RUHR UNIVERSITÄT BOCHUM

RUB

Walking Droplets

Project Number 9

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What the project is about

Droplets are silicone oil droplets, which bounce on a vibrating surface of the same oil. This is possible due to an air layer building up between the droplet and the surface, effectively preventing coalescence.While bouncing, the droplet generates a wave field called pilot wave; this field interacts with the droplet, causing it to wander around its contained area. At a given ratio of amplitude and frequency this motion resembles that of quantum particles. At this point the droplet is called “walking droplet“.

Three jumping droplets on silicon oil.To better determine the height of the jumps, a mirror was placed behind the droplets.
(50 cSt, U=2.98 V, I=0.54 A)

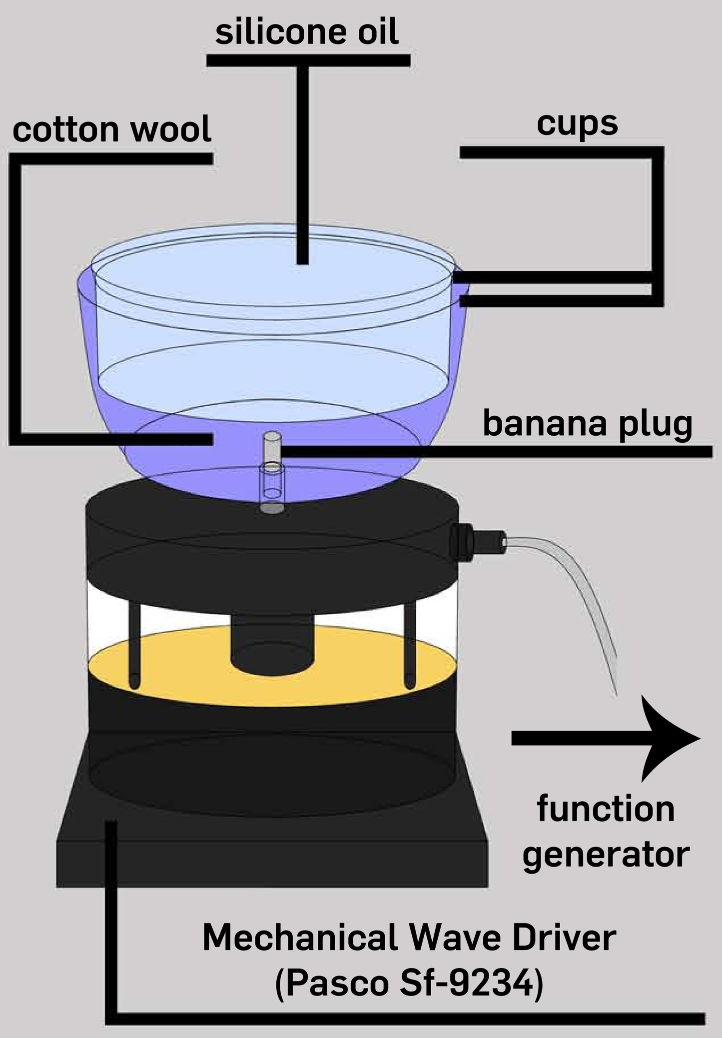
Objective

The aim was the creation of droplets with a focus on reaching the “walking phase“. The next step was to verify whether the droplets show quantum-mechanical behaviour such as particle interference at the double-slit or the tunnel effect. In addition, several droplets are expected to interact similar to molecules, e.g. forming stable configurations and rotating around a common axis; this assumption was to be scrutinised.

Three droplets which behave like a molecule
(U=2.98 V , I=0.54 A)

Experimental Setup

The experimental setup consists of a Mechanical Wave Driver mounted thereon a self-made trough. The trough is made out of a plastic cup inserted and glued into another cup. The gap between them is filled with cotton wool and underneath the inner cup a banana plug is attached, which reaches through the outer cup and connects the construction with the Wave Driver. The upper cup is then filled with silicone oil (50cSt, 0.96 g/cm³). A function generator and an amplifier are used to run the Wave Driver which is linked to a computer to analyse the frequency with the program Handyscope 2. Two multimeters measure current and voltage. To create a droplet we dipped a toothpick into the oil and pulled the toothpick out quickly.



