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Decrypting the Central Mystery of Quantum Mathematics: Part 2. A Mountain of Empirical Data Supports TEW

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Abstract

The Theory of Elementary Waves (TEW) is based on three new Axioms that lead to a different understanding of quantum mathematics. There is a massive amount of research data that supports TEW. This article will take six well established experiments from mainstream scientific journals and re-interpret their results from a TEW point of view. Although it is usually asserted that QM explains all existing quantum experiments, that is only true if you can convince yourself that the quantum world is weird. But how could the quantum world be weird, when the classical world, of which the only constituents are quantum, is "normal" (not weird)? Schrődinger's cat does not represents our everyday experience. If you adopt TEW Axioms, suddenly the quantum world transforms itself into looking ordinary, like everyday Nature. If, for example, time only goes forwards, never backwards; if there is no such thing as a quantum eraser; if nothing is transmitted faster than the speed of light, then TEW Axioms allow you to make sense of a quantum world which QM can only explain if you allow for weirdness throughout Nature. By Occam's razor TEW Axioms are better because they lead to a simpler, more coherent model.

Keywords Theory of Elementary Waves

Mathematics Subject Classification (MSC2010): 81Q65 Alternative Quantum Mechanics

1 Introduction

This is the second in a series of four articles describing a new approach to quantum mathematics.[1-4] In the preceding article, about the double slit experiment, we proposed a change of Axioms. We proposed to move the entire structure of quantum mathematics from the wobbly Axioms of Quantum Mechanics (QM) to the solid Axioms of the Theory of Elementary Waves (TEW), which are:

A. Wave function collapse occurs *before* we measure something,
B. There is *no* wave particle duality,
C. Waves travel in the *opposite* direction as particles.

Given that quantum mathematics is the most valuable and accurate science that humans have ever had, is it safe to change the platform in such a potentially disruptive way? If you had a computer built on the platform of a silicon chip that had a flaw, that flaw might make it vulnerable to meltdowns and hackers. That chip is akin to the wrong Axioms of QM. But moving all of quantum math to a new platform is a high risk proposal. Would the TEW Axioms cause the whole system to crash and burn? Why would we want to do something so risky? Why can't we limp along as we were before, enjoying the equations and trying to avoid thinking about how the quantum world "really" works?

The motivation for such a change of platforms is the paradox that quantum mathematics is so astonishingly good, but somehow QM convinces us that the quantum world is weird, either beyond human comprehension, or asking us to accept absurdities like Schrődinger's cat, or data being erased backwards in time. Furthermore if the quantum world is so weird that humans cannot understand it, then how does it happen that when you build Nature out of weird bricks, you end up with an everyday world that is not weird?

The advantage of having scholarly journals to discuss these issues, is that we can lay out the proposed change of Axioms, think about and debate them, and figure out what would be the risks versus benefits of moving quantum math to this new platform.

In this article we will examine six published quantum experiments. We will investigate these experiments in detail, telling you what the research question was, the research design, what QM believes the experiment says and what TEW believes the experiment says. Judge for yourself. This is a trial. You are the jury. Who is on trial? The TEW Axioms.

Here are the six experiments that form the bulk of this article:

1. A quantum eraser experiment by Kim et. al.
2. A neutron interferometer experiment by Kaiser et. al.
3. A Stern Gerlach magnet experiment
4. Wheeler's interferometer thought experiment
5. Davisson and Germer's "proof" of wave particle duality
6. Pfleegor and Mandel's attenuated laser interference experiment

This article will allow you to see how the TEW Axioms actually work under laboratory conditions.

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2 Quantum Eraser experiment

In a double slit experiment you see an interference fringe pattern on the target screen only if you do not know which slit the particle went through. If you discover which slit was used, the interference pattern vanishes. Kim, Yu, Kulik, Shih and Scully published data from an experiment in the year 2000 allegedly showing that you can have an interference fringe pattern on the target screen, but if **at a later date** you learn which slit was used, then that data will be erased backwards in time![5]

This experiment is often cited as proof that the quantum world is "weird." We will re-analyze the data and show that, if you adopt the TEW Axioms, this experiment does NOT show any erasure of data, nor does it show that an effect can precede its cause. The experiment shows that there is nothing remarkable about the quantum world. It is just plain ordinary, like the world of everyday experience.

2.1 Description of the experiment

This experiment takes the output from a double slit apparatus and splits each photon into two entangled photons. One of the photons, called the "signal photon" etches an interference wave pattern on a target screen. At a later time the "idler photon" is randomly assigned either to a detector that allows us to know which slit was used, or to another detector that prevents us from knowing which slit was used. If the idler photon reveals which slit was used, then the interference wave pattern on the target screen is allegedly erased, backward in time. If the idler photon does not disclose which slit was used, then the interference wave pattern on the target screen is preserved.

That is what the experimenters believe the experiment does. Actually the last paragraph does not describe what actually occurs in this experiment. It only describes what a conventional viewpoint would erroneously lead you to believe you see. It is like a card trick or a magic trick. What appears to happen and what actually happens are different.

The terms "signal" and "idler" are of historical interest, but those words have no meaning today. We could call them "photon # 1" and "photon # 2."

To reiterate: iff we subsequently know which slit was used, then allegedly the interference fringe pattern on the target screen vanishes, even though that pattern was allegedly inscribed at an earlier time. The timing of cause and effect are reversed.

TEW has a different explanation. We find zero evidence of a quantum eraser, nor of complementarity, nor of time going backwards. The core of the TEW perspective is:

- Wave function collapse occurs *before* we measure something,
- Waves travel in the *opposite* direction as particles.

In this experiment wave function collapse is located at the laser, not at the detectors. The term "wave function collapse" means "when a decision is made." We claim that "Elementary Waves" start at the detectors and move to the laser. All wave interference is incident to the laser. The photon, about to be launched from the laser, is confronted by four incident Elementary Waves, and randomly chooses among them. That is the ONLY decision in this experiment. By the time a photon leaves the laser it is following one of four trajectories, each of which will take it to a pair of detectors. This mechanism allows us to explain all the data from this experiment, with no magical effects.

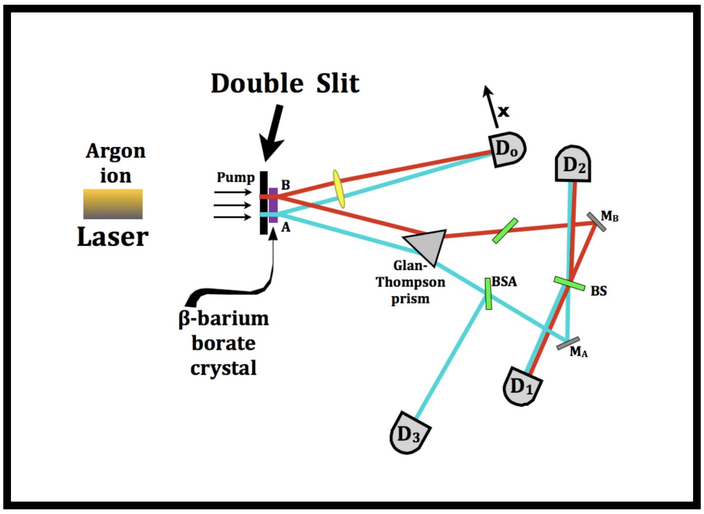

Figure 1: Apparatus used in quantum eraser experiment, color coded for whether a photon came through the upper slit (B = red) or lower slit (A = aqua). In the published article the laser is omitted from the diagram (it is off the left margin), and the main emphasis is on what they call the "SPDC" which is the object we call "$\beta-$barium borate crystal." The letter "x" above the D_0 detector (top right) means that detector moves up and down the "x" axis to capture data about an interference fringe pattern, as if it were sweeping across the target screen of a double slit experiment.

Figure 1 shows the apparatus used. This diagram is color coded: if a photon goes through the upper slit (B) then its trajectory is colored red. If a photon goes through the lower slit (A), its trajectory is colored aqua blue.

There is a pivotal difference between Figure 1 and the equipment diagramed in Kim's published article: we include the Laser. Kim et. al. regarded the Laser as so unimportant that it was not even included in their diagram: they alluded to a "pump" off the left margin of their diagram. Their description focuses on what they call the "SPDC" as the place where the photons start.

From our viewpoint everything important in this experiment takes place at the laser, and we call the "SPDC" a "BBO Crystal." When photons come from the argon laser on the left, the photons first encounter a double slit apparatus, followed by a crystal made of $\beta - BaB_2O_4$ (BBO crystal). This crystal causes type-II spontaneous parametric down conversion (SPDC), meaning that the crystal takes each photon of 351.1 nm coming through one of the slits, and splits it into two offspring: photons of 702.2 nm each, orthogonal to one another.

First we will describe the QM viewpoint, then the TEW viewpoint.

2.2 QM viewpoint

Detector D_0 moves up and down the "X" axis (top right of Figure 1) so that it sweeps across the full width of a double slit screen, if there were such a screen. This movement allows D_0 to record an interference wave pattern from the screen.

The idler photon goes down into a complicated arrangement of other detectors. It doesn't arrive at those detectors until picoseconds after the signal photon has made its pattern. The other detectors are arranged so that if ***detector*** D_1 ***or*** D_2 clicks then you ***don't know*** which slit was used, which means in Figure 1 that both red and aqua lines enter those detectors.

On the other hand, if the idler photon strikes ***detector*** D_3 ***then we do know*** that only slit A was used, which means in Figure 1 that only an aqua line enters that detector. No red line enters detector D_3. If you were standing at detector D_3 you would be able to see slit A, but you could not see slit B. The final data show that if detector D_3 clicks, then there is no data coming from D_0. They claim that means the wave pattern has been erased backwards in time.

The mathematics published in the Kim article implies there was another detector D_4 not shown in the diagram. D_4 would be symmetrical with D_3. It would receive a photon from BSB (beam splitter B) so that only a red line would enter D_4, no aqua line.

Kim et. al. say they have predicted results using standard QM equations, which we are about to show you. Data are based on a pair of detectors clicking simultaneously. For example, if D_0 clicks a few picoseconds before D_1, that means that a signal photon has been detected at D_0, and its twin has been detected at D_1. Therefore for the D_0, D_1 pair, the variable R_{01} would count "one click."

The variable R_{0i} represents the variable counting the combination of detectors D_0 and D_i both clicking during time period T. Let $T = 0$ be the time when photons leave the SPDC (BBO crystal). Then the Glauber equation is:

$$R_{0j} \propto \frac{1}{T}\int_0^T \int_0^T dT_0 dT_j \left\langle \Psi \middle| E_0^{(-)} E_j^{(-)} E_j^{(+)} E_0^{(+)} \middle| \Psi \right\rangle \tag{1}$$

$$= \frac{1}{T}\int_0^T \int_0^T dT_0 dT_j | \left\langle 0 \middle| E_j^{(+)} E_0^{(+)} \middle| \Psi \right\rangle |^2 \tag{2}$$

where T_0 is the detection time for D_0, and T_j is the detection time for D_j where $j = 1, 2, 3, 4$, and where $E_{0,j}^{(\pm)}$ are the positive and negative frequencies at detector D_0 and D_j. The entangled state of the type II SPDC is denoted $|\Psi\rangle$.

$$|\Psi\rangle = \sum_{s,i} C(k_s, k_i) \alpha_s^\dagger(\omega(k_s)) \alpha_i^\dagger(\omega(k_i)) |0\rangle \tag{3}$$

where

$$C(k_s, k_i) = \delta(\omega_s + \omega_i - \omega_p)\delta(k_s + k_i - k_p) \tag{4}$$

for the SPDC and ω_j and k_j where $j = 1, 2,$ or 3 are respectively the frequency and wave vectors for the $s =$ signal, $i =$ idler and $P =$ pump (i.e. laser), and they assign ω_p and k_p to be constants. The creation operators for the signal and idler photons are denoted $\alpha_s^\dagger$ and $\alpha_i^\dagger$. The δ functions are calculated for infinite interaction time for an infinitely large SPDC.

$$\Psi(t_0, t_j) \equiv \left\langle 0 \middle| E_j^{(+)} E_0^{(+)} \middle| \Psi \right\rangle \tag{5}$$

where $\Psi(t_0, t_j)$ is the wave function, and where $t_0 \equiv T_0 - L_0/c$ and $t_j \equiv T_j - L_j/c$ where $j = 1, 2, 3, 4$ and where L_0 or L_j is the optical distance from the BBO crystal to detectors D_0 or D_j.

The four wave functions correspond to four combinations of detectors D_0 with each of the other detectors D_j as follows:

$$\Psi(t_0, t_1) = A(t_0, t_1^A) + A(t_0, t_1^B) \tag{6}$$

$$\Psi(t_0, t_2) = A(t_0, t_2^A) - A(t_0, t_2^B) \tag{7}$$

$$\Psi(t_0, t_3) = A(t_0, t_3^A) \tag{8}$$

$$\Psi(t_0, t_4) = A(t_0, t_4^A) \tag{9}$$

Detector D_4 is implied in the bottom equation, but, as we said before, the authors did not include D_4 in Figure 1. In the equations just itemized, the upper index of t (A or B) indicates which slit in the double slit the photon came through (slit A or slit B) and that determined which part of the SPDC was used. For simplicity they used only the longitudinal integral, and wrote the two photon state in terms of k_e and k_o in the following equation:

$$|\Psi\rangle = A_0' \int dk_e \int dk_o \delta(\omega_e + \omega_o - \omega_p) \times \Phi(\Delta_k L) \alpha_{k_e}^\dagger \alpha_{k_o}^\dagger |0\rangle \tag{10}$$

where $\Phi(\Delta_k L)$ is a sinc-like function:

$$\Phi(\Delta_k L) = (e^{i(\Delta_k L)} - 1)/i(\Delta_k L). \tag{11}$$

Combining equations 5 and 11, they find that

$$A(t_i, t_j) = A_0 \int dk_e \int dk_o \delta(\omega_e + \omega_o - \omega_p) \times \Phi(\Delta_k L) f_i(\omega_e) f_j(\omega_o)(e^{-i(\omega_e t_1^e + \omega_o t_2^o)}). \tag{12}$$

where $f_{i,j}(\omega)$ is assumed to be a Gaussian of a hypothetical spectral transmission filter in front of detector $k_{i,j}$. To complete the integral they define Ω_e and Ω_o to be the center frequencies of the SPDC, $\Omega_e + \Omega_o = \Omega_p$ and they define ν to be a small tuning frequency, such that when they define $\omega_e = \Omega_e + \nu$ and $\omega_o = \Omega_o - \nu$, the relationship $\omega_e + \omega_o = \Omega_p$ is true. Therefore they can expand k_e and k_o around $K_e(\Omega_e)$ and $K_o(\Omega_o)$ respectively.

