Second Talk

Process based reality epistemology applied to optical phenomena

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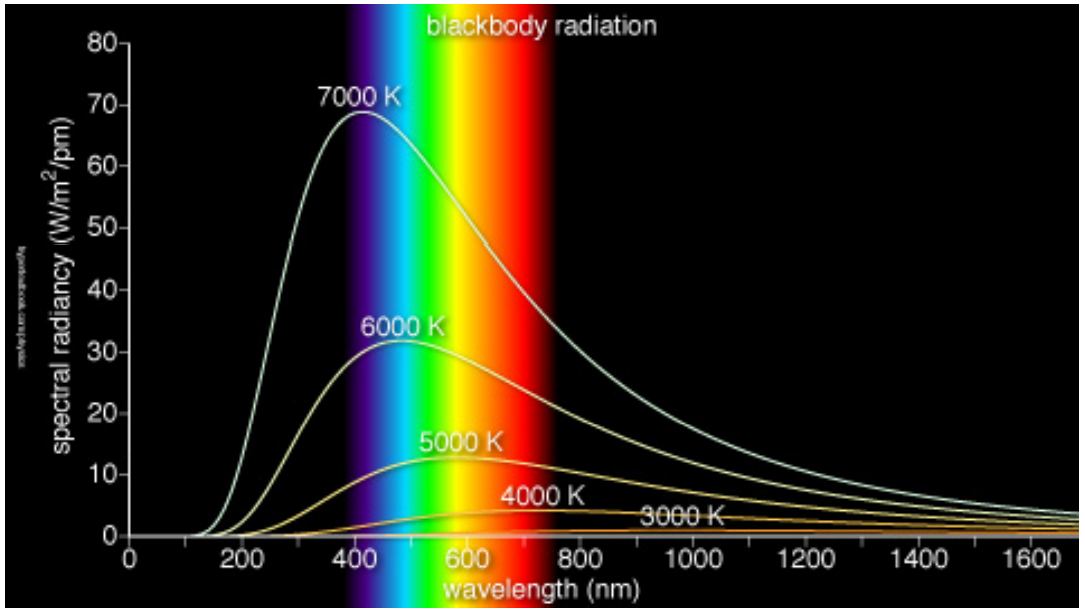
Precision spectroscopy of black-body radiations & their empirical fitting by Planck gave birth to Quantum Mechanics

The size of the energy quantum is $h\nu$:

$$W(\nu) = \frac{2\pi h}{c^2} \frac{\nu^3}{\exp(h\nu / kT) - 1}$$



However, Planck believed that light energy is quantized only at emission and absorption but propagates as a diffractively spreading wave packet!

Universality of superposition effects as measurable transformation (SEMT) is at the core of doing science

• 1. **Measurable transformation:** We can scientifically measure only re-producible quantitative ***transformations*** that are experienced by our interactants (or detector-detectee, or sensor-sensee).

• 2. **Energy exchange:** Any transformations in measurable physical parameters requires ***energy exchange*** between the interactants.

• 3. **Force of interaction** The energy exchange must be guided by a ***force of interaction*** between the interactants and it must be strong enough to facilitate the exchange of energy, which are usually constrained by the characteristic limitations of each interactant.

• 4. **Physical superposition:** All force rules being distance dependent, energy exchange between the Interactants requires that they must experience each other as **locally present or *physically superposed*** entities (experience each other within their sphere of influence). Superposition effect is an **active local process**, not a passive mathematical principle !

• **5. Sensors register and report incomplete information about the sensees:** All sensors wear vision- limited "quantum goggles" and report through "band-limited" communication channel. Thus, we are for ever challenged to re-construct cosmic logics to solve the little cosmic puzzles. Putting them together into one cosmic puzzle is even more formidable starting with only incomplete information.

The conceptual framework behind all mathematical formulations must accommodate these universal steps behind all quantitative measurements.

All of our theories are necessarily provisional and incomplete!

The model of nature, which our human logics aided mathematics construct, is limited by our model of thinking (epistemology). Neither the correctness of a mathematical theory nor the limited set of measurements that we can perform can guarantee that our theory has captured the final cosmic logics we seek for!

Incomplete information paradigm, i^2-P

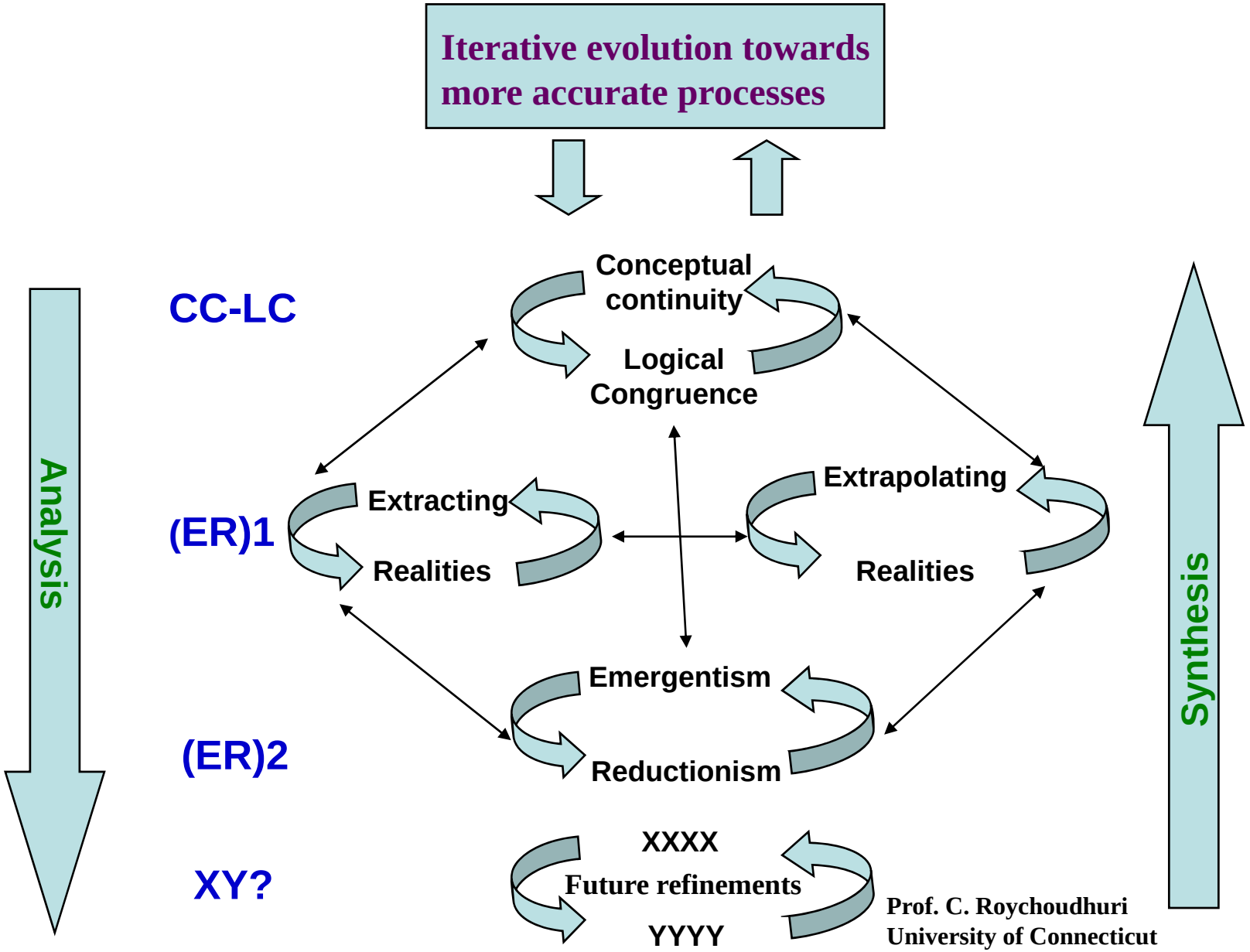
• First, all of our theories are based on incomplete sets of observations in contrast to the infinite number of incessant interaction processes behind the cosmic evolution.

• Second, all the measured information are necessarily incomplete because (i) the interactants respond to each other using a limited set of their normal "quantum compatible characteristics" (not all four forces are operative) and (ii) the measured transformation data are usually "censored" by our complex measuring systems.

Is there hope for us to do better?

•All "correct" scientific theories have always been superseded and/or invalidated by new theories!

Epistemology to refine incomplete information towards actual realities



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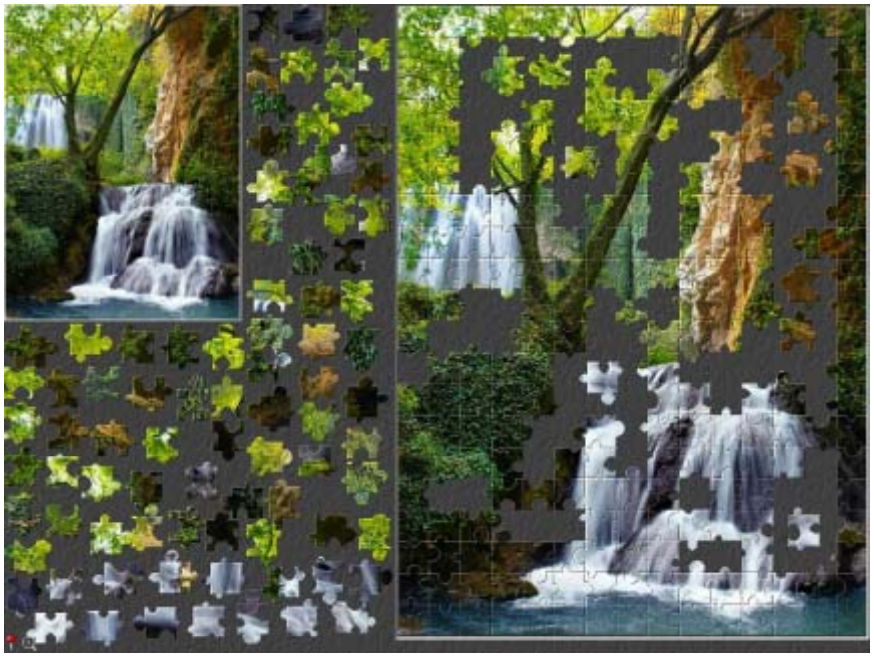
The structure of the epistemic loop must also evolve with our evolution!

“Change is the only constant”!

Today's half a dozen "solved puzzles" are not yet harmoniously integrate-able!

Each one of the current "successful" theories are logically self-congruent and self-consistent in mapping the behavior of different domains of nature with only partial integrate-ability: (i) classical theory, (ii) special relativity, (iii) general relativity, (iv) quantum mechanics, (v) quantum field theories, (vi) cosmology, (vii) string theory, etc.



The creator has not given us the picture of the cosmic puzzle to assure us of our preliminary successes. Further, we confuse ourselves as if we have found the ultimate solution because the puzzle pieces are cut out with only a small number differentiable shapes - theory can fit in sometimes in wrong places. Note that we have, so far, discovered only four forces that keep the entire cosmic universe keep on evolving with its own logics!

The creator has not given us the picture of the cosmic puzzle to assure us of our preliminary successes!

We need tools to anchor our contextual logic, which must be revised as we progress!

1. Natural interaction processes are causal (logical).
2. Energy is conserved in interaction processes.
3. All interaction processes are local, locality is being defined by the range of the interacting force(s).
4. **Well formed light beams do not operate on each others energy distribution in the absence of mediation by material dipoles.**
5. Running time is not a directly measurable physical parameter. It is a derivative of measurable undulation frequencies of different natural harmonic oscillators.
6. All interactions requiring energy exchange must take a finite time.
7. All detectable physical entities are space and time finite and can acquire only a finite velocity.
8. Upper limit on “c” has been a very useful guide (superluminal velocities are to be doubted).
9. Etc.

Summary

• **We proposes a methodology of thinking (epistemology) to assist scientific exploration of real physical processes in nature (ontology).**

• **First assumption:** Whatever we sense (experimentally or observationally), always represents real interactions between **manifest physical entities** of nature. We must learn to extend our logics to **un-manifest entities**!

• **Second assumption: Nature is causal.** It evolves through causal (logical) interactions between different entities, which are validated by the very successes of our logical hypotheses organized by human mathematical theories.

• **Objective of science:** Understand and **visualize all the processes** taking place in nature, which are at the root of all of our observable cosmic and biospheric evolution.

• **Root of incompletenes-1:** We do not know any of the natural entities completely. Further, the transformations (change) that we measure or observe do not provide us with the complete information regarding neither all the forces that the interactants are experiencing, nor can they relay to us through our measuring device(s) all the information regarding any particular transformation they experience in any experiment.

• **Root of incompleteness-2:** We are also forever challenged to create a causal theory about nature by inventing (imaginary) human logics to fill in the gap of incomplete information to construct a theory that hopefully will map the cosmic logics behind the interactions we are studying.

• **Significance of "incomplete information paradigm" (i^2P) – 1:** We need a scientific epistemology that allows us to iteratively keep on refining and modifying our human logics in all "successful" theories and convert them closer and closer to our goal of mapping the cosmic logics.

• **Significance of i^2P – 2:** It underscores the inevitability of paradoxes, contradictions and confusions in our conceptual interpretations of any theory explaining our observations.

• **Proposed epistemology, EPR:** In this article, we explore these paradoxes regarding wave-particle duality of photons and suggest possible resolutions of such paradoxes.

Human logic vs. cosmic logic

Thus, we must maintain serious scientific doubts on the imposition of interpretations like non-causality on causal mathematical relations and the underlying interactions as non-local when they represent interactions between physical interactants through forces, which are always of finite range. Therefore, our interpretation process requires a well structured methodology of thinking, or an epistemology to sort out the difference and connectivity between different *human logics* (epistemology) that have organized the theories and the *cosmic logics* (ontology) that run all the real *interaction processes* in our universe. If we treat all the "working" theories as inviolable, we will never succeed advancing science very much further. Almost thirty years of failure to find anything fundamentally new in physics clearly tells us that we need to reassess all the hypotheses that are behind all these different "successful" theories [1-3] and revisit the purpose of physics. We believe that the motto of classical physics, understanding and visualizing the physical processes undergoing in nature, should be our key guidance.

Framing a question determines the answer we create

Framing a question determines the answer we create by developing a theory around various observations. The frame of our enquiring mind, or the model of our thinking, which is varied and quite complex, determines how we frame our questions. This makes debating different interpretations of the same theory sometimes confusing, the best example being the unresolved [6] “Bohr-Einstein debate” over *reality* about quantum mechanics [7]. Another good example is our insistence on the same questions like, “what are light quanta?” [8], which has yielded very little new information about the deeper nature of light for over a century. Semi classical analysis yields most of the light-matter interactions [9]. Formalism of quantum mechanics (QM) “works” very well and Schrödinger’s equation has opened up a flood gate of accurate predictions about the quantum world of micro universe. Obviously, QM must have captured a good amount of fundamental *realities* regarding interaction *processes* behind atoms, molecules and their interactions. Instead of accepting conceptual problems of QM as a guide to discover better or newer theories [10], we are mystifying nature to be non-causal whenever our attempt to visualize the micro world becomes unsuccessful.

Why “nobody understands quantum mechanics”?

Culturally we have become so accustomed to accept “nobody understands quantum mechanics” that we do not question the current interpretations and accept that QM is “complete”. We are still engaged in creating wide ranges of non-causal, non-local interpretations leading to accept teleportation, delayed superposition, etc., to accommodate Dirac’s statement, “photon interferes only with itself”, which perhaps appeared logical in 1930.

No simple recipe as to when human logics perfectly maps cosmic logics!

We must also acknowledge at the outset that the proposed epistemology itself being a product of *human logics*, it must be scrutinized, modified, changed as we progress farther towards mapping *cosmic logics* with increasing accuracy.

2. Classical physics nurtured the emergence of quantum physics by seeking reality in nature

3. Accept a higher order challenge: What is the purpose of the cosmic evolution?

• Nature appears to be a creative system engineer.

• So, exploring and extrapolating the logical congruence between the diverse biospherical and cosmo-spherical *processes* would lead us closer to the purpose, if any, behind the apparent perfectly logical yet, incessantly evolving and changing "intelligent design".

• We can define the purpose behind human evolution if we can assign a purpose behind cosmic evolution!

• Our sustainable evolution depends upon learning to (i) first manage the biospheric evolution, and then (ii) become cosmic travelers!

• The best option is to become reverse engineers. In fact we already are. Our continuously evolving technologies and socio-politico-economic structures attest to that.

Let us focus on:

• How can we promote the *discovery* of actual *realities* in nature driven by *cosmic logics* rather than staying limited to the *invention* of realities that are esthetically pleasing to our *human logics*?

• How can we promote wealth creation processes through *inventions* by focusing on understanding the interaction *processes* in nature?

Processes in nature are our best anchors to understand nature!

A bit of history to connect on what I have worked on at INAOE from 1974 -78 and then ran away without finishing what I wanted to do?

