AMOP Lecture 2
Thur. 1.16 -Tue 1.21-Thur 1.23.2014

Relativity of wave-optics and Lorentz-Minkowski coordinates I.

Ch. 2 of Unit 8 CMwBang! and p.1-23 Relativity&QuantumTheory by Rule&Compass

1. Optical wave coordinates and frames

Old-fashioned vs. New-fashioned spacetime frames

Dueling lasers make lab frame space-time grid (CW or PW)

Comparing Continuous-Wave (CW) vs. Pulse-Wave (PW) frames with Review of Light

2. Applying Occam's razor to relativity axioms

Einstein PW Axioms versus Evenson CW Axioms (Traditional: The "Roadrunner" Axiom)

CW light clearly shows Doppler shifts

Check that red is red is red,...green is green is green,...blue is blue is blue,... etc.

Is dispersion linear?... does astronomy work?... how about spectroscopy?

Is Doppler a geometric factor or arithmetic sum?

Introducing rapidity $\rho = ln\ b$.

That old Time-Reversal meta-Axiom (that is so-oo-o neglected!)

3. Spectral theory of Einstein-Lorentz relativity

Applying Doppler Shifts to per-space-time (ck,ω) graph

CW Minkowski space-time coordinates (x,ct) and PW grids

Relating Doppler Shifts b or r=1/b to velocity u/c or rapidity ρ

Connection: Conventional approach to relativity and old-fashioned formulas

1. Optical wave coordinates and frames

→ *Old-fashioned vs. New-fashioned spacetime frames*

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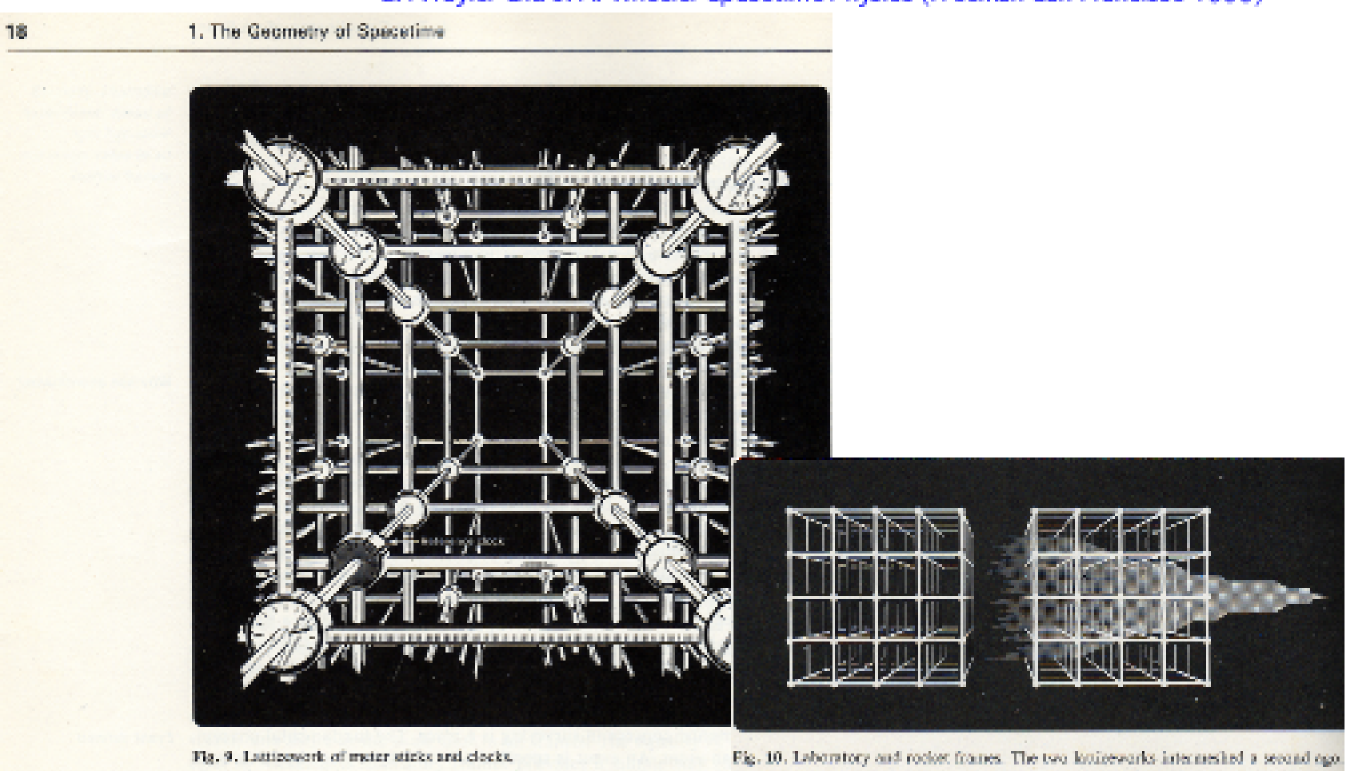
Comparing Continuous-Wave (CW) vs. Pulse-Wave (PW) frames

• *Optical wave coordinate manifolds and frames*

Shining some light on light using complex phasor analysis

Old-fashioned meter-stick-clock frames

E. F. Taylor and J. A. Wheeler Spacetime Physics (Freeman San Francisco 1966)



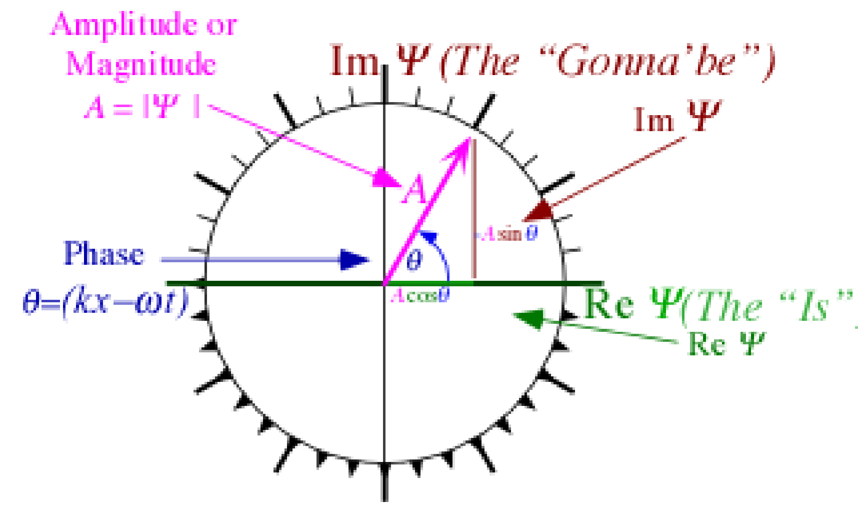
New-fashioned laser clocks & meter sticks

Complex Phasor Clocks : Tesla's AC "phasor"

