Resonance tunneling in Faraday pilot wave model

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Motivation & background

The pilot wave model is able to recreate quantum dynamic, and the dynamic of model is similar to de Broglie's pilot wave theory. Different from Copenhagen interpretation, which says the position of a particle is determined in anytime, and its wave-like characteristic is caused by its pilot wave. Through using this model, quantum-like effects can be observed in microscope. This model has proved itself by recreating many quantum effects such as single & double slits diffraction of particle [1], single barrier tunneling of particles [2] and particle position distribution in a circular well [3]. The above reminds us an effect called resonance tunneling. It's widely used on a diode called Resonance Tunneling Diode(RTD), and we didn't see any articles about recreating this effect in this model. Therefore, it gives us a question: can this model recreate it? Which later became our project article.

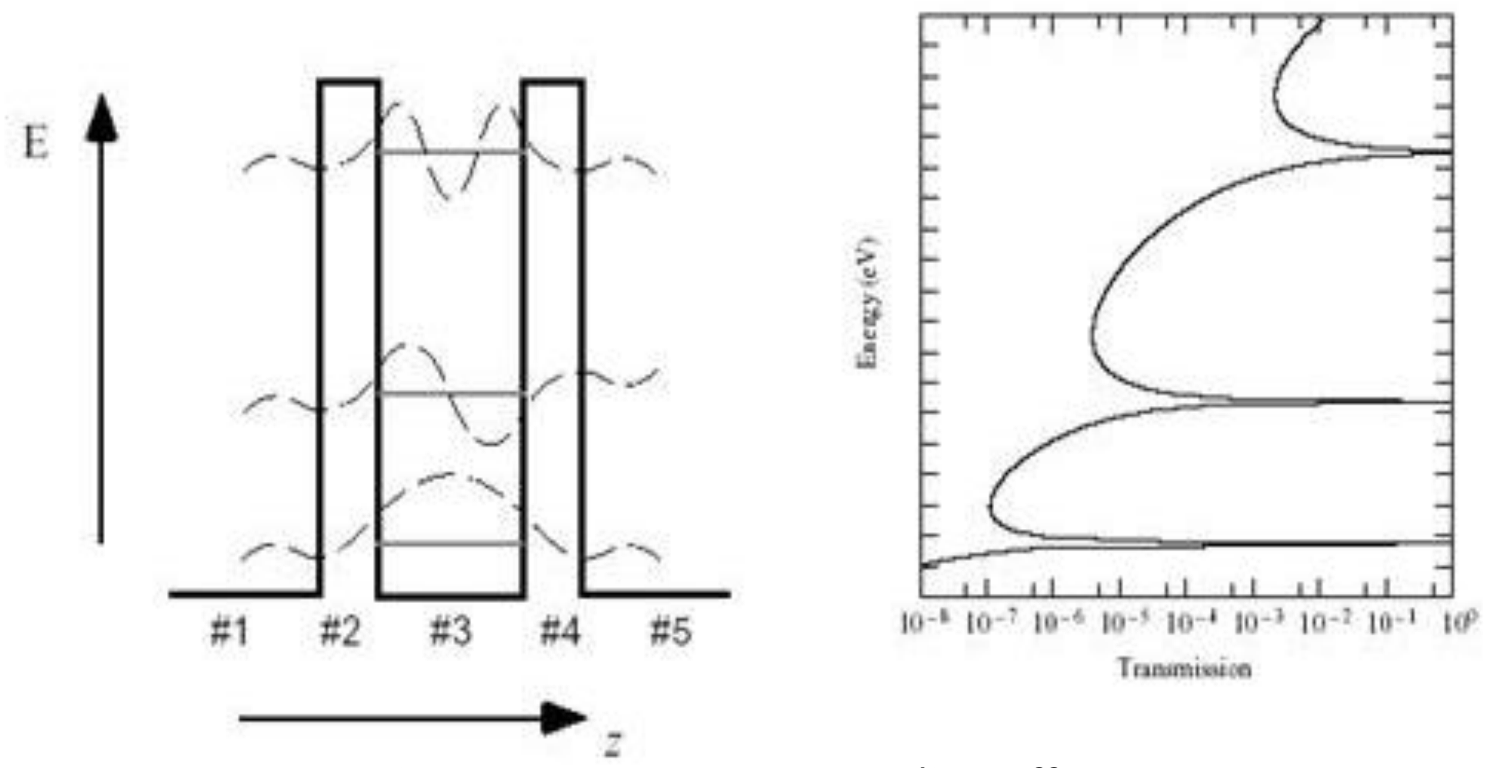

Figure 1: Resonance tunneling effect.

