A New Oscillator for Experimentation with Pilot Wave Hydrodynamics

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Introduction

When a horizontal fluid bath is vibrated vertically, fulfilling certain parameters, a millimetric droplet can be levitated on the bath's surface and walk across the surface of the bath, propelled by the waves it creates on each bounce. While this phenomenon of levitating droplets is in and of itself interesting, many experiments afterward have shown that the levitating droplets, which are sometimes referred to as walkers, model particle-like and wave-like nature at the macroscopic scale. Subsequently, walkers may be used to demonstrate many quantum mechanical phenomena at the macroscopic scale.

If the bath and oscillator system are not perfectly level (i.e., perpendicular to the forces acting along the axis of oscillation) or some external force acts upon the droplet (i.e., if someone breaths on it), the walker will not exhibit the desired behavior as, due to its minuscule size and weight, it is very sensitive to any external force.

For this project, we have developed a system that uses magnets to suspend the bath and is fully moveable in the x, y, and z axes. Through the use of this system, the bath can be leveled in every axes with millimetric precision after it has been placed on the oscillator used to drive the bath. Thus, more precise data can be taken from the experimental setup.

Proof of Concept

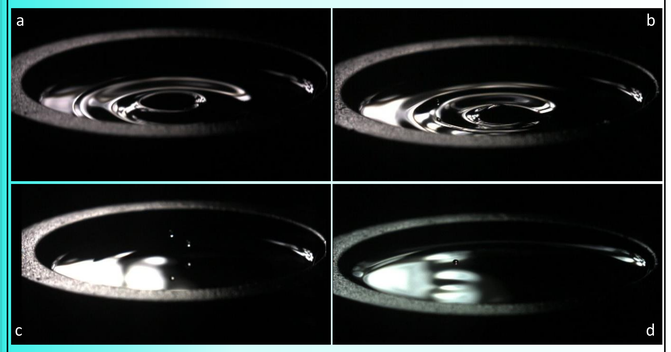

Figure 5.
a) Stable standing waves **b)** Stable standing waves with a droplet confined in a circular corral
c) Two droplets interacting with one another **d)** Walker propelled by pilot wave interference

Droplet Heat Map Color Scale

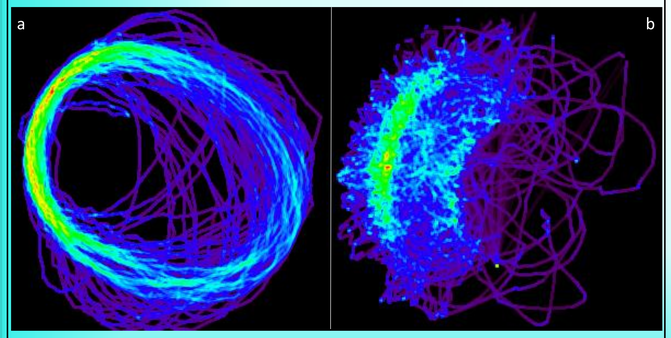

Figure 6.
a) Density map of trajectory over time with a droplet confined in a circular corral, clearly favoring left side
b) Density map of trajectory over time of walker, clearly favoring the left side

The Setup

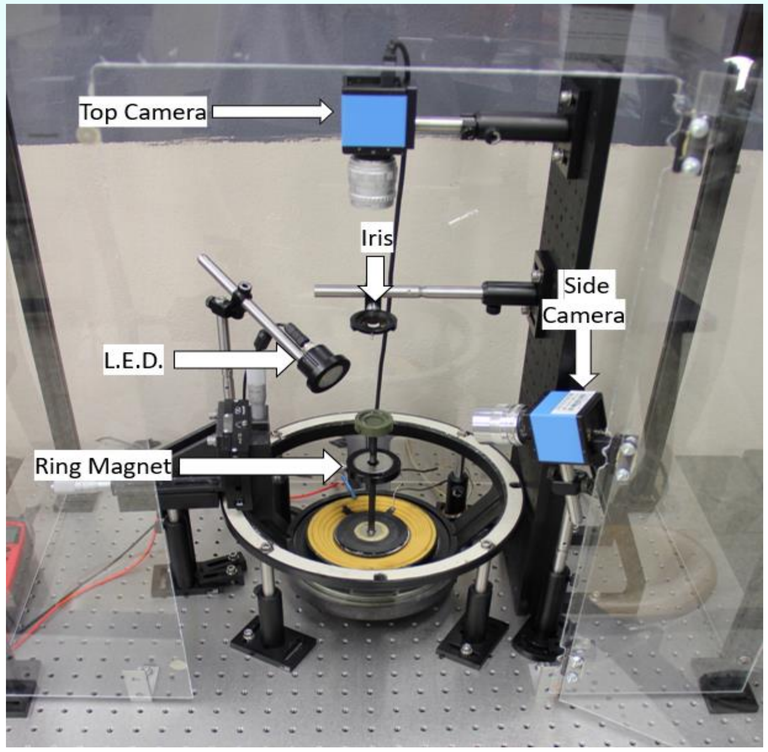

Figure 1. The new oscillator which uses magnets to hold the bath upright and is adjustable in all axes

With this new setup, a ring magnet was used to repel a disk magnet (See Fig. 3), which held the bath aloft and level. In addition, the cameras were used for documenting and tracking the droplet, a process that was aided by the iris to reduce residual brightness and allow the tracker program to see only the droplet. The speaker, upon which the bath sat, oscillated the bath in a sinusoidal fashion to bounce the droplet (See Fig. 2). Finally, the whole system was protected from external influence by a plexiglass covering.