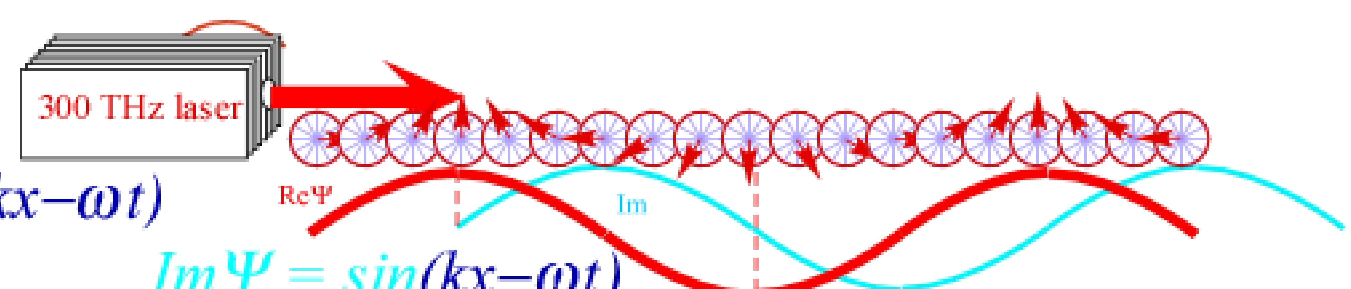
Quantum Phasor Clock

$$\Psi = Ae^{i(kx-\omega t)}$$
$$= A\cos(kx-\omega t)$$
$$+i\,A\sin(kx-\omega t)$$

