Wave-particle duality: A proposed resolution

Pons, D.J.[1] Pons, A.D., Pons, A.M., Pons, A.J.

Abstract

There are several integration problems of fundamental physics that still lack coherent solutions, the case in point being wave-particle duality. While empiricism and mathematical modelling have served physics well, they have not yet been able to achieve integrated causal models. Conventional theories and approaches have only provided partial solutions, and it is possible that a more radical reconceptualisation of fundamental physics may be required. This work comes at the issue from a totally different approach: it applies engineering design thinking to the problem. The result is the cordus conjecture, which proposes that the photon, and indeed all matter 'particles', has an internal structure comprising a 'cordus': two reactive ends that each behave like a particle, with a fibril joining them. The reactive ends are proposed to be a small finite distance apart, and energised [typically in turn] at a frequency. When energised they emit a transient force pulse along a line called a hyperfine fibril [hyff], and this makes up the field. This concept is used to explain the path dilemmas of the single photon in the double-slit device, and the wave behaviour of light including the formation of fringes by single photons and beams of light. In addition it provides a tangible explanation for frequency. It also yields new quantitative derivations for several basic optical effects: critical angle, Snell's law, and elsewhere Brewster's angle. Thus the proposed cordus structure resolves wave-particle duality at a conceptual level. The cordus conjecture does away with the current weirdness of wave-particle duality: there is no need for virtual particles, superposition, observer dilemmas, pilot waves, intelligent photons, or parallel universes. A simple deterministic, unintelligent photon with dual modes of existence is all that is required. Cordus suggests there is a deeper mechanics that subsumes both quantum mechanics and wave theory. From this cordus perspective, wave and particle behaviours are simply the different output behaviours that the internal system of the photon shows depending on how it is measured. The duality and the apparent incongruity of quantum mechanics and wave theory is an artefact of the limited formulations of those theories, and the conflict does not exist at the deeper level of mechanics. While the present paper only addresses wave-particle duality, the wider work provides an integrative conceptual solution for several other enigmatic effects. Cordus is simpler and more logically consistent across a wider range of phenomena than quantum mechanics or wave theory. Even more surprising, and unexpectedly contrary to the prevailing probabilistic paradigm of quantum mechanics, cordus suggests that the next deeper level of reality is deterministic.

Il existe plusieurs problèmes d'intégration de la physique fondamentale qui requièrent, encore à ce jour, une solution cohérente. Le problème en question ici est celui de la dualité onde-particule. Alors que l'empirisme et la modélisation mathématiques ont bien servit la physique, ils n'ont pas, à ce jour, permis l'élaboration de modèles causaux intégrés. Les théories et approches conventionnelles n'ont fournit que des solutions partielles, et il est possible qu'une reconceptualisation plus radicale de la physique fondamentale soit nécessaire. Ce travail traite ce problème avec une toute autre approche en appliquant des processus de pensée relatifs au génie de conception. Le résultat est la « conjecture de cordus « qui propose que le photon et en fait toute particule matérielle a une structure interne comprenant un « cordus « : deux extrémités réactives se comportant comme des

[1] *Please address correspondence to Dr Dirk Pons, University of Canterbury, Christchurch, New Zealand. Email dirk.pons@canterbury.ac.nz*

particules connectées par une « fibrille «. Il est proposé que ces deux extrémités réactives, séparées par une petite distance finie, sont énergisées [typiquement tour à tour] à une certaine fréquence. Lorsqu'elles sont énergisées, elles émettent une force impulsive transitoire le long d'une ligne appelée fibrille hyperfine créant ainsi un champ de force. Ce concept est utilisé pour expliquer les dilemmes de la trajectoire d'un photon dans l'expérience de la double fente et le comportement ondulatoire de la lumière incluant la formation de frange par un photon unique et de rayon lumineux. De plus, cela donne une explication tangible pour la fréquence. Cela induit également de nouveaux raisonnements quantitatifs pour plusieurs effets d'optique : l'angle critique, la loi de Snell, et ailleurs l'angle de Brewster. Donc, la structure en cordus proposée résout le problème de la dualité particule-onde au niveau conceptuel. La conjecture cordus élimine l'étrangeté de la dualité particule-onde : il n'y a pas besoin de particules virtuelles, de superposition, de dilemme d'observateur, d'ondes pilotes, de photons intelligents, ou d'univers parallèle. Un simple photon déterministe, non-intelligent avec un mode d'existence dual est tout ce qui est requis. Cordus suggère qu'il existe un mécanisme plus profond qui subsume la mécanique quantique et la théorie des ondes. Vu de cette « perspective cordus », les comportements ondulatoires et particulaires sont simplement les comportements que le système interne du photon démontre en fonction de la façon dont il est mesuré. La dualité et l'apparente incongruité de la mécanique quantique et de la théorie des ondes ne sont que des artefacts de la limite de la formulation de ces théories, et ce conflit n'apparait pas au niveau plus profond de la mécanique. Alors que cet article n'adresse que le problème de la dualité onde-particule, ces travaux fournissent une solution conceptuelle intégrative à plusieurs autres effets énigmatiques. Cordus est plus simple et plus consistant du point de vue de la logique pour un grand nombre de phénomènes tant quantiques qu'ondulatoire. Encore plus surprenant et inattendu, en contraste avec le paradigme stochastique de la mécanique quantique, cordus suggère que le prochain niveau plus profond de la réalité est déterministe.

Keywords: wave-particle duality, photon, light, double-slit, double slot
Document: Pons_2011_WaveParticleDuality_E2.2.22.doc

1 Integration problems in fundamental physics

The dominant existing frameworks for fundamental theoretical physics are quantum mechanics [QM] for particles, electromagnetic wave theory [WT] for light, electrostatics and magnetism, and general relativity [GR] for gravitation. While those conventional theories are generally accepted as valid in their particular areas, there is the unfortunate problem that they do not integrate well, see Figure 1. Furthermore, they sometimes give weird explanations to simple phenomena, this being particularly the case with QM. Also, there are many areas that they simply do not explain at all, or give conflicting interpretations.