1. I invited Nobel Laureate Willis Lamb at INAOE during the academic year 1976-77 to convince him that the problem of "photon" derives from assuming that the Fourier transformed frequencies due to a pure amplitude pulse are not real physical. Lamb was the most vocal "Anti photon" person at that time. I failed miserably! During the preceding years, all my papers mentioning this connections were summarily rejected. I was afraid for my long term livelihood! and left for US industry.
2. I came to INAOE in 1974 after my Post Doc and PhD from the Institute of Optics, Rochester, leaving many lucrative jobs in developed countries to enjoy freedom of research while learning about Latin American Culture (being familiar with the Asian and Western cultures). I was fully supported by my colleagues and I did enjoy my stay. I also used to have many lively discussions on quantum problems with the founding members of the Sociedad Epistemologia de Mexico, of which I was also one.
3. I came to US as a Fulbright Scholar and wanted to work under experimentalist Mandel at the Physics Department, University of Rochester. Unfortunately, my very first day encounter did not go well! I proposed to work to show that single photon interference is non-causal. He did the favor of transferring me to the Institute of Optics and helped me become a reverse engineer to understand nature's cosmic engineering wonders! Besides, my job opportunities became plentiful then.,
4. My introduction to Quantum Mechanics was by an Indian Professor, a student of Dirac from England. He was a very powerful professor. He completely shattered my sense of understanding of hands-on experimental physics and the related mathematical formulations in which I was very good at (at least I used to think!). I was still longing for reality in physics and I was not aware of Feynman's dictum: "Nobody understands Quantum Mechanics!"
5. Finally, in 1992, at the end of my "professional carrier" I decided to use the Western Democratic system and decided to organize a "political action committee" (PAC!) to explore: "The Nature of Light: What Are Photons?"

Do I understanding spatial Fourier transform & behavior of photographic pictures with raster lines?

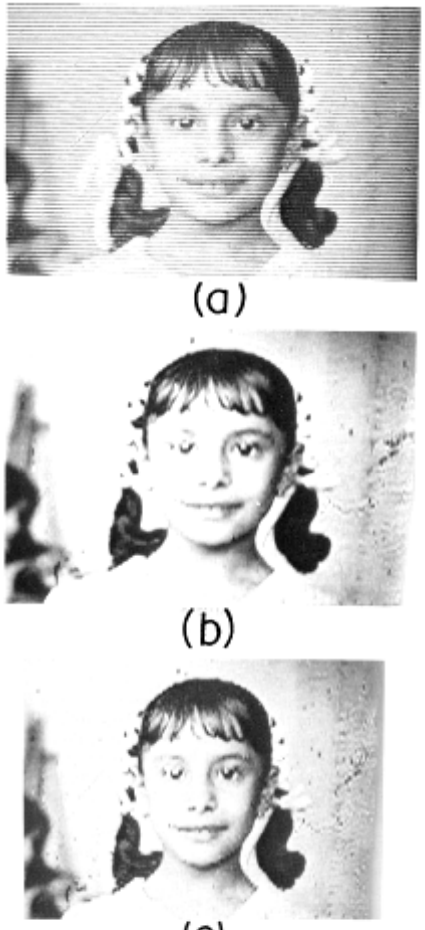


Fig. 4. Object sampled by opaque raster and its filtered images: (a) object; (b) image from zero order; and (c) image from first order.

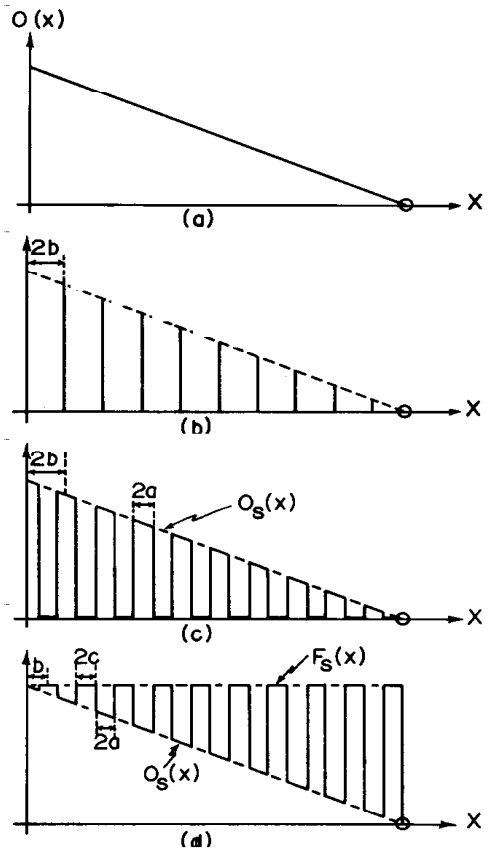


Fig. 1. Object functions: (a) original idealized object; (b) object sampled by a series of delta functions; (c) object sampled by lines of finite width, leaving unsampled regions completely opaque; and (d) object sampled by lines of finite width, leaving unsampled regions completely clear.

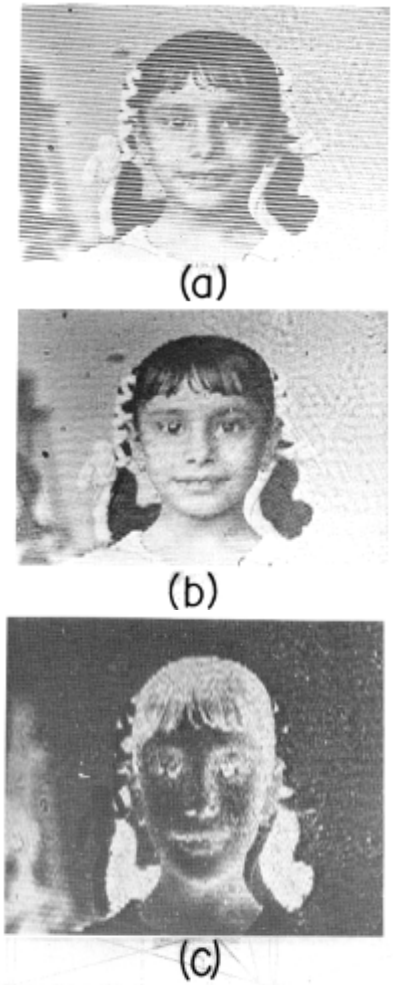


Fig. 5. Object sampled by clear raster and its images: (a) object; (b) image from zero order; and (c) image from first order.

C. Roychoudhuri & D. Malacara; Appl. Opt. **14**(7), 1683 (1975); "Spatial Filtering and Image Positive-Negative Reversal".

“Ask and ye shall receive!”

But, only if your epistemology guides you to ask the right question, and then only nature yields the “visual picture” behind its interaction processes!

Well formed light beams do not operate on each others energy distribution in the absence of mediation by material dipoles.

What are the consequences?

Publications from INAOE (1975-78)

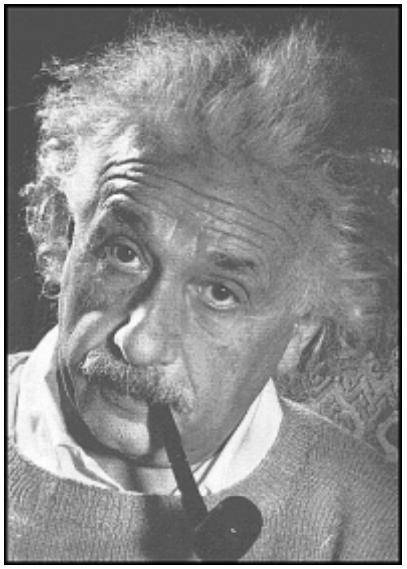
1. C. Roychoudhuri, J. Siqueiros & E. Landgrave; p.87-94, Proc. Conf. *Optics in Four Dimensions*, Eds. M. A. Machado Gama & L. M. Narducci, American Institute of Physics (1981); "Concepts of spectroscopy of pulsed light".
2. C. Roychoudhuri; Foundations of Physics, **8**(11/12), 845 (1978); "Heisenberg's Microscope - A Misleading Illustration".
3. C. Roychoudhuri & S. Calixto; Boletin. Inst. Tonantzintla, **2**(3), 187 (1977); "Spectroscopy of Short Pulses".
4. C. Roychoudhuri, Boletin. Inst. Tonantzintla, **2**(3), 165 (1977); "Causality and Classical Interference and Diffraction Phenomena".
5. A. G. Laguna-Alaya & C. Roychoudhuri; Boletin Inst. Tonantzintla, **2**(2),109, (1976); "States of Polarization in a Gas Laser with Internal Mirrors".
6. C. Roychoudhuri; Bol. Inst. Tonantzintla **2**(2), 101 (1976); **"Is Fourier Decomposition Interpretation Applicable to Interference Spectroscopy?"**
7. C. Roychoudhuri, R. Machorro & M. Cervantes; Bol. Inst. Tonantzintla **2**(1), 55 (1976); **"Some Interference Experiments and Quantum Concepts, II".**
8. C. Roychoudhuri; Opt. Eng.; **16**(2), 173 (1976); "Passive Pulse Shaping Using Delayed Superposition".
9. C. Roychoudhuri; J. Opt. Soc. Am.; **65**(12), 1418 (1976); "Response of Fabry-Perot Interferometers to Light Pulses of Very Short Duration". (The analysis of this paper is followed and cited in two books: a. "Fabry-Perot Interferometers"; G. Hernandez, Cambridge U., 1986 and b. "The Fabry-Perot Interferometer"; J. M. Vaughan; Adam Hilger, 1989.)
10. C. Roychoudhuri; Bol. Inst. Tonantzintla **1**(5), 259 (1975); "Two Beam Interference Experiments and Some Quantum Concepts".
11. C. Roychoudhuri & D. Malacara; Appl. Opt. **14**(7), 1683 (1975); "Spatial Filtering and Image Positive-Negative Reversal".
12. C. Roychoudhuri, J.C. Fouere & A. Cornejo; Appl. Opt. **14**(9), 2051 (1975); "Temporal Coherence Length and Speckle: A Simultaneous Approach to Those Problems in Holography".
13. C. Roychoudhuri & R.H. Noble; Am. J. Phys. **43**(12), 1057 (1975); "Demonstration using a Fabry-Perot. II. Laser Modes Display". (This paper is also reprinted in the book, "Lasers: Selected Reprints", Eds. D.C. O'Shea & D.C. Peckham; Am. Assn. Physics Teachers, 1982.)
14. C. Roychoudhuri; Am. J. Phys. **43**(12), 1054 (**1975**); "Demonstration Using a Fabry-Perot. I. Multiple-Slit Interference".

List of recent publication by the author based on CC-LC-(ER)^2 epistemology & non-interference of light [2003-07]

1. "Shall we climb on the shoulders of the giants to extend the REALITY horizon of Physics?" by C. Roychoudhuri, invited talk at the 4th International Conference on "Quantum Theory-Foundational Reconsiderations", at Vaxjo U., Sweden, Jun.11-16, 2007; to be published in 2007.
2. "Can classical optical superposition principle get us out of quantum mysticism of non-locality and bring back REALITY to modern physics?" by C. Roychoudhuri, invited talk at the ETOP conference at Toronto, Jun.3-5, 2007; to be published in 2007 by SPIE;
3. *The Nature of Light: What Is a Photon? by* C. Roychoudhuri, A. F. Kracklauer & Kathy Creath,; CRC Press (2007); in preparation.
4. "Can a deeper understanding of the measured behavior of light remove wave-particle duality?" by C. Roychoudhuri, SPIE Proc.**Vol.6664**, paper #2 (to be published, Aug. 2007).
5. "Can we get any better information about the nature of light by comparing radio and light wave detection processes?" by C. Roychoudhuri and P. Poulos, SPIE Proc.**Vol.6664**, paper #12 (to be published, Aug. 2007).
6. "Can the hypothesis 'photon interferes only with itself' be reconciled with superposition of light from multiple beams or sources?" by C. Roychoudhuri, N. Prasad and Q. Peng, SPIE Proc.**Vol.6664**, paper #24 (to be published, Aug. 2007).
7. "Bi-centenary of successes of Fourier theorem! Its power and limitations in optical system designs" by C. Roychoudhuri, invited paper, Proc. SPIE Vol. **6667**, paper #18 (Oct. 2007).
8. "If EM fields do not operate on each other, why do we need many modes and large gain bandwidth to generate short pulses?" by C. Roychoudhuri, N. Tirfessa, C. Kelley & R. Crudo,; SPIE Proceedings, Vol. **6468**, paper #53 (2007).
9. "Locality of superposition principle is dictated by detection processes" by C. Roychoudhuri, Phys. Essays **19** (3), September 2006.
10. "Spectral Super-Resolution by Understanding Superposition Principle & Detection Processes", by C. Roychoudhuri and M. Tayahi, Intern. J. of Microwave and Optics Tech.**,** July 2006; manuscript ID# IJMOT-2006-5-46: http://www.ijmot.com/papers/papermain.asp.
11. "Various ambiguities in re-constructing laser pulse parameters" by C. Roychoudhuri and N. Prasad, proceedings of the October, 2006 IEEE-LEOS Annual Conference, Montreal, Canada; invited.
12. "Do we count indivisible photons or discrete quantum events experienced by detectors?" by C. Roychoudhuri and N. Tirfessa, Proc. SPIE Vol.**6372**-29 (2006).

List of recent publication by the author based on CC-LC-(ER)^2 epistemology & non-interference of light (list-p.2) [2003-07]

13. "If EM fields do not operate on each other, how do we generate and manipulate laser pulses?" by C. Roychoudhuri, D. Lee and P. Poulos, Proc. SPIE Vol.**6290**-02 (2006).
14. "Are dark fringe locations devoid of energy of superposed fields?" by C. Roychoudhuri and C. V. Seaver, Proc. SPIE Vol. **6285**-01 (2006), invited.
15. "A critical look at the source characteristics used for time varying fringe interferometry" by C. Roychoudhuri and N. Tirfessa, Proc. SPIE Vol.**6292**-01, (2006), invited.
16. "Role of the retinal detector array in perceiving the superposition effects of light" by C. Roychoudhuri and V. Lakshminarayanan, Proc. SPIE Vol.**6285**-08 (2006).
17. "Reality of superposition principle and autocorrelation function for short pulses" by C. Roychoudhuri, Proc. SPIE Vol. **6108**-50 (2006).
18. "If superposed light beams do not re-distribute each others energy in the absence of detectors (material dipoles), can an indivisible single photon interfere by/with itself?" by C. 18. Roychoudhuri, SPIE Conf. Proc. **5866**, pp.26-35 (2005).
19. "If superposed light beams do not re-distribute each others energy in the absence of detectors (material dipoles), can an indivisible single photon interfere by/with itself?" by C. Roychoudhuri, Proc. SPIE Vol.**5866**, pp.26-35 (2005).
20. "*The Nature of Light: What Is a Photon?* Eds. C. Roychoudhuri, Katherine Creath and A. F. Kracklauer, Proc. SPIE Vol.**5866** (2005); Year of Einstein Special Conference.
21. "Propagating Fourier frequencies vs. carrier frequency of a pulse through spectrometers and other media" by C. Roychoudhuri, Proc. SPIE Vol.**5531**, 450-461(2004).
22. *The Nature of Light: What is a Photon?*", Guest Eds. C. Roychoudhuri & R. Roy, Optics & Photonics News Trends; special issue of OPN, October 2003. [http://www.osa-opn.org/abstract.cfm?URI=OPN-14-10-49].
23. "Measuring properties of superposed light beams carrying different frequencies" by D. Lee and C. Roychoudhuri, Optics Express **11**(8), 944-51, **(2003)**, [http://www.opticsexpress.org/abstract.cfm?URI=OPEX-11-8-944].
24. "Limits of DWDM with gratings and Fabry-Perots and alternate solutions" by C. Roychoudhuri, D. Lee, Y. Jiang, S. Kittaka, M. Nara, V. Serikov and M. Oikawa, Proc. SPIE Vol.**5246**, 333-344, (2003), invited.



“What are light quanta?”

This is a wrong question!

For it presumes that emission of a quantum mechanically bound quantized electron necessarily require the absorption of a single indivisible photon to match the energy requirements.

$$\Delta E_{p,q} = h\nu \quad \text{and} \quad \Delta E_{p,q} \neq (\frac{1}{2}h\nu + \frac{1}{3}h\nu + \frac{1}{6}h\nu), \text{ etc.}$$

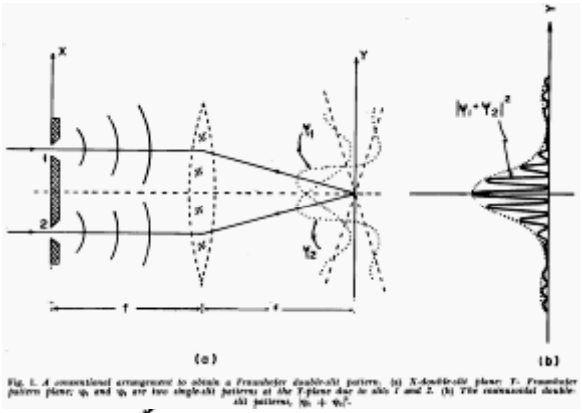
Yet, in all multi-beam non-linear optics and multi-frequency heterodyne detection, material dipoles are routinely summing energies from different sources.