Phasor clocks turn clockwise in time for positive ω



300THz Laser plane wave $\langle x,t\,|\,k,\omega\rangle = Ae^{i(kx - wt)}$

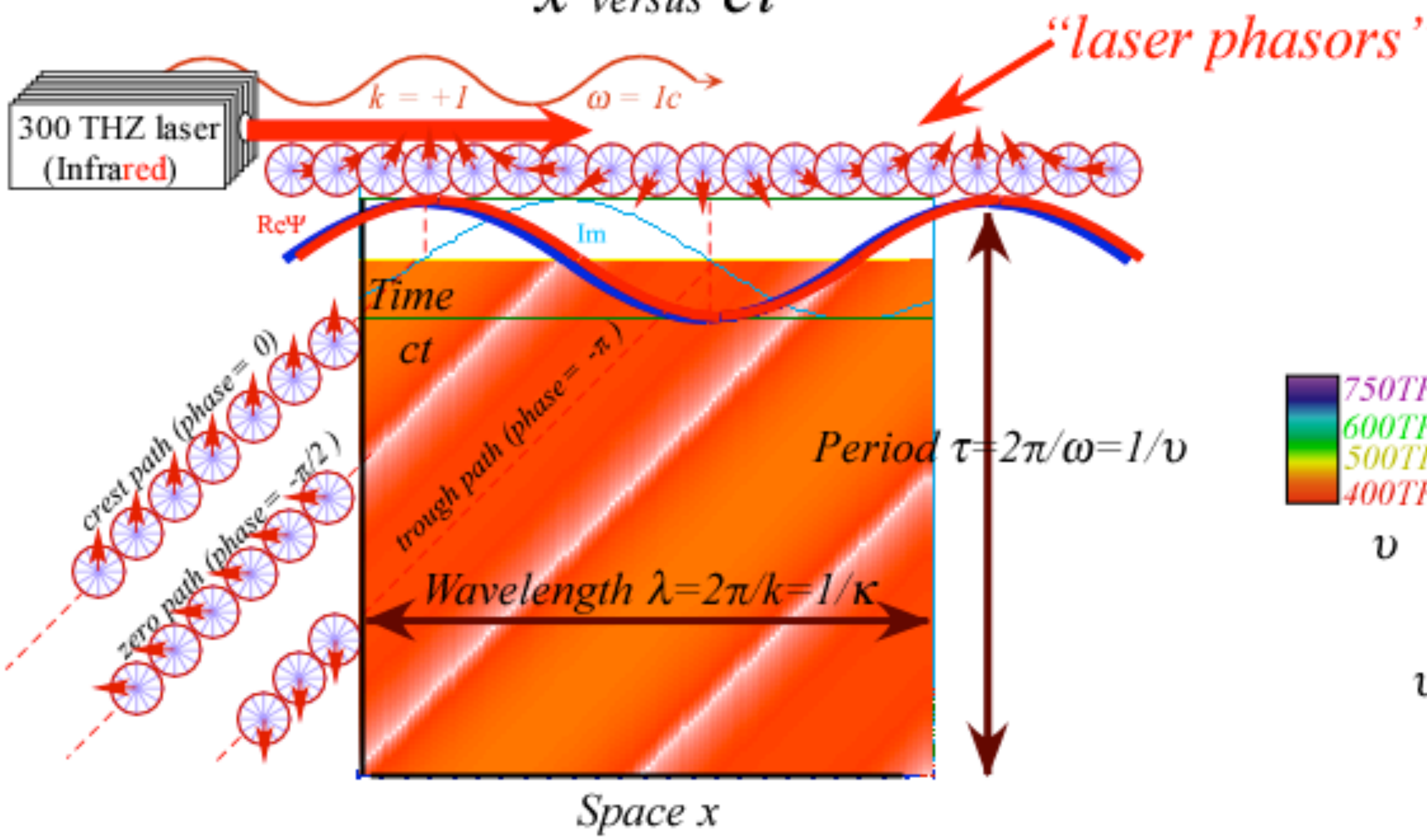


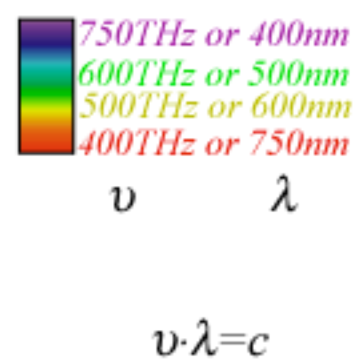
$Re\,\Psi = \cos(kx-\omega t)$

$Im\,\Psi = \sin(kx-\omega t)$

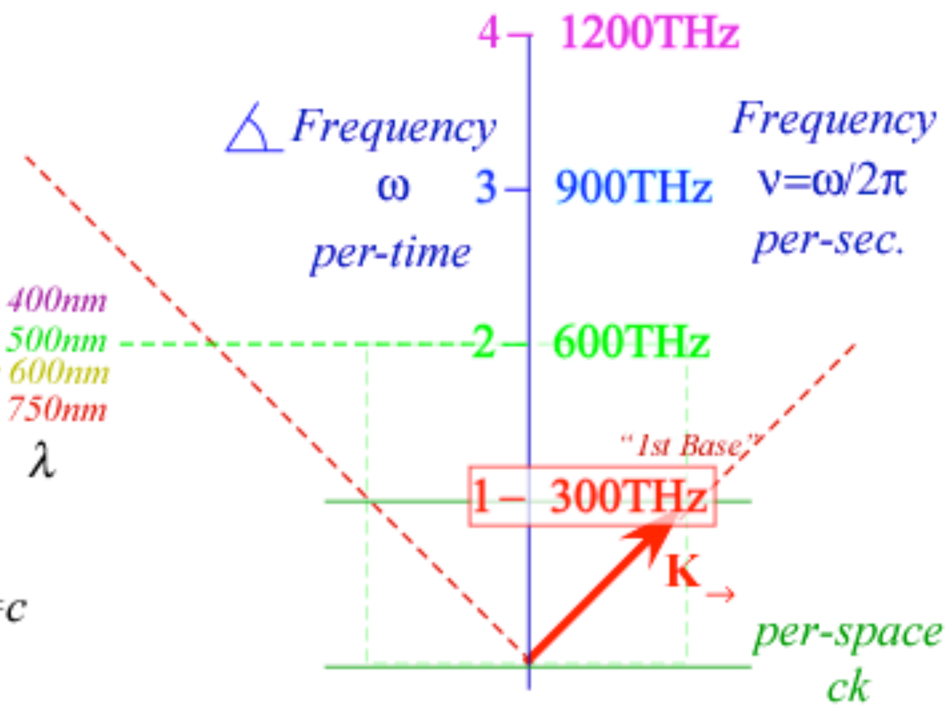
New-fashioned laser clocks & meter sticks (contd.)
Dual views:

(1.) Spacetime
x versus ct





(2.) Per-Spacetime
ω versus ck



Single plane-wave meter-stick-clocks are too fast (can't catch'em)

(...But at least this view is constant)

Interfering wave pairs needed to make rest frame coordinates...

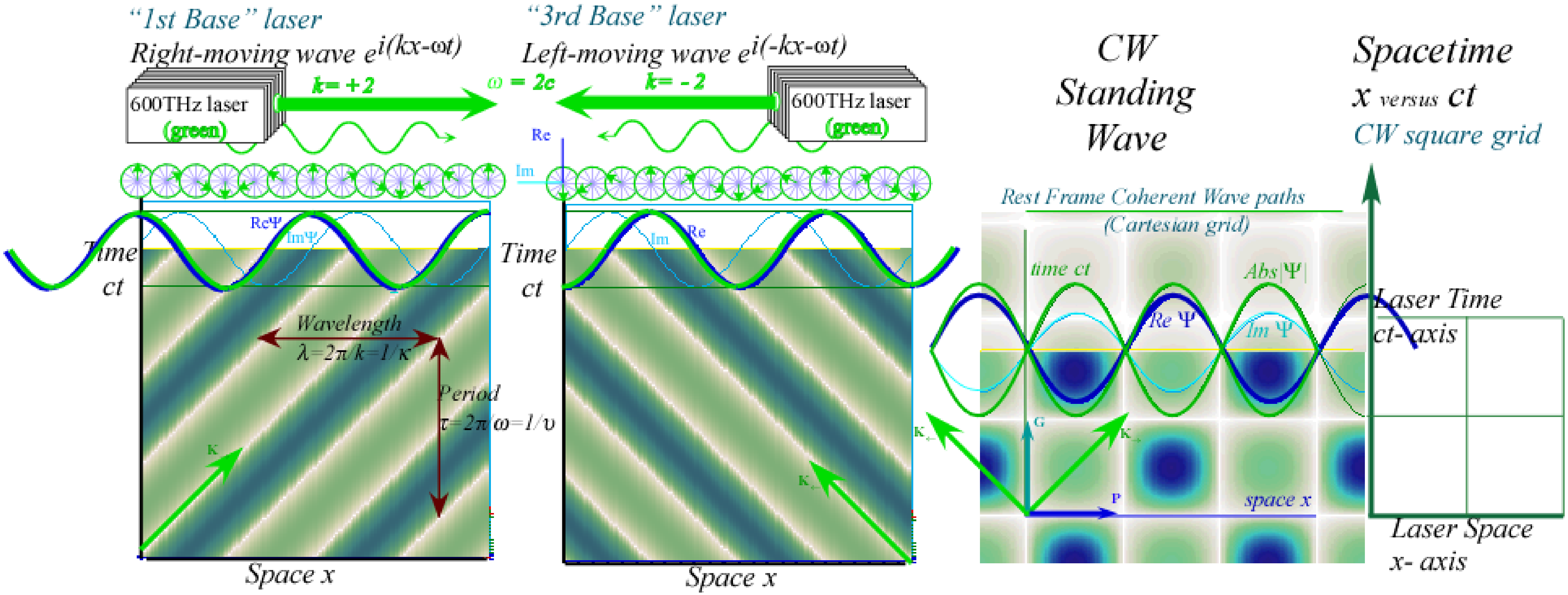
1. Optical wave coordinates and frames

Old-fashioned vs. New-fashioned spacetime frames

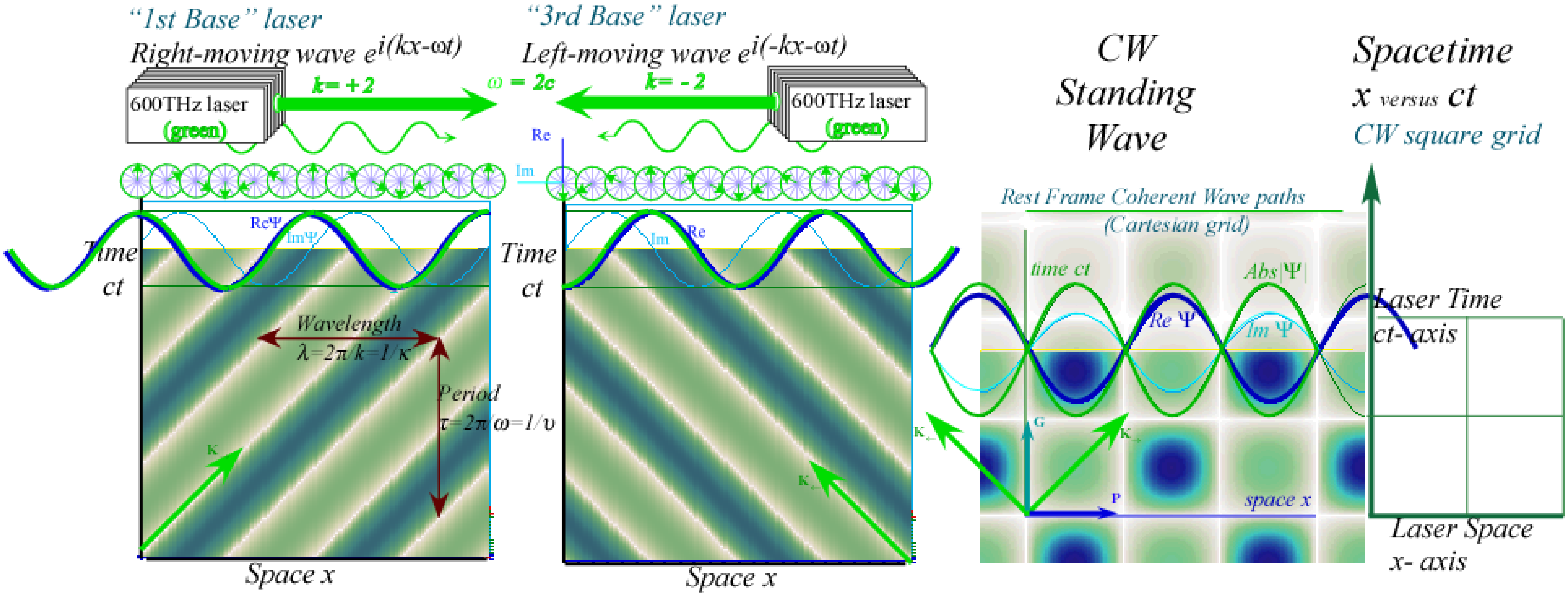
→ *Dueling lasers make lab frame space-time grid (CW or PW)*