Completing the integral, the wave packet for the two photons coming from the SPDC is:

$$A(t_i, t_j) = A_0 \Pi(t_i - t_j) e^{-i\Omega_i t_i} e^{-i\Omega_j t_j}. \tag{13}$$

They dropped the e, o indices.

The shape of $\Pi(t_i - t_j)$ is determined by the bandwidth of the spectral filters and the parameter DL of the SPDC, where $D \equiv 1/u_o - 1/u_e$. If the filters are removed they obtain a rectangular pulse function $\Pi(t_1 - t_2)$. By "rectangular" they mean: $\Pi(t_0 - t_j) = 1$ if $0 \le (t_0 - t_j) \le DL$ and is otherwise 0.

Clearly the two amplitudes $\Psi(t_0, t_1)$ and $\Psi(t_0, t_2)$ overlap at both $t_0 - t_j$ and $t_0 + t_j$. Therefore interference is expected in both the counting rates of coincidences R_{01} and R_{02}, but the different sign will result in a phase shift of π.

$$R_{01} \propto cos^2(x\pi d/\lambda f) \text{ and} \tag{14}$$

$$R_{02} \propto sin^2(x\pi d/\lambda f) \tag{15}$$

For R_{01} and R_{02} they will have a standard interference and diffraction pattern:

$$R_{01} \propto sinc^2(x\pi a/\lambda f)cos^2(x\pi d/\lambda f) \tag{16}$$

$$R_{02} \propto sinc^2(x\pi a/\lambda f)sin^2(x\pi d/\lambda f) \tag{17}$$

where d is the distance between slits A and B, a is the width of each slit (equal widths) and $\lambda = \lambda_s = \lambda_i$ is the wavelength of the signal and idler photon, and f is the focal length of the lens between the BBO crystal (SPDC) and the D_0 detector. A lens (shown in yellow in Figure 1) is used to bring the detector D_0 closer to the BBO crystal, in order to force the D_0 detector to collect data picoseconds earlier than any of the other detectors.

The data show that there is or is not an interference pattern on detector D_0 depending on which detector the idler photon strikes. These data conform to the mathematics developed above.

The researchers conclude that they have created a quantum eraser like that originally proposed by Scully and Drűhl.[6] Because of quantum entanglement they are able to observe both the particle-like and wave-like behavior of a quantum of energy. Even after the signal photon has been detected by D_0 that signal can be erased or not erased, based on what subsequently happens to the idler photon at another detector.

2.3 TEW viewpoint

TEW has a drastically different view. Elementary Waves start at the detectors and go to the laser. All wave interference is located in proximity to the laser. Photons follow the waves backwards. What the D_0 detector measures is reality. If detector D_0 sees an interference pattern, that means waves are interfering as they impinge on the laser. If detector D_0 no longer sees an interference pattern, that means wave interference at the laser has ceased. No data is ever erased. Detector D_0 never tells us a lie.

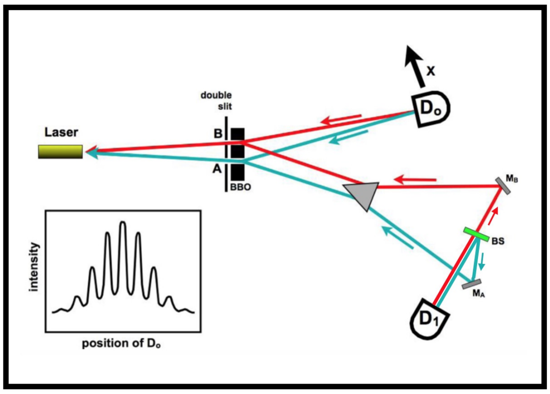

Figure 2: TEW model: Elementary rays of 702.2 nm (red or aqua) originate from the detectors and move to the BBO crystal, where they combine into red or aqua rays of 351.1 nm heading toward the laser. Since two rays impinge on the laser, there is ***wave interference, the intensity of which is shown in the small graph in the lower left*** (hypothetical data). Some detectors are omitted from this diagram, for simplicity.

You cannot inscribe a pattern on the D_0 screen and then erase it, for the simple reason that the screen shows us a picture of what is real. You can only change the interference pattern on the D_0 screen by eliminating the interference, and that is located in proximity to the laser.

During this discussion it is good to glance at Figures 2 and 3, remembering that the trajectories are color coded. Any trajectory connected to slit B (the upper slit) is colored red. Any trajectory connected to slit A (the lower slit) is aqua blue.

Figures 2 and 3 focus on the elementary rays traveling from the detectors, to the BBO crystal, backwards through the double slit, and impinging on the laser. As you will learn momentarily, a photon in the laser makes a random choice which of four incident Elementary Waves it will follow backwards. After that there are no other decisions. The outcome of the experiment is 100% determined by the time a photon leaves the laser.

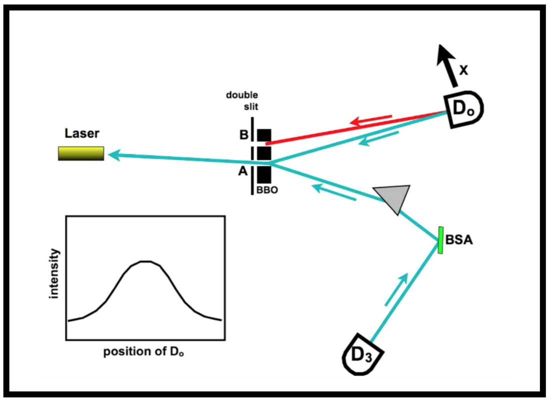

Figure 3: Simplified TEW model: Detector D_3 puts out an aqua elementary ray of 702.2 nm, but no red ray, for the simple reason that it cannot "see" slit B (the upper slit) because of how the equipment is constructed. The BBO crystal is unable to make a red ray of 351.1 nm going toward the laser because of lack of ingredients (one of the two red rays of 702.2 nm it needs is missing). Therefore there is no wave interference at the laser, because it takes two waves of 351.1 nm to make interference. Therefore the final dataset reports NO INTERFERENCE, because there is no superposition of waves in proximity to the laser, as shown in the small graph at the lower left (hypothetical data).

In order for there to be wave interference, there need to be ***two*** elementary rays of 351.1 nm impinging on the laser: one red, the other aqua. If there is no interference pattern in the final dataset, that means one of those two rays is absent. That is the key to understanding this experiment. It explains all the data.

Each detector puts out elementary rays of 702.2 nm, and those waves follow the trajectories (red or aqua), moving toward the BBO crystal. If you compare Figures 2 and 3 you will see that in one case a 351.1 nm red ray can form inside the BBO crystal, but in the other case it cannot form, because half of its ingredients are missing. Therefore there is an interference pattern in Figure 2 but no interference pattern in Figure 3.

Can 702.2 nm red rays comes from detector D_3? No! That is impossible, because that detector cannot see the upper slit (B). The equipment is so constructed that a ray from D_3 can reach the lower slit (aqua ray) but not the upper slit (red ray). Therefore inside the BBO crystal no red ray of 351.1 nm can form. ***Therefore, if the detector D_3 is involved, there is NO red ray moving from the upper slit to the laser, no interference in proximity to the laser, and no interference pattern on the target screen.***

The word "interference" refers to the superposition of Elementary Waves of 351.1 nm traveling from the double slit toward the laser (red and aqua in the diagrams). If there is interference then there need to be two such waves of 351.1 nm incident to the laser, which requires that there be two waves of 702.2 nm incident to the upper slit (B), which is impossible if detector D_3 is involved. Memorize that last sentence and you will understand the experiment!

In this model ALL decisions are made at the laser, a dozen nanoseconds earlier than when QM thinks decisions are made. This is the first Axiom of TEW: that wave function collapse occurs prior to the photons reaching the detectors. In this experiment wave function collapse occurs at the laser.

No decisions are made at the beam splitters, nor at the detectors. At each beam splitter an idler photon follows its predetermined trajectory in one direction or the other. It has no choice. After a photon is emitted by the laser, the elementary ray that triggered it becomes the trajectory for the photon to follow backwards. After a photon is emitted by the laser the ball game is over: its contribution to the final data is already determined.

Decisions are made by the photon inside the laser. The photon has a choice of four elementary rays, but it can only choose one of them, and it makes that choice at random:

1. Waves from D_0 and D_1 coming through both slits and interfering;
2. Waves from D_0 and D_2 coming through both slits and interfering;
3. Waves from D_0 and D_3 coming only through slit A: no interference;
4. Waves from D_0 and D_4 coming only through slit B: no interference.

If the photon randomly chooses # 1 or # 2 (from the list above) then the final data will show an interference pattern on the target screen (D_0). If the photon randomly chooses # 3 or # 4 (from the list above), then the final data will show no interference pattern on the target screen (D_0).

In summary: from a TEW viewpoint the experiment is easy to explain and shows nothing remarkable. There is zero evidence in this experiment of a quantum eraser, nor of complementarity, nor of time going backwards.

What this illustrates is that, if you adopt the three TEW Axioms, the quantum world is not weird. It is similar to the world of everyday experience. There is no boundary of "weirdness" that separates the quantum world from the classical world. That raises the question whether the "weirdness" which QM discovers in the quantum world is an artifact of having incorrect Axioms. We think: Yes!

Many people think we need an alternative to QM, but they cannot stomach the idea of waves traveling in the "wrong direction." Well, take a look at this quantum eraser! There is no logical way to explain it unless waves travel in the "wrong direction." So if you reject TEW, then what we say is: enjoy your quantum eraser!

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3 Neutron Interferometer experiment

A research team founded by Helmut Rauch did the basic research that created the field of neutron interferometry. The team was and is highly respected. The publication which we will focus on is written by Helmut Kaiser, Russell Clothier, Samuel Werner, Helmut Rauch, and H. Wőlwitsch and was published in *Physical Review A* in 1992.[7]

3.1 The courtroom

The Bailiff announces: "All rise. The Court of Public Opinion is now in session, the Honorable Judge Impartiality presiding." Everyone remains standing until the judge is seated. You are seated in the jury box. The judge then ask the bailiff to call the day's docket, at which point the bailiff says, "Your Honor, today we have only one case, which is **The People Versus the Axioms of TEW**."

The judge then asks the attorneys for each side if they are ready to begin the trial. The Prosecution rises and says:

Opening Statement by the Prosecutor: "May it please the court and ladies and gentlemen of the jury, my name is Quant Orthodoxy, counsel for the people in this action. This experiment is one of the most elegant experiments in quantum mechanics. We will use it in our indictment against the three Axioms of TEW. Basically the experiment shows unusual results in a perfect neutron interferometer when a nearly perfect (NP) silicon crystal analyzer is inserted in front of the detector. The experiment is compelling evidence that the quantum world is so weird that it cannot be understood. The researchers did some heavy mathematical lifting, explaining the weirdness in terms of how a **coherent** signal could be conjured out of an **incoherent** signal by mathematical means.

"A brief summary is that this carefully done experiment by leading physicists, published in a highly respected physics research journal. This experiment produces surprising results. There is an box within which wave interference occurs, and afterwards a beam leaves the box and a detector measures the results. Under certain circumstances the output data shows a flat line when all interference is eliminated inside the box. But when they put a special lens in front of the detector, the lens is able to change the flat line to a sinusoidal curve. The researchers present mathematics to attempt to explain this astonishing change. But fundamentally this experiment demonstrates that the quantum world cannot be explained. It cannot be understood. The experimenters admit that their final data make no sense, and that is the point. That PROVES that the quantum world is weird. The defense attorney's attempt to say otherwise makes no sense. The overwhelming majority of quantum experts endorse the viewpoint that I am about to explain. Almost no experts ever heard what the defense attorney alleges."

The defense attorney's opening statement: "This experiment does not prove the quantum world is weird. It proves that QM cannot give a coherent explanation of what is happening in this experiment. TEW however can. The experiment shows that an increasing amount of Bismuth inside the box (the interferometer) stops all interference inside the device. However when a lens (an NP Analyzer Crystal) is inserted outside of, and downstream from the box, robust interference is restored upstream, inside the box, which the researchers are unable to explain.

"We say that **IF** the presence or absence of a lens in front of the detector causes or destroys wave interference upstairs inside the box, **then the lens controls the experiment.** That can only happen if the lens is upstream from the box, which means that zero energy waves start at the detector, flow backwards through the box, up into the nuclear reactor, and from time to time a neutron follows the waves backwards. We claim this experiment proves that TEW is correct and QM is wrong."

The prosecutor stands up and addresses the jury (you): "This is so preposterous that no reply should be needed! There is no such thing as zero energy waves traveling in the wrong direction. Forget what the defense just told you. The only reasonable explanation is that wave particles travel from the nuclear reactor, through the interferometer, and into the detector. The fact that the special lens (NP Analyzer Crystal) in front of the detector creates a robust sinusoidal

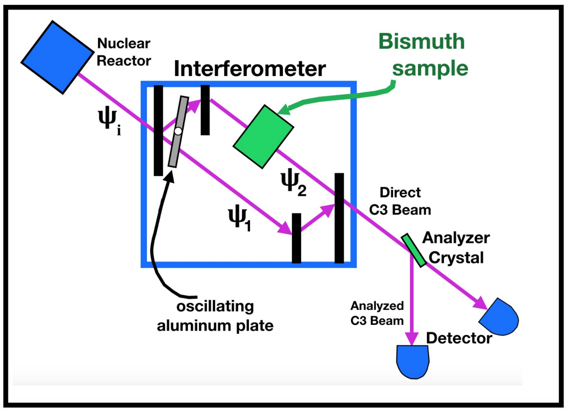

Figure 4: **The Experiment.** A perfect silicon crystal Neutron Interferometer (NI) used in the Kaiser et. al. experiments. The black rectangles represent the four perfect silicon blades. The ^3He detector (blue) in the lower right can be rotated so that the NP Analyzer Crystal (a small green rectangle on the right) is either outside the neutron beam, or in the center of the neutron beam, in which case we call the neutron beam "analyzed" and the neutrons refract straight down to the other position of the detector. All data from this experiment come from that detector, in one position or the other.