Principle

As we know, there will be a Faraday wave when a fluid bath vibrating vertically with an acceleration above Faraday threshold. When we drive a shaker beneath a fluid bath with an acceleration right below the threshold, the interruption from a bouncing droplet will create a local Faraday wave packet on the fluid surface. Simultaneously, the droplet can be regarded as a quantum particle, and the Faraday wave packet is like the pilot wave, such a guided droplet called a "walker". [4]

Figure 2: A walker moving on the fluid surface [5].

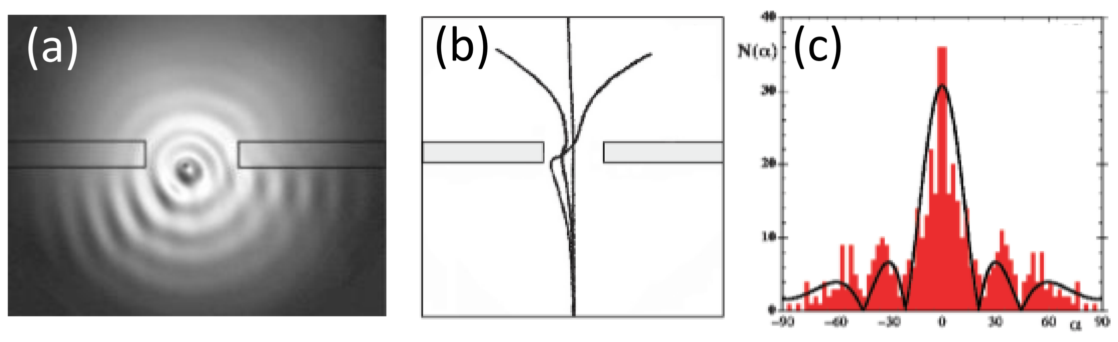

Figure 3 [1]: (a) A walker go through a slit. (b) Trajectory of walkers near the slit. (c) The distribution of the walkers after go through a single slit.

A walker can also represent tunneling effect, by adding a "barrier" in front of the walker. A barrier is a shallow area in the dish. Considering that matter wave can't oscillate in a potential barrier, a shallow enough area will make Faraday wave behave like the matter wave in a potential barrier