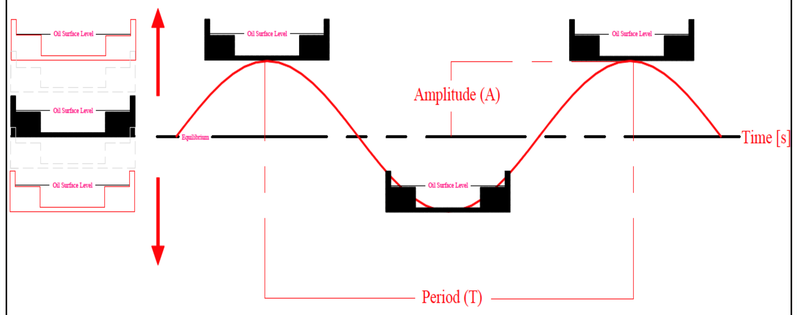

Figure 2. Diagram demonstrating the oscillation of the bath (Orback et al. 2018)

Acknowledgments

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Magnetic Leveling

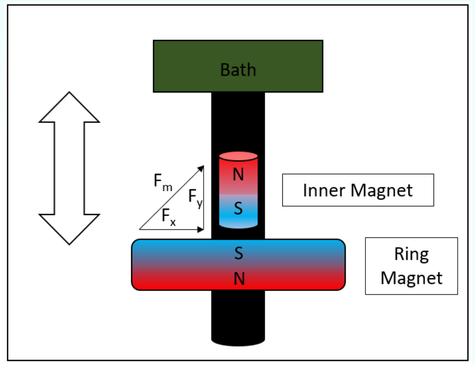

Figure 3. Overview of the use of magnets to keep the system level

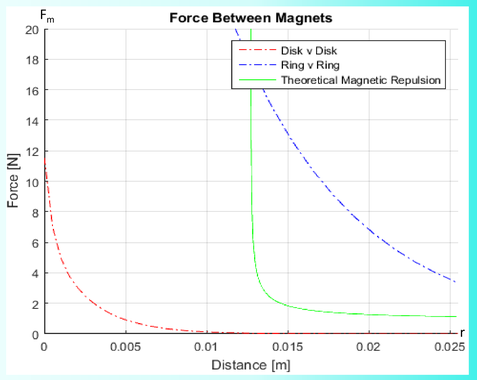

Figure 4. Two-term exponential regression model estimating the force of repulsion between the magnets

As demonstrated in Fig 3, a ring magnet was placed around the shaft that held the bath, and within that shaft another magnet was placed. Because the magnets were oriented with like poles facing each other, the magnets naturally repelled and the bath was held upright by the horizontal component of the magnetic force (F_x). In addition, the vertical component of the magnetic repulsion (F_y) was used to reduce the amount of preloaded mass on the oscillatory system. One large challenge faced in this setup was determining if the ring magnet was able to repel the magnet within the shaft with enough force to hold the bath in the correct position. To calculate the viability of the system, the mass of the bath was measured and used as the target mass for the magnets to hold. To find the perfect distance to force ratio for the setup, the *K&J magnetic calculator* (*https://www.kjmagnetics.com/calculator.asp)* was used to estimate the forces. Because our apparatus called for a disk magnet and a ring magnet, and K&J's magnetic calculator only provided the repulsive force between two magnets of the same type (i.e., ring on ring or disk on disk), two data sets were collected, one for a disk magnet repelling a disk magnet, and one for a ring magnet repelling a ring magnet. Then, the theoretical magnetic repulsion required was plotted (see Fig. 4) to determine the viability of the magnetic-oscillatory system.

Discussion

While we achieved the goal of our research by building an oscillator for pilot wave hydrodynamics research, which would keep the bath more level and stable during experimentation, we were hindered by time constraints. We were able to get good standing waves and droplets bouncing on the surface, however, achieving perfect walker-like behavior was more difficult.

As evidenced in Figure 6 (a), while the amplitude was high and the droplet was trapped in a trough of the standing wave, the droplet followed a circular trajectory, slightly favoring the left side. However, when the amplitude was reduced to achieve walker-like behavior, the droplet exhibited the behavior—albeit favoring the left side as compared to Figure 7.

In the future, we would like to test how bath dimensions affect the trajectory of the walker.

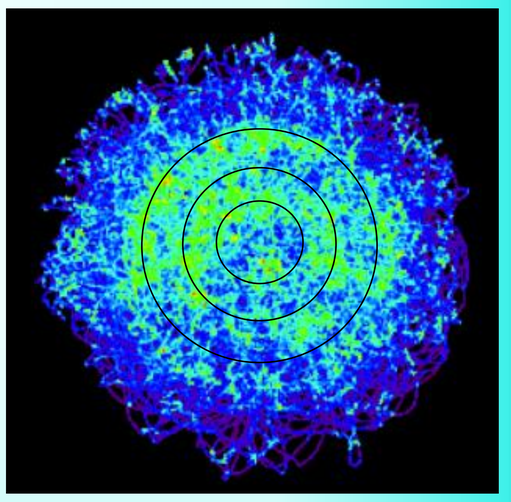

Figure 7. Standard to which our data was compared (Orback et al. 2018)

References

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