# Opening up the enquiring minds to:
Discover, invent and innovate -
In the fields of Optical Science and Engineering

How to explore & utilize nature-allowed processes for our long-term well-being!

Prof. ChandraSekhar Roychoudhuri
Physics Department, University of Connecticut, Storrs, CT

Reference: "Causal Physics: Photon by Non-Interaction of Waves", by C. Roychoudhuri, Taylor & Francis, 2014; Paperback, 2017.

June 14, 2017
University of Dayton, Ohio
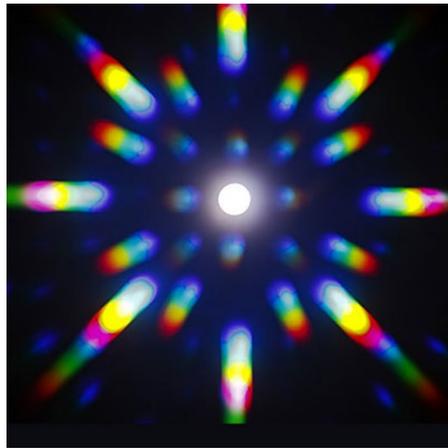
Optical Phenomena in Light of NIW

LECTURE 2

Prof. Chandrasekhar (Chandra) Roychoudhuri
Chandra.Roychoudhuri@UConn.edu
Femto Macro Continuum & Physics Department, University of Connecticut, Storrs, CT 06269

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University of Dayton, Ohio

Re-visiting the origin of unrecognized NIW

Enquiry:

Why did modern physics missed recognizing the NIW-property?

Answer:

(i) We failed to distinguish between the mathematical *un-observable* Superposition Principle (SP) & the *observable* Superposition Effect (SE).

(ii) We are focused in modeling validating measurable data; while neglecting how to explicitly model the underlying *invisible physical processes* that give rise to the data!

$$d(\tau) = \chi a_1 r e^{i\pi} e^{i2\pi v(t+\tau)} + \chi a_2 t e^{i2\pi vt}; \quad \Leftarrow \text{Joint amplitude stimulation.}$$

$$D(\tau) = \left| \chi a_1 r e^{i\pi} e^{i2\pi v(t+\tau)} + \chi a_2 t e^{i2\pi vt} \right|^2 = \chi^2 \left| a_1 r e^{i\pi} e^{i2\pi v(t+\tau)} + a_2 t e^{i2\pi vt} \right|^2$$

$$= \chi^2 [(a_1^2 r^2 + a_2^2 t^2) - 2a_1 a_2 tr \cos 2\pi v\tau]$$

$$= 2\chi^2 a^2 [1 - \cos 2\pi v\tau]; \text{ when } r^2 = t^2 = 0.5 \text{ and } a_1 = a_2 = a$$

We remained focused only on data modeling epistemology.

The "Superposition Principle" is initiation of the *state of stimulation* (interaction) . "Superposition Effects" is the physical transformation after the *state of energy transfer* is completed (generating measurable data).

The effects emerge due to *interaction processes* after simultaneous stimulations induced on detectors by multiple signals. The Copenhagen Interpretation (CI) of QM does not encourage us to visualize these processes.

CI encourages us to remain comfortable with:
Measurable Data Modeling Thinking (MDM-T)

However, we need to add:
Interaction Processes Mapping Thinking (IPM-T)
Your mind will feel empowered to innovate many novel tools and technologies; which will assure our sustainable evolution.

Learning to distinguish between SP & SE

Standard mathematical Superposition Principle (SP) does not represent any physical interaction process.

Generalized SP: $\quad E_{total} = \sum_n E_n(\nu) \equiv \sum_n a_n(t)\exp(i2\pi\nu_n t)$

HF integral as SP $\qquad U(P_0) = \dfrac{-i}{\lambda}\iint_{\Sigma} U(P_1)\dfrac{\exp(ikr_{01})}{r_{01}}\cos\theta\ ds$

Learning to distinguish between SP & SE

Standard mathematical Superposition Principle (SP) does not represent any physical interaction process.

Generalized SP; Solution to Wave Eq.:
$$E_{total} = \sum_n E_n(\nu) \equiv \sum_n a_n(t)\exp(i2\pi\nu_n t)$$

Huygens-Fresnel integral:
$$U(P_0) = \frac{-i}{\lambda}\iint_\Sigma U(P_1)\frac{\exp(ikr_{01})}{r_{01}}\cos\theta\,ds$$

Re-write SP as a physical process – stimulated dipoles; which would lead to measurable Superposition Effect (SE).

Generalized SP:
$$\Psi_{total} = \sum_n E_n(\nu) \equiv \sum_n \chi_n(\nu_n)a_n(t)\exp(i2\pi\nu_n t)$$

Huygens-Fresnel
$$\Psi(P_0) = \frac{-i}{\lambda}\iint_\Sigma \chi(\nu)U(P_1)\frac{\exp(ikr_{01})}{r_{01}}\cos\theta\,ds$$

In general, the polarizabilty parameter cannot be taken out of the integral as a detector constant.

Learning to distinguish between SP & SE; *Photo detection*

Observable Superposition Effect is a Quadratic Energy Exchange Process.

Mathematical rule can fool us!

**Generalized SE:**

$$D_{Det.} \equiv \left|\Psi_{total}\right|^2 = \left|\sum_n \chi_n(\nu_n)E_n(\nu)\right|^2$$

$$= \left|\sum_n \chi_n(\nu_n)a_n(t)\exp(i2\pi\nu_n t)\right|^2$$

Electronic Detector Spectral Sensitivities

Figure 3

From the web

Only for an extremely narrow band of frequency, can one assume the constancy of the linear dipolar stimulation factor, and re-write:

$$D_{Det.} \equiv \left|\Psi_{total}\right|^2 = \chi^2\left|\sum_n E_n(\nu)\right|^2 = \chi^2\left|\sum_n a_n(t)\exp(i2\pi\nu_n t)\right|^2$$

Does this imply *waves can sum themselves*, or operate on each other and re-organize their spatial and temporal energies? Can human mathematical rule dictate nature how she ought to behave?, *Or, her causal rules dictate how humans should learn to re-organize their logical thinking and mathematics?*
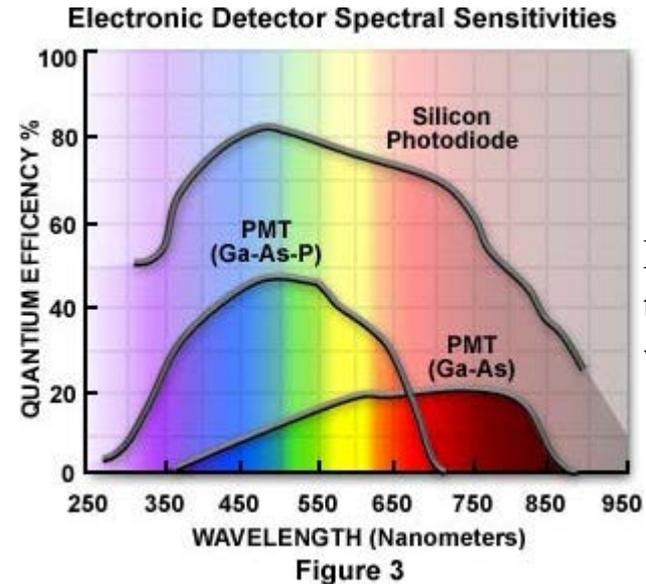
In general, the polarizabilty parameter cannot be taken out of the integral (or, the summation) as a detector constant. Otherwise, we lose how to keep track of physical interaction processes.
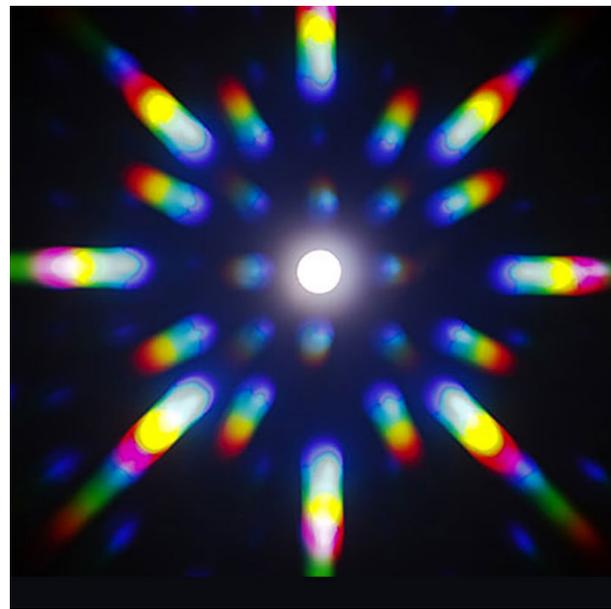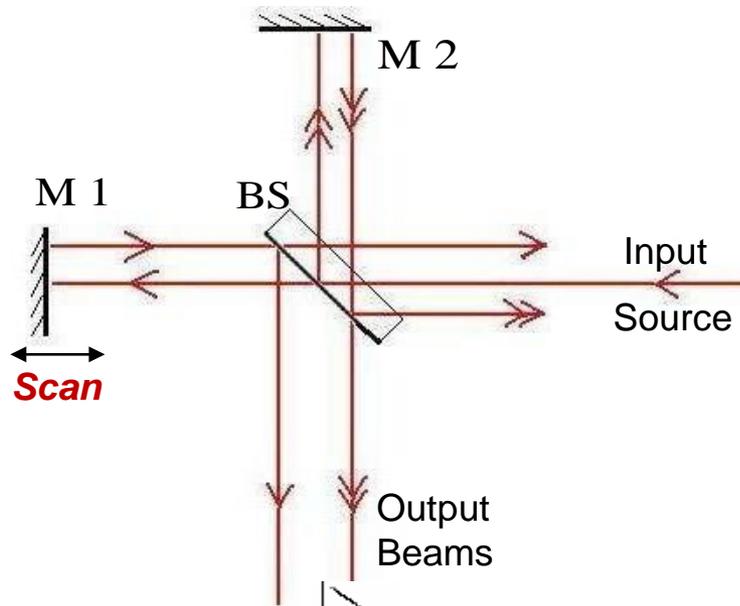
From Optics &
Photonics News

Pure Classical Superposition Effect without photo detectors
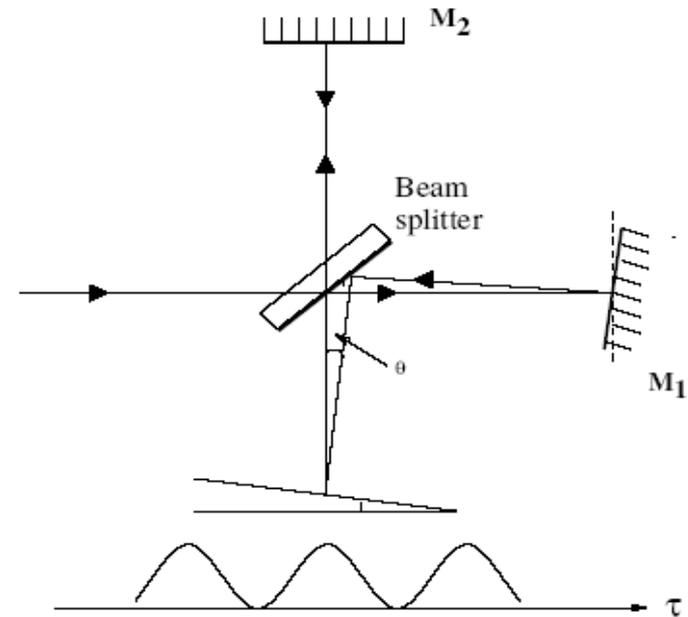
We are using an undergraduate interferometry experiment. Superposition Effects (SE) of collinearly superposed optical beams with
phase-steady single frequency

Superposition Effect as Energy Re-direction vs. Re-distribution. How?

Filter-Mode; Scanning Mode

"Temporal fringes". Requires scanning. Wave fronts must be identical with co-linear Poynting vectors
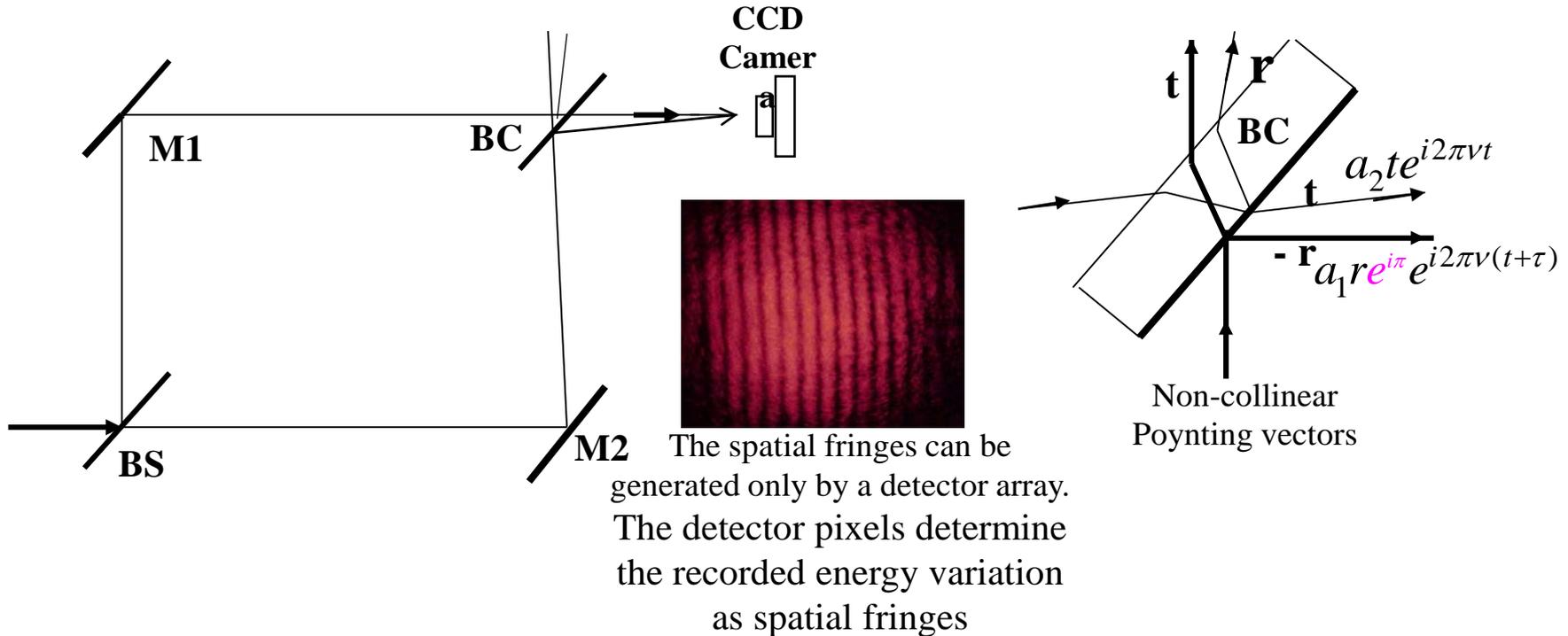
Fringe-Mode

Spatial fringes. Requires no scanning. Wave fronts can be dissimilar and the Poynting vectors must be non-collinear.

13

Traditionally we use interferometer in the *"fringe mode"*

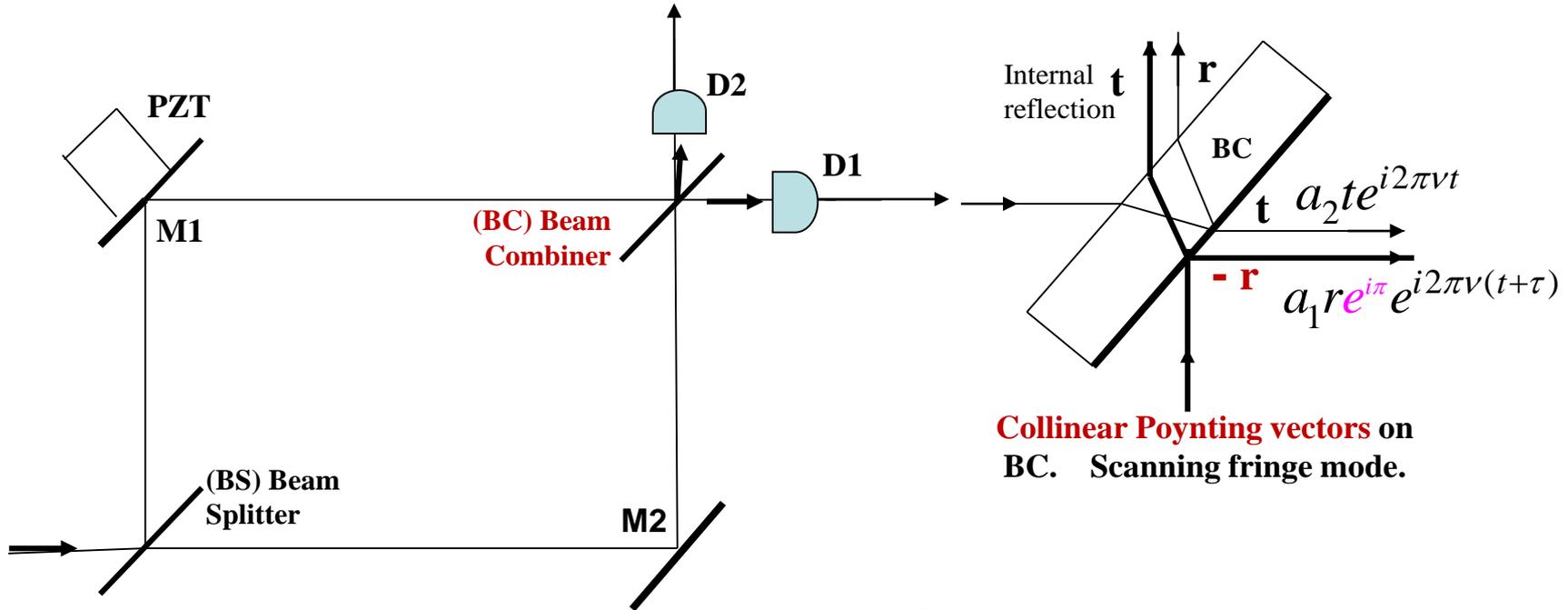**If the Poynting vectors are non-collinear, the BC remains constant at 50% for both the directions.**

The spatial fringes can be generated only by a detector array. The detector pixels determine the recorded energy variation as spatial fringes

Non-collinear Poynting vectors

$$D(\tau) = \left| \chi a_1 r e^{i\pi} e^{i2\pi v(t+\tau)} + \chi a_2 t e^{i2\pi vt} \right|^2 = \chi^2 \left| a_1 r e^{i\pi} e^{i2\pi v(t+\tau)} + a_2 t e^{i2\pi vt} \right|^2$$

$$= \chi^2 [(a_1^2 r^2 + a_2^2 t^2) - 2a_1 a_2 tr \cos 2\pi v\tau]$$

$$= 2\chi^2 a^2 [1 - \cos 2\pi v\tau]; \ when \ r^2 = t^2 = 0.5 \ and \ a_1 = a_2 = a$$

⇑ Linear dipolar polarizability of the detector molecules.

However deeper enquiry becomes very interesting when the interferometer is in the *"scanning mode"*!

If the *Poynting vectors are collinear*, the effective reflectance or transmittance of the BC oscillates from 0 to 100%, when the beams are of equal intensity.

This is a different phenomenon under beam "collinearity" condition; the output intensity oscillates between the two ports when one of the mirror is scanned.
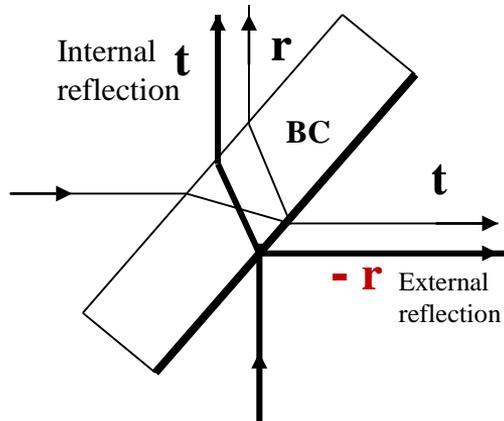

Collinear Poynting vectors on BC. Scanning fringe mode.

$$D(\tau) = \left| \chi a_1 r e^{i\pi} e^{i2\pi v(t+\tau)} + \chi a_2 t e^{i2\pi vt} \right|^2 = \chi^2 \left| a_1 r e^{i\pi} e^{i2\pi v(t+\tau)} + a_2 t e^{i2\pi vt} \right|^2$$

$$= \chi^2 [(a_1^2 r^2 + a_2^2 t^2) - 2a_1 a_2 tr \cos 2\pi v\tau]$$

$$= 2\chi^2 a^2 [1 - \cos 2\pi v\tau]; \ when \ r^2 = t^2 = 0.5 \ and \ a_1 = a_2 = a$$

⇑ The dielctric boundary plays the role of re-directing energy.

# *What are the physical processes* behind a 50% beam combiner becoming a 100% transmitter, or a reflector?

PZT

M1

(BC) Beam Combiner

D2

D1

(BS) Beam Splitter

M2
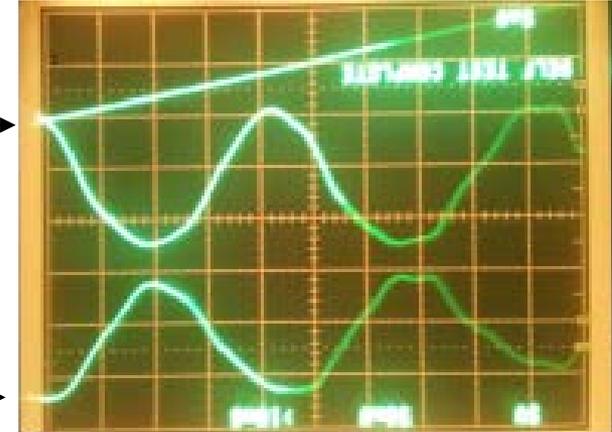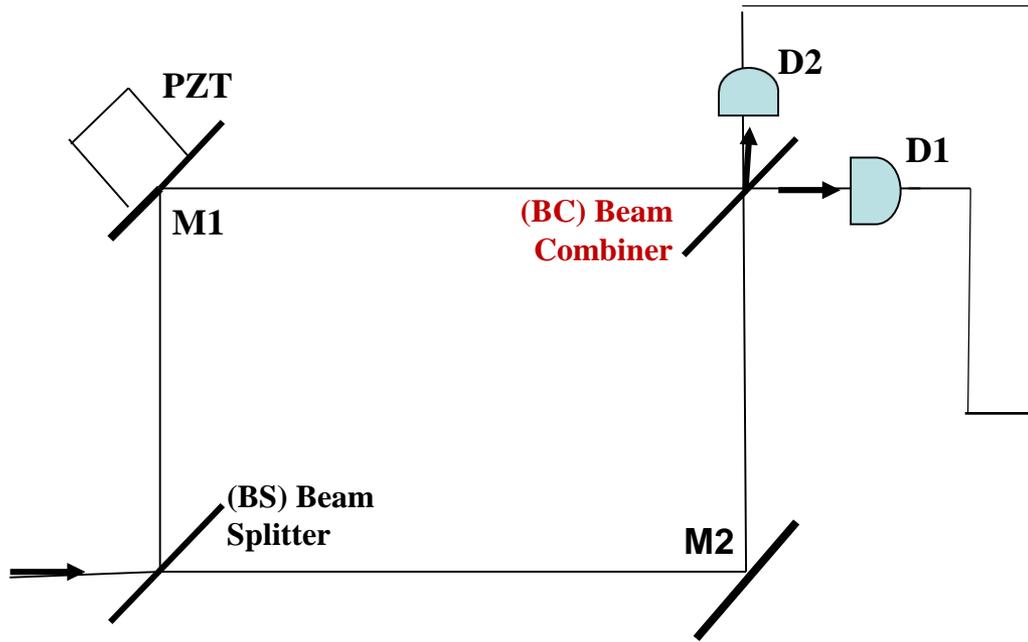
As M1 is scanned (straight inclined line on top) all the energy of both the beams could go to D1 or to D2, depending upon the phase conditions. The 50% BC effectively oscillates between being a 100% reflector or a 100% transmitter.

Internal reflection **t** **r**

BC

t

- r External reflection

Collinear Poynting vectors on BC. Scanning fringe mode.
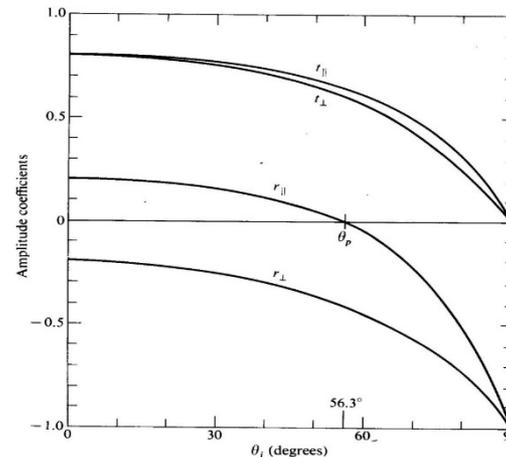
Note "pi" phase shift between external and internal reflection.

From Hecht

14

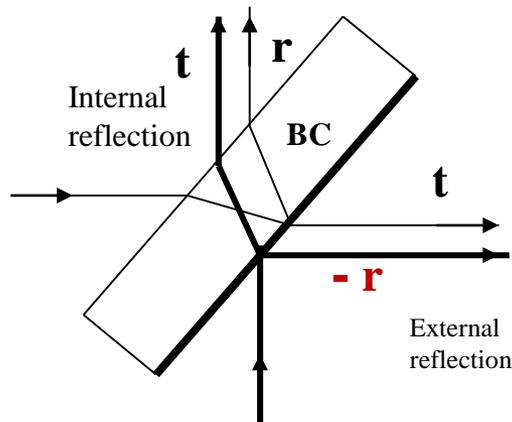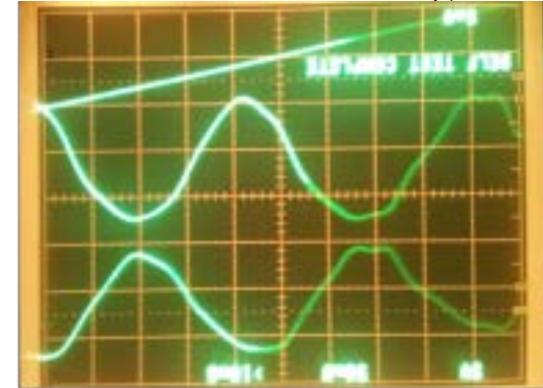C. Roychoudhuri, Femto Macro Continuum & University of Connecticut.

Video: Oscilloscope voltage display
How does a 50% beam combiner becomes 100% transmitter, or a reflector?
The interferometer is in the "scanning mode"!

PZT

M1

(BC) Beam Combiner

D2

D1

(BS) Beam Splitter

M2
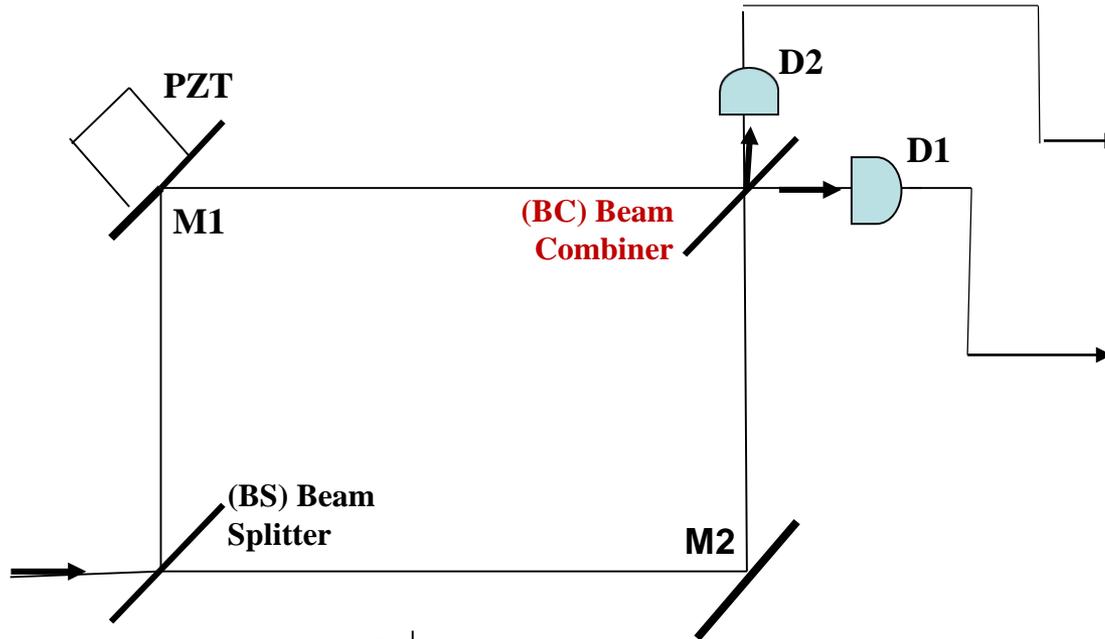
Video of scanned fringes.

t   r

Internal reflection

BC

t

- r

External reflection

Collinear Poynting vectors on BC.   Scanning fringe mode.

The dipolar behavior of classical molecular clusters, under the influence of oscillating electric vectors from the opposite sides of a boundary layer, DETERMINES which way the wave energy can propagate and in in what quantity!

Video: Visual display of oscillating intensity
How does a 50% beam combiner becomes 100% transmitter, or a reflector?
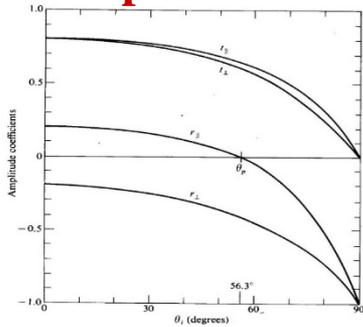### The interferometer is in the "scanning mode"!

