A QED-Compatible Wave Theory of Light, Electrons, and their Interactions

Henry Lindner
www.henrylindner.net

Waves vs. Particles

- **Wave Theory**—Light a wave in an electromagnetic (EM) **medium**
- **Particle Theory**—Light is a particle flying through a **void**

  - **Different** physical **qualities** and i**mplications**.
  - Both theories **cannot** be true of **freely propagating** light.
  - It should be easy to tell with theory is true.
  - **Wave-particle duality** is a **contradiction**; a violation of the first rule of philosophy.

Explains or can accommodate:	Wave in Medium	Particle in Void
Wavelength and frequency	Yes	No
Polarization	Yes	No
Invariant velocity independ. of source velocity	Yes	No
Superpositioning (interference)	Yes	No
Spreading, Diffraction	Yes	No
Continuous spectrum (gamma to radio waves)	Yes	No
Laser	?	?
Blackbody Effect	?	?
Photoelectric Effect	?	?
Compton Effect	?	?
Anti-correlation and other photon experiments	?	?
Quantum Electrodynamics	?	?

"Classical" Waves

Falsified Theory

Wave-Particle Truth Table

Quantum Electrodynamics Works

- In ***QED***, Richard Feynman presents QED as a **mathematical scheme** to **predict observations**.
- QED is **not** a physical theory of light and electrons.
- In QED, light sources produce **amplitude vector arrows** that **shrink** with distance (inverse square law) and **rotate** with time (accord. to frequency): "**shrinks and turns**"
- These amplitudes "**go everywhere**" at ***c***. (Huygens-Fresnel wave model)
- Adding up the resultant arrows for **all** possible paths renders a **final amplitude**.
- The **square** of the **amplitude** represents the **probability** of an **observed light-matter interaction** occurring at that **place** and **time**.

FIGURE 11. *A photon bouncing off the back surface of a thin layer of glass takes slightly longer to get to A. Thus, the stopwatch hand ends up in a slightly different direction than it did when it timed the front reflection photon. The "back reflection" arrow is drawn in the same direction as the stopwatch hand.*

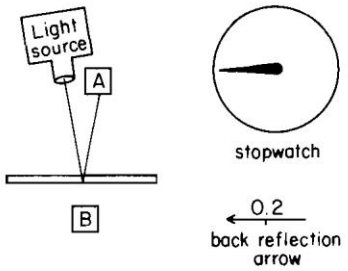
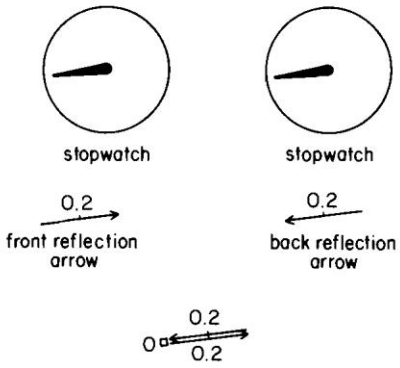
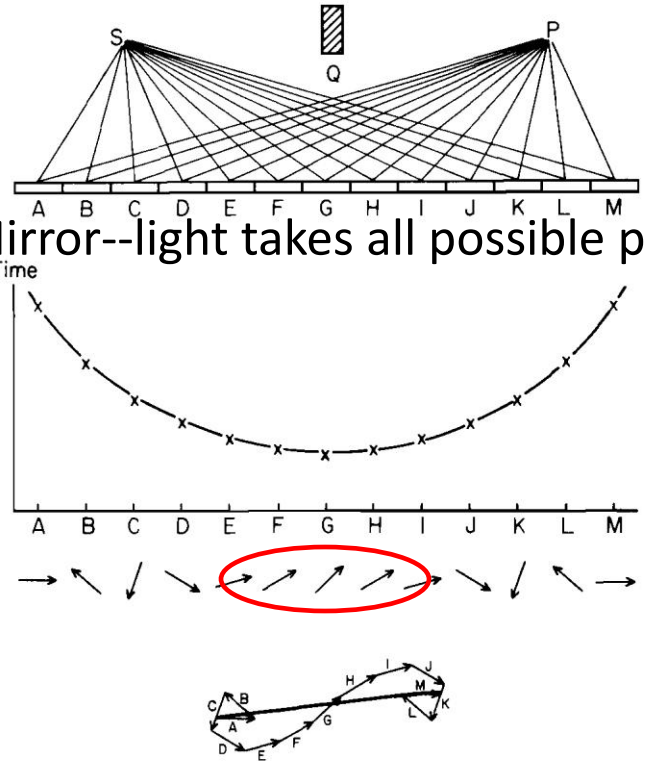


FIGURE 15. *When the sheet of glass is just the right thickness to allow the stopwatch hand timing the back reflecting photon to make one or more extra full turns, the final arrow is again zero, and there is no reflection at all.*





Mirror--light takes all possible paths

FIGURE 24. *Each path the light could go (in this simplified situation) is shown at the top, with a point on the graph below it showing the time it takes a photon to go from the source to that point on the mirror, and then to the photomultiplier. Below the graph is the direction of each arrow, and at the bottom is the result of adding all the arrows. It is evident that the major contribution to the final arrow's length is made by arrows E through I, whose directions are nearly the same because the timing of their paths is nearly the same. This also happens to be where the total time is least. It is therefore approximately right to say that light goes where the time is least.*

Amplitude arrows "shrink" with distance and "turn" with frequency in time.