A case in point is wave-particle duality. For example in the double-slit experiment, light apparently sometimes behaves like a wave, and sometimes like a particle, depending on how it is observed. WT and QM adequately describe the fringe and particle behaviours respectively, but their explanations do not overlap. Thus there is no single integrated explanation for wave-particle duality.

Furthermore, while QM has exquisite mathematical models for the particle behaviour, the physical interpretation of those models results in really strange predictions of reality e.g. superposition, and some explanations that are beyond physics, e.g. virtual particles and parallel universes. That in itself would not be a problem except that we do not actually see reality behaving the way QM predicts, especially not at the macroscopic scale.

The null explanation is then to simply accept the paradoxes and consider the matter intractable. That seems to be the current state of physics. Thus comparatively little progress has been made at the big-picture level: many of the issues identified in the figure above have been known for nearly a century, and are still unresolved. The issue preventing resolution is not obviously resources, since many people have been engaged in the pursuit and vast financial resources have been put into large capital works. Instead, it may be that we have simply painted ourselves into a conceptual corner, one where there is no solution. Therefore, there may be value in coming at the issues from a totally different approach, i.e. use a different cognitive way of thinking.

Is the duality even worth solving?

It is acknowledged that in many ways wave-particle duality is no longer relevant to current discourses in physics. Generation after generation of physicist have been trained to accept the duality as the reality, and it has become an accepted and seldom-questioned premise. Moreover, it is indeed a workable premise. This is because the tools of QM and WT, though lacking integration, are still sufficient for most of what physicists want to do, and the popular many-worlds theory provides a convenient belief-system to bridge the residual ambiguities. A vast, and very successful, intellectual edifice in the form of quantum mechanics has been constructed for physics, despite wave-particle duality. That it has been possible to achieve so much, without directly solving the duality, seems to be evidence supporting those who claim that the duality is irrelevant: that it is only a curiosity and need not be solved at all.

Nonetheless, the underlying cognitive dissonance is still there, even if papered over with intellectual coping mechanisms. Thus there are two reasons why we should nonetheless persist with exploring wave-particle duality. First is the reason of curiosity: because it is still an unanswered problem, regardless of its perceived relevance. Second is the epistemological reason: because it is just possible that the weirdness of wave-particle duality is not so much because reality is weird [a common interpretation], but rather a symptom that the conceptual foundations of our existing theories are fundamentally wrong. The integration problems in physics therefore suggest that there might be a deeper physics, a better theoretical foundation that provides a more coherent explanation across the many phenomena. Thus we take the perspective of discontent - that cognitive dissonance and lack of integration between theories are symptoms of a deeper conceptual lack. We see value in exploring new conceptual solutions to wave-particle duality, and that is the purpose of this paper and the wider work to which it refers.

However, if there is a deeper theory, e.g. one that subsumes both wave and particle perspectives, it is not obvious what that might be. Also, there is reason to believe, per Bell's theorem, that no theory of internal [or hidden] variables is possible for the photon and particles generally. Thus the problem of wave-particle duality may be fundamentally unsolvable.

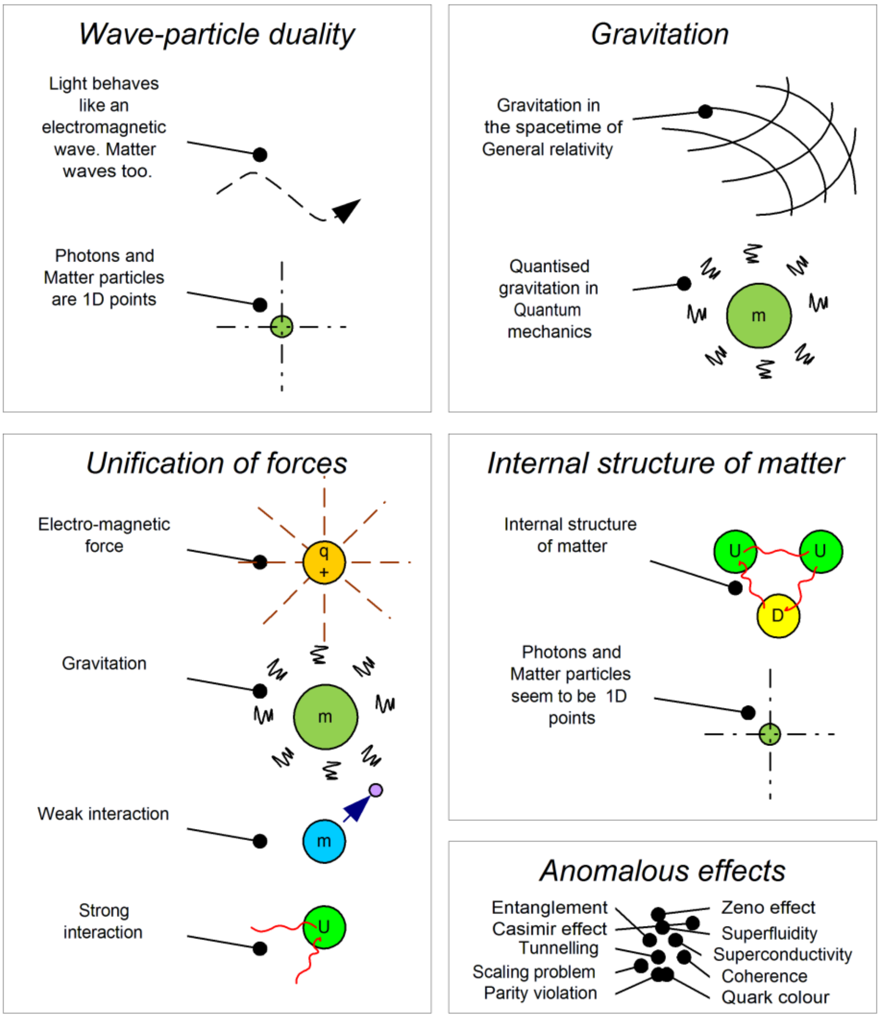


Figure 1: Areas where there are integration problems in conventional physics. The first shown here is the problem of wave-particle duality, where light behaves as either a wave or particle depending on how it is observed. Another is gravitation, particularly the integration of general relativity and quantum mechanics. Unification of forces is another area of difficulty, the biggest obstacle being the unification of gravitation with the others. There is also the more tacit problem of the internal structure of matter: particles seem to be 1 dimensional points and some theories predict that they have no further internal structure [e.g. for the photon], yet other particles like the proton are known to be composed of still smaller particles though the structure itself is unknown. Finally, there is the problem of the various anomalous effects: observed phenomena that are difficult to explain. The wider integration is also missing: an ideal theory would explain ALL of the above.