It also implies complete neglect of the fact that light cannot propagate without continuous diffraction, with or without any obstruction by apertures.

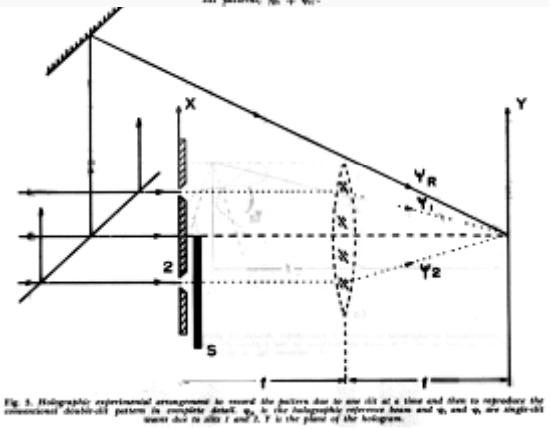
"Which way" does the photon travel?

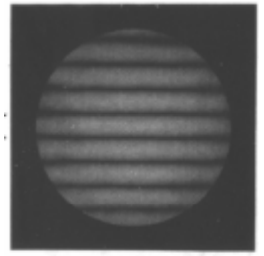
This is a wrong question for it starts with the assumption that photons are indivisible particles and yet they can gather time-separated two different phase information regarding the existence of the two slits while determining its site of arrival. This does not appear to me as causally valid scientific question.

$$\psi_1 = ae^{i2\pi\nu\tau_1};\quad \psi_2 = ae^{i2\pi\nu\tau_2}$$
$$|\psi_1+\psi_2|^2 = |\psi_1|^2 + |\psi_2|^2 + \psi_1^*\psi_2 + \psi_1\psi_2^*$$
$$= 2a^2[1+\cos 2\pi\nu(\tau_1-\tau_2)]$$

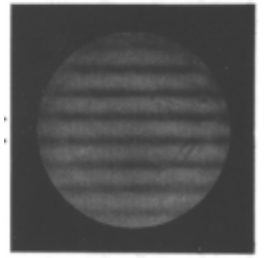


$$E_1 = ae^{i2\pi\nu\tau_1};\quad E_2 = ae^{i2\pi\nu\tau_2}$$
$$\psi_1 = \chi_{(1)}ae^{i2\pi\nu\tau_1};\quad \psi_2 = \chi_{(1)}ae^{i2\pi\nu\tau_2}$$
$$|\psi_1+\psi_2|^2 = |\psi_1|^2 + |\psi_2|^2 + \psi_1^*\psi_2 + \psi_1\psi_2^*$$
$$= 2\chi_{(1)}^2a^2[1+\cos 2\pi\nu(\tau_1-\tau_2)]$$

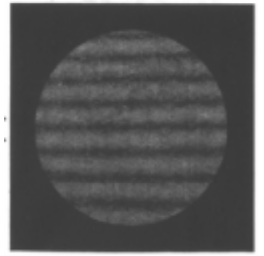




Standard double-slit pattern.



Reconstructed hologram - each slit recorded separately.



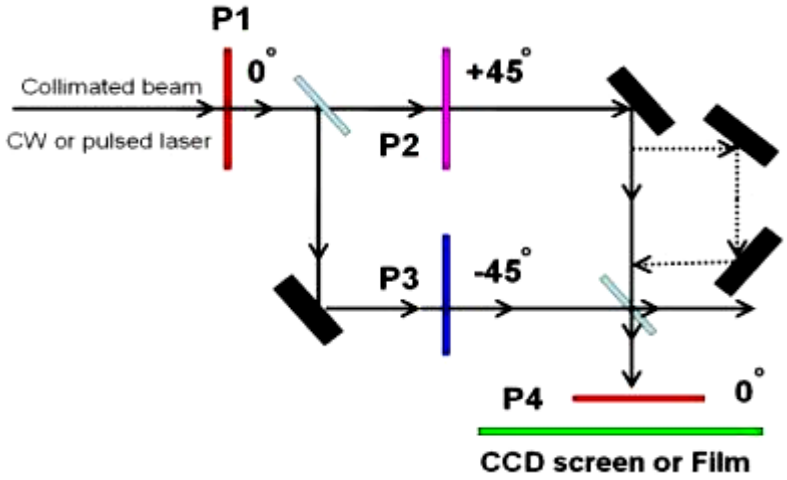
Real-time holography – one slit recorded, second slit projected through.

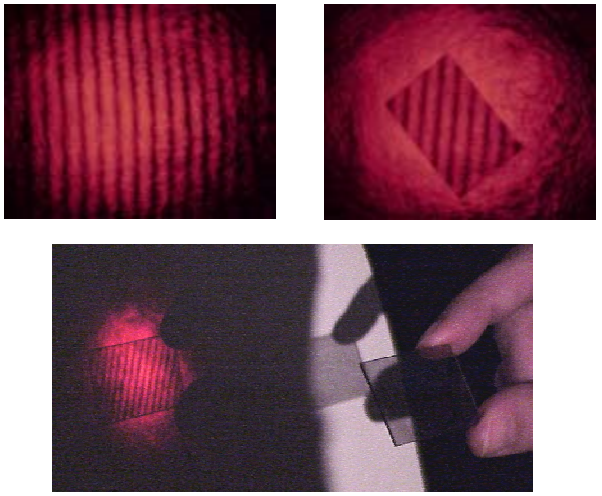
A non-causal question draws out a non-causal answer from our epistemology !

C. Roychoudhuri, R. Machorro & M. Cervantes; Bol. Inst.Tonantzintla 2(1), 55 **(1976)**; "Some Interference Experiments and Quantum Concepts, II".

The locality of Mach-Zehnder (MZ) fringes are underscored using a small piece of Polaroid in front of the detector screen when the two superposed MZ beams are deliberately made orthogonally polarized.

Spatial locality of MZ fringes by post- manipulation of the beams outside the MZ by a polaroid of spatially limited size, on the detector plane.





Top-Right: Schematics of the MZ interferometer with four polarizers to assure proper manipulation of the state of polarization while keeping the amplitudes of the two beams very closely equal. Top-left: The two states of polarizations are parallel in the two MZ arms. Bottom-left: The two states of polarizations are orthogonal to each other in the two MZ arms indicating complete loss of fringe effect, except in the middle of the screen where a linear polarizer is placed right on the detector plane bisecting the two orthogonal directions.

Discrete “clicks” do not prove the existence of indivisible photons. Electrons are quantized and photographic films are made out of discrete grains. Besides single photons are not detectable!

At extreme low light level the pinhole diffraction rings become undetectable!

Panarella: “This paper reviews a series of experiments carried out during the early eighties, which suggest that the simultaneous presence of multiple photons (multiple units of hv) makes possible the registration of a single photographic blackening spot or the emission of a single photoelectron.”

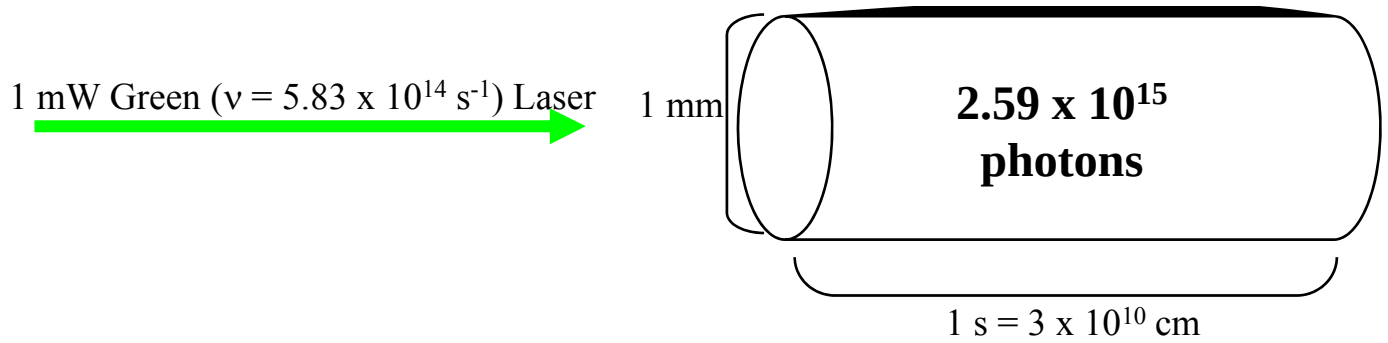
a
3.91<8> photons.
20 sec. exposure

b
2.27<9> photons.
17h36min exposure

c
5.19<10> photons.
336h26min exposure

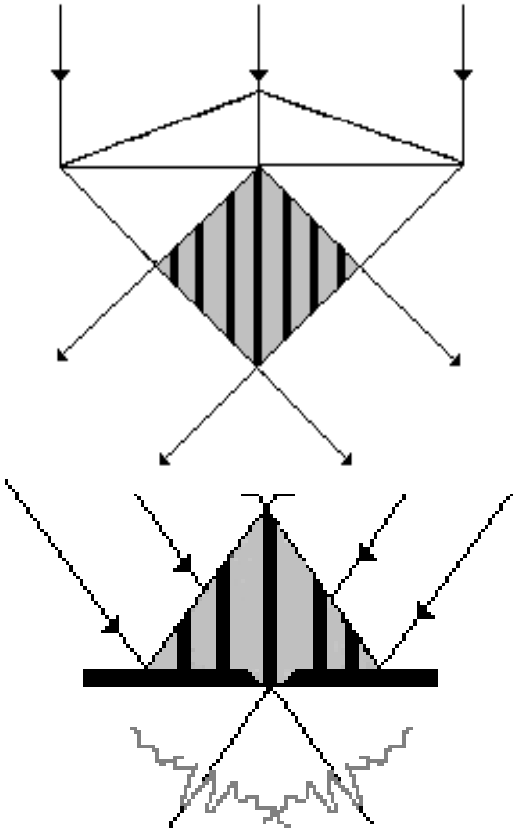
E. Panarella, SPIE Proc. Vol. **5866**, pp.218-228, (2005), “Single Photons have not been detected. The alternative photon clump model”. See also by E. Panarella, “Nonlinear behavior of light at very low intensities: the photon clump model”, p.105 in *Quantum Uncertainties – recent and future experiments and interpretations*, Eds. W. M. Honig, D. W. Kraft & E. Panarella, Plenum Press (1987).

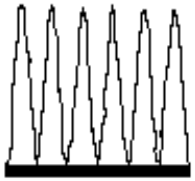
An electromagnetic field cannot deliver energy at a rate faster than its finite velocity c or c/n



A remarkably low flux of EM field energy passes through an atomic volume !
Some very complex process lies behind the delivery of ΔE amount of energy for the transfer of a photo electron from one state to another.

Let's replace Young's "single beam double-slit interferometer" by Chandra's "double-beam single-slit interferometer" using a Fresnel's bi-prism





- If I slide the single slit on a "dark fringe" location, would I produce two independent single-slit diffraction patterns or no light at all ?!!
- What would happen if you put a ground glass right behind the slit opening?

Maxwell & Fourier: In the absence of actual linear *interactions between the fields*, a linear summation (superposition) does not have any physical validity.

Mathematically Maxwell's wave equation can accept the linear superposition of many sinusoids, but it does not represent a physical situation:

$$\nabla^2 \bar{E} = (1/c^2)\partial^2 \bar{E}/\partial t^2 \qquad b_{total}(t) = \sum_n b_n \exp[-i2\pi\nu_n t]$$

Well before Maxwell, Fourier established a very useful theorem for handling a time finite signal by its mathematical transform in the frequency space using the well-known integral. Since EM fields do not operate on each other, simple superposition of infinite trains of many frequencies cannot contract their energy into a finite pulse. We need saturable absorber to create mode lock lasers. Just as a pulse cannot be synthesized just by the fields alone, same way, a pulse cannot be decomposed into infinite trains of component frequencies unless a medium can be found to carry this out. A nonlinear medium can produce different frequencies, but they can be only a specific set of harmonics determined by the material characteristics.

$$a(t) = \int_0^\infty \tilde{a}(f)\exp[-i2\pi ft]df \qquad \tilde{a}(f) = \int_0^\infty a(t)\exp[-i2\pi ft]dt$$

We have deliberately used different symbols for the frequencies used by Maxwell's wave equation and the Fourier's time-frequency theorem to underscore the difference between the actual (or physical) carrier frequencies for EM waves and the generalized Fourier's mathematical frequencies, which may or may not be identical for all cases of actual situations.

Only when we multiply the field amplitude coefficients by the dipolar susceptibilities of the interacting medium, the equations starts representing physical interaction processes! Susceptibility contains the material quantum properties!!

Representing superposed EM fields

In the absence of any interacting medium, n-superposed EM fields of n-frequencies, should be presented without connecting them with operational mathematical symbols, since light beams do not operate on each other: $\vec{e}_{total}(\nu,t) \in \vec{e}_1(\nu_1,t);\vec{e}_2(\nu_2,t);.....\vec{e}_n(\nu_n,t)$

In the presence of an interacting medium, the collective dipole undulation can be represented by the superposition of a set of **dipole undulations** which are allowed by the material quantum conditions; the rest of the EM fields should be left out of the superposition set:

$$\vec{d}_{total}(t)=\vec{e}_1(\nu_1,t);....[\vec{d}_p(\nu_p,t)+\vec{d}_{p+1}(\nu_{p+1},t)+.....+\vec{d}_{p+r}(\nu_{p+r},t)];....;\vec{e}_n(\nu_n,t)$$

$$\vec{d} = [{}_{(n)}\vec{\chi}][\vec{a}]$$

For anisotropic media, it is a painful computation process!

The *process* of summation implied by 'Superposition Principle' is done by the material dipoles, and not by the EM fields!

Re-think quantum communication by manipulating only light !!

Effects of uncritical acceptance of Fourier theorem as effectively a principle of Classical Physics and Quantum Physics

Classical Physics

Space-space transform; optical signal processing

- **Delay-frequency transform; Fourier transform spectroscopy (FTS)**
- **Time-frequency transform, classical spectrometry**
- **Time-frequency transform, Coherence theory**
- **Time-frequency transform, Coherence theory**
- **Time-frequency transform, laser mode locking**
- **Time-frequency transform, pulse dispersion**
- **Bell's theorem and interference as an emergent phenomenon**

Quantum Physics

1. Heisenberg's uncertainty relation

2. Dirac's second quantization (?) $[a, a^{+}] \equiv$ {Einsatein's A & B Coefficients}

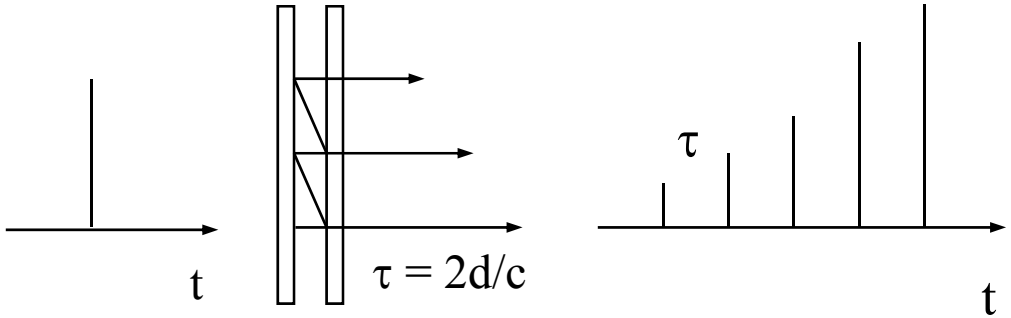
3. Bell's inequality {Two term Fourier superposition?}

How does a spectrometer really work?

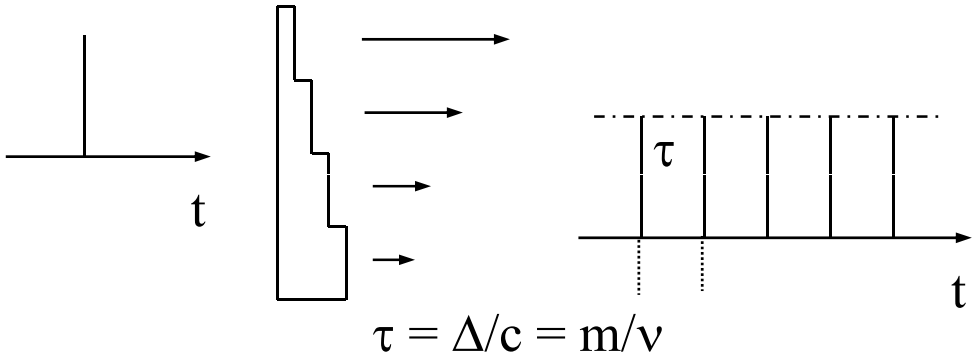
Gratings & Fabry-Perots are pulse replicators

Incident beam is replicated into a periodically delayed train of new beams and then they are superposed to generate the "spectroscopic" dispersion.

