}\mu_L(2\pi f_0)^{5/3}$
   (ρ :density, σ :surface tension, μ_L :viscosity, f_0:forcing frequency=60Hz)
2. Diameter of droplet (~0.8mm)
3. Forcing amplitude of the speaker (V_{pp}=11.4V)
4. Depth of oil (shallow: 0.7mm) (deep: 5.7mm)



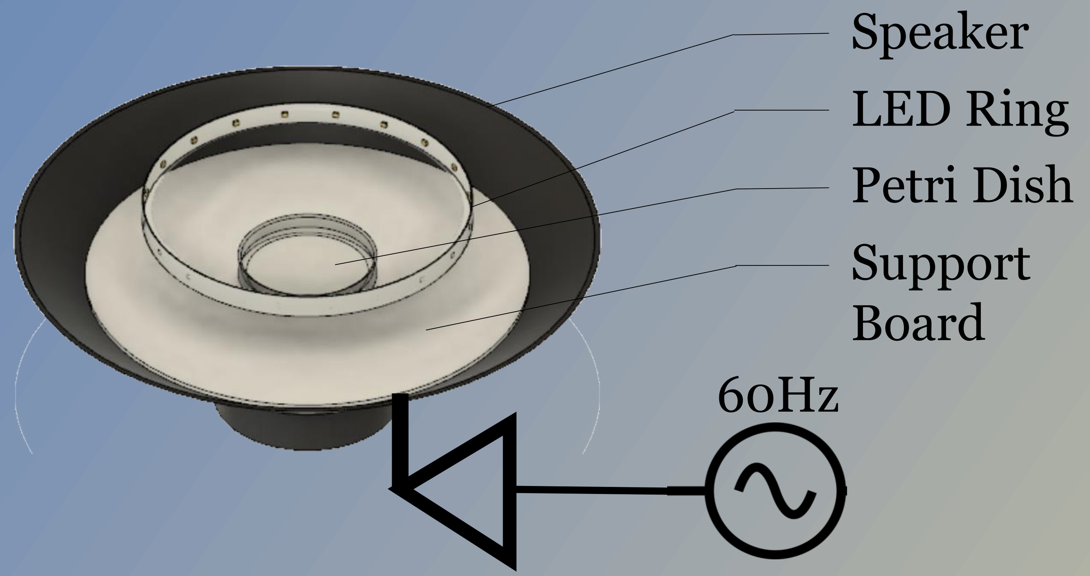
(a) Bouncer [2]

(b) Walker [2]



[1]

Setup

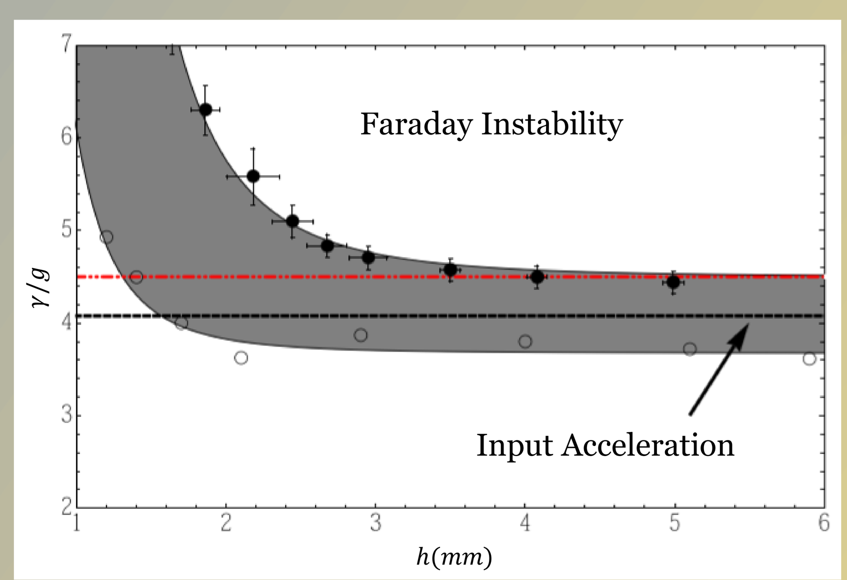


1. The petri dish is fixed on a speaker with a horizontal supporting board.
2. The speaker is driven by a 60Hz, 11.2V sinusoidal wave →walking droplets
3. LED ring is used for better illumination