Comparing Continuous-Wave (CW) vs. Pulse-Wave (PW) frames

Zeros of head-on CW sum gives (x,ct)-grid



Zeros of head-on CW sum gives (x,ct)-grid



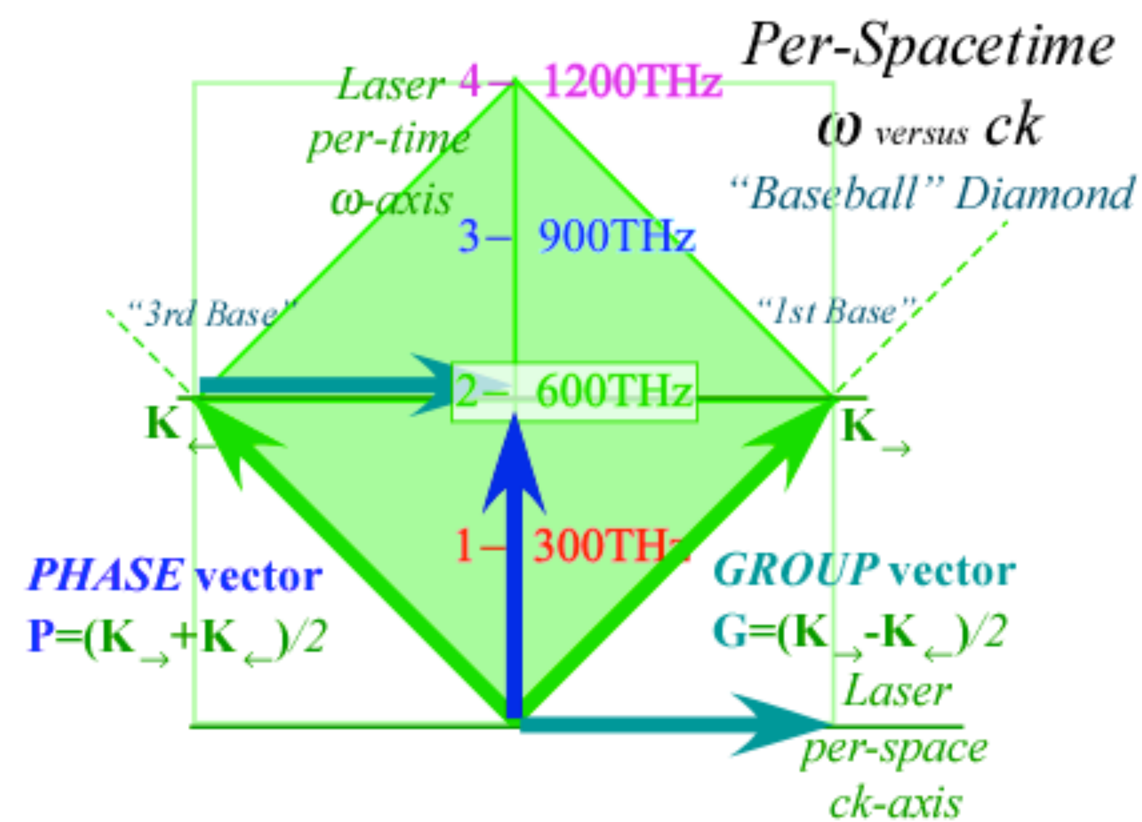
Find zeros by factoring sum:

$$\Psi = \underbrace{e^{ia}}_{(kx-\omega t)} + \underbrace{e^{ib}}_{(-kx-\omega t)}$$

$$= e^{i(a+b)/2}\left(e^{i(a-b)/2} + e^{-i(a-b)/2}\right)$$

Phase factor: $\exp i\left(\frac{a+b}{2}\right) = e^{-i\omega t}$

Group factor: $2\cos\left(\frac{a-b}{2}\right) = 2\cos(kx)$



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Dueling lasers make lab frame space-time grid (CW or PW)

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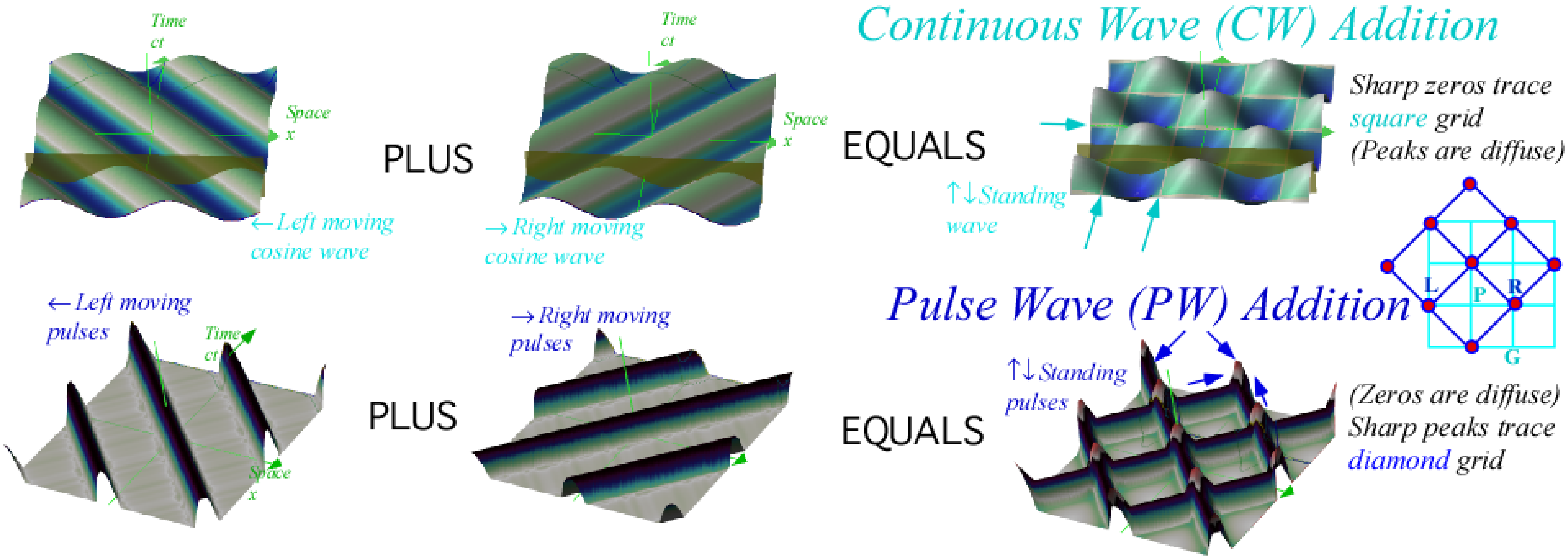
http://www.uark.edu/ua/pirelli/php/waves_interfering_montage.php