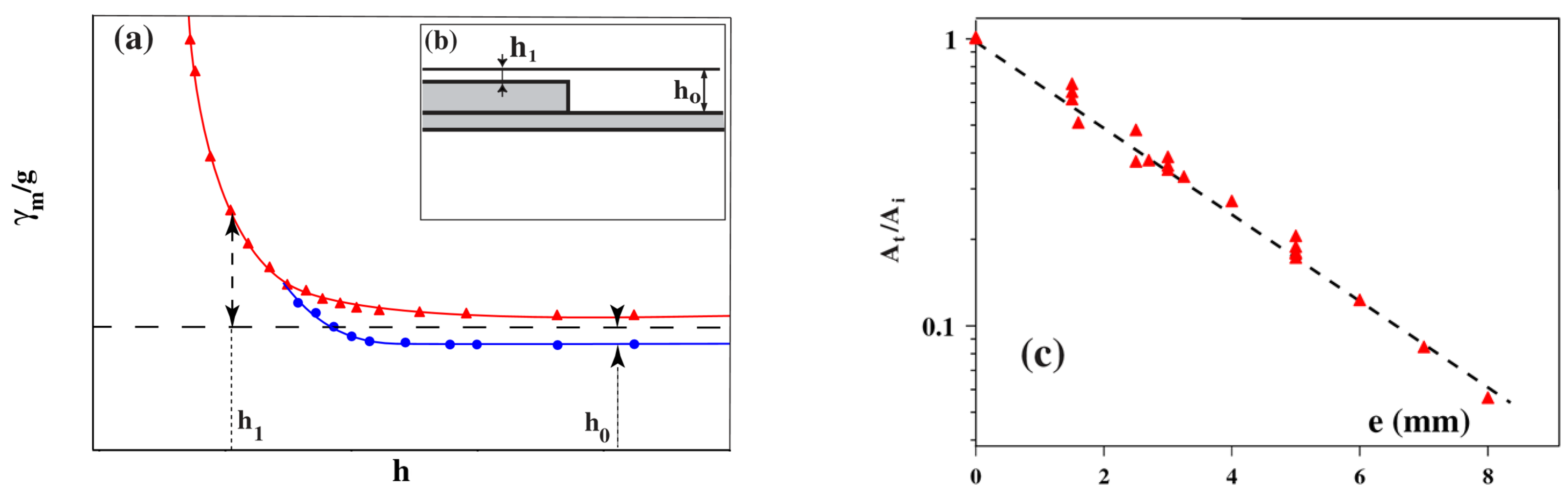

Figure 4 [3]: (a) Faraday threshold in different protrusion height, red is without droplet, and blue is with a droplet on it. (b) Potential barrier in a dish fill with fluid. (c) tunneling possibility exponential decay as the barrier thickness increase.

Setup

We replace the shaker into speaker, and a dish attached on it by hot glue. The dish contains two parts: Petri dish and the terrain on it(5-b yellow part), the terrain part is made by 3D printing, and it is also attached on the Petri dish by hot glue.

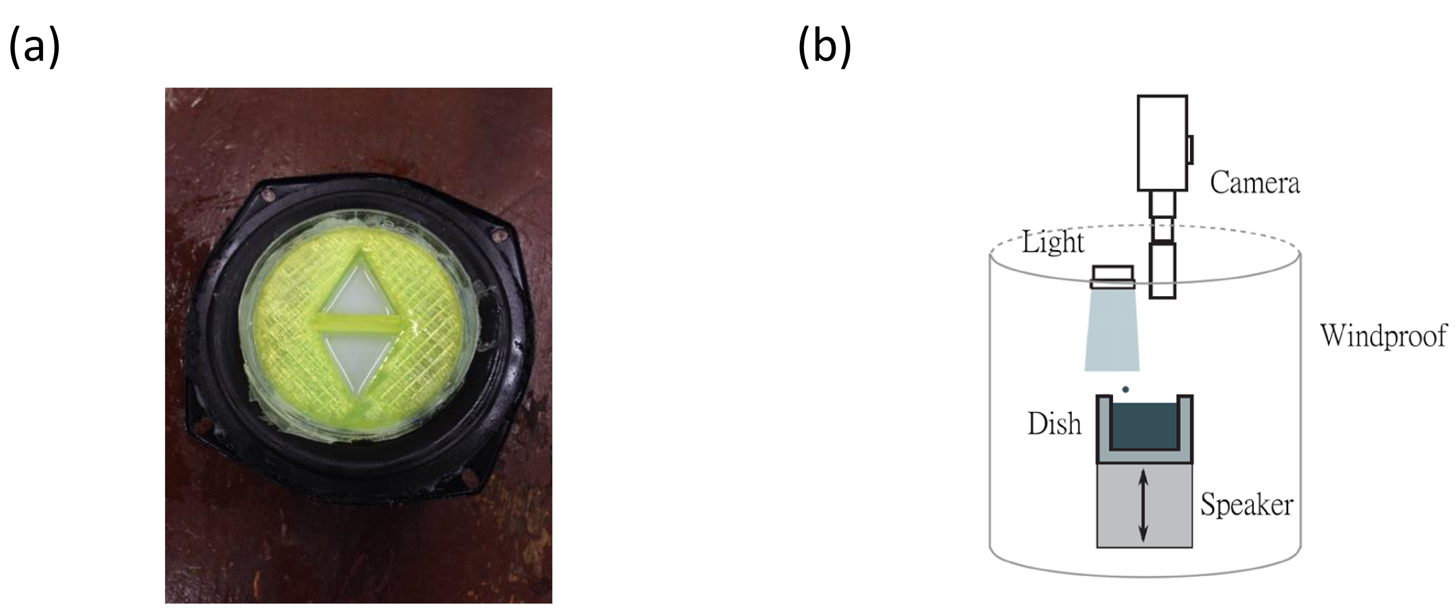

Figure 5: (a)A picture of our real setup. (b)The main setup contains a speaker as a shaker and a dish contains silicon oil as fluid bath. Lighting source and camera shoot from top. By adding s wind proof to prevent effect from air flow.

Experiment

If the tunneling probability only depend on the thickness of the barriers, no matter how wide the width between two barriers is, the tunneling possibility of a walker will remain the same, but with resonance tunneling, things get different.