Where amplitudes add up due to similar paths (least time) is "where the photon goes".

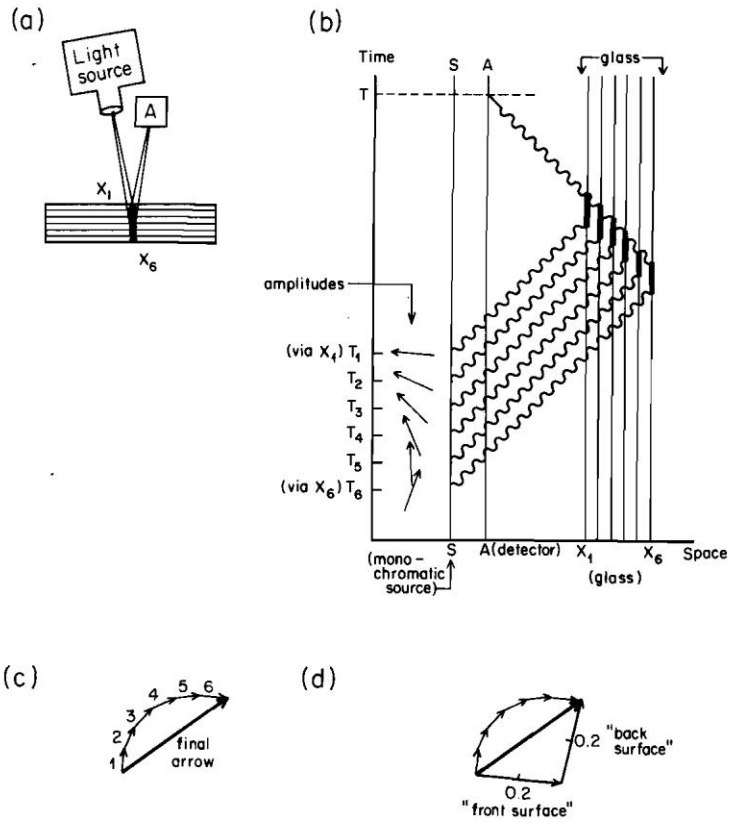
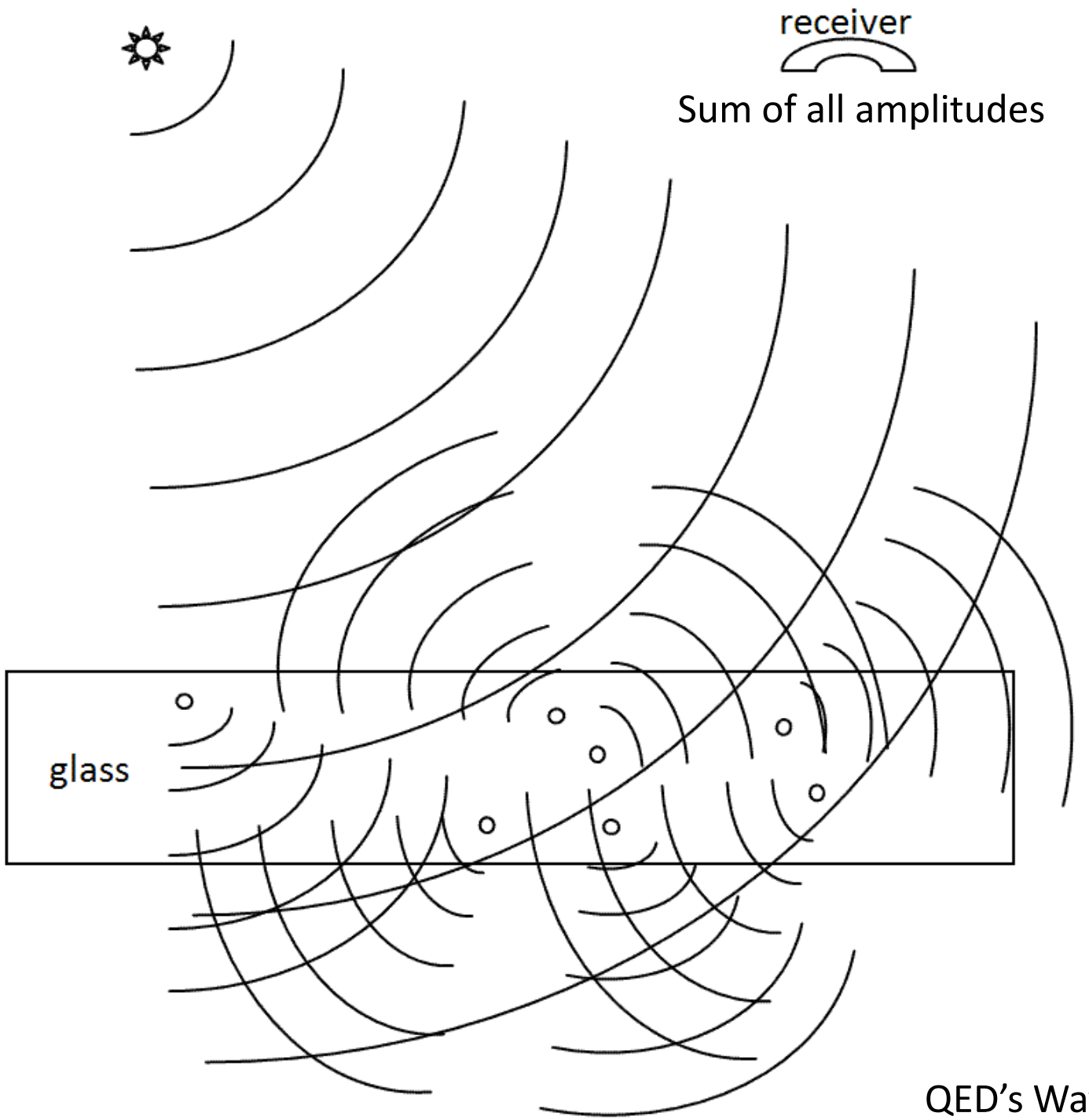