2 Approach taken

While empiricism and mathematical modelling have served physics well, they have not yet been able to achieve integrated causal models. But epistemic uncertainty is not unique to fundamental physics: other disciplines have their own conundrums, and have developed their own methods for complex problem-solving. Perhaps applying a problem-solving method from outside of physics might give insights? The Cordus conjecture is the result of an application of engineering design thinking to the problem.

Methodology

This paper applies the cognition of engineering design. The conventional scientific method involves collecting empirical data, checking hypotheses, and formulating theories [fitting relationships to data]. Variables are usually quantitative and the objective is to find precise objective causal relationships [usually mathematical algorithms] describing how the input variables determine the observed behaviour. The cognitive skill required is analysis, and the logic is deductive.

In contrast, design cognition seeks to find a satisfactory rather than a perfect solution. The cognitive skill required is creativity and intuition. Design involves multiple sub-optimisations using quantitative and qualitative variables, being processed by objective algorithms as well as subjective heuristics, along solution paths that are only partly evident at the outset. It forms a mechanism for innovation generally and new product development specifically. It looks like a messy process from the outside, but has its own logic of synthesis.

Applying design cognition to fundamental physics would not seem a natural choice of methodology. Nor is it likely to generate the objective relationships of causality [mathematical expressions] that are so particularly prized in physics. Nevertheless it is a valid approach elsewhere, and has potential to provide surprises.

Process

The starting point was that simple yet subtle experiment: wave-particle duality of the photon in the double-slit device. The process was to apply design intuition, creativity and simple logic, and come up with a starting concept. This core concept is called the Cordus Conjecture [1]. As the name indicates, it is conjectural. This idea is novel in that it does not build on existing concepts. It is an unorthodox conceptual departure from existing frameworks and does not need them, and therefore does not reference them. Thereafter we considered other areas of dis-integration in physics, and sought to reverse-engineer the known phenomena, adding conjectures and intuitive material, and noting the necessary assumptions along the way. Thus the central strand in the Cordus conjecture is a set of lemmas, and these we do not attempt to prove, nor are they provided in this summary paper. The resulting Cordus model is primarily conceptual and descriptive, rather than mathematical, at least at this point in time. It is a system model created with the logic of synthesis. The results are likewise descriptive concepts, rather than mathematical expressions. The Cordus conjecture is given below, followed by an elaboration of its mechanics, where relevant to the topic of wave-particle duality.

3 Cordus conjecture

The Cordus conjecture is that all 'particles', e.g. photons of light, electrons, and the protons in the nucleus of the atom, have a specific internal structure. This structure is a 'cordus': two reactive ends that each behave like a particle, with a fibril joining them. The reactive ends are a small finite distance apart, and energised [typically in turn] at a frequency. When energised they emit a transient force pulse along a line called a hyperfine fibril [hyff], and this makes up the field, see Figure 2 for application to the photon [2].

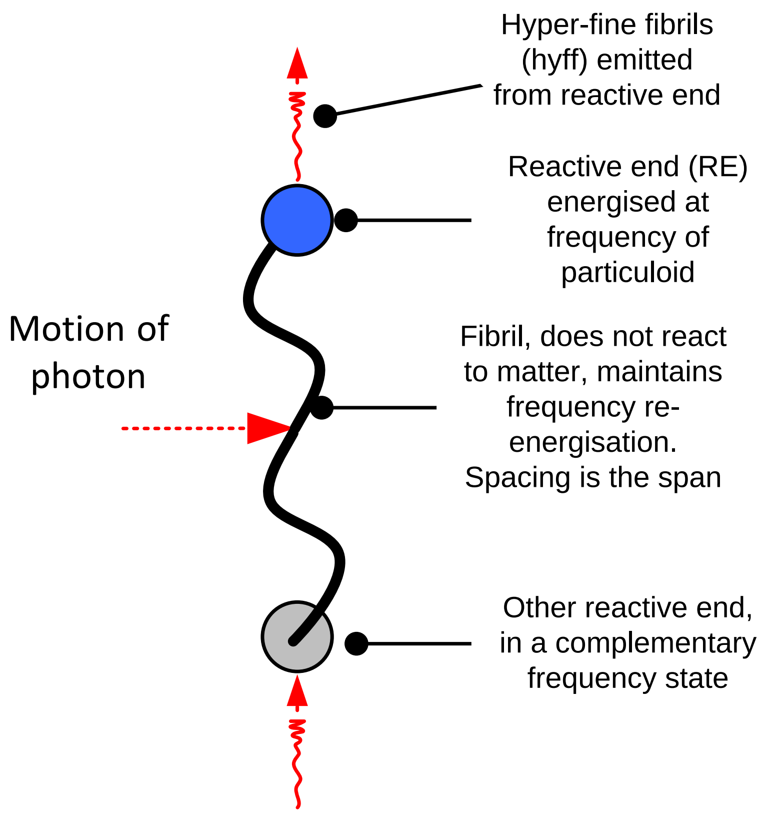


Figure 2: Cordus model of the photon. It is proposed that the photon probably only has a single radial hyff at each reactive end, whereas the electron has three, but the fundamental structural concept is similar. Image is in the common domain http://en.wikipedia.org/wiki/File:CordusConjecture2.21_PhotonCordus.png

