APS physics APRIL MEETING 2022

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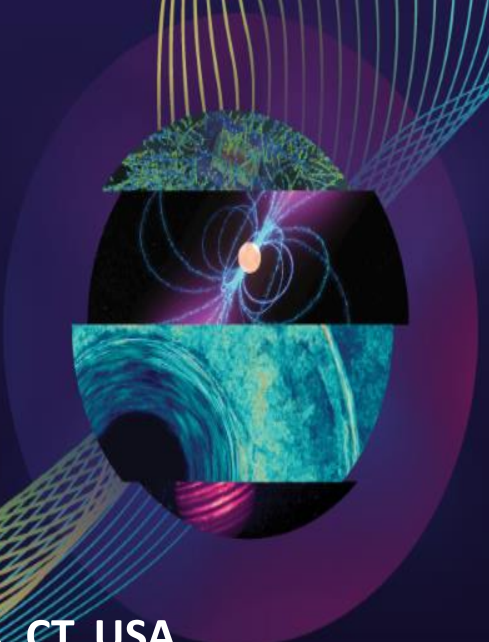
Session #: Z05.00004 Roychoudhuri.MP4

Benefits of using asymmetry in modeling physics phenomena

Mystery of the double-slit



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Connecting "Asymmetry" with the "Double-slit", as a case example.

- It is often heard that the only mystery in Quantum Mechanics is understanding the single-photon double-slit diffraction pattern!

- We present asymmetric double-slit analysis to establish the reality of both the signals, which stimulate the detector that displays the double slit fringes.
  - **No Wave-particle Duality is needed!**

The methodology of our thinking:

- We incorporate Interaction Process Mapping Thinking (IPM-T) to appreciate that all data are generated through (i) stimulation or interaction with the detector, (ii)followed by energy exchange between the incoming signals and the detector & (iii) the physical transformation in the detector becomes the data.

- We also accept that the mathematical logics, when validates the data, the embedded logic represents physical interaction process.

Implementing IPM-T

Mentally visualizing interaction processes in our apparatus

1. ***Data gets generated through the following steps: (i) a force guided interaction, which (ii) leads to energy transfer & then (iii) physical transformation. The transformation in the detector becomes the data. No interaction, no data! This is missing in current physics 2-slit discussions.***

2. ***Interaction is always "local", since the effective range of all forces are range dependent. Fringes emerge on the detector array.***

Mathematical logics of a working theory embeds Interaction Process

1. Superposition Principle is not an observable phenomenon.

$\Psi = \psi_1 + \psi_2$; only a correct mathematical statement, not physics!

Who or what executes the opeartor "+" and responding to ψ_1 & ψ_2

2. Emergence of fringes of Superposition Effect (SE): It must be understood as interactions between diffracted signals and a detector. *It is a "local" phenomenon; nothing mysterious.*

$$\Psi = \chi(\nu)\psi_1 + \chi(\nu)\psi_2;$$

Light & detector must share a ν-driven interaction.

Even then Ψ is not observable;

only $\Psi^*\Psi$ is observable (in QM).

$$D(\nu) \equiv |\Psi|^2 = |\chi(\nu)\psi_1 + \chi(\nu)\psi_2|^2;$$

$\chi_1(\nu)$ for linear frequency resonant optical detector

Traditional symmetric representation of double-slit diffraction pattern, with the detector's role. [Ref.#8]