PZT

M1

(BC) Beam Combiner

D2

D1

(BS) Beam Splitter

M2

t   **r**

BC

t

- r

Collinear Poynting vectors on BC. Scanning fringe mode.
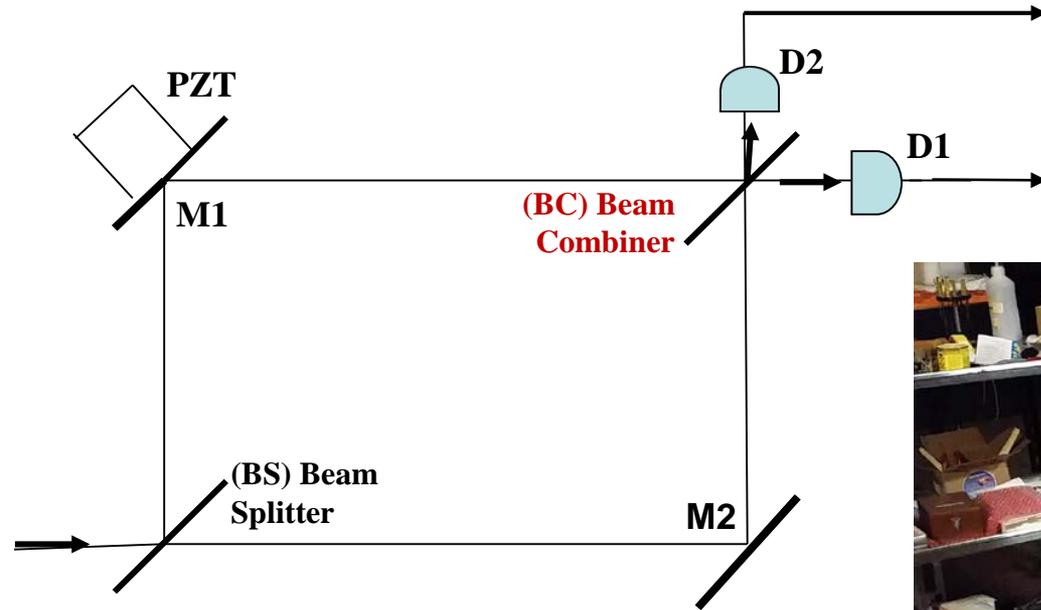
(***Video***) Visually observable pure classical superposition effect generated by a beam combiner. No quantum detector used!
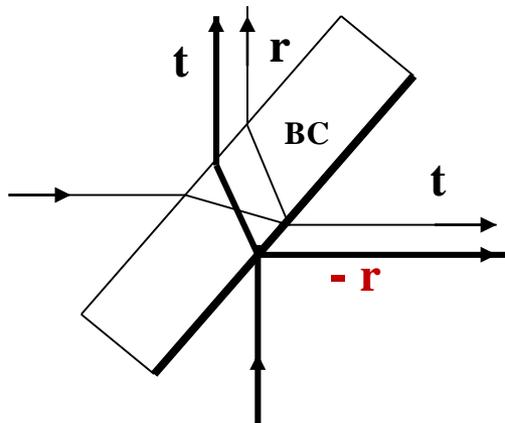
The two light signals must stimulate the boundary-layer molecules simultaneously from the two opposite sides for the energy re-direction (Supreposition Effect) to take place. Even if "indivisible single photon" existed; we would need two of them to incident simultaneously from the opposite sides of the beam combiner.

C. Roychoudhuri, Femto Macro Continuum & University of Connecticut.

The phenomenon of the capability of re-directing energy of both the beams into one or the other direction is built into classical electromagnetism. The postulate of "single photon interference" effectively denies this easily observable classical property!!

Summation of the amplitude

$$d_{right}(\tau) = a_1 r e^{i2\pi v(t+\tau)} + a_2 t e^{i2\pi vt}$$

$$d_{up}(\tau) = a_1 t e^{i2\pi v(t+\tau)} + a_2 r e^{i2\pi vt}$$

Apparent energy

$$D_{right}(\tau) = \left| d_{right} \right|^2 = a_1^2 r^2 + a_2^2 t^2 + 2a_1 a_2 tr \cos 2\pi v\tau$$

$$D_{up}(\tau) = \left| d_{up} \right|^2 = a_1^2 t^2 + a_2^2 r^2 + 2a_1 a_2 tr \cos 2\pi v\tau$$

$$D_{total}(\tau) = D_{right}(\tau) + D_{up}(\tau) = a_1^2 + a_2^2 + 4a_1 a_2 rt \cos 2\pi v\tau$$

Collinear Poynting vectors on BC. Scanning fringe mode.

Real energy

$$D_{total}^{real}(\tau) = D_{right}(\tau) + D_{up}(\tau) = a_1^2 + a_2^2 = 2a^2 \text{ (for } a_1 = a_2 = a\text{)}$$
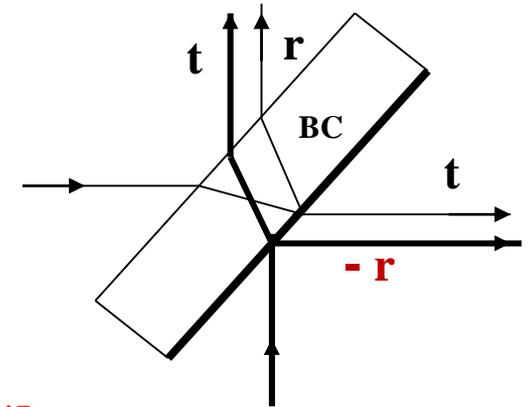
$$d_{right}(\tau) = a_1 (r e^{i\pi}) e^{i2\pi v(t+\tau)} + a_2 t e^{i2\pi vt}$$

$$D_{right}(\tau) = \left| d_{right} \right|^2 = a_1^2 r^2 + a_2^2 t^2 - 2a_1 a_2 tr \cos 2\pi v\tau$$

A 50% beam combiner re-directs all energy of both the beams in the "up" direction, zero in the right. The physical properties of the boundary layer is critically important!

$$D_{right}(\tau = 0) = (a_1 r - a_2 t)^2 = 0, \text{ when } a_1 / a_2 = t / r. \quad \Longleftarrow$$

$$D_{up}(\tau = 0) = 2a^2; \text{ when } R=T=0.5 \text{ and } a_1 = a_2 = a.$$

17

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Logical inconsistency behind the postulate: "single photon interfere"

How does a 50% beam-combiner in an interferometer become 100% reflector or a 100% transmitter?
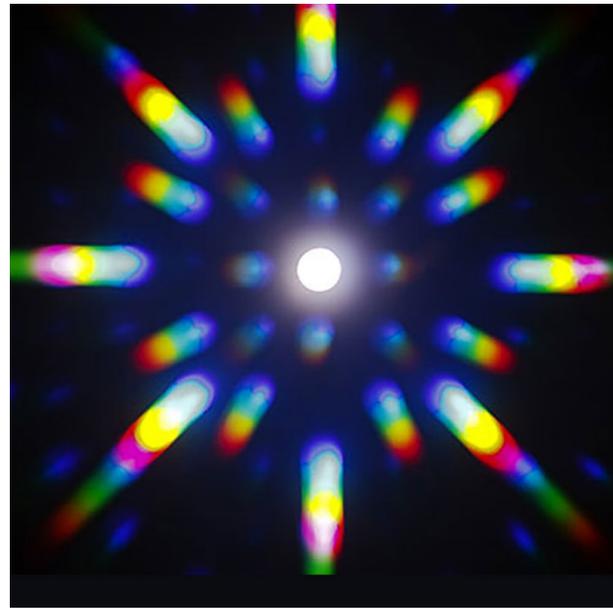
Let us now look at some major optics/physics phenomena in light of NIW

1. Diffraction as Superposition Effect
2. Superposition Effects with two collimated beams
Fourier transform Spectroscopy vs.
Light beating spectroscopy
3. Superposition Effect with Multiple Beam
A causal theory of spectrometry.
4. Superposition Effects & Emergence of Laser
Modes, CW and Mode Locked
5. Superposition Effects and Group Velocity
(Material Dispersion!)
6. Two-beam Superposition Effect & "Coherence"
7. The "Photon" Concept
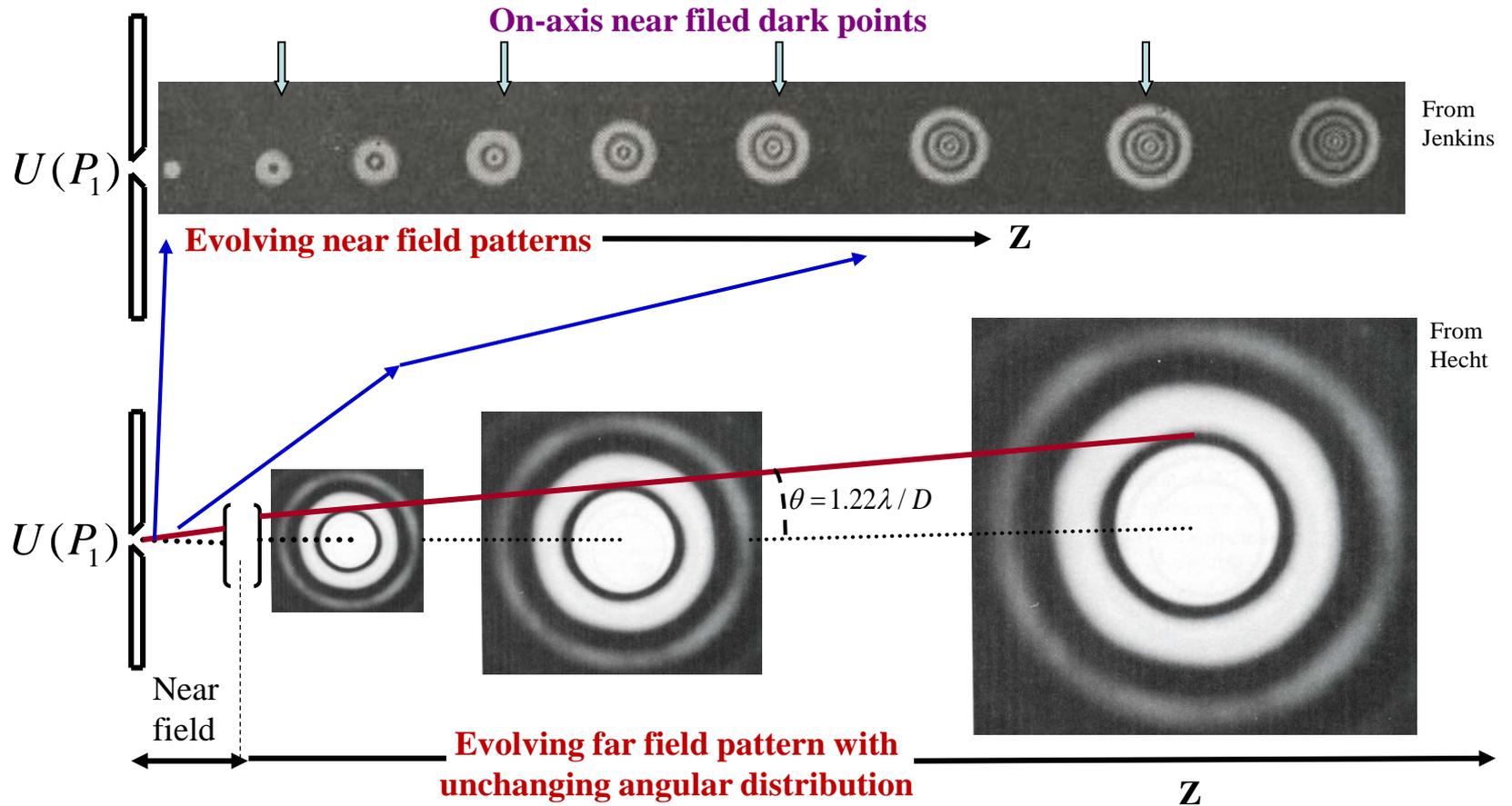*8. Huygens' Complex Tension Field and Cosmology*

1. Diffraction as Superposition Effect

SP

$$U(P_0) = \frac{-i}{\lambda} \iint_\Sigma U(P_1) \frac{\exp(ikr_{01})}{r_{01}} \cos\theta \, ds$$

SE

$$I(P_0) = \left| \frac{-i}{\lambda} \iint_\Sigma \chi(\nu) U(P_1) \frac{\exp(ikr_{01})}{r_{01}} \cos\theta \, ds \right|^2$$

On-axis near filed dark points

$U(P_1)$

From Jenkins

Evolving near field patterns ⟶ **z**

$U(P_1)$

$\theta = 1.22\lambda / D$

From Hecht

Near field

Evolving far field pattern with unchanging angular distribution

z

Huygens' Principle of secondary wavelet is more self-consistent and enduring than
Einstein's "Indivisible light quanta"

Huygens' Principle vs. Einstein's "Indivisible light quanta"!

Near-field trajectories of "indivisible light quanta", emitted from "A" and "B", are strongly curvilinear to accommodate in-phase and out-of-phase superposition of these "quanta". *What is the force that creates this curvilinear re-direction of "photons"? Further, the causality, the foundation behind constructing physics theories, is seriously compromised to accommodate "single photon interference"!*

Poynting Vector $\vec{S}_A$
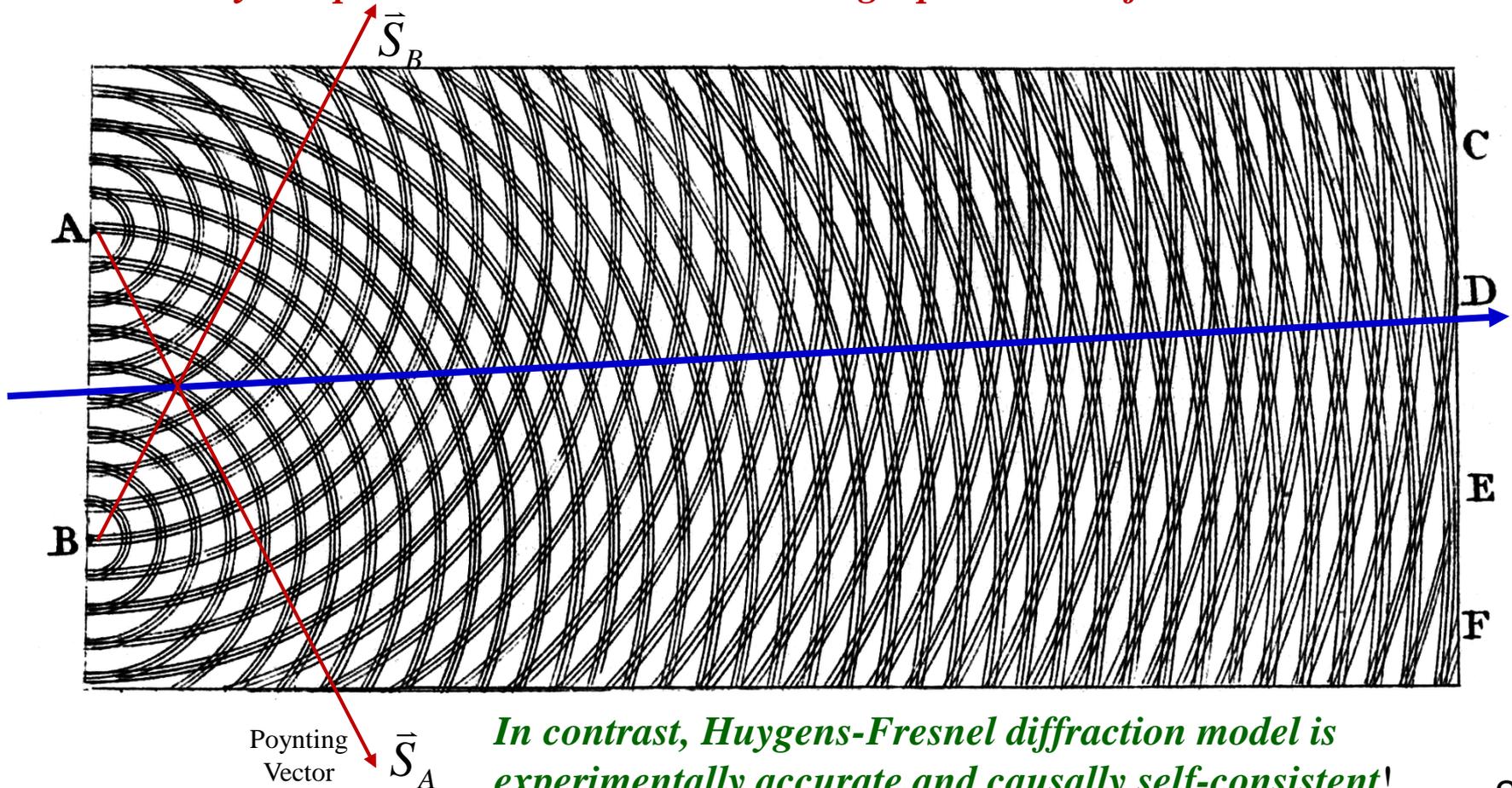
In contrast, Huygens-Fresnel diffraction model is experimentally accurate and causally self-consistent!
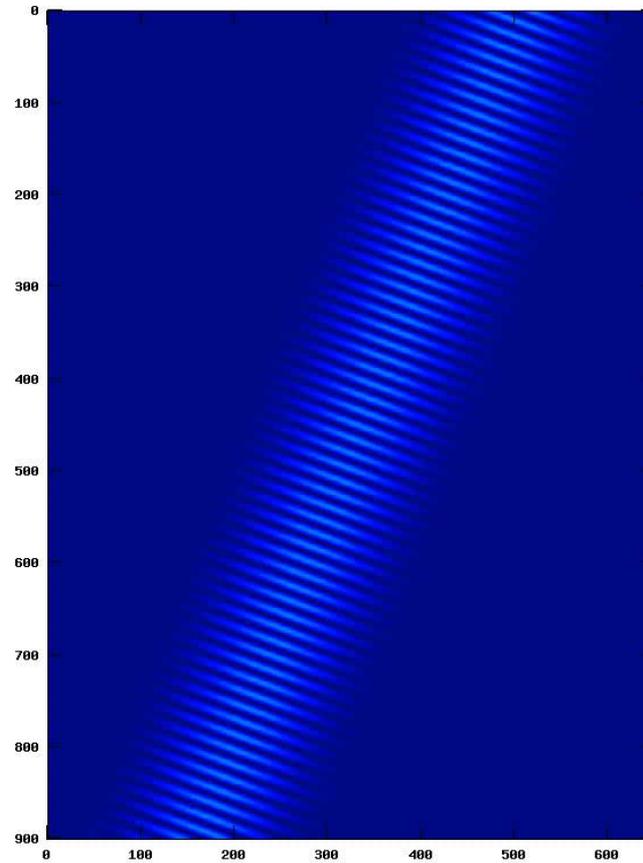
24

2. Superposition Effects with two collimated beams

Experimental appreciation of detection system's
➢ **"Intrinsic QM integration time"**
➢ **"Device integration time (LCR)"**

Superposition of Same frequency
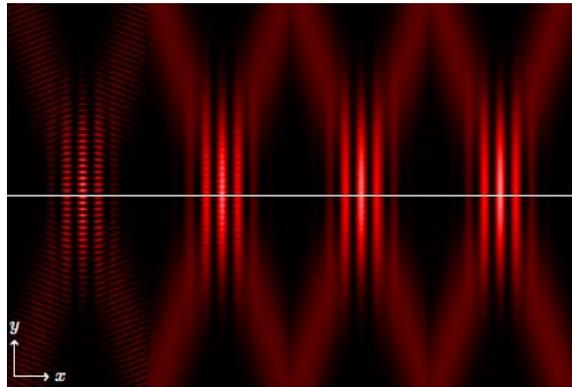**Superposition of Different frequencies**

Video simulation.

Successful math reveals more built-in *causing processes* in the detector

"Intrinsic QM time integration"

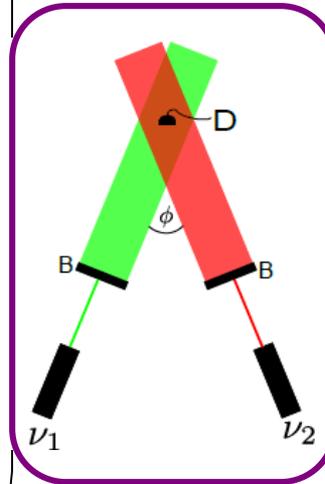Same frequency

(a) $T = 0$ (b) $T = 1/2\nu_0$ (c) $T = 1/\nu_0$ (d) $T = 2/\nu_0$

$$I_{rl.}(\tau) = \left[a\cos 2\pi\nu(t - \tau/2) + a\cos 2\pi\nu(t + \tau/2)\right]^2$$

$$= 4a^2 \cos^2 2\pi\nu t \; \cos^2 \pi\nu\tau$$

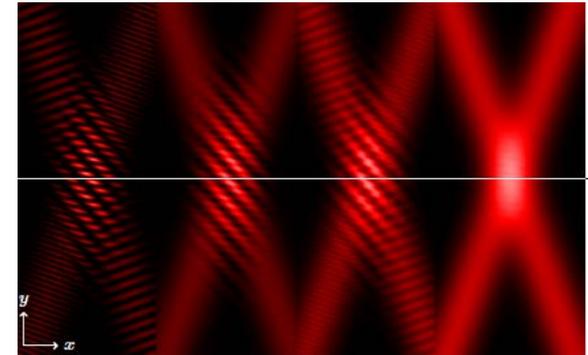$$\left\langle I_{rl.}(\tau)\right\rangle_T = 2a^2 \cos^2 \pi\nu\tau$$

In the optical domain, we cannot detect oscillations in the bright fringes at optical frequencies.

But, electrical engineers do with radio waves, because the detecting LCR circuits are not quantum devices.

Detection system's "time integration"

Two frequencies

(a) $T = 0$ (b) $T = 1/\nu_1$ (c) $T = \frac{2}{\nu_1 + \nu_2}$ (d) $T = 2/\nu_2$

$$D_{rl.}(t,\tau) = \left[\begin{array}{c} \chi a \cos 2\pi\nu_1(t - \tau/2) \\ + \chi a \cos 2\pi\nu_2(t + \tau/2) \end{array}\right]^2$$

$$D_{cx.}(t,\tau) = \left|\chi a_1 \; e^{i2\pi\nu(t-\tau/2)} + \chi a_2 \; e^{i2\pi\nu(t+\tau/2)}\right|^2$$

$$= 2\chi^2 a^2 \left[1 + \cos 2\pi\{(\nu_2 - \nu_1)t + (\nu_2 + \nu_1)(\tau/2)\}\right]$$

Michelson hypothesized that different optical frequencies do not "interfere" because his detectors, eyes and photographic plates are long-time integrators.

Superposition of Radio and optical waves generate distinctly different responses in our detectors!

Consistently apply interaction process mapping epistemology

Massive number of classical conduction electrons oscillate in response to the amplitudes of the waves
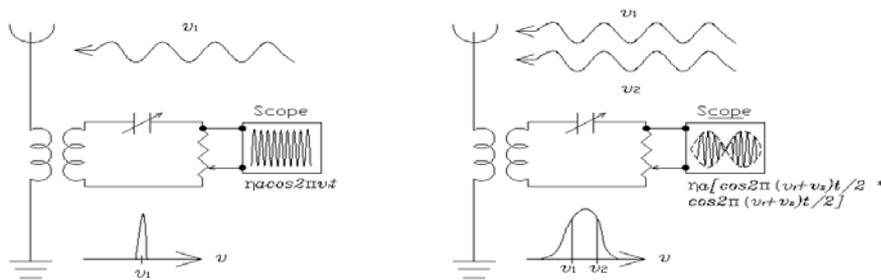
QM-bound valence electrons get stimulated as quantum dipole systems by the amplitudes of the E-field and DISCRETE electrons are transferred to the upper band.
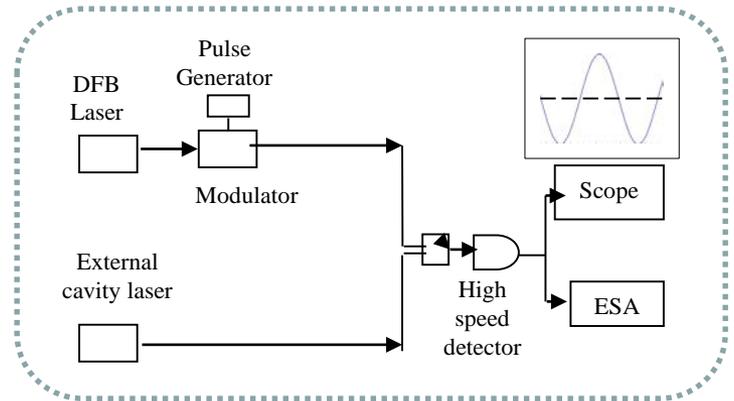
Recorded result: No sign of Fourier summation

EM fields: $E(t, \nu_{1,2}) = a \cos 2\pi \nu_{1,2} t;$

Current: $I_{LCR}(t, \nu_{1,2}) = \eta a \cos(2\pi \nu_{1,2} t + \varphi);$

Voltage: $V_{LCR}(t, \nu_{1,2}) = \eta a \cos 2\pi \nu_{1,2} t$

Power: $I_{LCR} V_{LCR} = \eta^2 a^2 \cos 2\pi \nu_{1,2} t \cos(2\pi \nu_{1,2} t + \varphi)$

Superposed current:

$I_{LCR}(t, \nu_1, \nu_2) = \eta a [\cos 2\pi \nu_1 t + \cos 2\pi \nu_2 t]$

$= 2\eta a \cos 2\pi \dfrac{\nu_2 + \nu_1}{2} t \cdot \cos 2\pi \dfrac{\nu_2 - \nu_1}{2} t$

The (two-term) time-frequency Fourier theorem (TF-FT) works.

$i(\tau) = \left| \chi e^{i 2\pi \nu_1 t} + \chi e^{i 2\pi \nu_2 t} \right|^2$

$= 2\chi^2 [1 + \cos 2\pi (\nu_1 - \nu_2) t]$
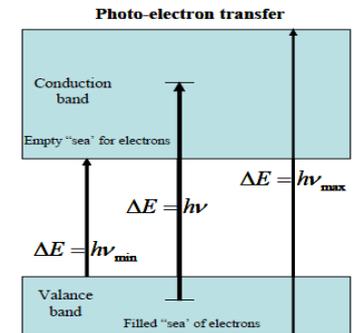
Photo-electron transfer

$h\nu$ becomes "quantized" or assumes a unique value only when ν assumes a unique number (h being a constant).

The time-frequency Fourier theorem (TF-FT) does not work.

29

Light-matter interaction *processes* do not follow mathematical algorithm steps required by TF-FT

1. Fourier frequencies of the AM envelope are absent from the data.

2. Complex algorithm for Fourier decomposition is not carried out by optical detectors

Pulse Generator

DFB Laser

Modulator

External cavity laser

High speed detector

Scope

ESA

Electrical spectrum with optical beat at 14.37GHz

Electrical spectrum with optical beat at 14.37GHz, Data rate: 2.5Gb/s

Power (dBm)

frequency in GHz

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

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.

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

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Light-matter interaction *processes* do not follow mathematical algorithm steps required by TF-FT

Fourier synthesis does not take place for light-atom interactions

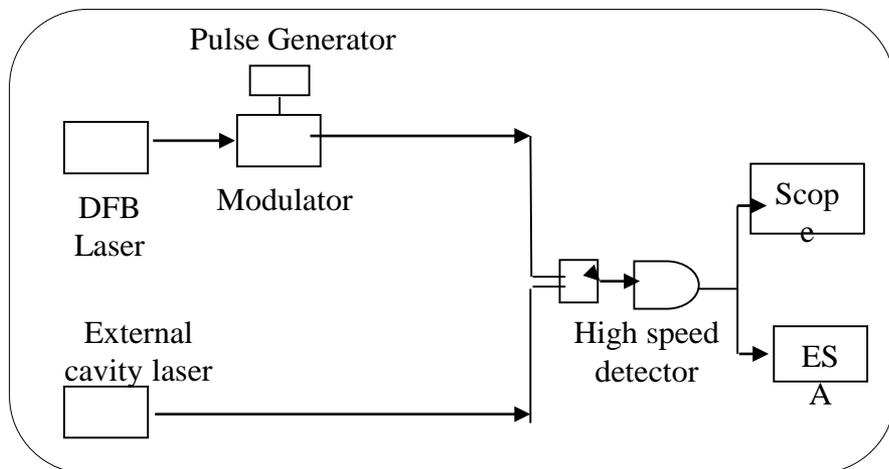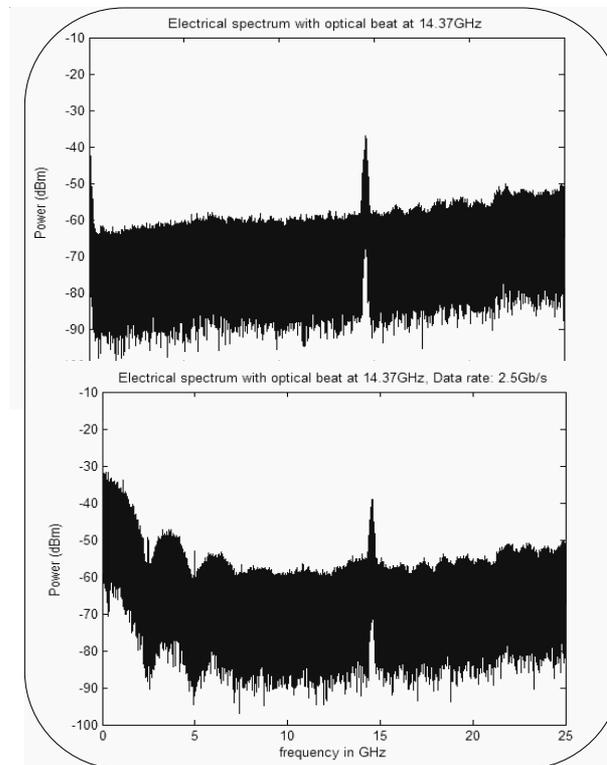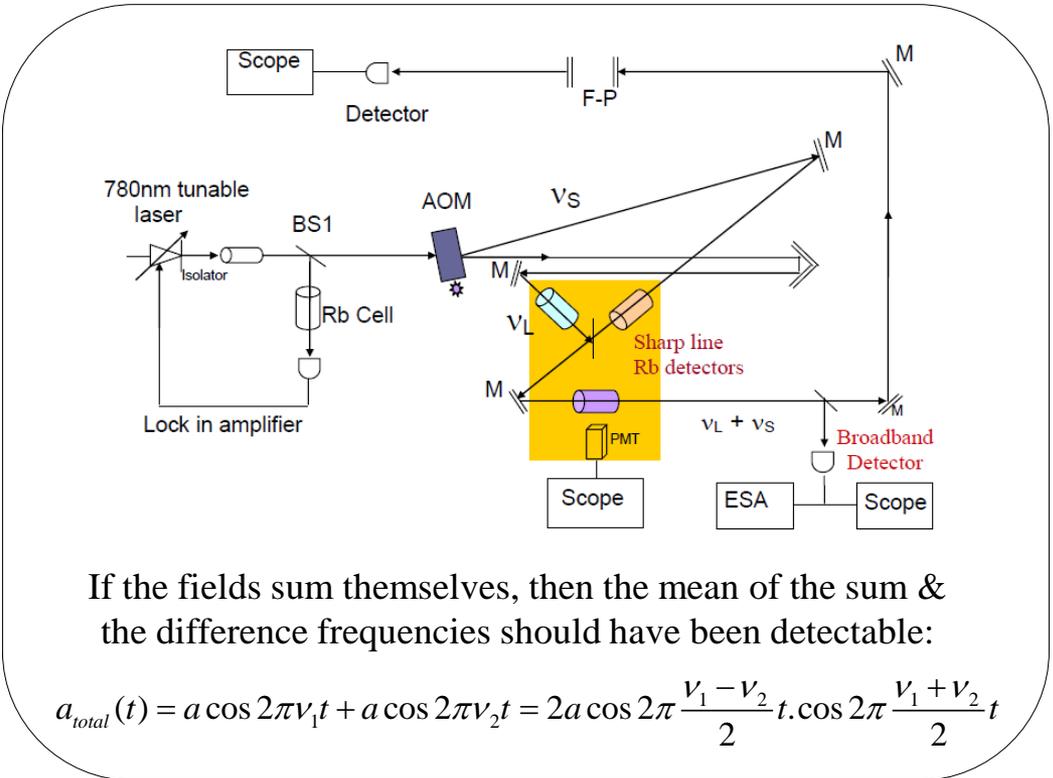If the fields sum themselves, then the mean of the sum & the difference frequencies should have been detectable:

$$a_{total}(t) = a\cos 2\pi\nu_1 t + a\cos 2\pi\nu_2 t = 2a\cos 2\pi\frac{\nu_1 - \nu_2}{2}t.\cos 2\pi\frac{\nu_1 + \nu_2}{2}t$$

In reality, the **narrow-band atomic dipoles** recognize original carrier frequencies only.