To test whether resonance tunneling exists in this system, a problem need to be fixed first. Although a walker will move in a straight line, the initial moving direction is uncontrolled in a free cavity. Therefore, it's hard to make the droplet "incident" into the barriers perpendicularly. There is one way to fix that - the shape of the dish.

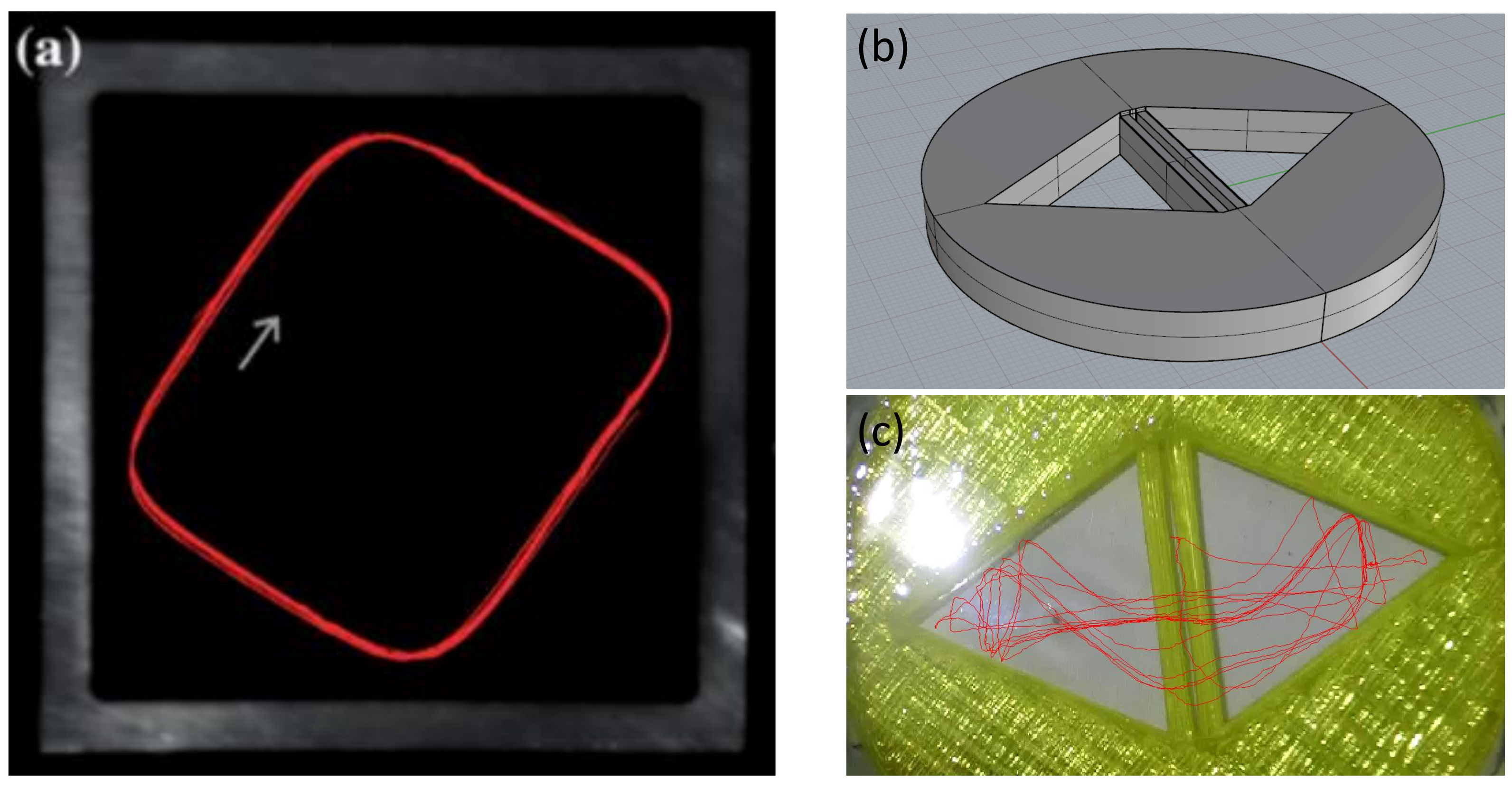

Figure 6: (a) A walker will keep moving in a straight line in a free cavity. (b) A dish design from reference [3], it has 2 triangular area in both sides of the barriers. (c) The real droplet's trajectory in dish 6-b, almost every incident is perpendicular to the barrier.

