Cordus optics: Part 2.1 Frequency

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Abstract
Conventional particle and wave theories struggle to explain the frequency of photons and matter in a coherent manner using natural physics. This paper applies the cordus conjecture to develop a model for frequency of the photon. The interpretation is that there really is a part of the photon cordus that moves with a frequency. The 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. This cordus model for frequency readily explains polarisation and tunnelling, and the concept is fundamental to other developments of the cordus mechanics including the reflection and refraction of particuloids. The implications are that frequency is not just an intrinsic variable, but a physical effect within the photon. The cordus frequency is a fundamental conceptual building-block in creating an integrated solution that unifies wave and particle behaviour. It is a powerful concept that is coherent across many other phenomena too, including matter particuloids and it contributes subsequently to the cordus model for granular fields.

Keywords: particle; wave; frequency; internal variable; electric field; tunnel; hyff; transmissivity; opacity; electron
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1 Introduction

Frequency is an important concept in wave theory, optics, and quantum mechanics. However those theories struggle to explain frequency in physical terms.

From the wave theory (WT) perspective, the frequency of light is the oscillation of the electric and magnetic fields. However this is not entirely satisfactory as it still does not explain the origins of those fields, nor explain why the fields reverse polarity. The conventional answer is that light is nothing more than a self-propagating field disturbance, but that is arguably only a trite answer. There is a circular reasoning at work that suppresses the question of 'what really is frequency?'

Quantum mechanics (QM) does not help either. It perceives the world ambivalently, either as point particles or spread out in a probabilistic wave-functions. Properties like frequency, spin, and momentum are all

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acknowledged, but are simply demoted to being intrinsic variables, i.e. assumed *not* to correspond to any real geometry or internal functionality. Usually Bell's Theorem is interpreted as meaning there *cannot be* any internal variables anyway. So QM does not get us any closer in understanding what frequency might be, because it uses a denial reasoning of its own to simply avoid the question.

Nonetheless it is an important question to answer, and as this paper shows, the answering of it leads to the resolution of wave-particle duality and to a deeper mechanics that underlies both Wave theory and Quantum mechanics.

This bracket of papers shows how the Cordus concept (ref. 'Cordus Conjecture') can also be applied to conventional optical effects. This is worth doing since particle solutions have otherwise fared poorly at explaining wave behaviour in a coherent manner using natural physics. This bracket is in two parts. The first, which is this paper, develops a novel model of the underlying mechanism for frequency of the photon. Frequency is conjectured to be linked to the dynamic internal states of the photon. Photon tunnelling is explained. The second develops the cordus mechanics for the interaction of light with surfaces: reflection and refraction.

The outcome of this work is a set of basic underlying principles of the proposed cordus mechanics. It is recommended that the 'Cordus Conjecture' bracket of papers be read before this one, as the fundamental concept of a 'cordus' is described there.

Cordus Background

The concept of a cordus is that a photon consists not of a point but of two reactive ends (RE) connected together with a fibril. The Res emit hyff (hyperfine fibrils), which are lines of electrostatic force. The companion paper 'Cordus conjecture', describes the background to this idea, applies it to path dilemmas in the double-slit device and Mach-Zehnder interferometer, and uses it to explain fringes. It is shown that the Cordus conjecture is conceptually able to resolve wave-particle duality.

Method

The approach taken is a continuation of that described in the companion paper 'Cordus conjecture', and not detailed here. Briefly, it involves reverse-engineering the system: it uses logic, conjecture and intuition to build on the existing cordus model, thereby postulating a set of mechanisms that can plausibly explain the known system-behaviour. Specifically, to postulate internal variables for the photon sufficient to explain optic effects. It is like trying to work out the contents of a black box by observing its outputs in different situations, and synthesising a working-model that is sufficient to explain as many of the situations as possible.

Results

This is a design way of thinking, being very different to the conventional mathematical analytic approaches, and the outcome is likewise more qualitative than quantitative. Thus we term the results a *conceptual solution*. Being conceptual means that the broad principles are described, within which a whole class of solutions are possible. Where possible we single out the most promising of these specific solutions and term it the *working model.* Along the way we note the underlying assumptions as a series of *lemmas.* These we do not attempt to prove: they are simply to make the premises explicit so that they can be evaluated later. The lemmas make up the central strand through the three papers.