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

The photo electric process being quadratic, the broad-band dipole complexes make electron transfer only at the beat (difference)

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

$$= 2\,{}^{(1)}\chi^2 a^2 [\text{slow detector circuit}]$$
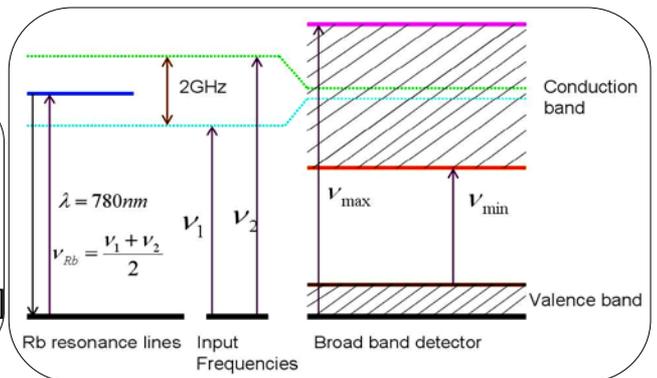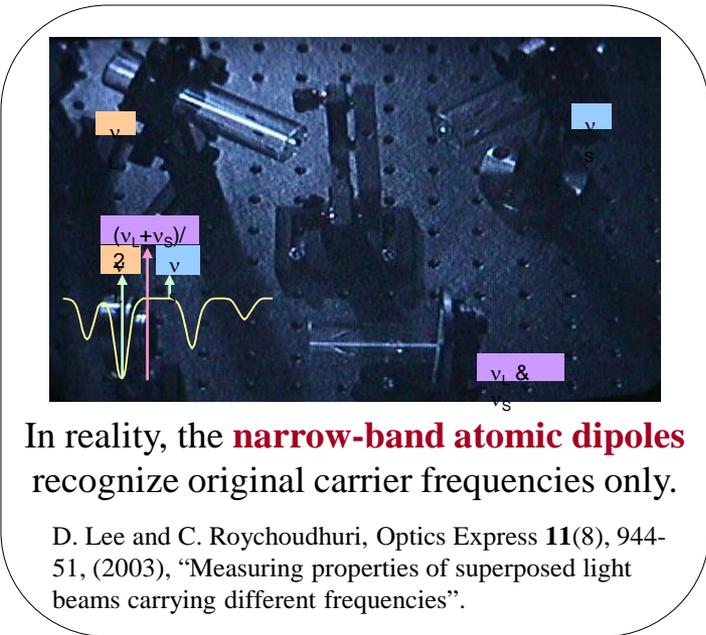
Fourier transform Spectroscopy vs. Light beating spectroscopy

Detectors' signal integration time constant dictates which of the two spectroscopy one can carry out; Fourier or Heterodyne!

Differentiating between Fourier transform spectroscopy & light beating spectroscopy

Detector's electronic time constant dictates the type of observe photo current.

Understanding "process" guided Physics:

Non-interference between different frequencies $\Longleftrightarrow$ **Long detector integration time.**

Consider the Michelson is illuminated by a CW He-Ne laser running two equal modes.

M 2

M 1   BS

Input

(ν_1, ν_2)
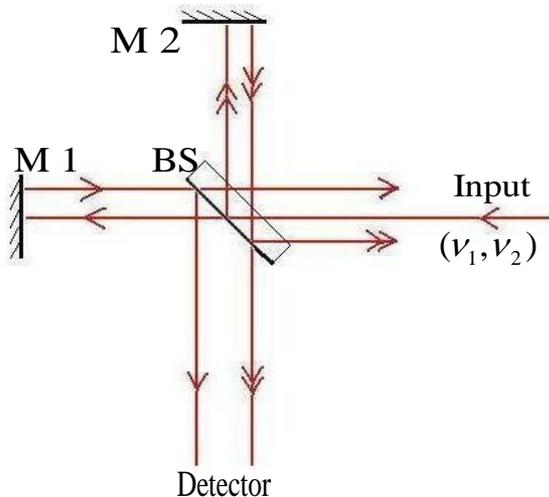
Detector

A slow detector response gives FTS results:

$$D(\tau) = \left| e^{i2\pi\nu_1 t} + e^{i2\pi\nu_2 t} + e^{i2\pi\nu_1(t+\tau)} + e^{i2\pi\nu_2(t+\tau)} \right|^2$$

$$= \left| e^{i2\pi\nu_1 t} + e^{i2\pi\nu_1(t+\tau)} \right|^2 + \left| e^{i2\pi\nu_2 t} + e^{i2\pi\nu_2(t+\tau)} \right|^2$$

$$= 4 + 2\underline{(\cos 2\pi\nu_1\tau + \cos 2\pi\nu_2\tau)}$$

Remove the "DC" signal and Fourier transform:

$$D_{Osc.}(\tau) = \cos 2\pi\nu_1\tau + \cos 2\pi\nu_2\tau$$

$$\tilde{D}(\nu) = \delta(\nu - \nu_1) + \delta(\nu - \nu_2)$$
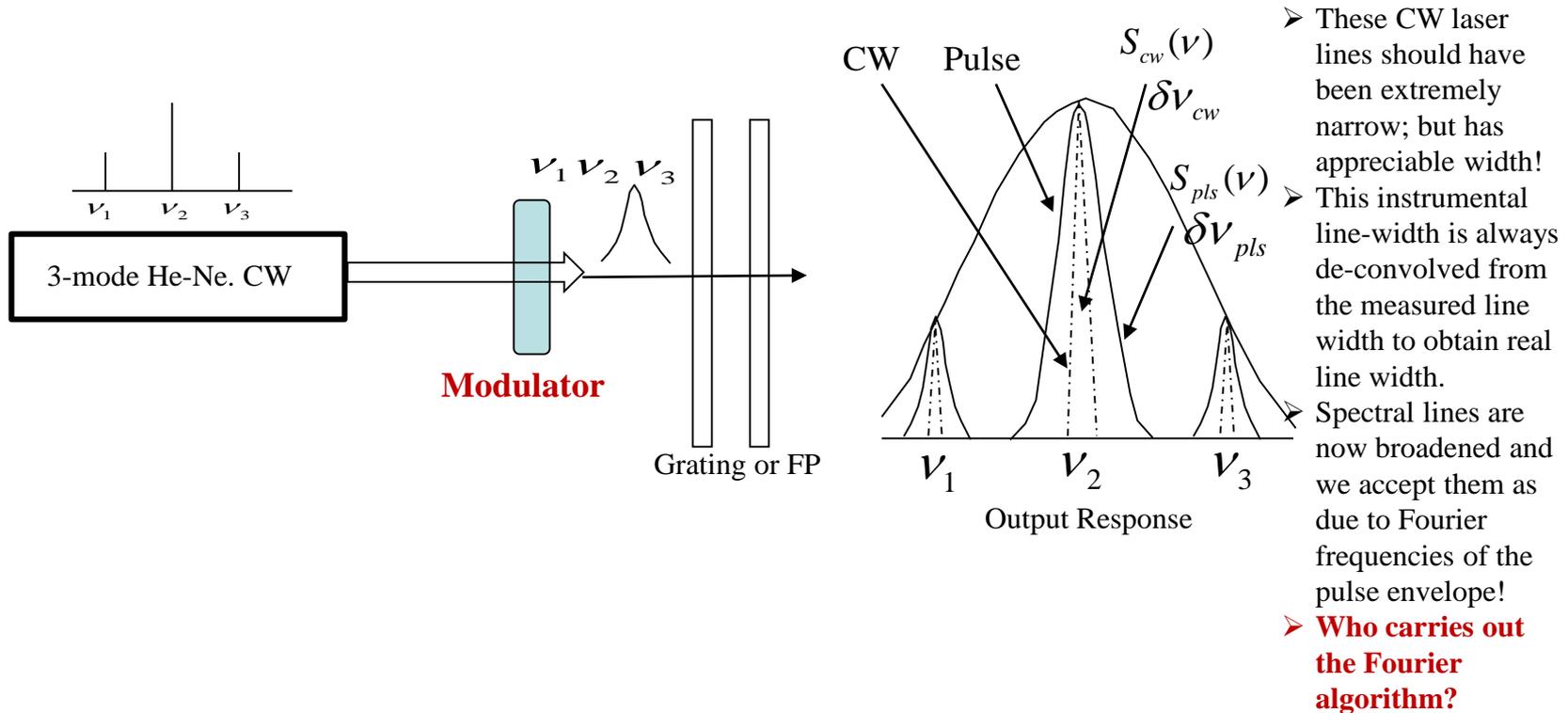
A fast detector gives LBS results:

$$D(\tau) = 4 + 2\cos 2\pi(\nu_1 - \nu_2)t$$
$$+ 2[\cos 2\pi(\nu_1 - \nu_2)(t+\tau) + \cos 2\pi\{(\nu_1 - \nu_2)t + \nu_1\tau\}$$
$$+ \cos 2\pi\{(\nu_1 - \nu_2)t - \nu_2\tau\}$$
$$+ 2\underline{[\cos 2\pi\nu_1\tau + \cos 2\pi\nu_2\tau]}$$

33

3. Superposition Effects with Multiple Beams

A causal theory of spectrometry

Conceptual contradiction in classical spectrometry; accepted without questions by QM theorists!

When the laser beam is pulsed, we interpret the spectrum in a very different way!

> ➤ These CW laser lines should have been extremely narrow; but has appreciable width!
> ➤ This instrumental line-width is always de-convolved from the measured line width to obtain real line width.
> ➤ Spectral lines are now broadened and we accept them as due to Fourier frequencies of the pulse envelope!
> ➤ **Who carries out the Fourier algorithm?**

(i)   Measure the pulse envelope.
(ii)   Store in a memory.
(iii)   Carry out the Fourier decomposition integral.
(iv)   Process each Fourier monochromatic component independent of others.

Is the instrumental line width limit, $\delta\nu\delta t \geq 1$, a fundamental principle of nature?
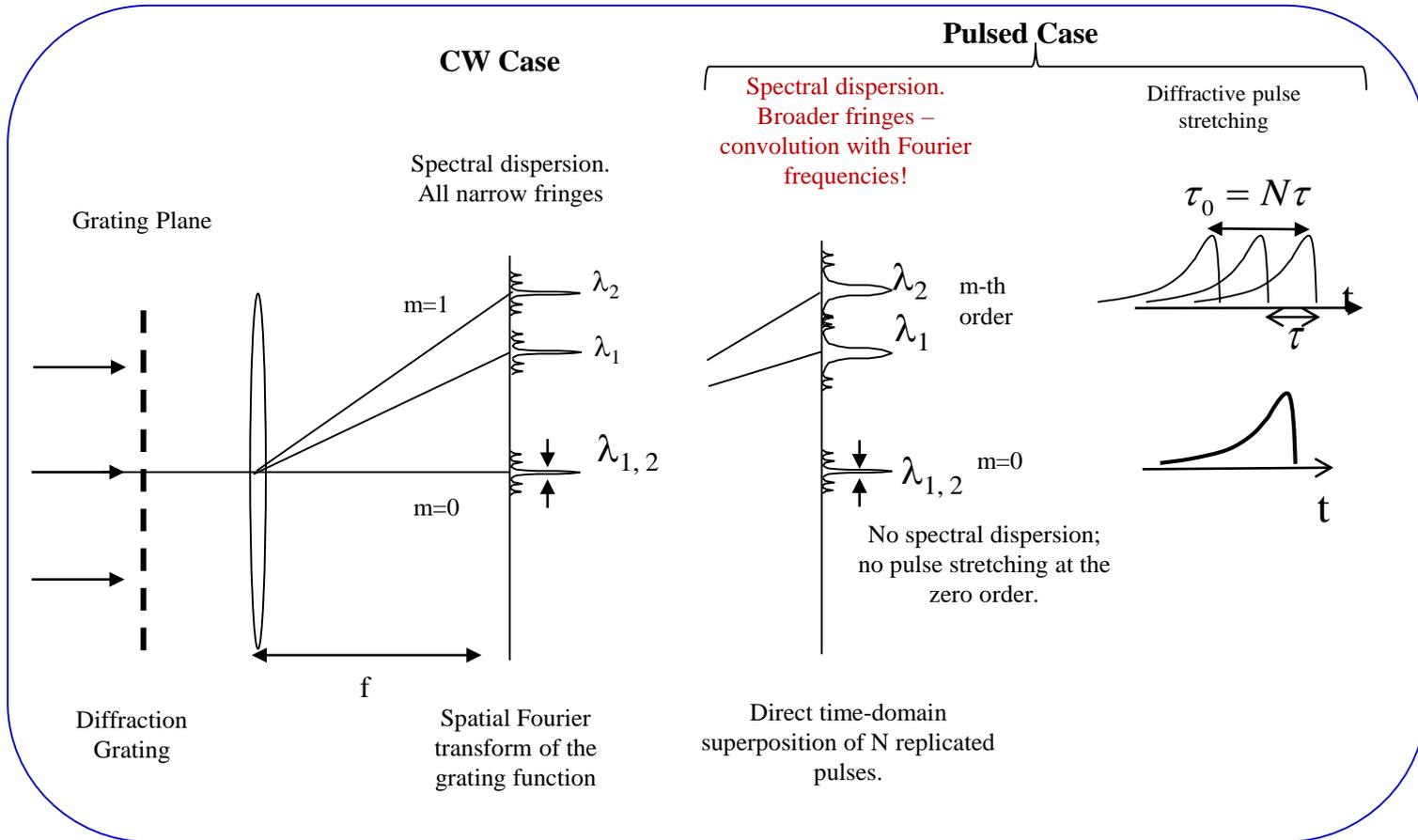

CW   Pulse

$S_{cw}(\nu)$
$\delta\nu_{cw}$

$S_{pls}(\nu)$
$\delta\nu_{pls}$

ν_1 ν_2 ν_3

3-mode He-Ne

Modulator

Grating or FP

Output Response
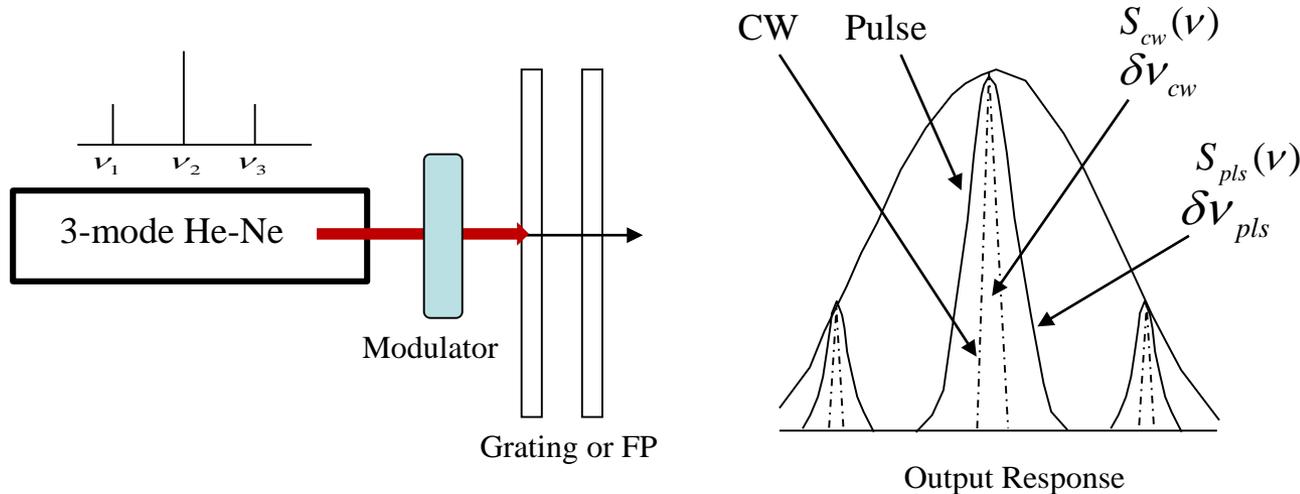
- **Neither** $S_{cw}(\nu)$ **nor** $S_{pls}(\nu)$ **represent any new carrier frequencies. Gratings and Fabry-Perots are linear pulse replicators. They cannot introduce any new optical frequencies. Only non-linear light-matter interaction processes are capable of generating new optical frequencies.**

- **The problem lies with the framing of the optical spectrometric theory! Classical theory has been assuming that light beams of infinite temporal duration with a single carrier frequency exist, which is causally impossible! Even a CW laser has to be turned on and off!**

- **All natural light sources emit time-finite pulses with unique carrier frequencies determined by the characteristic resonant or quantum oscillation period.**

Why do we mix up SS-FT and TF-FT?

SS-FT **TF-FT** **Reality**

Pulsed Case

CW Case

Spectral dispersion.
Broader fringes –
convolution with Fourier
frequencies!

Diffractive pulse
stretching

Spectral dispersion.
All narrow fringes

$$\tau_0 = N\tau$$

Grating Plane

λ_2

m=1

λ_2

m-th
order

λ_1

λ_1

t

$\lambda_{1,2}$

$\lambda_{1,2}$ m=0

t

m=0

No spectral dispersion;
no pulse stretching at the
zero order.

f

Diffraction
Grating

Spatial Fourier
transform of the
grating function

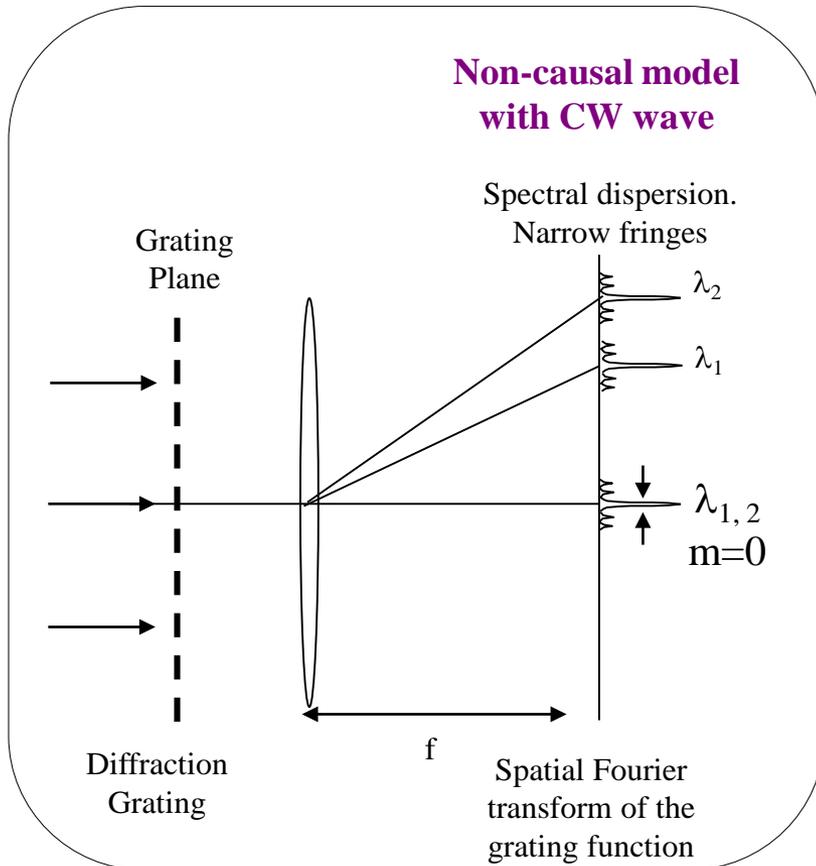Direct time-domain
superposition of N replicated
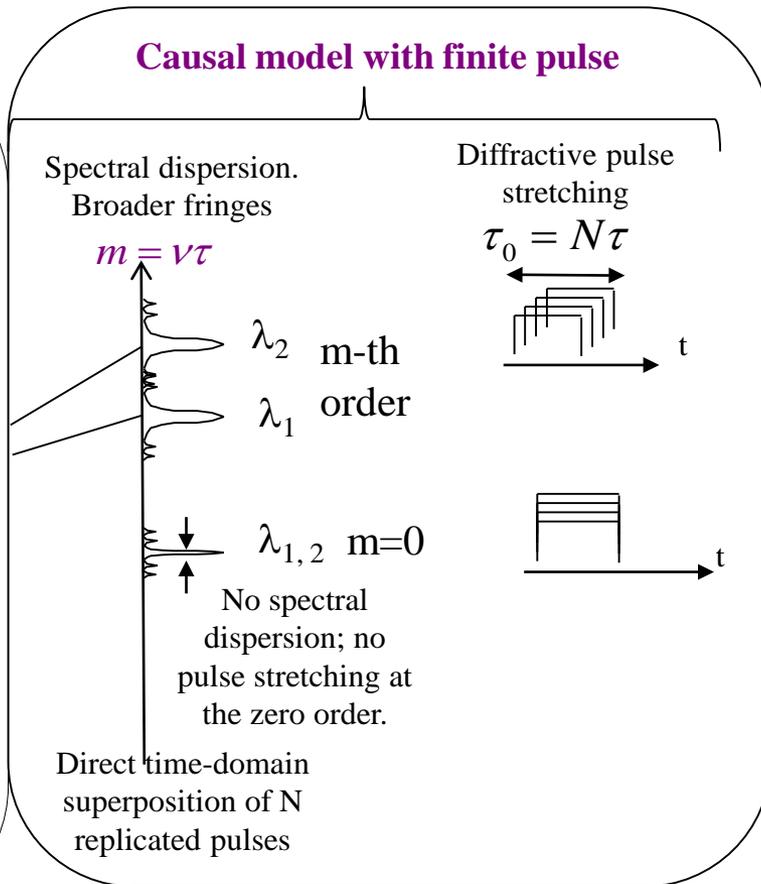pulses.

Fourier mode is a non-causal signal

$$I_{cw}(\nu,\tau) = \frac{1}{N^2} \frac{\sin^2 \pi N \nu \tau}{\sin^2 \pi \nu \tau} \equiv \frac{1}{N} + \frac{2}{N^2} \sum_{p=1}^{N-1} (N-p)\cos[2\pi p \nu \tau]$$
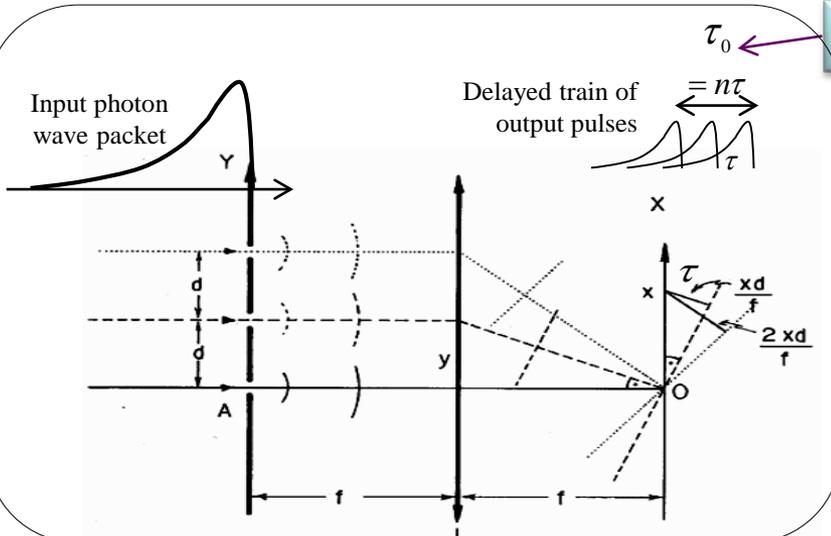
Modeling with non-causal signal!

Modeling with causal signal!

Non-causal model with CW wave

Causal model with finite pulse

Spectral dispersion. Narrow fringes

Grating Plane

λ_2

λ_1

$\lambda_{1,2}$ m=0

Diffraction Grating

f

Spatial Fourier transform of the grating function

Spectral dispersion. Broader fringes

$m = \nu\tau$

Diffractive pulse stretching

$\tau_0 = N\tau$

λ_2 m-th

λ_1 order

t

$\lambda_{1,2}$ m=0

No spectral dispersion; no pulse stretching at the zero order.

Direct time-domain superposition of N replicated pulses

t

Causal formulation: A finite envelope with a fixed carrier frequency

τ_0 — **1**

Input photon wave packet

Delayed train of output pulses $= n\tau$

1. Spectrometers have a time constant.

2. Pulses longer than the time constant resemble CW response.

3. Spectral fringe broadening for shorter pulses mathematically appears as a convolution of the Fourier spectrum & CW response.

Only source generated carrier frequency is the physical information.

Time varying amplitude:
$$i_{out}(t) = \sum_{n=0}^{N-1}(1/N)a(t-n\tau)\cdot\exp[i2\pi\nu(t-n\tau)]$$

Time varying intensity:
$$|i_{out}(t)|^2 = \left|\sum_{n=0}^{N-1}(\chi/N)a(t-n\tau)\cdot\exp[i2\pi\nu(t-n\tau)]\right|^2$$

Time integrated energy:
$$I_{pls}(\nu,\tau)| = \frac{\chi^2}{N} + \frac{2\chi^2}{N^2}\sum_{p=1}^{N-1}(N-p)\gamma(p\tau)\cos[2\pi p\nu\tau]$$

Detecting dipole carries out the summation of multiple stimulations.

Autocorrelation function:
$$\gamma(p\tau) = \int d(t-n\tau)d(t-m\tau)\ dt \Big/ \int d^2(t)\ dt$$

2

$$\underset{\delta t\to\tau_0=N\tau}{Lt.}\ I_{pls}(\nu,\tau) = \frac{\chi^2}{N} + \frac{2\chi^2}{N^2}\sum_{p=1}^{N-1}(N-p)\cos[2\pi p\nu\tau] \equiv \frac{\chi^2}{N^2}\frac{\sin^2\pi N\nu\tau}{\sin^2\pi\nu\tau} \equiv I_{cw}(\nu,\tau)$$

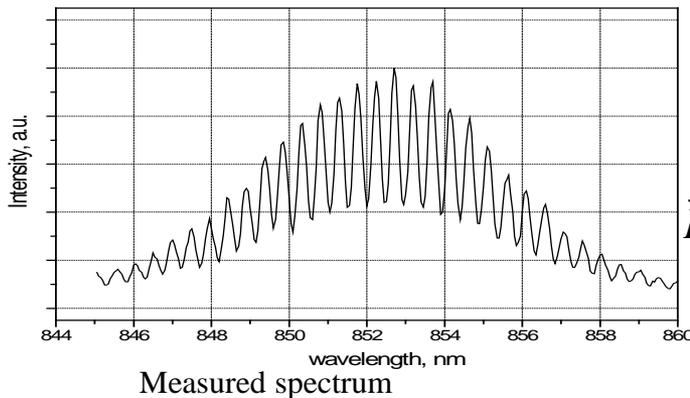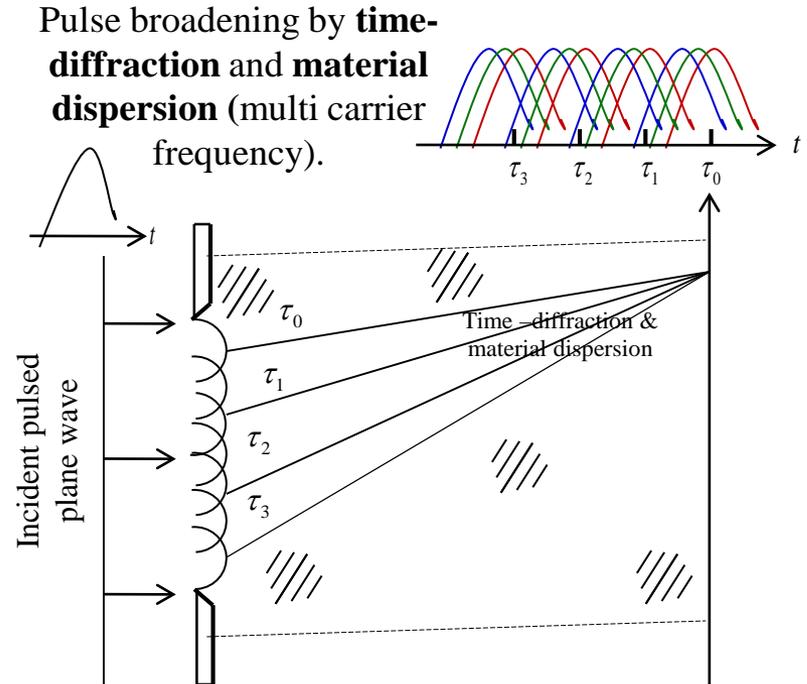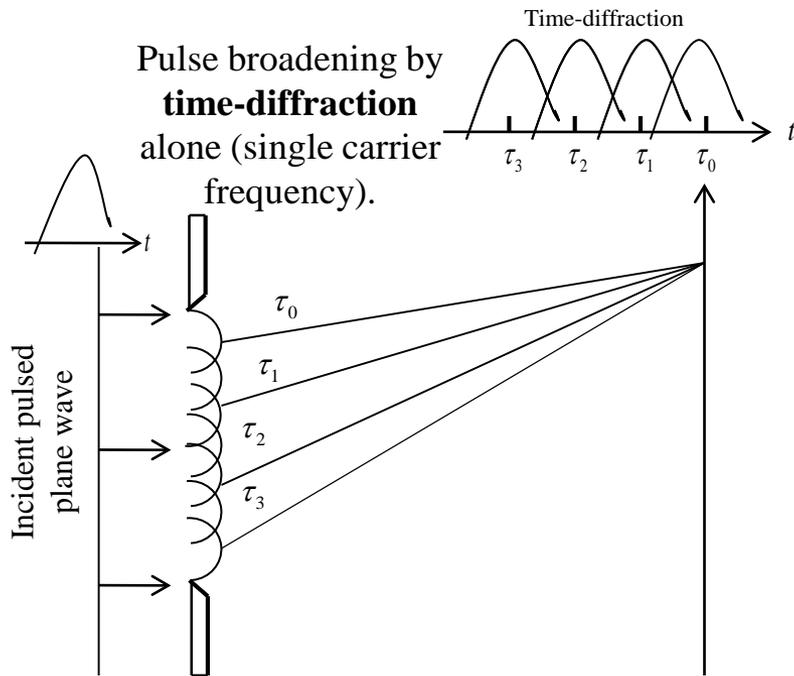$$I_{pls}(\nu,\tau) \approx \int_{-\infty}^{\infty}|i_{out}(t)|^2 dt = I_{cw}(\nu)\otimes\tilde{A}(\nu)$$

3

Pulse broadening due to propagation happens through two separate optical phenomena – (i) Time-diffraction & (ii) Material dispersion.

Pulse broadening by **time-diffraction** alone (single carrier frequency).

Time-diffraction

τ_3 τ_2 τ_1 τ_0 t

Incident pulsed plane wave

t

τ_0
τ_1
τ_2
τ_3

Pulse broadening by **time-diffraction** and **material dispersion** (multi carrier frequency).

τ_3 τ_2 τ_1 τ_0 t

Incident pulsed plane wave

t

τ_0
τ_1
τ_2
τ_3

Time –diffraction & material dispersion

Intensity, a.u.