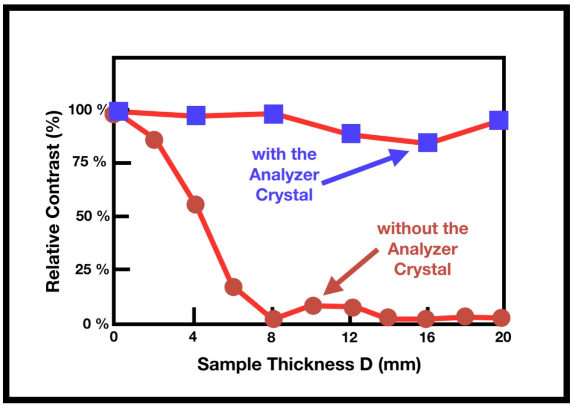

Figure 5: **This Figure is the central focus of this trial.** The red curve shows that with an increasing thickness (D) of Bismuth across the horizontal axis, all interference dies out (on the vertical axis). An NP Analyzer Crystal turns the red curve into the blue curve, which shows robust interference no matter how much Bismuth is used. The prosecutor says the graph means a "coherent" signal (blue curve) has been conjured up from an "incoherent" signal (red curve) by mathematical means. The defense attorney says that what the detector shows is "REAL," meaning that the Analyzer Crystal produced robust interference upstream inside the interferometer.

wave entering the detector is odd. Kaiser et al. show that this occurs because the lens brings out a coherent signal (meaning a robust sine wave) from an incoherent signal (meaning a flat line). This demonstrates that we don't fully understand quantum waves, because clearly the superposition of many plane waves in this case has been rearranged by the lens, so that the waves add together in an unexpected way."

The prosecution asks the jury to appreciate the humility of the researchers, humility that is evident in their citing "Wheeler's smoky dragon," a cartoon published by John Archibald Wheeler to illustrate that sometimes unexplainable things happen in quantum experiments.[8]

The defense attorney stands up and addresses the jury: "Let's review it one more time. The same experiment is repeated twice. Once without a special lens, once with a special lens in front of the detector. The detector is outside and downstream from the box where the interference is located. In both cases the experiment shows the effect of an increasing amount of Bismuth on the wave interference inside the box. If the prosecutor's viewpoint were correct, the Bismuth would strangle off all interference in both cases, but the special lens (Analyzer Crystal) would conjure a strong sinusoidal curve out of a flat line. If that were true it would violate the Second Law of Thermodynamics, the one about entropy. A flat line means all coherence has been lost and entropy is large. A sinusoidal curve would mean entropy is

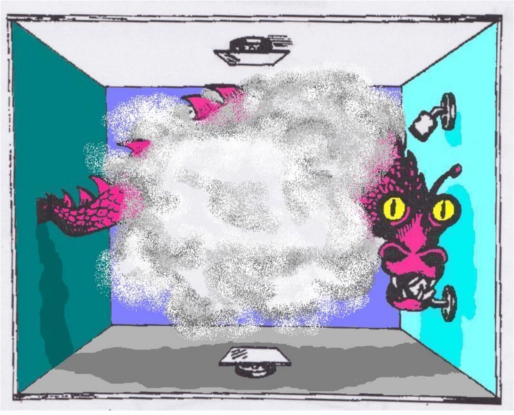

Figure 6: Wheeler's smoky dragon: symbolizing the fact that unexplainable things sometimes happen in quantum experiments. This is included in the Conclusions section of the article by Kaiser, Clothier, Werner, et.al. One hint that something is wrong is when a cartoon of a dragon is referenced in a serious scientific journal such as *Physical Review A*, a journal not known for its sense of humor.

small and all the energy has been restored to the sinusoidal curve. The special lens does not put any energy into the data. You be the judge."

You are the jury, so you decide. Here is a short summary of the experiment, followed by a detailed account of what the equation says.

3.2 Brief sketch

Since the production of "coherence" out of "incoherence" requires unusual mathematics, the report starts with an extended discussion of how Fourier transforms allow an assortment of plane waves to be added into a superposition so as to produce a wave packet. The implication is that if the waves were re-arranged unusual results might appear, such as the production of a "coherent" out of an "incoherent" flat line of output data at the end of the experiment.

The Kaiser research team sent a beam of neutrons Ψ_i into an interferometer, within which the beam was divided into two beams Ψ_1 and Ψ_2, then re-combined into one beam that exited the interferometer through an exit door called C3 and hit a detector. All data comes from that detector. Where Ψ_1 and Ψ_2 bifurcated there was an oscillating aluminum plate, which created a phase difference between Ψ_1 and Ψ_2, so that when they re-joined there was an a sinusoidal curve (interference pattern).

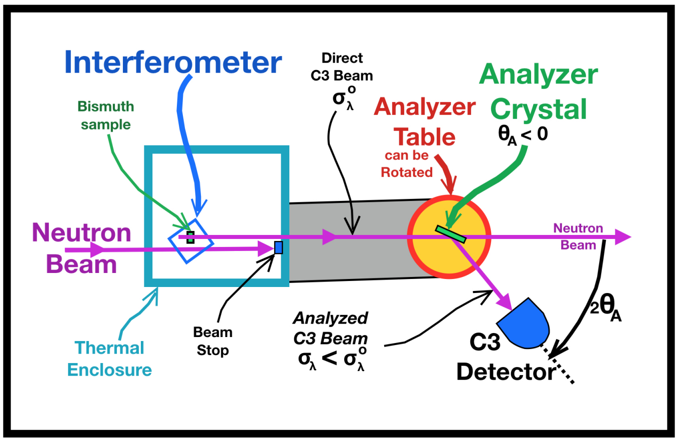

Figure 7: The interferometer (shown in blue) is dwarfed by its surroundings. The analyzer table is 60 centimeters downstream from the interferometer. The ^3He Detector (also shown in blue) can be rotated into the Direct C3 Beam without an Analyzer Crystal, or it can be rotated (as in this diagram) into the (111) Antiparallel Configuration with the NP Analyzer Crystal. The angle of the Analyzer Crystal is $\theta_A = -22.0^o$ (its Bragg angle) and therefore the angle $2\theta_A = -44.0^o$ in this diagram.

Bismuth is a metal of atomic number 83, which slows down neutrons and neutron waves. They put a sample of Bismuth of various widths D in the upper path Ψ_2 but not the lower path Ψ_1. As they increased the sample from $D = 0\ mm$ to $D = 5, 10\ mm$, etc, the upper wave packet (which had a coherence length Δx of only 86 Angstroms) no longer overlapped neatly with the lower Ψ_1 wave packet, so there was a diminishing amount of interference: the sinusoidal curves flattened out toward a straight line. With 12 or more mm of Bismuth there was zero interference, apparently meaning that the upper wave packet had been so delayed that the lower wave packet Ψ_1 had left the interferometer before the Ψ_2 packet arrived at the reunion point. A full sample of $D = 20\ mm$ of Bismuth causes a 435 Angstroms delay in Ψ_2, which is five times the coherence length Δx of that Ψ_2 wave packet.

Then the researchers repeated exactly the same experiment, with only one tiny change. Downstream from the interferometer, in front of the detector, they inserted a “nearly perfect” Analyzer Crystal of silicon: $\Delta\theta = 0.02^o$ full width at half maximum (FWHM), $\eta_A = 0.0035$ rad. That crystal is shown as a small green rectangle in Figures 5 and 7. The crystal was expected to decrease the scatter of wavelengths of the neutron beam, and increase the center of the Gaussian, so the beam would penetrate the ^3He detector better. Such an Analyzer Crystal should have no effect on the interference occurring upstream inside the interferometer.

To their astonishment, the NP Analyzer Crystal totally restored almost ALL contrast in the output data (meaning that a flat line became a robust sinusoidal curve) at the detector. Even with a fat sample of $D = 20\ \ mm$ of Bismuth, there was robust interference, as if the Bismuth were invisible!

There are two interpretations of the results. The defense team says that when the detector detects a sine wave that means there was interference between Ψ_1 and Ψ_2 inside the box. The prosecutor says that when the detector shows a sine wave it is lying: there was NO interference Ψ_1 and Ψ_2 inside the box. The lens (Analyzer Crystal) produced this deceptive sinusoidal curve, even though nothing was happening inside the box. You are the jury, you decide!

The defense team claims the data proves that zero energy waves are starting at the detector and going backwards through the interferometer. Inside the interferometer the two beams Ψ_1 and Ψ_2 interfere with one another and produce a sinusoidal signal. As Bismuth is added it impedes the Ψ_2 beam, so that with enough Bismuth all interference dies out. However, when an Analyzer Crystal is added, the waves can penetrate straight through a fat block of Bismuth, as if it were not there. Therefore the addition of the Analyzer Crystal restores robust interference between Ψ_1 and Ψ_2 as reflected in a strong sinusoidal signal. The Elementary Waves starting at the detector, traveling “backwards” through the interferometer, then penetrate the nuclear reactor in the upper left of Figure 4. From time to time a neutron follows the waves backwards, and make the interference visible.

All waves always travel from lower right to upper left in Figure 4. The insertion of an Analyzer Crystal restores robust interference inside the interferometer. As always, TEW says that what the detector reports is true, it is reality. The detector does not lie. If the detector reports a strong sine wave, then there IS strong interference inside the interferometer. The Analyzer Crystal does not perform magic.

The prosecution team’s interpretation of the data is that:

1. The defense theory is too absurd to discuss, and
2. Complicated and obscure mathematics makes the problem go away.

According to the prosecutor the strong sine wave does NOT mean there is interference inside the interferometer. It means that mathematical equations have performed magic. **Since there is no interference (with enough Bismuth) therefore a flat line comes out of the interferometer. When the flat line enters the lens (Analyzer Crystal) it is converted into a strong sinusoidal curve.**

3.3 Details of the experiment

That ends our sketch of what you are about to read. Below are pages of mathematical equations and charts of data, with graphs, that are needed in order to explain this experiment in full detail.

The published article emphasizes that a neutron wave packet depends on a Fourier sum of plane waves. They alter the coherent overlap of two wave packets (Ψ_1 and Ψ_2) traversing a perfect silicon crystal neutron interferometer (NI) by placing a sample of Bismuth in the upper of the two paths. The optical potential of Bismuth is positive, so it causes a delay in the wave packet traversing it, so that when that wave packet (Ψ_2) re-joins the (Ψ_1) wave packet not exposed to Bismuth there is a loss of fringe visibility.

The superposition principle is the most important assumption in QM. It allows us to use a Fourier sum of plane waves with a spectrum $a(k)$ as follows:

$$\Psi(r,t) = \int a(k)e^{i(k\cdot r-\omega_k t}dk. \tag{18}$$

The plane waves add constructively in certain restricted areas, since the phases are correlated by $a(k)$

Figure 5 shows a perfect silicon NI, with a wave packet Ψ_i entering it in the upper left. The first silicon blade divides into two parts, Ψ_1 and Ψ_2 which follow diverging paths I and II. Both paths pass through a homogeneous aluminum slab that is rotating back and forth by $\pm 1^o$, so that the two paths have different phases. They call this slab the "phase rotator." It induces a variable phase difference between Ψ_1 and Ψ_2, of value $\phi_p(\alpha)$, given by this equation:

$$\phi_p(\alpha) = N_p b_p \lambda d \frac{sin^2\theta_1 sin\alpha}{cos^2\theta_1 sin^2\alpha} \tag{19}$$

where α is the oscillating angle of the slab, the neutron wavelength is λ, and $N_p b_p$ represent the density of the atom and the scattering length of the neutron. The thickness of the aluminum slab is d, and θ_1 is the Bragg angle of the NI.

The upper beam Ψ_2 also passes through the sample of Bismuth, the width (D) of which is controlled by the research team, and varies from zero to 20 mm. Pay attention to the variable "D" (thickness of Bismuth sample) as it will play a central role in this experiment. The Bismuth is perpendicular to the incident beam Ψ_2, has an atom density N, and a scattering length b. This slab of Bismuth, called the "sample", induces a spacial delay

$$\Delta l = -\frac{DV_{op}}{2E} \tag{20}$$

in Ψ_2, where E is the kinetic energy of the neutron, and it's optical potential is

$$V_{op} = 2\pi\hbar^2 Nb/m \tag{21}$$

and the neutron's mass is m. For now they make the assumption that the beam is not attenuated by the Bismuth sample. The two neutron beams, Ψ_1 and Ψ_2 recombine in the last perfect silicon blade and exit the NI.

If a detector is placed in an exit beam, it will measure a time-averaged intensity of

$$I(D,\alpha) = A\int_{-\infty}^{+\infty} |a(k)|^2 dk + B\int_{-\infty}^{+\infty} |a(k)|^2 cos[\phi_o + \phi_p(\alpha) + \chi_S(D)]dk \tag{22}$$

where ϕ_o is a constant that starts with a value $\phi_o = 0$. The counting rate $I(D,\alpha)$ is affected by the value of D and α, obviously. The variable B is for exit beam C3 and depends on how well the NI is functioning that day. Interferometers undergo subtle changes of shape over the course of a day. With the C3 exit beam usually $BC_3 \approx (0.5)AC_3$. The first integral in equation 22 is a constant. The second integral oscillates as they vary $\phi_p(\alpha)$. For example, if $|a(k)|^2$ is a Gaussian with S.D. $\sum_k$ then equation 22 gives us an intensity of:

$$I(D,\alpha) = A + B[cos\phi_o + \phi_p(\alpha) + \chi_S(D)]e^{-(NbD\sum_\lambda)^2/2} \tag{23}$$

where $\sum_\lambda = 2\pi\sum_k k^2$ is the width in wavelengths of the spectral distribution.

$$C_R(D) = e^{-(N_b D\sum_\lambda)^2/2}. \tag{24}$$

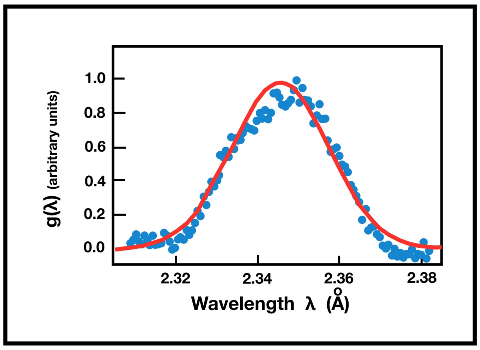

Figure 8: The wavelength (λ) of neutron waves forms a Gaussian curve. When an Analyzer Crystal is inserted into this beam (see next Figure), the horizontal spread of wavelengths decreases, and the height of the peak of the Gaussian increases greatly.

As they vary $\phi_p(\alpha)$ they trace out the sinusoidal pattern $I(D,\alpha)$ of an interferogram. They defined the "contrast" of the interferogram to be amplitude of the oscillations (from bottom to top of sinusoidal curve) divided by the mean value of the curve. Equation 24 shows that the contrast $C(D)$ decreases as the sample thickness D increases. This is important: it will be central to our conclusions about these experiments.

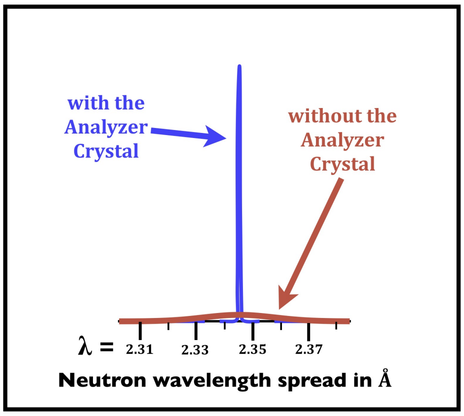

Figure 9: The red curve in this figure is the same Gaussian as shown in the previous Figure, but the vertical scale is compressed. The effect of the Analyzer Crystal (see blue curve) is to focus the neutron beam by increasing the height and decreasing the scatter of wavelengths λ. The effect is to focus the beam so it can penetrate better into the detector. One would think, "This should have no impact on the wave interference that already took place at an earlier time!"

