Cordus Conjecture: Part 1.2 Quo vadis, photon?

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Abstract
Photon path dilemmas are a difficult area for conventional physics. Typical situations are the double-slit device and interferometers. The problem manifests as an apparent ability of the photon to simultaneously take all paths through the device, but eventually only appear at one. It is shown that a cordus structure is conceptually able to resolve the path dilemmas in wave-particle duality. Explanations are given for the double-slit device and interferometers. The Cordus conjecture implies there is a deeper, simpler, deterministic, and more elegant reality beneath quantum mechanics and wave theory.

Keywords: wave-particle duality; double slit; interferometer

Revision 1

1 Introduction: Photon Path dilemmas

There are various path problems and paradoxes in wave-particle duality, and are a difficult area for conventional physics. Typical situations are the double-slit device and interferometers. The problem manifests as an apparent ability of the photon to simultaneously take all paths through the device, but eventually only appear at one. Existing theories of physics only partially explain the phenomena. This paper applies the cordus concept to conceptually resolve path dilemmas.

2 Existing approaches

Wave theory (WT) apparently adequately explains the situation as interference. However, that only applies to beams of light, whereas the behaviour also exists for individual photons. Quantum mechanics (QM) offers a solution for the particle case, using the concepts of superposition and wavefunction. However the explanations are strange and inconsistent with experience in the everyday world. The ideas of 'wavefunction' and probabilistic 'superpositon' are intrinsically mathematical, and attempts to translate these into physical mechanisms have not fared well. For example, the explanation that relies on virtual (or ghost) particles only adds more problems, because of the supposed undetectability of these particles.

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There are two easy-to-understand explanations for the path dilemma in wave-particle duality, intelligent photons and parallel universes, but both have difficulties. The first is to assume some intelligence in the photon: that photons know when a path is blocked, without even going down it (e.g. Mach-Zehnder interferometer), and adapt their behaviour in response to the presence of an Observer (e.g. Schrodinger's Cat, Zeno effect). This also raises philosophical problems with choice and the power of the Observer to affect the physical world and its future merely by looking at it. Thus the action of observation supposedly affects the locus taken by a photon, and thus the outcome. This concept is sometimes generalised to the universe as a whole. The second, and related solution is the metaphysical idea of parallel universes or many worlds, i.e. that each statistical outcome that does not occur in this universe does in another. This is currently a popular explanation. However it is fundamentally problematic in that these other universes are beyond contact and therefore the theory cannot be verified. Nor is it clear who/what keeps track of the information content of the vast number of universes that such a system would generate. There is no empirical evidence for the Parallel universes solution, so it requires faith to trust that as the solution. Both these explanations are cognitively convenient ways of comprehending the practicalities of wave-particle duality, but they sidestep the real issues.

The cordus concept provides an elegant solution for the path conundrum. In particular, an explanation is given here for the quantum particle behaviour of the photon in the double-slit experiment. Cordus provides a simple physical explanation for the particle-choice problem. Internal variables of the photon are inferred, and a physical interpretation is given of frequency. The concept of hyff is introduced. The path dilemmas in the Mach-Zehnder interferometer are explained, and in doing so a novel explanation arises for what a beam-splitter really does.

This paper is part 2 in a bracket of three. The first part describes the fundamental cordus concepts. i.e. the proposed internal structure of the photon. The present part solves the apparent path-dilemmas in the double-slit device, and also interferometers. The third develops a novel mechanism for the formation of fringes.