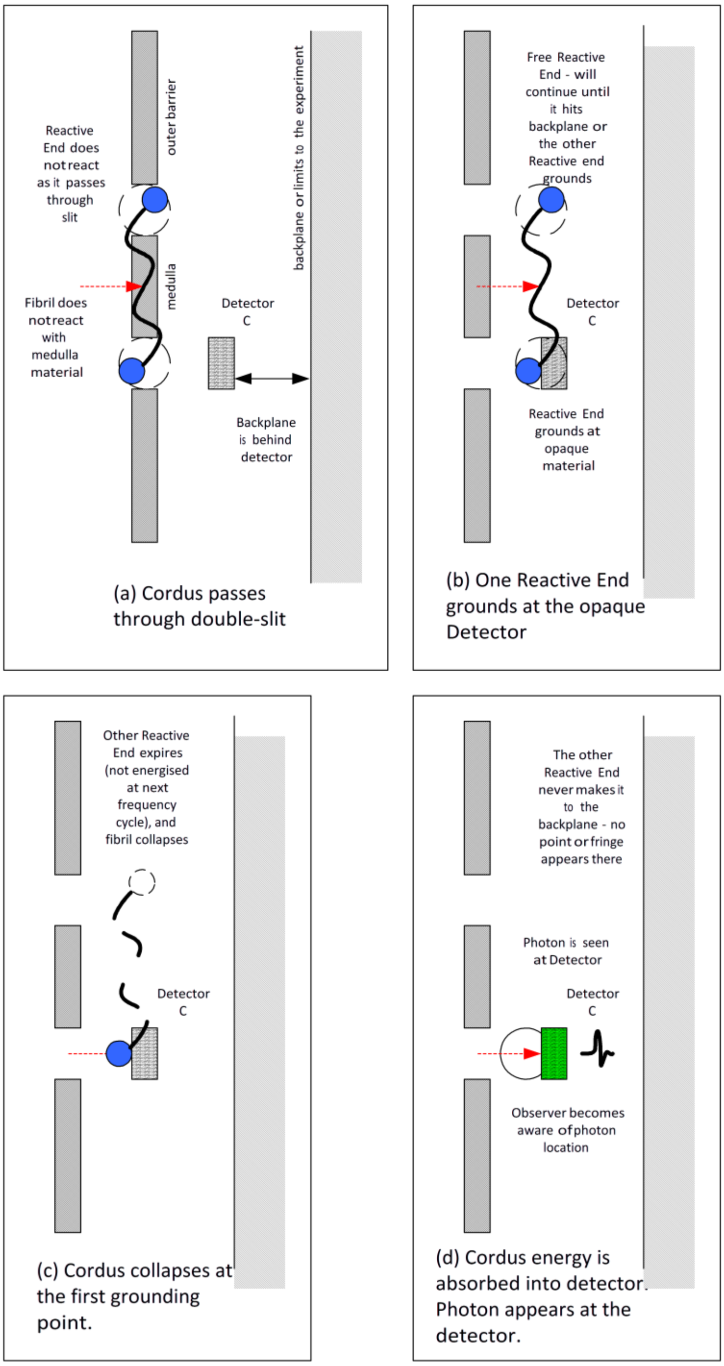
The core concept in the cordus conjecture is thus a particular bipolar internal structure for the photon and indeed all 'particles'. We term this a *cordus*, and emphasise that it is the *internal* structure of what is otherwise called a 'particle', and is not the same as a 'dipole' [separation of negative and positive charges] which is an *external* structure. Nor is it appropriate to call this a 'particle', because it is not a one-dimensional [1D] point. The idea of a cordus allows many puzzling phenomena to be explained at a conceptual level, starting with wave-particle duality [3, 4].

Double slit device

Light seems to behave either as a wave or a particle in the double slit experiment, and cordus explains this wave-particle duality. Thus the single photon, made up of a cordus, does pass through both slits: one reactive end through each slit. The reactive ends therefore take different paths [loci]. The natural variability of the span of the cordus means that the effect is only approximately dependent on the spacing of the slits.

Particle behaviour

Once through the slits, the whole photon collapses to, and therefore appears, at the first place where a reactive end is arrested, see Figure 3. This explains the observed phenomenon that blocking one slit, [or placing a detector only at one slit] causes the whole photon to appear there.



Photon behaviour in the double-slit experiment with only one detector

Figure 3: Photon behaviour in the double-slit experiment

Wave behaviour and fringes

This basic idea can also explain how the fringes arise in single gaps and double-slits. Each of the two reactive ends also interacts, through the hyff [electric field] with the opaque material bounding the slits. The hyff become engaged with the surface plane of the material and exert a quantised force that retards the reactive ends and bends its trajectory by set angular amounts, causing fringes at set intervals.

The double-slit device best shows the fringe behaviour because the short-span cordi are barred entry by the medulla. Thus the device imposes an upper and lower filter on the range of spans admitted. Hence narrower slits produce more pronounced fringes.

The two locations of the fringe are the modes of the reactive ends, and it is somewhat random as to which will ground first. Note that this explanation accommodates the fringe behaviour of both single photons and beams of coherent light. Thus a solitary photon will be deflected into discrete angular steps, and will appear at one of the fringe locations. A whole beam of coherent light will likewise form fringes because all the photons have the same discrete angular deflection, providing that they are of the same energy. In the cordus model higher energy particuloids [i.e. also higher frequency] have shorter spans.

This also explains why both photons and electrons form fringes: in both cases the fringes arise because of the interaction of the electric field, which is in discrete pulses, with the frontal surface plane of the matter bounding the slit.

Wave-particle duality

The significance of this is that one mechanism, the cordus, is able to explain all three phenomena in the double slit: the blocked-slit behaviour of an individual photon, the fringes formed by multiple photons taken singly, and the fringes produced by of a beam of light. The same mechanisms also explains photon path dilemmas in interferometers.