844   846   848   850   852   854   856   858   860
wavelength, nm

Measured spectrum

$$\overline{D}_{\Sigma v}(v, \tau) = S(v) \otimes \overline{D}(v, \tau);$$

$$\overline{D}(v, \tau) = \frac{\chi^2}{N} + \frac{2\chi^2}{N^2} \sum_{p=1}^{N-1} (N - p)\gamma(p\tau)\cos[2\pi p v \tau]$$

# 4. Superposition Effects & Emergence of Laser Modes, CW and Mode Locked

The Fourier summation predicts a single central carrier frequency! But the frequency comb is always present!

Spectral analysis of mode locked pulse train from He-Ne, Si-N micro ring & Ti-Sapphire macro cavity. Fourier synthesis is absent (NIW-property)!
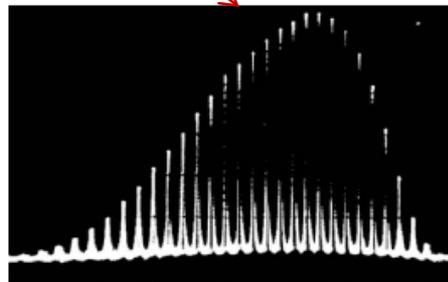
$$E_{cavity}(\nu_0,t) = \sum_{-(N-1)/2}^{+(N-1)/2} e^{i2\pi(\nu_0+n\delta\nu)t+i\phi_c} = e^{i2\pi\nu_0 t+i\phi_c} \sum_{-(N-1)/2}^{+(N-1)/2} e^{i2\pi(n\delta\nu)t} = \frac{\sin N\pi(t/\tau)}{\sin \pi(t/\tau)} e^{i2\pi\nu_0 t+i\phi_c} \equiv a(t-n\tau)e^{i2\pi\nu_0 t+i\phi_c}$$

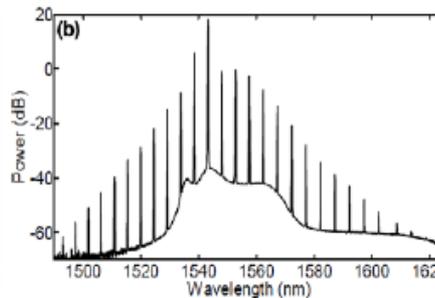All N-modes are present in the spectrum.

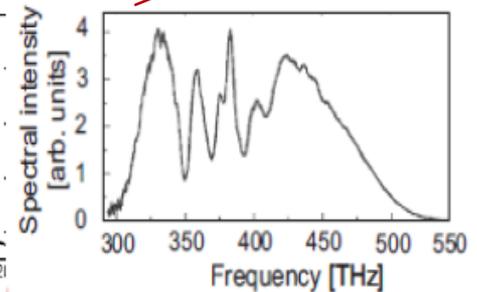Fourier synthesis to mean central frequency did not materialize in any examples!
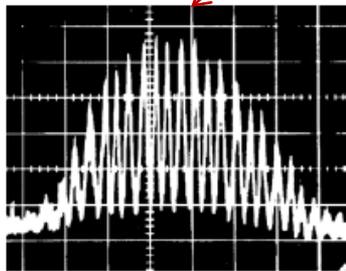
(a)   (b)   (c)   (d)

Frequency comb (optical spectrum) from mode locked nano second HeNe lasers (a,b), from a 300fs micro-cavity ring laser (c) and from ~4fs Ti-Sapphire laser (d). Cavity modes are present in each one of the pulse train because of Non-Interaction of waves (NIW). The spectrum in (d) is very complex, first, because the mode spacing is much smaller than the pulse response function of the spectrometer used and other complexities involved in the measurement.

(a). Allen, L.B., Rice, R. R., Mathews, R. F., "Two cavity mode locking of a He-Ne laser"; APL, Vol.15 (12), pp.416-418 (1969).
(b) Hargrove, L. E., Fork, R. L., Pollack, M. A.; "Locking of He-Ne laser modes induced by synchronous intracavity modulation"; Appl. Phys. Lett. 5, p. 4-5 (1964).
(c) Ferdous, F., Miao, H. , Leaird, D.E., Srinivasan, K., Wang, J., Chen, L., Varghese, L.,T., Weiner, A. M., "Spectral Line-by-Line Pulse Shaping of an On-Chip Microresonator Frequency Comb" http://arxiv.org/ftp/arxiv/papers/1103/1103.2330.pdf ; Conference Paper CLEO, May1 (2011).
(d) Krausz, F., "Attosecond physics", Rev. Mod. Physics, Vol. 81, Jan.-Mar.(2009).

C. Roychoudhuri, U. Connecticut & Femto Macro Continuum

## Then how does Krausz's group finds the Fourier mean frequency in their fs pulse?

The direct measurement of a f-sec pulse from a homogeneously broadened Ti-Sapphire "mode-locked" laser gives the Fourier central frequency !!

$$E(v_0,t) = \sum_{-(N-1)/2}^{+(N-1)/2} e^{i2\pi(v_0+n\delta v)t+i\phi_c} \underset{medium}{\overset{in}{=}} \chi(v,t)\frac{\sin N\pi\delta v(t-n\tau)}{\sin \pi\delta v(t-n\tau)} e^{i2\pi v_0 t+i\phi_c} = \chi(v,t)a(t-n\tau)e^{i2\pi v_0 t+i\phi_c}$$

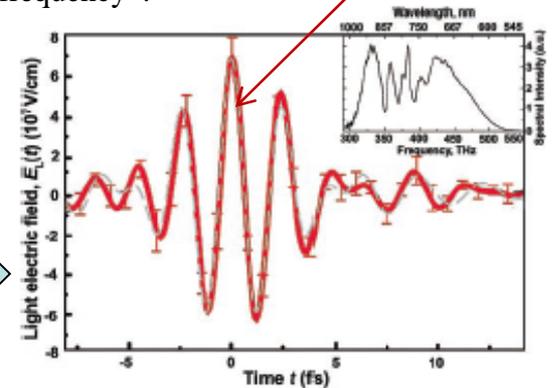Proper spectral measurement gives the mode **"frequency comb"**.
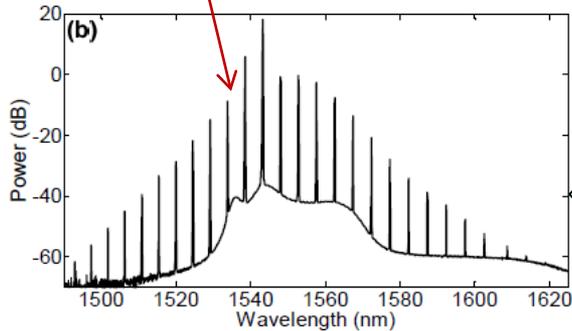
Specialized "amplitude" measurement gives the mean "carrier frequency"!
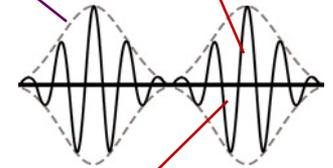
Both are reproducible measured data!

Spectrometer process.

Free electron acceleration process.

$$E(t) \sim \left[\text{Re}\sum_{-(N-1)/2}^{+(N-1)/2} e^{i2\pi(v_0+n\delta v)t+i\phi_c}\right]^2 = \left[a(t-n\tau)\cos(2\pi v_0 t + \phi_c)\right]^2$$
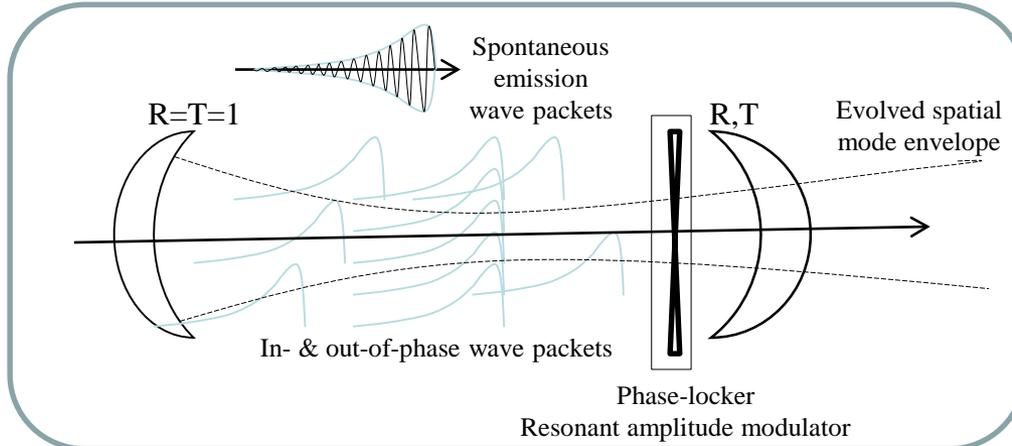
Physical process: Photo ionized free electrons carry out the linear summation and squared energy transfer!

"Direct Measurement of Light Waves"
Goulielmakis et. al., SCIENCE VOL 305 27 AUGUST 2004

C. Roychoudhuri, U. Connecticut & Femto Macro Continuum

Modeling "phase-locked-pulsation" as time-gating operation. Because Fourier synthesis, wave-wave interaction does not happen!

The intra-cavity phase-lockers (absorber, Kerr lens modulator, etc.) effectively function as time-gating switches, effectively creating amplitude modulation of the exiting laser field resonating with the cavity round-trip time.

Spontaneous emission wave packets

R=T=1

R,T   Evolved spatial mode envelope

In- & out-of-phase wave packets

Phase-locker
Resonant amplitude modulator

Since discrete quantum level transitions generate both the spontaneous and the stimulated emission wave packets, we should incorporate photon wave packet envelope function exp[licitly in our analyses.

Light amplitudes stimulating the phase-locker:
$$i_1(t) = \sum_m \sum_n a(t - t_n) \cdot \exp[i 2\pi \nu_m (t - t_n) + \varphi_m]$$

Amplitude stimulation of the phase-locker:
$$d_1(t) = \sum_m \sum_{n\ 1} \chi a(t - t_n) \cdot \exp[i 2\pi \nu_m (t - t_n) + \varphi_m]$$

Amplitude transparency of the phase-locker:
$$D_1(t) = \left| \sum_m \sum_{n\ 1} \chi a(t - t_n) \cdot \exp[i 2\pi \nu_m (t - t_n) + \varphi_m] \right|^2$$

Re-entrant amplitude: $i_2(t) = i_1(t) D_1(t) T$

Next round of iteration: $i_3(t) = \eta_g i_2(t) + \sum$ spontaneous emsns.

And so on: $d_3(t) = \chi i_3(t)$

$$D_3(t) = |d_3(t)|^2$$

Re-entrant amplitude: $i_4(t) = i_3(t) D_3(t) T$

44

5. Superposition Effects and Group Velocity (Material Dispersion!)
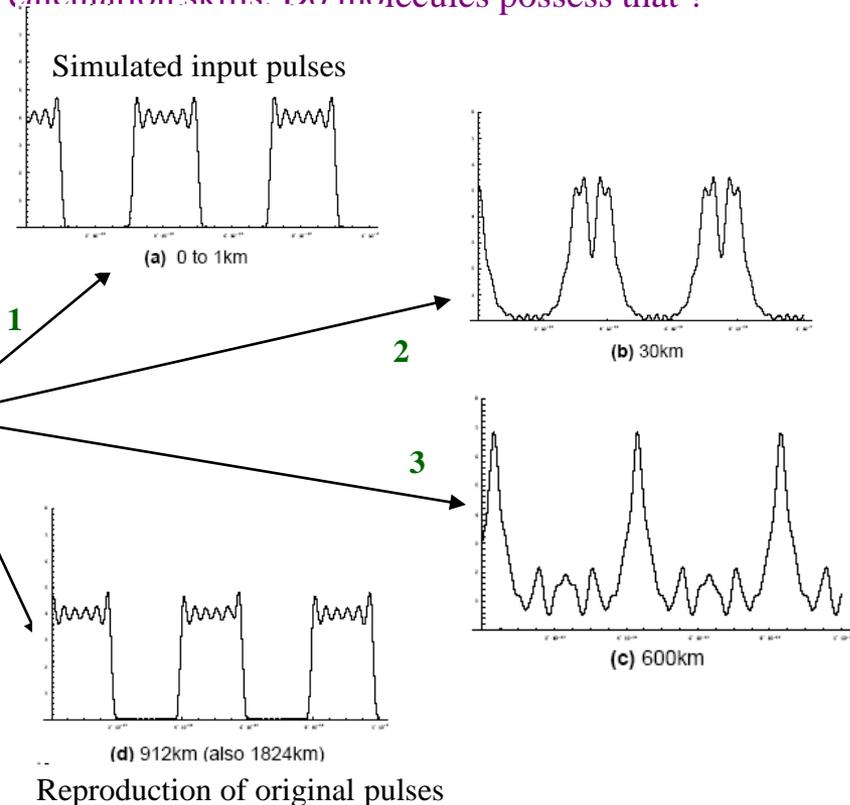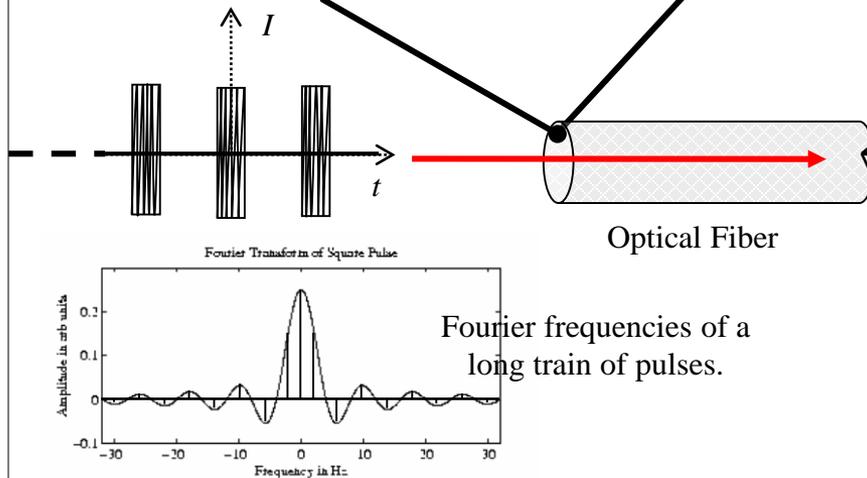
A linear tension field, while acting in the linear domain, can support only "phase" velocity dictated by the intrinsic tension-restoration force-constants in play. A tension filed cannot execute Fourier transform algorithm in the absence of non-linear devices with memory!

Propagating of Fourier frequencies (TF-FT) is a non-causal model!
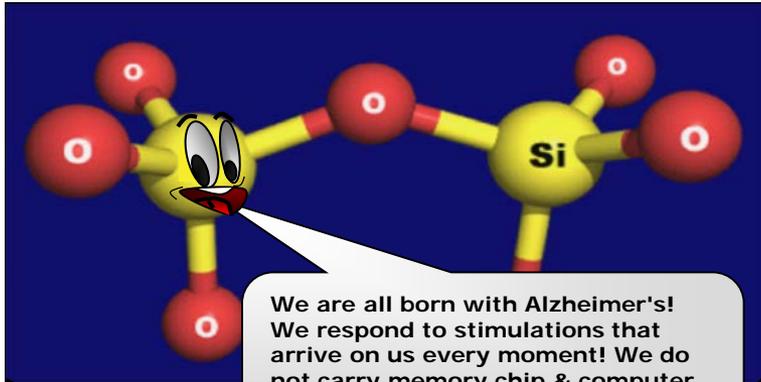
We are all born with Alzheimer's! We respond to stimulations that arrive on us every moment! We do not carry memory chip & computer to read any pulse envelope& Fourier transform it!

We must propagate the carrier frequency of the pulse, and not the fictitious Fourier frequencies of an imaginary envelope function to avoid paradoxical results like "super-luminal velocity of pulses! Carrying out Fourier transform requires (i) reading time, (ii) storage memory, & (ii) calculation skills. Do molecules possess that ?

Simulated input pulses

(a) 0 to 1km

(b) 30km

(c) 600km

(d) 912km (also 1824km)

Reproduction of original pulses

Optical Fiber

I

t

Fourier frequencies of a long train of pulses.

Fourier Transform of Square Pulse

Amplitude in arb units

Frequency in Hz

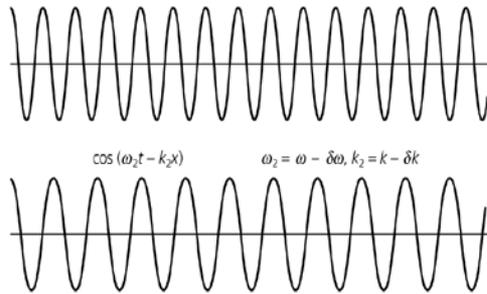# Non-causal model for group-velocity contradicts NIW-property

$$E(t) = \cos(k_1 x - \omega_1 t) + \cos(k_2 x - \omega_2 t) = 2\cos(\overline{k}x - \overline{\omega}t)\cos(dkx - d\omega t)$$

$$\overline{\omega} \equiv (\omega_1 + \omega_2)/2; \ \ \overline{k} \equiv (k_1 + k_2)/2; \ \ d\omega \equiv (\omega_1 - \omega_2)/2; \ \ dk \equiv (k_1 - k_2)/2$$
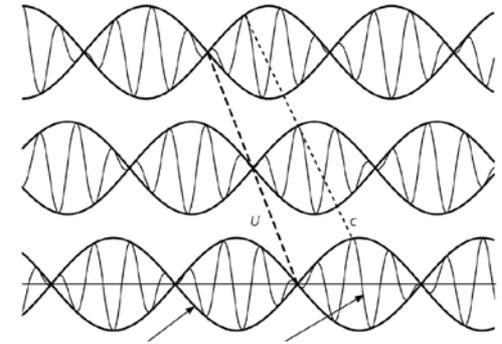
$$v_{ph.} = (\overline{\omega}/\overline{k}) = \overline{\nu}\overline{\lambda} = c/n(\overline{\omega}); \quad \text{and} \quad v_g = d\omega/dk$$

Notice that the group velocity is independent of pulse shape & size!

$$v_g = c\left[n(\lambda_0) - \lambda_0(dn/d\lambda)\right]^{-1}; \qquad n_g \equiv c/v_g = \left[n(\lambda_0) - \lambda_0(dn/d\lambda)\right]$$

$\cos(\omega_2 t - k_2 x)$ $\omega_2 = \omega - \delta\omega, \ k_2 = k - \delta k$

Waves do not re-organize their energies by themselves. But, a fast detector will follow such amplitude stimulation.
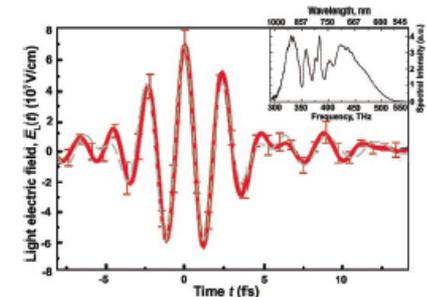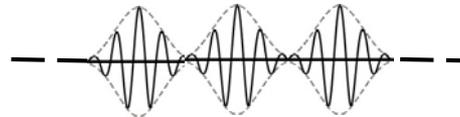

Mode locked frequency-comb Also has the same group velocity!

$$E_{cmplx.}(t) = \sum_{-(N-1)/2}^{+(N-1)/2} e^{i[(k+ndk)x - (\omega_0 + nd\omega)t]} = e^{i[kx - \omega_0 t]}\sum_{-(N-1)/2}^{+(N-1)/2} e^{in[dkx - d\omega t]}$$

$$= e^{i[kx - \omega_0 t]}\frac{\sin(dkx - d\omega t)N/2}{\sin(dkx - d\omega t)/2}$$

$$E_{real}(t) = \cos(kx - \omega t)\frac{\sin(dkx - d\omega t)N/2}{\sin(dkx - d\omega t)/2}$$

Direct Measurement of Light Waves - Goulielmakis et. al., SCIENCE VOL 305 27 AUGUST 2004.

6. Two-beam Superposition & "Coherence"

We re-define "coherence" as correlation of light beams with different parametric values, as perceived by an optical detector. Integration time of a detector plays a critical role in defining the fringe visibility.

I.   *Joint Spectral Correlation*
(light beams with frequency variations).
II.   *Joint Amplitude Correlation*
(light beams with temporal amplitude variations).
III. *Joint Spatial Correlation*
(light beams with independent multiple emitters).
IV.   *Joint Polarization Correlation*
(light beams with polarization variations).
V.   *Complex correlation*
(mixture of the above cases).

White light fringes with a Fresnel bi-prism

Propagating waves are always an orderly oscillatory excitation of a tension field within its linear restoration strength. NIW-property and steady velocity derives out of the tension characteristics. Waves, by themselves, cannot display the measured properties like "coherent", "incoherent" or "partially coherent".

$m = v\tau$
$m = 2$
$m = 0$
$\tau = 0$
Relative delay
τ
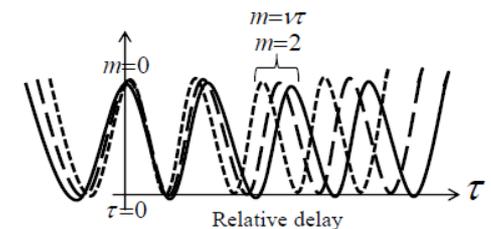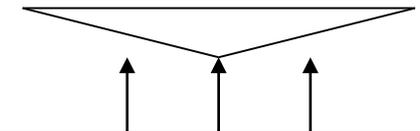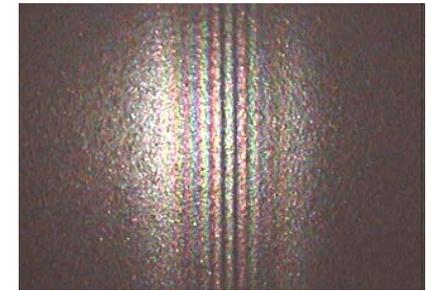
Light is never incoherent. Measured fringe visibility can be degraded by (i) detectors' time constant, translation of fringes, (iii) unequal amplitudes, (iv) etc.
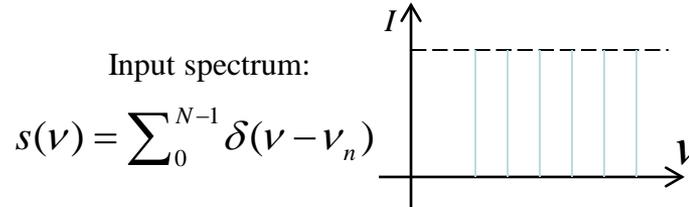
I. *Spectral correlation:* light beams with frequency variations.

Invention of Fourier transform spectroscopy

We must remember that it is the detector that carries out the superposition effect and dictates the final measurable data:

$$D_{\Sigma} = \left\langle \Psi\Psi^* \right\rangle = \left\langle \left| \sum_m \chi(v)E_m(v) \right|^2 \right\rangle$$
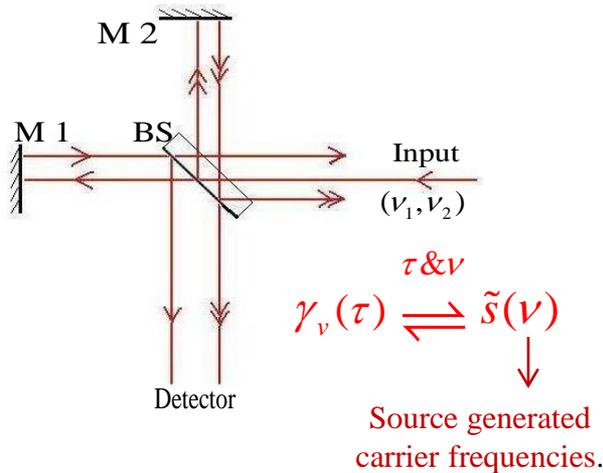
$$= \chi^2 \left\langle \left| \sum_m E_m(v) \right|^2 \right\rangle$$

Input spectrum:

$$s(v) = \sum_0^{N-1} \delta(v - v_n)$$

Long time averaged detector signal becomes time-independent but delay-dependent separately for each carrier frequency:

$$D_{\Sigma}(\tau) = \left[\sum_{n=0}^{N-1} \{ \chi e^{i2\pi v_n t} + \chi e^{i2\pi v_n (t+\tau)} \} \right]^* \left[\sum_{m=0}^{N-1} \{ \chi e^{i2\pi v_m t} + \chi e^{i2\pi v_m (t+\tau)} \} \right]$$

$$= \chi^2 \sum_{n=0}^{N-1} \left| e^{i2\pi v_n t} + e^{i2\pi v_n (t+\tau)} \right|^2 = 2\chi^2 \sum_{n=0}^{N-1} [1 + \cos 2\pi v_n \tau]$$

M 2

M 1   BS   Input
(v_1, v_2)

$\tau \& v$

$\gamma_v(\tau) \rightleftarrows \tilde{s}(v)$

Detector

Source generated carrier frequencies.

Michelson extracted only the delay-dependent oscillatory data after removing the DC signal:

Spectral correlation

$$D_{osc.}(\tau) = \sum_{n=0}^{N-1} \cos 2\pi v_n \tau \equiv \gamma_v(\tau)$$
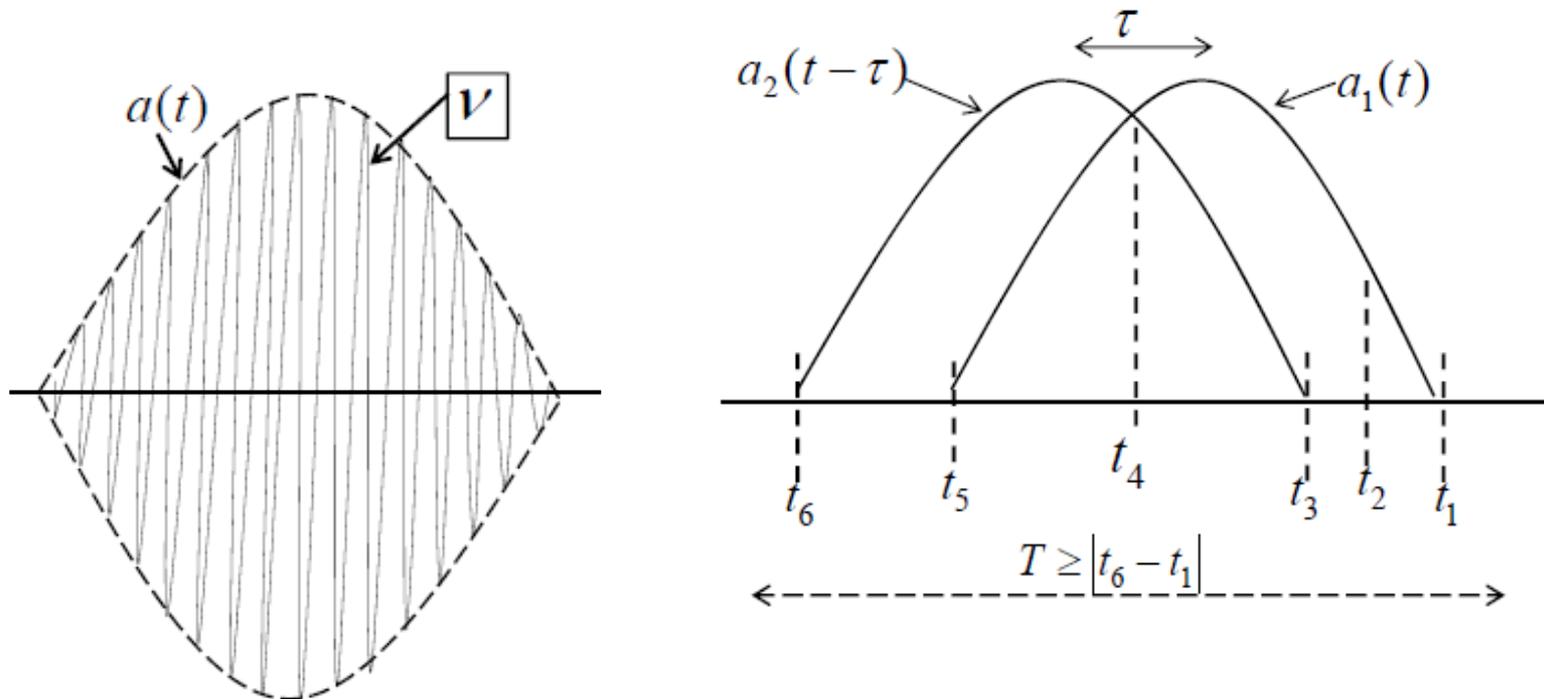
Fourier transform of this delay-dependent signal gives the physical spectrum of the source:

$$FT[D_{osc.}(\tau)] \equiv \tilde{\gamma}_v(\tau) = FT \left[\sum_{n=0}^{N-1} \cos 2\pi v_n \tau \right]$$

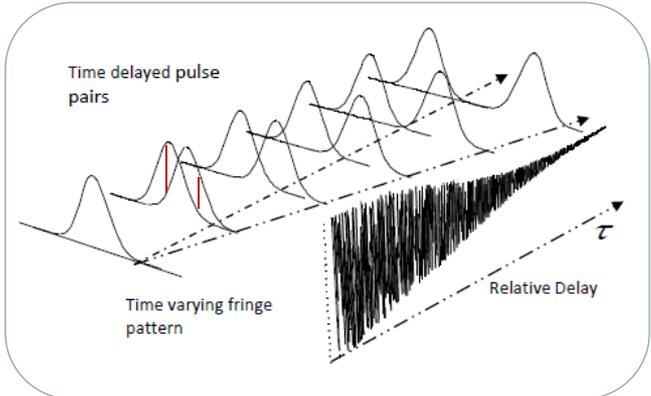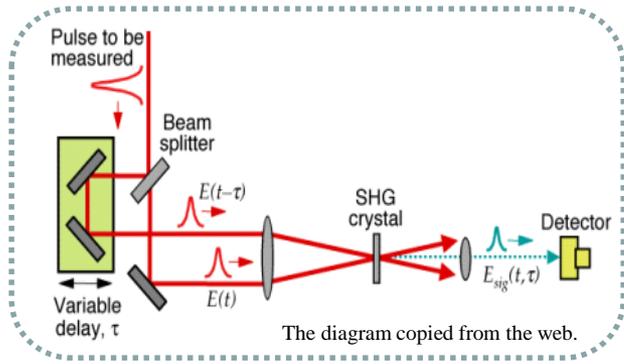$$= \sum_0^{N-1} \delta(v - v_n) \equiv s(v)$$

II. *Amplitude Correlation:* light pulses with temporal delays

➤ As long as the detector's integration time spans the entire duration of the displaced pair of pulses, the autocorrelation predicts the correct fringe visibility degradation.

➤ But, this degradation does not mean the physical presence of all the Fourier frequencies. That is a wrong interpretation using correct mathematics. **Data validation does not mean correct theory!**

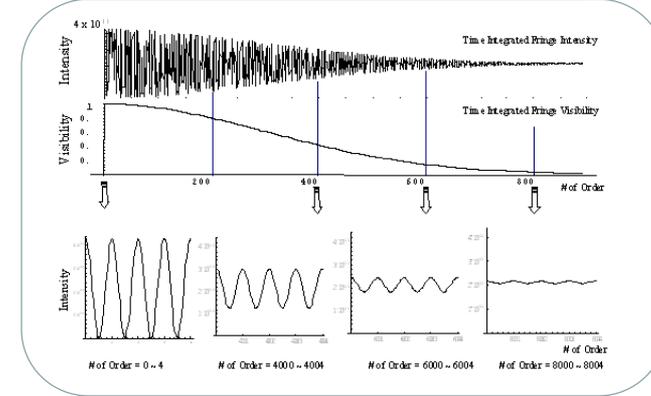## Critical issue: Detector's integration time interval

II. *Amplitude Correlation:* light pulses with temporal delays

Pulse to be measured — Beam splitter — $E(t-\tau)$ — SHG crystal — Detector — $E_{sig}(t,\tau)$ — $E(t)$ — Variable delay, τ

The diagram copied from the web.