Newton's "Fits" in Optical Interference

Newton complained that light waves have *"fits"* (what we now know as wave *interference* or *resonance*.)
Examples of interference are head-on collision of two *Continuous Waves (2-CW)* or two *Pulse Waves (PW)*



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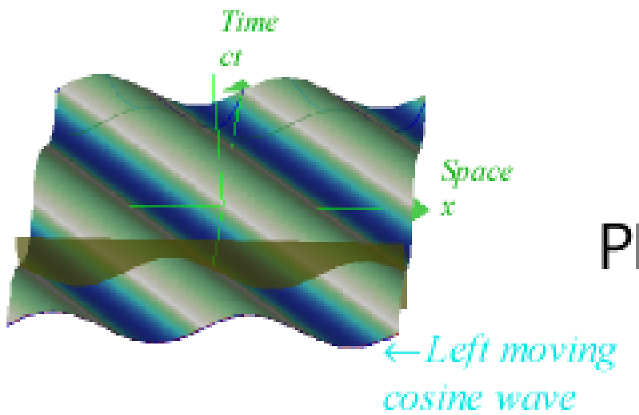
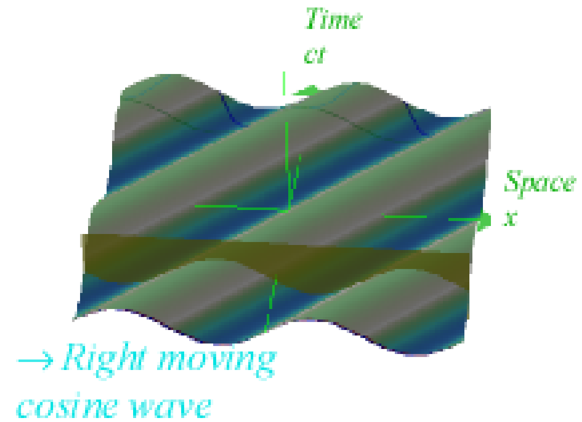
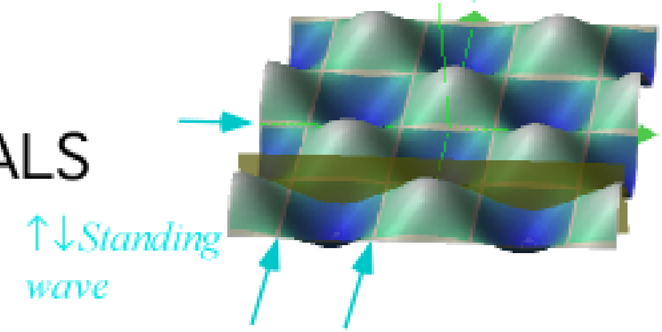
Continuous Wave (CW) Addition



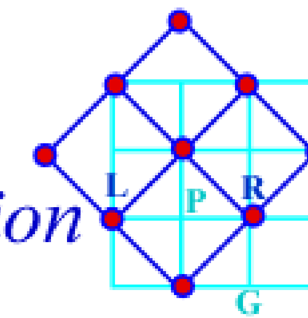
PLUS



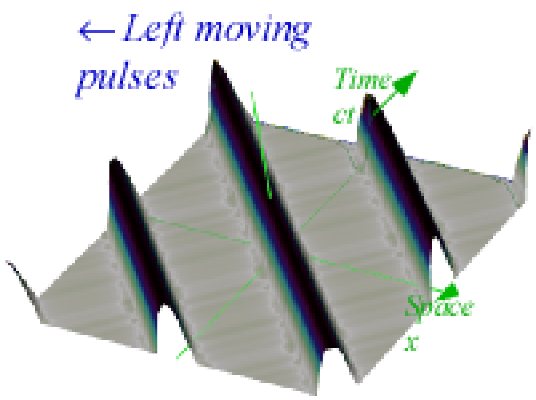
EQUALS



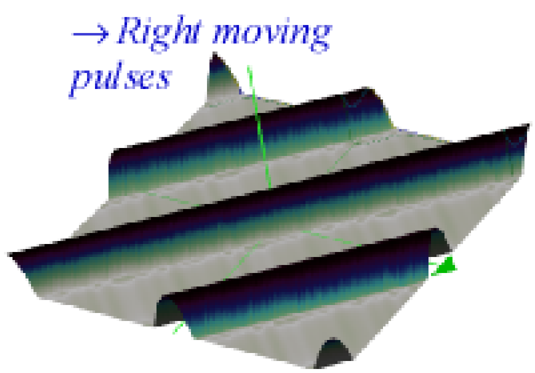
Sharp zeros trace square grid (Peaks are diffuse)