4 Cordus mechanics

The basic cordus concept is now expanded and grounded in known phenomena to extract the broader mechanics for optical reflection and refraction.

4.1 Cordus frequency

Conventional particle and wave theories struggle to explain the frequency of photons and matter in a coherent manner using natural physics. By comparison, the cordus readily provides a physical interpretation. Thus it is proposed that there really is a part of the photon cordus that moves with a frequency [5]. The current working model is for a reciprocal motion: the energy alternates between the two reactive ends across the span of the cordus, and the hyff represent the observable electric field, see Figure 4.

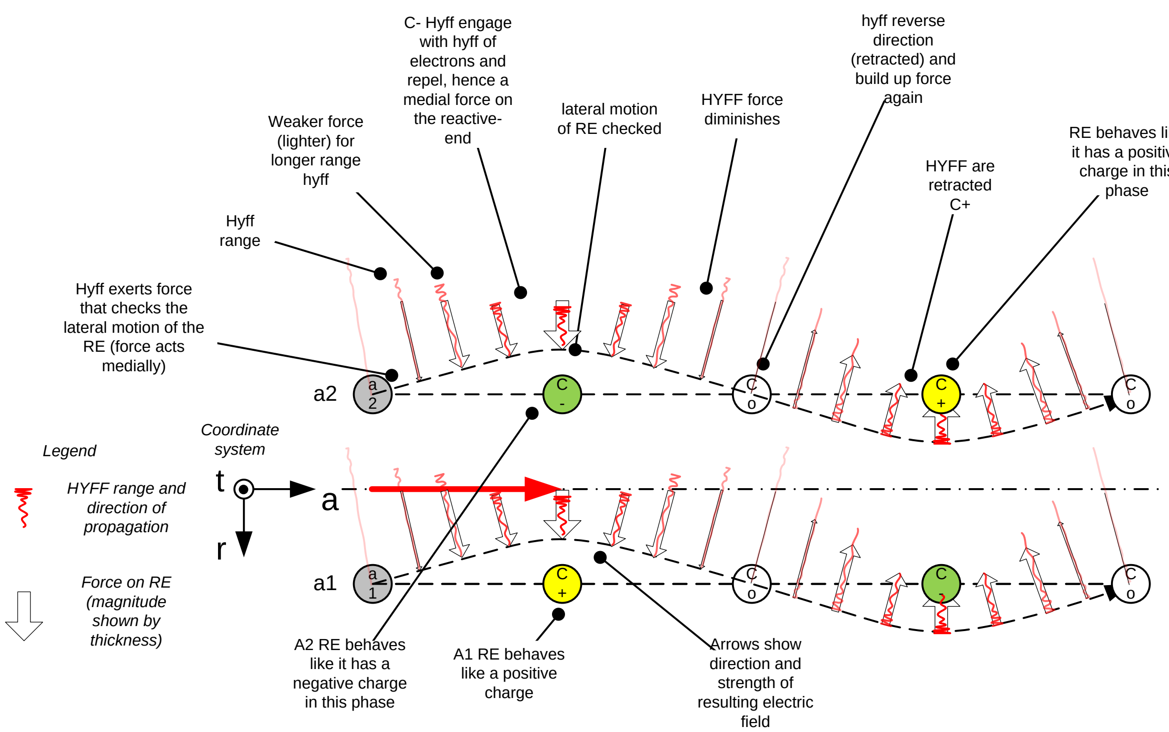


Figure 4: Working model for frequency behaviour of reactive ends.

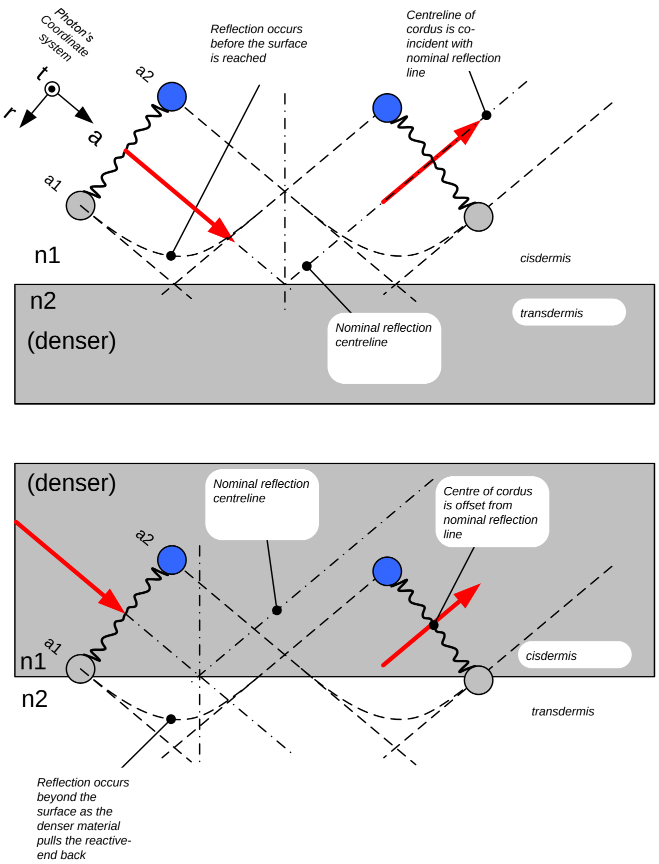
This cordus model for frequency readily explains polarisation too: this is the orientation of the cordus relative to the line of motion. It also explains tunnelling. This effect involves a photon occasionally going through a barrier [e.g. the space between two glass prisms] instead of being reflected. The effect requires a small gap, and is known to be dependent on frequency. Tunnelling, from the cordus perspective, is when a reactive end energises too late for its hyff to respond to the change of media, so the RE goes right on through into the next medium before it has time to re-energise.