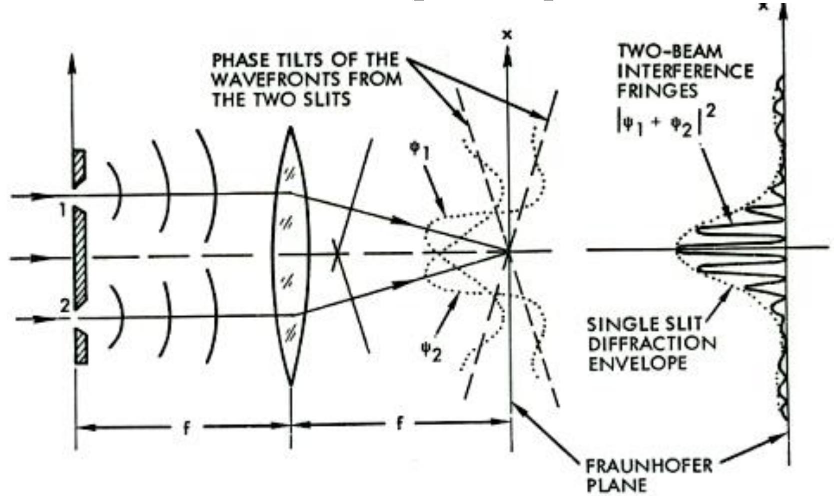
$$d(x) = \chi(\nu).2aE\text{sinc}(2\pi ax/\lambda f)e^{i2\pi bx/\lambda f} + \chi(\nu).2aE\text{sinc}(2\pi ax/\lambda f)e^{-i2\pi bx/\lambda f}$$

$\Rightarrow \chi(\nu)$ is the detector's quantum frequency resonant, linear, polarizability factor.

$$|d(x)|^2 \equiv D(x) = B^2\chi^2(\nu)\text{sinc}^2(\Lambda ax)\left[1+\cos(2\Lambda bx)\right]$$

where: $B^2 \equiv 4a^2(E_1^2 + E_2^2)$

$\Lambda \equiv 2\pi/\lambda f$



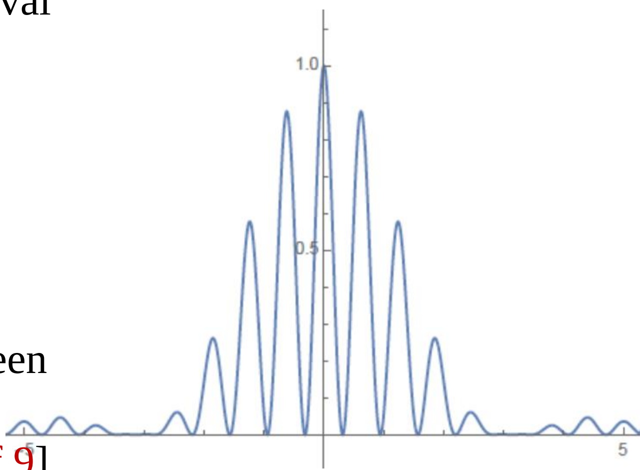
LOGICAL PROBLEMS BEHIND "SINGLE PHOTON INTERFERENCE"

The traditional explanation is that the statistical distribution law of arrival of the photon from the double-slit to the detection screen, follows the simple double-slit cosine law. The problems:

(i) We completely neglect the sinc-squared modulation of the cosine fringes; or, the **suppressions of photon arrival**.

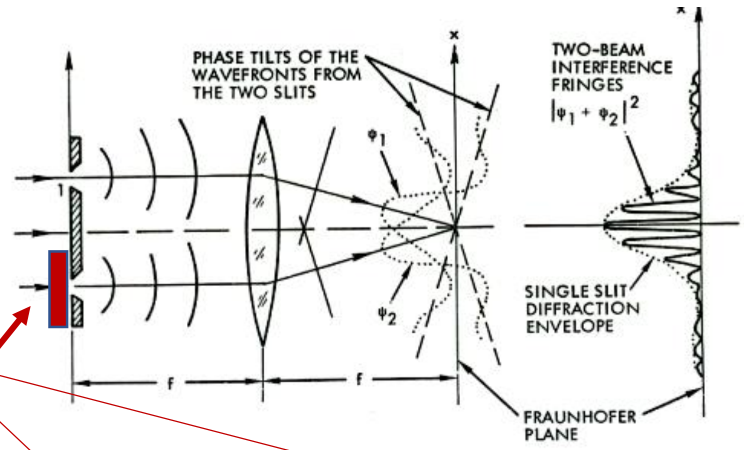
(ii) We wrongly assume that "**no photons arrive**" at the dark fringe locations.

(iii) The **physical reality of each of the two slit signals** can also be seen by using holographic-double-slit experiment, where slit signal is recorded separately, and then 2-slit fringes are reconstructed. [Ref.9]



We will explore "no photon arrival" problem in more detail later.

