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Resolution of the wave-particle paradox of light using a new approach

Part I: Theoretical considerations

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The men...



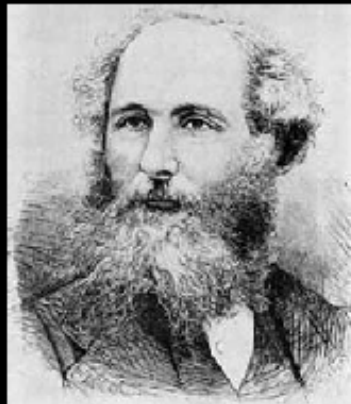
Huygens
1629 - 1695



Young
1773 - 1829



Fresnel
1788 - 1827



Maxwell
1831 - 1879



Sommerfeld
1868 - 1951

Outline

- What is wave-particle duality?
 - Scope: Photons
- The Three Huygens Processes
 - Classical Continuum
 - Random Yet Continuum
 - Finitely Sampled Random
- Clarification on randomness, isotropy
- Relationship between the continuum and quantum Views
- The necessity of aether in physical theory

What Is Wave-Particle Duality?

- A paradox thrown up in 20th century physics
 - And, unresolved till date
- Light spreads in space and produces interference pattern
 - Wave!
 - Ray description included (the limiting case of $\lambda \rightarrow 0$)
- Light absorption occurs in events that are discrete in space and time, and results in transfer of momentum, not just energy
 - Particle!
- But that is not enough; matter also shows wave-like character!
 - We address only photons here
 - All ideas here are applicable without modification in the context of electrons also...
 - ...but will take some more theory to explain

Attempts at Resolution

(Sometimes *really* funny ideas!)

■ Copenhagen School—the pervasive influence

■ Heisenberg:

- Formulation in terms of infinite matrices: $pq - qp \neq 0$
- But: Uncertainty as the base of knowledge

■ Bohr:

- Correspondence Principle—a reminder that this is physics, after all!
- But: “welcher weg” (“which way”) as a principle describing reality!

■ Born:

- Probabilistic interpretation of absorption/emission
- But: What about the physical meaning of ψ (i.e. not $|\psi|^2$)?

Some More Attempts...

- Hidden Variables etc.—the “deterministic” theories
 - Variant 1: Pilot wave figures out what lies ahead; particle of light travels accordingly
 - Variant 2: Light travels as a hidden wave, and due to some hidden variables, collapses to a point at absorption
 - Is light a single thing? → Duality not resolved at all!
- Many Worlds!
 - Particle is indivisible, and so cannot split at the two slits.
 - Therefore, the world does!
 - Logical End: *Infinite Worlds*
 - How do they connect to this world?

Status

- QED Model—Copenhagen Interpretation “done right”
 - Light as “probability wave” of quanta
 - “We don’t know what that means” — Feynman
 - We no longer care to see if God does play dice or not
 - But we can “shut up and calculate” — (attributed to) Dirac
- Post-QED View—the de-facto “standard” view as of today
 - Conceptually, still bizarre, but sanest of them all
 - Does not split the world at every instant
 - But lets photons from future to arrive at a point “just in time”
 - Until (?) that instant, lets Schrödinger's Cat stay alive and dead at the same time!
- *Obviously, physicists are exasperated!*
 - Though they can calculate—the mathematics is rigorous
 - But not necessarily clear

Where May We Begin?

- Feynman, the most direct-talking Nobel Laureate, said...
 - “We shall tackle immediately the basic element of the mysterious behavior in its most strange form. We choose to examine a phenomenon which is impossible, absolutely impossible, to explain in any classical way, and which has in it the heart of quantum mechanics.