Tools: Amplitude division and wave front division



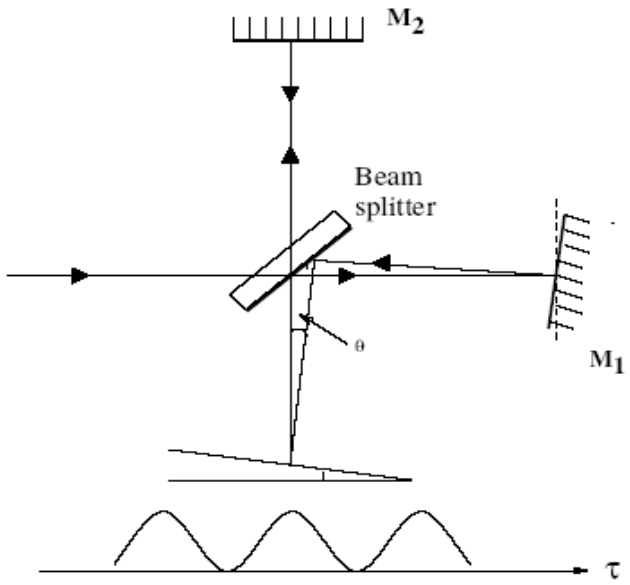
$$h(t) = \sum_{n=0}^{N-1} \left[TR^n, or \frac{1}{N} \right] \cdot \delta(t - n\tau)$$



All spectrometers have a time constant

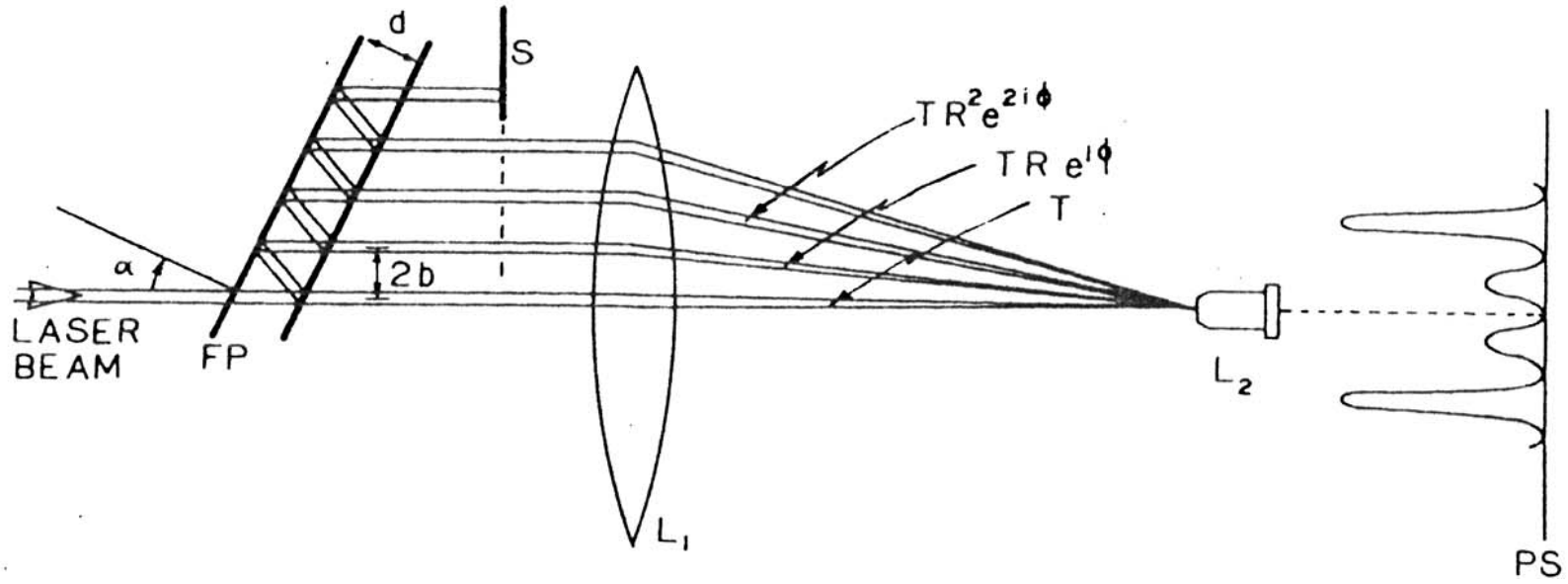
$$\tau_0 = N\tau$$

In contrast, Michelson spectrometer introduces continuously variable delay between only a pair of replicated beams



Conceptually, a Lummer-Gehrcke plate can simulate all two- and multiple-beam interferometers and gratings.

Accordingly, common approach can be made to develop the mathematical formulation

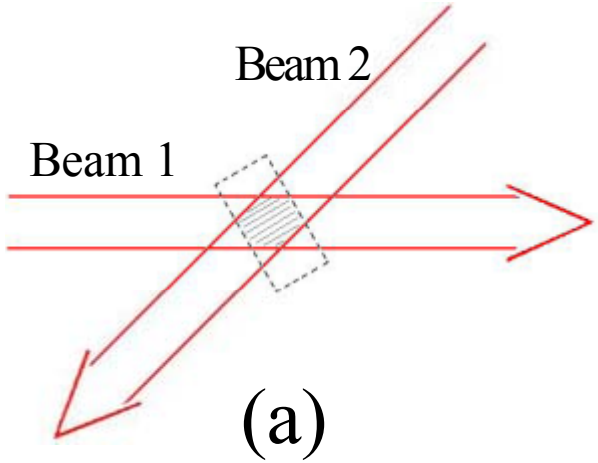


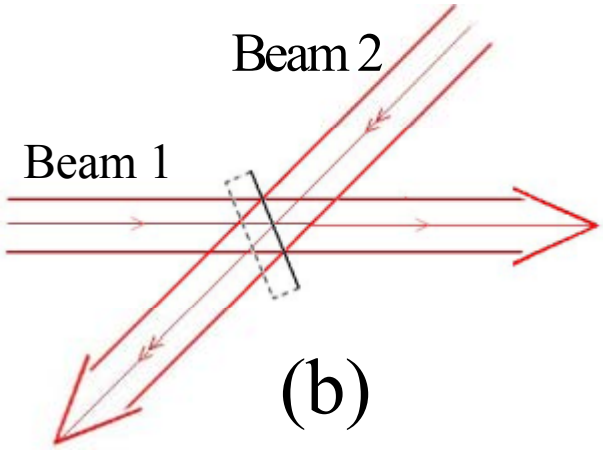
C. Roychoudhuri; Am. J. Phys. 43 (12), 1054 (1975); “Demonstration Using a Fabry-Perot. I. Multiple-Slit Interference”.

How does a beam splitter work?

Note the energy re-direction capability of a beam splitter only when the Poynting vectors of the transmitted and reflected beams are collinear!

Superposition effect become manifest only through the response of material dipoles.





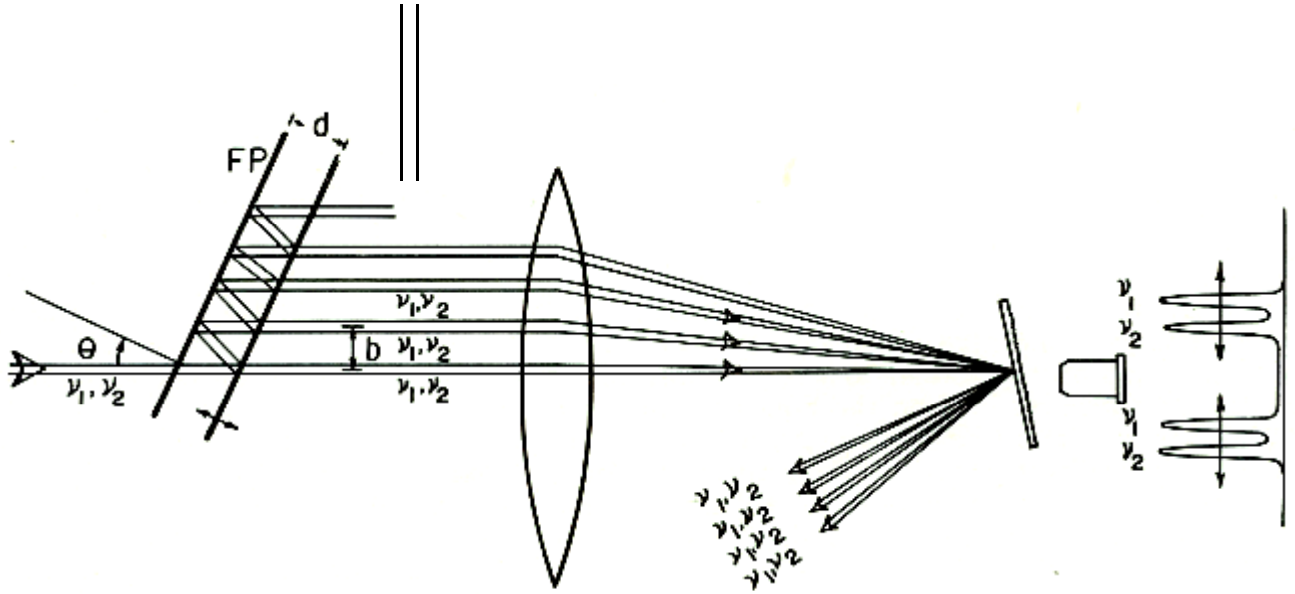
• Does the spatial and temporal energy distribution of two crossing light beams alter at all while passing through non-interacting medium?

• A 50% beam splitter can become a 100% transmitter or a reflector when two coherent and equal amplitude beams are incident on it from the opposite sides with **"pi" phase difference**.

• When there is only one indivisible photon at a time in the system, what would make the "photons" go one way or the other?

Without this "pi" phase difference one cannot have an interferometer with collimated beams!

How is the energy re-distributed by a grating or a Fabry-Perot?

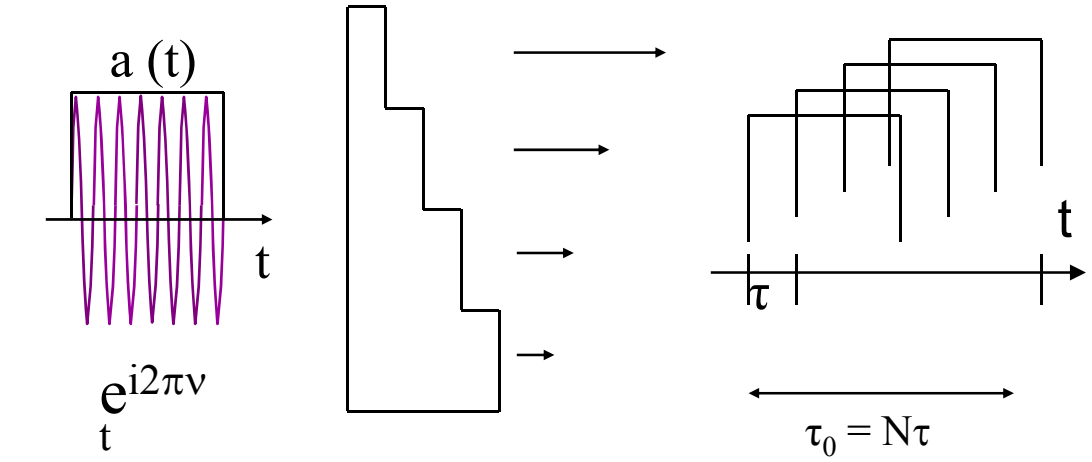


Experimental demonstration of **non-interaction of light beams** in spite of crossing each other at the focal plane, while at the same time, delivering the classical spectrometric information when a detector (or a scatterer) is placed in the plane of superposition

Time domain formulation –

generalized spectrometry

Appreciating the fringe broadening effects due to partial interference of partially overlapped pulses



Carrier frequency

The temporal impulse response: $$h(t) = \sum_{n=0}^{N-1}\left[TR^n, or \frac{1}{N}\right]\cdot\delta(t-n\tau)$$

The direct time domain approach: $$i_{out}(t,\nu) = h(t)\otimes a(t)\cdot e^{i2\pi\nu t}$$

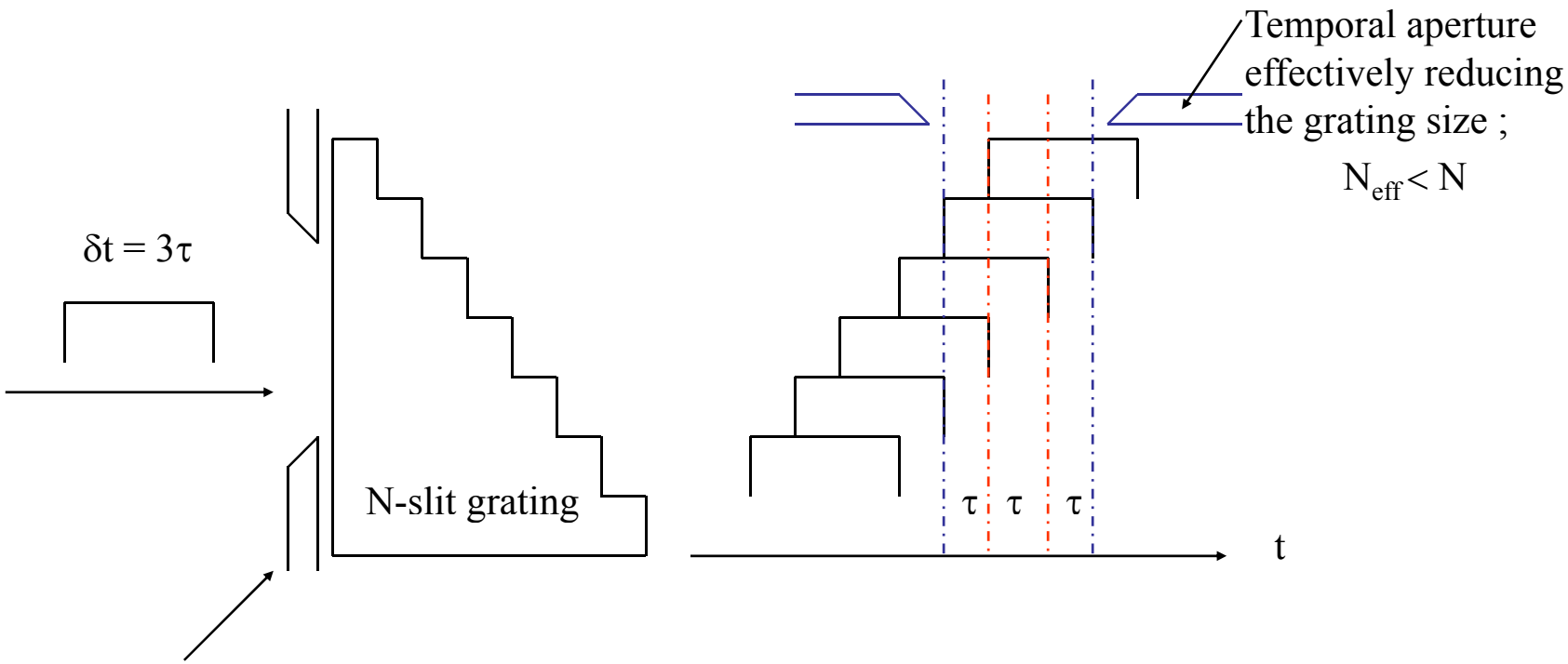
Fourier frequency approach:

$$\tilde{h}(f) = \sum_{n=0}^{N-1}\left[TR^n, or \frac{1}{N}\right]e^{i2\pi nf\tau} = \left[\frac{T}{1-R\,e^{i2\pi f\tau}}\right]_{FP}, or \frac{1}{N}\left[\frac{1-e^{i2\pi Nf\tau}}{1-e^{i2\pi f\tau}}\right]_{grating}$$

C. Roychoudhuri, “Propagating Fourier frequencies vs. carrier frequency of a pulse through spectrometers and other media”; Proc. SPIE Vol.**5531**, 450-461(2004); *Interferometry-XII: Techniques and Analysis*.