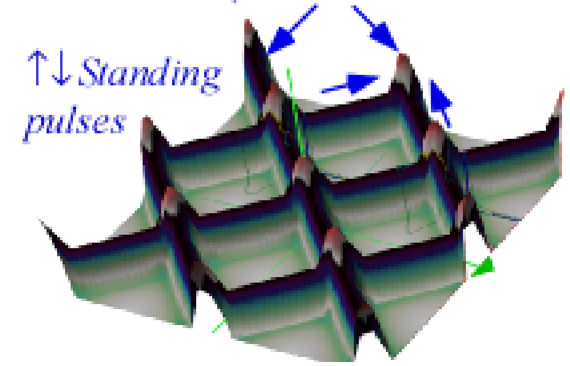
Pulse Wave (PW) Addition



PLUS



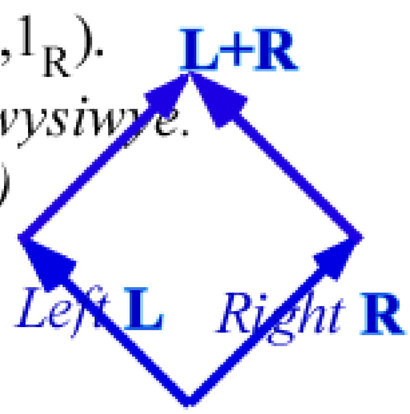
EQUALS



(Zeros are diffuse) Sharp peaks trace diamond grid

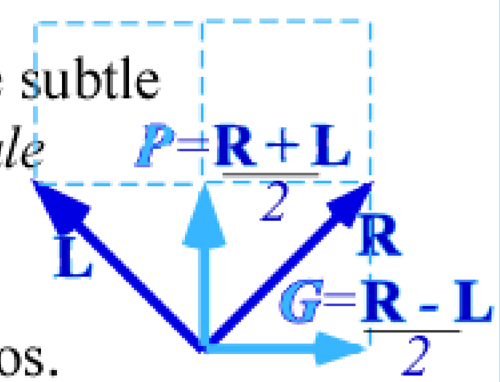
Pulse Wave (PW) sum compared with

- *PW* waves are OFF (0) or ON (1)
- *PW* sum is Boolean $(0_L,0_R),(0_L,1_R),(1_L,0_R),(1_L,1_R)$.
- *PW* time *peak-diamond* paths are *wysiwye.* *(What you see is what you expect!)*



Continuous Wave (CW) sum

- *CW* waves range continously from -1 to +1
- *CW* sum is more subtle and nuanced *interference*.
- *CW* time *zero-square* paths are subtle results of the *half-sum* ***P****-rule* and the *half-difference* ***G****-rule* of *phase* ***P*** and *group* ***G*** zeros.



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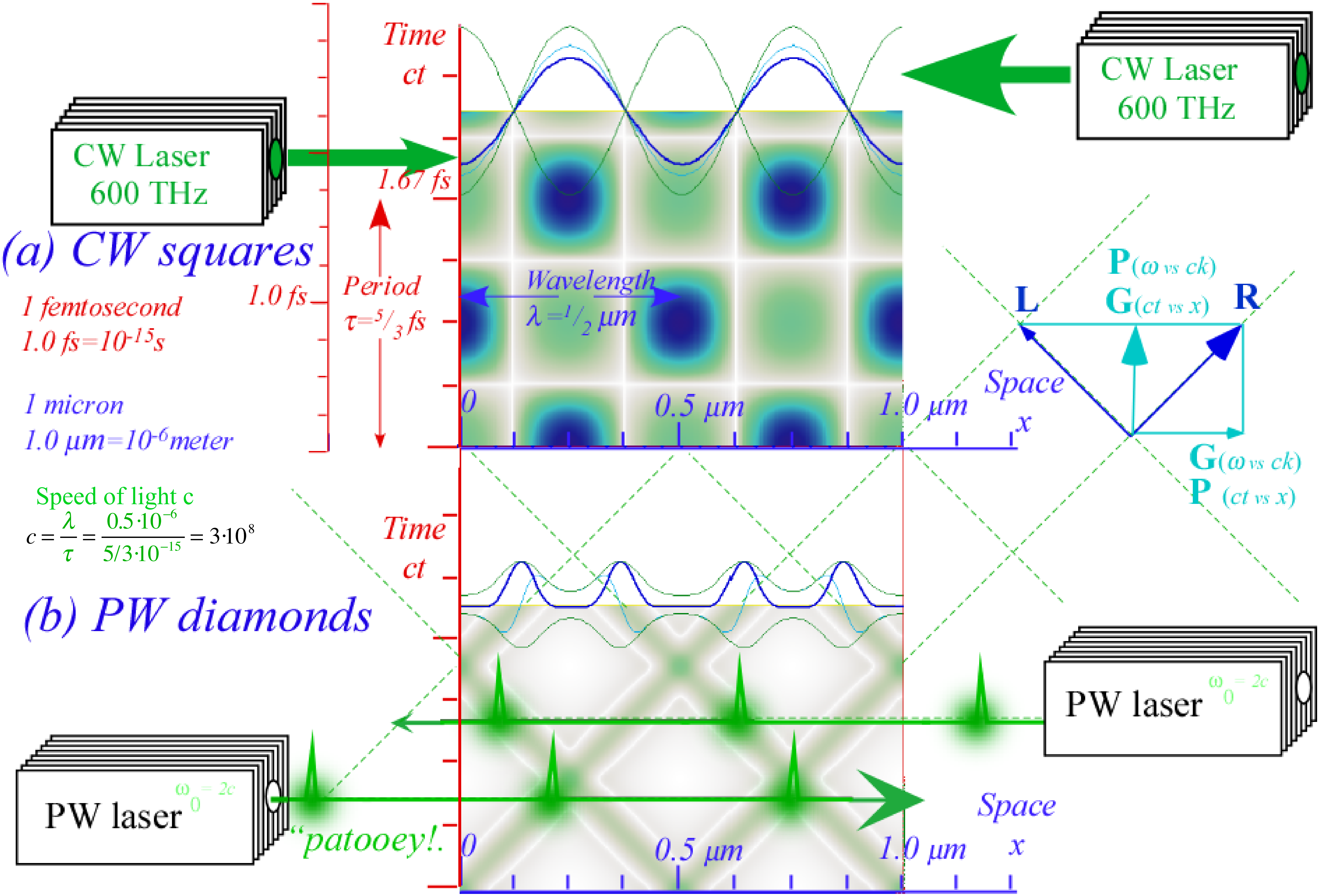

CW Laser
600 THz
CW Laser
600 THz
Time
ct
1.67 fs
(a) CW squares
1.0 fs
Period
τ=5/3 fs
Wavelength
λ=1/2 μm
1 femtosecond
1.0 fs=10-15s
1 micron
1.0 μm=10-6meter
0
0.5 μm
1.0 μm
Space
x
P(ω vs ck)
G(ct vs x)
L
R
G(ω vs ck)
P (ct vs x)
Speed of light c
c = λ/τ = 0.5·10−6 / 5/3·10−15 = 3·108
Time
ct
(b) PW diamonds
PW laser
ω0 = 2c
PW laser
ω0 = 2c
"patooey!.
0
0.5 μm
1.0 μm
Space
x

Light waves are the lead actors in our portrayal of *relativity* and *quantum theory*.

This differs from standard treatments following Einstein's original works that are based more on Newtonian notions of *particles, bodies,* and *rigid frames*.

Light, which Newton also regarded as fundamentally *corpuscular* (*particle*-like), had by the late 1800's been shown to have a fundamental *wave nature* due to work of (among others) Young, Huygens, and most notably, Maxwell.

Then one of Einstein's 1905 works, following Planck's 1900 hypothesis of *light quanta*, showed that light also had to have a *particle-like* nature.

?? ??

Wave-particle duality may be understood by looking at *interference properties* of *waves in general* and how that applies *in particular* to *light waves*.