Introducing asymmetry in the double slit experiment helps us appreciate that logics behind the math & interaction process with the detector do not support the postulate of: "single photon interference".



Assuming asymmetry in three parameters: amplitudes, polarizations $\vec{E}_1 \neq \vec{E}_2$ & phase.

$d(x)$ is the dipolar amplitude stmuation induced on the detector array by the two signals fron the two slits.

Both the stimulating fields must be frequency (wave length) resonant with the detector.

$$d(x) = \chi(\nu)2a\vec{E}_1 \text{sinc}(2\pi ax/\lambda f)e^{i2\pi bx/\lambda f} + \chi(\nu)2a(\vec{E}_2 e^{i\varphi})\text{sinc}(2\pi ax/\lambda f)e^{-i2\pi bx/\lambda f}$$

$$= \chi(\nu)2a\text{sinc}(\Lambda ax)\left[\vec{E}_1 e^{i\Lambda bx} + (\vec{E}_2 e^{i\varphi})e^{-i\Lambda bx}\right]; \text{ where } \Lambda \equiv (2\pi/\lambda f).$$

$$= \chi(\nu)2a\text{sinc}(\Lambda ax)e^{i\varphi/2}[\vec{E}_1 e^{i(\Lambda bx - \varphi/2)} + \vec{E}_2 e^{-i(\Lambda bx-\varphi/2)}].$$

$$D(x) = \chi^2(\nu)4a^2\text{sinc}^2(\Lambda ax)\left[E_1^2 + E_2^2 + 2\vec{E}_1 \cdot \vec{E}_2 \cos(2\Lambda bx - \varphi)\right]$$

$$= \chi^2(\nu)B^2\text{sinc}^2(\Lambda ax)\left[1 + \frac{2\vec{E}_1 \cdot \vec{E}_2}{(E_1^2 + E_2^2)}\cos(2\Lambda bx - \varphi)\right]; \text{where } B^2 \equiv 4a^2(E_1^2 + E_2^2)$$

Perfect symmetry (visibility) of cosine fringes is now broken.

"Photons" now arrive at the "dark fringe" loactions!!

Comprehensive math for the asymmetric double slit (contd.)

For pure phase asymmetry, with equal amplitudes & parallel polarizations:

$$D(x)_{ph.asym.}(x) = \chi^2(\nu)B^2\text{sinc}^2(\Lambda ax)\left[1+\cos(2\Lambda bx-\varphi)\right]$$

For pure amplitude asymmetry $E_1 \neq E_2$, with parallel polarizatiion, $\varphi = 0$:

$$D(x)_{amp.asym..}(x) = \chi^2(\nu)B^2\text{sinc}^2(\Lambda ax)\left[1+\gamma_{am.as.}\cos(2\Lambda bx)\right];\gamma_{am.as.} \equiv \frac{2E_1E_2}{(E_1^2+E_2^2)} = \frac{2\beta}{\beta^2+1};\beta \equiv \frac{E_1}{E_2}.$$

For pure polarization asymmetry $\vec{E}_1 \neq \vec{E}_2$, but $\left|\vec{E}_1\right| = \left|\vec{E}_2\right|$, with amplitude symmetry:

$$D(x)_{pol.asym.}(x) = \chi^2(\nu)B^2\text{sinc}^2(\Lambda ax)\left[1+\gamma_{po.as.}\cos(2\Lambda bx)\right];\gamma_{po.as.} \equiv \cos\theta, \text{(polarization angle)}.$$

Notice that amplitude & polarization asymmetry, $\gamma_{am.as.}$ & $\gamma_{po.as.}$ are simply fringe contrast (visibility) reducing factors. Therefore whenever $\cos\theta = 2E_1E_2/(E_1^2+E_2^2)$, the low visibility fringes will be indistingushable for the two cases.The data sets by themselves will not allow us to figure out the "physics" behind the interaction process, & the fringe visibility reduction.

The case of phase asymmetry between the two slits.