The maximum contrast occurs when there is no Bismuth at all: i.e. $C_{C3}(0)$. The equipment is imperfect, and they have to adjust their equations to fit that reality. While in theory the C_{C3} varies from 0% to 100%, in reality $C_{C3}(0) \approx 50\%$. To adjust to this imperfect equipment, they focus on the relative contrast $C_R(D) \equiv C(D)/C(0)$. They can calculate the relative contrast from the complex mutual coherence function $\Gamma(D, \alpha)$ as follows:

$$C_R(D) \equiv \frac{C(D)}{C(0)} = \frac{|\Gamma(D,\alpha)|}{|\Gamma(0,0)|} \tag{25}$$

where

$$\Gamma(D,\alpha) \equiv \left\langle \Psi_1^*(0)\Psi_2(\Delta l)\right\rangle = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} |a(k)|^2 e^{\phi_o + \phi_p(\alpha) + \chi_S(D)} dk. \tag{26}$$

Or, if the displacement Δl is parallel to k, one can replace $|a(k)|^2$ by the wavelength spectrum $g(\lambda)$ in the equation to calculate $\Gamma(D, \alpha)$:

$$\Gamma(D,\alpha) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} g(\lambda) e^{\phi_o + \phi_p(\alpha) + \chi_S(D)} dk. \tag{27}$$

In this experiment $\phi_p << \chi_S$, so that the oscillating aluminum plate has negligible effect on the contrast. Thus, with a Gaussian distribution $|a(k)|^2$, the contrast diminishes as a function of the thickness D of Bismuth as follows:

$$C_R(D) = e^{-(N_b D \sum_\lambda)^2/2} \tag{28}$$

Note that equation 27 for the intensitiy of $I(D, \alpha)$ depends only on $|a(k)|^2$. Therefore there are two equally valid interpretations of why the contrast decreases with increasing D (thickness of Bismuth sample).

1. A wave packet spreads as it moves forward, with slower waves falling to the back of the pack, and faster waves tending to move to the front. This Bismuth slows the upper wave packet on Ψ_2 so that when the two wave packets re-join in the last silicon blade they are spatially displaced by a distance $\Delta l(D)$ given by equation 28. The faster waves in the upper wave packet then overlap the slower waves in the Ψ_1 wave packet, with the result that the amplitude of interference "washes out" which reduces the contrast of the combined wave packet(s). If the Ψ_2 wave packet is delayed by more than the coherence length, then there is zero contrast.
2. If they picture the neutron beam as being an incoherent superposition of plane waves, then they can picture each plane wave k component generates its own intensity pattern $I(k, D, \alpha)$. Then the overall intensity $I(D, \alpha)$ is the integral of $I(k, D, \alpha)$ over the intensity distribution $g(k)$. When the upper wave packet passes through the Bismuth sample, each component experiences its own unique phase shift $\chi_S(k, D)$. The total intensity is thus a sum of sine waves of differerent wavelengths, leading to a decreased total contrast. As the Bismuth sample thickness (D) increases, the wave becomes "dephased" and the interferogram's contrast approaches zero.

At this point the defense attorney interrupts the presentation and says: “This second interpretation is not the usual way of understanding how plane waves can add together to produce a wave packet. The prosecutor is arguing a peculiar mathematical position in order to lay the foundation for a later allegation that a ‘coherent’ sinusoidal curve can allegedly be conjured out of an ‘incoherent’ flat line. In other words, the prosecutor is trying to use mathematical magic to make something impossible happen at a later time.”

Kaiser and the research team agree that their goal is to study a coherent neutron beam, and observe changes in the contrast of the interferogram detected in the C3 output beam. Unfortunately there are other factors that also decrease the contrast. This must be corrected for. As they mentioned earlier, the equipment is imperfect. First, the beam is attenuated as it passes through the Bismuth sample, although they did not mention it heretofore. The Ψ_2 wave is attenuated by $exp(-\zeta)$ because of the absorption and scattering cross sections of the material. In previous research with this equipment these researchers found the following loss of contrast with increasing sample thickness:

$$\left[\frac{C(D)}{C(0)}\right]_{att} = \frac{e^{-\zeta}}{a_1 + e^{-2\zeta} a_2} \tag{29}$$

where “att” means “attenuated,” and a_1 and a_2 are the fractions of the beam intensity on the lower and upper path through the interferometer, recognizing that $(a_1 + a_2 = 1)$. Thus if they want to know what the contrast would be without the attenuation by the sample of Bismuth, then they multiply their measured results (C_{meas}) by a factor f_{att} as follows:

$$C = C_{meas} \cdot f_{att} \tag{30}$$

where

$$f_{att} = C_{meas} \cdot e^{\zeta}(a_1 + e^{-2\zeta} a_2). \tag{31}$$

In this way they can correct the contrast for the effect of attenuation. They have measured these constants, and have made this correction.

In addition to attenuation, there are other factors that make their equipment less than perfect: thermal gradients, gravitational warping of the crystal, vibrations, and imperfect machining of the crystal. In view of these defects, it is understandable that they would achieve a maximum of 50 % rather than 100 % contrast.

3.4 Theory of crystal-analyzed coherence measurements

If they place their NI in a beam of neutrons with a Gaussian distribution of $\sum_{\lambda}^{0}$, and a distribution of of wavelengths

$$g_0(\lambda) = \frac{1}{\sqrt{2\pi}\sum_{\lambda}^{0}} e^{-(\lambda - \lambda_0^2/2(\sum_{\lambda}^{0})^2}. \tag{32}$$

(See Figure 7 which shows a Gaussian curve for $g_0(\lambda)$) When they place samples of Bismuth of thickness D in beam Ψ_2, the relative contrast is given by equation 32 with $\sum_{\lambda} = \sum_{\lambda}^{0}$. When the sample becomes thick enough (D) the contrast falls to zero.

Now consider placing an Analyzer Crystal in the exit beam C3. The Analyzer Crystal has a mosaic width of η_A and reflects out an exit beam with spectral width $\sum_{\lambda}$ with a Gaussian distribution of wavelengths. Such an analyzer crystal is shown in the lower right corner of Figures 5 and 6. Because the Analyzer Crystal decreases the scatter of wavelengths and increases the central peak of the Gaussian (see Figure 7), the contrast could be higher in that beam than in the C3 exit beam.

The defense attorney interrupts again, saying, “Once again the prosecutor is attempting to create an explanation for how they might later explain how the Analyzer Crystal conjures a robust sinusoidal curve out of a flat line. It is simply not believable!”

The prosecutor ignores the interruption and resumes the presentation of the experiment: The Analyzer Crystal accepts a Gaussian window of wavelengths

$$W(\lambda) = e^{-(\lambda - \lambda_0^2/2(\sum_{\lambda}^{0})^2}. \tag{33}$$

of width $\sum_{\lambda}^{A}$ as follows:

$$\sum_{\lambda}^{A} = \lambda_0 \eta_A \left| \frac{cos(\theta_I) \cdot cos(\theta_A)}{sin(\theta_I - \theta_A)} \right| \tag{34}$$

where θ_I is the interferometer Bragg angle ($\theta_A = -22^o$). The analyzer Bragg angle θ_A is negative for an antiparallel configuration such as the one we will report here. The letter A in the variable θ_A refers to the Bragg angle of the “Analyzer.”

Table 1: Spectral widths expected in C3 Direct and NP Analyzed beams

Beam	η_A **(rad)**	$\sum_A$	$\Delta\lambda/\lambda_0$
C3 Direct	———	0.0120	1.20 %
NP Analyzed	0.00015	0.00030	0.03 %

Table 2: Signal and background counting rates per minute

Beam	**Signal**	**Background**	**Time**
C3 Direct	1030	49.1 ± 1.2	5
NP Analyzed	32	61.2 ± 1.1	40

The spectrum $g(\lambda)$ reflected off the Analyzer Crystal is the product of the analyzer window $W(\lambda)$ and the incident spectrum $g_0(\lambda)$.

$$g(\lambda) = g_0(\lambda)W(\lambda) = \frac{1}{2\sqrt{2\pi}\sum_\lambda} e^{-(\lambda-\lambda_0^2/2(\sum_\lambda)^2} \tag{35}$$

where the width $\sum_\lambda$ is given by

$$\sum_{\lambda} = \sum_{\lambda}^{0} \frac{\sum_\lambda^A}{[(\sum_\lambda^0)^2 + (\sum_\lambda^A)^2]^{1/2}}. \tag{36}$$

The form of this equation insures that $\sum_\lambda < \sum_\lambda^0$ which is what they need for an antiparallel configuration.

How does this affect their measurements? The direct C3 exit beam coming out of the NI has a spectral width of $\sum_\lambda^0$. As we increase D (increase the sample thickness) its contrast $C_{dir}(D)$ diminishes as per equation 32 with $\sum_\lambda = \sum_\lambda^0$. However, if they insert an Analyzer Crystal, they find that the contrast $C_A(D)$ falls off at a slower rate.

$$C_A(D) = e^{-(NbD\sum_\lambda)^2/2} \geq C_{dir}(D) \tag{37}$$

When D gets high enough (a thick sample of Bismuth) the direct C3 beam becomes ***incoherent***, as manifest by a contrast of about zero.

3.5 The experiment

The research team had to decide what analyzer crystals to use, and what Bragg angles. Here we will report data gathered from a “nearly perfect” (NP) silicon crystal: $\Delta\theta = 0.02^o$ full width at half maximum (FWHM), $\eta_A = 0.0035$ rad. They used this NP Analyzer Crystal in the (111) antiparallel configuration. With an incoming neutron beam of $\lambda = 2.35$ the Bragg angle that they use is $\theta_A = -22.0^o$.

They machined samples of Bismuth to different thicknesses. It is a soft metal and difficult to work with in a machine shop. A sliver of soft metal 5 mm thick is extremely delicate, and demanded utmost attention to insert that delicate sliver into the tiny interferometer.

The Analyzer Crystal was mounted on a goniometer (Figure 6), the tilt and rotation of which were controlled by a step motor. That apparatus is called the “analyzer table” and is located $\sim 60cm$ downstream from the interferometer. When the crystal was placed in the C3 beam its tilt and position were optimized for obtaining the (111) Antiparallel Configuration.

The detector is black to thermal neutrons, and consists of three detectors, each of which is a 0.5 inch, cylindrical, 20-atm ^3He detector mounted on a neutron-shielding B_4C-epoxy cassette with a 1 X 1 inch collimated opening. This made the probability of detection constant in a horizontal plane. To see all parts of the neutron beam spectrum, all the C3 detectors were mounted horizontally.

The vast majority of neutrons coming through the interferometer are not refracted, because they fall outside the Darwin acceptance width. The “Direct Beam” also diverges and would spill into the C3 detector and would overwhelm the relatively weak C3 beam. So they placed a “Beam Stop” consisting of a B_4C-epoxy block inside the thermal enclosure (it can be seen in Figure 6).

As stated earlier, a NI operates far below 100 % efficiency. Dephasing causes a relative drop in contrast from a starting value of C_0 to $C(D)$. Therefore at each thickness of Bismuth sample they measured the contrast with the sample out (Bismuth not in the interferometer) and compared it to the contrast found with the sample in (i.e. Bismuth is inside the interferometer). Furthermore things change over the course of the day: the absolute contrast C_0 drifts up to $\pm 3\%$. To control for all these factors is tedious work, but they did it. For each interferogram they had two experimental runs: one without the Bismuth sample, the other with the Bismuth sample. They repeated this for every thickness of Bismuth, in order to control for the changes of the equipment over time: attenuation of contrast.

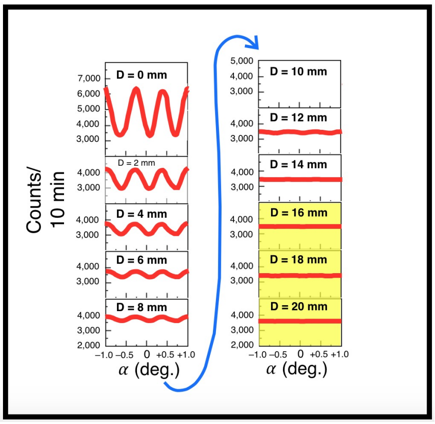

Figure 10: Compare the yellow area to Figure 11. Direct output data from detector C3, with increasing amounts of Bismuth (D = width of Bismuth sample). ***No Analyzer Crystal*** is present during this run of data.

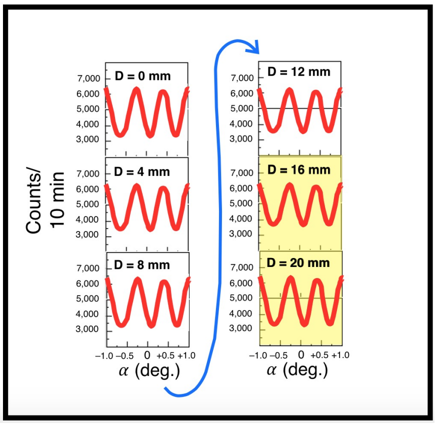

Figure 11: Compare the yellow area to Figure 10. Output data ***with NP Analyzer Crystal*** and increasing amounts of Bismuth.

Using standard statistical methods they calculated the sample-out contrast $C_o \pm \sum_o$ and the sample-in contrast $C_{in} \pm \sum_{in}$ and then used those numbers to calculate the relative contrast (which was their focus) $C_R \pm \sum_R$ using this equation:

$$C_R = \frac{C_{in}}{C_o}, \tag{38}$$

where

$$C_R = C_R \left| \left[\frac{\sum_o}{C_o} \right]^2 + \left[\frac{\sum_{in}}{C_{in}} \right]^2 \right|^{1/2} \tag{39}$$

3.6 Results

They calculated the relative contrast at a full range of D (thickness of Bismuth). Then they inserted their NP Analyzer Crystal in the (111) Antiparallel Configuration ($\theta_A = -22.0^o$). Because of the long run times for this configuration, they collected less data, meaning that they collected data for D at values 4, 8, 12, 16 and 20 mm. Therefore the data is slightly thinner for that run, but it is nevertheless dramatic and compelling data.

Summary argument by the prosecutor

"The conclusion to be drawn is a familiar one in QM: matter waves are not particles, and we have no right to think of them as such, even in a semi-classical way. The neutron wave-packet formalism is merely the mathematical description of Wheeler's quantum-mechanical 'great smoky dragon.' We know the neutron is a particle when it is emitted, and again when it is detected, but between those two times the connection between the neutron particle and the wave packet remains hidden, no matter how diligently we try to analyze the quantum questions with our classical tools.