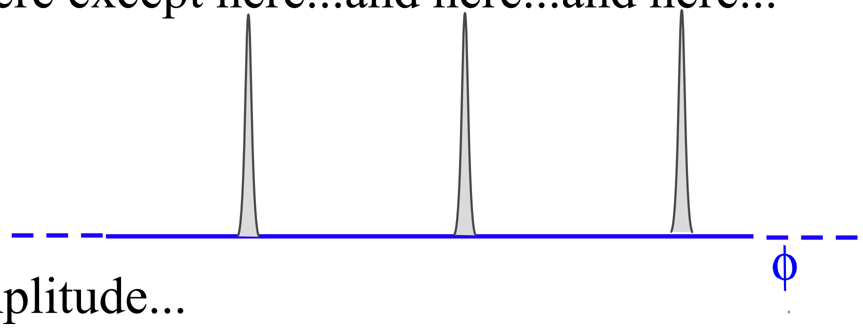
Relativity and *quantum mechanics* are practically the same subject when viewed in the light of wave *interference/resonance*, that is, *light wave addition*.

It helps to introduce two *archetypes* of light waves and contrast them.

The first *(PW)* is a *Particle-like Wave* or part of a *Pulse-Wave* train.
The second *(CW)* is a *Coherent Wave* or part of a *Continuous-Wave* train.

(1) The PW archetype

PW amplitude is *ZERO*
everywhere except here...and here...and here...



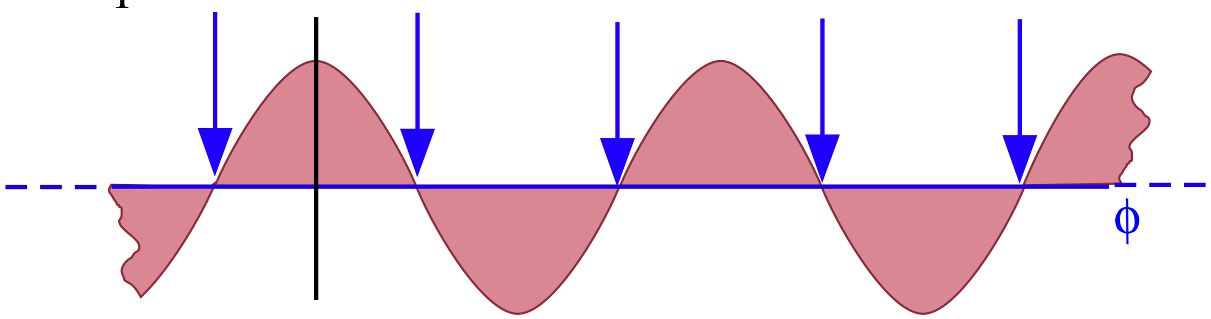
PW amplitude...
...is mostly flat *ZEROS*.
...but has sharp *PEAKS*.
...is best defined by where it *IS*.

Ideal *PW* shape is a *Dirac Delta function*.

(Discussed on next page)

(2) The CW archetype

CW amplitude is *NON-zero*
everywhere except here...and here...and here...and here...



...is mostly *NON-zero* with rounded crests and troughs.
...but has sharp *ZEROS*.
...is best defined by where it *IS NOT*.

Ideal *CW* shape is a *cosine wave (cos(ϕ))*

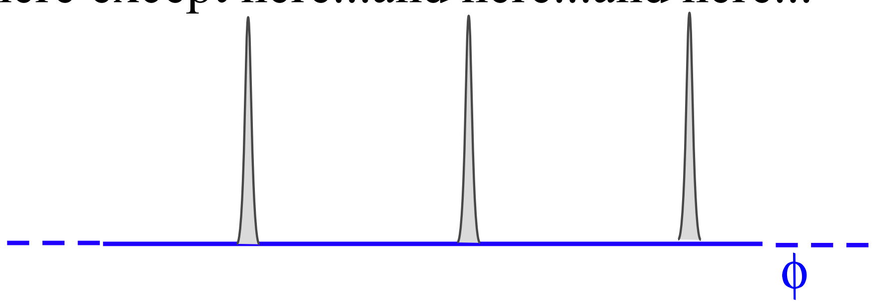
(Discussed on next page)

...continuing to contrast two light wave *archetypes*:

PW Pulse-Wave trains *versus* *CW Continuous-Wave* trains.

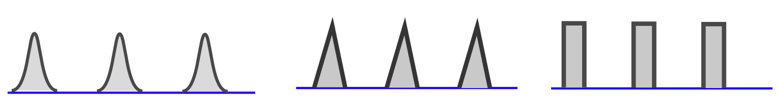
(1) The PW archetype

PW amplitude is *ZERO*
everywhere except here...and here...and here...



Ideal *PW* shape is the *Dirac Delta function* δ(ϕ)...
infinitely high at one point and zero elsewhere!
(Definition: $\delta(\phi)=\infty$ if $\phi=0$ else $\delta(\phi)=0$) Also,
its area is one! ($\int d\phi\, \delta(\phi)=1$) This mathematical
definition is not attainable in a laser lab.
(An infinite pulse uses all the energy in the universe!)

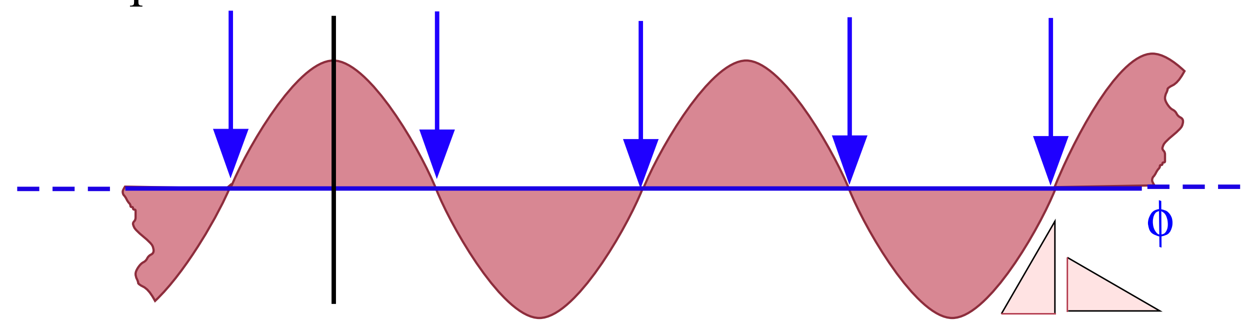
Real laser lab *PW* shape varies a lot...
...Gaussian? ...sawtooth?...square?...etc.



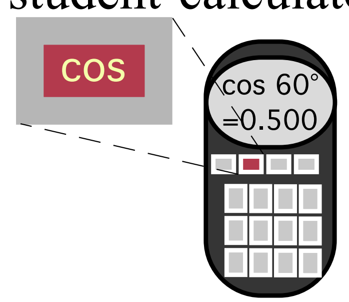
Quite a variety of shapes.
(A jungle of possibilities!)