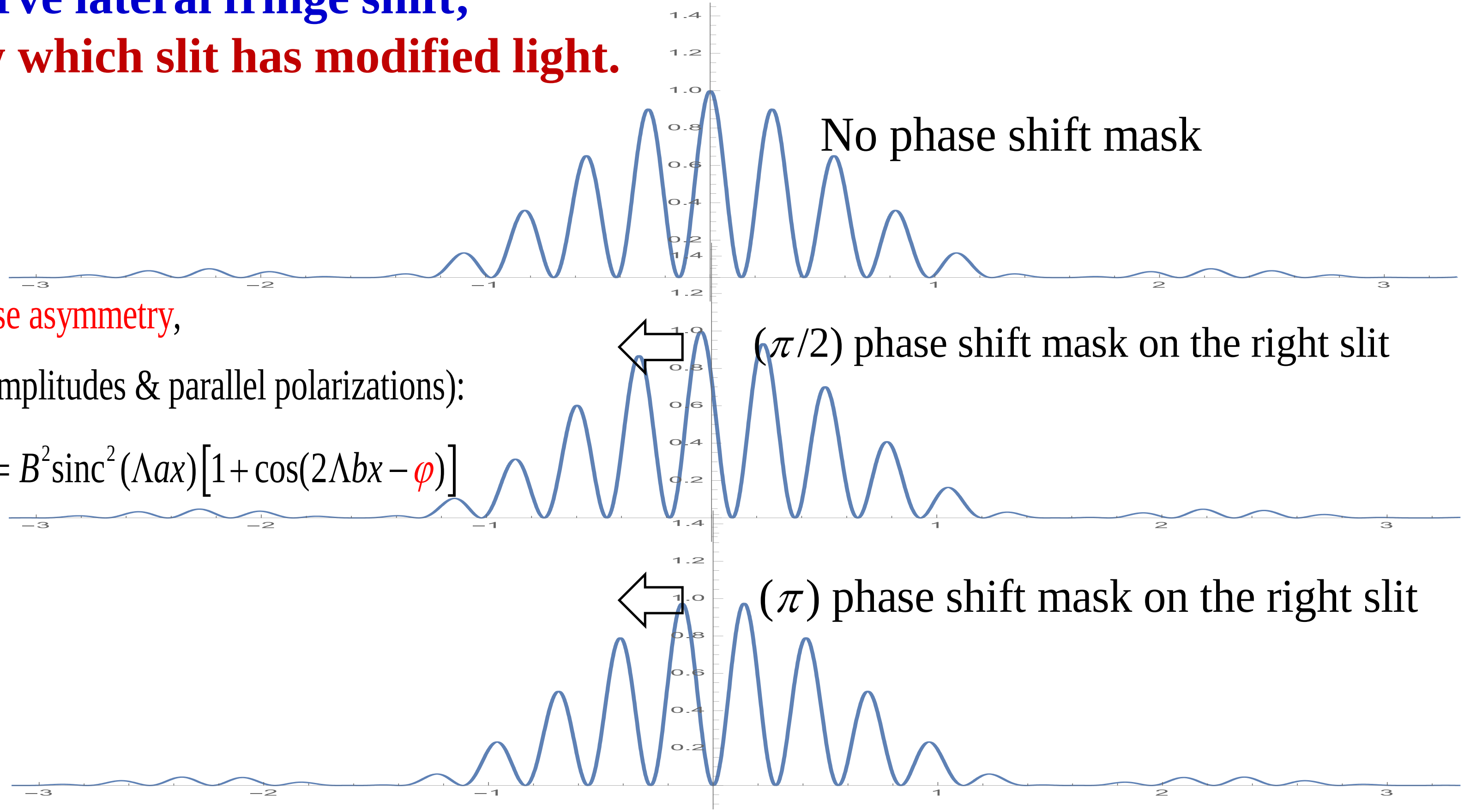
We observe lateral fringe shift;

we know which slit has modified light.

For pure phase asymmetry,

(with equal amplitudes & parallel polarizations):

$$|A(x)|^2_{ph.asym.} = B^2 \text{sinc}^2(\Lambda a x)\left[1 + \cos(2\Lambda b x - \varphi)\right]$$



“Which way photon traveled” is not a physics question. Nobody can determine the existence of a photon without destroying it! But, the “which way” path can be ascertained by (a) locating the detecting pixel and (b) computer modeling the Huygens-Fresnel diffraction theory.