Spatio-Temporal Fringe Broadening

Both space & time apertures create fringe broadening



- There are N replicated pulses
- Only 3 pulses are superposed partially at any time
- Simultaneous superposition of 3 pulses happen only for a fraction of the time N τ

Time integrated energy recorded by a detector

$$I''_{\text{pls}}(\nu,\tau)=\int_{-T_0/2}^{+T_0/2}\left|i_{out}(t)\right|^2 dt$$

After some mathematical processing and simplification:

$$I_{pls}(\nu,\tau)=\sum_{n=0}^{N-1}T^2R^{2n}+2\sum_{n\neq m}^{N-1}T^2R^{n+m}\gamma(|n-m|\tau)\cos[2\pi(n-m)\nu\tau]$$

For a Fabry-Perot

$$=\frac{1}{N}+\frac{2}{N^2}\sum_{p=1}^{N-1}(N-p)\gamma(p\tau)\cos[2\pi p\nu\tau]$$

For a Grating

The auto-correlation between the n-th and the m-the pulses:

$$\gamma(p\tau)\equiv\gamma_{nm}(\tau)\equiv\gamma(|n-m|\tau)=\frac{\int a(t-n\tau)a(t-m\tau)\ dt}{\int a^2(t)\ dt}$$

A generalized theory of spectrometry

The expression for time integrated fringe energy is identical to the classical CW formulation when the pulse length exceeds the spectrometer time constant

Take direct square modulus:

$$\tilde{H}(f) = \left|\tilde{h}(f)\right|^2 = \left|\sum_{n=0}^{N-1}\left(TR^n, or 1/N\right)e^{-i2\pi nf\tau}\right|^2 ; e^{-i2\pi ft}\,FT-Kernel$$

$$I_{cw}(f,\tau) \equiv \tilde{H}(f) = \left[\frac{T^2}{(1-R)^2 + 4R\sin^2\pi f\tau}\right]_{FP}, or \left[\frac{1}{N^2}\frac{\sin^2\pi Nf\tau}{\sin^2\pi f\tau}\right]_{grating}$$

Or, take the cross product of the two conjugate series:

$$I_{cw}(f,\tau) \equiv \tilde{H}(f) = \left(\sum_{n=0}^{N-1}\left(TR^n, or 1/N\right)e^{i2\pi nf\tau}\right)\left(\sum_{n=0}^{N-1}\left(TR^n, or 1/N\right)e^{-i2\pi nf\tau}\right)$$

$$= \sum_{n=0}^{N-1} T^2R^{2n} + 2\sum_{n\neq m}^{N-1} T^2R^{n+m}\cos[2\pi(n-m)f\tau]$$

For Fabry-Perot

$$= \frac{1}{N} + \frac{2}{N^2}\sum_{p=1}^{N-1}(N-p)\cos[2\pi pf\tau]$$

For grating

$$\underset{\delta t\to\tau_0=N\tau}{Lt.}\left[I_{pls}(\nu,\tau)\right] = I_{cw}(\nu,\tau) = I_{cw}(f,\tau); \nu \square \quad f\ !!$$

The “spectrally” broadened fringe, after time integration,

does conform to the Fourier intensity “spectrum”

when one cleverly juggles the math to use the Parseval’s theorem of energy conservation.

Time integrated fringe energy distribution is mathematically same by time- or Fourier-domain approach

The Fourier frequencies for the input pulse are:

$$FT[a(t)e^{i2\pi\nu t}] = \tilde{a}(\nu - f); e^{-i2\pi ft}\, FT - Kernel$$

The amplitude for the direct time-domain approach:

$$i_{out}(t,\nu) = h(t) \otimes a(t) \cdot e^{i2\pi\nu t}$$

Then the Fourier transform and the corresponding energy are:

$$\tilde{i}_{out}(f) = \tilde{h}(f) \cdot \tilde{a}(\nu - f); \qquad \left|\tilde{i}_{out}(f)\right|^2 = \tilde{H}(f) \cdot \tilde{A}(\nu - f)$$

Parseval's theorem of energy conservation:

$$\int_{-\infty}^{\infty} \left|i_{out}(t)\right|^2 dt = \int_{-\infty}^{\infty} \left|\tilde{i}_{out}(f)\right|^2 df$$

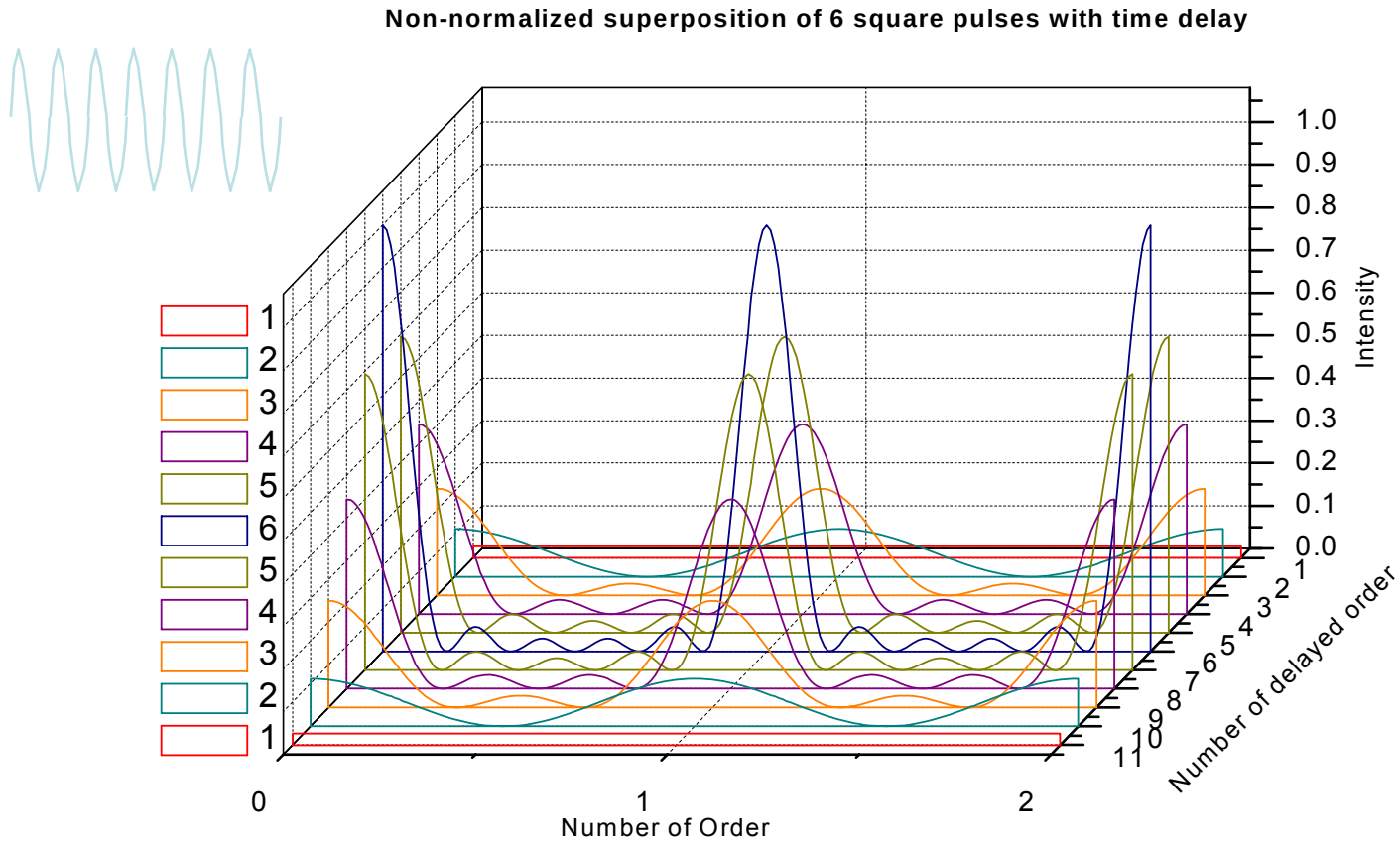
$$= \int_{-\infty}^{\infty} \tilde{H}(f) \cdot \tilde{A}(\nu - f) df = \tilde{H}(\nu) \otimes \tilde{A}(\nu)$$

$$\boxed{I_{pls}(\nu,\tau) \approx \int_{-\infty}^{\infty} \left|i_{out}(t)\right|^2 dt = I_{cw}(\nu) \otimes \tilde{A}(\nu)}$$

The time integrated fringe energy distribution, through time domain pulse propagation, is equivalent to convolution of the Fourier intensity spectrum of the pulse with the CW-intensity response of a spectrometer.

Time evolving fringe width as the replicated and partially superposed train of pulses propagates through a fast detector, like a streak camera.

The effective number superposed beams on the detectors changes with time giving rise to time varying fringe widths. These widths do not represent any new optical frequencies other than what was originally in the incident pulse. The diagram does not represent time varying optical spectrum!

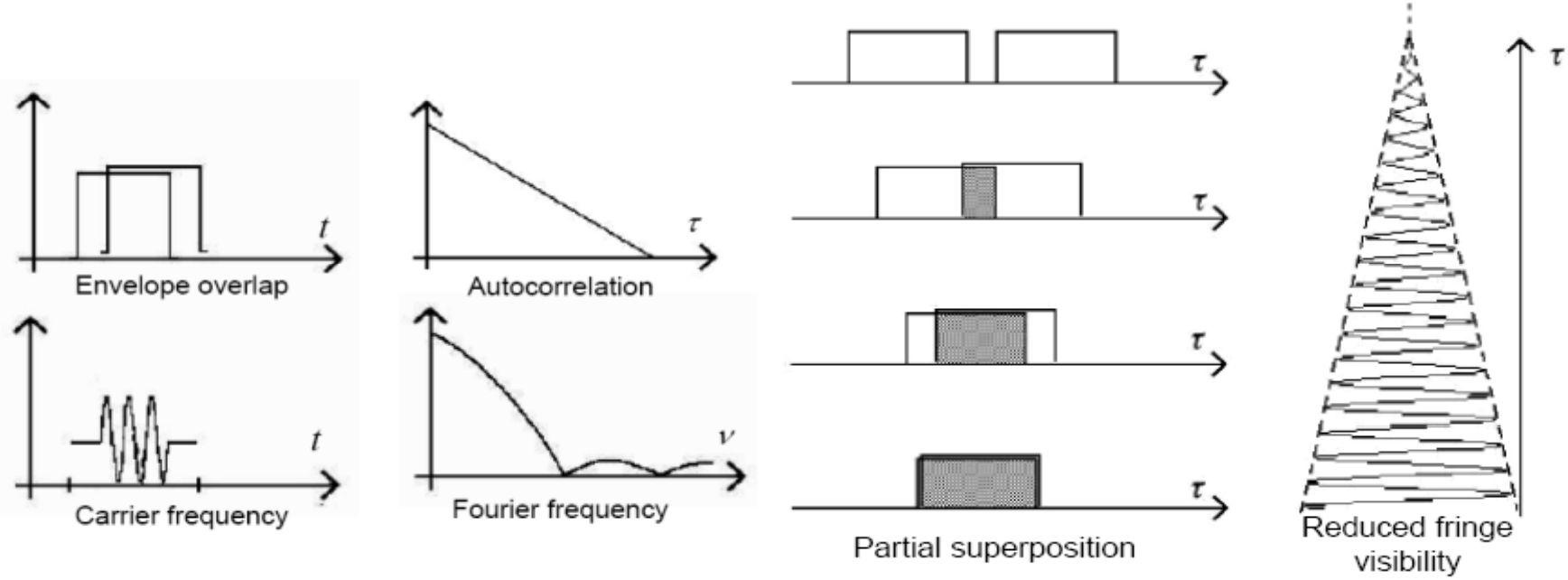


Any practical consequences ?

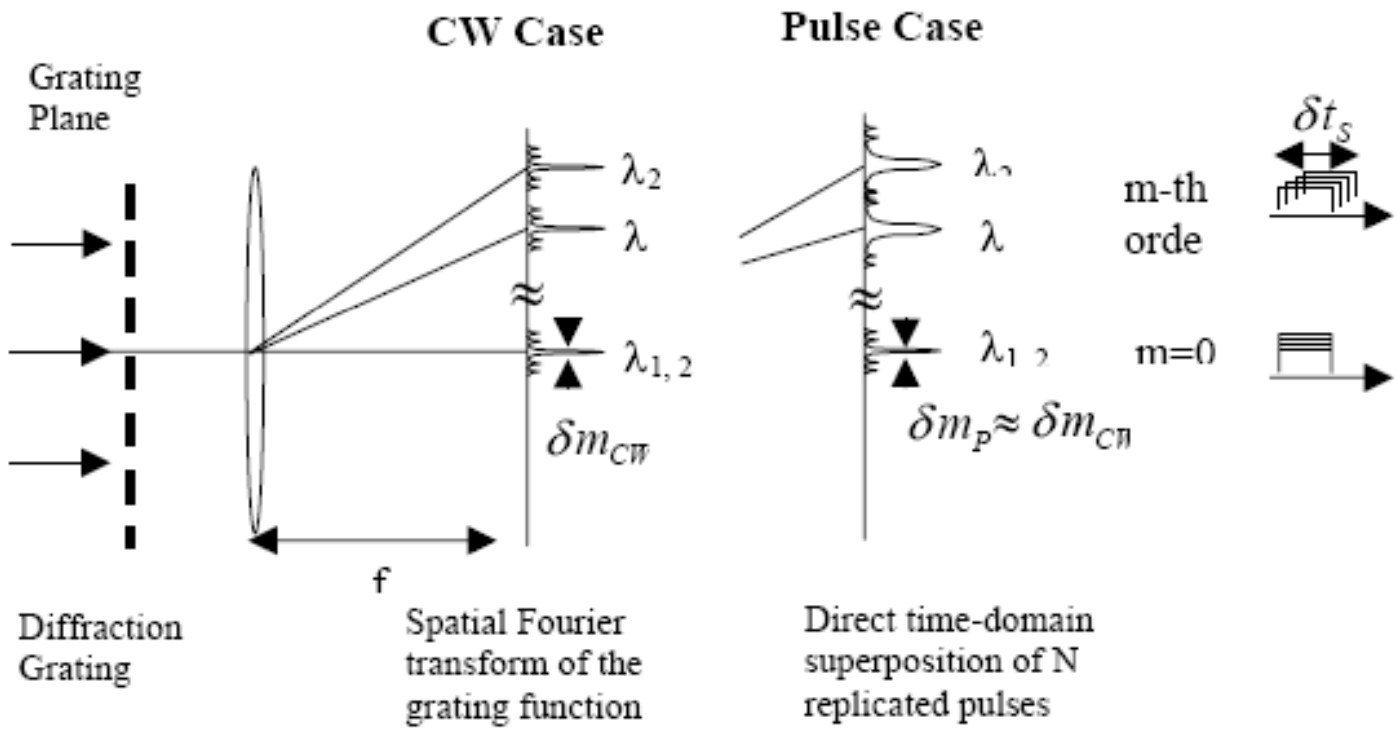
Wiener-Khintchine theorem

A simple way to appreciate the temporally changing amplitude effects in superposition as recorded by detectors that matches the prediction of the W-K theorem when there is only a single carrier frequency

Free space; single pulse!



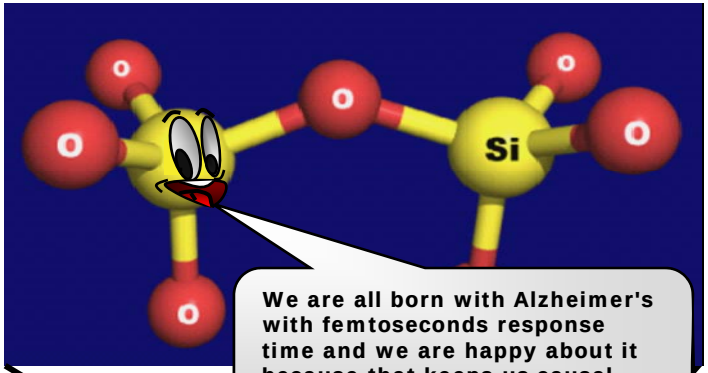
Appreciating pulse stretching as a time domain propagational delays, not a frequency dispersion!



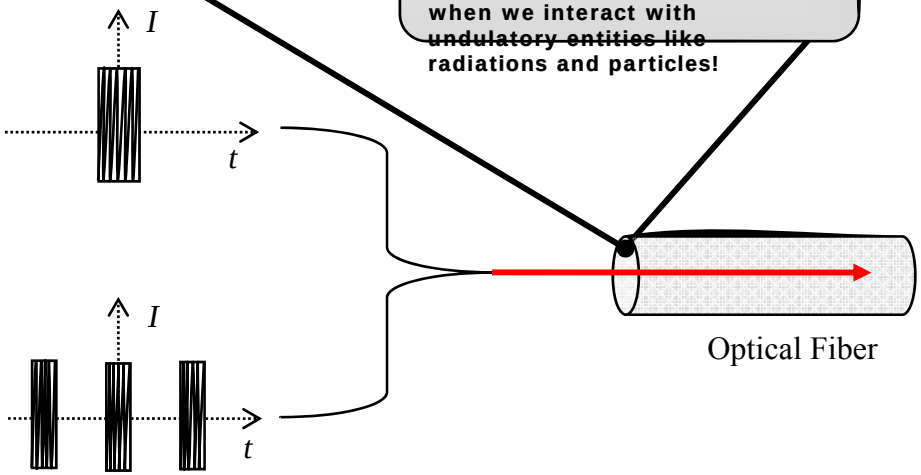
Pulse broadening is time-diffraction!

Dispersive vs. diffractive broadening

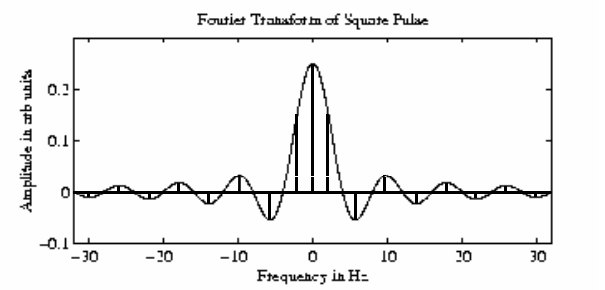
Can a silica molecule in a fiber really respond to the Fourier frequencies of a time pulse irrespective of the shape, duration and repetition of the input pulse?