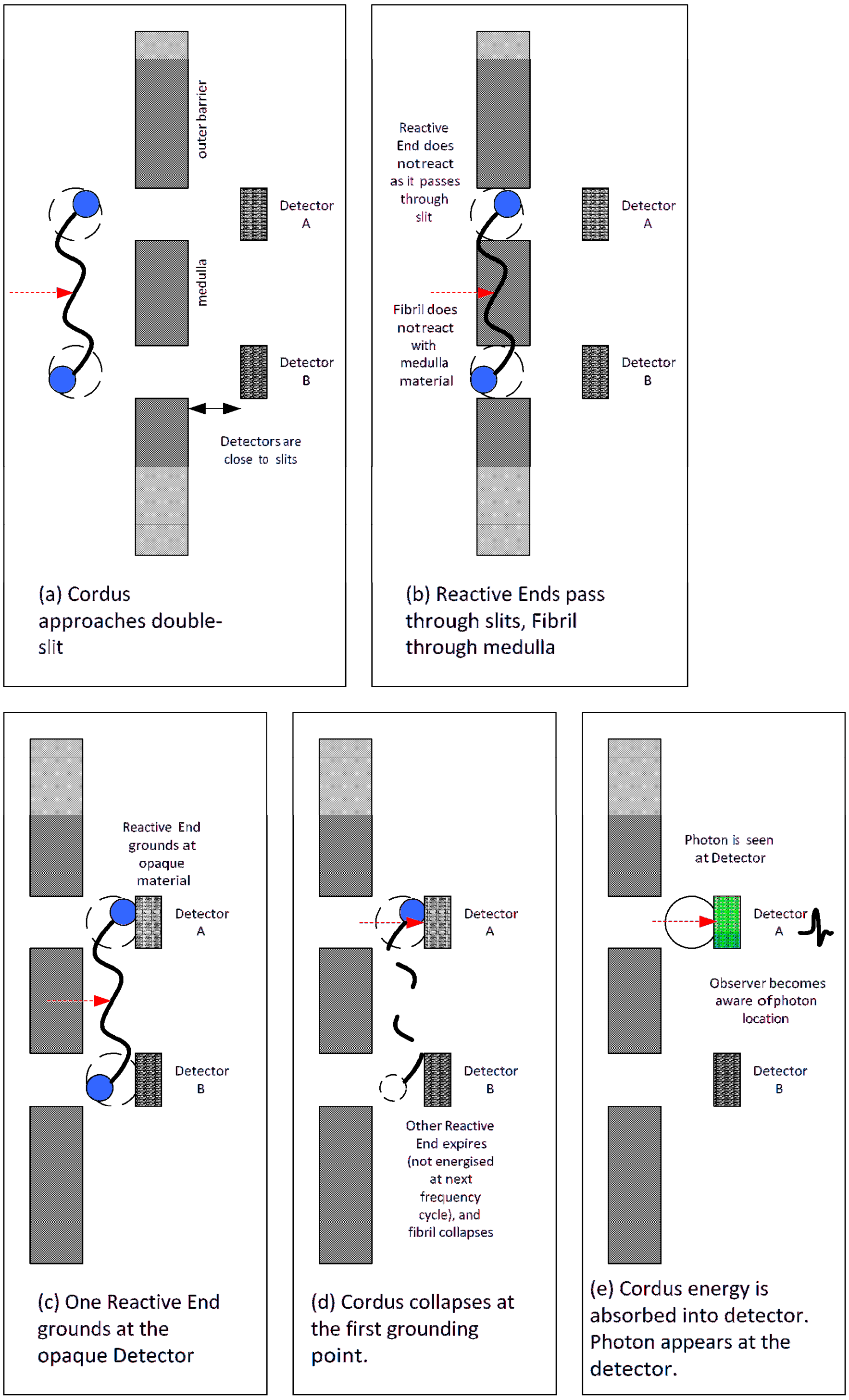
3 Particle behaviour in the Double-slit experiment

The Cordus concept offers an explanation of the quantum behaviour of the double-slit experiment: The photon is a cordus, and one reactive end passes cleanly through each slit. The fibril passes through the material between the two slits, but does not interact with it. The cordus explanation is that the photon *does* pass through both slots, not as 'real' and 'ghost' particles, but instead as a twin-ended particuloid. The variable nature of the cordus span (Lemma 5) permits the photon to go through gaps of different width, providing the gaps are small and arranged symmetrically along the path.

Default behaviour in double-slit

If a detector is placed *proximal* behind each slit, then whichever reactive end first hits the plate will be grounded (L.2.1) and the cordus will collapse to a single energy impulse at that detector, see Figure 1.

One of the detectors will thus register a photon arrival. However there is random variability in the position of the reactive ends so the next photon may ground on the other detector. Over time the two absorbent detectors will each obtain their share of impacts, providing that they are equally spaced from the slit.



(a) Cordus approaches double-slit

(b) Reactive Ends pass through slits, Fibril through medulla

(c) One Reactive End grounds at the opaque Detector

(d) Cordus collapses at the first grounding point.

(e) Cordus energy is absorbed into detector. Photon appears at the detector.