The results follow, starting with some basic preliminary premises on transparency and opacity, then moving on to develop a model of how frequency arises within the photon, followed by application to the basic optical phenomena of reflection and refraction.

2 Cordus Transparency and Opacity

In our daily experience we take for granted that light goes through some matter, but not others. Why is glass transparent while metals are not? More importantly, why is diamond transparent while graphite is not? As the latter question shows, even materials with the same chemical composition can have different optical properties. Why should light even be able to pass through solid matter at all?

The explanation up to here is that the photon-cordus is energised at a frequency (ref. 'Cordus conjecture'), and only interacts with material when energised. Those concepts are now further developed and extended to provide an explanation for transmissivity.

Lemma O.1 Electron interaction determines Transparency and Opacity

This lemma puts forward a set of assumptions for how the photon can transmit through matter.

O.1.1 Electron arrangements, including bonds, determine optical properties of a material more than nuclear configuration.

O.1.2 Cordus hyff interact with electrons in the substrate material.

O.1.2.1 The difference between transparency and opacity is whether the interaction is reversible.

O.1.2.2 We differentiate between stiff and compliant electron structures, corresponding to reversible and irreversible behaviour respectively, or elastic and inelastic interactions resp., and ultimately absorbance for the latter.

O.1.3 Stiff and compliant electron structures engage with the hyff force lines.

O.1.3.1 A reversible interaction occurs when the force is elastically recoiled (the energy is returned), and this corresponds to a stiff electron structure. In such cases the electron engages with the hyff energy but returns it, hence Transparency. This corresponds to passing observation: the cordus is not collapsed.

O.1.3.2 If the electrons are able to change energy level or plastically displace (incl. vibration, phonons, and plasmons), then this is a compliant electron structure. Such electrons absorb the energy (absorption is described later) and collapse the cordus, hence an Opaque material. This corresponds to intrusive observation.

O.1.4 In transmission through a transparent material, the reactive ends of the Cordus take time to interact with the material, and this causes a delay in the respective reactive end. Note that the two REs may be in different materials and therefore have different delays. The delay appears as slower speed.

O.1.5 Material variables: Material properties, particularly electron arrangements, determine reactivity of the material to the photon. These electron arrangements have their own natural frequencies and therefore the material properties vary with the frequency of the photon.[2]

Transparency

With Lemma 8, transparency exists when the hyff interaction is elastic. The hyff of the reactive end interact with electrons in the material, but are not absorbed, though they are delayed in the process. Why should such a delay even exist? Why not instant? We suggest it is because of the electron's mass, and any movement of mass requires velocity and acceleration, and hence time. Thus surface plasmons are electrons that move in response to input photons. To put it another way, the change in momentum $p=mv$ of the electron requires a force operating for a period of time.

Cordus also accommodates the frequency dependence: a material may be transparent to photons of one frequency, but opaque at another. The Cordus explanation is that the interaction between cordus and electron requires a degree of compatibility of frequency. High-energy photons cannot easily be absorbed by electrons, and so pass through. Conversely, low-energy photons may be dormant at the time of contact and therefore tunnel through the material (see below).

Thus the Cordus perspective is that atomic structure, particularly and almost exclusively electrons and their bonds, determines opacity and

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[2] Later in the series, (ref. 'Cordus in extremis') a mechanism is given whereby electrons have different frequencies depending on the bonds they are in, see the Cordus Time and the Level-of-Assembly lemmas.

transmissivity. A specific mechanism for absorption is proposed elsewhere (ref. ‘Cordus matter’).

3 Cordus Frequency

The observed external behaviour is that light appears to be a electric field that varies sinusoidally in strength. From the Cordus perspective, the reactive ends (REs) are the proposed internal structure that creates this effect, and at this point we need to create a working-model of how the mechanism might operate. This is necessary in preparation for explaining reflection and refraction phenomena.

Lemma O.2 Cordus Frequency

The reactive ends of the cordus change with the frequency. Up to here we have only defined two states: energised and dormant. With this lemma we set out a set of further assumptions to create a working model about the frequency behaviour of reactive ends. See also Figure 1.