AMPLITUDE & POLARIZATION ASYMMETRY

The un-balanced energies for both the cases trigger photo-electron emission at the "dark-fringe" locations

- The Superposition Effect is not a scattering phenomenon.
- It is the joint stimulation of the local detecting pixel by all the diffracted light waves from both the slits, which have evolved through the Huygens-Fresnel diffraction phenomenon.
- The resultant E-vector strength determines the DEGREE of dipole amplitude stimulation
- And, the square modulus of the amplitude stimulation determines the local quantity of wave energy absorbed at that location.

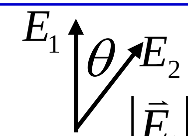
Unbalanced energies are in the visibility factors, γ

$$D(x)_{amp.asym..}(x) = \chi^2(\nu)B^2\text{sinc}^2(\Lambda ax)\left[1+\gamma_{am.as.}\cos(2\Lambda bx)\right]$$

$$D(x)_{pol.asym.}(x) = \chi^2(\nu)B^2\text{sinc}^2(\Lambda ax)\left[1+\gamma_{po.as.}\cos(2\Lambda bx)\right]$$

$$\gamma_{am.as.} \equiv \frac{2E_1E_2}{(E_1^2+E_2^2)} = \frac{2\beta}{\beta^2+1}; \beta \equiv \frac{E_1}{E_2}; E_1 \neq E_2$$

$$\gamma_{po.as.} \equiv \cos\theta$$

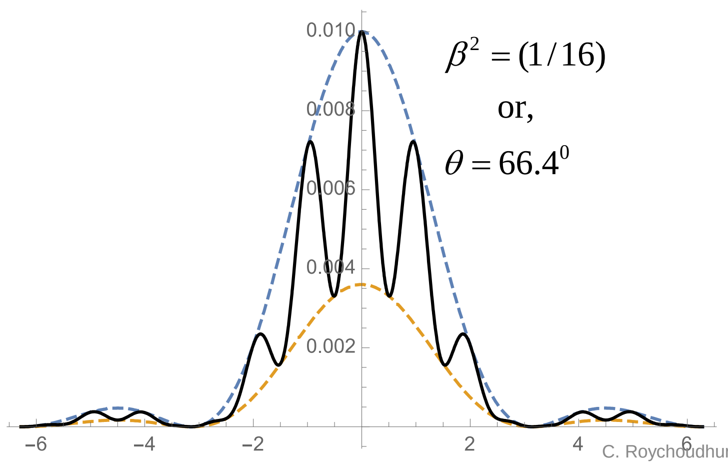


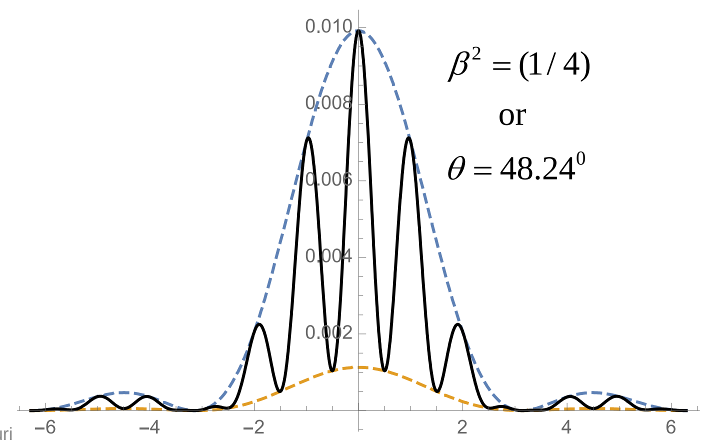
$$\left|\vec{E}_1\right| = \left|\vec{E}_2\right|$$

The "Gammas" represent FRINGE **VISIBILITY,** defined by Michelson during late 1800. They may appear here to be somewhat similar parameter above, but the physics of dipole stimulations are very different

$$V_{fringe}(x) \equiv (I_{\max} - I_{\min})/(I_{\max} + I_{\min})$$

"Photons" (light energy) do arrive at the dark-fringe locations!