Photon behaviour in the double-slit experiment with two close detectors

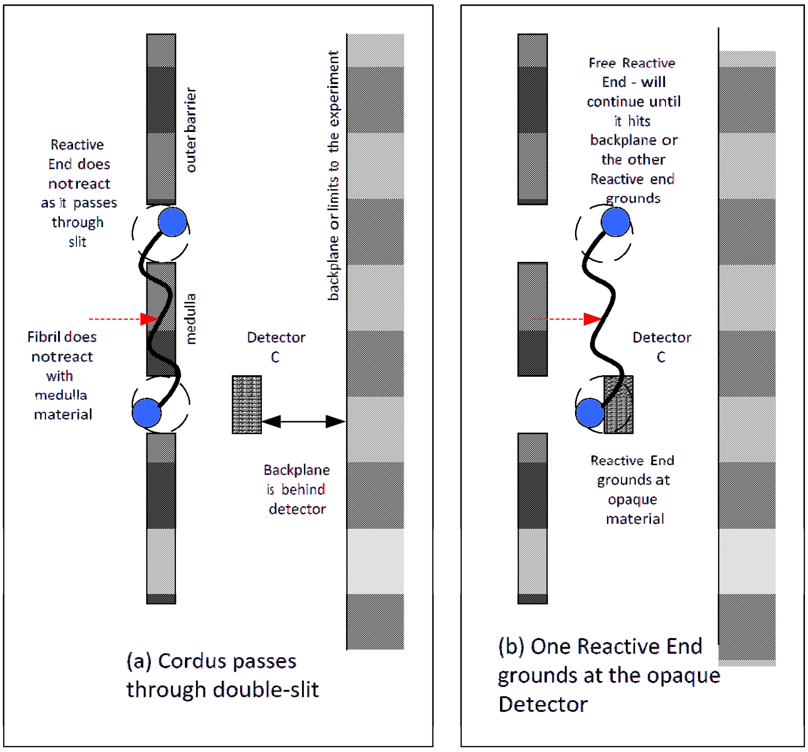
Figure 1: Photon behaviour in the double-slit experiment

Quantum behaviour in the blocked double-slit

If one of the slits is blocked by a detector, and the other is open, then the observed reality is that the photon always appears at the watched slit and never appears on the backplane.

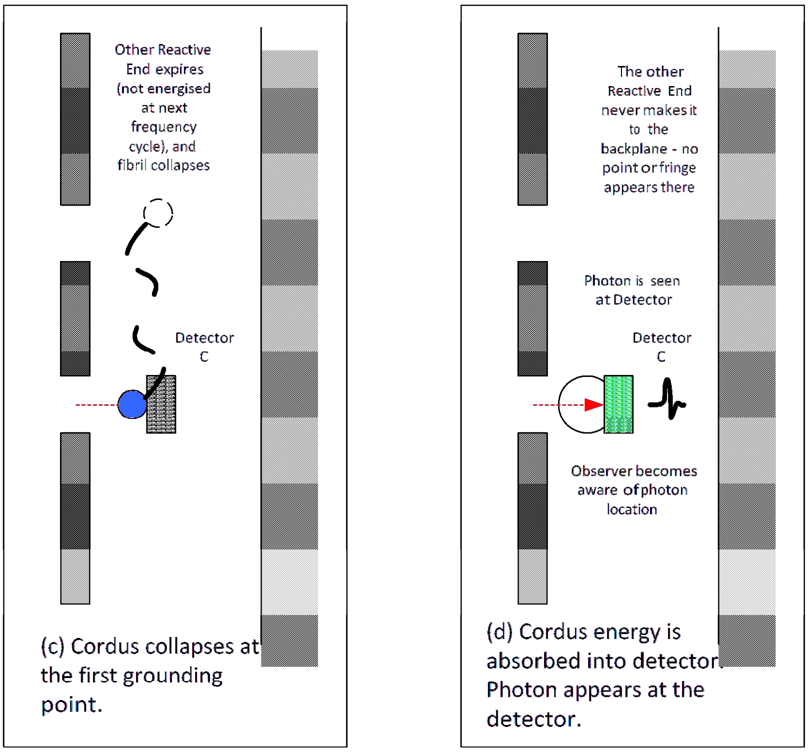
The Cordus Conjecture explains this quantum behaviour as follows, see Figure 2. Reactive ends pass through both slots as usual. Whereas the RE at the open slot is free to continue, that at the blocked slot is obstructed by the detector. This causes the cordus to be always grounded at the detector (as per L.2.4). The whole photon collapses at the detector, every time, even though the cordus did pass through both slots. Since the whole photon is grounded at the detector, there is no photon left to continue further, so no fringes appear even if a screen is placed behind the detector.

The Cordus Conjecture thus explains the observed behaviour. There is no choice in the photon, no free-will. However, there is still the matter of how if at all the Observer's watching of the quantum experiment predestines the outcome.