Computations

To create a walking droplet, a certain ratio of droplet radius must be present to bath acceleration, which is calculated as follows:

$$\Gamma = \frac{\gamma}{g} = \frac{A}{g} * (2\pi f)^2$$

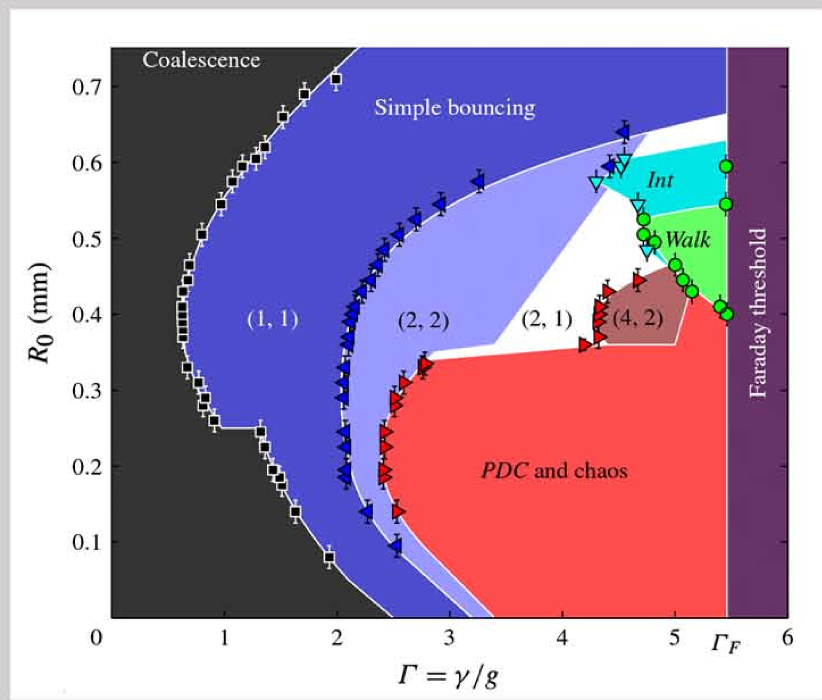
$\Gamma =$ dimensionsless forcing
$\gamma =$ bath acceleration $\quad f =$ frequency
$A =$ amplitude $\quad g = 9.81\frac{m}{s^2}$

Another important factor is dependent on the frequency, the vibration number:

$$\Omega = 2\pi * f * \sqrt{\frac{\rho * r_0^3}{\sigma}} \qquad r_0 = \text{walker radius}$$

$\rho =$ density $\quad \sigma =$ surface tension

this is representative for the droplet size.



PDC= period doubling cascade
Int= intermittent horizontal movement
Walk= walking regime
(http://math.mit.edu/~bush/wordpress/wp-content/uploads/2013/07/MB1-2013.pdf, Jan Molácek, John W. M. Bush “Drops bouncing on a vibrating bath“, 24 May 2013, Cambridge, USA, Page 587)