Time delayed pulse pairs — Time varying fringe pattern — Relative Delay — τ

$$D(\tau) = \left\langle \left| \chi a_1(t)e^{i2\pi vt} + \chi a_2(t-\tau)e^{i2\pi v(t-\tau)} \right|^2 \right\rangle$$

$$= \chi^2(I_1 + I_2)[1 + \beta |\gamma_t(\tau)| \cos(2\pi v\tau + \varphi)];$$

Where, $V(t,\tau) = \beta(t)|\gamma_t(t,\tau)|;\ \beta(t) = 1$ when $I_1 = I_2$.

χ^2 **Cancels out**

Temporal correlation

$$\frac{\int \chi a_1^*(t)\chi a_2(t-\tau)dt}{\left[\int |\chi a_1(t)|^2 dt\right]^{1/2}\left[\int |\chi a_2(t)|^2 dt\right]^{1/2}} = \gamma_t(\tau)$$

That detector carries out the summation implied by the superposition principle, is eliminated by our mathematical rule!!

$\tau \& f$ $t \& f$

$$\gamma_t(\tau) \rightleftarrows \tilde{A}(f) = |\tilde{a}(f)|^2 ;\quad a(t) \rightleftarrows \tilde{a}(f)$$

Mathematical Fourier frequencies.

Even though by the autocorrelation theorem, it is correct to state that the temporal autocorrelation and the Fourier spectral density function forma a Fourier transform pair, the real physical process is due to superposition of time-varying unequal amplitudes on the detector.

Temporal Correlation and Spectral Correlation compared

We need to separately identify (i) Temporal & (ii) Spectral correlations. [The susceptibility term has been omitted below.]

Michelson's assumption of non-interference of different optical frequencies is correctly mapped by the derivation behind Wiener-Khintchine's theorem – cross-product term terms are zero. Only when the detector is slow (time integrating), the physical detection processes is correctly mapped.
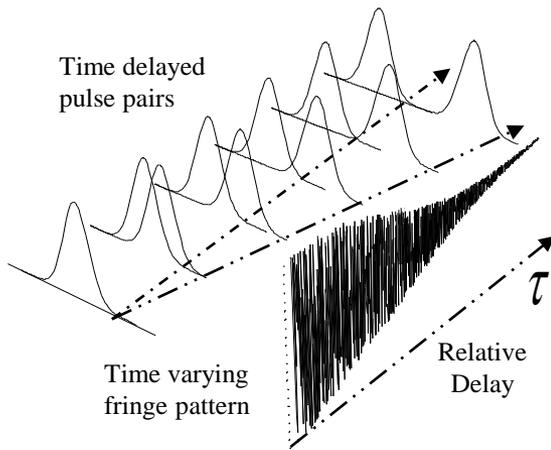
$$\gamma_t(\tau)$$

Temporal correlation

Time delayed pulse pairs

Fourier transform of an amplitude envelope:

$$a(t) = \int_0^\infty \tilde{a}(f)e^{-i2\pi ft}df \quad \text{Contrived spectrum}$$

$$\tilde{a}(f) = \int_0^\infty a(t)e^{i2\pi ft}dt$$

Time averaged correlation

τ

Relative Delay

Time varying fringe pattern

Computed fringe visibility degradation with delay

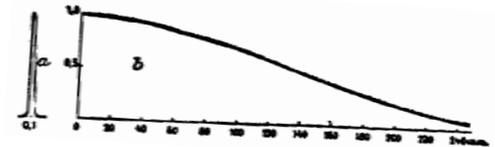**Note: The definitions are valid only for slow, not for fast, detectors !**

$$\gamma_\nu(\tau)$$

Spectral correlation

Fourier transform of actual spectral envelope

Physical spectrum $\quad |a(\nu)|^2_{norm} = \int_0^\infty \gamma_\nu(\tau)e^{-i2\pi\nu\tau}d\tau$

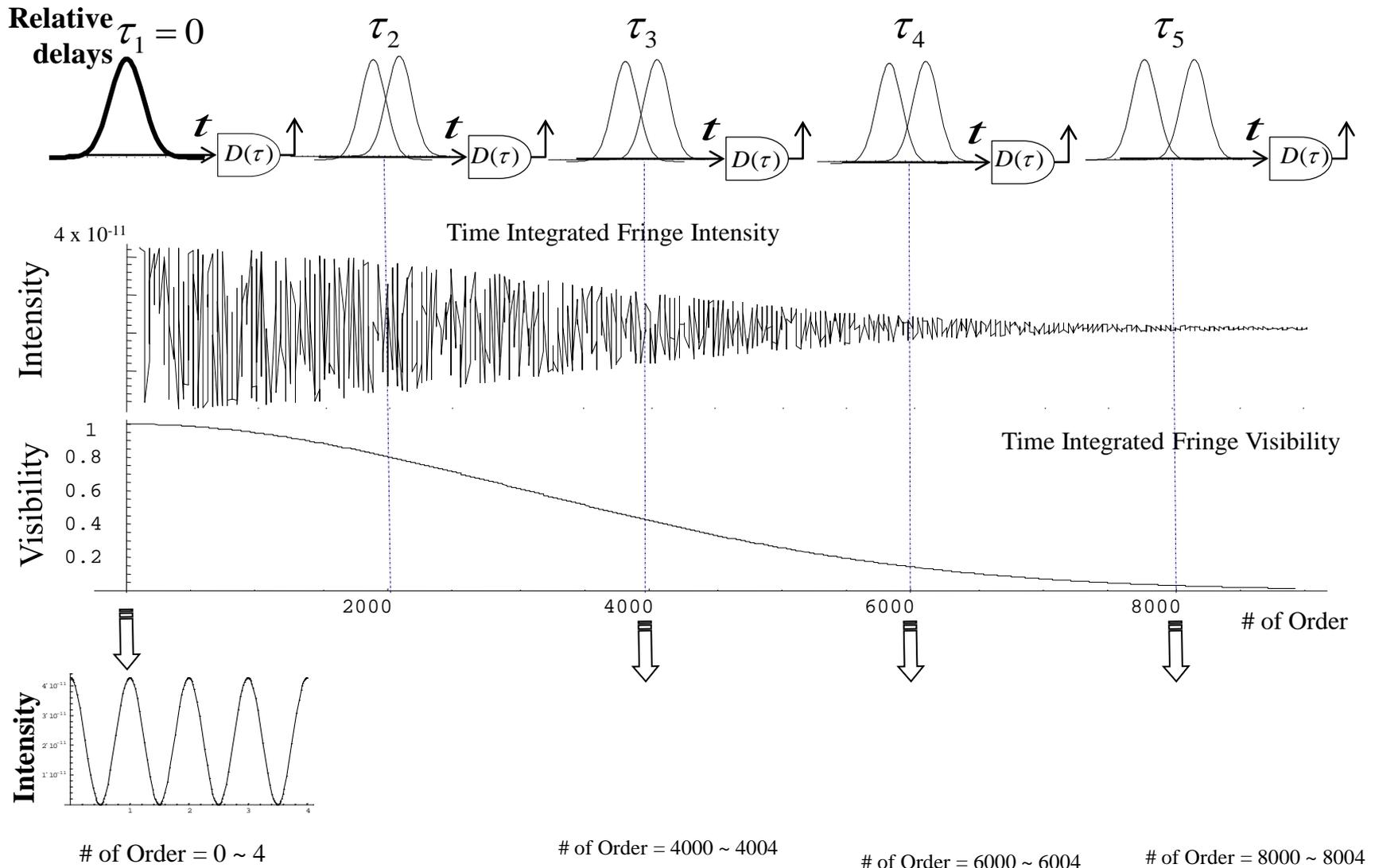$$\gamma_\nu(\tau) = \int_0^\infty |a(\nu)|^2_{norm} e^{+i2\pi\nu\tau}d$$

Michelson's visibility plot for Gaussian Cd-red line from CW discharge lamp

Michelson's visibility plot for Gaussian Na-D1 & -D2 lines from CW discharge lamp.

Expanded view of correlation (fringe visibility) reduction due to variable amplitude envelopes

Relative delays

$\tau_1 = 0$ τ_2 τ_3 τ_4 τ_5

t $D(\tau)$ t $D(\tau)$ t $D(\tau)$ t $D(\tau)$ t $D(\tau)$

Time Integrated Fringe Intensity

4×10^{-11}

Intensity

Time Integrated Fringe Visibility

Visibility

1
0.8
0.6
0.4
0.2

2000   4000   6000   8000

\# of Order

Intensity

$4 \cdot 10^{-11}$
$3 \cdot 10^{-11}$
$2 \cdot 10^{-11}$
$1 \cdot 10^{-11}$

1   2   3   4

\# of Order = 0 ~ 4   \# of Order = 4000 ~ 4004   \# of Order = 6000 ~ 6004   \# of Order = 8000 ~ 8004

IV. Polarization Correlation: Non-parallel E-vectors

Detecting dipoles directly respond to all simultaneously present polarized E-vectors. Follows QM-Projection or Malus' amplitude rule. Dipole, by definition, cannot simultaneously oscillate in two orthogonal directions.
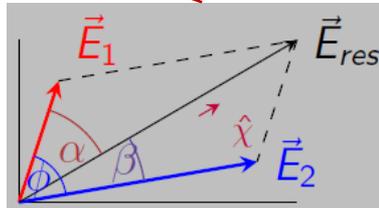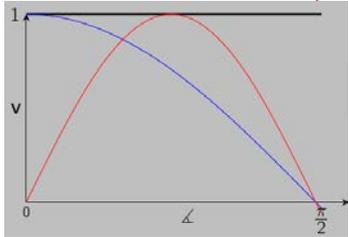
The electric vectors first sum themselves to generate the resultant E-vector, which then stimulates the detector:
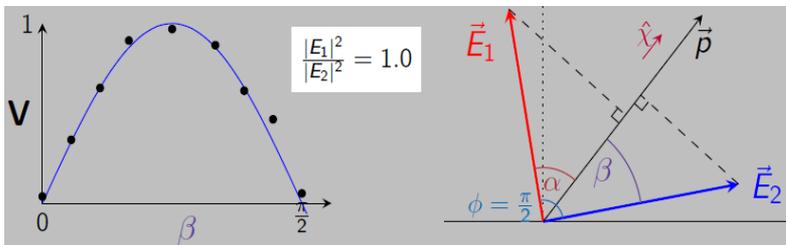
$$V \equiv \frac{2a_1 a_2 \cos\alpha \cos\beta}{[a_1^2 \cos^2\alpha + a_2^2 \cos^2\beta]} = 1(!!)$$

Zero visibility for orthogonal polarizations!
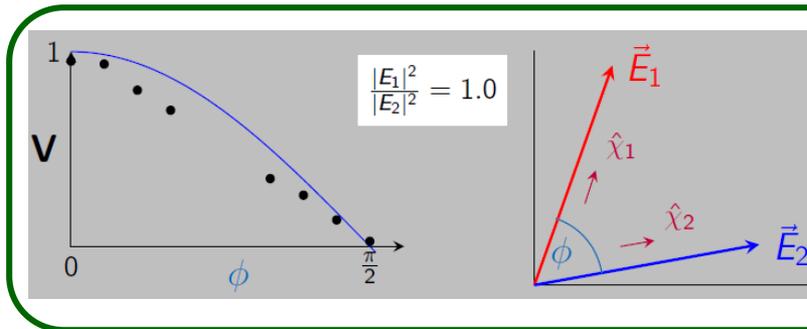
The electric vectors directly stimulate the detecting dipole:

$$V = 2a_1 a_2 \cos\varphi / [a_1^2 + a_2^2]$$

$$^{(1)}\hat{\chi}_1 \cdot {}^{(1)}\hat{\chi}_2 = \cos\varphi$$

$$\frac{|E_1|^2}{|E_2|^2} = 1.0$$

A polarizer before the detector takes the projection of the E-vectors along the preferred axis. The detector receives two parallel components:

$$V \equiv \frac{2a_1 a_2 \cos\alpha \cos\beta}{[a_1^2 \cos^2\alpha + a_2^2 \cos^2\beta]}$$

$$\frac{|E_1|^2}{|E_2|^2} = 1.0$$

C. Roychoudhuri, Femto Macro Continuum & University of Connecticut.
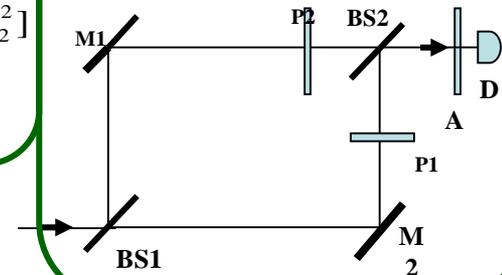
Helically rotating E-vector for an elliptically polarized beam, (after collinearly combining two orthogonally polarized beam), is a non-causal model and contradicts NIW-property.

By virtue of the NIW-principle, polarized light beams are not sum-able, orthogonal or not !
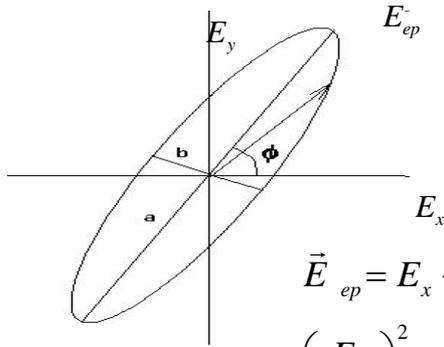
$$\vec{E}_{ep} = E_x + E_y = E_{0x}\cos(kz - wt) + E_{0y}\cos(kz - wt + \varepsilon)$$

$$\left(\frac{E_x}{E_{0x}}\right)^2 + \left(\frac{E_y}{E_{0y}}\right)^2 - 2\left(\frac{E_x}{E_{0x}}\right)\left(\frac{E_y}{E_{0y}}\right)\cos\varepsilon = \sin^2\varepsilon$$
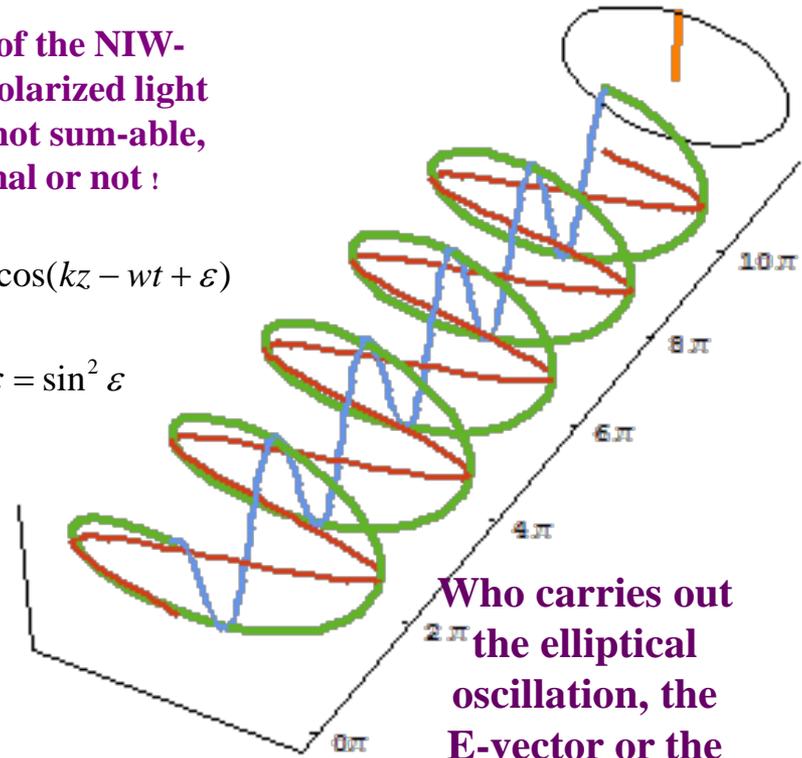
Who carries out the elliptical oscillation, the E-vector or the dipole vector ?

Polarization beam propagation theory remains correct! Each component is propagated separately

$$\begin{vmatrix} E_{out-x} \\ E_{out-y} \end{vmatrix} = \begin{vmatrix} a_{1x} a_{1y} \\ a_{2x} a_{2y} \end{vmatrix}\begin{vmatrix} E_{in-x} \\ E_{in-y} \end{vmatrix}$$

Intensity is: $I = \left|\vec{\chi}_x E_{out-x}\right|^2 + \left|\vec{\chi}_y E_{out-y}\right|^2$
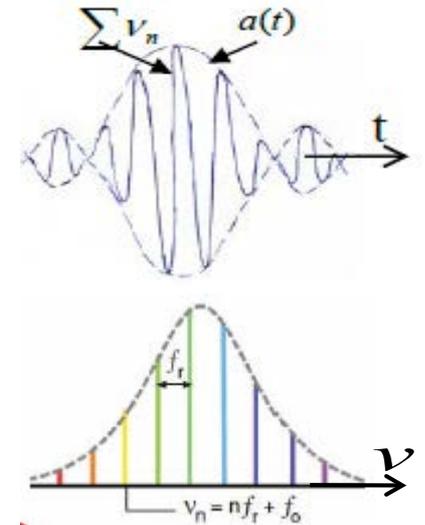
and not : $I = \left|E_{out-x} + E_{out-y}\right|^2$!

It appears that in Zeeman Effect, atoms spinning about the magnetic vector, do emit light with circularity spinning E-vector!
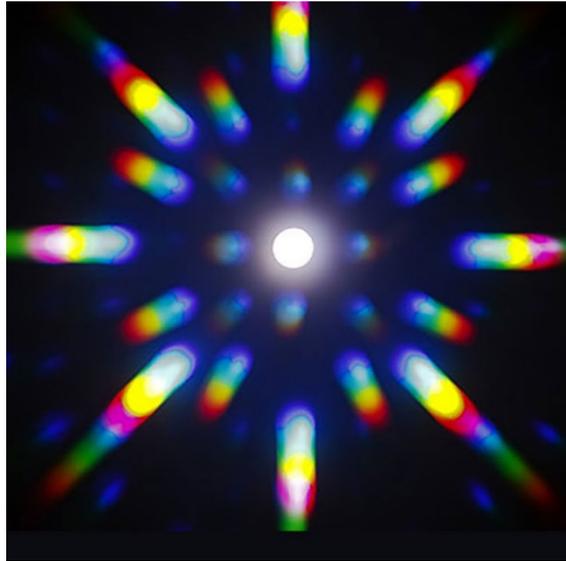
C. Roychoudhuri, U. Connecticut & Femto Macro Continuum

A case example

Autocorrelation of a single clipped pulse out of a perfectly phase-locked train of pulses containing N-longitudinal cavity-mode-comb (to distinguish from Fourier-comb) frequency:

$$D(\tau) = \int I(t,\tau)\, dt = \int \left| \sum_{-(N-1)/2}^{+(N-1)/2} b(t) e^{i2\pi(v_0 + n\delta v)t} + \sum_{-(N-1)/2}^{+(N-1)/2} b(t-\tau) e^{i2\pi(v_0 + m\delta v)(t-\tau)} \right|^2 dt$$

$$= \sum_{-(N-1)/2}^{+(N-1)/2} \int_{-\infty}^{+\infty} \left| b(t) e^{i2\pi(v_0 + n\delta v)t} + b(t-\tau) e^{i2\pi(v_0 + n\delta v)(t-\tau)} \right|^2 dt$$

$$= \sum_{-(N-1)/2}^{+(N-1)/2} \left[2E + 2\cos 2\pi(v_0 + n\delta v)\tau \int_{-\infty}^{+\infty} b^*(t)b(t-\tau) dt \right]$$

$$= 2E \sum_{-(N-1)/2}^{+(N-1)/2} \left[1 + \gamma_t(\tau) \cos 2\pi(v_0 + n\delta v)\tau \right]$$

$$= 2E \left[N + \gamma_t(\tau) \sum_{-(N-1)/2}^{+(N-1)/2} \left[\cos 2\pi(v_0 + n\delta v)\tau \right] \right]$$

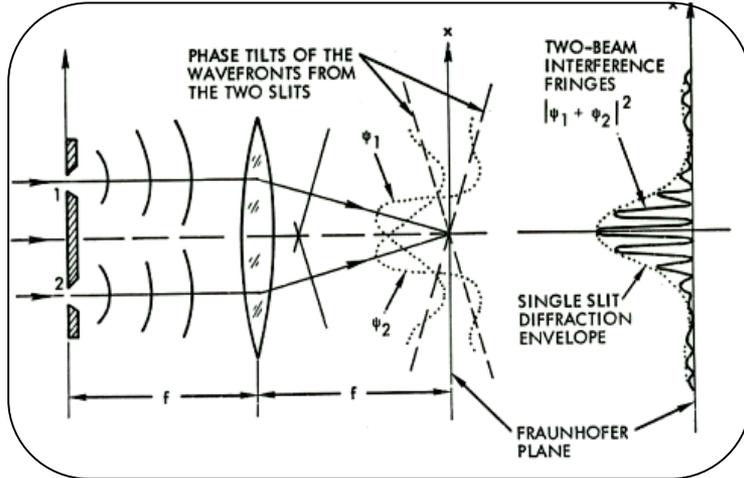$$= 2E \left[N + \gamma_t(\tau)\gamma_v(\tau) \right]$$

The Concept of "Photon"

Could it be true that our *ignorance*, about "which slit the photon went through", is at the root of superposition effect?

Do fringes emerge if we don't interrogate which slit they emerge from?
Causal information, phases and amplitudes, are retrievable by holographic interferometry!

Waves do not sum; detecting dipoles do:

$$E_1 = a_1 e^{i2\pi\nu\tau_1}; \quad E_2 = a_2 e^{i2\pi\nu\tau_2}$$

$$\left|\chi E_1 + \chi E_2\right|^2 = \chi^2 [a_1^2 + a_2^2 + 2a_1 a_2 \cos 2\pi\nu(\tau_1 - \tau_2)]$$

Double-slit setup for direct recording.

"Wave-particle duality" represents our ignorance. Ignorance should not be made into a new knowledge.

Holographic setup to validate reality of the two phase information from each slit.
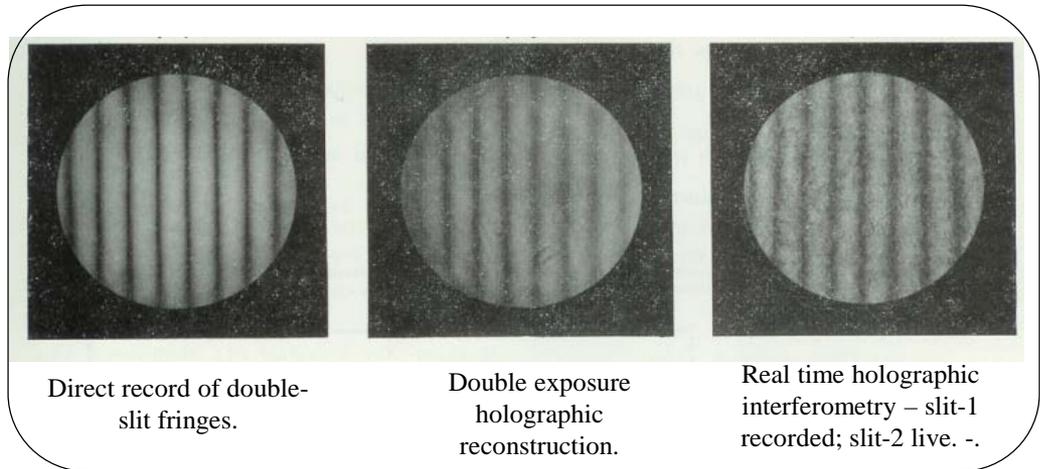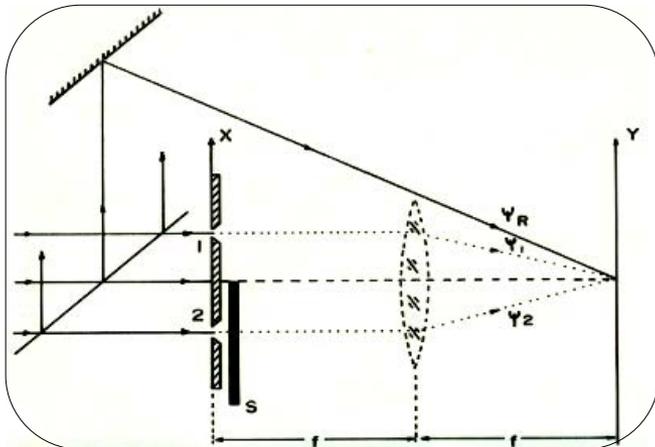
Direct record of double-slit fringes.

Double exposure holographic reconstruction.

Real time holographic interferometry – slit-1 recorded; slit-2 live. -.

Logical inconsistency behind the postulate:
(i) discrete photographic grains, or
(ii) discrete photo current pulses validate the presence of "indivisible light quanta"

In reality, Ag-Halide molecules and also the electrons in solids are always bound quantum mechanically.

If photons are classical wave packets, then why do we get discrete "clicks"? Is that really "photon counting"?

Detectors wear "Quantum Goggles"!
If Silver-Halide molecules and electrons are quantum entities having discrete binding energy. We should not assign their discrete transition behavior to light?

Discrete blackened photographic grains

Discrete photoelectric current pulses
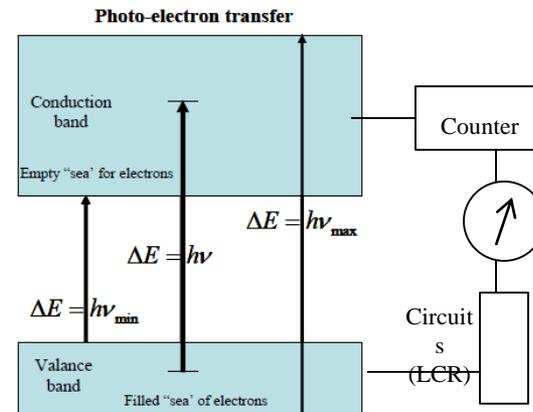
Photos from Hecht's book

Photo-electron transfer

Conduction band

Empty "sea" for electrons

$\Delta E = h\nu_{max}$

$\Delta E = h\nu$

$\Delta E = h\nu_{min}$

Valance band

Filled "sea" of electrons

Counter

Circuits (LCR)

$h\nu$ becomes "quantized" or assumes a unique value only when ν assumes a unique number (h being a constant).

What are the physical processes behind the emergence of discrete "clicks"?

C. Roychoudhuri, Femto Macro Continuum & University of Connecticut.

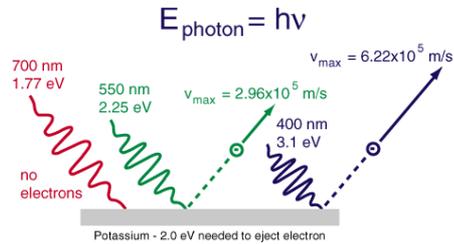**Logical inconsistency behind the postulate: photon as "indivisible quanta"!**

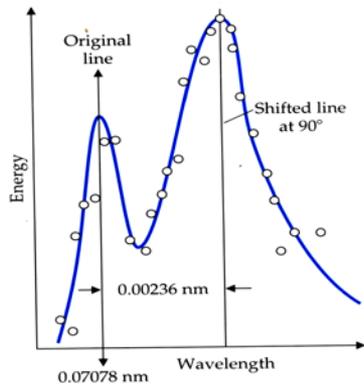Photon **energy is shared** between the binding metal & electron kinetic energy!

$$E_{photon} = h\nu$$

Photoelectric effect

Dividing photons

In **Compton scattering**, incident photon energy is divided into a lower energy photon and the release of a bound electron.

• Photon energy is depleted or increased during **Raman scattering**.
• Photon energy doubled in **two-photon resonance fluorescence**.

Semi-Classical processes

Photons are divisible & summable in light-matter interactions.

QM does not demand that a QM-entity can share its QM-transition-dictated energy only by interacting with a quantized entity with exactly matching energy-sharing capability!

Summing photons

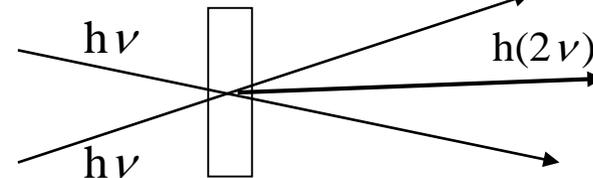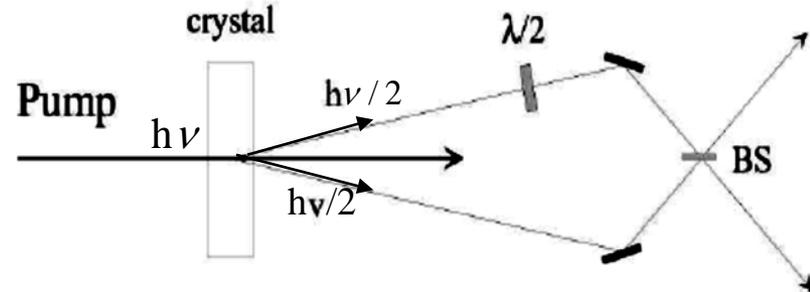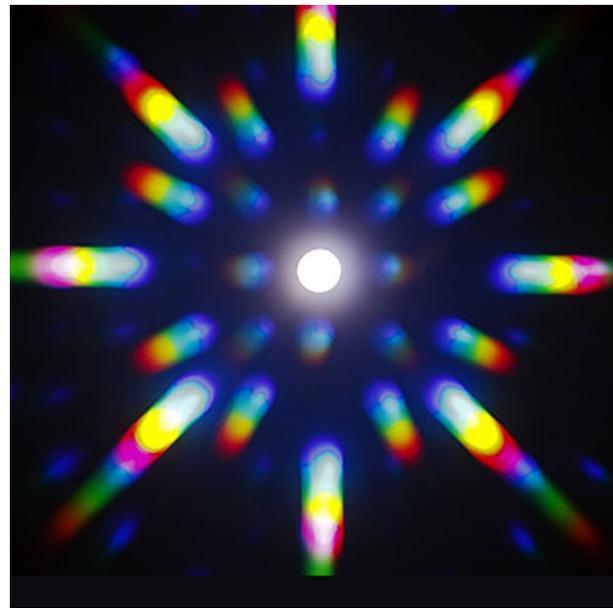

"Photons" are summed in non-collinear **2nd harmonic generation**

Dividing photons

"Photons" are split in non-collinear **down conversion**

Classical processes

65

Can the presence of a "single photon" energy be really verified ?

Detector's "quantum cup" cannot be filled by a weak beam

At very low flux, when the energy density is too low to contain necessary quantum of energy within ~λ-cube volume, detectors cannot undergo transitions.