FIGURE 68. *We begin our new analysis of partial reflection by dividing a layer of glass into a number of sections (here, six), and looking at the various*

Beyond the Classical Model of Reflection

Light amplitudes are absorbed and then re-emitted (scattered in all directions) by electrons **throughout** the glass



QED's Wave Model

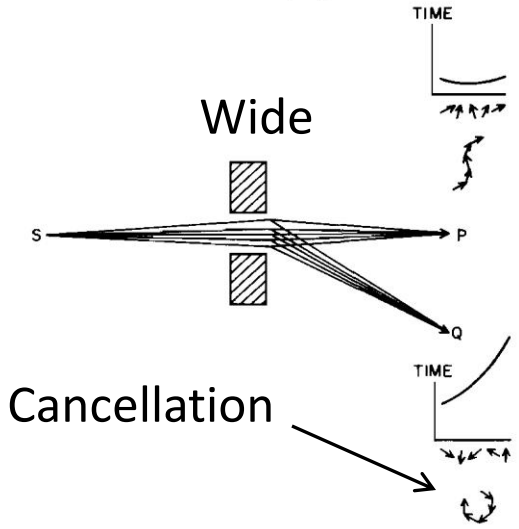


FIGURE 33. *Light travels in not just the straight-line path, but in the nearby paths as well. When two blocks are separated enough to allow for these nearby paths, the photons proceed normally to P, and hardly ever go to Q.*

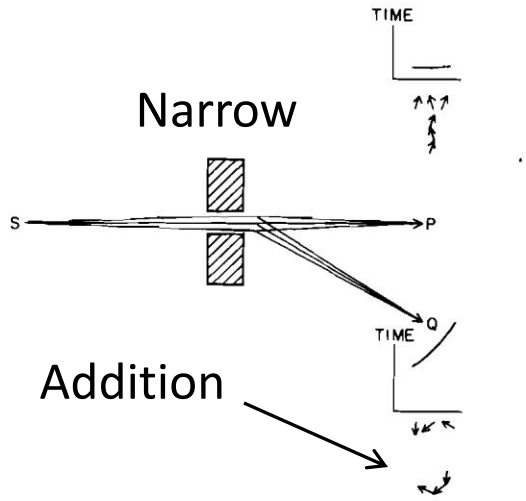


FIGURE 34. *When light is restricted so much that only a few paths are possible, the light that is able to get through the narrow slit goes to Q almost as much as to P, because there are not enough arrows representing the paths to Q to cancel each other out.*

Diffraction:

Wide aperture: More paths to Q of different lengths, **arrows cancel out**
Narrow aperture: Fewer paths to Q of similar length, **arrows add up**

Light amplitudes go **everywhere**, we only "see" light where they add up!

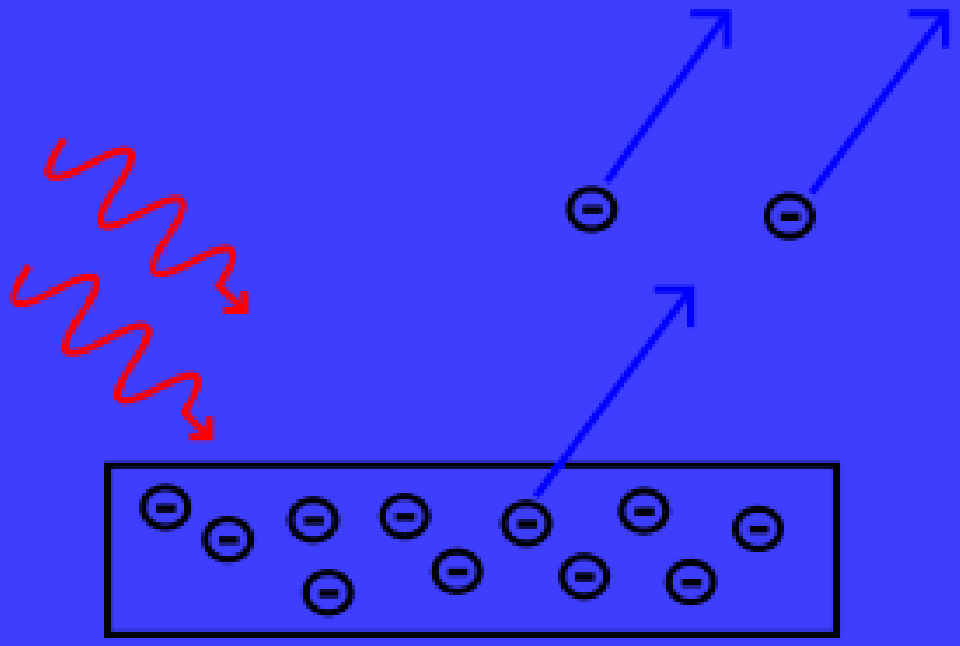
Wave spreading/superpositioning restated as a probability model!

