Interference in Quantum Mechanics, A Violation of the Law of Conservation of Energy

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All measurable phenomena in physics are irreducibly particle like and the wave picture of physical systems only arises when explaining a statistically relevant set of measurements of individual systems as an average. The wave picture arises in the effects of interference which can always be explained in the context of the state description of the interfering system, interference necessitates that the measurement outcomes be calculated by squaring the amplitudes after adding and non-interference is calculated by squaring before adding. Even though the calculation for each is independently valid, the ***change*** *in the statistics when one* ***modulates*** *between interference and non-interference, as in the quantum eraser, requires a violation of the law of conservation of energy. There is no "driving force" in the change of statistics. It is always a change in preparation that leads to the change of interference statistics, whilst in the calculation there is only a change in the state description. The irreducibly particle like nature of the quanta requires that there be a causal "driving force" in the change in statistics and a mere change in description is an insufficient explanation by the standards of energy conservation. We present the argument that indeed this has already all been proven in the historic 1991 study of the ZWM papers of quantum coherence.*

Wave Particle Duality by Statistical Correspondence

The first conceptual argument to arise in the history of quantum mechanics is that which questions how the description of quantum mechanics corresponds to the system being observed, an argument which highlights wave particle duality. This interpretational dichotomy, that the system of quantum mechanics may be considered a particle or a wave, has paved the way for much of the history of quantum experiment. The classic double slit interference experiment is often the discussion of choice when one wishes to explain wave particle duality in quantum mechanics. Somehow the experiments of interference have results which would indicate that the quanta has a wave property, even though they are quanta, particles. Because history has lead to the general acceptance of the irreducibility of the particle, when considering interference effects one is now left wondering how the particle like quanta displays a classical wave like effect of interference. The answer to this problem is simple, the irreducible quanta is a particle but it only satisfies the equations of quantum mechanics when considering a statistically relevant set of such particles. The theoretical calculation in an actual interference experiment is always an expectation value of a physical observable, it is an average. The real result of the interference experiment that the theoretical calculation is compared to is always a statistically relevant set of measurements of individual systems or particles. With this picture in mind we can see the reason for which particle like quanta display wave like features, because the description that they fulfill as a statistically relevant set is wave like.

Interference versus Non-interference

The effect of interference between possible sources of a quantum mechanical system is always an extremely difficult experimental preparation to achieve. On the other hand, the destruction of such interference is the easiest possible preparation to achieve, as there is always a great number of possible ways to destroy any interference pattern of quantum mechanics. For the standard interference effect one might destroy the interference by blocking one path, by misalignment of one path, by performing a unitary action on the system along one path, by delaying one path, etc. Many of these means to interference destruction would require preventing all the particles that travel one path from arriving at the final destination at the detection screen, and many would only require a modification to all the particles that travel one path whilst still allowing them to arrive at the detection screen. It is the latter case that most demands an explanation. It is often argued in the literature that the underlying reason for which all means to interference destruction will achieve their end goal of destroying interference is because of distinguishing information of path. Disregarding the need for a fundamental explanation we note that the general direction of explanation argued by the quantum physicist is always the same, it is always argued that there is a change to the state preparation which determines an appropriate change in the state description of the system and the new description will lead to a change in the end calculation of the statistical pattern, which is that of non-interference. A similar argument could be made for the change from non-interference to interference.

It is argued here (specifically for the case of single particle interference effects) that the *end change in the statistical configuration* of the measurements of individual systems in an experiment where there is a change in preparation which causes a destruction or re-creation of interference occurs in a matter that is only explained in the context of a *change in the state description*, and is specifically not explainable in the context of a real physical *driving force* which would be compliant with the laws of conservation of energy and momentum. We must ask as classical physicists, how is it that such a subtle change to the preparation may indeed cause such a drastic change in the measurable statistics? In the quantum eraser[1,2,3,4] of references 3 & 4 it is the insertion of a half wave plate in one path which destroys a single photon interference effect. How could the insertion of a half wave plate in one path cause such a drastic change in the measurable statistics of the system? Because of a change to the state description? Surely, if we were considering baseballs instead of particles we would need to ask such questions as "How does a change in the description of the baseballs change the measured position of the baseballs?", and "Where is the driving force behind the change in position of the baseballs?" Why do we not need to ask these questions when dealing with the quanta?