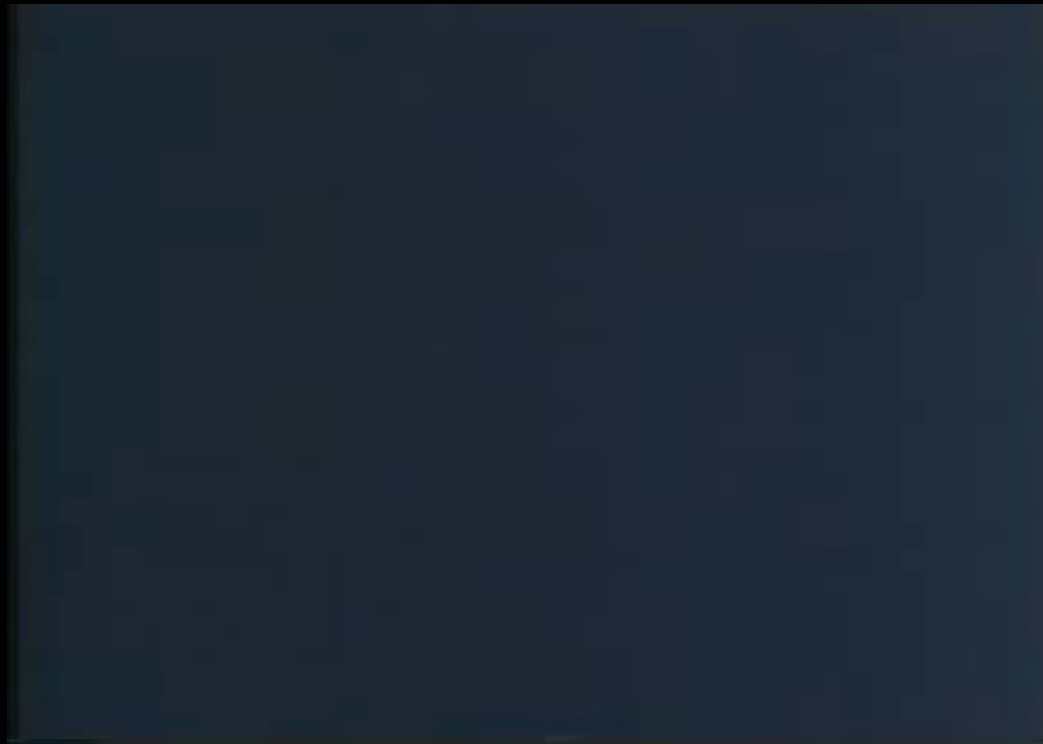
In reality, it contains the only mystery....

...In telling you how it works we will have told you about the basic peculiarities of all quantum mechanics.”

—*The Feynman Lectures on Physics, Vol. III, 1963*

Electron Diffraction Experiment

- Video clip by Tonomura et al (1989)
 - Copyright © Hitachi Ltd., Japan



Announcement

of the resolution of the duality

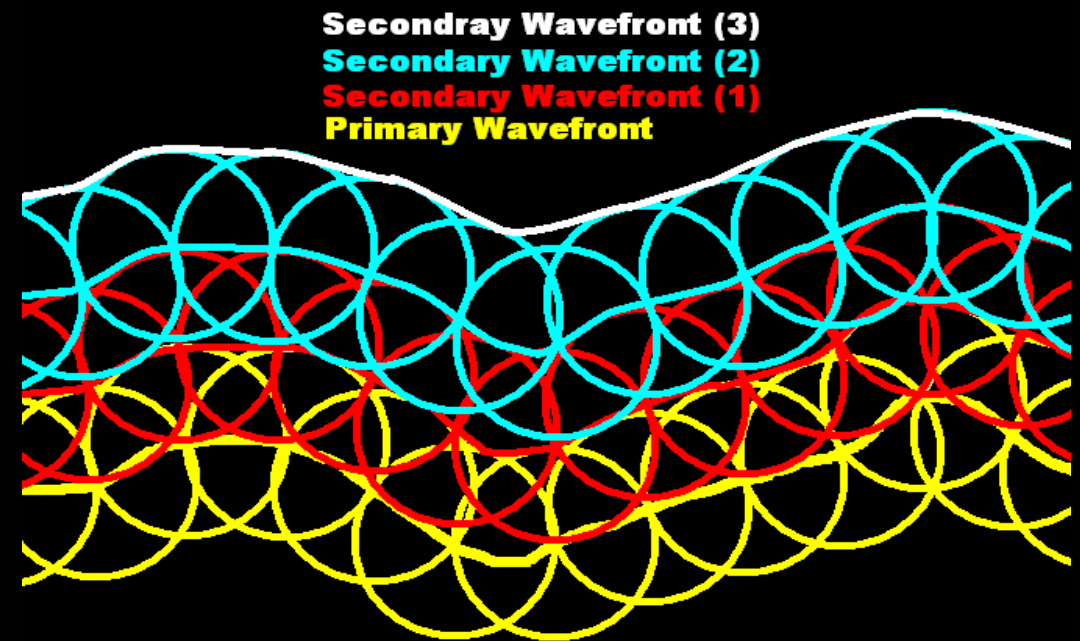
- We believe we can explain all of that...
- ... without repeating a single previously thought of offence to “the common sense” i.e. reason.
- In Part II, we make new predictions, to be verified experimentally.
- Our explanation is based on
 - Huygens' Principle
 - Geometric Probability
 - And, of course, much rethinking!