QED is a Wave Model of Light

- For **all** waves, amplitude^2 (ψ^2) equals **intensity**—the rate of flow of wave **energy** of that frequency!
- **In QED,** where the **wave-energy** is most **intense** is where electrons are most **likely** to absorb a **quantum** – where the "photon" is likely to "go".
- Feynman **admits** that there is **no actual photon flying** from A to B!
- He knows that trying to say **which way** the photon went produces **paradoxes, y**et he can't prevent himself from thinking about flying photons!
- Feynman somehow still believes that "light is made of particles" and so concludes that "**Nature is absurd**!"
- Feynman admits that **all aspects** of light and light-matter interactions are explicable by **wave theory** except the **photoelectric effect**.

The Photoelectric Effect

Incident UV or x-radiation frees electrons from metal



Quantized Light-matter interactions

Low-energy phenomena -- Photoelectric effect

Mid-energy phenomena -- Compton scattering

High-energy phenomena -- Pair production

Arguments Against Wave Theory

- **Frequency Dependence and Frequency Cut Off:** According to **classical** wave-particle interactions, more **intense** radiation of any frequency **should** produce higher-energy electrons. More **intense** EM wave-energy of **any** frequency **should** cause **some** electrons to be ejected.

- **Findings:** The kinetic energy of the ejected electrons **depends only** on the light **frequency**, not on the intensity. **No** electrons are ejected when the frequency is **below** the **cut-off frequency**, no matter how **intense** the radiation.

- **Conclusion:** Light is made of flying particles (?)

Eisberg, R., Resnick, R., *Quantum Physics,* 33 (1974)

- **Invalid Argument:** Findings prove only that **classical** wave-particle interactions do not explain these **quantized** interactions.

- **Reasonable Conclusion:** Electrons absorb EM wave-energy in **quanta** whose energy is **determined** only by **frequency-wavelength**.

Lamb, W., Scully, M., "The photoelectric effect without photons" (1969)

-

No Time Lag

- According to **classical** wave and particle theory, wave-energy emitted by a single electron **should** be distributed **equally** over a **spherically-spreading wavefront**, therefore the receiving electron **should** require **time** to absorb enough **energy** to be ejected.

- **Finding: No** such **time lag** is observed—**all** the **energy** from a **presumed** single electron emission is **absorbed** by a nearby electron nearly **instantaneously**.

- **Conclusion:** Light is made of flying particles (?)

- **Invalid Argument:** Evidence only proves that the **classical** wave-particle model is inadequate to explain the phenomenon.

- **Needed:** A **non-classical wave theory** of light and electrons and their interactions that **incorporates QED**!

Wave Theory of Light and Electrons

1. **An Electron is an Extended EM Wave-Structure:** It is not a **point particle.** It is composed of **circulating EM waves**. It is not a particle **associated** with a **field;** it ***is*** its **EM field.** It is as **large** as its influence in space.

2. **The Electronic Wave-Structure is Quantized:** The **amplitude** and other physical parameters of an electron's EM waves are **fixed** by its structure. Only the **wavelength-frequency** varies and determines the **momentum** of a **free electron** (de Broglie relation: $\rho = h/\lambda$).

3. **Electrons Incorporate and Expel EM Waves:** Absorbed waves increase the electron's **frequency** and therefore its wave-energy. When electrons **expel** waves into the environment, their **wave-number** (frequency) and thus total **wave-energy** are reduced.

Quantization is Electronic, not Luminal

4. **Electronic Wave-Energy Exchange with the Environment is Quantized:** Other physical parameters of the wave-quanta that electrons absorb (amplitude, length, width) are **fixed** by the electron's wave-structure. Only the **frequency-wavelength** is **variable** and determines the energy of the quantum ($E = hf$).

5. **Planck's Constant, *h*, is an Electron-Structure Constant:** It describes electrons ($m_e = {2R_\infty h}/{c\alpha}$) and the quanta they emit and absorb. It is applicable to all phenomena and "particles" involving electrons and positrons. It does **not** describe free EM radiation.

6. **Free EM Waves are not Quantized:** A quantum of light is emitted as a distinct wave-packet, but upon emission begins to **spread** in space like all waves (Huygens-Fresnel principle). It ceases to exist *qua* quantum.

Directional Emission

7. **Quanta are Emitted Directionally:** As in a beam, **not** with spherical symmetry in all directions. Upon emission of a quantum, an electron **recoils** in the opposite direction. **Individual** electronic **emissions** therefore **do not obey** the **inverse square law**.

8. **Spatial Spreading is Proportional to Wavelength:** The **shorter** the wavelength, the **less** the spreading of the wave-packet after emission. At very **short** wavelengths, the emitted quantum may appear to not spread at all over short distances.