“The results calls into question the relationship between a neutron particle and a wave packet. To say that a wave packet has a coherence length of Δx, we often think semi-classically that the wave packet somehow ‘is’ the localized neutron particle.

“We should consider what that conceptual picture means in light of this experiment. By reducing the wavelength spread they increase the longitudinal coherence length of the packet, according to the uncertainty principle:

$$\Delta x(\text{FWHM}) = \frac{1.034\ ^2}{\sum_{\lambda}} \tag{40}$$

“for $\lambda = 2.35\ ^2$.

“So in summary, the prosecution has demonstrated beyond any shadow of a doubt that the quantum world is weird and unpredictable. Therefore the jury should vote in favor of rejecting TEW, who allege that the quantum world is not weird.”

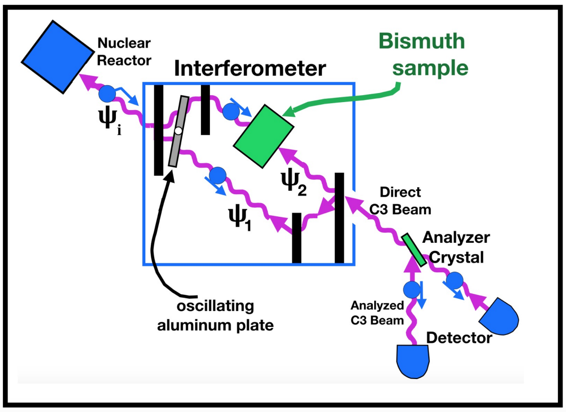

Figure 12: Neutron Interferometer with TEW interpretation. The central hypothesis of TEW is that quantum waves travel in the opposite direction as what we think, and that particles (in this case neutrons) follow them backwards.

Defense attorney rebuttal First, I want to thank the Kaiser research team for an incredibly valuable experiment. Neutron interferometers are important, and the Helmut Rauch team have discovered more about them than anyone else on earth. Thank you.

Why doesn’t the prosecutor believe what the detector is telling us? One of the most radical parts of TEW is that **we think that what detectors detect is reality.** Otherwise why use them? A cornerstone of science is that when the results of an experiment contradict your theory, then you need to discard your theory and rethink the whole thing. It is NOT acceptable to use your theory to discredit the results you just obtained.

This experiment said something loud and clear, which is when you insert an Analyzer Crystal the detector shows robust interference! Why go to all the trouble of doing this research if you don’t believe your own detectors? The detector speaks about interference taking place at the only place where interference could be located in this experiment: inside the interferometer.

The researchers obviously said to themselves, “This makes no sense!” If it makes no sense there are two routes to take. The first is to learn something new from the experiment. The second is to use all your mathematical skill to discredit the detector, by trying to prove that there was no interference but somehow your equations conjured “coherence” out of “incoherence.” Does that make sense? We think not.

What makes sense is to believe what the experiment tells us, which is that the insertion of an Analyzer Crystal produces robust interference upstairs, inside the interferometer. Let’s think about what that means. **It means that when there are 16 to 20 mm of Bismuth, then the presence or absence of an Analyzer Crystal produces the presence or absence of wave interference.** This is evident in the yellow areas of Figures 10 and 11. We are just putting the experimental results into words.

Mathematicians need to decide: What is the purpose of mathematics? It its purpose to illuminate reality, or should it be used to obscure reality by concocting unlikely interpretations of data that someone doesn’t like?

If an Analyzer Crystal down in the righthand corner, outside the interferometer, controls the interference inside the interferometer, then **the Analyzer Crystal must be upstream from the interference.** This suggests a model in which zero energy waves start at the detector, go backwards through the interferometer, and interact with atoms in the nuclear reactor. From time to time a neutron follows the wave backwards. That is what your experimental data are telling you!

With no Analyzer Crystal a wave packet had a coherence length of ΔX = 86.2 Angstroms. A sample of 20 mm of Bismuth would delay the wave packet by 435 Angstroms. So it is easy to see why all interference died out as more and more Bismuth was added. However with the addition of an NP Analyzer Crystal, the ΔX coherence length increases to 3450 Angstroms. So it is easy to see why waves penetrating backwards through the interferometer would easily pass through a fat block of Bismuth.

If you conduct experiments, the risk is that you might learn things!

The prosecutor's idea is that QM is not open to learning anything unorthodox. Therefore the prosecutor wants you to ignore the data.

Ironically the same problem was found in the previous experiment, about the quantum eraser. The problem was that the researchers did not believe what the detectors were telling them. When we re-analyzed their experiment we assumed that detectors tell us about reality. If the D_0 said there was interference, then we believed there WAS interference in front of the laser. If the D_0 said there was no longer interference, that did NOT mean the screen had been erased. It meant there was no longer wave interference!

Defense attorney's final summation Although the research team did elegant research, they were unable to explain their results. Whereas QM cannot explain the data, TEW can (see Figure 12).

The Judge's Charge to the Jury The proposal considered in this trial is to adopt the three Axioms of TEW as the platform for quantum math. Let me remind you what those Axioms are:

A. Wave function collapse occurs *before* we measure something,

B. There is *no* wave particle duality,

C. Waves travel in the *opposite* direction as particles.

This is a serious matter because our entire high tech economy is built on quantum math, and if we make a mistake and endorse Axioms that are wrong, the results could be catastrophic.

This experiment uses all three of the Axioms. First wave function collapse does not occur at the detector (according to TEW), rather it occurs inside the nuclear reactor. Second, elementary rays are allegedly traveling in the opposite direction as neutrons. And finally, that means that there is no wave particle duality. Therefore it is the three Axioms of TEW that are on trial here.

In order to understand the effect of this new Axiomatic platform, we are seeing how it works with quantum experiments that have been published in leading physics journals. Currently we are considering a neutron interferometer experiment by Kaiser, et. al. This is an experiment that produced unexpected results.

If you look at Figure 5 you can see the issue. The red line tapers down to zero with more and more Bismuth, whereas the blue line remains so high that you would not know there is Bismuth present. The prosecutor says that the blue line on Figure 5 does not mean there is interference. The prosecutor says that with sophisticated mathematics it is possible to believe that a "coherent signal" (the blue curve) has been conjured out of an "incoherent signal" (the red curve). The defense says that we should not use mathematics to discredit our experimental data, rather we should listen to the data, which is telling us that we live in a different kind of world than we previously believed.

So now you, the Jury, knowing that the stakes are high, must decide whether the Axioms of TEW can be trusted, or not.

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4 A Stern Gerlach experiment

There is an experiment with four Stern Gerlach magnets that mystifies scientists, but reveals its mysteries if we change our lens from the Axioms of QM to the Axioms of TEW. The mystery called Complementarity that haunts the double slit experiment, also haunts this experiment. The Figure below shows a "Z" and an "X" magnet.

If a silver atom starts at the oven on the left of Figure 14, passes through the string of four magnets and makes a dot on a target screen on the right, the outcome changes depending on whether we know or don't know which path the atom took across the middle pair of magnets (Z1 and Z2). The latter, Z2, is an upside down version of Z1. The silver atom could cross that middle pair with spin up or spin down. If we don't know which then we see only one spot on the target screen: the upper spot. If we do know, then we see spots at both points on the target screen.

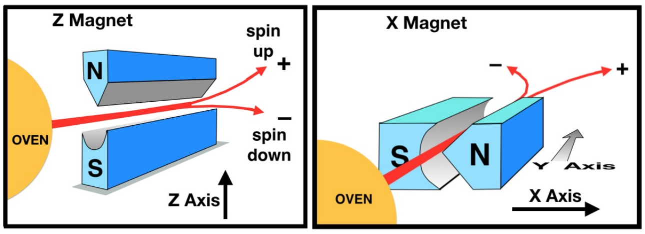

Figure 13: Stern Gerlach magnets.

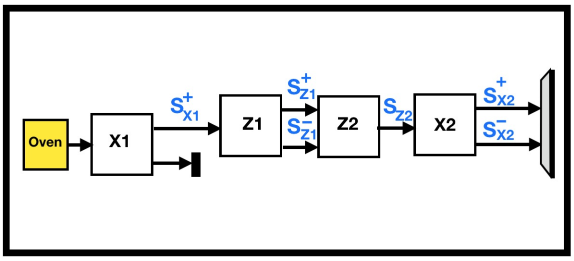

Figure 14: An experiment involving 4 Stern Gerlach magnets (the white squares). The focus is on the middle pair: Z1-Z2. For some odd reason it makes a difference whether we know or don't know whether a silver atom from the oven went across that pair with spin up or spin down! On the far right, the target screen will have one dot (the top one) if we don't know, but two dots if we do know.

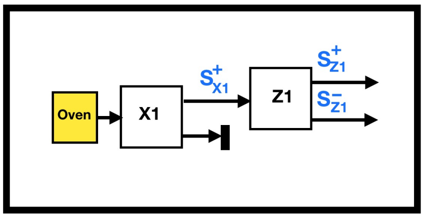

Figure 15: To introduce the reader to the symbolism we are adopting, this diagram shows only the first two magnets. This is a segue into a mathematical discussion of amplitudes, like $\Psi^{\pm}_{X2}$.

We will develop conditional probabilities for Figure 15, assuming we do not know whether the atom crossed the Z1-Z2 set of magnets with spin up or spin down, as follows.[9]

$$P(S_{Z1} = \frac{1}{2}\hbar \Big| S_{X1} = \frac{1}{2}\hbar) = \frac{1}{2} \tag{41}$$

$$P(S_{Z1} = -\frac{1}{2}\hbar \Big| S_{X1} = \frac{1}{2}\hbar) = \frac{1}{2} \tag{42}$$

Now we will use amplitudes like those from a double slit experiment. We define $\Psi^{\pm}_{X2}(S_{X2})$ be the amplitudes for the final outcome to the right of all four magnets (Figure 15) to be measured as $S^{\pm}_{X2}$.

If we DO NOT observe the middle pair, then ***we add the amplitudes then square them.*** The probability of the silver atom emerging in the upper stream on the far right:

$$S_{X2} = \frac{1}{2}\hbar \text{ beam is} \qquad P = \Big|\Psi^{+}_{X2}(\frac{1}{2}\hbar) + \Psi^{-}_{X2}(\frac{1}{2}\hbar)\Big|^2 = 1 \tag{43}$$

But the probability of the atom emerging in the lower stream:

$$S_{X2} = -\frac{1}{2}\hbar \text{ beam is} \qquad P = \Big|\Psi^{+}_{X2}(-\frac{1}{2}\hbar) + \Psi^{-}_{X2}(-\frac{1}{2}\hbar)\Big|^2 = 0 \tag{44}$$

Whereas if we DO OBSERVE the middle pair of Z1=Z2 magnets, then ***we should square the amplitudes then add them.*** The probability of the silver atom emerging in the

$$S_{X2} = \frac{1}{2}\hbar \text{ beam is} \qquad P = \left|\Psi^{+}_{X2}(\frac{1}{2}\hbar)\right|^2 + \left|\Psi^{-}_{X2}(\frac{1}{2}\hbar)\right|^2 = \frac{1}{2} \tag{45}$$

And the probability of the atom emerging in the

$$S_{X2} = -\frac{1}{2}\hbar \text{ beam is} \qquad P = \left|\Psi^{+}_{X2}(-\frac{1}{2}\hbar)\right|^2 + \left|\Psi^{-}_{X2}(-\frac{1}{2}\hbar)\right|^2 = \frac{1}{2} \tag{46}$$

The analogy with a double slit experiment is obvious. If we don't know which slit then the probability of a dot appearing at point "x" on the target screen is the sum of the amplitude that it came through slit A plus the amplitude that it came through slit B, squared. But if we do know which slit, we square the amplitudes BEFORE we add them. That is why the interference pattern vanishes.

For those who prefer plain speaking, what equations 43 to 46 say is that if we don't know the route across Z1-Z2 there is only one dot, but if we do know, there are two dots. HOWEVER, we will show that this mathematical approach is wrong. More on that below.

4.1 Disruptive effect of a flashlight and detector

It is impossible to believe that human consciousness makes much of a difference in Nature, since 99.99999 % of Nature is unobserved, and gets along perfectly well without us watching. Common sense tells us that David Mermin is wrong when he says, "Science has proved that the moon only exists when people are looking at it!"

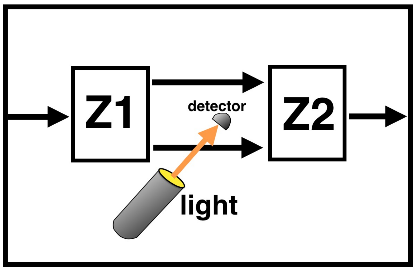

Figure 16: Humans only know which route if they have a detector collecting the information.

If it is not human awareness that produces one dot or two, what is it? The figure above shows a tiny flashlight and detector collecting information for the humans. Such a flashlight-detector emits energy, but only a tiny amount. Whereas that tiny amount is insignificant compared to the energy in a passing silver atom, it is an infinitely greater amount than the zero energy in an elementary ray traveling right to left. That ray, as you recall, is the flight plan that a silver atom will later follow. As in the double slit experiment, so also here, the energy of the flashlight detector destroys the superposition additivity of the elementary rays crossing Z1-Z2. It doesn't stop the elementary ray. Rather it destroys the ability of that wave to add to its twin in a superposition.

For those who prefer plain speaking, We are laying the groundwork for saying that the amplitudes in equations 43 through 46 should be dealt with using the following logic: If the flashlight is on then square the amplitudes before adding them. But, if the flashlight is off, add the amplitudes before squaring them. We are applying this math rule to the Elementary Waves, not to the silver atoms. In our view a silver atom is too stupid to know what we are talking about. All a silver atom knows is, "Do I, or don't I have a flight plan to follow backwards?"

But, as we hinted above, symmetry tells us that the math is wrong, as you will see in a minute.

4.2 What is happening with the Elementary Waves?

If we look at the elementary rays (these green arrows), we get astonishing results. If the flashlight is OFF, then consider to what happens to an elementary ray starting at the lower spot on the target screen, which we have named Green S^{-}_{X2}. The pivotal question, from a TEW viewpoint, is whether there is, or is not a green pathway connecting a point on the target screen (right) and the oven (left). We claim that there IS such a wall-to-wall pathway for the upper spot $X2^{+}$ on the target screen, ***but NOT for the lower spot*** $X2^{-}$. To prove this we will show you a diagram (Figure 18) of why the $X2^{-}$ spot has so much trouble.