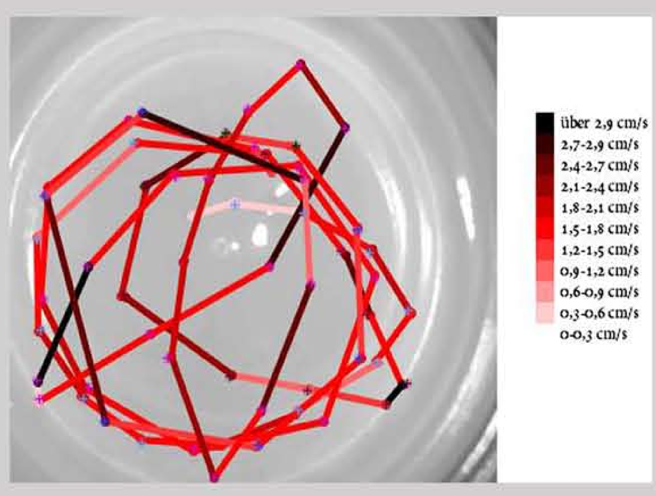
Conclusion

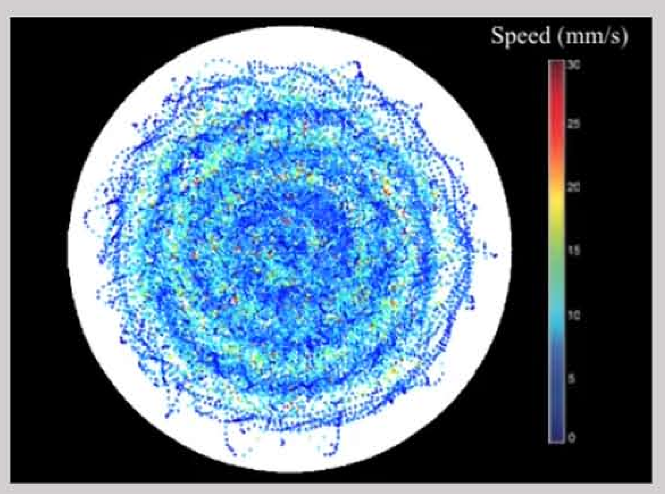
With two and three walking droplets it was possible to observe the molecular motions in form of translation, vibration and rotation (I=0.51 A, U=3,43V). During the rotation it was noticeable that the droplets move around a common axis.

While recording the trajectory it soon became clear that the droplets' orbital radius varied only slightly. Occasionally the droplets suddenly changed its direction, though it rarely crossed the centre.

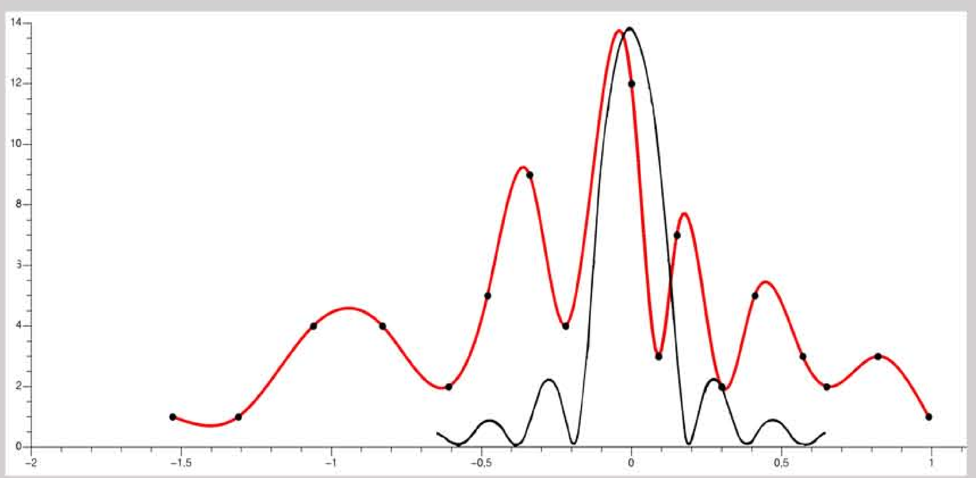
In the double-slit experiment it was found that the droplet themselves do not come into contact with the edges of the slit, but through the wave field they interact. The experiment's results show similar interference patterns as much smaller particles, which are subject to wave-particle dualism.

The tunnel effect-experiment did not bear expected results. It was not possible to recreate the tunnel effect; this was due to material restrictions of the tunnel barrier and the trough being slightly askew.





Trajectory of droplets in our trough (left) in comparison to a long-term recording of the MIT (http://youtu.be/nmCOygr08tE?t=1m39s)



X-axis: distance from the center in cm; Y-axis: number of droplets
red graph: experimental result; black graph: ideal double slit

Take Home Message

With the help of droplets, it is possible to form an analogue of quantum mechanical particles, which behave similarly in terms of wave particle duality and various effects.

We would like to thank Prof. Dr. U. Czarnetzki, Dr. K. Fischer and Mr. H. Nießler for their help with our project.

Sources: http://math.mit.edu/~bush/wordpress/wp-content/uploads/2013/07/MB1-2013.pdf, Jan Molácek, John W. M. Bush, “Drops bouncing on a vibrating bath“, 24 May 2013, Cambridge, USA
http://windw.dk/2013Bouncing.pdf, Øistein Wind-Willassen, Jan Molácek, Daniel M. Harris, “Exotic states of bouncing and walking droplets“, 13 August 2013, Cambridge, USA