A nano second (ns) pulse is one foot long in free space and it takes a ns to enter into a fiber.



The Fourier frequency distributions are very different for different pulses and pulse trains



BROADENING OF A SINGLE PULSE IN A DISPERSIVE MEDIUM

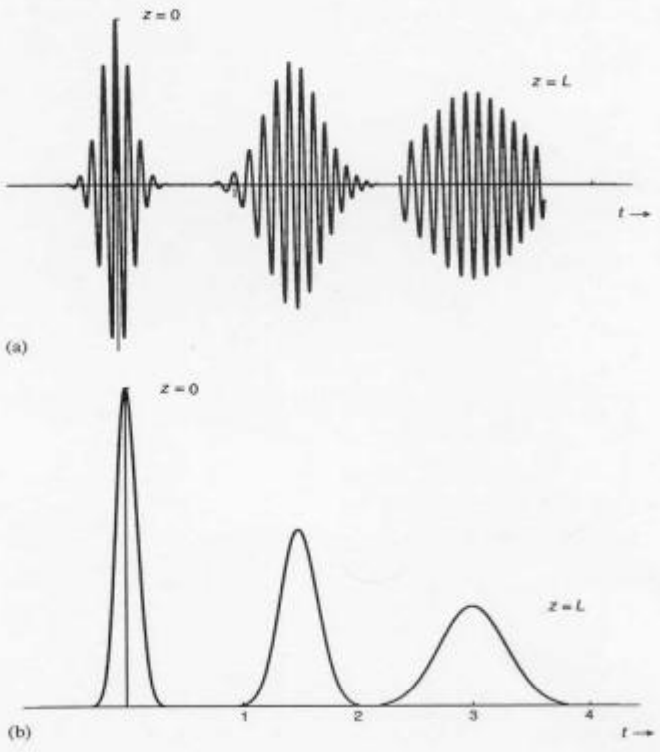
The imaginary envelope of the E-vector's amplitude distribution is represented by the superposition of the Fourier transformed frequencies. These frequencies are then propagated through the dispersive medium experiencing different velocities, or phase delays. Summing the phase delayed Fourier components give rise to the pulse broadening.

However, unlike the natural appearance of the spatial Fourier transform for far-field diffraction due to H-F principle, time-frequency Fourier transform is only a mathematical convenience; there is no supporting principle of Physics.

Fourier frequencies are of mathematical convenience. They do not represent real carrier frequencies of the EM field. Otherwise, we would not have to struggle so hard with non-linear optics to generate new optical frequencies.

The conceptual foundation of "Group velocity" is fundamentally erroneous!

Fig. 6.10: The temporal broadening of a Gaussian pulse. (a) The electric field distribution and (b) the corresponding intensity variation.



The corresponding intensity distribution is given by

$$I(z,t) = \frac{I_0}{(\tau(z)/\tau_0)} \exp\left[\frac{-2\left(t - \frac{z}{v_g}\right)^2}{\tau^2(z)}\right] \qquad (6.40)$$

which is plotted in Figure 6.10(b) for different values of z.

Figure 6.10 clearly shows the broadening of the pulse and shows that the peak of the pulse moves with the group velocity given by equation (6.1). We note that

$$\int_{-\infty}^{+\infty} I(z,t)\,dt$$

is independent of z, showing that the total energy contained in the pulse is conserved. From equation (6.40) we may note the following:

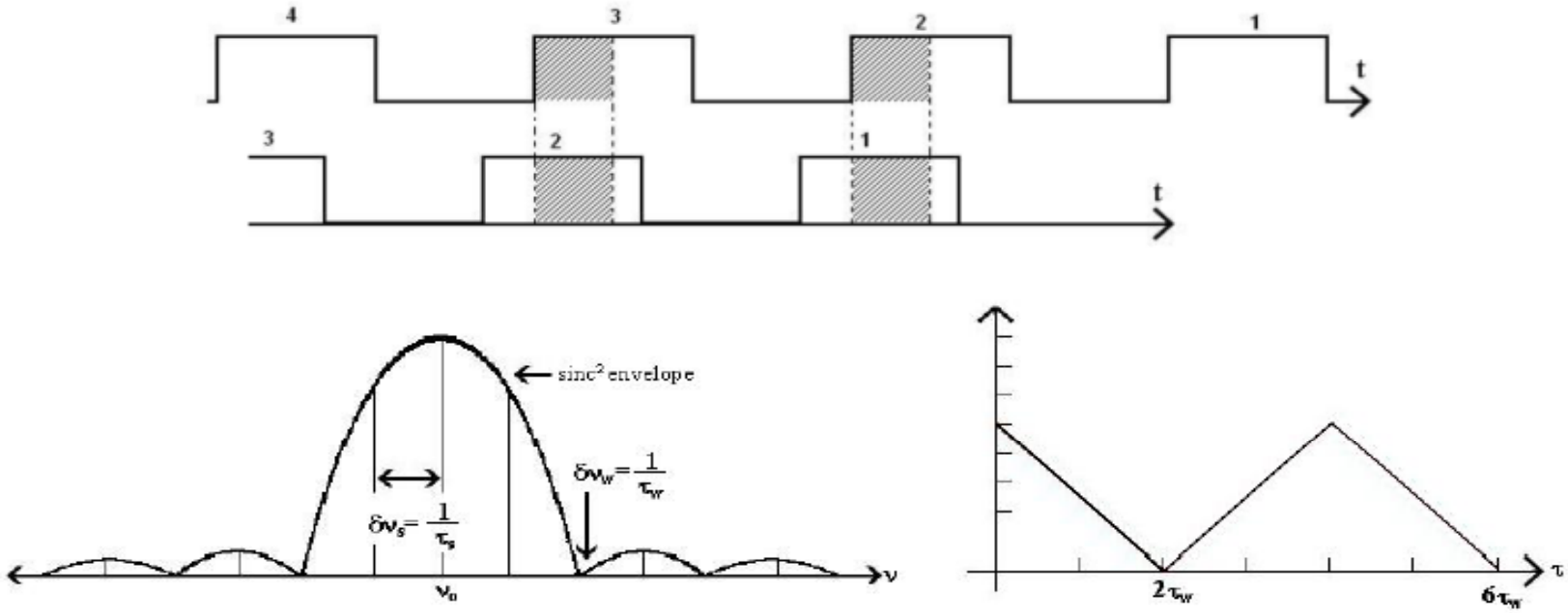
The pulse width at any value of z is given by

$$\tau(z) = \tau_0\left[1 + \frac{4z^2}{\tau_0^4}\left(\frac{d^2k}{d\omega^2}\right)^2\right]^{1/2} \qquad (6.41)$$

From Ghatak & Thyagarajan

A simple way to appreciate the temporally changing amplitude effects in superposition as recorded by detectors that matches the prediction of the W-K theorem

Free space; infinite train of pulses!



Free-space auto correlation measurements is not helping us to find distinction between Fourier frequencies and carrier frequency of pulses!

We need to introduce frequency sensitive dispersive material to discover the hidden paradoxes when we treat mathematical Fourier frequencies as real physical frequencies!

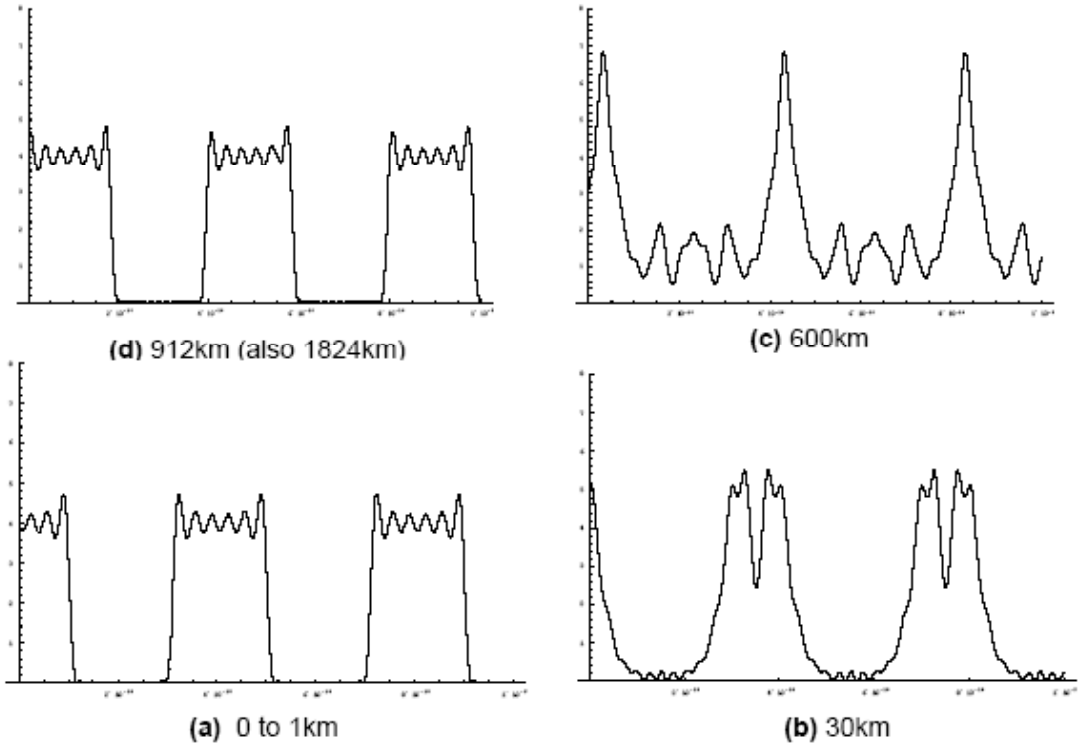
Proposed experiment to demonstrate invalidity of “group velocity”

A pulse shape can be reproduced – as if there is no pulse broadening !

• Pulse shape can be broadened as expected.

• Pulse shape can even be narrower than the input pulses!!

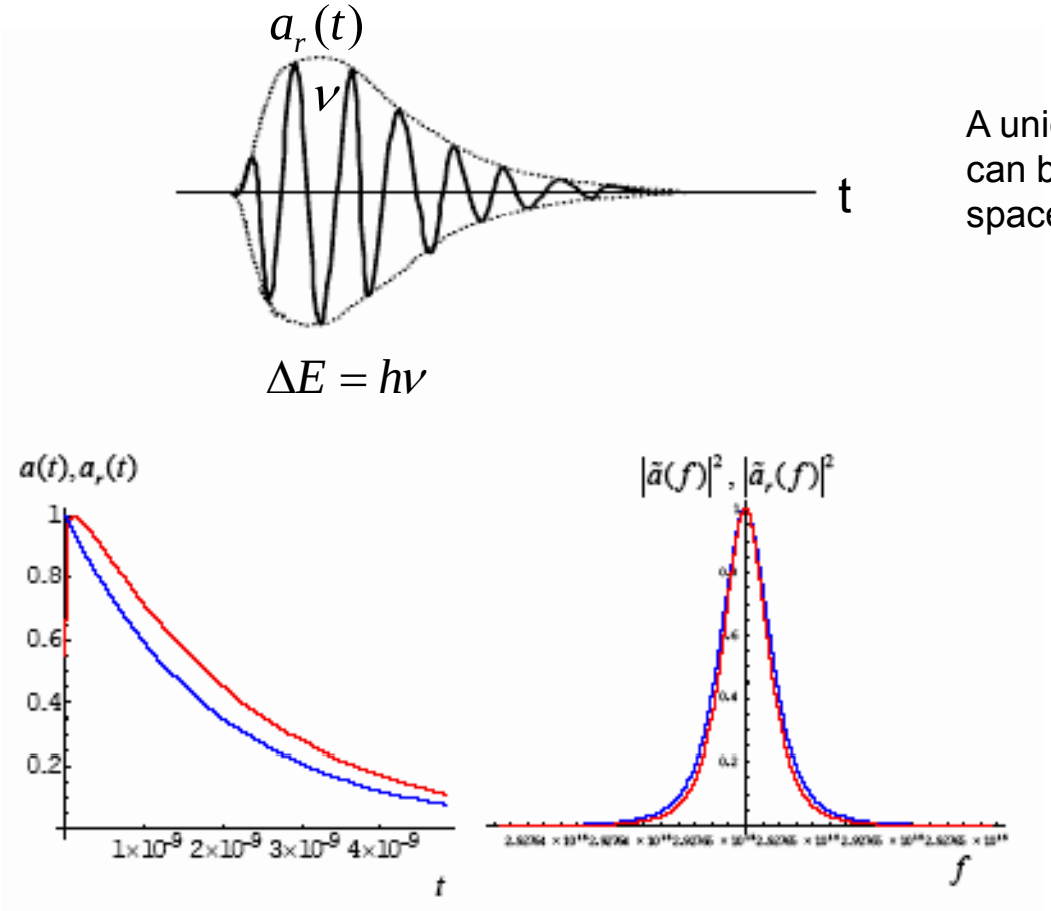
• So, the autocorrelation function is changing and corresponding spectrum, by W-K theorem, is changing, even though the propagation is linear!



Changing pulse shape due to propagation through different lengths of fiber

Mathematically correct linearity relations cannot negate the need of interaction processes that are absolutely essential for anything whatsoever to take place in nature.

A proposed model for a photon as a classical wave packet evolving out after an atom releases the energy



A unique carrier frequency v can be defined under a finite space and time envelope.

C. Roychoudhuri & N. Tirfessa, SPIE Vol. **6372**, paper #29 (2006); "Do we count indivisible photons or discrete quantum events experienced by detectors?"

If the spontaneously emitted photon is a classical wave packet, can we determine its envelope?

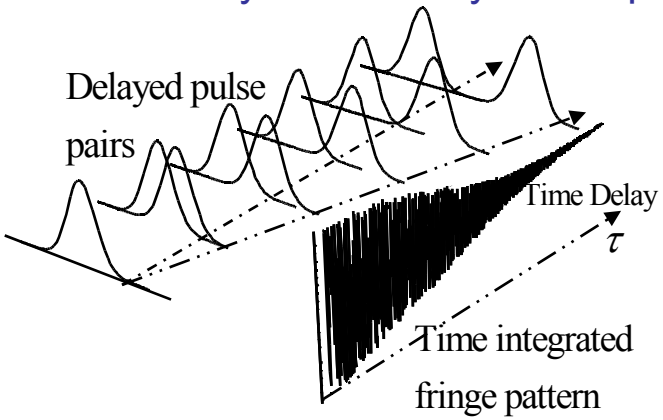
Photon as a wave packet : $\vec{a}(t)\exp[i2\pi\nu t]$

The time integrated fringe pattern and the detector autocorrelation functions are:

$$F_x(\nu,\tau)=\int_0^{T>2\delta t} I_{down}dt = 2TRE_{pls}[1-\gamma_{\det}(\tau)\cos 2\pi\nu\tau]$$

$$\gamma_{\det}(\tau)=\int_0^{T>2\delta t}\chi_1\vec{a}(t-t_1)\cdot\chi_1\vec{a}(t-t_2)dt\Big/\int_0^{T>2\delta t}\chi_1^2a^2(t)dt\equiv\gamma_{field}(\tau)$$

Mathematically the visibility envelope is identical to the pulse autocorrelation envelope:



$$V(\nu,\tau)=(E_{x,\max}-E_{x,\min})/(E_{x,\max}+E_{x,\min})=\gamma_{\det}(\tau)$$

The oscillatory component of the fringe for a single pulse:

$$F_{\text{osc}}(\nu,\tau)=C\gamma_{\det}(\tau)\cos 2\pi\nu\tau;\ C\equiv 2TRE_{pls}$$

The oscillatory component of the fringe for randomly emitted innumerable spontaneously emitted pulses:

$$F_{osc,discharge}(\nu,\tau)=C\gamma_{\det}(\tau)\int_{\nu_{\min}}^{\nu_{\max}}D(\nu)\cos 2\pi\nu\tau\ d\nu=C\gamma_{\det}(\tau)\tilde{D}(\tau)$$

Then the envelope of the photon can be determined via the autocorrelation function:

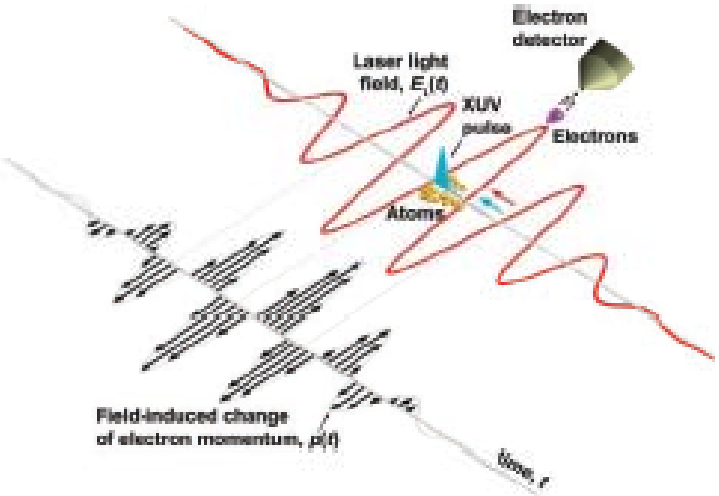
$$\gamma_{\det}(\tau)=\left[F_{osc,discharge}(\nu,\tau)/C\tilde{D}(\tau)\right]$$

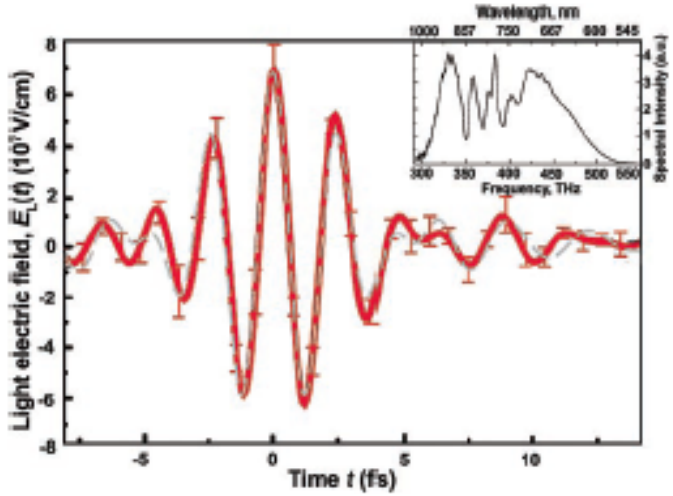
Is photon really an indivisible elementary particle?