Background EM Radiation

9. **Energetic Background Radiation:** In any space, there is significant EM wave-energy of **all frequencies** from **all near and distant sources** (man-made, thermal, radioactive, solar, Cosmic, etc.). This radiant energy creates a **highly energetic EM background** (quantum fluctuations, the "mode").

10. **Wave Interference is not Destructive:** the amplitudes of innumerable waves from all sources at all distances are **superimposed** at any given point in space. Wave energy is **not** destroyed. The EM **background** is **more energetic** than previously assumed (quantum fluctuations).

11. **Electrons are Coupled to the Background Radiation and other Electrons:** An electron cannot exclude background waves. Its waves are constantly **superpositioning** with background waves and the waves of other electrons. This coupling induces both quantum **absorptions** and **emissions**.

Need for Statistical Method

12. **The Absorbed Quantum is the Product of Superpositioning:** Its energy does not usually come from the **known source** only, but from the superposition of source and **background** waves.

13. **No Independent Knowledge of Emitters:** In any laboratory setup, the **location**, **timing**, **number**, **direction** and **spread** of emitted quanta are **unknown**. Statements about emissions are only **inferences** from **detection events**.

14. **Statistical Prediction:** Since the quantum emissions in the source **cannot be known**, nor the **background radiation** or the **state** of the receiving electrons, we can only make **statistical** predictions concerning **where** and **when** detection events occur.

Answers to No Time Lag Objection

- **Unknown Emitters:** We cannot **"see"** emissions, only **detections.** A **detected** quantum absorption may be the product of **many** simultaneous quantum emissions in the source.

- **Directional Emission:** There is little diffractive **spreading** at shorter wavelengths, therefore the **inverse-square law** does **not** apply; a larger percentage of any single emitted quantum's wave-energy can impinge upon another electron.

- **Electron Size:** The electron is as **large** as its **EM influence** in space, so its reaction **cross-section** is **larger** than generally assumed.

- **Background EM:** The wave-energy that the electron absorbs does not come from the **source** alone, but from the **superpositioning** of **source** and **background waves**.

Demonstration of Wave-Principles

- In a low-light experimental setup, photoelectric detectors registered **"dark" counts** even when the source was **not** operating (energetic **background EM** radiation).

- The "photons" from a source were then **filtered** to the **intensity** of **one-tenth "photon"** (waves can be filtered, not particles).

- This **sub-photonic** EM wave-energy is sufficient, even at a distance of **one meter**, to produce **additional** photomultiplier **counts** (**directional emission** of the wave-packet plus **superposition** of source waves and background waves.)

  Bennett, C., Brassard, G., Ekert, A., "Quantum Cryptography", Scientific American, 267, No. 4, 31 (1992)

- An **electron** bound to an isolated hydrogen atom was detected, by its **scattering** of light, at a distance of **several centimeters**.

  Aharanov, Y., quoted in "Quantum Philosophy", Sci. Am., 267, No. 1, 100 (1992)

- Experimentalist Carver Meade asserts that **electrons** are **waves** that **expand** to fit whatever container they are in. He claims that it is easy to make an electron that's **10 feet across**.

  Mead, C., Interview, The American Spectator, 70-75, Sept/Oct (2001)

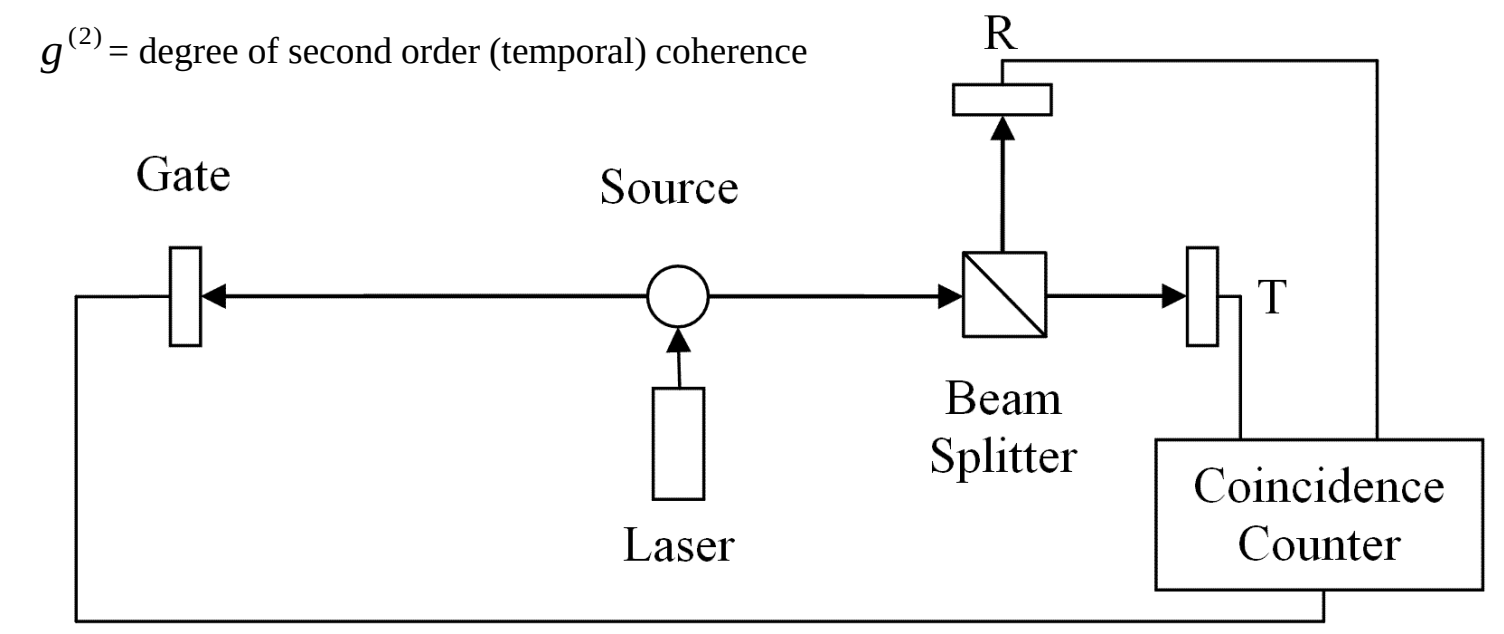
  Mead, C., Collective Electrodynamics, MIT Press (2000)