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."
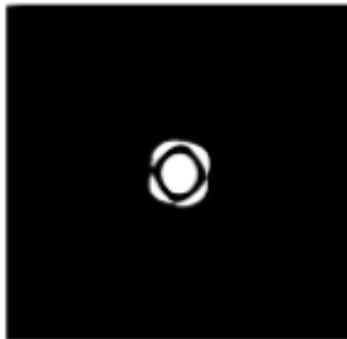
a	b	c
3.91<8> photons. 20 sec. exposure	2.27<9> photons. 17h36min exposure	5.19<10> photons. 336h26min exposure
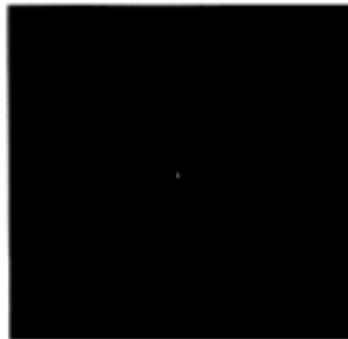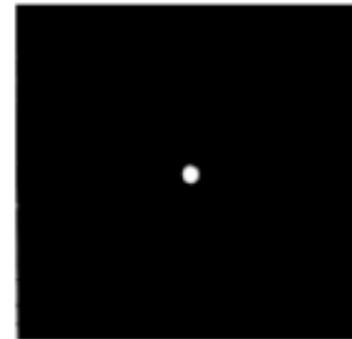
E. Panarella, SPIE Proc. Vol. **5866**, pp.218-228, (2005), "Single Photons have not been detected. The alternative photon clump model". See also by E. Panarella, "Nonlinear behavior of light at very low intensities: the photon clump model", p.105 in *Quantum Uncertainties – recent and future experiments and interpretations*, Eds. W. M. Honig, D. W. Kraft & E. Panarella, Plenum Press (1987).

Appreciating detectors' large quantum "Suction Cup" volume!

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

1 mm

$1 mJ = 2.59 \times 10^{15}$ photons

1 mW Green laser
$(\nu = 5.83 \times 10^{14} \text{ s}^{-1})$

$1 s = 3 \times 10^{10}$ cm

Atomic
Volume

1 Å

1 Å

8.62 x 10^{-18}
Photons

Needed suctio-cup radius

$> (100\lambda)^3 = (10^2 \times 5000A)^3$

$= 1.25 \times 10^{17} A^3$
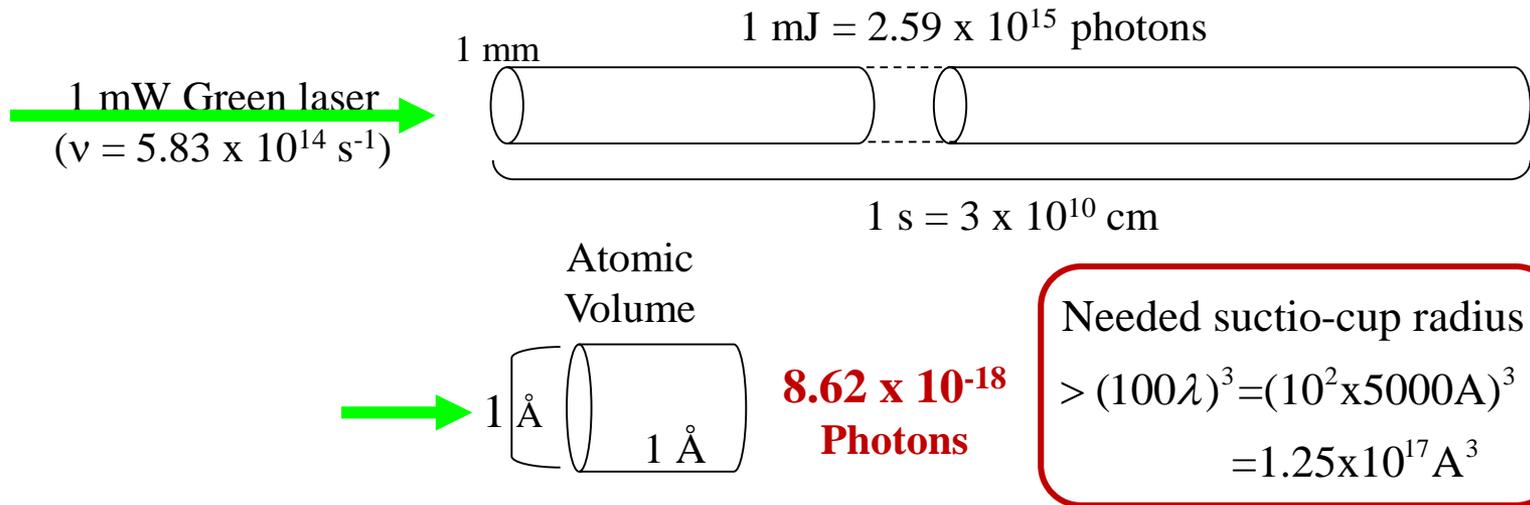
A remarkably low flux of EM field energy passes through an atomic volume!
Some very complex process lies behind the delivery of ΔE amount of
energy for the transfer of a photo electron from one state to another, which
QM has not succeeded in explaining, or modeling!

**This is why nobody has succeeded measuring
the response time for photo-electron emission!**
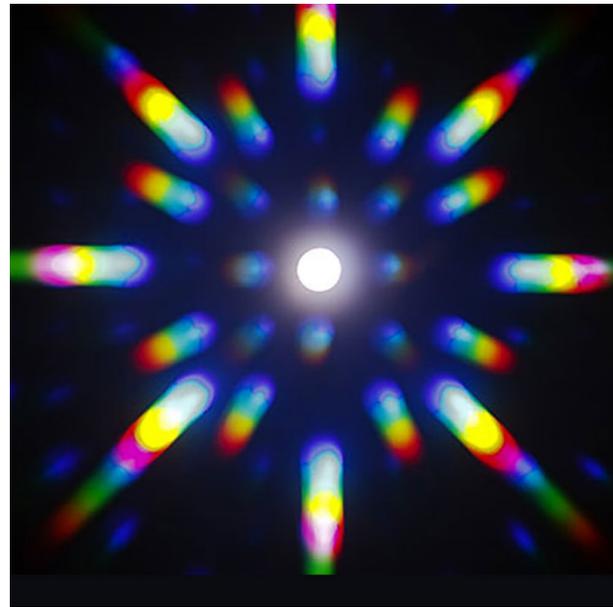
Semi-Classical model for photon wave packets

The map of a photon congruent with most observations?

Carrier frequency is the QM predicted frequency. Natural line width is the artifact (instrumental response function) due to a finite duration of the wave packet.

$$\left(\Delta E_{min} =\right) h\nu_{min} \leq h\nu \leq h\nu_{max} \left(= \Delta E_{max}\right)$$

$\Delta E = h\nu_{mn}$

Ato m

Photo-electron transfer

Conduction band

Empty "sea' for electrons

$\Delta E = h\nu_{max}$

$\Delta E = h\nu$

$\Delta E = h\nu_{min}$

Valance band

Filled "sea' of electrons

hν becomes "quantized" or assumes a unique value only when ν assumes a unique number (h being a constant).

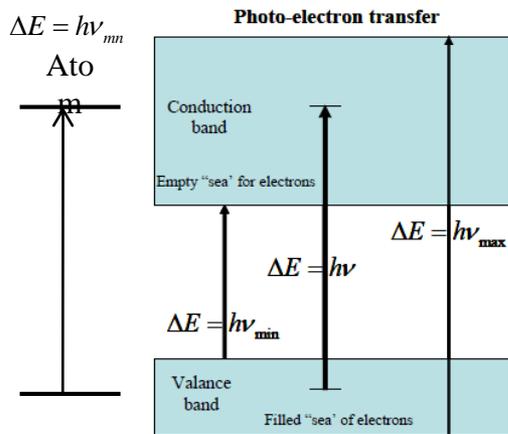Super-exponential envelope

ν_{mn}

Integrated energy under the envelope $\big\} \Delta E_{mn} = h\nu_{mn}$

Measured spectrometer line width will be "almost" Lorentzian (QM prediction), which is a Fourier transform of an exponential envelope!
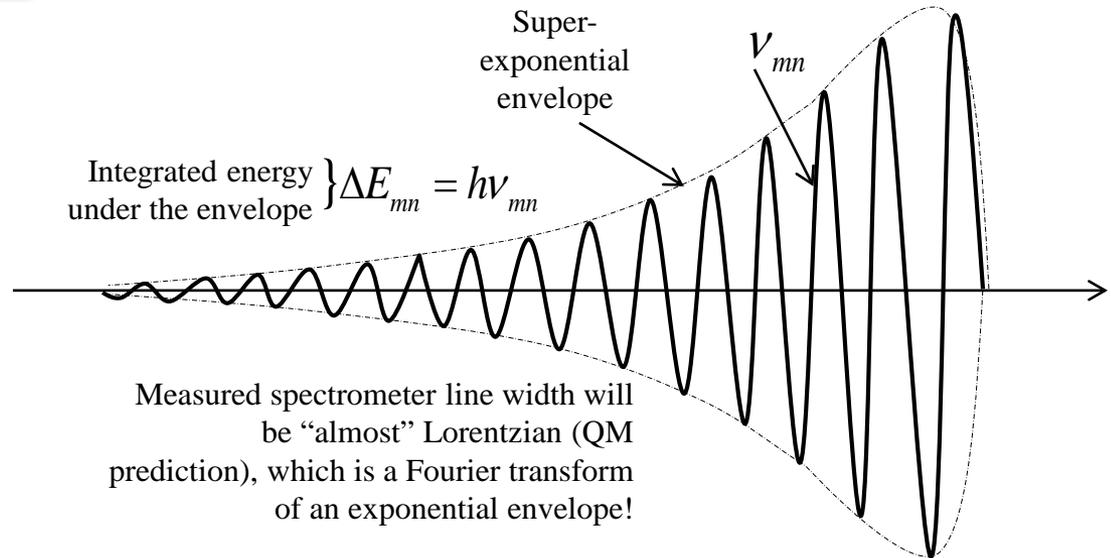
❖ 1. All photon energy packets emitted through spontaneous and stimulated emission processes evolve into super-exponential classical pulses, which can co-propagate or cross propagate without interacting with each other.
❖ 2. Super-exponential pulses evolve following Maxwell's wave equation (and hence, follow Huygens-Fresnel's diffraction integral).
❖ 3. Photon wave packets are divisible at all material boundaries and sum-able by suitable detecting dipoles.
❖ 4. They propagate at a constant velocity in space as they are undulations of the Complex Cosmic Tension Field.

How to measure the photon envelope?

Super-exponential envelope

ν_{mn}

Integrated energy under the envelope $\} \Delta E_{mn} = h\nu_{mn}$

Measured spectrometer line width will be "almost" Lorentzian (QM prediction), which is a Fourier transform of an exponential envelope!
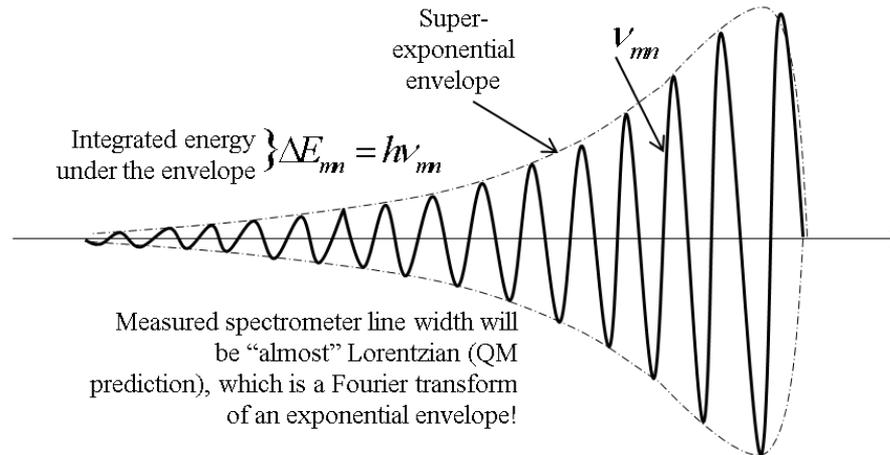
Leveraging grating response function

$$D(\nu,\tau) = \int_0^{>\tau_0} \left| i_{out}^{norm}(\nu,t) \right|^2 dt$$

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

$$D_{Dplr.}(\nu,\tau) = G(\nu) \otimes D_{N-bm.}(\nu,\tau)$$

Leveraging 2-beam response function

$$D_{2-bm.}(\nu,\tau) = A[1 + \gamma_a(\tau)\cos 2\pi\nu\tau]$$

$$D_{Dplr.}(\nu,\tau) = G(\nu) \otimes D_{2-bm.}(\nu,\tau)$$
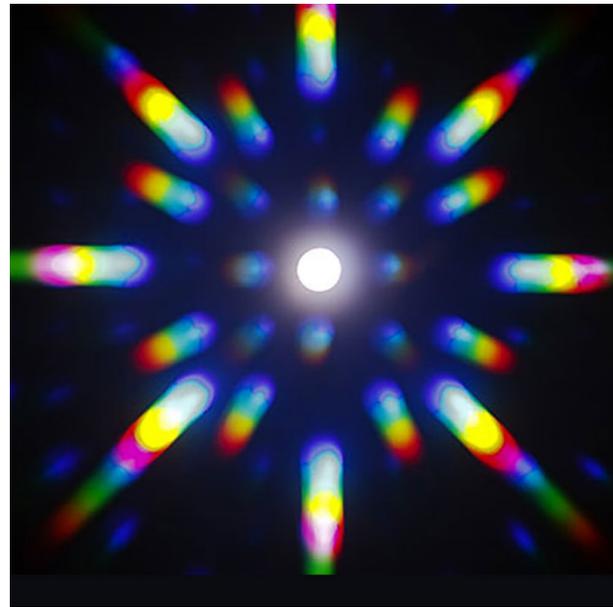
Resolution of Wave-particle Duality

Superposition
of mono-energetic particles

"Can particle scattering analysis explain all interference experiments"

C. Roychoudhuri & A. Cornejo, Bol. Inst. Ton. Vol.1, No.4 , pp.245-6 (1975)

$$I(P_n) = \left|\chi U(P_n)\right|^2 = \frac{1}{\lambda^2}\left[\chi \iint_\Sigma U(P_{screen})\frac{\exp(ikr_n)}{r_n}\cos\theta \; ds\right]^2$$
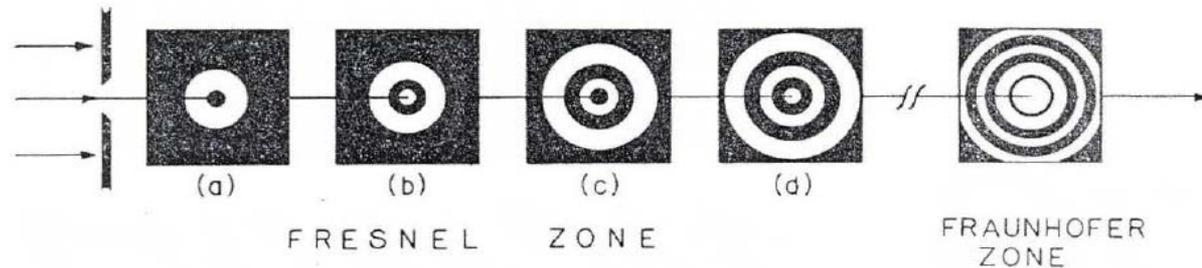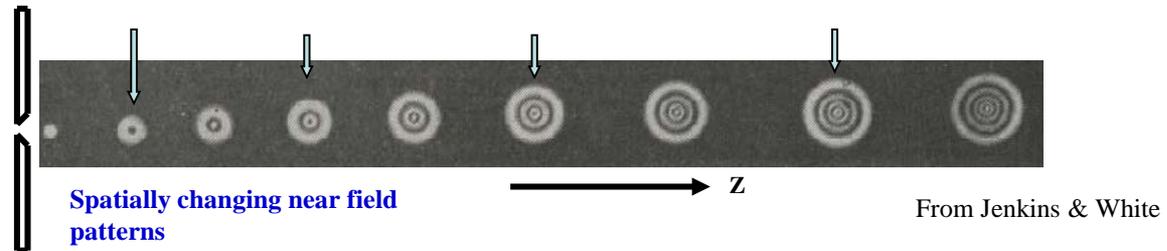
Spatially changing near field patterns

Z

From Jenkins & White

(a) (b) (c) (d)

FRESNEL ZONE

FRAUNHOFER ZONE

Wave-particle-duality started as our 'lack of knowledge' some 400 years ago. In 20th century we have made it a 'new knowledge'!
We suppressed our enquiring minds for many generations!
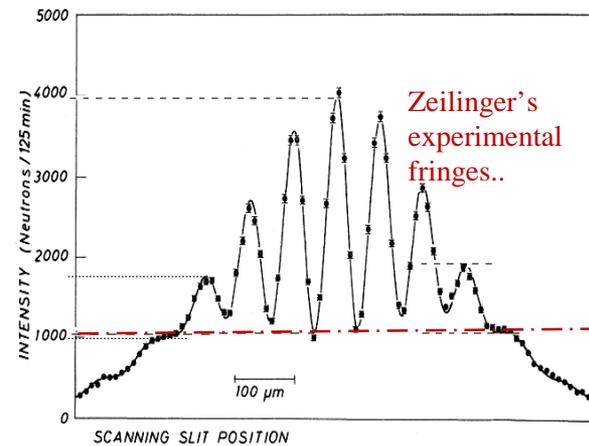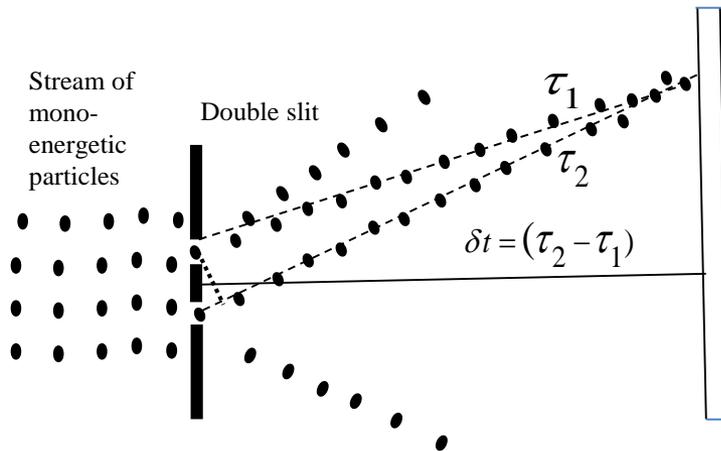
Stream of mono-energetic particles

Double slit

τ_1

τ_2

$\delta t = (\tau_2 - \tau_1)$

Zeilinger's experimental fringes..

Very poor fringe contrast.

INTENSITY (Neutrons / 125 min)

5000

4000

3000

2000

1000

0

100 μm

SCANNING SLIT POSITION

Wave-particle-duality started as our 'lack of knowledge' some 400 years ago. In 20th century we have made it a 'new knowledge'!

(a) **There is no need to accept wave-particle duality in this universe!**

(b) **We must learn to differentiate between Superposition Principle (SP) and Superposition Effect (SE).**

Zeilinger's experimental fringes..

$$\Psi \equiv \psi_1 + \psi_2 = \chi a_1 e^{i2\pi\nu\tau_1} + \chi a_2 e^{i2\pi\nu t_2}$$

Plotted cos-squared fringes. **Very poor fringe contrast**.

First zeros

First zeros

$$SP: \Psi \equiv \psi_1 + \psi_2 = \chi a_1 e^{i2\pi\nu\tau_1} + \chi a_2 e^{i2\pi\nu t_2}$$

$$SE: |\Psi|^2 = |\psi_1|^2 + |\psi_2|^2 + \psi_1^*\psi_2 + \psi_1\psi_2^* = \chi^2 A[1 + \gamma \cos 2\pi\nu\tau]$$

$$A \equiv (a_1^2 + a_2^2); \quad \gamma \equiv 2a_1a_2/(a_1^2 + a_2^2); \quad \tau \equiv (t_2 - t_1).$$

Only when $a_1 = a_2$, fringe visibility $\gamma = 1$.
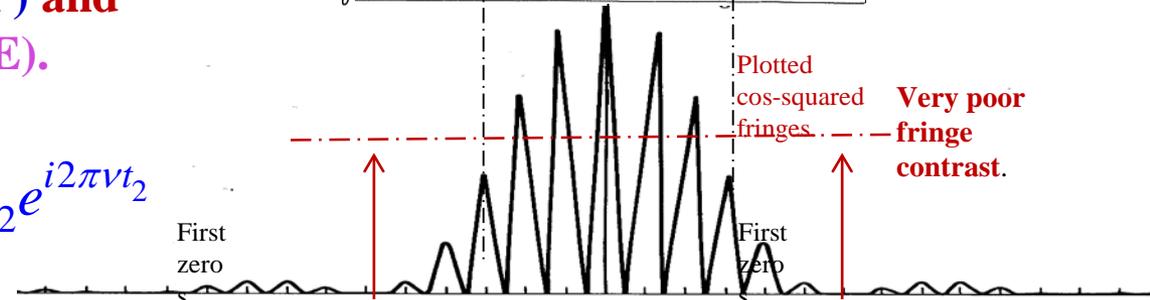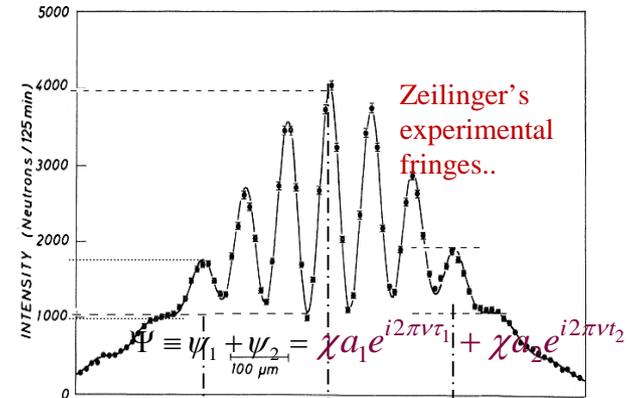
Proposed double-slit experiment with a Rb-atomic beam
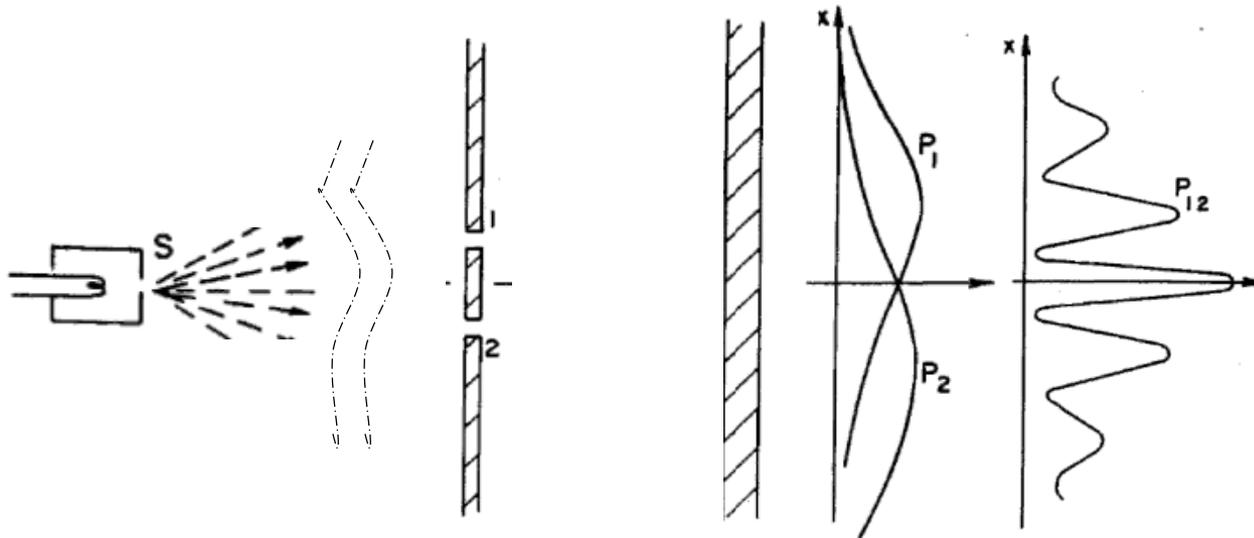
From Feynman Lecture on QM

Diagrams adapted from Feynman's book.

Double-slit superposition effects generated by a Rb-beam
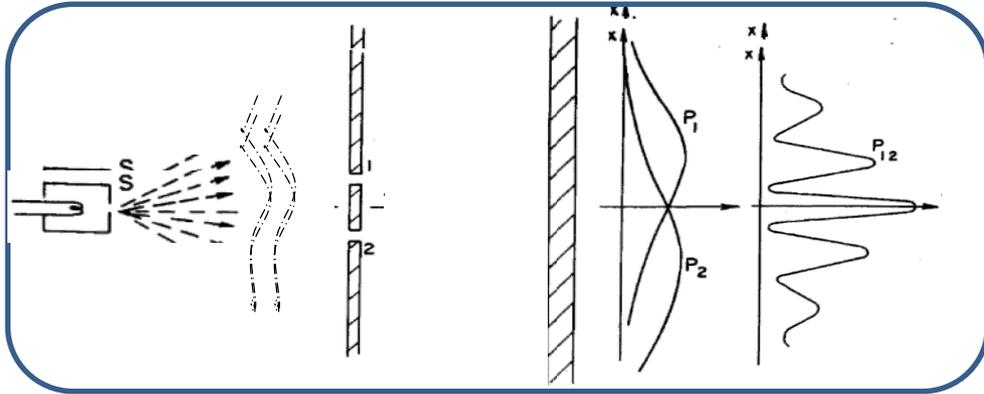
Conceptual data as depicted in Feynman's book

Diagrams adapted from Feynman's book.

Data as would be recorded by a densitometric scan of the photographic plate.

Sum of displaced Gaussians

Data as would be recorded by triggering Rb-Fluorescence.
[My prediction]

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Beam 2

Beam 1

• In two-beam interferometers, the dielectric boundary layer of the final beam combiner plays a crucial role of "interaction". It imposes a π-phase delay for the "external" reflection and re-directs the energy 100% in one way or the other, if the relative phase delay between the opposing incident beams is odd numbers of π and the two amplitudes are equal.

• A beam combiner cannot function in the absence of simultaneous presence of photon wave packets from both sides of the beam splitter boundary layer – it's an interaction process.

• In fact, when the opposing beams are non-collinear, the 50% beam combiner functions as a regular 50% beam splitter. The superposition effect is then generated by the molecules of the detector following the beam combiner.

[*] C. Roychoudhuri, Proc. SPIE Vol. **6108**-50(2006); "Reality of superposition principle and autocorrelation function for short pulses".
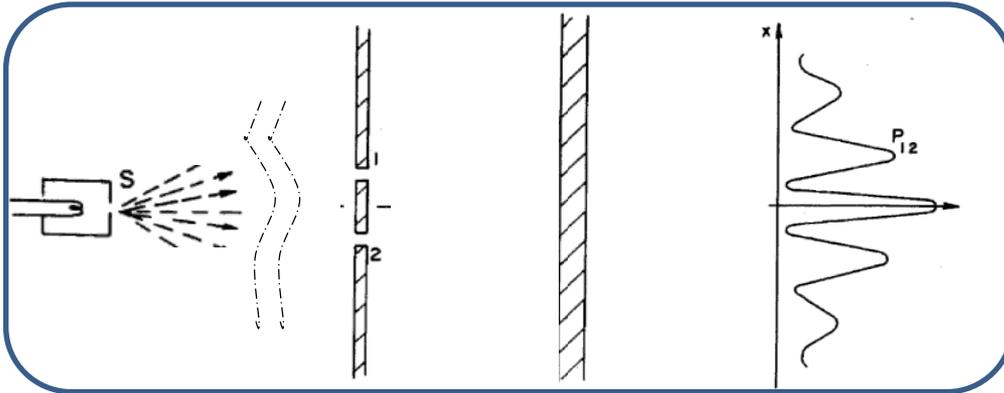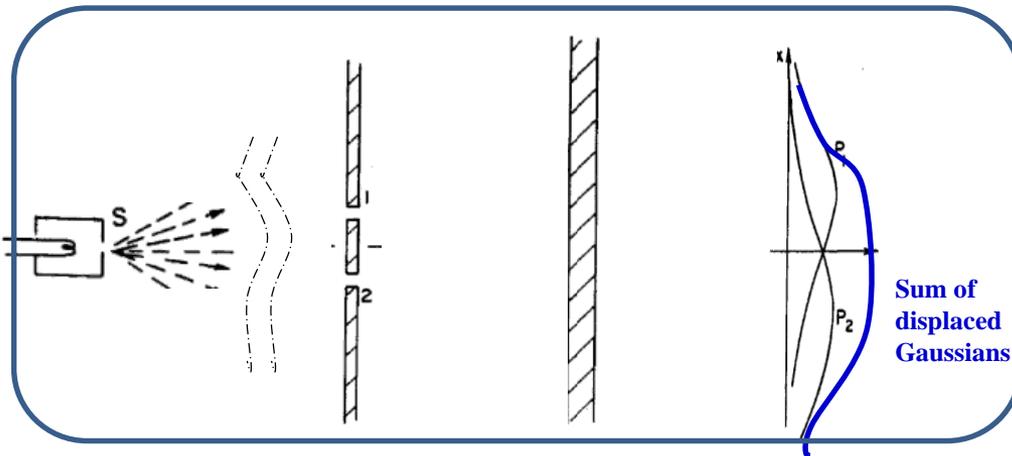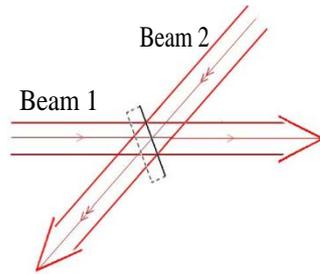
Bell's Inequality theorem is inapplicable to superposition effects due to photons.

• It important to recognize that, by virtue of the universal NIW-property of wave amplitudes, the Superposition Principle (SP), representing the sum of complex amplitudes, is not a detectable (observable) phenomenon!

•However, the Superposition Effect (SE), the measurable physical transformation in a detector, proportional to the square modulus of the sum total amplitude stimulations, is a detectable (observable) phenomenon.

• Bell's Inequality Theorem deals with the un-observable sum of complex amplitudes. Hence, it does not represent a measurable physical phenomenon.

78

Deeper Significance of NIW in Astrophysics

The final frontier of physics;
Space as a Complex Tension Field (CTF)

1. **What constitutes space?: The space is a Complex Tension Field; photons and particles are its undulatory excited states.**
2. **What are photons?: Photons are linear excitations of the CTF** induced by quantum dipoles during downward transitions; the emergent wave packets are semi-exponential corroborating Lorentzian line widths
3. **What are particles?: Particles are non-linear excitations of the same CTF.** They are localized self-looped self-resonant complex oscillations and hence quantized. The Q of resonance determines the lifetime.
4. **Resolution of wave-particle duality:** The above models with new information about photons and particles eliminate the need for using wave-particle duality.
5. **Doppler Effects due to source velocity & detector velocity:** Just like sound waves, optical emitter velocity generates *real* (permanent) frequency shift on the emitted wave compared to the intrinsic quantum transition frequency. Detector s with different relative velocities perceive the same incident frequency as different *apparent* frequencies; just as it is true for sound.
6. **Cosmological Redshift is not due to Expanding Universe.**
7. **The stationary CTF could represent the Cosmological Inertial Rest Frame.**

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What constitutes space?