Physical reality of two signals out of two slits! [Ref.9]

Unbalanced energy gets detected at the "dark fringe" locations!

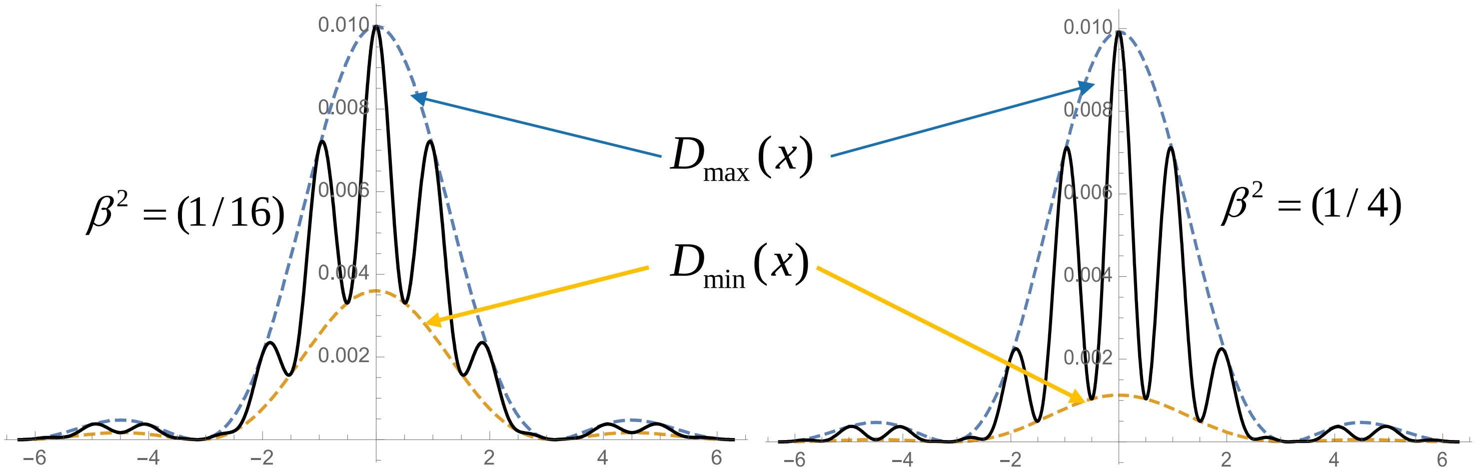
"Photons do not arrive at dark fringe locations" is not correct physics.

Back to the simple original amplitude asymmetry:

$$D(x) = \chi^2(\nu)4a^2\text{sinc}^2(\Lambda ax)\left[E_1^2 + E_2^2 + 2E_1 \cdot E_2 \cos 2\Lambda bx\right]$$

The maxima & minima of the fringes are when the cosine factor is +/-1:

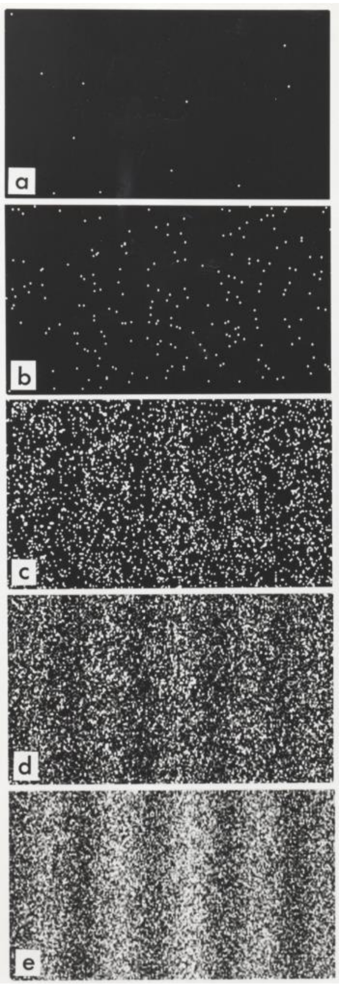
$$D_{\min}(x) = \chi^2(\nu)4a^2\text{sinc}^2(\Lambda ax)\,[E_1 - E_2]^2$$
$$D_{\max}(x) = \chi^2(\nu)4a^2\text{sinc}^2(\Lambda ax)\,[E_1 + E_2]^2$$



