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New Interpretation of Quantum Theory

— Classical Theory with Quantum Observation

Zhang Chang-kai

Department of Physics, Beijing Normal University, Beijing, China
E-mail: phy.zhangck@gmail.com

Abstract
The quantum world remains a mystery for decades. Ever since its birth in 116 years ago, the interpretation of quantum wave function has been a central topic discussed broadly by numerous intelligent physicists. However, the current main stream interpretation — Copenhagen Interpretation — is based on probability with which plentiful brilliant physicists, including Einstein, are not content. Although this interpretation has been testified by copious experiments, we still hope to provide a “development” of this interpretation without using probability, and therefore a classical theory with quantum observation can be made possible.

Keywords
Interpretation; Quantum Theory

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Introduction

As a mathematical framework, Quantum Mechanics is not so complicated. Howbeit, when trying to read predictions of quantum theory, one meets difficulties led by its probability-based interpretation. For quite a long time, physicists feel uncomfortable about Copenhagen interpretation. Nonetheless, it is too successful for us even to make some modifications. Hence, physicists are forced to accept the strangeness of quantum phenomena. However, in this article, we try to construct a brand new interpretation for quantum theory which is totally compatible with Copenhagen interpretation and does not necessarily requires probability. And this inspires us that a quantum observational result can also be generated through a classical theory.

Particles or Detectors

In this section, we are going to further discuss the Copenhagen interpretation, which will be the basis of the following illustration. First, let’s look at one of the common expression of Copenhagen interpretation

Copenhagen Interpretation. *The wave function provides the probability density of finding some particles at some quantity.*

However, there is one word in the above sentence that lacks definition — “find”. So a more rigorous expression will read

Copenhagen Interpretation. *The wave function provides the probability density of interaction between some particles and the instrument at some quantity.*

This expression avoids the term “find”, but introduce another undefined term — “instrument”. This is the core that we want to cope with. Traditional Quantum Mechanics ends here, since a further investigation will not lead to anything that causes difference in experiment. Notwithstanding, this might be the very point in making quantum theory mysterious.

The quantum world is full of uncertainties. Generally, the uncertainties are considered to be the case of particles, which means a particle might not be able to *have* a certain physical quantity. Yet regarding the above enhanced expression, one can draw this conclusion only if the uncertainties of instrument has been eliminated, which is exactly the thing that has not yet been proved.

Orthodox quantum theory regard the above condition as an assumption. But here, we take exactly the opposite condition, i.e. the uncertainties we observe come all from the instruments. To formulate this, we first give the definition of an instrument

Definition. *An instrument is a step function* $H(\varepsilon - \varepsilon_0)$.

This definition is applicable to most of the instruments for their usage of state transition as an indication. The readings of instrument stay at 0 for low energy and jump to 1 when some particle with enough energy to make the instrument particles reach the threshold ε_0 comes.

Next, we need some important assumption

Assumption 1. *The instrument satisfies Boltzmann distribution, i.e. the probability density of the instrument to have an initial energy is*

$$\mathcal{P}(\varepsilon) = \frac{1}{kT}\exp\{-\frac{\varepsilon}{kT}\} \tag{1}$$

where ε is the energy, k is the Boltzmann constant and T is the temperature of the instrument.

Assumption 2. *The equivalent energy a particle can bring to the instrument within range q to $q + \mathrm{d}q$ is*

$$\varepsilon_p = kT\ln[\Psi^2(q)\mathrm{d}q] \tag{2}$$

where T is the temperature of the instrument and $\Psi(q)$ is the wave function of quantity q.

Thus, if the test particle can excite the instrument, the total energy provided by the instrument and the test particle should exceed the threshold energy. Thus, the probability of the instrument being excited will be

$$\begin{aligned} P &= \int_{\varepsilon_0-\varepsilon_p}^{\infty}\mathrm{d}\varepsilon\,\frac{1}{kT}\exp\{-\frac{\varepsilon}{kT}\} \\ &= \exp\{-\frac{\varepsilon_0}{kT}\}\Psi^2(q)\mathrm{d}q \propto \Psi(q)\mathrm{d}q \end{aligned} \tag{3}$$

The first factor is just a constant. Thus, the probability density for the instrument indicating the particle to have quantity q will be

$$\mathcal{P}(q) = \Psi^2(q) \tag{4}$$

which is exactly the formulation desired.

The God's View

The discussion in the above section infers the possibility to construct a god's view similar to the classical Theory of Relativity. In Relativity, observers and particles are all considered to be world lines. If we want to predict the measurement results of some observer, there is a standard procedure: first, construct a coordinate system; second, find the world line of the observer and test particles; third, calculate the decomposition coefficient of test particles to the observer.

Here, we see that all events, including observer and test particles, are depicted with the help of a coordinate system. However, the coordinate system itself may well not be an observer or even does not have a physical correspondence. This is what is called the god's view, which means that there can be a virtual administrator that can perceive all events and predict the observational results attained by every observer.

We hope that this method can be extrapolated to the quantum theory. Imagine that all particles (including instrument particles) behave classically. This indicates that the bottom of the world can be described in a god's view which is classical but not observable. In order to gain the observational result, we need a state $|\psi\rangle$ assigned to each particle (just as the 4-velocity in Relativity). The wave function still provides the probability density of a particle having certain quantity to excite the instrument. Nevertheless, the probability density here is consequently a statistical probability density and it comes solely from the instrument particles. And we believe that this kind of statistical probability can be derived through classical statistical model.

Standard Interpretation

Based on the above discussion, we present our suggested standard interpretation of quantum theory

Standard Interpretation of Quantum Theory.

The particle is described by a classical field which follows classical equation of motion. Each field is assigned with a state which indicates the statistical possibility density (visibility) of the particle to interact with instrument at certain quantity.

Perspective

Most proposals about the interpretation of quantum theory are just some tricks of ideas, since they are not able to bring about any observational difference. Howbeit, the interpretation introduced here is not among them. Until now, we still have two things to do.

Theoretically, equation (2) is left unproved. We can only say till now that it is an assumption and if it is correct, the whole scheme works. The standard interpretation requires that under the god's view, particles behave classically. Thus, there should be a derivation to obtain formula (2) through statistical method.

Experimentally, this interpretation can lead to some results that can be verified by the experiments. For instance, if we now want to measure the position of a particle, i.e. $q = x$, there will be

$$P = \exp\{-\frac{\varepsilon_0}{kT}\}\Psi^2(x)\mathrm{d}x \tag{5}$$

It is indeed proportional to $\Psi^2(x)\mathrm{d}x$. However, if now we make the threshold energy ε_0 a function of x, which means the energy needed to excite the position detector is varying along space, the result will be

$$P = \exp\{-\frac{\varepsilon_0(x)}{kT}\}\Psi^2(x)\mathrm{d}x \tag{6}$$

We see that the first coefficient is no longer a constant, which causes difference in experiment. This indicates that this interpretation is more like a theory instead of an interpretation. And this theory will give a prediction that if the threshold energy of the instrument varies along certain quantity, the visibility of that quantity of a particle will no longer be proportional to the given wave function, which can be checked by future experiments.