Anti-Correlation Experiments

Argument for Photon:

1. According to **classical** theory, a 50/50 BS sends **equal** wave amplitudes to R and T.
2. Therefore detections at R and T **should** be **correlated—both or none**.
3. Classical predication: $g^{(2)}(0) \geq 1$ Actual: $g^{(2)}(0) << 1$ $g^{(2)}(0) = \frac{N_{GTR} N_G}{N_{GT} N_{GR}}$
4. **Finding:** In **low intensity** experiments, $N_{GTR} N_G << N_{GT} N_{GR}$
5. **Conclusion:** Light is particles; photon goes **one way** or the **other** at the BS.

Thorn, J., Am. J. Phys, 72 (9) (2004)



QED Wave-Theory Explanation

1. There are **no flying photons**, only spreading light wave **amplitudes** from an **unknown number** of source emissions and scatterings.

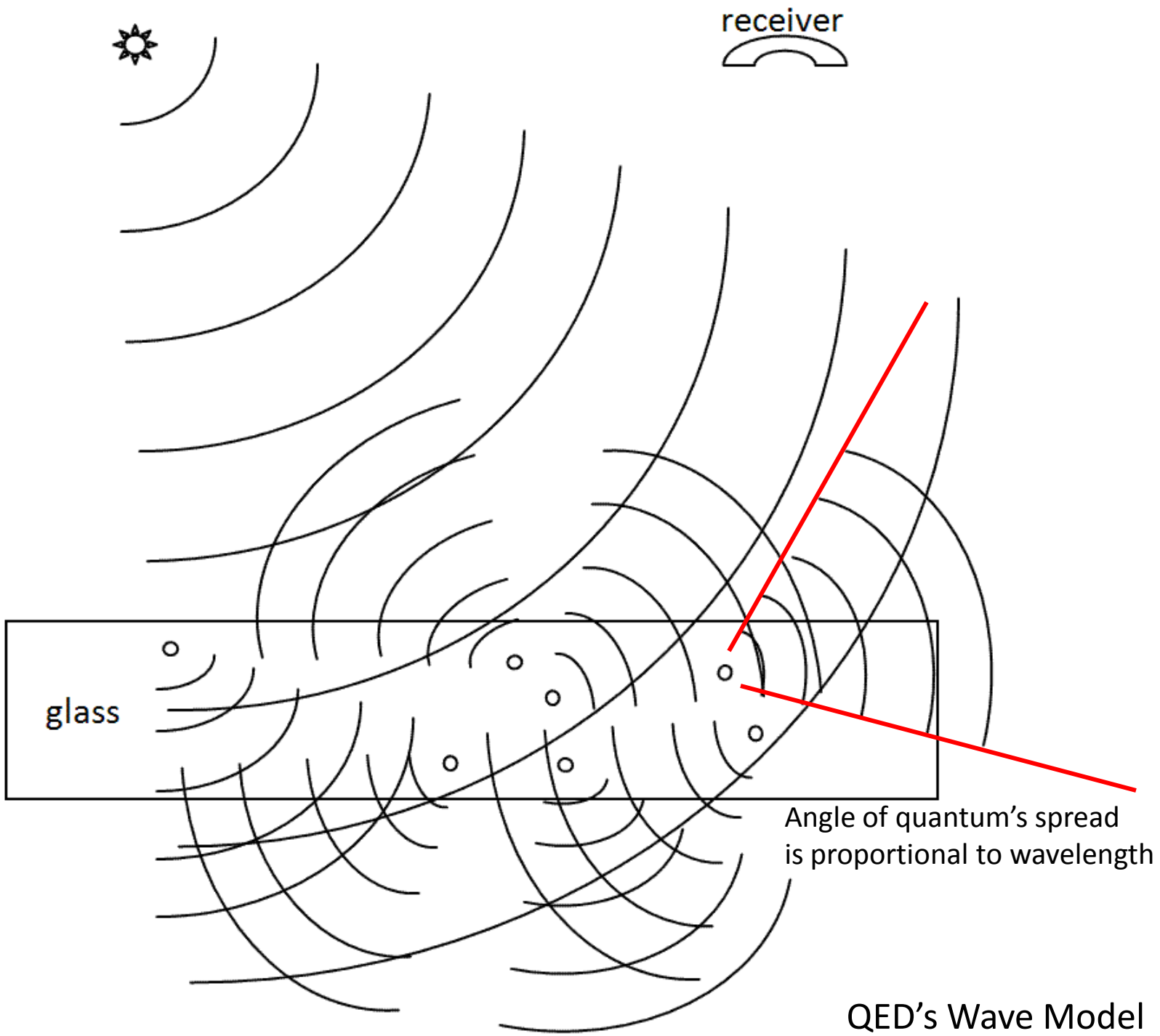
2. **No. of emissions > No. of detections** due to amplitude **shrinking** and **scattering**.