“Direct Measurement of Light Waves”

Goulielmakis et. al., SCIENCE VOL 305 27 AUGUST 2004

ABSTRACT: The electromagnetic field of visible light performs 1015 oscillations per second. Although many instruments are sensitive to the amplitude and frequency (or wavelength) of these oscillations, they cannot access the light field itself. We directly observed how the field built up and disappeared in a short, few cycle pulse of visible laser light by probing the variation of the field strength with a 250-attosecond electron burst. Our apparatus allows complete characterization of few-cycle waves of visible, ultraviolet, and/or infrared light, thereby providing the possibility for controlled and reproducible synthesis of ultra broadband light waveforms.





- The electric vectors of the trillions of photons in the pulse must have been executing the undulation absolutely in step along the entire space and time length together in the specified polarized plane.
- The experiment implies that the shape of the photons must be controllable by optics and pulsed lasers to any arbitrary space and time domain.
- Can a space and time finite photon have a well defined single frequency?

Heterodyne spectroscopy & spectral super-resolution

Basic equations

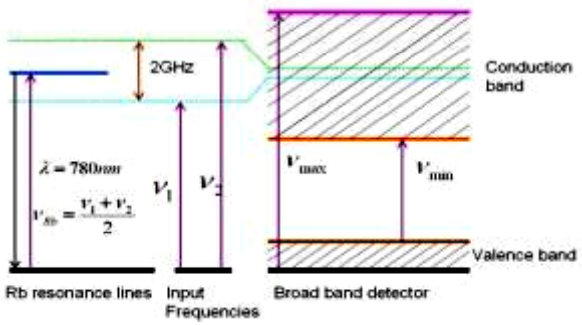
When two CW laser beams of two different carrier frequencies are superposed, the photo current is proportional to:

$$I(t)=\left|\vec{d}e^{-i2\pi\nu_1 t}+\vec{d}e^{-i2\pi\nu_2 t}\right|^2=2d^2+2\vec{d}\cdot\vec{d}\cos 2\pi(\nu_1-\nu_2)t$$
$$=2d^2[1+\cos 2\pi(\nu_1-\nu_2)t]$$

When one of the two CW laser beams is amplitude modulated, the photo current is proportional to:

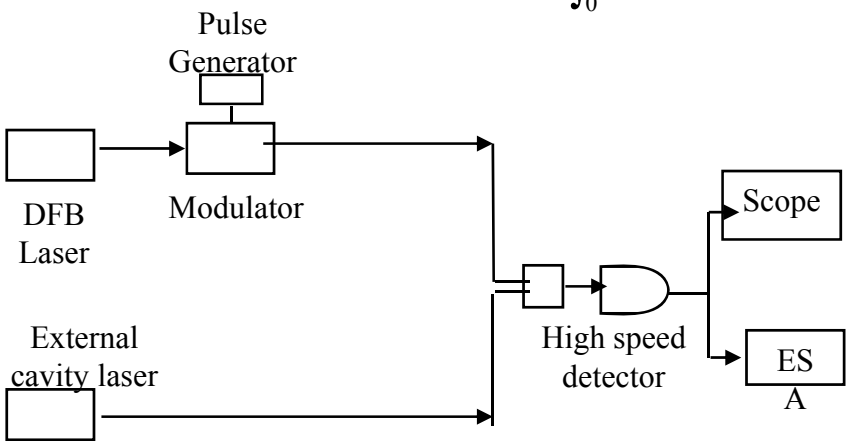
$$I(t)=\left|\vec{d}_{cw}e^{-i2\pi\nu_{cw}t}+\vec{d}_p(t)e^{-i2\pi\nu_p t}\right|^2=d_{cw}^2+d_t^2(t)+2\vec{d}_{cw}\cdot\vec{d}_p(t)\cos 2\pi(\nu_{cw}-\nu_p)t$$

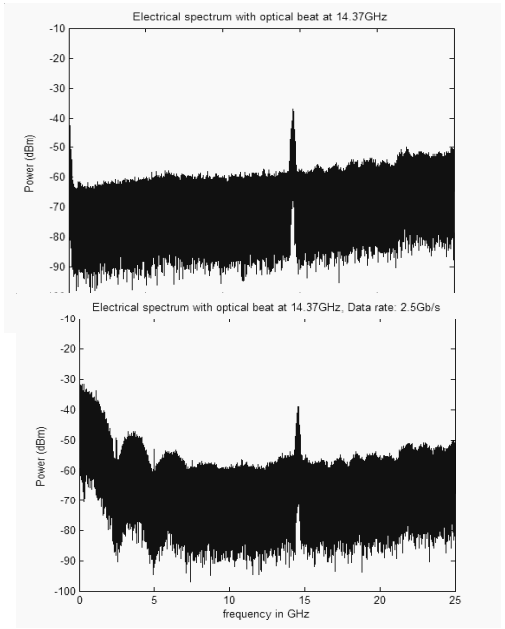
Where, the pulse used is a super Gaussian, square-like pulse: $\vec{d}_p(t)=\vec{1}\exp[-(t/2\tau)^{2m}]$



Fourier decomposition: Does an AM signal really contain the Fourier frequencies?

$$\tilde{a}(f) = \int_0^\infty a(t)\exp[-i2\pi ft]dt$$





$$I(t) = \left|\vec{d}_{cw}e^{-i2\pi\nu_{cw}t} + \vec{d}_p(t)e^{-i2\pi\nu_p t}\right|^2 = d_{cw}^2 + d_p^2(t) + 2\vec{d}_{cw}\cdot\vec{d}_p(t)\cos 2\pi(\nu_{cw}-\nu_p)t$$

The difference frequency is 15 GHz and the modulation frequency is 2.5 GHz. The high speed photo detector and ESA can separate out the modulation frequency and the carrier frequency difference by heterodyne spectroscopy.

$$\delta\nu\delta t \geq 1$$

Since time-frequency Fourier theorem is not a fundamental principle of nature, its corollary, the classic time-frequency bandwidth limitation, cannot also be a fundamental principle of nature.

The above experiment is a demonstration of spectral super resolution!

C. Roychoudhuri and M. Tayahi, "Spectral Super-Resolution by Understanding Superposition Principle & Detection Processes", Intern. J. of Microwave and Optics Tech., July 2006; manuscript ID# IJMOT-2006-5-46:

http://www.ijmot.com/papers/papermain.asp

$$\delta\nu\delta t \geq 1$$

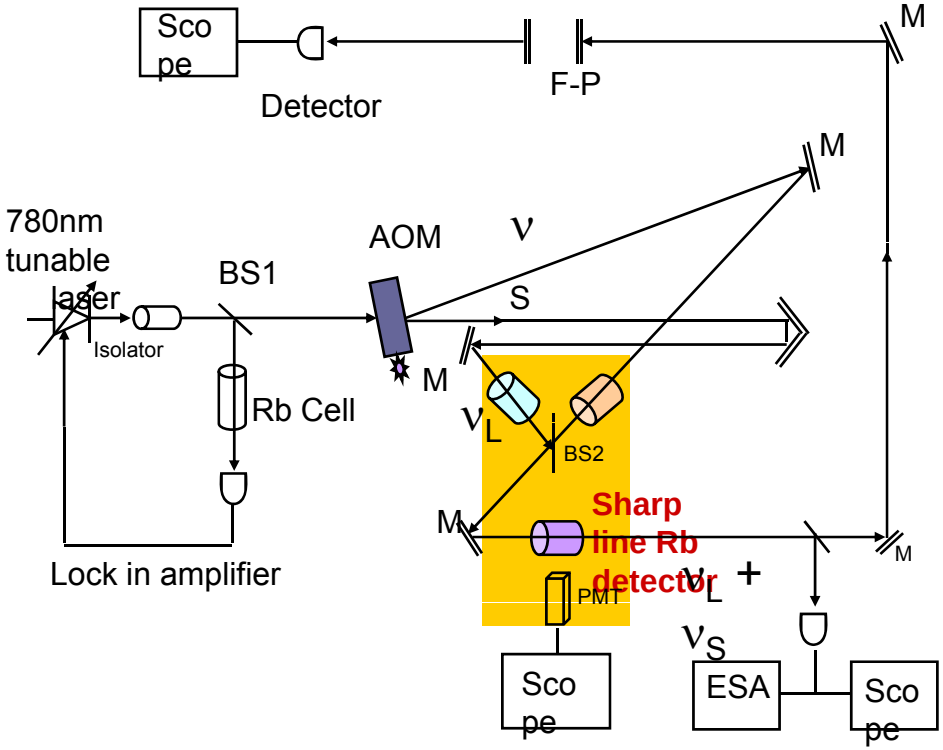
is nothing but fringe broadening effect due to partial overlap of replicated pulses by spectrometers

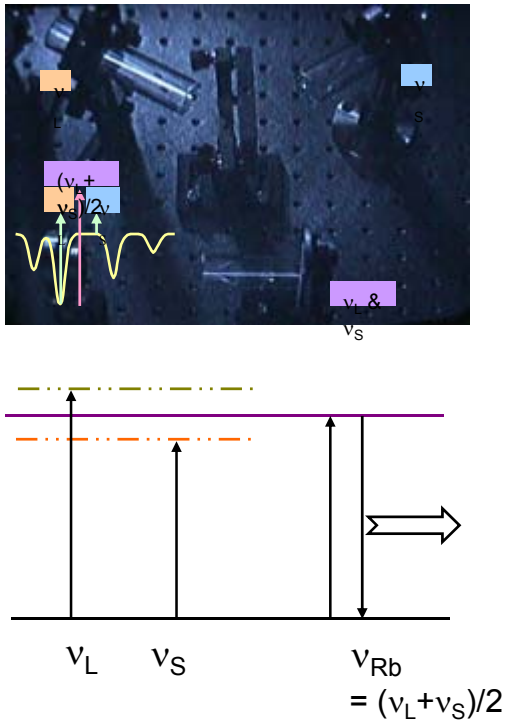
Like spatial super resolution, spectral super-resolution is a practical reality!

Does Fourier synthesis really work?

Light beams of different frequencies do not synthesize themselves into pulses with a new mean carrier frequency.

If Fourier synthesis is not a physical process, could the Fourier decomposition of a pulse into many frequencies be a physical process?





D. Lee and C. Roychoudhuri, Optics Express **11**(8), 944-51, (2003), "Measuring properties of superposed light beams carrying different frequencies".

Conclusion

1. Reality Ontology should be applied consistently to all mathematical formulation that represents physical processes in nature.

2. EM fields do not interact with each other. We see light through the eyes detecting dipoles that wear quantum goggles.

Several years ago at our UConn seminar, William D. Phillips, the 1997 Nobel Laureate, said something like the following at the end of his talk to describe repeated opposition in accepting his experimental low temperature values by theoreticians, but they repeatedly modified the theory to accommodate his results anyway:

When a theoretician gets a result, it is his/her truth.

But

When an experimentalist gets a result, it is God's truth!

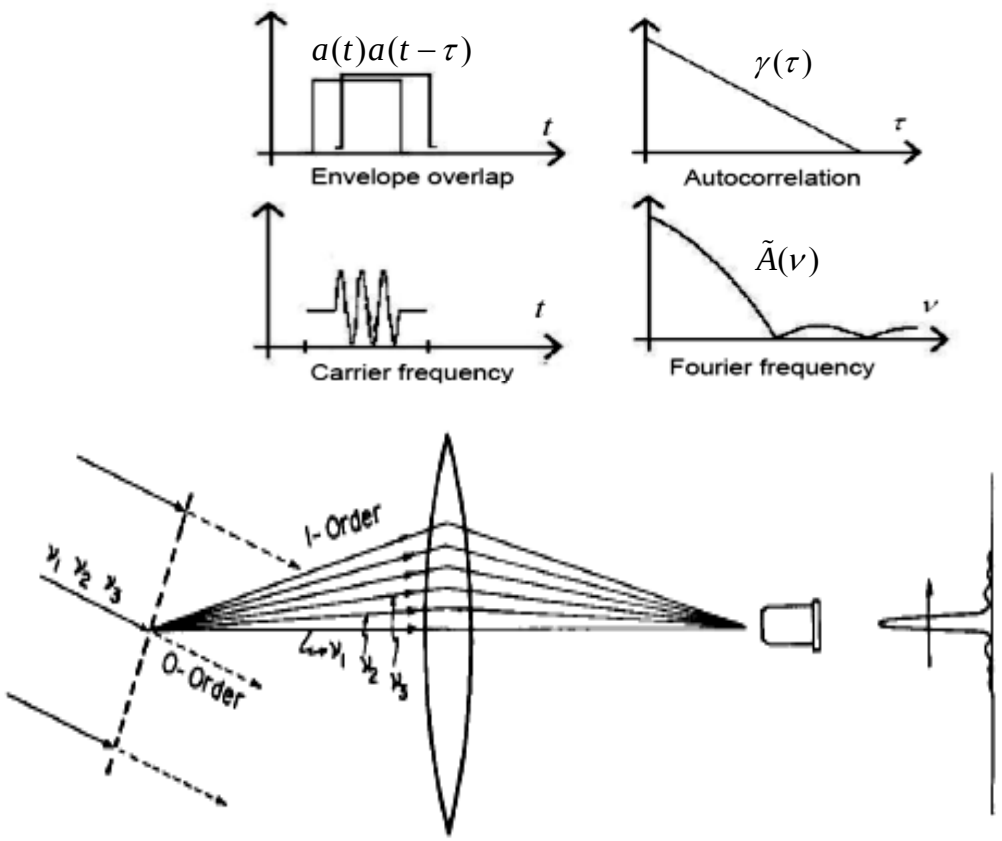
Is Fourier decomposition interpretation applicable to interference spectroscopy?

If pure amplitude modulation really generated Fourier frequencies, then:

1. We should have declared Fourier theorem as a principle of nature, like say, Huygens-Fresnel principle!

   And

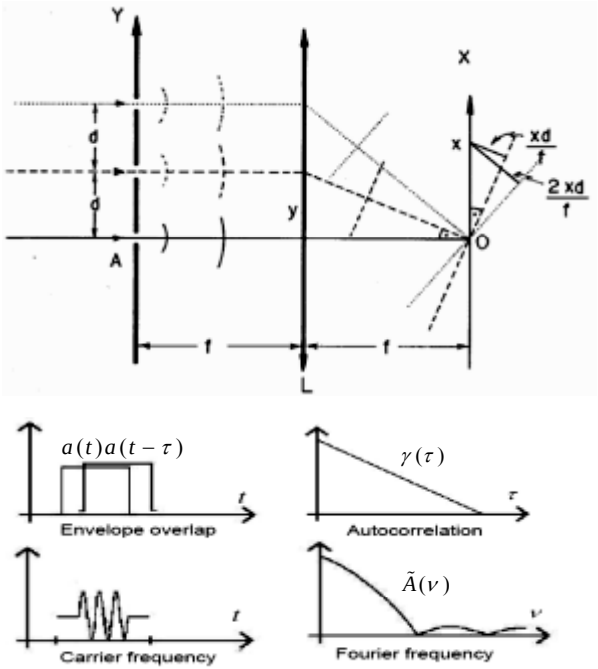
2. The grating spectrometer output should show temporally evolving (heterodyne or beat) fringes.