O.2.1 The electric field of light is the external manifestation of the hyff. This implies certain features of the cordus frequency mechanism:

O.2.1.1 The electric field does not represent the state of the photon, nor even the free-body diagram for the reactive-end. Instead it shows the direction and strength of force on a small test-charge placed near the photon’s locus. The electric field therefore indicates how the RE is interacting with charged matter.

O.2.1.2 The direction of the electric field is the same whichever side of the locus the test-charge is placed.

O.2.1.3 In turn this implies that the forces on the two reactive ends, a1 and a2, of the photon must be in a consistent direction: the direction of hyff force must be preserved across the span.

O.2.1.4 In turn this implies that the REs must be in *opposite* frequency states. See also O.2.3.

O.2.2 The hyff are transient, and manifest externally as the electric field.

O.2.2.1 The hyff are dynamic and grow outwards and then retreat, at the frequency of the photon.

O.2.2.2 The outward growth of the hyff correspond to say negative electric field, and retreating to positive field.

O.2.3 We identify four *frequency states* of the hyff for any one reactive end:

C- (outward growth of hyff),
C^ (maximum extent),
C+ (hyff retraction),
Co (dormant).

There is a smooth change between these: they are not discrete states.

O.2.4 The hyff exert forces between the reactive-end and the material in the medium.

O.2.4.1 The strength of the hyff varies between *frequency states.* Whether or not the variation is linear or sinusoidal is not determined here.

O.2.4.2 Hyff forces are strongest at closer range. Thus range and strength of hyff are inversely related.

O.2.5 The behaviour of the reactive end depends on its frequency state at the time it encounters a medium or the surface of a second medium. The current working model follows.

O.2.6 Assume: C- results in the RE being repulsed by the bulk (tends to move medially towards the cordus centre-line in many cases), with the force being determined by the strength (inverse of range) of the C- hyff and material properties (e.g. refractive index).

O.2.7 C+ results in the reactive end being attracted into the bulk (tends to move laterally away from the cordus centre-line in many cases).

O.2.8 The net force on a RE is the cumulative exposure over the preceding period. Thus the behaviour in the other states is influenced by the timing of the C- and C+ states alongside and this introduces an element of variability to the outcome.

O.2.9 A dormant reactive-end tunnels (embeds) into the material, or across the interface, when it is in the Co state.

O.2.9.1 This means that it continues in a straight line, and its future locus is determined by the next frequency state.

O.2.9.2 Tunnelling occurs regardless of the material properties (stiff or compliant) and without the photon reacting to the material.

O.2.9.3 The reactive end can only tunnel through one dermis (defined below). Thereafter it becomes reactive with the next frequency cycle, and its fate is determined by its new frequency state and the material properties.

O.2.9.4 If a 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. The thickness of the layer is therefore important, as is the frequency of the photon (wavelength).

O.2.10 Hyff are entirely in the (rt) plane (current working model), see Figure 1.

O.2.10.1. It does not make sense to have hyff in the axial direction (a), given that both the hyff and the cordus would both be moving at speed c.

O.2.10.2 Whether the hyff are a flat disk or only a single filament is unspecified. The current working-model is illustrated with only a single hyff in the r-plane. This is consistent with the observed polarisation of the electric field.

If desired for ease of understanding, assign approximate physical significance to the *frequency states:* C- is somewhat like an electron, C+ a positron. They are transient electric fields, but not necessarily a full unit charge.[3] Depending on the frequency model, this gives two or four change-overs (strokes) per cycle, see Causa 2. The current working-model is for four strokes.

Causa 2 Working model for frequency

Many variants are possible for how the hyff, electric field, and frequency operate. The main variables are the number of events ('strokes') inside the photon that are ascribed to one frequency cycle, the relative states of the reactive-ends (including whether one or both reactive ends are active at the same time), and the behaviour (including force & extent) of the hyff. Any model of frequency has to fit the observed electric field of the photon. Thus we have reverse-engineered a proposed model for frequency, based on the above lemmas. This *working model* is shown in Figure1.