The Three Huygens Processes

- Huygens “process” is not a part of standard terminology—we introduce the term
- A systematic modification to the process indicated by the original Huygens’ principle:
 - Classical (Continuum)
 - The original process, modified by Fresnel, and re-modified by us
 - Random, Yet Continuum
 - Obvious, but never stated before as such
 - Finitely Sampled
 - Applicable for describing quantum phenomena

The First Huygens' Process Classical (Continuum) - 1

- Finite domain (unlike Fresnel)
- Monochromatic radiation (unlike quantum field theories)
- Wavelets (unlike Fresnel)
- Constant λ (unlike in scattering)
- Wavelets are generated at each point within the region of the primary wavelet (unlike in Huygens)
- Isotropic wavelets—no obliquity (unlike any previous view)



The First Huygens' Process

Classical (Continuum) - 2

- Wavelets do not indefinitely expand—restricted to size λ
 - Wavelets only act locally
 - In our approach, this is the place to begin explain Heisenberg's "uncertainty" principle
- Reflection and refraction follows ordinary laws
- Wavelets are infinite in number even in a finite region
- Wavelets are region-filling
- Spreading and evolution of the global field occurs through
 - Cascades of wavelets in space
 - Feedback-based generation of wavelets in time
- Wave-amplitude is radiant flux density
- Cardinality of the region remains the same
 - Integration at a point is actually surface integration
 - The infinitesimal sphere excludes the point
 - The place for tackling the renormalization infinities, in our approach

The First Huygens' Process

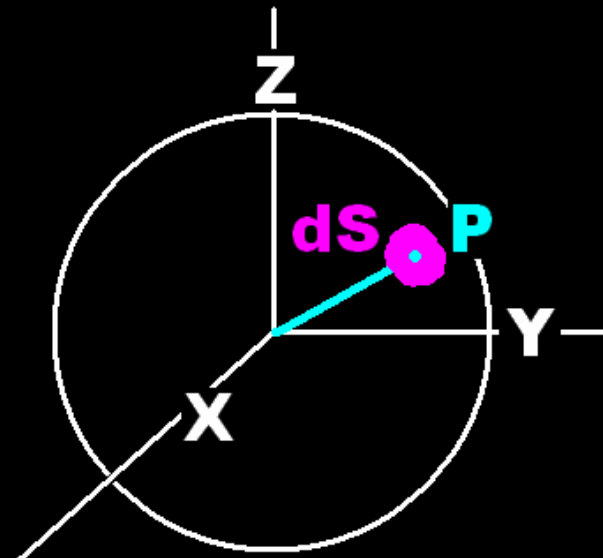
Classical (Continuum) - 3

- Huygens wavelets mutually interfere
- “Terminal Absorption” at region boundaries—a new term for ease of modeling
 - Absorption without re-emission
 - Permanent transmission out of region boundaries
 - Physical implication → Infinite sink
- Wavelet generation is thermodynamically non-dissipative
 - Because light obeys inverse-square law for *intensity*
- Process obeys causality: Primary wavelet causes its secondaries
- Process has temporal order: Primary wavelet are generated before their secondaries
 - Unlike quantum mechanical theories, including Feynman's QED