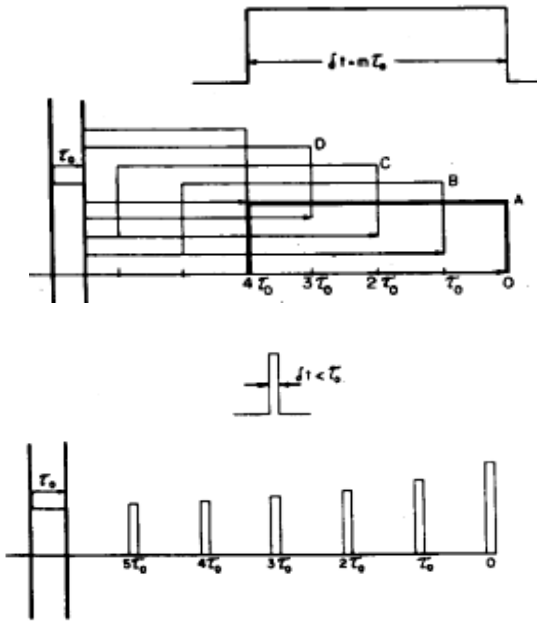


C. Roychoudhuri; Bol. Inst. Tonantzintla **2** (2), 101 (1976); "Is Fourier Decomposition Interpretation Applicable to Interference Spectroscopy?“

Is Fourier decomposition interpretation applicable to diffraction and beam propagation phenomena?

How can we get rid of the time when everything has a finite velocity and finite time for interaction?



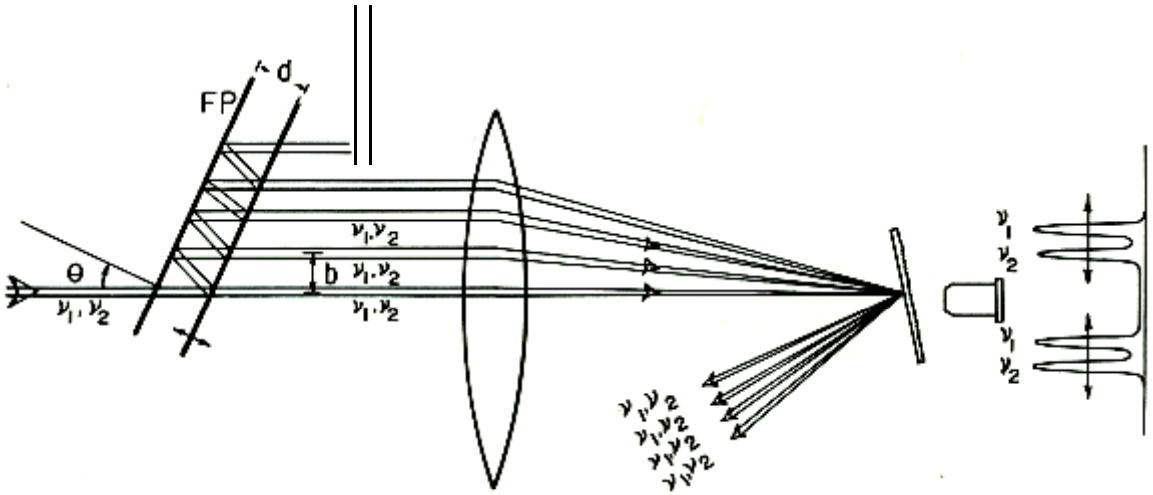


1980 “Optics in Four Dimensions” conf. at Ensenada was triggered by my JOSA paper and was led by the then ICO President Adolf Lohman.

1. C. Roychoudhuri; J. Opt. Soc. Am.; **65** (12), 1418 (1976); "Response of Fabry-Perot Interferometers to Light Pulses of Very Short Duration".
2. C. Roychoudhuri, Boletin. Inst. Tonantzintla, **2** (3), 165 (1977); "Causality and Classical Interference and Diffraction Phenomena".
3. C. Roychoudhuri & S. Calixto; Boletin. Inst. Tonantzintla, **2**(3), 187 (1977); "Spectroscopy of Short Pulses".
4. C. Roychoudhuri, J. Siqueiros & E. Landgrave; p.87-94, Proc. Conf. *Optics in Four Dimensions*, Eds. M. A. Machado Gama & L. M. Narducci, American Institute of Physics (1981); "Concepts of spectroscopy of pulsed light".

What are the processes behind separation of energies due to different frequencies in spectrometers?

Within the actual domain of physical superposition of the light beams, what are the processes behind the registered energy variation ("interference fringes")?



Experimental demonstration of **non-interference of light beams** in spite of crossing each other at the focal plane, while at the same time, delivering the classical spectrometric information when a scattering surface or a detector is placed in the plane of superposition.

Interacting material dipoles facilitate energy separation!

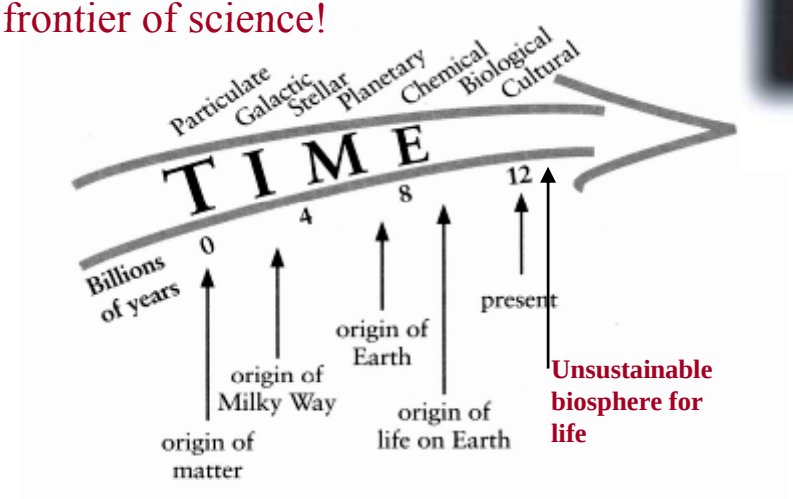
C. Roychoudhuri; Bol. Inst. Tonantzintla **2** (2), 101 (1976); "Is Fourier Decomposition Interpretation Applicable to Interference Spectroscopy?"

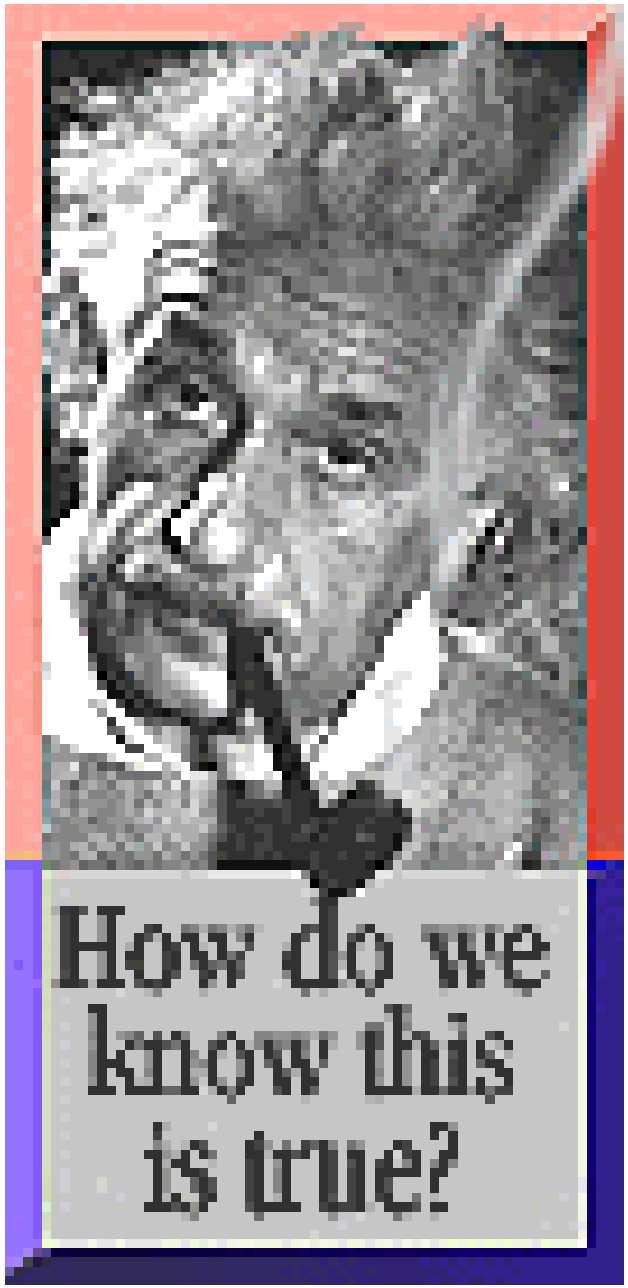
The Cosmic Medium -- the final frontier of science!

Thank you for thinking of becoming a cosmo-evolution-congruent realist!

The Sun is not immortal, but our genes could be, if we allow them to be!

Our destiny is to journey to other solar systems by navigating through the Cosmic Medium -- the final frontier of science!





Healthy doubt is the only insurance for the sustainable evolution of human minds!

There is no absolute truth for us. All of our knowledge is incomplete as it maps only a fraction of the ongoing processes in the cosmic universe. Our individualized 100 billion neural cells are not capable of articulating all the truths of the universe even if any one of us really knew them all. Historically, truths we excavate out of nature come in small and large packages that we must learn to integrate and re-integrate coherently with time.

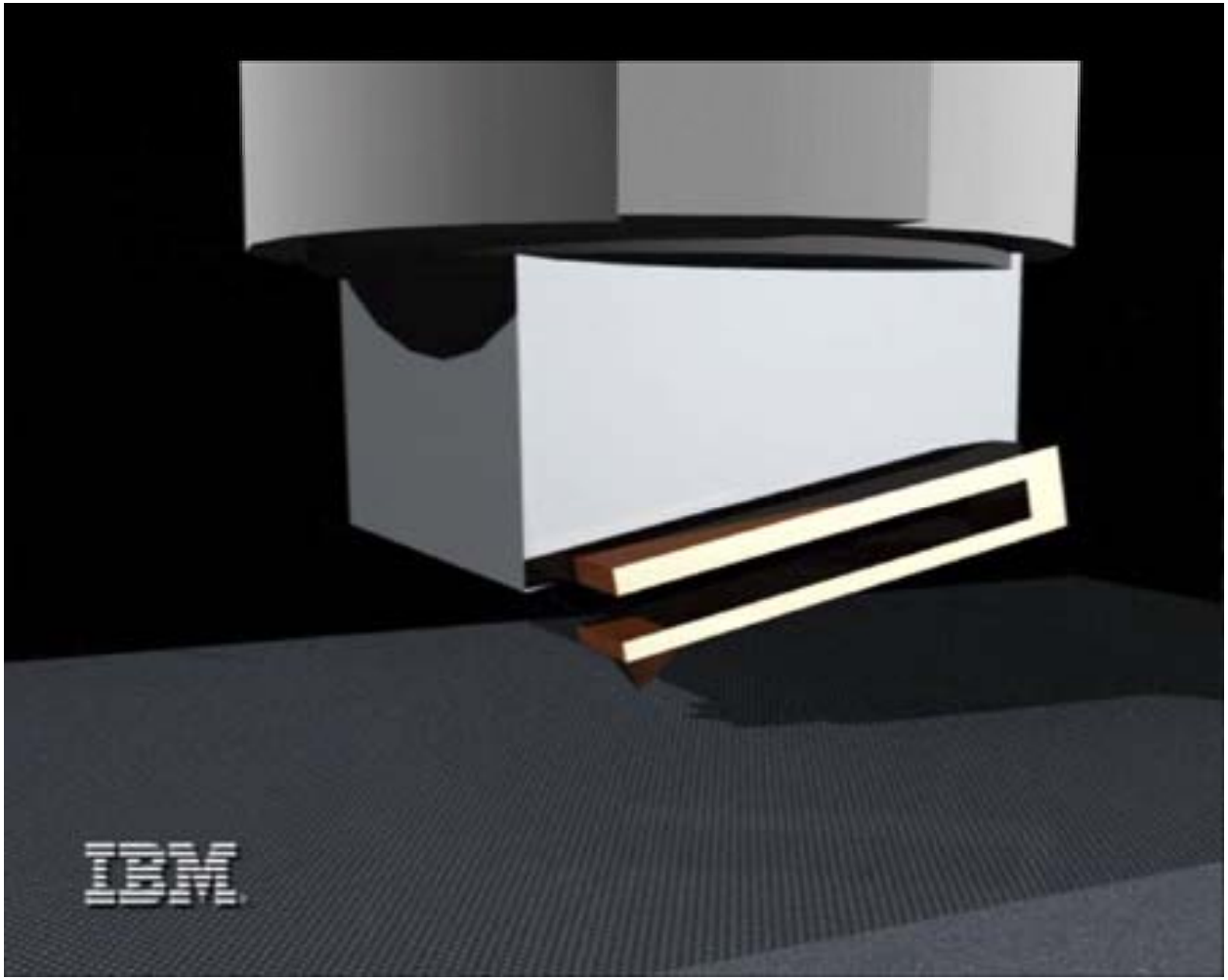
Newton aptly said that the horizon of his knowledge got larger only because he was able to stand on the shoulders of his predecessor “giants”!

We are luckier today because we now have a pyramid of many giants built over many centuries. Let’s have the courage to climb on the top of the pyramid built out of all the giant scientists!

Even simple scattering of light can be quite inspiring !

Thank you for your patience and giving me an opportunity to be with you!

Atoms are localized entities that can be manipulated one by one



A new kind of atomic force microscope measures the forces required to push atoms along a surface by using a tiny piezoelectric tuning fork (shown here in gold). The vibrations of the tuning fork generate a small current. When the probe's tip (the inverted pyramid on the bottom of the tuning fork) is positioned close to an atom on a surface, the frequency of the tuning fork changes slightly, varying the current.

Publications from INAOE

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2. C. Roychoudhuri, J. Siqueiros & E. Landgrave; p.87-94, Proc. Conf. *Optics in Four Dimensions*, Eds. M. A. Machado Gama & L. M. Narducci, American Institute of Physics (1981); "Concepts of spectroscopy of pulsed light".
3. C. Roychoudhuri; Foundations of Physics, **8**(11/12), 845 (1978); "Heisenberg's Microscope - A Misleading Illustration".
4. C. Roychoudhuri & S. Calixto; Boletin. Inst. Tonantzintla, **2**(3), 187 (1977); "Spectroscopy of Short Pulses".
5. C. Roychoudhuri, Boletin. Inst. Tonantzintla, **2**(3), 165 (1977); "Causality and Classical Interference and Diffraction Phenomena".
6. A. G. Laguna-Alaya & C. Roychoudhuri; Boletin Inst. Tonantzintla, **2**(2),109, (1976); "States of Polarization in a Gas Laser with Internal Mirrors".
7. C. Roychoudhuri; Bol. Inst. Tonantzintla **2**(2), 101 (1976); "Is Fourier Decomposition Interpretation Applicable to Interference Spectroscopy?“
8. C. Roychoudhuri, R. Machorro & M. Cervantes; Bol. Inst. Tonantzintla **2**(1), 55 (1976); "Some Interference Experiments and Quantum Concepts, II".
9. C. Roychoudhuri; Opt. Eng.; **16**(2), 173 (1976); "Passive Pulse Shaping Using Delayed Superposition".
10. C. Roychoudhuri; J. Opt. Soc. Am.; **65**(12), 1418 (1976); "Response of Fabry-Perot Interferometers to Light Pulses of Very Short Duration". (The analysis of this paper is followed and cited in two books: a. "Fabry-Perot Interferometers"; G. Hernandez, Cambridge U., 1986 and b. "The Fabry-Perot Interferometer"; J. M. Vaughan; Adam Hilger, 1989.)
11. C. Roychoudhuri; Bol. Inst. Tonantzintla **1**(5), 259 (1975); "Two Beam Interference Experiments and Some Quantum Concepts".
12. C. Roychoudhuri & D. Malacara; Appl. Opt. **14**(7), 1683 (1975); "Spatial Filtering and Image Positive-Negative Reversal".
13. C. Roychoudhuri, J.C. Fouere & A. Cornejo; Appl. Opt. **14**(9), 2051 (1975); "Temporal Coherence Length and Speckle: A Simultaneous Approach to Those Problems in Holography".
14. C. Roychoudhuri & R.H. Noble; Am. J. Phys. **43**(12), 1057 (1975); "Demonstration using a Fabry-Perot. II. Laser Modes Display". (This paper is also reprinted in the book, "Lasers: Selected Reprints", Eds. D.C. O'Shea & D.C. Peckham; Am. Assn. Physics Teachers, 1982.)
15. C. Roychoudhuri; Am. J. Phys. **43**(12), 1054 (1975); "Demonstration Using a Fabry-Perot. I. Multiple-Slit Interference".
16. J.C. Fouere, C. Roychoudhuri, Opt. Com. **12**(1), 29 (1974); "A Holographic Radial and Lateral Shear Interferometer".
17. C. Roychoudhuri, Opt. Com. **10**(2) 160 (1974); "Dynamic and Multiplex Holography with Scanning Fabry-Perot Fringes".