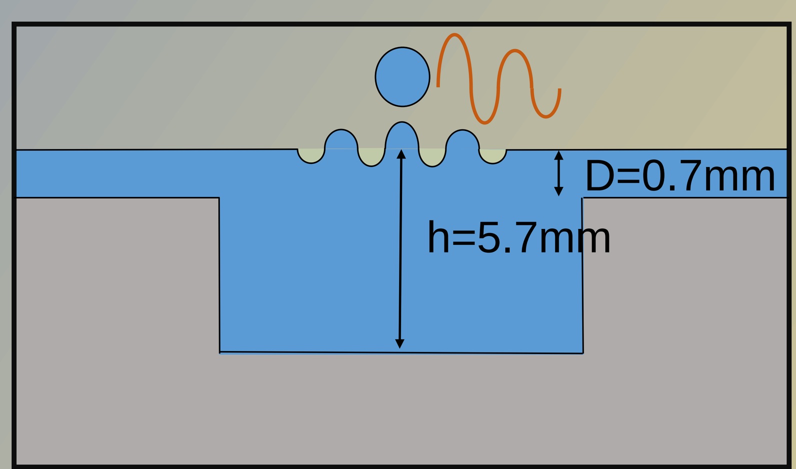
Potential Well

For shallow depth, the required forcing amplitude should be larger to maintain the walking motion. Hence, the droplets can be bounded in the corrals but still transmit weak pilot waves out.

The motion is studied with different inter-corral distances Δd.

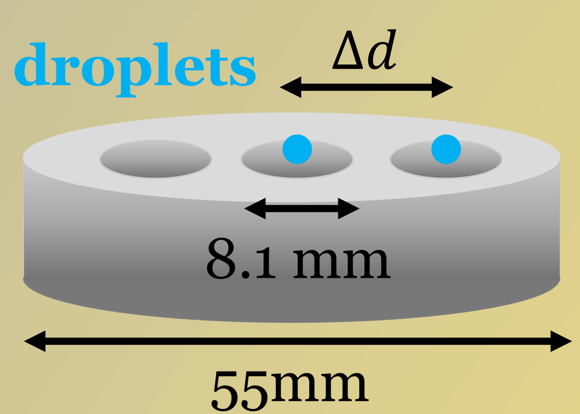


[2]



Acrylic barrier

Δd=1.4, 1.5, 1.7, 6, 12 mm



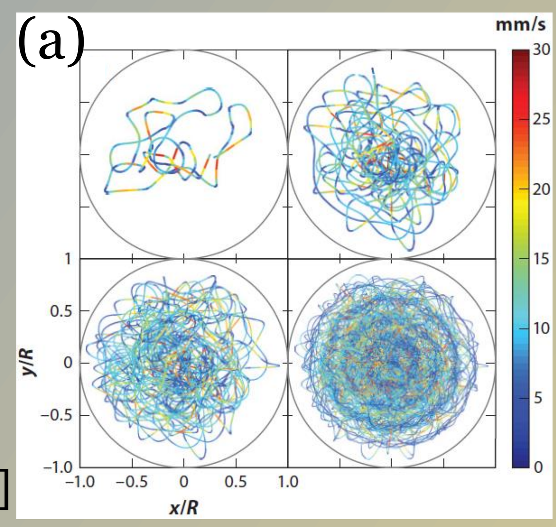
Reference

[1] J. Fluid Mech. (2006), vol. 554, pp. 85–108
[2] R. Carmigniani et al. / Experimental Thermal and Fluid Science 54 (2014) 237–246
[3] Annu. Rev. Fluid Mech. 2015. 47:269–92

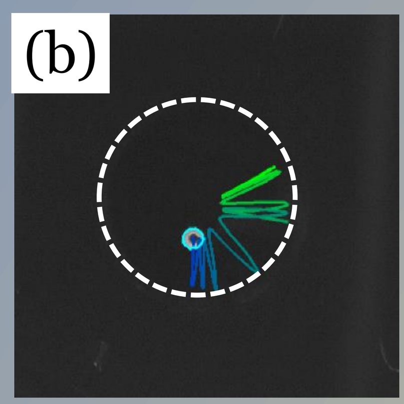
Bound Single Walker

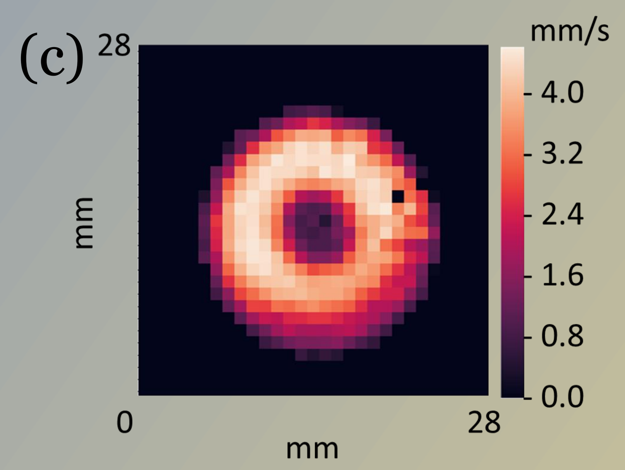
- Unbound single walker (a):