(a) Cordus passes through double-slit

(b) One Reactive End grounds at the opaque Detector



(c) Cordus collapses at the first grounding point.

(d) Cordus energy is absorbed into detector. Photon appears at the detector.

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

Figure 2: Photon behaviour in the double-slit experiment with only one detector.

Observer's powers

Whether or not an Observer is looking at the double-slit experiment is irrelevant: it is whether the observation is *passive* or *intrusive* that is important (Lemma 3). Simply passively watching from outside the lines of action (optical paths) does not influence the outcome, according to the present concept. The only thing that is really important is intrusive observation: when the Observer's eye (or her proxies in the form of photon detectors or screens) are in such a position as to intercept the photon and suitably constructed (opaque) to arrest it.

If the observer uses passing observation at one slot, then it slows that reactive end and thereby affects fringe patterns, but more of that later. The Lemmas 1-3 are sufficient to explain path effects, but not fringes, so the further explanation of the double-slit is delayed until additional lemmas are constructed.

4 Mach–Zehnder interferometer

Quantum dilemmas also arise in the Mach–Zehnder interferometer. This device has two output paths, hence two detectors, see Figure 3. The light source strikes partial mirror PM1, where the beam is 'split' into path 7 and L, the two beams 'recombine' at partial mirror PM2, and then proceed to detectors DA and DB. However there are some anomalous results, especially for single photons.

MZ Default mode

In the default mode the photon, and indeed the whole beam, will selectively appear at one of the detectors. This can easily be explained using conventional optical wave theory. The paths are not identical regarding the reflection and refraction encountered, and the usual explanation is based on the delays, i.e. phase shift in wavelength, for the different reflection and refraction on the two paths.

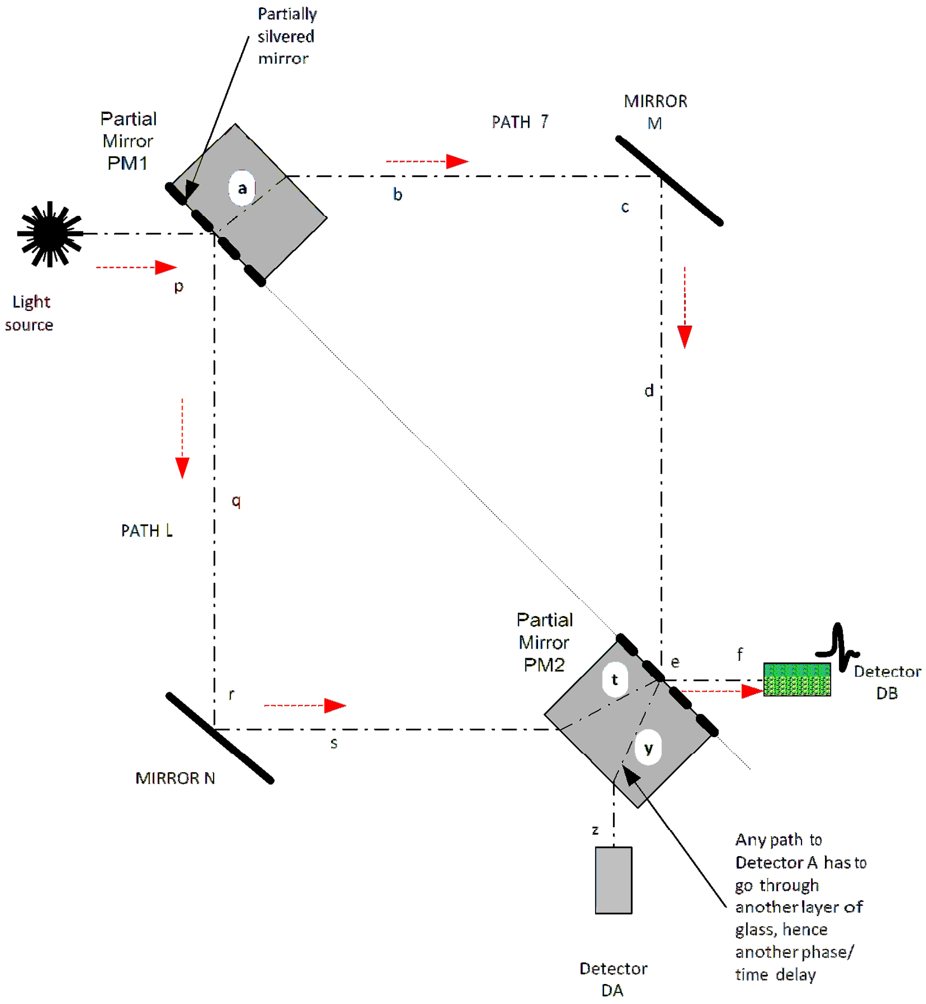


Figure 3: Mach–Zehnder interferometer in default mode. The photon appears at DB.