Result

The results show that there are three situations: (1) The droplet pass through the barriers. (2) The droplet stuck in the barriers. (3) Droplet reflect from barriers. Counting (1) as 1 pass, (2) as 0.5 pass, and (3) as 0 pass, taking 100 incident data and calculate the probability.

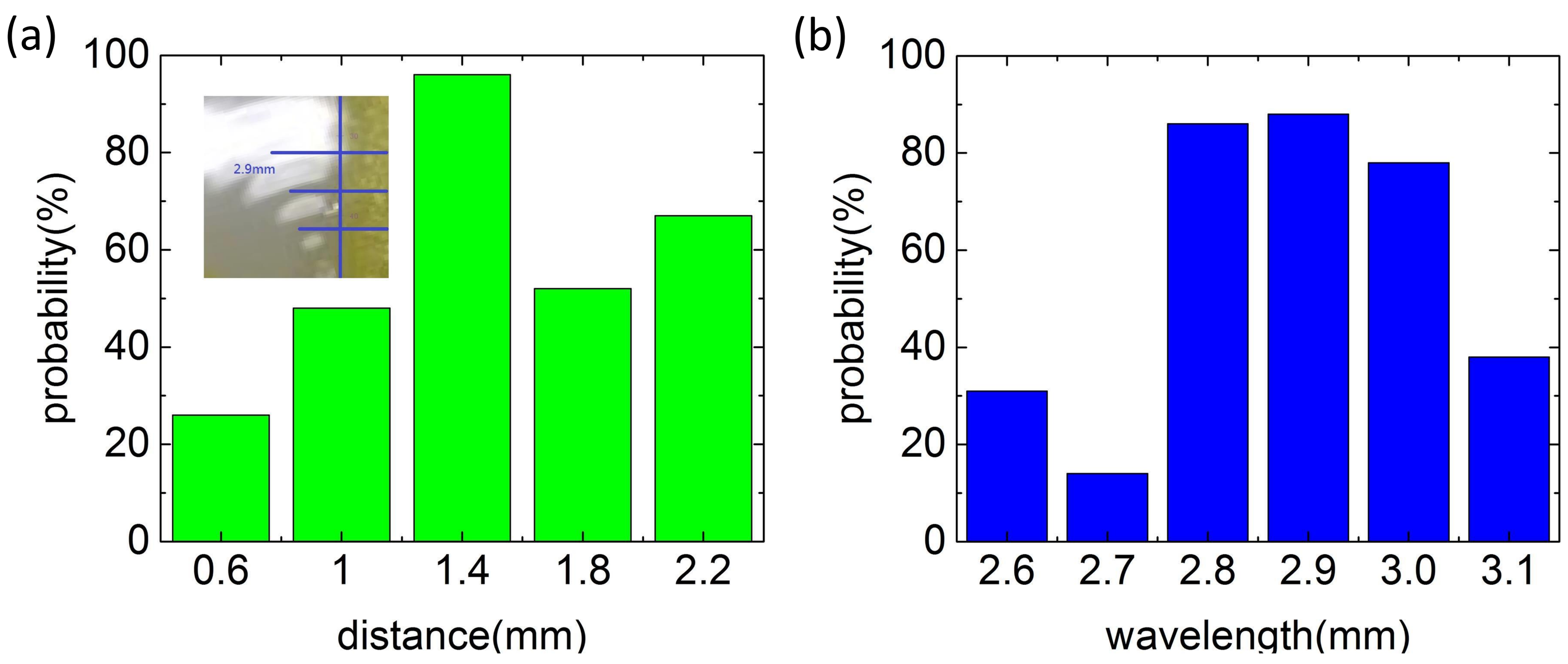

Figure 7: (a)The probability in different barrier width with 1cm oil depth, the wave wavelength of the packet is 2.9mm. (b)The probability in different wavelength on 1.4mm barrier width dish, wavelength be changed by adjusting frequency variation, and the wavelength determined by Faraday wave dispersion relation $\omega_F^2 \approx \sigma k_F^3/\rho$ [4].

Conclusion

The probability peak is pretty obvious in both experiment. As expect, they will appear at width = half of the wavelength. It's such an exciting result that how accurately this model can describe the real quantum dynamic system. Simultaneously, it shows that maybe Einstein was right: "God does not play dice with the universe".

Reference

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