1. The motion is random except for the low probability in space near the boundary.
2. Speed decrease near the boundary.



[3]





- Bound single walker (b,c):

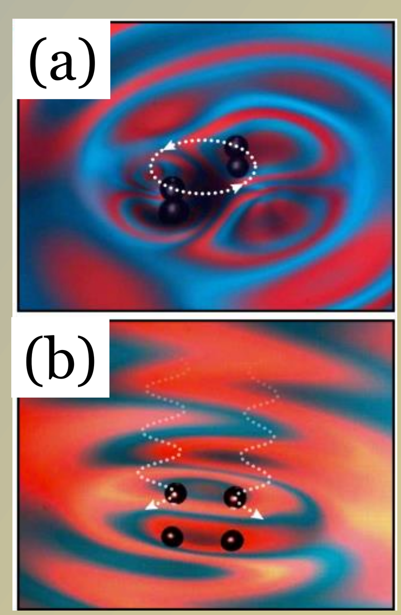
1. The oil droplet bounces back and forth between the corral boundary and the center of the corral. And the bouncing axis rotates as the time goes by.
2. Speed decrease near corral boundary and center.

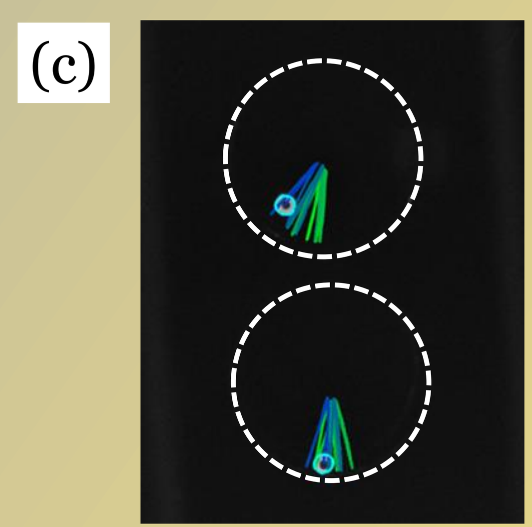
Bound Two Walkers

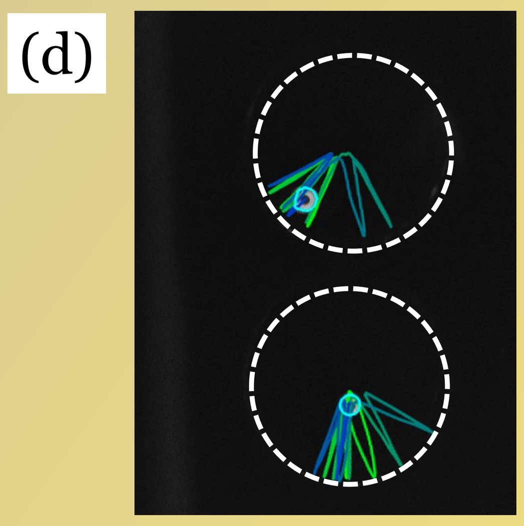
Modes for two walkers

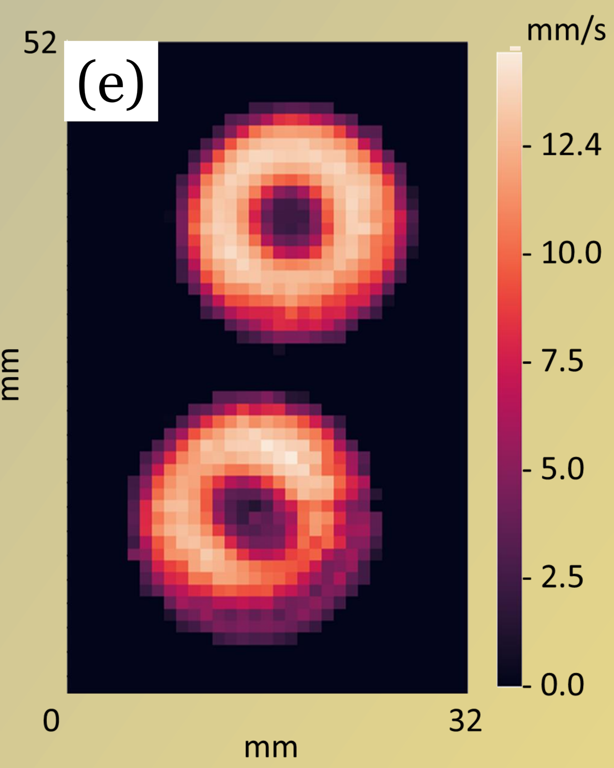
1. Orbiting mode (a)
2. In-phase and out-of-phase vibration mode (b)