From the wave theory perspective the explanation is that the light beam experiences a phase shift of half a wavelength where it reflects off a medium with higher refractive index (otherwise none), and a constant phase shift k where it refracts through a denser medium.

The beam on path 7 to Detector DB experiences k + ½ + ½ phase-shift (at a, c, and e), see Figure 3, whereas to reach Detector DA requires an additional k (at y). Similarly, the beam on path L to Detector DB experiences ½ + ½ + k (at p, r, and t). As these are the same, the classical model concludes that the two beams on 7 and L result in constructive interference at DB, so the whole output appears there, providing that the optical path lengths around both sides of the interferometer are equal.

The L beam into Detector DA experiences ½ + ½ + k + k phase-shift (at p, r, t, and v) whereas the 7 beam into DA experiences k + ½ + k phase-shift (at a, c, v). As these differ by half a wavelength, the usual explanation is that the two beams interfere destructively and no light is detected at DA. This is a satisfactory explanation for light beams.

Quantum problems

The quantum weirdness arises because this behaviour still occurs for a single photon, which is supposed to go down only one path. Thus self-interference seems to be required, or virtual particles.

Worse, if one of the paths is blocked by a mirror that deflects the beam away, then the beam still appears at DB, regardless of which path was blocked. The photon seems to 'know' which path was blocked, without actually taking it, and then take the other. Various explanations have been put forward for how this might happen, but they tend to be weird rather than physical.

The obvious Cordus explanation is that each reactive end takes a different path, and the phase difference (which is accepted by the Cordus Conjecture) through the glass at y means that the reactive end is delayed at Detector DA, so does not appear there. The existing Cordus lemmas could be applied, assuming that each reactive end has a 50% chance of being reflected at a partial mirror, and the phase delay through the glass at y means that the reactive end gets to detector DB before DA. However this is unsatisfactory because a decision tree of the Cordus path options suggests that ¼ of photons should still appear at DA even if DA is precisely located relative to DB. Something is missing from the Cordus explanation, and the solution was to add assumptions about the reflection process, which are shown in Lemma 7. (For precursor lemmas 4-6 see part 1.3).

Lemma L.7 Beam-splitter

This lemma describes a set of assumptions for how a beam-splitter operates. It identifies the variables that determine which path the exit light takes.

L.7.1 In a usual full-reflection, i.e. off a mirror, both reactive ends of the cordus, which are separated by the span, separately reflect off the mirror.

L.7.2 Reflection does not collapse the cordus: it is of the passing rather than intrusive type.

L.7.3 When encountering a partially reflective surface, e.g. a beam-splitter or partially silvered mirror, the outcome depends on the state (energised vs. dormant) of the reactive end at the time of contact.

L.7.3.1 A RE will reflect off a mirror only if it is in one state, here assumed to be the energised state, when it encounters the reflective layer.

L.7.3.2 A dormant RE passes some way into a reflective layer without reacting. Only if it reacts *within the layer* will it be reflected.

L.7.3.3 If the reflective layer is thin enough, a dormant RE might only re-energise once it is *through the layer*, in which case it is not reflected. Hence tunnelling.

L.7.3.4 The thickness of the layer is therefore important, as is the frequency.

L.7.4 The orientation of the cordus (polarisation) as it strikes the beam-splitter is important in the outcome.

L.7.4.1 If the reactive ends strike at suitable timing such that each in turn is energised (dormant) as they engage with surface, then the whole cordus may be reflected (transmitted).

L.7.4.2 It is possible that only one RE is reflected and the other transmitted straight through, see Figure 4.

