# The hunt for the quantum collapse

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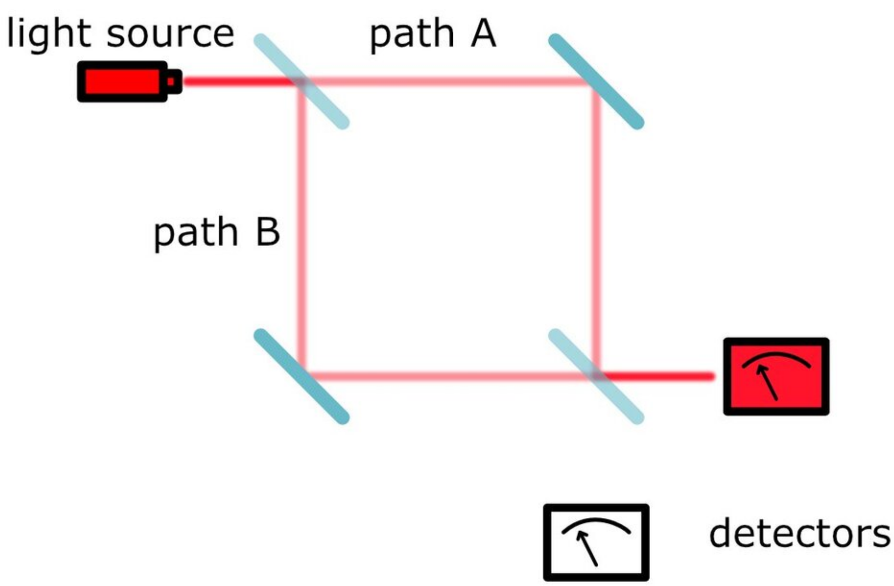



Interference of superpositions going through A and B: only one detector will detect a signal. Credit: Leiden University

The most famous cat in science is Schrödinger's cat, the quantum mechanical mammal, which can exist in a superposition, a state that is alive as well as dead. The moment you look at it, one of both options is chosen. Leiden University physicists simulated an experiment to catch this mysterious moment of choice red handed.

In quantum mechanics, the physics of the smallest bits of matter, this moment of choosing is called the collapse of the wave. In the journal *Physics Status Solidi B*, Tom van der Reep, Tjerk Oosterkamp and other physicists of Leiden University and Geneva University describe how they hope to catch this mysterious moment using a quantum mechanical setup using photons of microwaves in the roles of the dead-and-alive cat.

"Superpositions are quite common in quantum mechanics," says Oosterkamp, 'but in the macroscopic world in which we live, you never see them." A cat is either alive or dead, not both. According to the widely accepted Copenhagen interpretation of quantum mechanics, this is because the superposition disappears as soon as one makes a measurement on the photon (or the cat).

## Collapse of the wave function

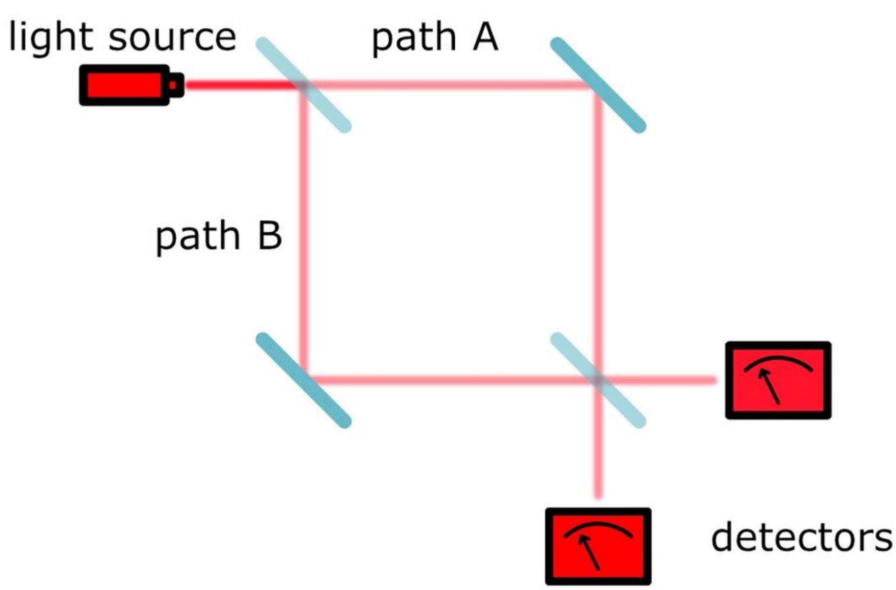
Oosterkamp adds: "But nowhere in this Copenhagen interpretation, it is explained how this would work. What exactly is "a measurement"? Any measurement apparatus will consist of atoms obeying the laws of quantum mechanics, so what sets the measurement process apart? Is it the size of the measurement apparatus? Its mass? Something else? Nobody knows. There are even interpretations in which a measurement only occurs when it is done by a conscious observer, or in which the Universe would split up in several variants.