3. **Non-Classical:** Low intensity →"graininess". Individual absorption/emission events dominate → greater **deviation** from "classical" predictions

4. When there are only a **few** absorption/emission events in the BS, amplitude partitioning will **vary** from **50/50**; can even be **0/100**!

5. **GRT coincidences** will be **rare :** The BS **scatters** light in **all** directions, so if the source sends **equal amplitudes** towards the Gate and BS, **just sufficient** to produce a detection at the Gate, R and T will receive much **smaller amplitudes.**

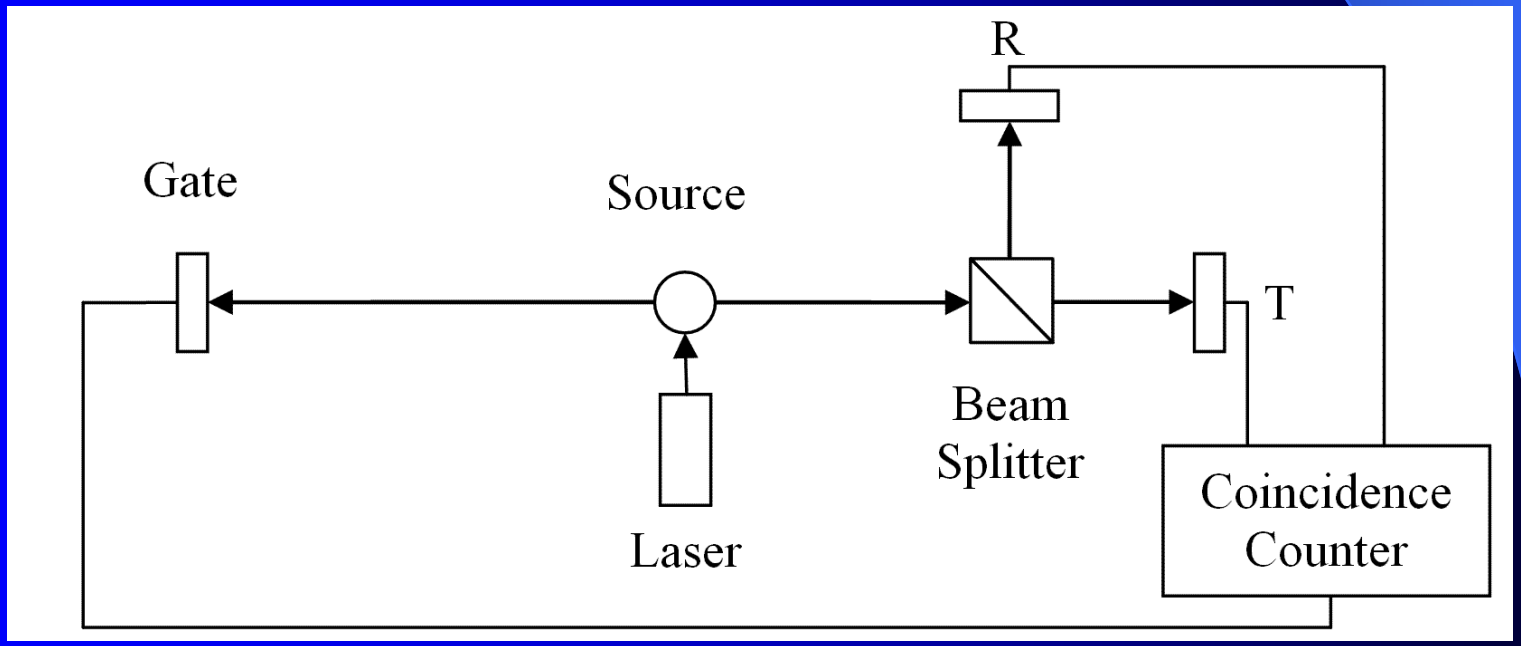
6. **GR** or **GT coincidences** will occur: sufficient **amplitude** at R or T requires some combination of **multiple–emission** output, **uneven** R-L down-converter output, **uneven** beam splitting, and a **contribution** from random **background radiation**.