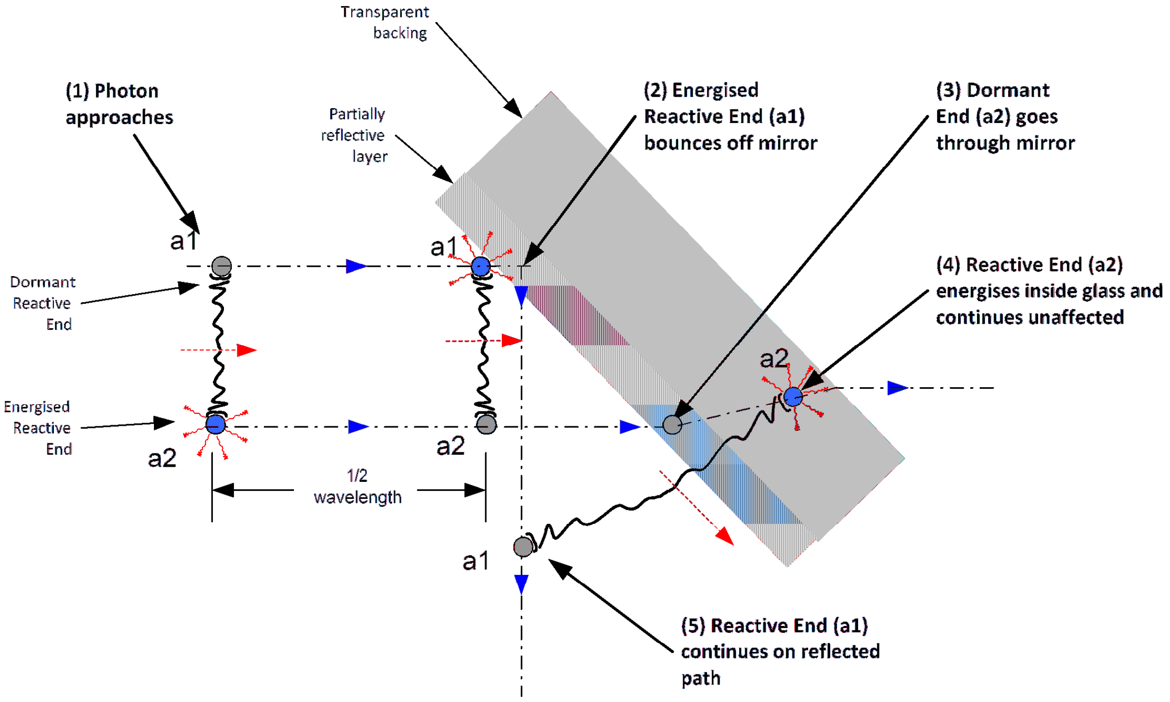


Figure 4: A beam-splitter reflects only the energised reactive end. The dormant RE passes through. The diagram shows a p-polarised cordus, but the principles generalise to other forms of polarisation. The key determinant of path is the state (energised/dormant) of the pair of reactive ends at contact with the mirror.

The relevant points from that lemma are that a reactive end will only reflect if it is a suitably energised state at the point of contact. Otherwise it goes deeper into the material. If by going deeper it passes through the reflective layer of the beam-splitter, then it continues without being reflected, see Figure 4. Thus cordus-photons striking the beam splitter will have two obvious outcomes: both ends reflect, or neither reflect (both transmit through). These outcomes depend on the orientation (polarisation) of the cordus, the precise phase location of the energised reactive end when it makes contact, and the frequency relative to the thickness of the mirror. The lemmas also admit the possibility that the beam-splitter may send one reactive end each way, if the two reactive ends differ in their state when they impact. If this is the case then it raises the possibility that the 'beam-splitter' is sometimes a 'photon-splitter', i.e. changes the span.

This lemma also explains the variable output of the beam-splitter: with one input beam, generally two beams will be observed emerging from a beam-splitter, because of the variable orientations of the input photons ensure that a mixture of whole and split cordi will go down each path. However if the polarisation of the input beam is changed then the beam splitter will favour one output.

Cordus explanation: default MZ mode

With Lemma 7 the Cordus explanation of the MZ device may now be continued. We consider a single photon, but the principles generalise to a beam of many. The photon reaches Partial Mirror PM1, see Figure 5; the energised reactive ends reflect off the mirror, the dormant ends go through. Depending on the orientation of the cordi, some whole cordi go down path 7, some down L, and some may be split to go down both. The polarisation of the photon is therefore important in the outcome.