To reiterate: for TEW the pivotal question is whether you can or cannot draw an unbroken line from wall to wall (from target to oven). The reason that is the pivotal question is because we know that sooner or later a silver atom will follow

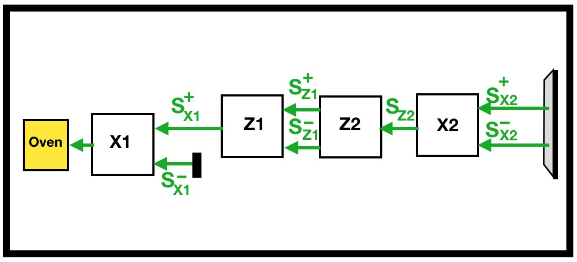

Figure 17: A first map of elementary rays. We turned the arrows of Fig 14 around and changed the color to green.

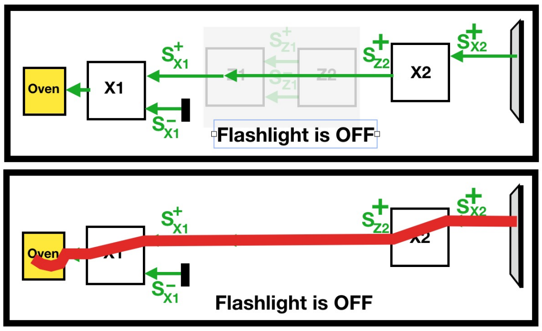

Figure 18: If the flashlight is OFF then the middle pair of magnets Z1-Z2 act as if they are not present. A green line from the UPPER spot on the target screen CAN reach the oven if the flashlight is off. Therefore sooner or later a silver atom will come across that highway. To emphasize that we drew the highway in red.

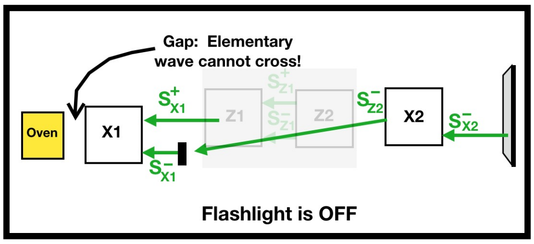

Figure 19: If the flashlight is OFF then the middle pair of magnets Z1-Z2 act as if they are not present. A spin-down elementary ray starting at the target screen remains spin-down as it crosses three magnets, where it discovers that the spin-down doorway of magnet X1 is blocked, so it cannot enter that magnet and cannot reach the oven. Therefore no silver atom will be able to follow it backwards. Therefore there will be no spot at the bottom of the target screen.

such a pathway backwards and make a dot on the target screen IFF such a green pathway exists. ***No pathway*** $\equiv$ ***no dot on target screen!*** The green line (an Elementary Ray) is the flight plan that a silver atom will subsequently follow backwards.

4.3 Why the quantum math (stated above) is wrong

Looking at the whole apparatus, what is obvious is that there is no spot at S^{-}_{X2} because the doorway named S^{-}_{X1} is blocked. To understand that sentence, you have to picture the ENTIRE experiment in your mind, and think about vertical symmetry, meaning what would happen if the entire apparatus were flipped vertically. If, by flipping the equipment, we moved that block from the lower to the upper doorway of $X1$ then the pattern on the target screen would be inverted, as in Figure 21.

This approach to the double slit experiment is different than the mathematical approach we took in equations 43 through 46. If we invert the experiment so as to block the UPPER pathway (on the left) near the X1 magnet, when the flashlight is off, then we should find only one dot IN THE LOWER POSITION on the target screen. (Figure 21)

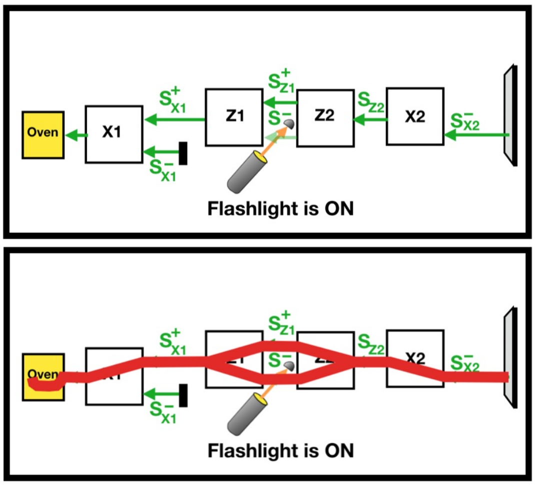

Figure 20: If the flashlight is ON then the middle pair of magnets Z1-Z2 process an Elementary Wave from the lower spot on the target screen in the way that is shown here. The red line shows that there is a wall-to-wall pathway, which is THE PIVOTAL ISSUE for a TEW analysis of this Stern-Gerlach experiment. As a result there will be dots at BOTH places on the target screen in the final dataset.

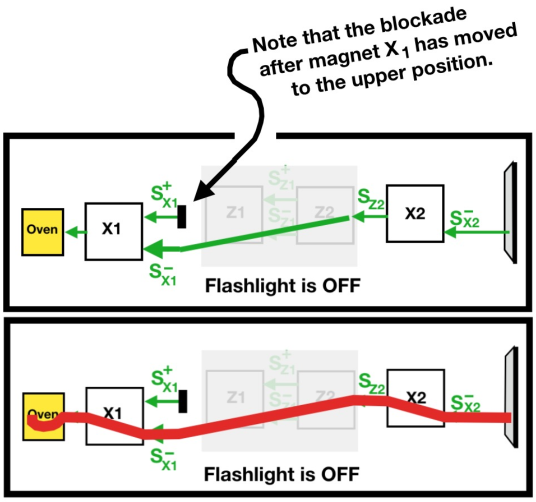
Note that the blockade after magnet X_1 has moved to the upper position.

Figure 21: Here we inverted the experiment, i.e. flipped it vertically. Therefore the barrier after X1 moved from the lower to the upper pathway. This inverted the final data. Now there is no dot at the upper position (S^+_{X2}) but there is a spot at the lower position (S^-_{X2}) on the target screen.

Since we inverted the experiment, therefore the UPPER exit of X1 is blocked, the LOWER exit of X1 is open. Consider what happens when the flashlight is off (see Figure 21).

This change in the arrangement of the left side of the Stern Gerlach magnets is not recognized in the quantum math. What would be the probability for one or two dots on the target screen on the right, with this new arrangement on the left? Here is what we said about equations 43 and 44. If the middle pair of magnets Z1-Z2 are not observed, then the probability of the atom emerging in the

$$S_{X2} = \frac{1}{2}\hbar \text{ beam is} \qquad P = \left|\Psi^+_{X2}(\frac{1}{2}\hbar) + \Psi^-_{X2}(\frac{1}{2}\hbar)\right|^2 = 1 \tag{47}$$

But the probability of the atom emerging in the

$$S_{X2} = -\frac{1}{2}\hbar \text{ beam is} \qquad P = \left|\Psi^+_{X2}(-\frac{1}{2}\hbar) + \Psi^-_{X2}(-\frac{1}{2}\hbar)\right|^2 = 0 \tag{48}$$

The mathematics is WRONG. Aside from the fact that it contradicts the Elementary Wave picture, it also violates common sense about symmetry. If the entire experiment was flipped vertically, the results should also be flipped vertically.

But the math doesn't work that way. So there is something wrong with the math. What we conclude from common sense is that there is more going on in this experiment than equations 43 to 46 know about.

4.4 Intrinsic SPIN

There is one more thing to be said about the Stern Gerlach experiment. We have shown that somehow **Elementary Waves CARRY SPIN**! That is big news! It raises the question whether the "Intrinsic Spin" of electrons is intrinsic to the electron, intrinsic to the Elementary Wave, or both. It is another question we don't know the answer to. But this one is really, really interesting. This is huge!

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5 A Wheeler delayed choice Interferometer Experiment

John Archibald Wheeler dreamed up an experiment to investigate the mysteries of wave particle duality. He proposed that a photon could be put into an interferometer (see Figure 22) where it would be forced to become either a wave (traveling around both arms of the interferometer), or a particle (traveling on one arm or the other, but not both). We can tell which it is by how we collect data from the interferometer. If the device is in a "closed" configuration (meaning that the two arms intersect) then we look for wave interference which would tell us that the quantum chose to be a wave. If the device is in an "open" configuration (the two arms don't intersect, rather each arm leads to a detector), then when a detector "clicks" we will know it was a particle.[10]

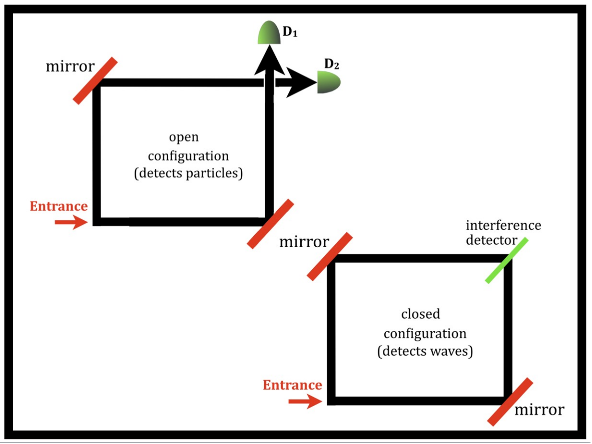

Figure 22: Wheeler's idea about two arrangements of an interferometer. Upper left, an open configuration tests for a particle traveling across one of the arms of the apparatus and causing either detector D1 or D2 to "click." Lower right, a closed configuration looks for interference caused by a wave crossing the two arms of the interferometer and interfering when they meet.

Wheeler took the idea further. He speculated that our decision to look for a wave or a particle, is what causes the quantum to behave one way or the other. This opens the question how the quantum of energy would know in advance how it is about to be tested.

Then Wheeler took his speculation to another level. He hypothesized that this mechanism would operate backwards in time. In other words, if we wait until the quantum has made an irreversible decision at the front door of the interferometer, to act like a wave or particle, meaning the quantum is somewhere inside the apparatus, and we subsequently decide to test it one way or the other, Wheeler's hypothesis was that the quantum would have figured that out in advance, and would already be a wave if we were going to test it as a wave, or it would be a particle if we were going to test it as a particle.

Is this the ultimate in quantum weirdness? The quantum's decision at the front door (the effect) precedes the cause (the researchers subsequently deciding to test it as a wave or as a particle).

The amazing thing is that the leading journal *Science* published an article in 2007 in which a research team led by Jacques had built Wheeler's interferometer and had "proved" that **Wheeler's hypothesis was correct: A decision to test a quantum as a wave or particle caused the quantum to behave that way at an earlier time. This is backwards in time cause and effect.**[11-12] This experiment is often cited to "prove" that the quantum world is weird, that it cannot be understood based on what we learn in the classical world.

The Figure 23 shows the Mach Zehnder interferometer used by Jacques et al. That interferometer was 48 meters wide (half a football field), which caused the photon to take a long time (160 ns) crossing it, which gave the researchers time to have a random number generator (which took 40 ns) to determine whether the equipment would subsequently test the quantum as a wave (closed configuration) or as a particle (open configuration). The switch that determined which way they were going to test the quantum was an Electrical Optical Modulator (EOM). **What Jacques et. al. found was that when they looked for a wave they saw a wave and when they looked for a particle they saw a particle.** They declare that was "proof" that Wheeler's hypothesis was correct. Proof that the quantum world is weird.

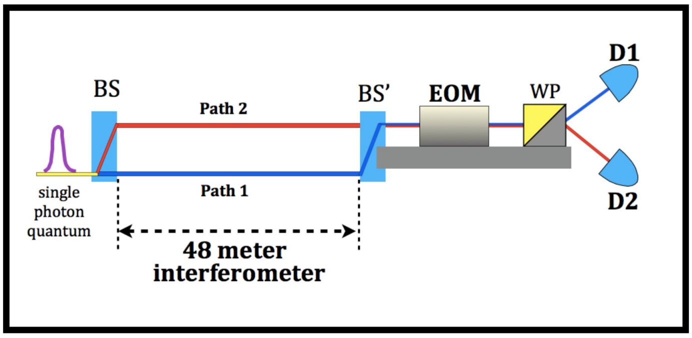

Figure 23: The Mach-Zehnder interferometer used by Jacques et. al. is as wide as half a football field. BS and BS' are a YVO_4 beam splitter and reverse beam splitter. The lower path (Path 1) has a horizontal polarization; the upper path has a vertical polarization. Paths 1 and 2 are separated by 4 mm. EOM is Electrical Optical Modulator, WP is a Wollaston prism, and D1 and D2 are silicon avalanche photodiode detectors 1 and 2. After a quantum of energy enters the interferometer (lower left) and makes its decision to cross as a wave (on both paths) or as a particle (on only one path), a random number generator (not shown) causes the EOM to determine the angle of polarization, which determines how the results are measured.

5.1 There is a background story

In a previous study the authors developed the technology used in this study. They managed to store a single photon quantum of energy inside a cavity in a diamond: a nitrogen (N) vacancy (V) inside a diamond nanocrystal. They used a pulsed laser at a wavelength of 532 nm with a 800 ps pulse duration to excite a single photon stored in such an N-V vacancy. The 50 pJ energy per pulse was high enough to pump the defect in the diamond to an excited level, so that a photon popped out. By this method they were able to generate a single quantum of energy, one photon at a time. The time duration for such an N-V center is 45 ns. They used the laser to bump out a photon once every 436 ns. By this method they had a technology to emit one single quantum of energy at a time, and the long duration (436 ns) between photons meant that they were studying only one photon at a time.[13]

They had to prove mathematically that they had been successful in generating one single photon at a time. They used the following equation to assure us that they were dealing with a single photon. A single quantum photon should violate this equation:

$$\alpha = \frac{N_C \times N_T}{N_1 \times N_2} \geq 1 \tag{49}$$

Where N_T is the number of trigger pulses applied to the N-V diamond emitter. If they force the photon to go through a Fresnel bi-prism and measure it with two detectors, D1 and D2, then N_1 and N_2 are the count of photons going to those detectors respectively, and N_C is the count of photons that make both detectors click simultaneously. If light behaves like a classical wave, with many photons then the equation $\alpha = (N_C \times N_T)/(N_1 \times N_2)$ is ≥ 1. However, if they are dealing with only a single photon at a time, then α is approximately zero, or in any case significantly less than one, which violates equation 49.

Their control in the previous study was low intensity laser light, that they used as a sample of multiple photons simultaneously. The number of photons in such a laser pulse is determined by a Poisson distribution:

$$P(k) = e^{-\lambda} \frac{\lambda^k}{k!} \tag{50}$$

Equation 49 showed $\alpha = 1.00 \pm 0.06$ for the dim laser light, which was significantly different than $\alpha = 0.13 \pm 0.01 < 1$ for the single photon they produced from the N-V cavity in a diamond. Thereby they proved that their technology could produce a single photon, one at a time, and that the photon was allegedly capable of acting like a wave and/or a particle when it encountered a Fresnel bi-prism.