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Huygens' Principle requires the space to be a Complex Tension Field (CTF)

1. How can every point along the propagation of a wave serve as the source for secondary wavelets? Where does the energy for the secondary source come from?

2. How does a wave keep on propagating perpetually without the originating source continuously pushing it?

Waves do not carry the substance of the medium that sustains the necessary tension field. Neither does it carry any energy. The energy remains with the tension field. Only a wave group, as an excited state of the tension field. moves on!

EM wave equation for free space. This is derived from Maxwell's constituent eqautions

$$\nabla . E = 0 \quad \nabla \times E = -\partial B / \partial t$$

$$\nabla . E = 0 \quad \nabla \times B = (1/ c^2)\partial E / \partial t$$

$$\frac{\partial^2 E}{\partial t^2} = c^2 \ \nabla^2 E$$

But, it can also be derived emulating a stretched string model!

The constancy of "c" everywhere requires the space to be a stationary and complex tension field

All "working" theories indicate cosmic space is not a vacuum!

Foundation behind most of the successful theories of physics is the concept of field, proposed by Faraday:

- ➤ **Electro statics:** ε_0

- ➤ **Magneto statics:** μ_0

- ➤ **Electromagnetism:** $c^2 = \dfrac{\varepsilon_0^{-1}}{\mu_0}$

- ➤ **General relativity:** "Curvature of space" [potential gradient in some tension field?]

- ➤ **QM, QED, QCD, String theory:** "Zero point energy", "Background fluctuations", "Quantum Foam"

$$\alpha = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{\hbar c}$$

It does not make sense to describe cosmic space as a vacuum and not accept it is some form of a Complex Tension Field (CTF).

Even primary school experiments tell us that:

**The space simply cannot be empty.
Space is a complex modifiable "medium"!**

Annular magnets with opposite polarity attracts each other.

Annular magnets with same polarity repels each other. Space between them has "magnetic tension" that helps the upper magnet floating against gravitational tension.

A still blade changes the "magnetic tension" from repulsive to attractive by creating opposite polarities on its two sides.

An wooden blade, being "non-magnetic" does not alter the "magnetic tension" of the space.

Deriving EM wave equation as per classical string wave model assuming "vacuum" can experience electric & magnetic tensions.

Classical string wave derivation:

The wave equation for a string under tension is derived by equating two balancing forces. Inertia times acceleration of an elemental string length equals the restoring tension force. Displacement of string position is "y".
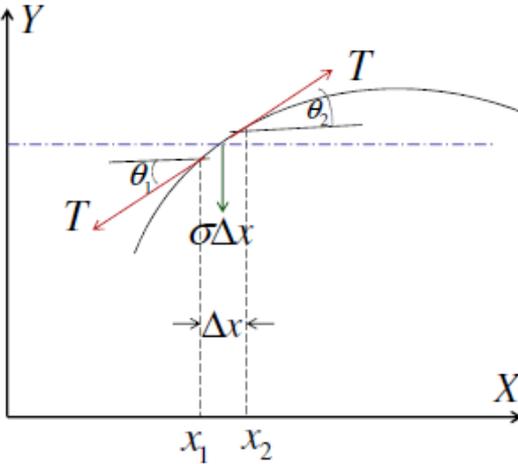
$$ma = F$$

$$\sigma\Delta x \frac{\partial^2 y}{\partial t^2}(x,t) = \Delta_x (T\sin\theta) \approx T\Delta_x\left(\frac{\partial y}{\partial x}\right)$$

→ Inertia to material movement

$$\sigma\Delta x \frac{\partial^2 y}{\partial t^2}(x,t) = T\Delta_x \frac{\partial y}{\partial x} \quad\Rightarrow\quad \frac{\partial^2 y}{\partial t^2}(x,t) = \frac{T}{\sigma}\frac{\partial}{\partial x}\frac{\partial y}{\partial x}(x,t) = v^2 \frac{\partial^2 y}{\partial x^2}(x,t)$$

$$\boxed{\frac{\partial^2 y}{\partial t^2} = v^2 \frac{\partial^2 y}{\partial x^2}; \quad v^2 \equiv T/\sigma}$$

EM wave derivation as per string model:

The wave equation for "vacuum" under tension is derived by equating two balancing forces. Mass times acceleration of an elemental string length equals the restoring tension force. Displacement of string position is "y".

$$ma = F$$

$$\mu_0\Delta x \frac{\partial^2 y}{\partial t^2}(x,t) = \Delta_x (\varepsilon_0^{-1}\sin\theta) \approx \varepsilon_0^{-1}\Delta_x\left(\frac{\partial y}{\partial x}\right)$$

→ Inertia to magnetic field generation

$$\mu_0\Delta x \frac{\partial^2 y}{\partial t^2}(x,t) = \varepsilon_0^{-1}\Delta_x \frac{\partial y}{\partial x} \quad\Rightarrow\quad \frac{\partial^2 y}{\partial t^2}(x,t) = \frac{\varepsilon_0^{-1}}{\mu_0}\frac{\partial}{\partial x}\frac{\partial y}{\partial x}(x,t) = c^2 \frac{\partial^2 y}{\partial x^2}(x,t)$$

$$\boxed{\frac{\partial^2 y}{\partial t^2} = c^2 \frac{\partial^2 y}{\partial x^2}; \quad c^2 \equiv \varepsilon_0^{-1}/\mu_0}$$
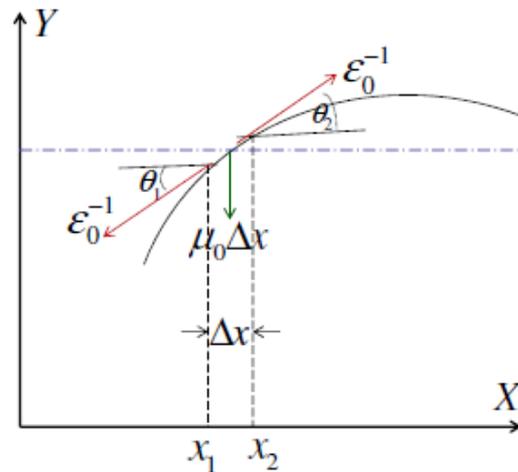
What are particles?

Does ψ really represent the "Abstract Mathematical Probability 'Pilot' Wave" as per Born; or, is it a real physical oscillatory amplitude of some field-gradient?

Fine structure constant fro particles: $\alpha = \dfrac{1}{4\pi\varepsilon_0}\dfrac{e^2}{\hbar c} = \dfrac{\mu_0^{1/2}}{4\pi\varepsilon_0^{1/2}}\left(\dfrac{e^2}{\hbar}\right)$

Velocity of light: $c^2 = \left(\dfrac{\varepsilon_0^{-1}}{\mu_0}\right)$

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Particles are not plane waves!
Neither are they piloted by some other waves!

Does ψ really represent the "Abstract Mathematical Probability 'Pilot' Wave" as per Born; or, is it a real physical oscillatory amplitude of some field-gradient?

All these harmonic undulations can be expressed by the same exponential function:

$$a \exp(i\omega t) \equiv a \exp(i2\pi\nu t) = a \exp(iEt/\hbar); \, with \, the \, postulate: \, E = h\nu$$

Diagrams adapted from web
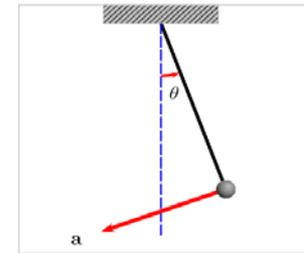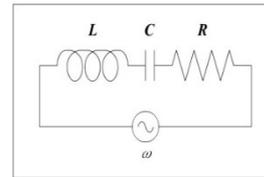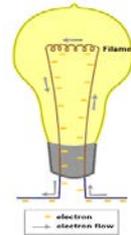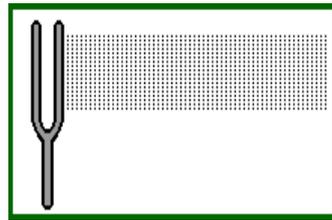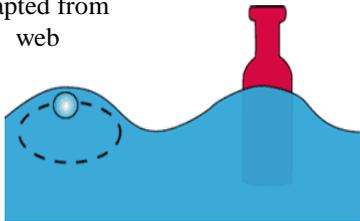
If the particles are localized resonant oscillations of the vacuum (Complex tension Field, or CTF; then Schrodinger's "wave function" represents real physical harmonic excitations rather than various abstract mathematical probability amplitudes as "Pilot or plane waves".
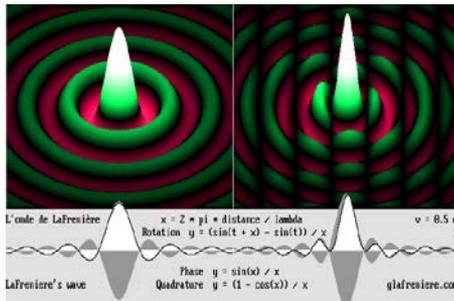
SCHRODINGER

$$i\hbar \frac{\partial \psi}{\partial t} = \left(\frac{p^2}{2m} + V \right)\psi = H\psi$$

Mathematical plane wave does not exist in the real world !

❖ Wave-particle duality started as "lack of detailed knowledge". It is not a new definitive knowledge

Then, what are particles?
They are also oscillations of the same CTF!

Particles are localized resonant oscillations of other component tension fields of the same CTF. The oscillations are most likely self-looped doughnut-like to acquire their "localized" properties. These are not De Broglie's Pilot Waves guiding the material particles existing independent of CTF.

Particles have internal oscillations (energy) that determines their very existence, which is already captured by Schrodinger's expression for free particle:

$$\psi_{in} = e^{-i(^{in}E)t/\hbar} = e^{-i(^{in}f)t}; \quad \text{where} \quad ^{in}E = h\,(^{in}f)$$

I am hypothesizing that particles acquire a different kind of external oscillation frequency as they kinetic motion and energy while "falling" into potential gradients produced in the CTYF by other particles. There are no force. There are only potential gradients generated in the CTF due to the localized oscillations of particles.

$$\psi_k = e^{-i(^{k}E)t/\hbar} = e^{-i(^{k}f)}; \quad \text{where} \quad ^{k}E = h\,(^{k}f)$$

Notice that the kinetic energy can be related to the particle mass and velocity and hence a fictitious De Broglie wavelength. For zero velocity, the De Broglie wave length is infinite; but the kinetic frequency is zero (well defined):

$$^{k}E = m\mathrm{v}^2/2 = h\,(^{k}f) \quad (^{k}\lambda)(^{k}f) = \mathrm{v} \Rightarrow (^{k}\lambda) = \mathrm{v}/(^{k}f) = h\mathrm{v}/(m\mathrm{v}^2/2) = 2h/p$$

Waves and particles, both are emergent excited states of CTF of certain energy; which is still held by CTF.
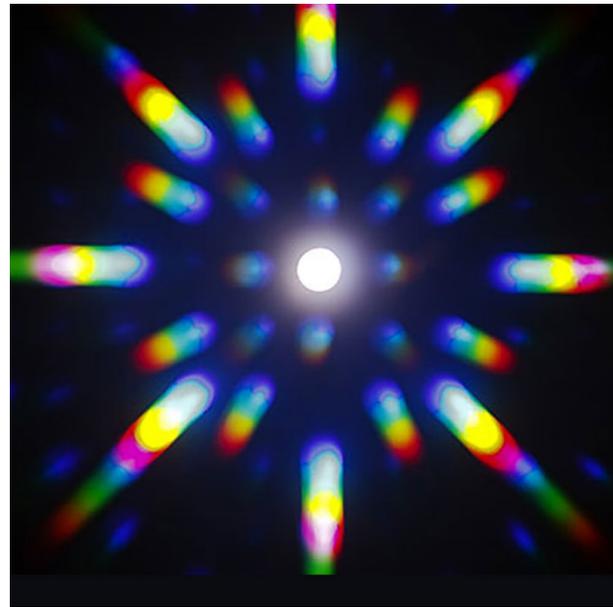
Doppler Effects due to source velocity & detector velocity are different

The same CTF is experienced by the spontaneously emitting atoms in the corona of stars and those inside the Earth bound discharge tube

Implications

➢ **The optical Doppler Effect is a classical effect as originally developed by Doppler – the source velocity and detector velocities are discerned by the emitting and detecting quantum atoms!**

➢ **Internal quantum translon frequency remains same in stars' corona and on earth-bound discharge tube.**

Consequent Implication

➢ **Cosmological Redshift is not all due to Doppler Effect. Hence, the universe may not be expanding as fast we now believe!**

Stellar & earthly **stimulated absorption** spectrometric line-broadening tells us that the detector "knows" its velocity to remain QM-congruent!

Eq.1

Spontaneous emission individual events

$$_{med.}^{\pm}\nu = {_{QM}}\nu(1 \mp \mathrm{v}_{src.}/c)^{-1}$$

$$_{med.}^{\pm}\nu$$

$_{QM}\nu$

$\pm\vec{\mathrm{v}}_{src.}$

Distribution

$\delta\nu$

Red Doppler shift $Dplr.$ $_{QM}_{src.}\nu$ Blue Doppler shift

Emission spectrum
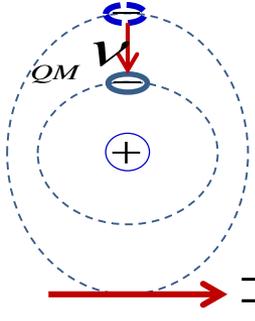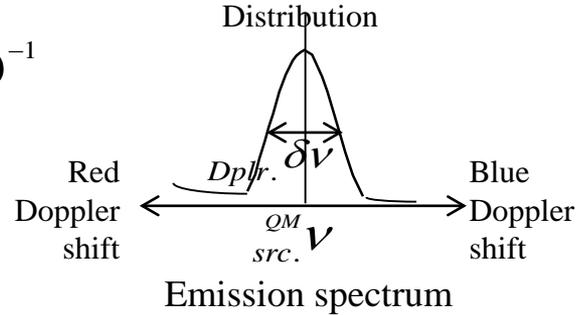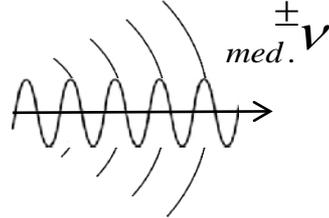
The light emitting atoms could be from a star or from a lab lamp.

C. Roychoudhuri, U. Connecticut & Femto Macro Continuum

Stimulated absorption individual events

Eq.2

Broad spectrum in a medium

$_{med}\nu$

$_{QM}\nu$

$$\nu_{det.\pm}$$
$$= {_{med.}}\nu(1 \pm \mathrm{v}_{det.}/c)$$
$$\equiv {_{QM}}\nu$$

$\pm\vec{\mathrm{v}}_{det.}$

Distribution

$\delta\nu$

$Dplr.$

Red Doppler shift $_{QM}_{src.}\nu$ Blue Doppler shift

Absorption spectrum
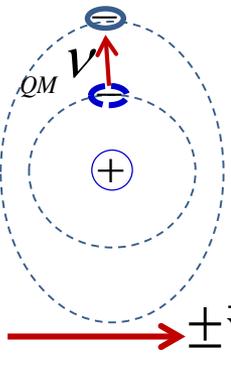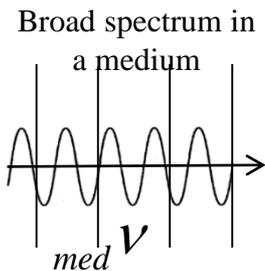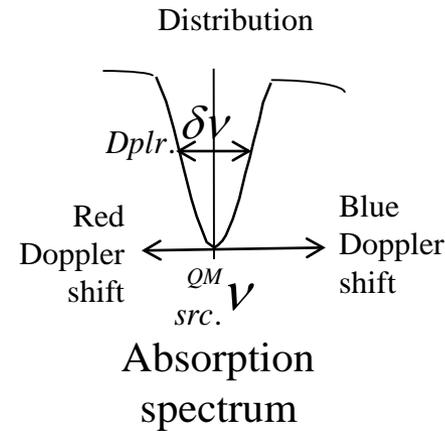
The light absorbing atoms could be in a star or in a lab tube.

The only way an absorbing atom can be QM-congruent is to resonate with that frequency, $_{med}\nu$, which will appear to as $_{QM}\nu$ given its specific velocity $\pm\vec{\mathrm{v}}_{det.}$. The source velocity is unknown to it.

92

Simultaneous spectral analysis of spontaneous and stimulated emissions from Ne-atoms from a He-Ne laser

High resolution spectrometers.

1.5 GHz Doppler broadened spontaneous emission spectrum

1.5   GHz

Less than 100KHz Narrow laser mode spectral lines

$\delta v = c/2L$

v_1 v_2 v_3

Combined Output Spectra
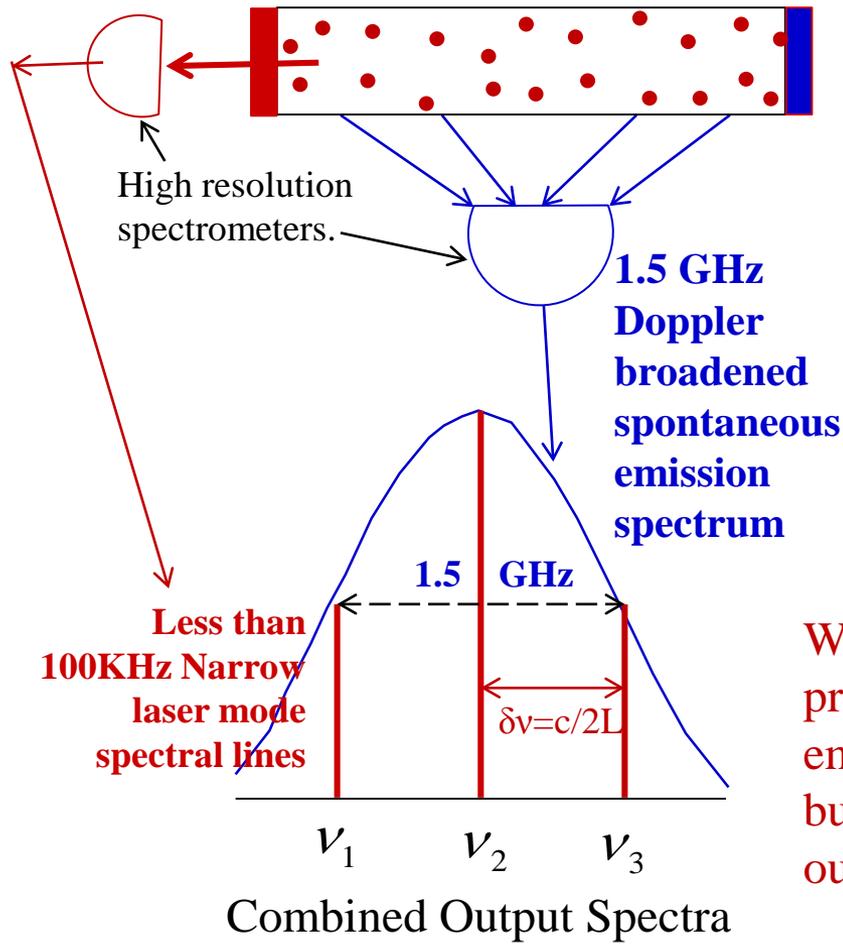
What is the physical process behind the emergence of very sharp but multiple frequencies out of gas lasers?

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Understanding spontaneous emission process

Stationary emitter

Stationary detector

$$_{det.}^{\pm}\nu = {}_{QM}^{mn}\nu$$

Upper lasing level n

Spontaneous emission ΔE_{mn}

$${}_{QM}^{mn}\nu$$

Lower lasing level m

$${}_{\Delta E_m}det. \ v = 0$$
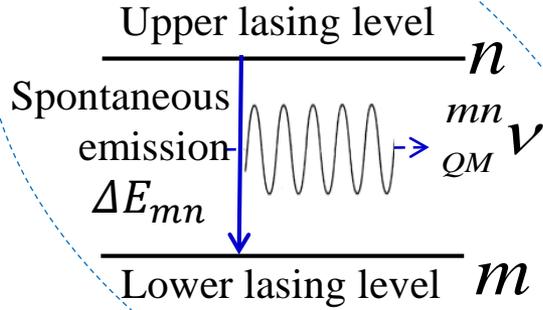
$${}_{src,} v = 0$$ No Doppler shift; impossible except at 0-Kel..

Moving emitter

Stationary detector

$$_{det.}^{\pm}\nu = {}_{QM}^{mn}\nu(1 \mp v_{src.} / c)^{-1}$$

Upper lasing level n

Spontaneous emission

$${}_{QM}^{mn}\nu$$

Lower lasing level m

$${}_{det.} v = 0$$
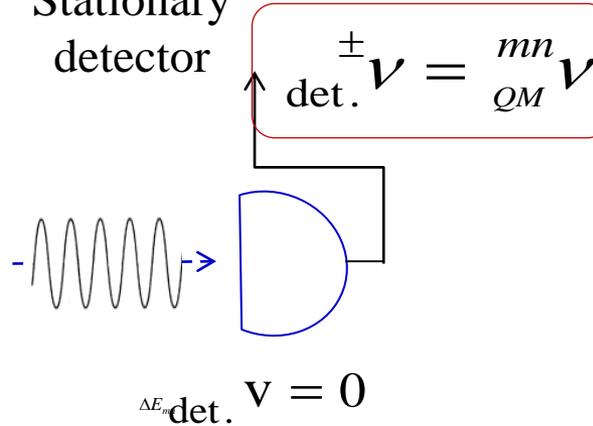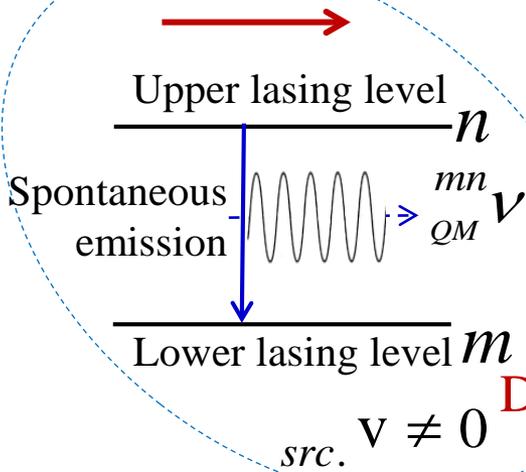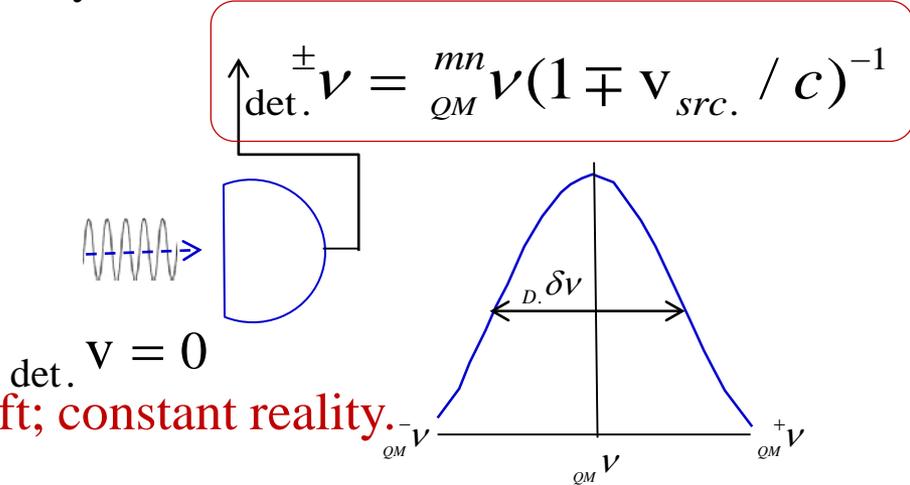
$${}_{src.} v \neq 0$$ Doppler shift; constant reality.

$${}_{D.}\delta\nu$$

$${}_{QM}^{-}\nu \qquad {}_{QM}\nu \qquad {}_{QM}^{+}\nu$$

Measurable physical Spectrum

Stimulated emission tells source & detector velocities are discernible!

Moving emitter.
Spontaneous emission.

Upper lasing level

n

$_{QM}^{nm}\nu$

Spontaneous emission

Lower lasing level

m

$_{src.}v \neq 0$

Free-space propagation between atoms

$$_{det.}^{\pm}\nu = {}_{QM}^{mn}\nu(1 \mp v_{src.}/c)^{-1}$$

Doppler shifted in free space

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Stimulated emission tells source & detector velocities are discernible!

Moving emitter.
Spontaneous emission.

Upper lasing level

$$n$$

$${}^{nm}_{QM}\nu$$

Spontaneous emission

Lower lasing level $$m$$

$$_{src.}\mathrm{v} \neq 0$$

Free-space propagation between atoms

$$_{det.}^{\pm}\nu = {}^{mn}_{QM}\nu(1 \mp \mathrm{v}_{src.}/c)^{-1}$$

Doppler shifted in free space

Stimulated photons in free-space with the same Doppler shifted frequency to match the cavity-allowed $c/2L$ modes.

$$_{det.\pm}\nu = {}_{med.}\nu(1 \pm \mathrm{v}_{det.}/c)$$

$$= {}^{nm}_{QM}\nu \frac{(1 \pm \mathrm{v}_{det.}/c)}{(1 \mp \mathrm{v}_{src.}/c)}$$

$$= {}^{nm}_{QM}\nu; \ \text{for} \ \vec{\mathrm{v}}_{det.} = \vec{\mathrm{v}}_{src.}$$

Moving emitter.
Stimulated emission

Upper lasing level

$$n$$

Perceived frequency $${}^{nm}_{QM}\nu$$

Lower lasing level $$m$$

$$_{src.}\mathrm{v} \neq 0$$

Relative axial vectorial velocity must be zero for effective QM resonance.

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Stimulated emission tells source & detector velocities are discernible!

Moving emitter.
Spontaneous emission.

Upper lasing level

n

Spontaneous emission

$\underset{QM}{nm}\nu$

Lower lasing level

m

$_{src.}\mathrm{v} \neq 0$

Free-space propagation between atoms

$$\underset{det.}{\pm}\nu = \underset{QM}{mn}\nu(1 \mp \mathrm{v}_{src.}/c)^{-1}$$

Doppler shifted in free space

Stimulated photons in free-space with the same Doppler shifted frequency to match the cavity-allowed $c/2L$ modes.

$$_{det.\pm}\nu = _{med.}\nu(1 \pm \mathrm{v}_{det.}/c)$$
$$= \underset{QM}{nm}\nu\frac{(1 \pm \mathrm{v}_{det.}/c)}{(1 \mp \mathrm{v}_{src.}/c)}$$
$$= \underset{QM}{nm}\nu; \ \text{for} \ \vec{\mathrm{v}}_{det.} = \vec{\mathrm{v}}_{src.}$$

Perceived frequency

Moving emitter.
Stimulated emission

Upper lasing level

n

$\underset{QM}{nm}\nu$

Lower lasing level

m

$_{src.}\mathrm{v} \neq 0$

Internal quantum transition frequency always remains same.

Relative axial vectorial velocity must be zero for effective QM resonance.

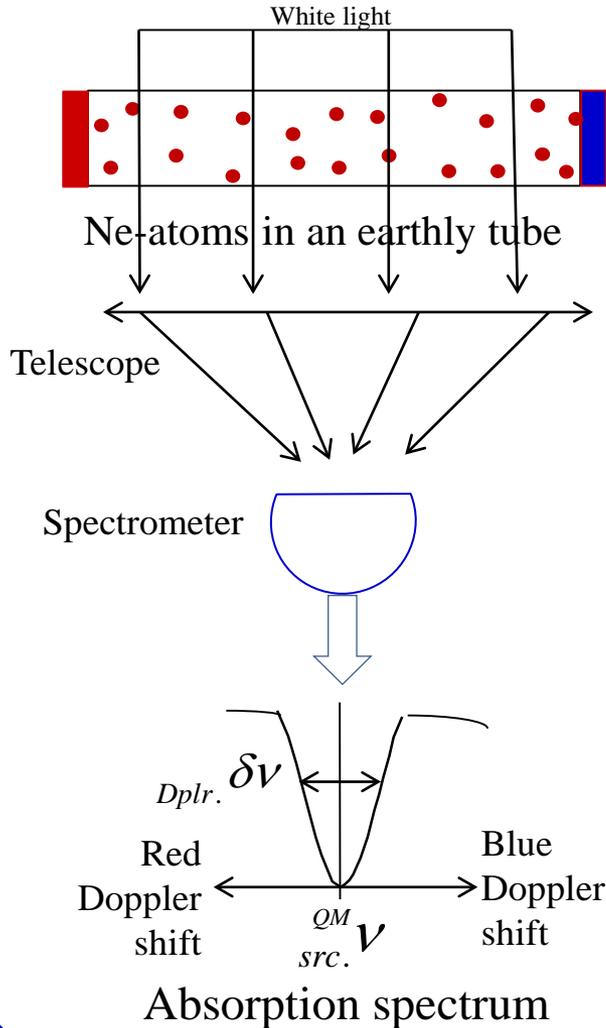$_{QM}^-\nu$ $_{D.}\delta\nu$ $_{QM}\nu$ $_{QM}^+\nu$

Measurable physical Spectrum

Cosmological Redshift is not due to Optical Doppler Effect

Understanding absorption spectroscopy
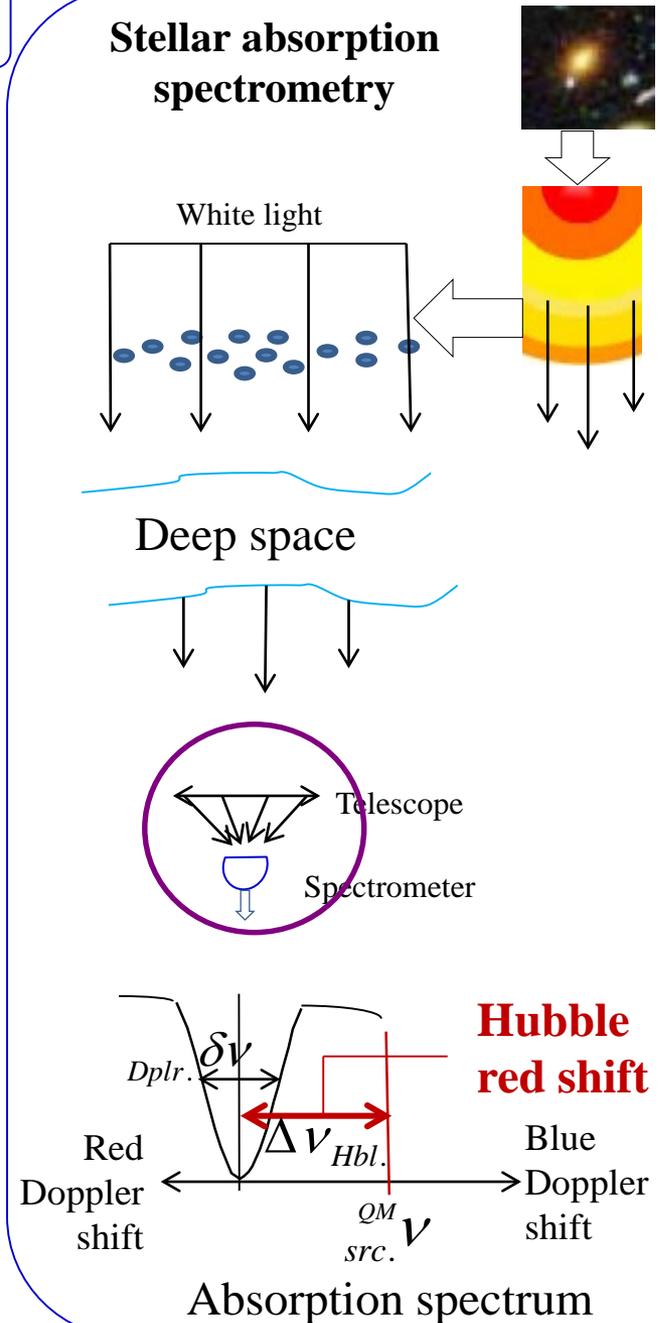
Terrestrial absorption spectrometry

White light

Ne-atoms in an earthly tube

Telescope

Spectrometer

$_{Dplr.}\delta\nu$

Red Doppler shift

Blue Doppler shift

$_{src.}^{QM}\nu$

Absorption spectrum

Do the atoms move with respect to the "star-frame", or the "earth-frame", or the "lab-frame" or the "vacuum-frame"?