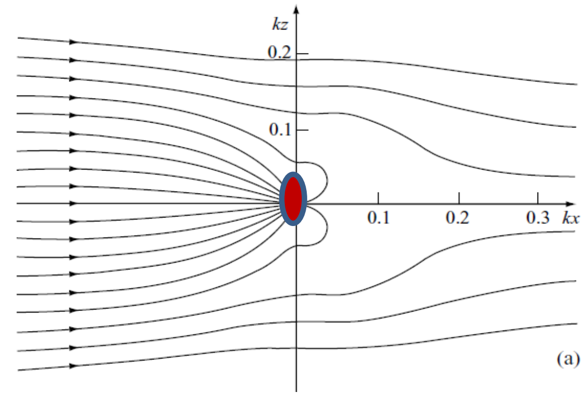
When $[E_1 - E_2]^2$ is not zero, there is extra unbalanced energy available for the detecting dipole to absorb. It does so, proving that "photon non arrival" is a wrong postulate.

Granularity in fringes has nothing to do with "Photon" being "indivisible", or not.

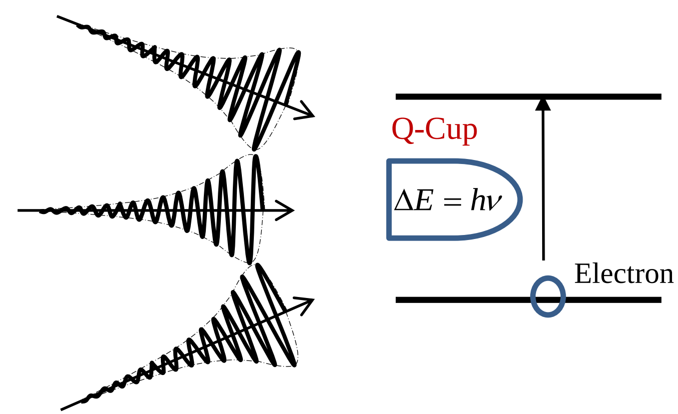
Origin of granularity lies with the micro-granular structure of the detector array and resonant dipoles' very larger area of energy absorption cross-section.



1. Both the photographic (Ag-Halide crystallites) plate and the modern CCD array have granular structure to create high resolution pictures. They are frequency sensitive quantum detectors. All sufficiently enlarged picture will show granularity. Both of their physics of exposure process is quantum mechanical. E-vector frequency determines the exposure potential.
2. As the flux or the rate of energy flow of light gets very low, the probability of energy availability per pixel gets reduced. Consequently, a longer period of exposure is required to get higher density of pixels getting exposed. There is also "push-pull" effect from field to dipole (detector) energy transfer [Ref.1]. A resonant dipole can absorb energy out of the field of an area very much larger than its physical size, thus robbing energy from the neighboring pixels at low flux.



See p.53 in *Introduction to Quantum Optics, by* H. Paul, Cambridge U. Press, 2004..



Quantum-Cup model for light absorption.

Conclusion

1. Superposition Principle is only a correct mathematical statement. Superposition Effect can become DATA only if a proper resonant detector has been used. Entanglement is a questionable concept because QM formalism does not permit measurement of the amplitude state, and hence no physical access.

2. Data validating successful mathematics by itself cannot guide us to visualize the physical interaction process that generate data in our instruments. We need to incorporate them explicitly.

3. Symmetry and beauty of mathematics, without explicit incorporation of interaction parameter, should not be the generic guide to model physics. [See Ref.13]

4. Asymmetric double slit, with the incorporation of interaction process, restores the semi-classical model for superposition effect without any mystery.
   3a. Real physical signals from both the slits must simultaneously stimulate the detector.
   3b. Hence, "single photons" cannot generate superposition effect.

4. Wave-particle duality (WPD) is an unnecessary "crutch" to justify the non-existent "single photon" interference. QM formalism stands tall without WPD.

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