The Second Huygens Process

Random, Yet, Continuum - 1

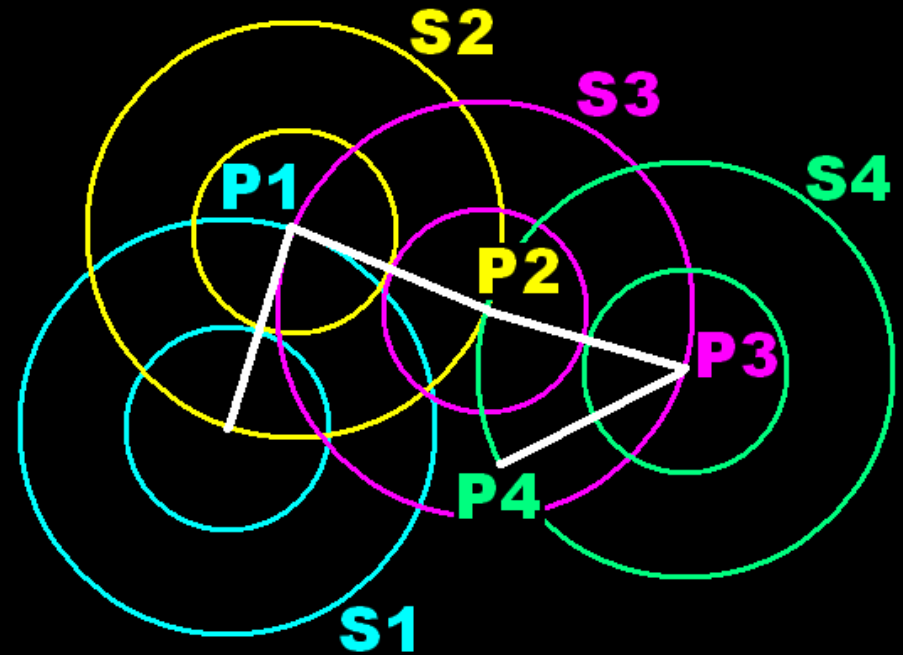
- Apply geometric probability
- The sampling is on the surface—not in the region enclosed by the surface
- An infinite number of spheres of increasing $r \leq \lambda$ exhaust the wavelet region
- Sampling the sphere surface involves infinitesimal surface area and yields a point
- Uniform sampling \rightarrow uniform density of sampled points
- Infinite points needed to exhaust a given surface



The Second Huygens Process

Random, Yet, Continuum - 2

- The algorithm (here considered only for $r = \lambda$)
 - Radiate a wavelet
 - Sample the surface
 - Draw displacement
 - Radiate again
 - So on and so forth...
- To get the continuum description, fully exhaust each wavelet region (i.e. infinite series of concentric surfaces within it)



The Second Huygens Process

Random, Yet, Continuum - 3

- If sampling is random, but fully exhaustive (without repetition), it still means a continuum description!
 - The often missed point!

- Randomness...
 - ...means the absence of a particular form of order in a system
 - ...does not mean absence of orderliness as such
 - The so-absent order may or may not be essential to the system definition. For example:
 - Moire's fringes:
 - Order that is essential to system definition
 - Motion of gas molecules in kinetic theory
 - Molecules follow a kind of order that is not essential to the system definition. Hence, random.

The Third Huygens Process

Finitely Sampled, Random - 1

- Finite sampling means the surface of Huygens wavelet is not fully exhausted during sampling
 - Unlike in continuum random process
 - The sampling, here, is unspecified—may be random or systematic
- For a field solution truly representative of the continuum picture, the uniformity of the sampling is a must
- Conversely, if sampling is with uniform probability distribution, then the sampled field does truly represent the corresponding continuum field
- Quantum is spatially discrete, and has wavelike characteristics in the large-flux situations. Therefore,
 - Huygens' wavelets have to be isotropic
 - The finite sampling has to follow uniform probability distribution

The Third Huygens Process

Finitely Sampled, Random - 2

- For quantum description, given the current state of the experimental art, the sampling scheme has to be taken as random...
- ...but isotropic and uniform
- Randomness introduced in theory, in this manner, does not imply
 - Loss of causality
 - Loss of temporal order
- Quantum randomness (or probabilistic nature of quantum phenomena) only means we have not yet discovered the law that will specify the order in which sampling scheme selects the points from a Huygens surface

The Third Huygens Process

Finitely Sampled, Random - 3

- Quantum propagation is random but deterministic, for the same reason molecules in kinetic theory follow deterministic paths
 - Kinetic theory has never been described as fundamentally probabilistic
- In our approach, the criterion for distinction between quantum and continuum is: The size of the set of sampled points in a Huygens' wavelet
 - Finite size → Quantum mechanics
 - Infinite size → Continuum (classical) mechanics

The Necessity of Aether - 1

- Explaining quantum propagation requires the Third Huygens' Process (i.e. finitely sampled, random)
- Conformance to the continuum wave description in the quantum large-flux situations requires isotropic Huygens wavelets
- Quantum propagation involves transport of momentum and energy
- Geometrical point contacts cannot lead to isotropy in the exchange of momenta (forces)
- Isotropy requires infinite connectivity

The Necessity of Aether - 2

- The only way to have isotropy in the Huygens' Processes is to have a physical continuum that ensures it
- Further, account of phase (not discussed here) again requires a physical continuum
- The physical, but non-material continuum is aether!
- Inclusion of aether in theory is fundamentally justified on the basis of physical—not mathematical—considerations
- Caution: Different views of aether over a period of time

End of Part I