Many might interject at this point with the argument that quantum mechanics naturally conserves energy and momentum because the Hamiltonian is invariant under specific displacements which leads to the argument that the associated operator of the displacement is a constant of motion[5]. This argument fails to explain why some preparations have interference and others don't, and it fails to answer what is the underlying cause of the difference between the two, interference and non-interference. The underlying principles of interference are simply not explained by quantum mechanics, this is an argument of quantum mechanics which has yet to be fully resolved.

The only proper explanation is the one we have mentioned earlier, the determination of the state description for the two preparations. If we are to consider the possibility of modulating between these two preparations, we must consider a "choice" of the preparation which when taken modifies the preparation from that of interference to non-interference. So we assume that when the choice is taken by the preparation manager there is no interference observed, and when the choice is not taken there is interference observed. To be exact, when a measurement is observed of an interfering system it will only display interference if the space time coordinates of the measurement are on the future light cone of an event which occurs at the spatial point of the choice preparation at a time while the preparation was such that the choice was not made[6]. So if the system is subject to the "choice made" preparation at the time it is in the region of the choice it doesn't display interference at the time of measurement, otherwise it does. This gives us the false sense of security that there is no violation occurring in this type of experiment with interference modulation, because the individual systems that encounter a given preparation will be observed in accordance with the state determined for that preparation. But can we be so certain? If a preparation of a system is set up in a given manner to have a specific description that is matched by observation, then any change to the preparation which also changes the observations should be able to account for the change in observations in a manner that conserves energy. *If there is a spatial displacement of the positions of the observed measurements that is caused by the change in preparation, then the change in preparation must specifically account for the required input of energy into the system which would be required to cause these displacements in position*.

Do the subtle changes of preparation in these experiments of quantum mechanics where there is a modulation of interference truly account for the end changes in the observations in a manner that conserves energy? It is argued here that any of the above mentioned "preparation changes" that cause a modulation of interference measurements, a change which is always merely explainable by a change in state description, necessarily constitutes a violation of the law of conservation of energy.

Empirical Evidence

The above stated claim, that the creation and destruction of a single photon interference effect violates conservation of energy, is a bold claim to make. One might not consider this an obvious conclusion to come to when surveying the modern literature of quantum mechanics. However it is the case that for one specific study in the history of quantum optics, the ZWM study[7,8], there is already evidence to support this claim. In this study there is an investigation of induced coherence between commonly pumped downconversion crystals. The outputs of the downconversion crystals, entangled pairs of photons referred to as signal and idler, are able to be combined in a way that the two possible sources of idler are overlapped and aligned while the signals are combined at exact optical path lengths to produce a single photon interference effect. This is the only historical demonstration of a single particle interference effect between possible sources of an individual system that occurs while its entangled partner system is available to be detected in coincidence. The main conclusion reached by the authors is that the interference is decisively dependent upon the *in principle knowability of path*. If the idlers are not aligned properly, then the possibility exists to determine the path of the signal and interference is destroyed. This study is also the basis of references 6 and 2 where in reference 6 a theoretical study is presented which considers a time dependent modulation of the "choice" of preparation to destroy or create interference. Specifically in reference 2 the authors present the utility of using the ZWM setup as a quantum eraser, where the "choice" of the preparation is to either misalign or align the idlers so as to destroy and re-create the interference of the signals respectively.

This specific action of alignment of the idlers is mentioned in the original ZWM study as being a central criterion in the determination of the state description. With the alignment properly prepared the theoretician is justified in excluding one of the idler modes in the combined state description and treating the two modes as one, which leads to the calculation of interference in the correlation function. This is important, as we see that the action of our "choice" in preparation, to align or misalign, only has the effect of changing the state description. If the misalignment preparation is chosen then the state description must include all four modes with one for each idler and signal, which leads to non-interference in the calculation of the correlation function. The authors are particularly clear about one point in all four papers, it is the *in principle ability to determine the path* that results from misalignment of the idlers which leads to a destruction of interference between signals. It is the change to the ***state description***, specifically a change in state description which is determined by a change in preparation of the idlers that destroys interference in the signals. Clearly in this study we can all agree that there is no such causal mechanism or driving force that is exerted upon the signals which leads to the change in its measurable statistics. *There exists no argument which would present a classical mechanical account of how the action taken on the preparation of the idler beams leads to a change in the measurable statistics of the entangled signals*. This exact point is thoroughly discussed in reference 6.