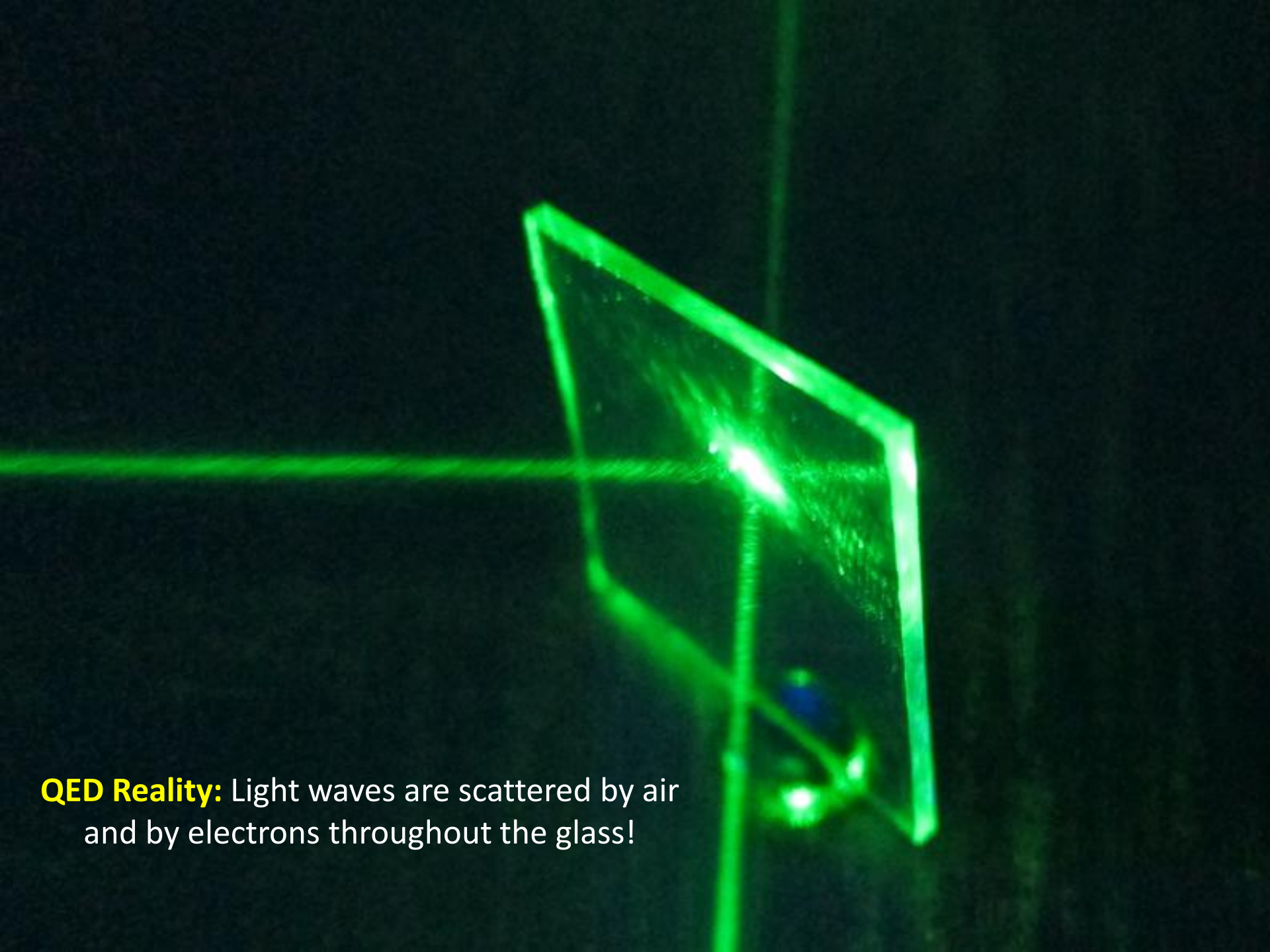


QED's Wave Model

Impossible, Miraculous Photons!

1. **No** flying photon has ever observed. It is a poor inference from **detections**.
2. **Impossible knowledge:** The **number**, **direction**, **spreading**, and **scattering** of quantum emissions from down-converter crystal and BS **cannot** be **known.**
3. **Miraculous photons:** supposed single flying photons are **magically** guided either **straight through** a **BS** or **reflected intact**, are "**focused**" by lenses, etc. How can **light** pass through mm's of glass (10^{22} atoms/cm^3) and have **no interaction** with any electrons?





QED Reality: Light waves are scattered by air and by electrons throughout the glass!

Explains or can accommodate:	Wave in Medium	Particle in Void
Wavelength and frequency	Yes	**No**
Polarization	Yes	**No**
Invariant velocity independ. of source velocity	Yes	**No**
Superpositioning (interference)	Yes	**No**
Spreading, Diffraction	Yes	**No**
Continuous spectrum (gamma to radio waves)	Yes	**No**
Laser	Yes†	**No***
Blackbody Effect	Yes†	**No***
Photoelectric Effect	Yes†	**No***
Compton Effect	Yes†	**No***
Anti-correlation and other photon experiments	Yes†	**No***
Quantum Electrodynamics	Yes†	**No***

* Requires wave modeling to predict "where the photon goes"

† Requires quantization of electronic absorption-emission of light, plus…

Light is a Wave

- The flying photon theory is **incompatible** with the evidence. (0% probability)
- Radio waves, x-rays, light, etc. are all **waves** in a medium: they differ only in their **frequency**, degree of **spreading**, how they are **generated**, and how they **interact** with matter.
- **No Quantum/Classical schism:** There is **one electrodynamics** that deals with **both** the **quantized** electronic absorption/emission of light **and** the **non-quantized** interactions.
- This **wave theory** of light and electrons is consistent with **QED** and eliminates all **paradoxes**.
- **Nature** is not absurd; it always makes **sense** when our theories **conform** to the facts.