In that earlier study they showed that a single photon can generate an interference pattern with a Fresnel bi-prism. This convinced them that they had proved that a single photon is both a particle and also a wave that can interfere with itself. That discovery from the previous study inspired them to try this experiment, which is called a "Wheeler *gedanken* experiment." *Gedanken* is a German word meaning "thought."

5.2 Back to the Wheeler experiment

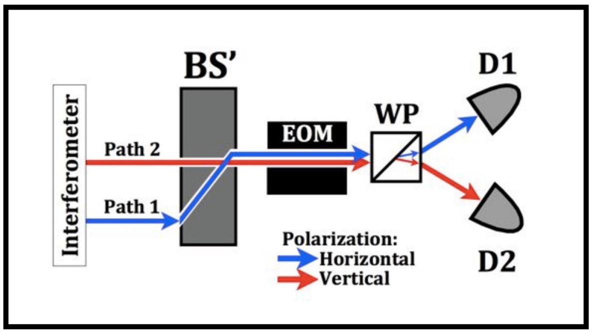

Figure 24: This shows the output area of the Jacques experiment. In the second beam splitter BS' the horizontal and vertically polarized photons are re-combined. That device (BS') rocks back and forth so as to create a phase shift and interference of Ψ_1 and Ψ_2. If the EOM is "OFF" it acts as if it is not present. The photons then enter the Wollaston prism where they are assigned to one detector or the other, depending on their polarization.

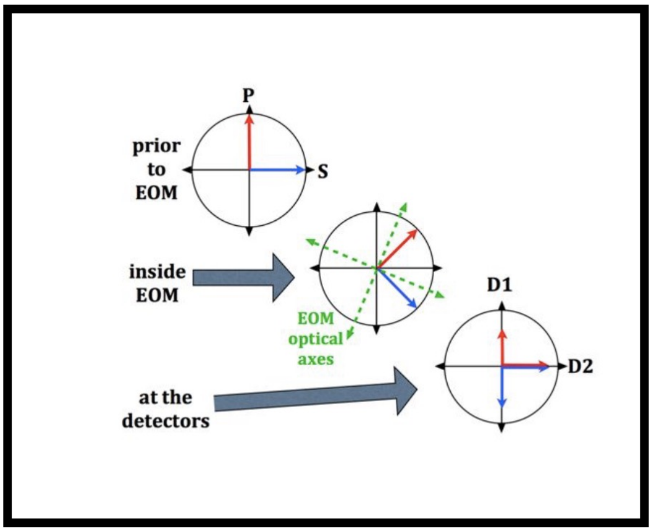

Figure 25: How the EOM affects angle of polarization. If the EOM is "OFF" it acts as if it is not present. If it is "ON" it rotates the polarization by $\pi/4$. At the detectors, D1 gets all horizontally polarized photons, D2 gets vertically polarized, but if the axis has been rotated by $\pi/4$ inside the EOM, the photons have interference inside the WP and have a $\pm cos^2\phi$ chance of being assigned to D1 or D2.

Figures 23 through 25 explain the equipment used by Jacques et al in the Wheeler *gedanken* experiment. A phase shift ϕ was implemented between the two pathways by having the second BS' reverse beam splitter rock back and forth. Therefore if the quantum was crossing the interferometer as a wave, there would be a phase difference between the two paths, and therefore interference inside the WP prism. This would register at the detectors (D1 and D2) as $Y = \pm cos^2\phi$.

In conclusion Jacques et al. believe the graphs in Figure 26 prove that Wheeler's hypothesis was correct. The random choice in the output area whether to test the quantum as a wave (EOM is "ON") or as a particle (EOM is "OFF") has caused the quantum of energy to enter the front door of the interferometer as a wave or a particle. Cause and effect are reversed in time. The random number generator and state of the EOM was the "cause" whereas the earlier decision of the photon as it entered the front door of the interferometer was the "effect."

Therefore, QM believes it has PROVED that the quantum world is weird. The journal *Science* which published this study, is one of the two top scientific journals in the world.

The proof of their allegation is that when they look for a wave, they find a wave, and when they look for a particle they find a particle. The random choice which way to test the quantum was made AFTER the quantum had entered the front door of the interferometer, but BEFORE it reached the output area.

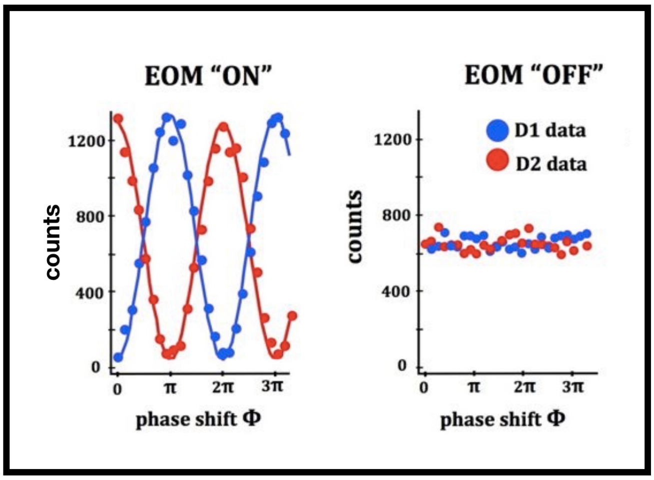

Figure 26: Output data upon which the entire Jacques experiment rests. On the left the equation is $Y \approx \pm 650 \times (cos^2\phi) + 700$. On the right it is $Y \approx 700 \pm 70$. When the EOM is "ON" they are testing for waves, and the sinusoidal waves on the left show that they see waves. When the EOM is "OFF" they are testing for particles, and the pattern on the right shows that they see particles.

5.3 TEW critique of the Wheeler *gedanken* experiment

We claim that zero energy waves start at the detectors D1 and D2 and go backwards through the interferometer. Every quantum that enters the interferometer's front door (lower left in Figure 23) becomes a photon, and every photon travels on only one beam of the interferometer. Every time a detector clicks it is because a photon hits it. If a wave hits a detector without a photon, there will be no click.

Think about it! If every time you look for a wave you find a wave, and every time you look for a particle you find a particle, that proves that BOTH waves and particles are ALWAYS present. There is zero evidence in this experiment that the waves turn into particles, or vice versa.

The equipment was so designed that if you found a particle you could not simultaneously test whether a wave was present, nor vice versa. To say that the quanta were either waves or particles, was an ASSUMPTION on the part of Jacques et al. That assumption was never tested.

Imagine that I have a camera with two lenses. The only way I can see reality is through that camera. **One lens can only see men; the other lens can only see women.** I go into Time Square and look at the crowds through my camera. When I look at the crowds I find something astonishing. When I use one lens I see only women. When I use the other lens I see only men. **I conclude, obviously, that the women are turning into men, and the men are turning into women! Furthermore, I conclude that my choice of lens is what causes the men to become women or the women to become men.**

So I wonder if I change lenses faster perhaps I will catch the moment when the transition is happening. I devise a way to switch lenses in 40 ns, which is faster than the light from across the street can reach my lens. But when I look through my camera I discover the same thing: all the women have already become men, or, if I use the other lens, all the men have already become women. I conclude, obviously, that **my choice of lens is the "cause," and the gender change, which is the "effect," is occurring backwards in time, caused by my choice of lens.**

This is an irrefutable test. It is absolute proof that Wheeler was correct! Since this experiment is a valid proof that the quantum world is weird, and that time can go backwards, it is easy to see why the top scientific journal in the world (*Science*) published the article and gave it international prominence.

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6 The Davisson Germer experiment, 1928

During the 1920's the foundations of QM were being constructed. Louis de Broglie proposed in 1924 that there was a wave associated with every particle. De Broglie proposed $\lambda = h/p$ where h is Planck's constant and p is momentum. He also proposed $E = h\nu$ where E is energy and ν is the frequency of the wave. Although De Broglie tended to think of the particle following something which he later called a "pilot wave," most physicists endorsed the idea of a duality of wave and particle.

Bohr said that our language does not adequately describe quantum phenomena. There is something that, looked at one way appears to be a wave, and looked at another way appears to be a particle. The double slit experiment appears to show that particles could behave like waves and vice versa.

In 1927 Clinton Davisson and Lester Germer at Bell Labs were studying the surface of a crystal of nickel by firing slow electrons at such a crystal. The angle at which electrons reflected off the crystal was like X-Ray diffraction discovered by William Bragg and Max von Laue.

When Davisson and Germer fired an electron gun at 54 volts at a crystal of nickel, they found an unusual "spur" in the data at 50^o (Figure 29). That spur could only be explained if a wave of $\lambda = 1.67$ were refracting through the crystal, and the electrons were interacting with such a wave.[14, 15]

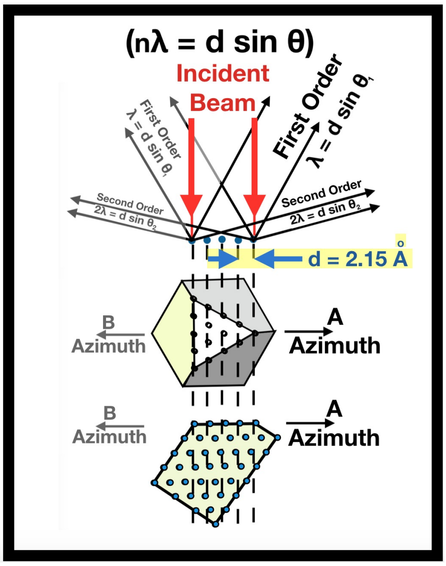

Figure 27: Electron refraction in a Nickel crystal, according to Davisson. The diffraction system of atoms in a crystal is like a line grating, but not just one grating, rather many of them piled on top of one another as shown at the bottom. The constant "d" has a value 2.15 Å when $\theta = 50^o$ and 54 volts so $n\lambda$ has a value 2.15 $\times sin\ 50^o = 1.65$.

The caption to Figure 27 says "$n\lambda$ has a value 2.15 $\times sin\ 50^o = 1.65$." Davisson says this is very close to the de Broglie equation:

$$\lambda = h/mv = \sqrt{\frac{150}{V}} \tag{51}$$

Davisson says that "The length of a phase wave of a 54 volt electron is about

$$\sqrt{\frac{150}{54}} = 1.67 \tag{52}$$

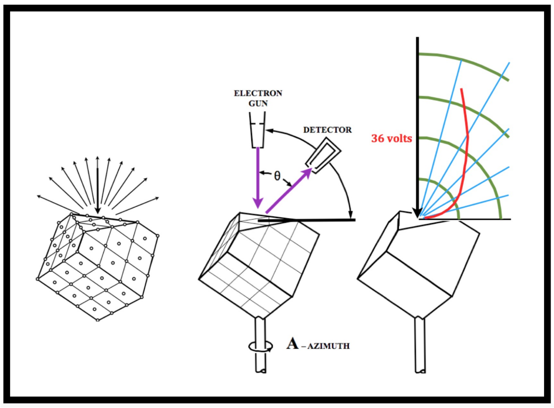

Figure 28: Electrons shot down from a gun at various voltages, come off the nickel crystal at angle θ. Scientists can control the amount of voltage, and the angle θ at which the detector is set. They can also measure the amount of current coming through the detector.

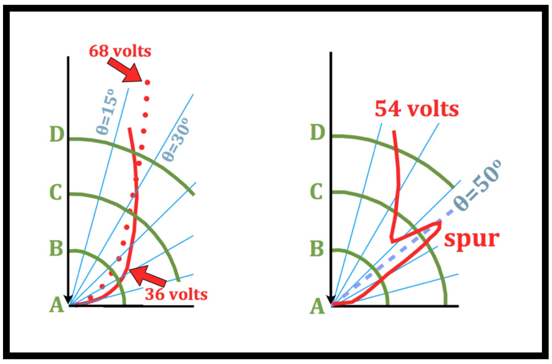

Figure 29: Voltage and angles θ of electrons coming up from a Nickel crystal show an unusual ***spur*** at 50^o and 54 volts. This ***spur*** is the central focus of the wave-particle discussion. The spur indicates the electrons are interacting with waves of 1.67 Å refracting through the crystal. QM says this "proves wave particle duality." But there is NO evidence which direction the waves are traveling.

He said, "There are circumstances in which it is more convenient to regard electrons as waves than as particles. We will allow perhaps that electrons have a dual nature. When they produce tracks in a cloud chamber they are particles. When they refract through crystals they are waves. A similar situation exists with X-Rays. When they refract through crystals they are waves, but when they give rise to the Compton effect or cause emission of electrons from atoms they are particles: quanta of photons."[16]

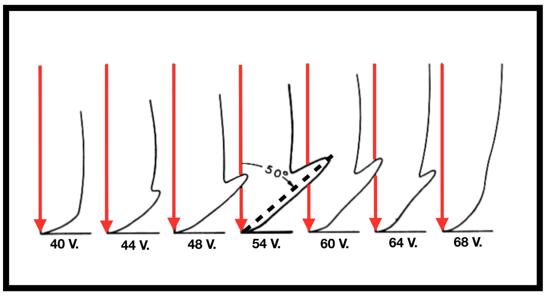

Figure 30: The unusual ***spur*** noted in the previous Figure, is visible only at a few voltages.

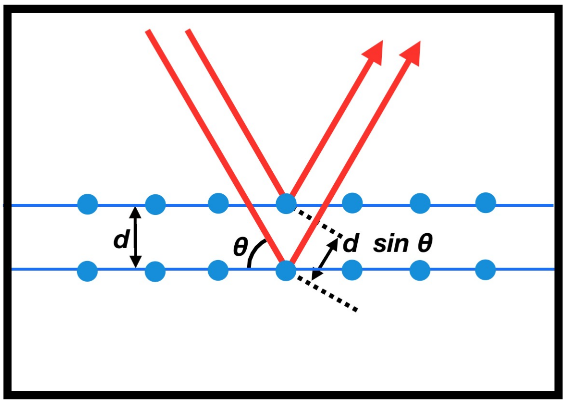

Figure 31: Bragg diffraction. Two beams with the same phase impinge on a crystal and are scattered off two atoms. The lower beam travels an extra length of $2\ d\ sin\ \theta$. Constructive interference occurs when this length is equal to a multiple of the wavelength: $n\lambda = 2\ d\ sin\ \theta$.

6.1 TEW comment on the Davisson Germer experiment

It is easy to see why all textbooks of physics say that the "Davisson Germer experiment proved wave particle duality." The experiment is elegant. It argues that the "spur" evident in the Figures above is similar to the way X-Rays refract through crystals.

The problem with Davisson's statement, or any QM statement about wave particle duality, is that it makes an unproved assumption: that waves and particles travel in the same direction. When electrons are refracting through a Nickel crystal, or X-Rays through another crystal, that assumption sounds self-evident. However, from a logical viewpoint, the phenomena could just as well be explained if the waves came from the detector and electrons or photons follow them backwards.