The ZWM study is decisive, not only as empirical evidence to the dependence of interference upon the in principle knowability of path, but also as evidence to the violation of conservation of energy that occurs when one modulates this in principle knowability of the preparation in such a way to modulate the measurable statistics of interference, in general for all interference effects. In the ZWM study the authors have eliminated all other possible alternative explanations, because the preparation is such that there is no causal influence of the "choice" of preparation on the interfering system. It is the state description which is fundamental to interference effects of quantum mechanics. The determination of the state description is always chosen in accordance with its preparation and a modulation of this preparation which might merely infer path information is enough to modulate the measurable statistics in a manner that needn't be in accordance with the law of conservation of energy. The law of conservation of energy is *peripheral* to quantum mechanics.

Collapse as an Explanation?

To understand the difference between states of interference and non-interference one might wish to also consider the irreducible randomness of measurement collapse. This is important to our understanding of interference because interference is a statistical effect. In statistical measurements there is an underlying random influence to those individual events that make up the statistical set. In the case of spatial interference, the individual events are position measurements of individual particles that only fulfill the position distribution of their state description as a statistically relevant set of such measurements. These individual events are randomly influenced, and the description only gives us a general picture of the outcome of an individual measurement. It could be said that an individual position measurement has a non-zero probability of success for all possible positions within the combined uncertainty over three dimensions. Since these individual position measurements are partially random, we have no explanation as to *how* they add up to fulfill their description at the end of the day. This argument can be made both for the case of interference and the case of non-interference, both simply end up fulfilling their position distribution at the end of a collection of a statistically relevant number of position measurements. Considering the randomness of quantum mechanics only shows us where quantum mechanics *lacks* an explanation of the difference between interference and non-interference statistics. One only considers collapse when taking into account the mechanics of an individual system, and quantum mechanics is not a mechanics of individual systems.

Empirical Protocol

In order to give empirical testability to the claims made here concerning a violation of the law of conservation of energy, we suggest a simple protocol[9]. First, one must prepare a single-particle spatial interference effect that has a "choice of preparation" which can be utilized to destroy and re-create the interference. The "choice" has to be modulated in a manner so that the observed statistics are modulated between interference and non-interference. The frequency of modulation should be chosen so that it is as quick as possible while still allowing a statistically relevant set to be observed in each half period. Both choices of interference and non-interference must exist for a long enough time to allow for a significant number of observations so that each will display a statistically relevant set in a full period of modulation. With things prepared this way we would expect to have the quickest possible modulation between systems that display the statistics of both states. If the single particle interference effect was that of an optical interference effect with a Mach-Zehnder interferometer as in references 3 & 4 then one would simply modulate the insertion of the half wave plate, and this would modulate the statistics observed between interference and non-interference.

The statistical display of the observations has to be utilized in a manner that the change between interference and non-interference is used to drive a motor which performs the sole task of delivering this energy of modulated statistics to its environment. This would necessitate that the preparation not use a detector for display of the statistics but rather a screen which drives the motor. If the single particle interference effect was that of an optical interference effect with a Mach-Zehnder interferometer as in references 3 & 4 then one might simply use a screen with a sub-bandgap material that would become ionized by the incident photons. With this preparation, any changes in the statistics due to the modulated "choice" would cause a proportional change in the ionizing potential. This modulation of ionizing potential could easily be used to drive a motor which liberates its energy to the environment.

The final setup is to immerse the whole preparation into an adiabatically sealed bath with the appropriate thermodynamic data collection. The whole apparatus has two designated inputs, the pump for the interfering system and the frequency generator for the modulation of the "choice". By setting up this preparation in two scenarios, one with the modulation of choice acting on the system to deliver the modulation of statistics which drives the motor (scenario 1), and another with the modulation of choice removed from affecting the system but still immersed in the bath (scenario 2), by taking the difference in the temperature curve between the two scenarios one can measure whether there is indeed a violation of conservation of energy occurring. If there is a violation of conservation occurring than we would expect the temperature curve of scenario 1 to have a linear increase in temperature that deviates from the curve of scenario 2. If no such difference is found between the temperature curves of scenario 1 and 2 than we can conclude that there is indeed a conservation of energy occurring and that there is a *driving force* that is causing the change in statistics.

References

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