The Leiden physicists decided to open the hunt for the collapse from the perspective of an amplifier that is as simple as possible. They're starting out with photons of microwaves, a form of light, in a superposition. In their setup, the photons take a route A as well as route B.

This superposition can be detected by merging routes A and B again. The particles will interfere with themselves, which means that they will only be detected in one of two exit directions. When there is no superposition, and hence no interference, the particles will exit in both directions. So far, this is standard quantum mechanical fare, proven in many experiments.

## Low temperatures

The next step is introducing a measurement. "In every measurement in a quantum mechanical system, there is an element of amplification," says Oosterkamp, 'since you are translating a small signal to a larger one. So perhaps this amplification step constitutes the cause of the collapse of the wave function."



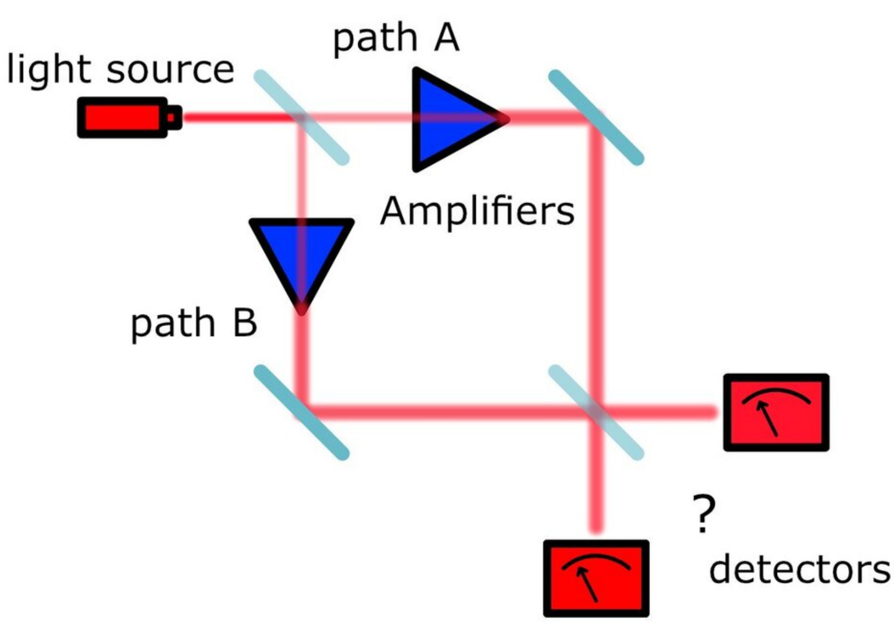

No interference: both detectors detect light. Credit: Leiden University

So the physicists place a so-called parametrical amplifier in route A and B of their setup. This is a type of amplifier that can be described well quantum mechanically, which is based on a large number of superconducting Josephson junctions.

For this, an ultra-cold temperature of 50 millikelvin is needed, a twentieth of a degree Celsius above the absolute zero temperature of -273,15 degrees Celsius. Such low temperatures are also needed to ensure that the disappearance of interference is not just caused by the heat in the setup.

## Red handed

The idea is to slowly ramp up the amplification, and see what happens to the interference. In their article, the physicists describe how the collapse of the wave function would cause a 'measurable decrease' of the interference. So the setup is a way to catch the collapse red-handed.



What will happen when the photons are amplified? Will the wave function collapse? Credit: Leiden University

"If we succeed at that, that would be terrific," says Oosterkamp. "Of course, then you would want to tweak the parameters to see what changes will influence the moment of collapse. But in this piece, we show that it can be done."

## Quantum computers

The paper was a calculation exercise, the setup is now being built. Oosterkamp's group has the right cooling machines to execute the experiments, but it will be a hell of a job to develop the necessary parametric amplifiers that pair a high amplification with very low production of heat.

The experiment is a cooperation with colleague Alessandro Bruno, who started the company QuantWare, which produces these amplifiers for future quantum computers. "Hopefully, tests will show that the amplifiers remain cold enough," says Oosterkamp. "Then, we can really hope to carry out these experiments."

**More information:** Thomas H. A. van der Reep et al. An Experimental Proposal to Study Collapse of the Wave Function in Traveling-Wave Parametric Amplifiers, *Physics Status Solidi B* (2020). DOI: 10.1002/pssb.202000567

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