There are three compelling arguments for the latter. First, the double slit experiment cannot be explained if QM is correct, and can be explained if TEW is correct. Second, Kim et. al's quantum eraser experiment violates our common sense if QM is correct, whereas it is easy to understand that experiment if waves travel in the opposite direction. Third, the Kaiser et. al. neutron interferometer experiment cannot be explained by QM and can be explained by TEW.

If we limit our attention to the Davisson Germer experiment, we can make three conclusions:

- The experiment does not "prove" wave-particle duality. It proves wave-particle interaction.
- The experiment can equally well be explained by QM or TEW Axioms.
- It never occurred to Davisson or Germer that the waves might be traveling in the opposite direction as the electrons.

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7 The Pfleegor and Mandel attenuated laser experiment, 1967-68

Brief Overview: You are about to read about an experiment in which individual photons, one at a time, are behaving in a pattern that can only be described as an interference fringe pattern. The experiment is so designed that it is impossible that the photon has interfered with itself, nor has it interfered with another photon. The most likely of the remaining option is that there are zero energy quantum waves from two directions causing interference that is invisible because of zero energy. When a photon comes along from time to time, it is like a kayak going over standing waves in a river, making wave interference visible.

Background: In a double slit experiment there is a debate about the relationship between the waves and the particles. It is widely taught that wave-particle duality means that each photon (or particle) interferes with itself. According to that way of thinking the waves and particles would be intimately connected, or identical. The TEW viewpoint is that the waves and particles are disconnected, indeed they are traveling in opposite directions.

An experiment was conducted by Robert Pfleegor and Leonard Mandel in 1967 using two independent Helium-Neon lasers that were putting out very faint, attenuated light, with the two beams crossing at a small angle θ.[17-18] They found an interference fringe pattern in the crossed beams, which would not be so remarkable except that there was only one photon coming from one laser or the other on rare occasions. Having two photons in the experiment at the same time was statistically unlikely. A photon takes 3 $nsec$ to cross this apparatus, which is followed by 150 $nsec$ of silence, with no photons. Indeed photons were so scarce that in twenty μsec they only recorded 19 photons.

There were so few photons in the experiment that there would only be one photon from time to time, with a long period in between with no photons at all. In other words, the two He-Ne lasers crossed paths (with polarization aligned), but the light was so faint that a photon from one laser would register, then a quiet spell, then a photon again, perhaps from the other laser. If there were interference, one could not attribute it to a wave-particle interfering with itself, because there were two lasers. **Each laser was interfering with the other laser, but not with itself.**

The experiment only makes sense if some kind of zero energy wave from one laser is interfering with a zero energy wave from the other laser. Only a photon, which came along on rare occasions, could make a detector "click." What the Pfleegor and Mandel demonstrated is that there is wave interference in these data.

Franco Selleri, an Italian physicist, cites this experiment as evidence of zero energy quantum waves (one from each laser) interfering with one another. The interference pattern would slowly become visible because the rare photon crossing such a space manifests an interference fringe pattern. The detector could only see photon particles, not zero energy waves.

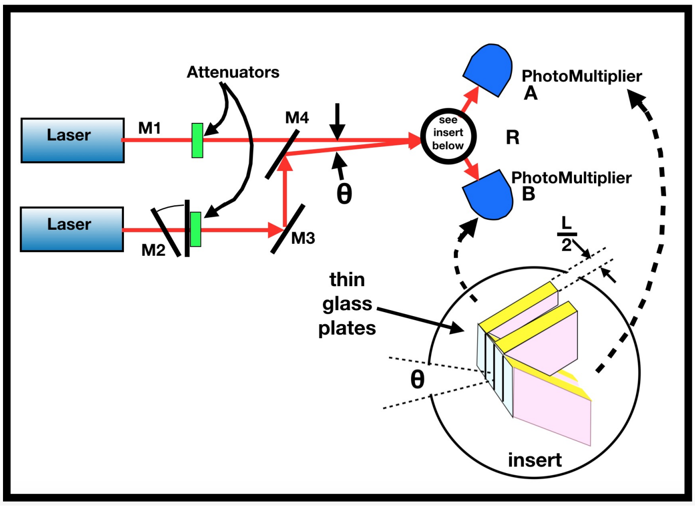

Figure 32: Equipment used by Pleegor and Mandel. Two He-Ne lasers with correlated polarization put out attenuated beams: one photon from time to time. The two beams (shown in red) have a small angle θ between them. The two beams do intersect, which is why there are interference fringes. The contents of circle R are shown in an insert in the lower right: stacks of thin plates of glass. All the odd numbered plates (1, 3, 5 . . .) send photons to one PhotoMultiplier (i.e. Detector) and the even number send photons to the other PhotoMultiplier. There is a relationship between the width of the interference fringe maxima (l), the width of a glass plate ($L/2$), and that is related to the angle θ.

Selleri advocated zero energy quantum waves independent of particles, which particles would follow in the same direction as the wave. This idea was similar to pilot waves, a theory promoted by Louis de Broglie, who loved Selleri's work. De Broglie said he loved Selleri's research.

TEW teaches that there are zero energy "quantum waves" but they travel in the opposite direction as the particles. Neither Selleri, Pfleegor nor Mandel ever thought of that idea. But the Pfleegor and Mandel experiment is fascinating because it strengthens the argument that waves and particles are not two aspects of the same quantum phenomenon.

7.1 Materials and methods

The two He-Ne lasers had their polarization aligned, and crossed paths at small angle θ. The angle was 2 degrees or less.

The interference data was captured by a stack of thin glass plates (Figure 32), each of which had a thickness of about half an interference fringe of the laser beams. The glass was so arranged that photons from plates 1, 3, 5 and odd number plates went to PhotoMultiplier A, and the even number plates (# 2, 4, 6, etc.) were sent to PhotoMultiplied B. When the half-fringe spacing coincides with the plate thickness, the fringe maxima falls on the odd numbered plates, at which time the even number plates should receive approximately zero photons. The position of the fringe maxima fluctuates over time, but if the number of photons n_1 increases for one channel, the number of photons n_2 should decrease over the other channel, providing the fringe spacing is right for a stack of plates of that thickness $(L/2)$. Thus there should be a negative relationship between the counts n_1 and n_2.

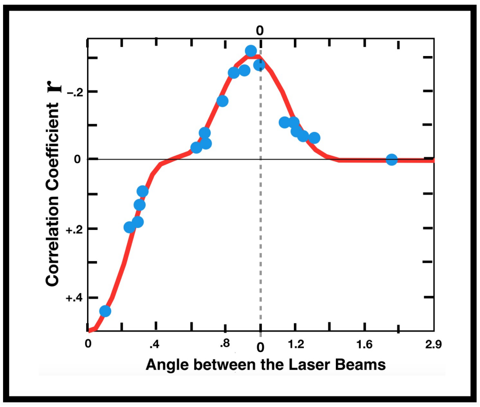

Figure 33: Correlation of two Lasers for 19 photons, compared to the red line predicted by QM equations. The interference fringe (proof of wave interference) is found in the peak at point "0" on the horizontal axis. Statistically the blue dots fall on the red line so accurately that Pfleegor and Mandel report that this graph proves the interference effect for which they were searching.

The correlation coefficient is defined:

$$r = \frac{\langle \Delta n_1 \Delta n_2 \rangle}{\sqrt{\langle (\Delta n_1)^2 \rangle \langle (\Delta n_2)^2 \rangle}} \tag{53}$$

Since the two photomultipliers should have a negative relationship to one another, therefore the vertical axis in Figure 33 is "upside down" in the sense that the correlation variable "r" has negative values on the upper part of the axis, and positive values on the lower part of the axis.

The experiment was repeated for various angles θ between the light beams, corresponding to various spacings l for the interference fringes.

The angle θ is shown as the horizontal axis of Figure 33, is expressed as the ratio of plate thickness L to fringe half spacing l. When the lasers are aligned so they are parallel to each other there should be a correlation such that the two photomultipliers are both seeing a peak (or a valley) at the same time.

7.2 Results

The authors developed quantum equations that predict what the results should be, which is the red curve shown on Figure 33. There is excellent correspondence between the observed data (blue dots) and what the theory predicts (red curve).

If you think of other interference fringe patterns with, say, three bright areas. In this experiment their methods took the three peaks and added them together into one, which is the peak you see in the middle of Figure 33.

This type of experiment is dependent on the attenuated strength of the optical field. For every 3 $n\ sec$ that a photon spent in the equipment, there were about 150 $n\ sec$ during which nothing was happening.

7.3 TEW conclusions

This experiment by Pleegor and Mandel disproves the QM thesis that a wave particle interferes with itself. That idea cannot explain these results because each laser beam was interfering with the other laser beam, but NOT with itself. Therefore a photon, which is fired very rarely, demonstrates an interference fringe pattern (i.e. the peak in the center of Figure 33) because of being guided by zero energy quantum waves that are present even when there is no photon in the equipment.

These data support the idea that there are zero energy quantum waves, and that particles follow such waves. The waves exist even when there are no particles.

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8 Summary

There is a widespread but incorrect idea that there is a mountain of empirical evidence supporting QM, and that a newcomer like TEW would need to inspire new research at a time when there is no funding for new research. The reality is more complicated.

TEW is not another science. It is a change of Axioms. It is a new way of viewing existing research. No NEW research is needed in order to find empirical support for TEW. This article has presented six experimental studies.

1. A quantum eraser experiment by Kim et. al.
2. A neutron interferometer experiment by Kaiser et. al.
3. A Stern Gerlach magnet experiment
4. Wheeler's interferometer thought experiment
5. Davisson and Germer's "proof" of wave particle duality
6. Pfleegor and Mandel's attenuated laser interference experiment

What these experiments prove is that although Nature appears weird when viewed through quantum Axioms, Nature appears normal and familiar when viewed through TEW Axioms.

This article has presented a simpler and more logical explanation than QM of these six experiments. We appeal to Occam's Razor. The TEW view is simpler and hangs together better than the QM view. TEW ends up with a picture of Nature at the quantum level that is recognizable as the same Nature that we know from our everyday experience.

The basic reason that the QM Axioms are wrong, is that you cannot build the Nature we know out of bricks that are weird. $\sum_n (weird_n + WEIRD_n) = \textbf{BIZARRO} \neq Nature$. It is that simple.

Therefore we propose that TEW Axioms are supported by a mountain of empirical research. The reason we present 6 rather than 150 research studies is that this article is already long enough. We have made our point.

8.1 What can we learn from these experiments about Elementary Waves?

We learn from the Pfleegor and Mandel experiments that there are zero energy waves that are invisible in the environment. Photons follow these waves. The photons are different than the waves because mostly there are no photons, but the waves persist and continue to experience wave interference.

We discover that these zero energy waves from one laser cause interference patterns when they intersect zero energy waves from another laser. The experiment was designed in such a way that one photon or wave could not interfere with itself, because one laser interfered with the other but not with itself.

We learn about the direction of these waves from several of the experiments: Kim's quantum eraser experiment, Kaiser's neutron interferometer experiment, the Stern Gerlach experiments and Wheeler's interferometer thought experiment. None of those experiments make sense if the waves travel in the same direction as the particles. All make sense if they travel in opposite directions.

We learned that Davisson and Germer's experiment did not "prove" wave particle duality, as all the textbooks say. Rather they proved interaction between waves and electrons. Their data do not show which direction the waves were traveling vis-á-vis the electrons. The Davisson and Germer data are consistent with TEW on that issue.

8.2 How do we view Nature, based on this research?

TEW has to do with relationships between things. If you look at this sentence, then you give this sentence permission to respond to you. It is subtle, gentle, not coercive. You see this sentence by looking **through** the elementary rays, like looking through a microscope or telescope.

Elementary Waves emanate from your rods and cones, impinge on these letters, and photons follow backwards the Elementary Waves continuing to emanate from your eyes. You can only see your environment **through** the medium of Elementary Waves. With no waves you would be blind and isolated, as we are about to prove.

In a moment when we discuss a Stern Gerlach magnet experiment, imagine that you are the bottom spot on the target screen, and you desire to see a silver atom. Remember to ask yourself this question: Why can't I see a silver atom?

Energy and matter ($E = m \cdot c^2$) constitutes half of nature. These zero energy Elementary Waves, which allow you to connect with your environment, constitute the other half. Without the Elementary Waves there would be no Schrődinger waves, and the particles around you and inside you would collapse into a dry pile of dust. Energy and matter provide the raw materials, but Elementary Waves provide the shape.

There is poetry in Elementary Waves. To be immersed in an ocean of Elementary Waves does not make anything happen. But it means that you are connected to possibilities. Something might happen.

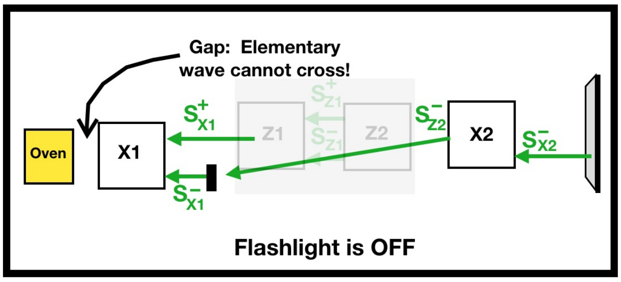

Figure 34: ≡ Figure 18. If the flashlight is OFF then the middle pair of magnets Z1-Z2 act as if they are not present. A spin-down elementary ray starting at the target screen remains spin-down as it crosses three magnets, where it discovers that the spin-down doorway of magnet X1 is blocked, so it cannot enter that magnet and cannot reach the oven. Therefore no silver atom will be able to follow it backwards. Therefore there will be no spot at the bottom of the target screen

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This Figure explains why no silver atom makes a dot at the lower position on the target screen (S_{X2}^-) if we don't know which pathway is used (spin up or spin down) between the central Z1-Z2 pair of magnets. In other words, if there is no little flashlight, then there is no lower mark on the target screen.

Consider what happens if an Elementary Wave is absent. Suddenly something is impossible. We are so accustomed to being connected, to being immersed in an ocean of possibilities, that it is jarring to recognize how isolating it would be if there were no Elementary Wave. Something we take for granted, would be unavailable. There is a gap, something we cannot experience. Without elementary rays we are unplugged, not rooted in our environment.

No Elementary Wave ≡ no silver atom coming your way. You can energize the silver atom as much as you want, but when there is no Elementary Wave that means there is no flight plan, and that is the decisive factor. The silver atom has no way to fly to your location.

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9 Acknowledgment:

The author thanks Lewis E. Little who taught him the Theory of Elementary Waves, and challenged him to develop a corresponding mathematics. Little said, "You are the one with a degree in mathematics."

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