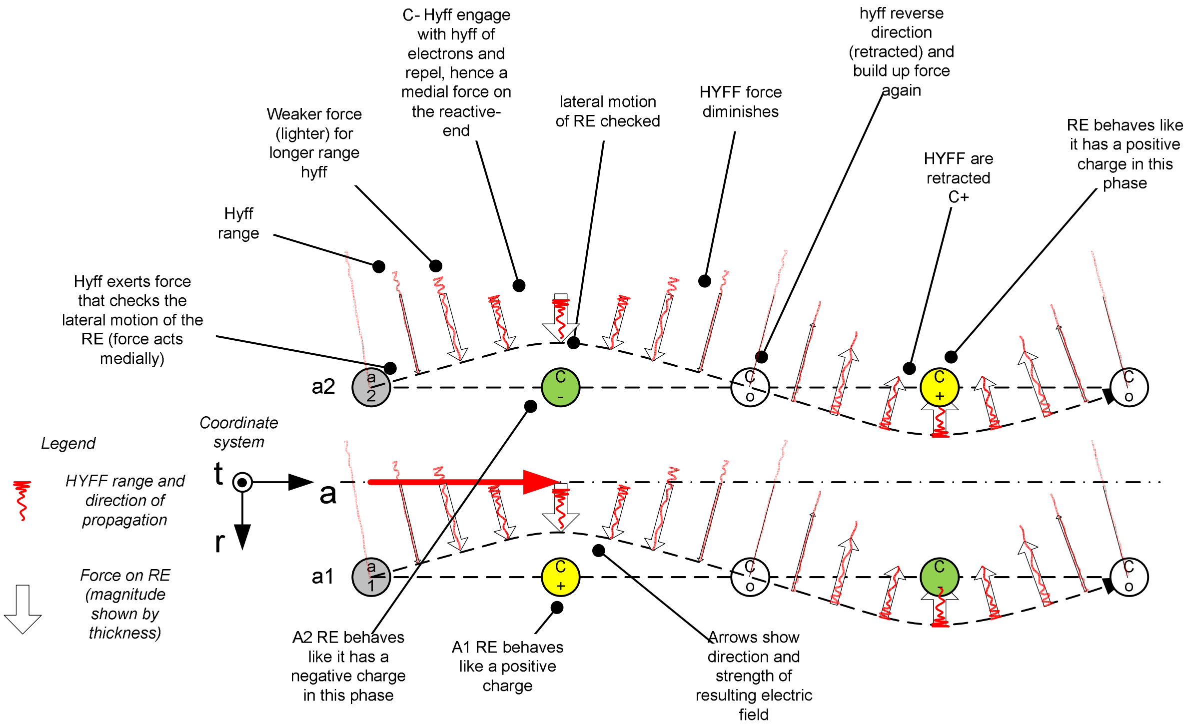

Figure 1: Working model for frequency behaviour of reactive ends.

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[3] Later work on quarks and the internal structure of the proton implies that the photon with its single hyff might have a single +- 1/3 electric charge (ref. 'Cordus in extremis'). However the exact charge is not relevant at this point.

The main features of the model are that the C- hyff are outward-propagating (simply a sign convention), and their interaction with the surrounding medium is one of repulsion (O.2.6). To the extent to which the material is able to offer recoil, i.e. higher refractive index, the C- hyff bends the locus of *that reactive end* away from the material with higher refractive index. The C+ hyff have the opposite effect (O.2.7).

Journey through matter

The two effects constantly counter each other, partially or completely undoing the course-corrections made by the previous state. When the cordus is embedded in a homogeneous material then the reactive ends move in a sinusoidal lateral wriggle, according to this model. The model predicts the hyff forces on the cordus will put the reactive-ends into parallel sinusoidal loci. There is a constant interaction between the momentum of the reactive-end along its current locus, and the hyff forces deflecting it into a new path. Thus the photon does not travel in a straight line but weaves from side to side as it interacts with the medium. Hence the lateral wriggle causes the speed of propagation of light in a material to be slower than in a vacuum. This also explains why greater density of the medium causes slower speed of light.[4]

The locus of the a1 and a2 reactive-ends is shown in Figure 1. The amount of deviation depends on how forcefully the medium interacts with the hyff, i.e. the refractive index. This provides a qualitative explanation for why the speed of light is slower in denser media: it has to travel a longer path.