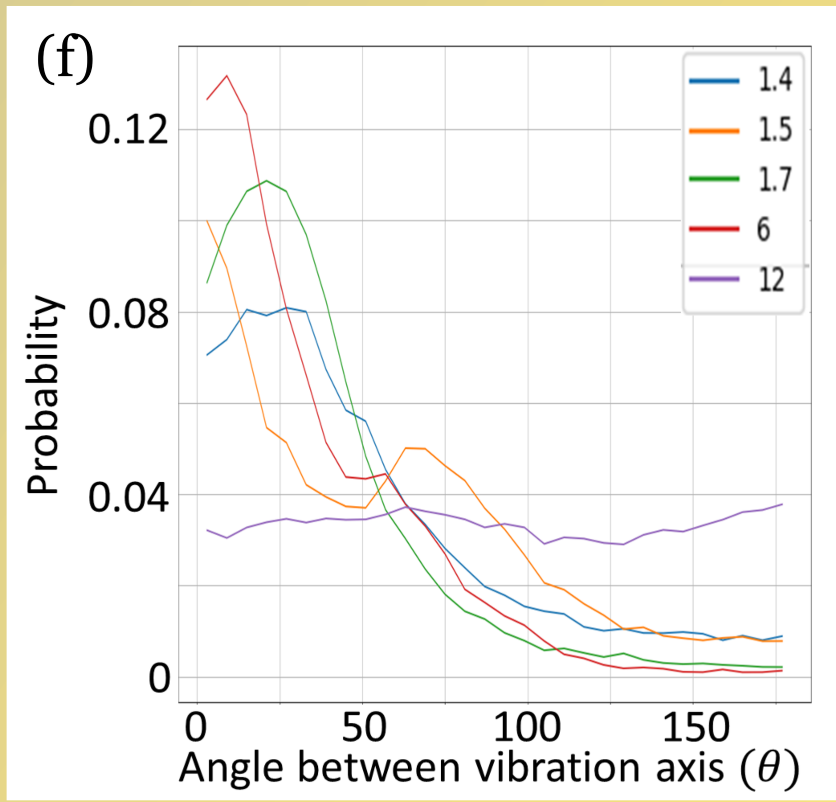
For the bound two walkers, they are in in-phase vibration mode (c,d).



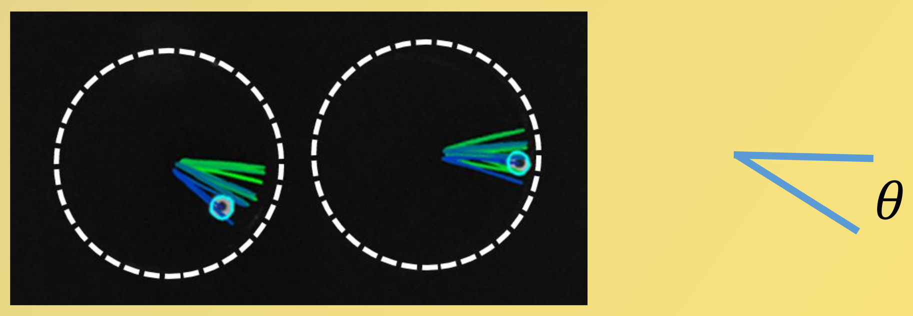








Two droplets are vibrating in its own axis and an angle is defined in polar coordinate for each axis ($\theta_1(t)$, $\theta_2(t)$).
And, the angle difference $\theta(t)$ between two is analyzed.



- The limited distance for bound walker interaction is $\Delta d < 12\ mm$

1. For $\Delta d = 1.4, 1.5, 1.7, 6\ mm$, there are interaction between two walkers. And there are much more in-phase vibration mode than out-of-phase vibration mode.
2. For $\Delta d = 12\ mm$, there are no interaction between two walkers. The probability

Conclusion

1. For a bound walker, one of the ends of the bouncing motion is the corral center.
2. For two bound interacting walkers, most of the vibration modes are in phase.
3. The limited distance for bound walker interaction is $\Delta d < 12\ mm$.