4.2 Reflection

Optical effects such as reflection and refraction are conventionally best described by electromagnetic wave theory, at least when they involve beams of light. Wave theory takes the perspective that a beam of light is not so much a stream of photons, as a continuously existing electromagnetic wave, comprising an electric field and a magnetic field. From the perspective of wave theory, reflection is caused by the mirror surface absorbing and re-emitting its own EM waves. Depending on the perspective taken, these interfere with each other or with the incident wave to produce the reflected wave. The mathematics of wave theory accurately quantifies the phenomenon, though its qualitative explanations are not intuitive. Nor does that theory does not explain why single photons should also show such behaviour. Explaining basic optical effects is not possible with classical particle mechanics, and even with quantum mechanics it is not straight forward and the descriptive explanations not particularly intuitive.

Optical effects can be explained from a cordus particuloid perspective [6]. Importantly, this explanation is applicable for single photons and beams of light. The Cordus explanation is that both reactive-ends of the cordus separately reflect off the surface as their hyff interact elastically [lossless] with the substrate. The precise locus taken by a reactive end depends on its frequency state at the time it approaches the surface, and the nature of the surface. Thus the reflection is not a sharp instant change in direction occurring at the surface, but rather a curved transition. Depending on the situation, that curve might occur above the surface [cisdermis] or beneath it [transdermis].

Consequently the centreline of the reflected cordus may be laterally offset from the nominal: the photon is displaced sideways from where it should be by simple optics. This effect is known for p-polarised light at total internal reflection, and is termed the Goos–Hänchen effect. The Cordus explanation is that the actual reflection occurs in the transdermis in this situation, and Figure 5 provides a graphical explanation of how the offset arises. Phase changes at reflection are also explainable [6].



(a) Reflection off a denser material (n2>n1)

(b) Internal reflection off a less dense material (n2<n1)

Figure 5: Reflection occurs as a curved transition some

distance off the surface (a), not an abrupt change at the precise surface. In the case of internal reflection (b), the transition may occur in the second medium and result in the centre of the cordus being offset from the nominal.

Cordus derivation of critical angle

Critical angle for internal reflection is also explainable [6]. Internal reflection is when light passes from a region of high refractive index n_1 to lower n_2, e.g. glass to air. The critical angle is where total internal reflection occurs, i.e. no transmission, and is known to be: $\sin(\theta_c) = n_2/n_1 = \lambda_1/\lambda_2$ where λ are the wavelengths.

The Cordus explanation is that at the critical angle θ_c the reactive end a1 is inserted into in the faster material n_2 at t=0, and therefore moves forward a distance $\lambda_2/2$, see Figure 6. This motion is parallel to the surface because this is the angle of refraction. By comparison at the same time reactive end a2 continues to travel distance λ_1 in the slower medium, before it later also enters the faster medium, at t=1/2 of a frequency cycle. RE a1 is thus accelerated by the sudden freedom of being in the faster medium. The angle θ_c is steep enough to push the RE out of the slower medium, but only steep enough to place it at the boundary. A moment later the second RE is likewise positioned at the boundary.

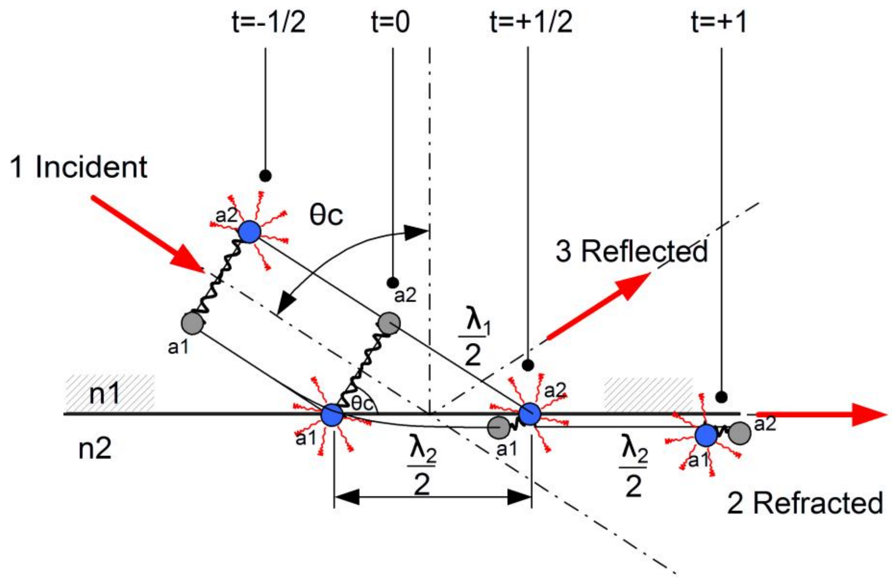


Figure 6: Geometry of the cordus at the critical angle ϑ_c for total internal reflection.

The important points are:

- Over the period from t=0 to t=1/2 cycles, a1 moves $\lambda_2/2$ whereas a2 moves $\lambda_1/2$, because they are in different media.
- The angle θ_c is such that there is only a half-cycle of frequency involved.

The angle at which the above two conditions is met is apparent from inspection of the geometry in the figure, $\sin(\theta_c) = \lambda_1/\lambda_2$, and this is the same as the critical angle derived from optics. For more details see reference [1].

4.3 Refraction

The bending of light as it enters an inclined boundary is usually explained in optical wave theory as a change in the speed [phase velocity], such that the wavelength changes but not the frequency. The angle of refraction θ_2 in the second medium 2 is given by Snell's law: $\sin\theta_2 = v_2/v_1 . \sin\theta_1 = n_1/n_2 . \sin\theta_1 = \lambda_2/\lambda_1 . \sin\theta_1$ where the angles are measured from the normal to the surface, and v are the velocities in the two media. Explanations vary for *how* the change in speed occurs. The wave interpretation is that the delay occurs because the electric field interacts with the electrons to radiate a delayed wave, thereby forming the new but slower wave. Hence the Huygens–Fresnel principle that each point on the wave propagates new waves and these interfere.