# We posit that it is the "Vacuum-frame", which is stationary everywhere!

Like stimulated emission frequency, absorption freq. is determined by the velocity of the "detector" only!

Stellar absorption spectrometry

White light

Deep space

Telescope

Spectrometer

$_{Dplr.}\delta\nu$

Red Doppler shift

$\Delta\nu_{Hbl.}$

Hubble red shift

Blue Doppler shift
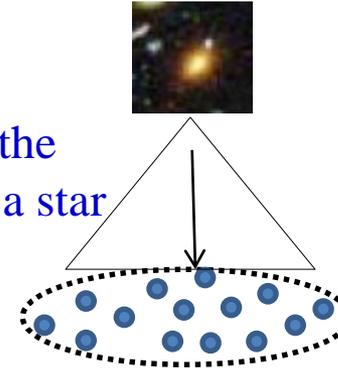
$_{src.}^{QM}\nu$

Absorption spectrum

We can safely assume that the space between the Ne-atoms inside a sealed tube on earth is the same as that between the atoms emitting light from distant stars (in Galaxies).

Atoms in the corona of a star
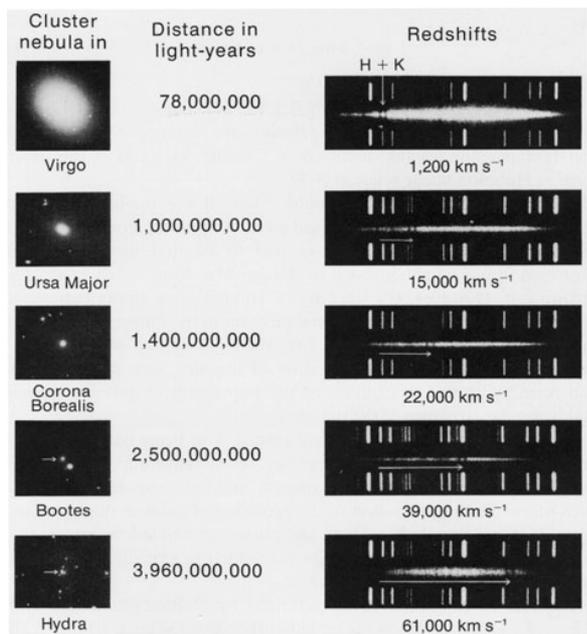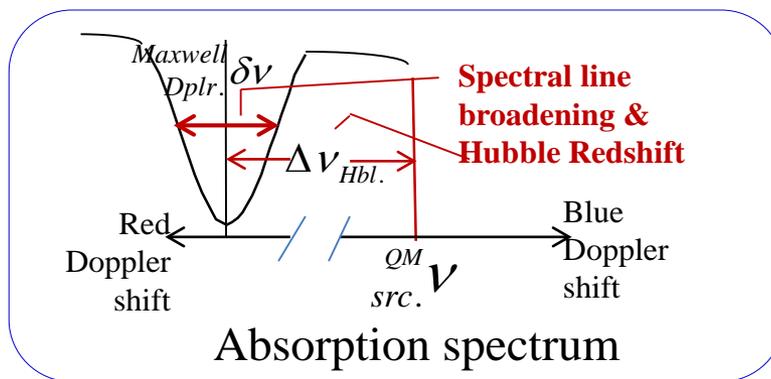
Ne-atoms in an earthly tube
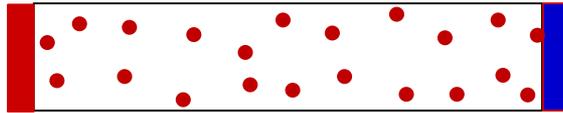
➤ The fact that the absorption line spectra measured on earth, whether from a laboratory sample or from a distant star, show the same identical Maxwell-Doppler characteristics, quantum absorption/emission phenomena perceive these velocities as identical with respect to the universal vacuum, which we call CTF (Complex tension Field)

➤ Physical processes behind Maxwell-Doppler phenomenon, in emission and absorption, also forces us to acknowledge that atoms as emitters and as "detectors" (stimulated absorption and emission) clearly can discern their separate velocities with respect to the CTF or the cosmic vacuum.

➤ Accordingly, the cosmological or Hubble red shift is a physically different phenomenon; most likely, it is other than Doppler shift.
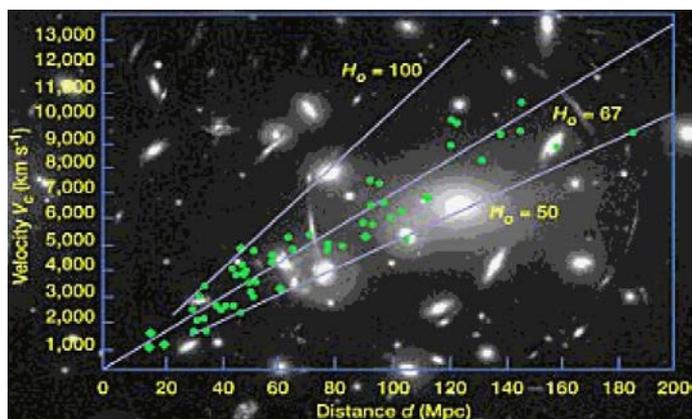
C. Roychoudhuri, U. Connecticut & Femto Macro Continuum

Absorption lines, as absence of real signal, cannot undergo physical changes!

Cluster nebula in | Distance in light-years | Redshifts H + K
- Virgo: 78,000,000 — 1,200 km s⁻¹
- Ursa Major: 1,000,000,000 — 15,000 km s⁻¹
- Corona Borealis: 1,400,000,000 — 22,000 km s⁻¹
- Bootes: 2,500,000,000 — 39,000 km s⁻¹
- Hydra: 3,960,000,000 — 61,000 km s⁻¹

http://astro.wku.edu/astr106/H_K_redshift.jpg

Photos borrowed from web.

Emission and absorption physical processes are identical in all stars.

Maxwell Dplr. $\delta\nu$

Spectral line broadening & Hubble Redshift

$\Delta\nu_{Hbl.}$

Red Doppler shift

QM $src.$ ν

Blue Doppler shift

Absorption spectrum

$$\left[\begin{array}{c} \text{Hubl.} \\ \text{Redshift} \end{array} \Delta\nu \right]_{\substack{\text{Due to} \\ \text{travel to} \\ \text{earth.}}} \ggg \left[\begin{array}{c} \text{Maxwell} \\ \text{Dopler} \end{array} \delta\nu \right]_{\substack{\text{Due to} \\ \text{atoms' vel.} \\ \text{in star.}}}$$
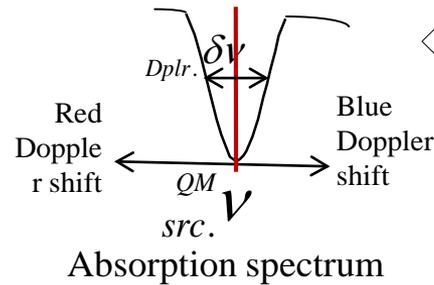
We posit that Cosmological (Hubble) Red Shift during cosmic travel of star light is different from source/emitter velocity dependent Doppler shift. **Do we really have an expanding universe?**

C.R., "Hijacking of the 'holographic principle' by cosmologists"; Proc. SPIE Paper #8833-15

Since QM is correct, we propose to send a rocket with a spectrometer to a distant galaxy and measure the Doppler broadened absorption spectrum.
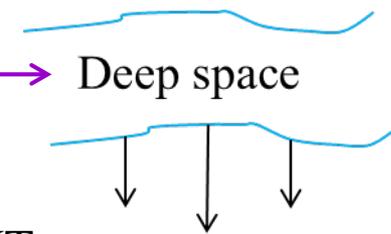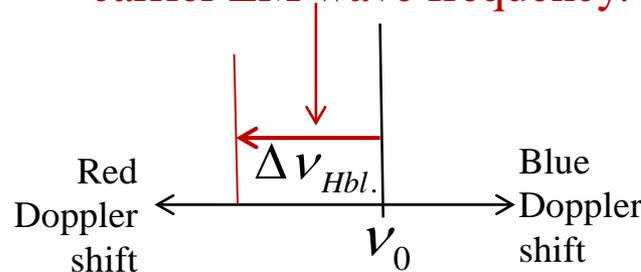
One star

Satellite by a star in a distant galaxy

On-site data;
No Hubble shift.

Telescope

Spectrometer

$Dplr.$ δv

Red Doppler shift $\longleftarrow$ $\underset{src.}{QM} v$ $\longrightarrow$ Blue Doppler shift

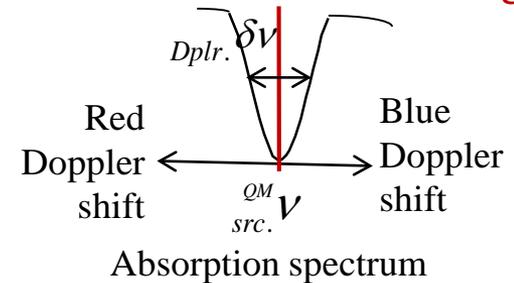Absorption spectrum

Data to earth

The vacuum, or the cosmic space, is the stationary reference frame

Deep space

Hubble red shift of the carrier EM wave frequency.

BUT

Retrieved data;
No Hubble broadening.

$Dplr.$ δv

$\Delta v_{Hbl.}$

Red Doppler shift $\longleftarrow$ v_0 $\longrightarrow$ Blue Doppler shift

Red Doppler shift $\longleftarrow$ $\underset{src.}{QM} v$ $\longrightarrow$ Blue Doppler shift

Absorption spectrum

102

It is better to re-frame our questions: What kind of experiments can discern the Doppler shifts due to source and detector velocities & separate them from Cosmological red-shift due to vast propagation distances?

Real Doppler shift due to star velocity w.r.t. CTF!

Apparent Doppler shift due to detector velocity w.r.t. CTF !

$$_{erth.}^{\pm}\nu = {}_{QM}^{nm}\nu \frac{(1 \pm v_{det.} / c)}{(1 \mp v_{src.} / c)}$$

$_{QM}\nu$ $_1 V_{sorc.}$

$_{med.}\nu_1$

$_{QM}\nu$ $_2 V_{sorc.}$

$_{med.}\nu_2$

$V_{Det.}$

$_{QM}\nu$ $_3 V_{sorc.}$

$_{med.}\nu_3$

From the web.

V1; ν1

V2; ν2

V3; ν3

V4; ν4

V5; ν5

V6; ν6

V7; ν7

Adapted from the web.
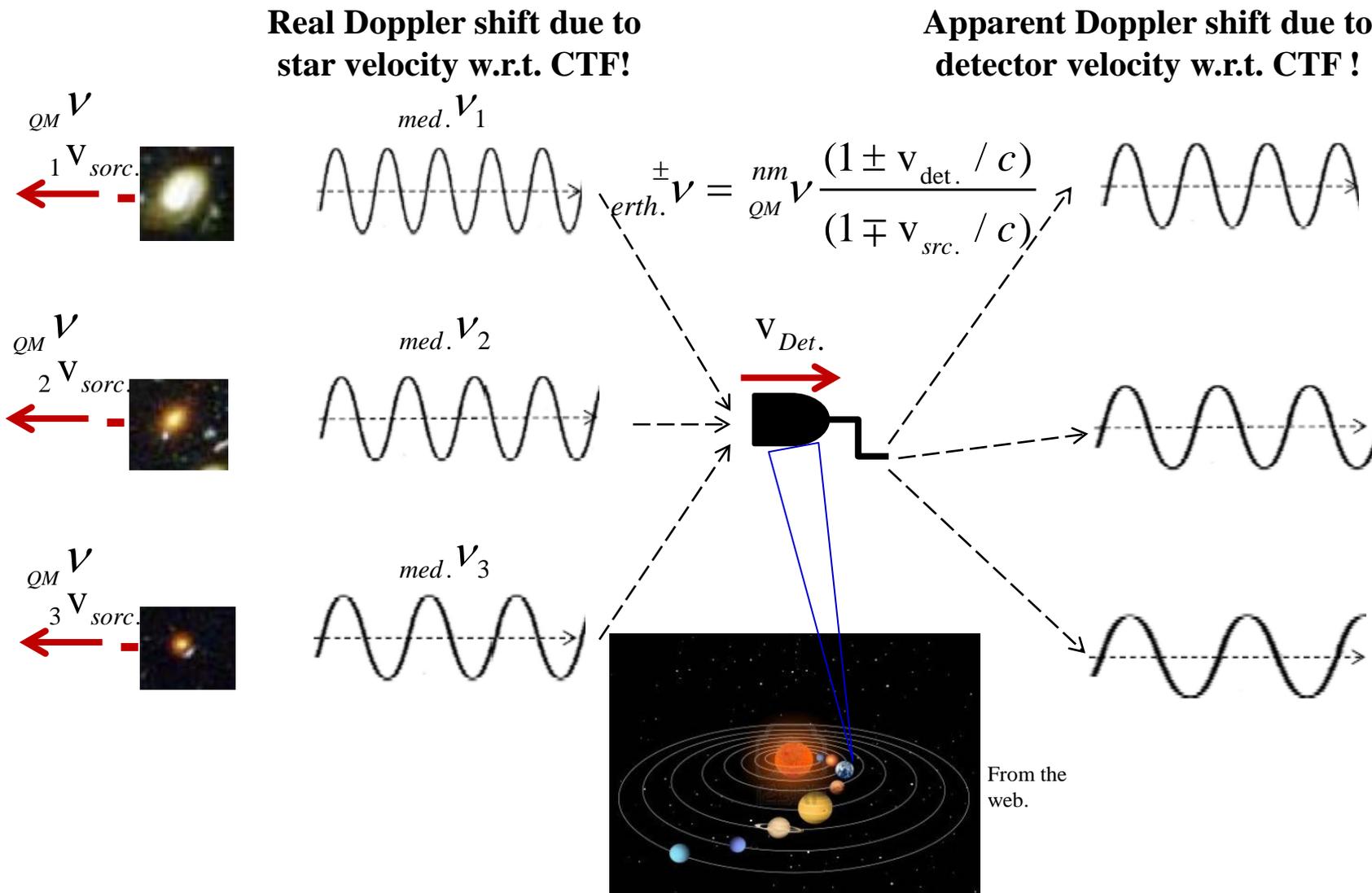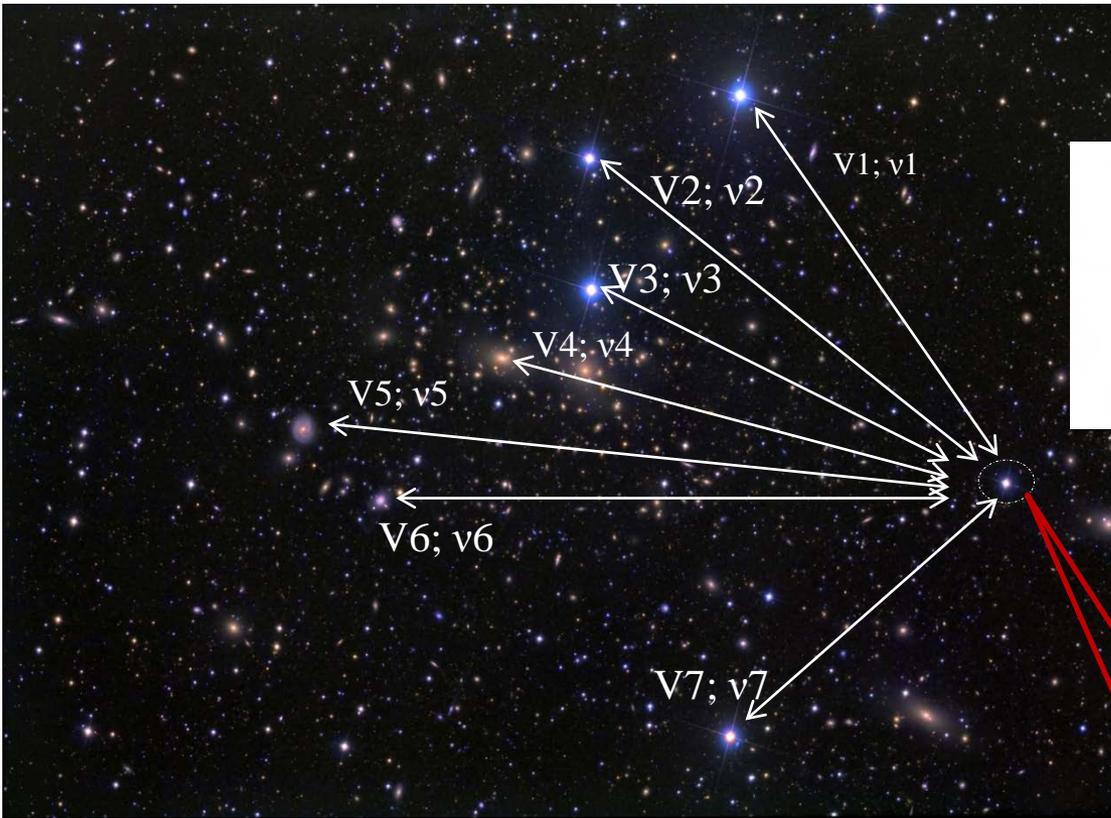
Does optical Doppler shift depend only on the relative velocity between the source and the detector?
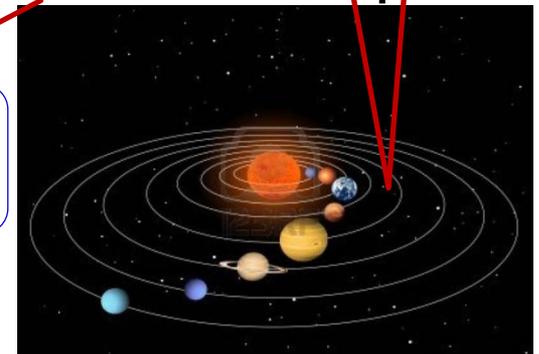
Should we explain cosmological red-shift as exclusively due to optical (Relativistic) Doppler shift?

http://www.astronet.ru/db/xware/msg/1244892/comacluster_rowe_big.jpg.html

CTF is the cosmological inertial rest frame.

Various ether drag experiments can be explained by considering EM waves and particles as diverse types of oscillations (excitations) of the same stationary CTF.

1. Concept of "ether" has not been wiped out by MM experiments.
2. A moving mirror approaching an oncoming light pulse will reach it earlier than a stationary one. That is how we do interferometry.
3. Bring the pulse laser in MM experiment. How far the vertical mirror should be so that a pico second pulse misses it.

# Michelson-Morley null result does not invalidate the existence of a "ether" [Cosmic Tension Field (CTF)]
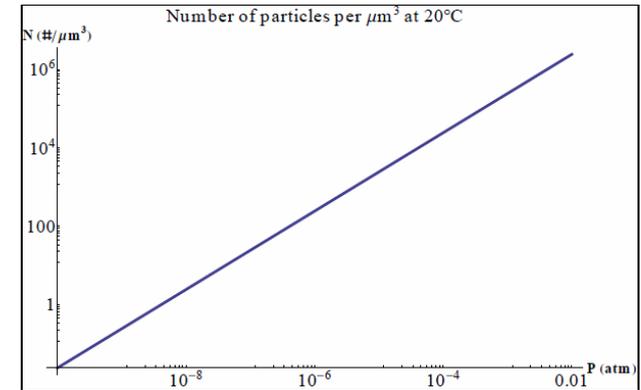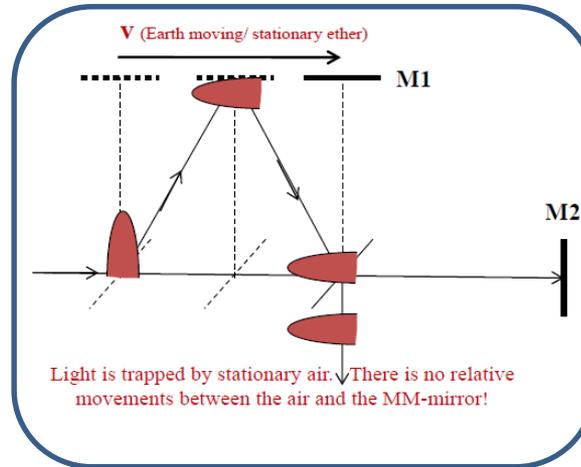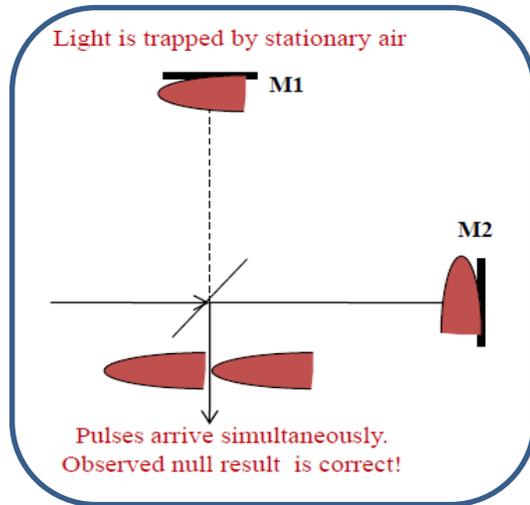
- Light beams travel along the original Poynting vector, which can be re-directed as per Snell's laws. Light beam does not follow a moving mirror. The vertical beam would go straight up and come straight down, if the horizontal mirror size is wide enough to reflect it even after lateral translation.
- M-M experiment measure relative phase difference between the returned beams. The set up does not directly measure light velocity. Drawing inference becomes complex because CTF, that sustains the EM waves, is stationary and even the air is stationary with respect to the interferometer!
- The vacuum of 19th and 20th century vacuum is not good enough to simulate pure CTF. 100 particles per micron cube, giving 10<-6> atmos. is still a physical medium for light.
- Modified space experiment is suggested in the next slide.

1. F. Selleri, "Noninvariant one-way speed of light and locally equivalent reference frames"; Found. Phys. Lett. 10, 73-83 (1997)
2. S.J.G. Gift, "Successful Search for Ether Drift in a Modified Michelson-Morley Experiment Using the GPS"; Applied Physics Research Vol. 4, No. 1; February 2012. www.ccsenet.org/apr

We need to measure the real velocity of light.

M-M experiment tries to measure relative phase difference!
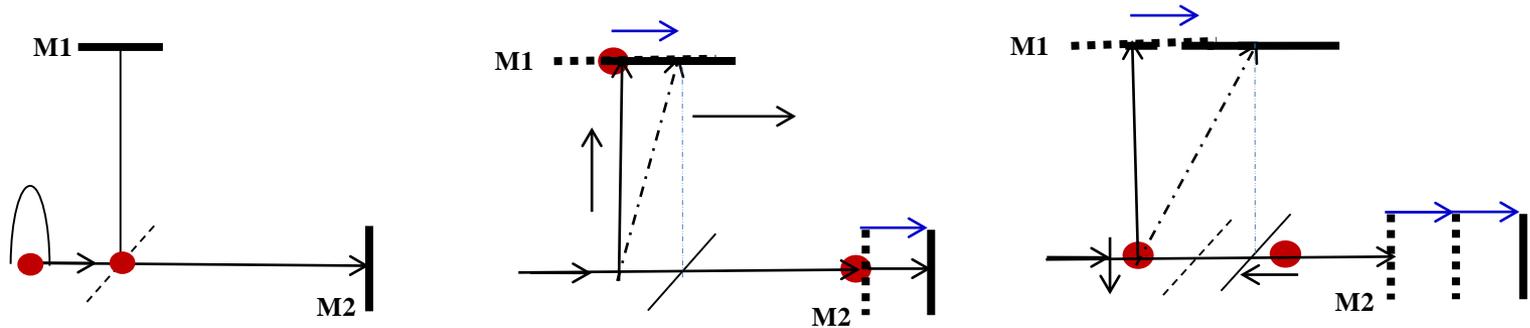

A short pulse of light illustrates the point. The M-M interferometer is immersed in stationary air or stationary CTF (modified ether). Light travel direction is completely controlled by the Poynting vector, not by the direction of the movement of the interferometer. So, the pulse on its vertical journey, on arrival, may just get reflected from the edge of the top mirror. On its return, it may not even encounter the beam splitter, if the interferometer arm-length is made very very long! No interferometry can be done either in air or in vacuum.

$$\delta x = v\delta t$$

When the evacuated box does not move with respect to CTF (ether).
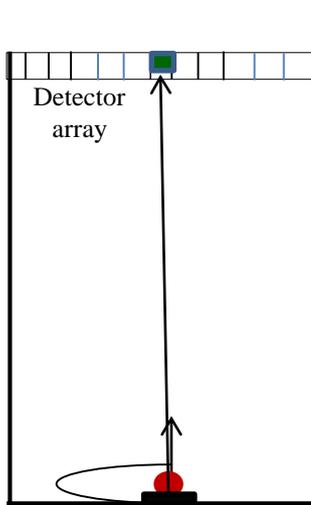
Detector array

When the evacuated box does move with respect to CTF (ether).
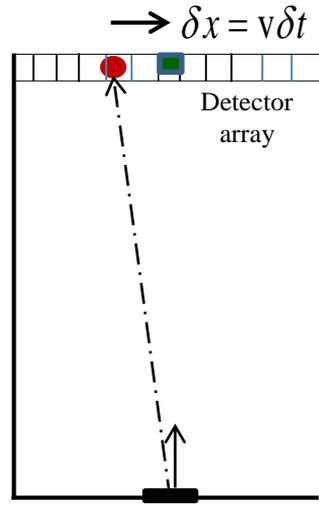
Detector array

Measuring non-drift of ether (CTF) in deep space. Or, one-way velocity of light!

➤ Exploit earth's orbital velocity 30km/s
➤ Use "centering" detector array of pitch 100 micron.
➤ The necessary distance between the pico second pulsed diode and the detector array should be a minimum of 1meter. For 1 pixel shift in the arrival of light.

We believe the postulate of the space as a Complex Tension Field will facilitate our desire to build a unified field theory of EM waves and stable particles.

➢ Ch.11 and 12 in "Causal Physics: Photon Model by Non-Interaction of Waves" by CR; publisher CRC, 2014.

➢ See also various papers in this conference and the panel discussion of this year.

Key messages of the talk

1. **Re-discovery of the NIW-Property:** In the process of enquiring the causal physical processes behind TF-FT (Time-Frequency Fourier Theorem), we have discovered the generic NIW-Property (Non-Interaction of Waves), which physics has been neglecting for centuries.

2. **Formulation of causal physics depends upon not using non-causal mathematics of transformations:** New formulation of spectrometry using a finite pulse restores causality and validates the NIW-property. (Photon appears as a finite wave packet out of this formulation; but not discussed here.)

3. **A stationary CTF is required by the NIW-property:** The capability of a tension field to push away external perturbation within its linear restoration limit, gives rise to the perpetual velocity of a wave packet.

4. **Optical Doppler effect is "Classical":** The validity of the NIW-property, the need for a stationary CTF, & QM-validated atomic transition rules, together dictate this classicality.

5. **Cosmological red shift is a "medium" dependent phenomenon:** The physical processes behind the origin of spectroscopic absorption lines lie within the stars; not outside.

6. **Be evolution-congruent and add IPM-T to your repertoire:** We have been evolving through technology innovation by emulating nature allowed processes. For our sustainability, we have urgent need to know the processes behind all natural phenomena. Iteratively refine IPM-E over and above the prevailing MDM-E.

➢ **Think Evolution-Process Congruent**
➢ **Think like a reverse system engineer to visualize the invisible processes going on in nature.**

How do we
know this
is true?

Are there any questions?

❖ **We never know what is absolutely true!**

    ❖ **Our thinking must be evolution congruent.**

❖ **Sustained evolution requires continuous tools and technology innovations.**

    ❖ **Technology innovation is simply emulation of interaction processes allowed in nature**

    ❖ **We should consistently demand visualization of the invisible interaction processes.**

❖ **Demand on process visualization will automatically force us to keep on iterating our theories for continuous improvement.**

❖ **Healthy doubt is the only insurance for continued evolution of human minds !**

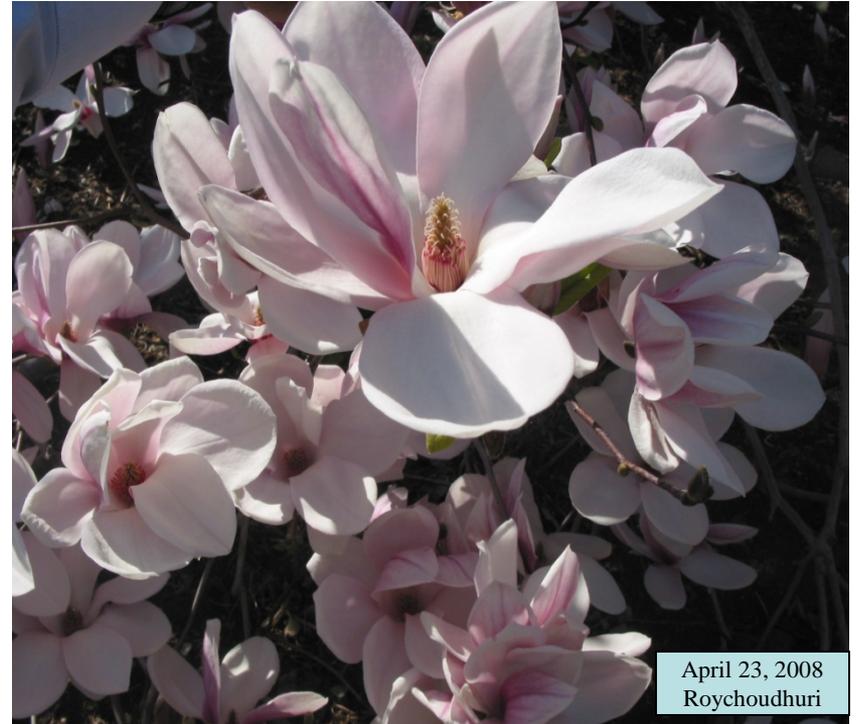# We must overcome our "Messiah Complex"!
Our enquiry must continue perpetually.

My paper download site: http://www.natureoflight.org/CP/

There are always a lot of light behind the dark clouds!

6AM, November 5, 2016. My Backyard Deck

April 23, 2008
Roychoudhuri

Thank you for your attention !