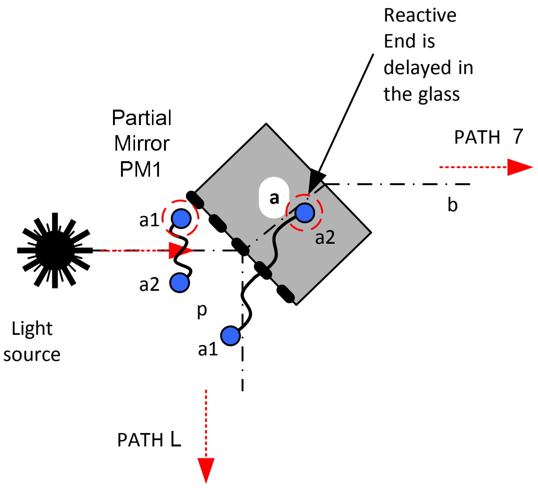


Figure 5: First partial mirror of the Mach-Zehnder interferometer.

The whole photons pose no particular problem, but a split cordus needs explanation: a1 reflects off the surface and continues on path L (pqrst). The dormant a2 reactive end passes through the mirror surface, reenergises too late within the transparent backing, does not reflect, and continues on path 7 (abcd). Note that the order is unimportant: it is not necessary that the energised RE reaches the surface before the dormant RE. Nonetheless, regardless of the order, the RE that was energised at the mirror (a1 in this case), is always reflected (takes path L). This is important in the following explanation. Assuming equal optical path length along 7 and L, which is the case, then both reactive ends come together again at Partial Mirror PM2, having undergone several frequency reversals.

The explanation assumes that the path length is such that the reactive ends are all in the opposite state to PM1, i.e. the path lengths are not only equal, but a whole even multiple of half-wavelengths. The cordi that have travelled whole down path 7 or L now divert to Detector DB. For the split cordi the explanation follows: when reactive end a1 reaches the mirror surface of PM2 it is now in the dormant state, and therefore passes through to Detector DB. By contrast reactive end a2, which was dormant at PM1 is now energised at PM2, and reflects, taking it also to Detector DB. See Figure 6.

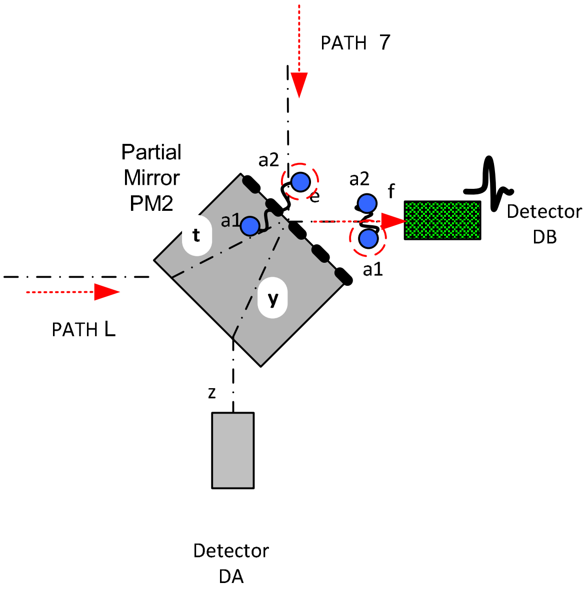


Figure 6: Second partial mirror of the Mach-Zehnder interferometer.

Therefore the photon always appears at Detector DB, regardless of which path it took. The partial mirrors achieve this by sorting and if necessary splitting the photons, and the arrangement between the mirrors ensures that the second mirror reverses the operation of the first. The effect holds for single photons as well as beams thereof. From this perspective the MZ interferometer is an unexpectedly finely-tuned photon-sorting device that auto-corrects for randomness in the frequency phase.

Cordus explanation: open-path MZ mode

Conventionally the wave-particle dilemma occurs when one of the paths is blocked, since it suggests the weird solution that photon ‘knew’ which path was blocked without actually taking it. For example a mirror is inserted at S, but the photon still appears at Detector DB. Likewise a mirror at D still causes the photon to appear at Detector DB, see Figure 7, despite the apparent mutual exclusivity of these two experiments.