When the cordus encounters two different materials then the size of the effect depends on location relative to the two media, and this means that the corrective forces do not cancel each other, so consequently the photon takes a bent path. Thus the behaviour of the C- and C+ hyff is important in the explanation of reflection and refraction effects, as shown in part 2.2.

The other main feature of the current working model is that the hyff at the opposite reactive-end act in the same direction, and this makes them the *complementary frequency state*: e.g. when a1 is in C- state, a2 will be C+. Consequently the dormant phase is only momentary, unlike in some of the other C.2 models. This concept is important later in the introduction of a fundamental interaction called *complementary frequency state synchronisation (CoFS),* which in turn is proposed as the explanation of photon entanglement, the Pauli exclusion principle, and strong force, among other effects (ref. ‘Cordus matter’, ‘Cordus in extremis’).

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[4] However this does not explain why the speed of light in a vacuum is finite. That explanation is given by the Fabric-of-the-Universe concept in ‘Cordus in extremis’.

The current working model is for reactive ends that energise in turn at the end of a cordus, i.e. a reciprocating frequency model. At this point it is an open question how the fibril sustains this reciprocation of energy.[5]

4 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. It is usually explained as a probability from the wave-equation, or the particle's evanescent wave leaking through an energy barrier (hence 'evanescent wave coupling').

In the special case where there is a thin later n_2, sandwiched between two other media n_1 and n_3, then it is known that some photons will pass through n_2 apparently without being affected by it. Specifically, some photons are not refracted in n_2 but continue from n_1 to n_3 as if n_2 did not exist. This effect is known as tunnelling, and the term is applied to a variety of situations where a particle appears not to noticing an intervening barrier, e.g. tunnelling electron microscope.

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. Or to put it another way, the RE has a dormant phase during which it does not react to matter but nonetheless moves forward.

The Cordus explanation is that the gap geometry (width and angle), frequency, and polarisation are such that (a) the REs both pass through the reflective layer without reacting (both dormant in turn, from L.7.3.2), and (b) there is no imbalance in the number of frequency cycles encountered by the REs in the media, and therefore no pitching moment and hence no refraction.

High-energy photons, e.g. X-rays, do not reflect easily but tend to pass through material. The Cordus explanation is that their frequency is too high for the electrons to engage with, rather than a tunnelling effect. On the other hand, low energy photons, e.g. radio-waves, can have appreciable dormant periods in which they don't react to the change in medium, so they too can tunnel.

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[5] Spin is more easily conceptualised as roll rotation that indexes the fibril in 180^o increments. If the Cordus conjecture holds up and there arises a need to explore deeper mechanisms in the fibril, then there may be value in remembering that reciprocation is the outward functional behaviour of frequency, not necessarily the internal mechanism.

5 Conclusions

The concept of ‘frequency’ is a core theoretical construct within wave theory, optics, and quantum mechanics. Yet strangely none of these theories are able to explain frequency in physical terms. ‘Frequency’ is only a disembodied intrinsic property of the wave or photon. In contrast Cordus offers a physically coherent interpretation for frequency.

This interpretation is that there really is a part of the photon cordus that moves with a frequency, The working model is for a reciprocal motion: the energy alternates between the reactive ends across the span. In this way it is proposed that the photon has internal variables that create the output that we observe as frequency. This is a type of ‘hidden-variable’ solution, and while the conventional interpretation of QM is that such solutions are expressly prohibited by Bell’s Theorem, that theorem is refuted in a companion paper (ref. ‘Cordus matter’). The implications are that frequency is not just an intrinsic variable, but a physical effect within the photon.

This cordus model readily explains several other optical variables: polarisation is alignment of the cordus; and tunnelling is travelling through material when unenergised. The cordus frequency is important in subsequent explanations of reflection and refraction (part 2.2). As such, it is a fundamental concept in creating the integrated solution that unifies wave and particle behaviour.

It is a powerful concept as it is coherent across many other phenomena too. For example the cordus frequency model developed here in an optical context is also applicable to frequency in the context of particuloids of matter (ref. ‘Cordus matter’) and permits a re-conceptualisation of de Broglie frequency, electron orbitals, atomic structure, proton structure, and fields.