The Cordus explanation for refraction [7] is that the inclined incoming cordus strikes the surface and one reactive-end and then the next penetrates into the second medium n_2. Assuming the case where n_2 is more dense, e.g. from air to glass, then the cordus slows down. The case is shown in Figure 7.

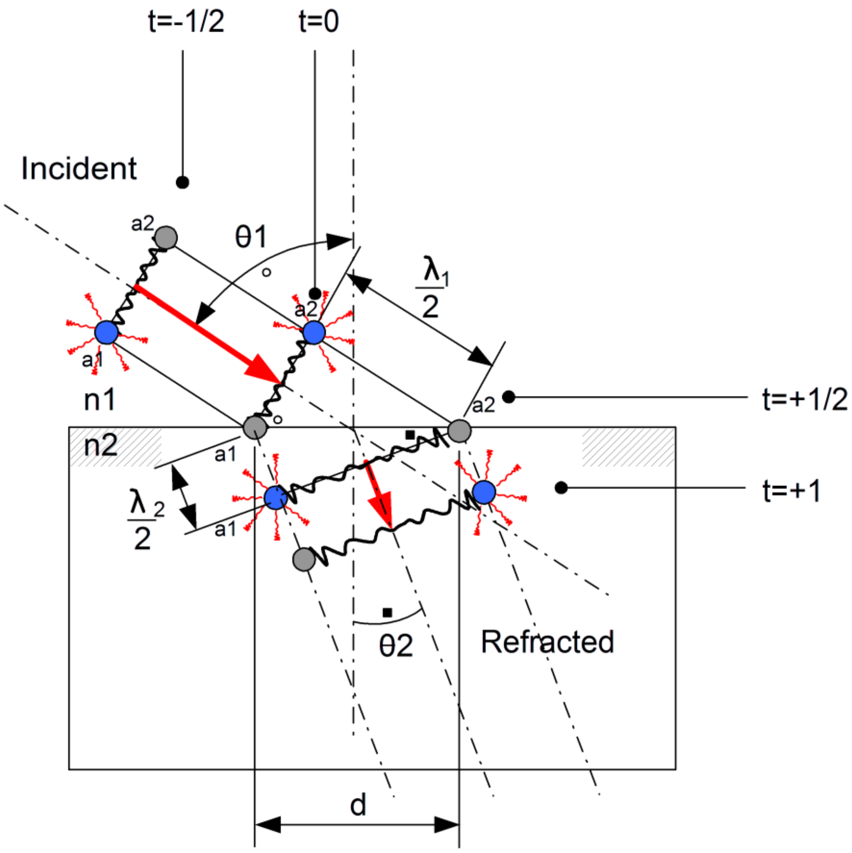


Figure 7: Refraction involves a dormant reactive-end penetrating into the second medium, and being angularly deflected with reduction in speed.

Cordus derivation of Snell's Law

The separation of the reactive ends along the interface, in Figure 7, is given by $d = \lambda_2/(2.\sin\theta_2) = \lambda_1/(2.\sin\theta_1)$, which simplifies to Snell's law. The frequency and other forms arise by noting that v_1=f. λ_1 and v_2=f. λ_2 and n = c/v where c is velocity of light in vacuum.

Birefringence is also explained by cordus, and Brewster's relationship derived. The cordus mechanics for optical phenomena are the same for single photons and beams of light, which is an advantage compared to wave theory. The same cordus mechanics are logically consistent with those for the double-slit device. Therefore cordus can explain particle behaviour, fringes, and optical effects, using a single coherent mechanics. The cordus explanation does not need the conventional concept of 'interference'. In fact cordus refutes interference as a physical mechanism. Instead cordus asserts that interference is only a mathematical model of the en-masse behaviour of the hyff from multiple cordi.

5 Discussion

Outcomes

What has been shown here is a *conceptual* resolution of several problems in fundamental physics:

1. The proposed two-ended cordus structure of the photon readily explains the path dilemmas of the photon in the double-slit device: one reactive end goes through each slit, and the photon collapses and becomes detected at the obstacle which first stops one of the reactive ends. The same principle is also explains the path dilemmas in the Mach-Zehnder interferometer. Thus the 'particle' behaviour of the photon can be explained.

2. The cordus structure can also explain the wave behaviour of light, particularly the formation of fringes in gaps, apertures, and the double-slit device. The suggestion is that these fringes form, not from classical destructive/constructive interference, but by the interaction of the electric field, which is discrete, with the frontal surface plane of the matter bounding the slit.

3. Cordus also provides a tangible explanation for frequency of the photon, electron and matter generally. By comparison the 'frequency' of a particle is an abstract indefinite concept in quantum mechanics.

4. Cordus also provides a novel explanation for the standard optical effects of reflection and refraction. The cordus conjecture as a whole is primarily conceptual, being a thought-experiment, but this is one area where it goes further: it provides a quantitative derivation of critical angle, Snell's law, and Brewster's angle. This is novel in that the derivations are from a cordus particuloid perspective, which has a very different set of starting assumptions to wave theory or quantum mechanics.

Wave-particle duality

Thus the proposed cordus structure resolves wave-particle duality, at least at a conceptual level.

The Cordus conjecture does away with the current weirdness of wave-particle duality: there is no need for virtual particles, superposition, observer dilemmas, pilot waves, intelligent photons, or parallel universes. A simple deterministic, unintelligent photon with dual modes of existence is all that is required.

From this cordus perspective, wave and particle behaviours are simply the different output behaviours that the internal system of the photon shows depending on how it is measured. The duality and the apparent incongruity of quantum mechanics and wave theory are artefacts of the limited formulations of those theories - the conflict does not exist at the deeper level of mechanics.

Some may argue from a phenomenological position that no solution of hidden internal variables, such as cordus proposes, is permissible, as per Bell's Theorem. However cordus refutes that theorem and shows it to be an artefact created by circular reasoning based on the flawed premise that particles *must* be 1D point particles [8]. Thus Bell's Theorem is irrelevant and is not an impediment to hidden-variable solutions.