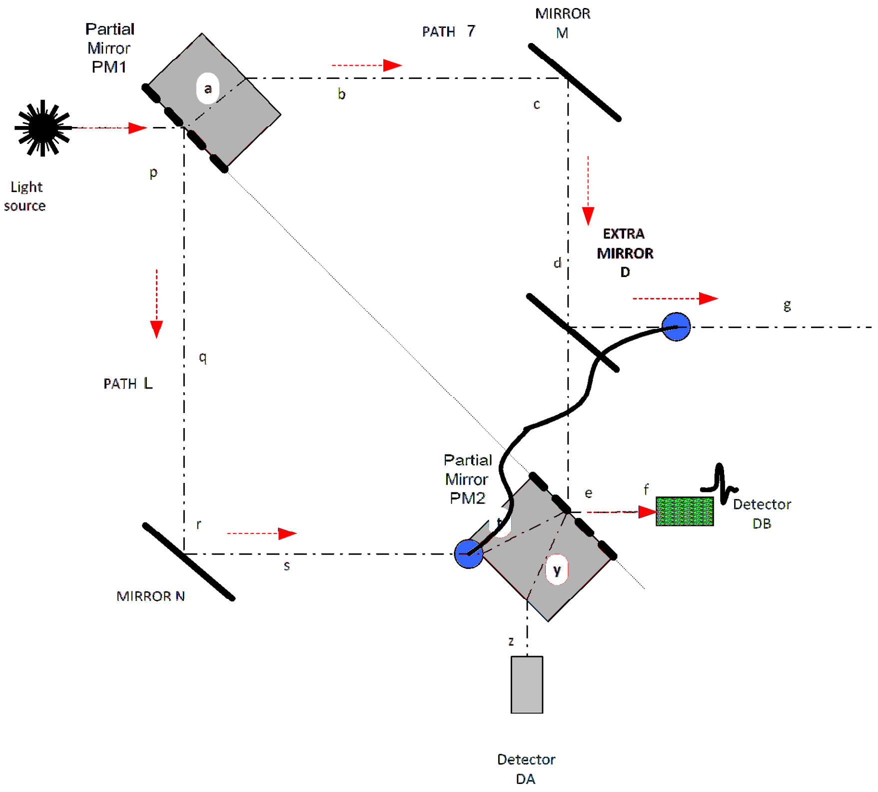


Figure 7: Inclusion of an extra mirror at D still results in photons arriving at Detector DB.

The Cordus explanation is that the reactive ends are constrained by the partial mirrors to converge at DB. Regardless of which path, 7 or L, is open-circuited, the remaining whole cordi and the split cordi (providing they are not grounded first at g) will always appear at DB.

Cordus explanation: sample mode

The MZ device is used to measure the refractivity ks of a transparent sample placed in one of the legs, say S. The observed reality when using a beam of photons is that a proportion of the beam now appears at detector DA. The wave theory adequately explains this based on phase shift and constructive (destructive) interference. By comparison the Cordus explanation is that the sample introduces a small time delay to the (say) a1 reactive end of the split cordus, which means that it arrives slightly late at partial mirror PM2. If sufficiently late then a2 reaches the mirror in an energised state (it usually would be dormant at this point), and therefore reflects and passes to detector DA. If a2 is only partially energised when it reaches the mirror, then its destination is less certain: a single photon will go to one or the other detector depending on its precise state at the time. The proportioning occurs when a beam of photons is involved, as the random variabilities will place them each in slightly different states, and hence increase the probability of heading to one particular detector.

If the 7 or L path in the MZ device is totally blocked by an opaque barrier (unlike the mirror mode), then the whole cordi in that leg ground there, as do the split cordi. However the whole cordi in the remaining leg continue to DB as before.

5 Conclusions

Quo vadis, photon? Where is the photon going?

One of the central quantum dilemmas of the double-slit device is the ambiguity of where the photon is going, and which path it will take. Existing approaches either reconfigure the photon as a wave, or treat the problem as simply probabilistic. The solution proposed here is simply that where the photon appears will depend on which of its two reactive ends are first obstructed. In turn that depends on how the obstruction is made, and at which instant the Observer does it.

God does not play dice - the Observer does, by selecting the method of how intrusively or passively to make the observation, and the timing of when in the cordus frequency cycle to make the intervention. However the Observer may have little control over the latter, hence the observed probabilities of QM emerge as a measuring artefact.

Thus Cordus offers a way to reconceptualise the photon and resolve path dilemmas in a natural way that does not require invisible particles, parallel worlds, pilot waves, intelligent photons, or the mere presence of an Observer. We no longer need the weirdness of conventional explanations. A companion paper (ref. 'Cordus matter') shows why Bell's Theorem is not a constraint against hidden-variable solutions.

Cordus also implies that the existing paradigm of quantum mechanics is not the reality, only a mathematical approximation. In particular, Cordus suggests that superposition, the ability of a particle to be in two places at once, is only a high-level simplification of the underlying behaviour of internal variables. While superposition is a useful rough statistical concept for average particles, it is unreliable as a physical explanation for individual cases. The implications of the Cordus conjecture are that there is a deeper, simpler, deterministic, and more elegant reality beneath quantum mechanics and wave theory.