Implications

This paper explains only some of the features of the cordus conjecture. While it has not solved all the integration issues raised in the introduction, the wider work progresses this further. The concept has also been applied conceptually to matter more generally, thus explaining: entanglement, locality, electron spin & orbitals, Pauli exclusion principle, Zeno effect, Heisenberg uncertainty principle, Aharonov-Bohm effect, Atomic bonding, Entropy, Superfluidity including quantum vortices and heat conduction, Superconductivity including Meissner effect, Josephson effect, Coherence, Casimir effect, Electrostatic field and granulation [quantisation] thereof, Magnetism, Gravitation and mass, Spacetime, Lorentz, Relativistic nature of the vacuum, Finite speed of light in vacuum, Colour and Charge of quarks, Mass excess/deficit.

Thus one simple cordus idea provides a unified conceptual framework that gives a logically consistent interpretation across the many physical phenomena. In almost every case listed above the cordus explanations are substantially different to those of the conventional theories of quantum mechanics, wave theory, and general relativity.

Comparison with electromagnetic wave theory

The biggest difference between wave theory and the cordus explanation is their interpretation of the mechanism for fringes. Wave theory explains fringes as 'interference': two separate waves of light differing by full [or half] fractions of wavelengths and thus constructively [or destructively] interfering. From the cordus perspective photons do not actually physically interfere or add together, and 'interference' is only a convenient mathematical analogy, not a real physical phenomenon for light. Nonetheless, the quantitative mathematics of Wave theory is useful as a computational representation. The Cordus explanation is that fringes are caused instead by interaction of the hyff with opaque planes.

How do quantum mechanics and wave theory fit in?

From the cordus perspective both conventional theories, quantum mechanics and wave theory, are mathematical simplifications of a deeper mechanics. Those theories represent the average and en-masse [respectively] *output behaviour* of the particuloid, not the behaviour of the inner system. The weirdness of conventional wave-particle duality is not because the photon is fundamentally weird, but because the existing conceptual frameworks of quantum mechanics and wave theory are inadequate: their mathematics are sufficient for forward propagation of effect [prediction], but give unreliable results when used for backward inference of causality [explanation].

Epistemological implications

Cordus is a thought-experiment. The treatment is primarily conceptual and descriptive, and the cordus mechanics only lightly sketched out. It is a conceptual model, not so much a full theory with all the details worked out. Thus the validity is uncertain, and the concept requires further critical evaluation. However, if cordus should be correct, then the implications are profound, as it provides a radical and wide-reaching reconceptualisation of fundamental physics.

The cordus conjecture conceptualises a new candidate solution for the problem of wave-particle duality. Through the lens of the cordus conjecture [which we acknowledge may be incomplete or even plain wrong], a whole new deeper level of fundamental physics becomes visible. That deeper level seems to subsume the mathematics of quantum mechanics, wave theory, and general relativity, while simultaneously invalidating the physical interpretation of superposition and the wave-function. So cordus may turn out to be a profound epistemic discontinuity, an earthquake of disruption to the edifices built on conventional theories of physics, and an entry portal to the next deeper level of mechanics.

As the cordus conjecture shows, the double-slit device and the problem of wave-particle duality are cognitive springboards: solve them and many of the other integration problems [see Figure 1] suddenly come within reach, at least in principle. Thus this is exciting work, and even if the cordus idea itself ultimately proves not to be the solution, there would seem to be value in persisting with this design-type of approach, even if it is unorthodox to mainstream physics.

6 Conclusions

The purpose of this paper was to explore new conceptual solutions to wave-particle duality, by applying a cognitive style used in engineering design. The results are radically unorthodox, and surprising. The implications are that the conceptual foundations of our existing theories are fundamentally wrong. Change the conceptual foundations and suddenly the potential exists for solving wave-particle duality, and several other integration problems.

It is proposed that the photon does have internal structure, and the cordus conjecture sets out that proposed structure. Thus the photon, and indeed all so-called matter 'particles', has a two-ended cordus structure. This one idea is conceptually able to explain both particle and wave behaviours. It explains the path dilemmas in the double-slit device, as well as the fringes made by single photons or a beam of light. It also derives the quantitative relationships for several optical reflection and refraction effects. Cordus makes sense of the concept of frequency, which is otherwise a problematic concept in physics.

While the present paper only addresses wave-particle duality, the wider work provides an integrative solution that covers a wide range of enigmatic effects in physics. Cordus suggests there is a deeper mechanics that subsumes both quantum mechanics and wave theory. Perhaps surprisingly, Cordus is also simpler and more coherent across a wider range of phenomena than quantum mechanics or wave theory on their own.

Even more surprising, and unexpectedly contrary to the prevailing probabilistic paradigm of quantum mechanics, cordus suggests that the next deeper level of reality is deterministic.

Acknowledgements

We acknowledge with gratitude the assistance of Dr Mathieu Sellier for translating the abstract.

List of captions

References

1. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J., *Cordus Conjecture: Overview*. (2011).http://vixra.org/abs/1104.0015 6 Apr 2011
2. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J., *Cordus Conjecture: Part 1.1 Quis es tu photon?* . (2011).http://vixra.org/abs/1104.0016 6 Apr 2011
3. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J., *Cordus Conjecture: Part 1.2 Quo vadis, photon?* (2011).http://vixra.org/abs/1104.0017
4. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J., *Cordus Conjecture: Part 1.3 Explanation of fringes*. (2011).http://vixra.org/abs/1104.0018
5. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J., *Cordus optics: Part 2.1 Frequency*. (2011).http://vixra.org/abs/1104.0019
6. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J., *Cordus optics: Part 2.2 Reflection*. (2011).http://vixra.org/abs/1104.0020
7. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J., *Cordus optics: Part 2.3 Refraction*. (2011).http://vixra.org/abs/1104.0021
8. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J., *Cordus matter: Part 3.1 Wider Locality*. (2011).http://vixra.org/abs/1104.0022