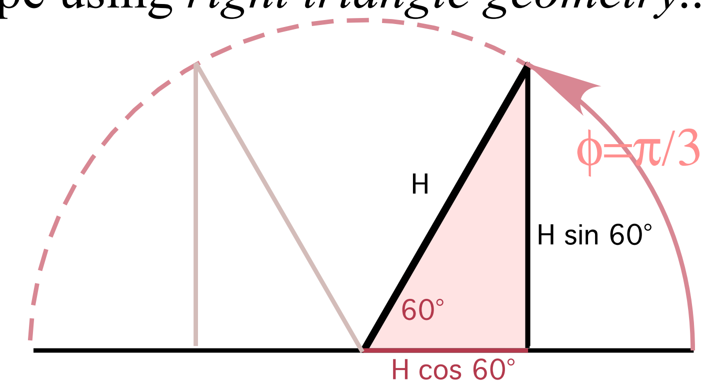
(2) The CW archetype

CW amplitude is *NON-zero*
everywhere except here...and here...and here...and here...



Ideal *CW cosine wave (cos(ϕ))* shape using *right triangle geometry*...
is found in student-calculators,



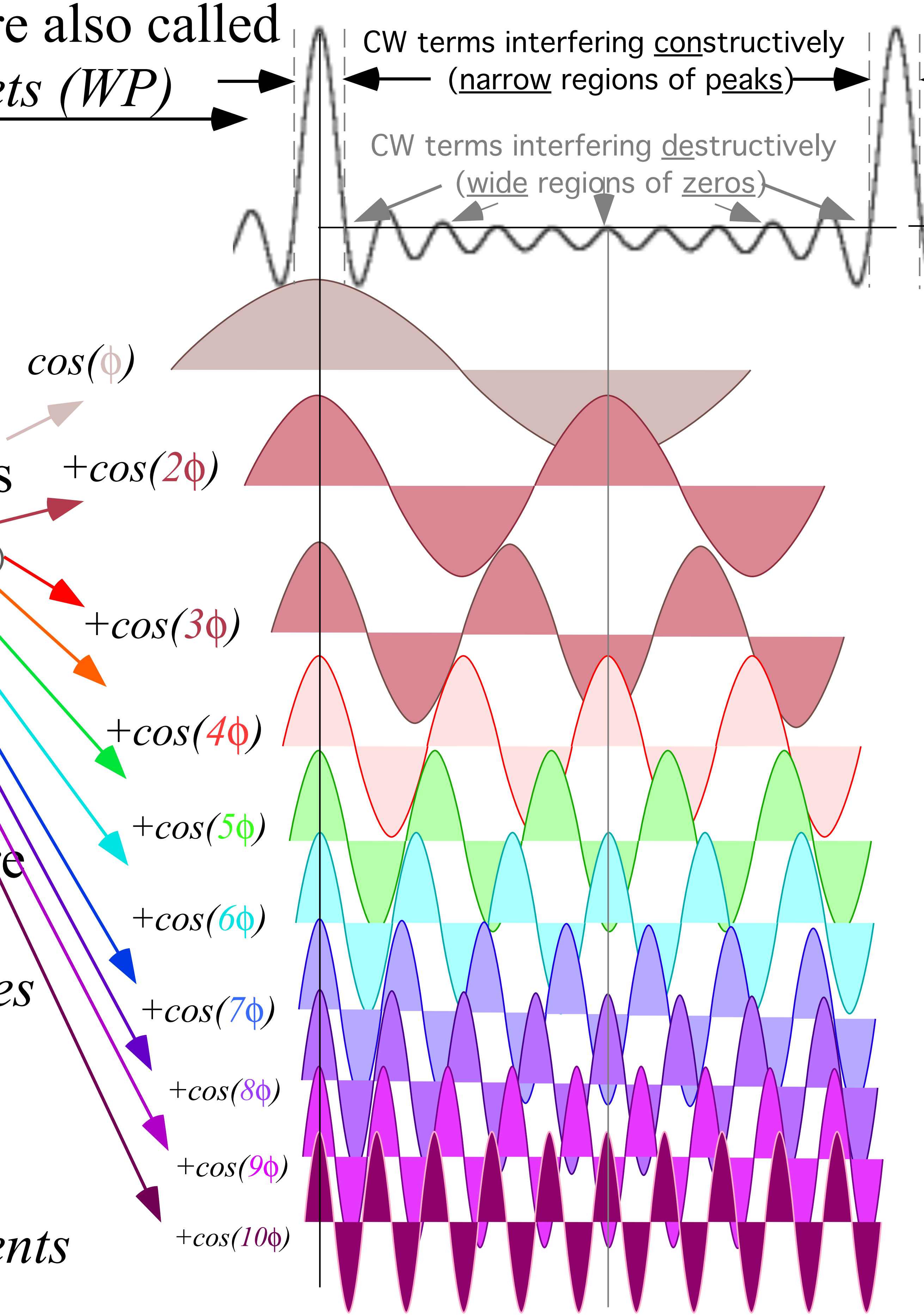


Real laser lab *CW* shape is very nearly a *cosine wave* and can be
tuned precisely to any *frequency* (or *color* if it's in *visible* spectrum)

versus

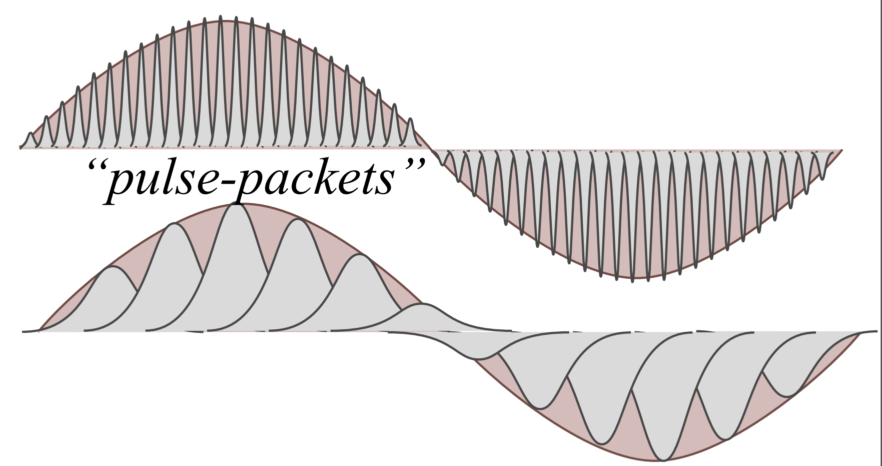
All the same shape.
(Differing only in *frequency*, amplitude, and *phase*)

PW forms are also called *Wave Packets (WP)* since they are interfering sums of many *CW* terms
(10-Cosine Waves make up this pulse)



CW terms are also called *Color Waves* or *Fourier Spectral Components*

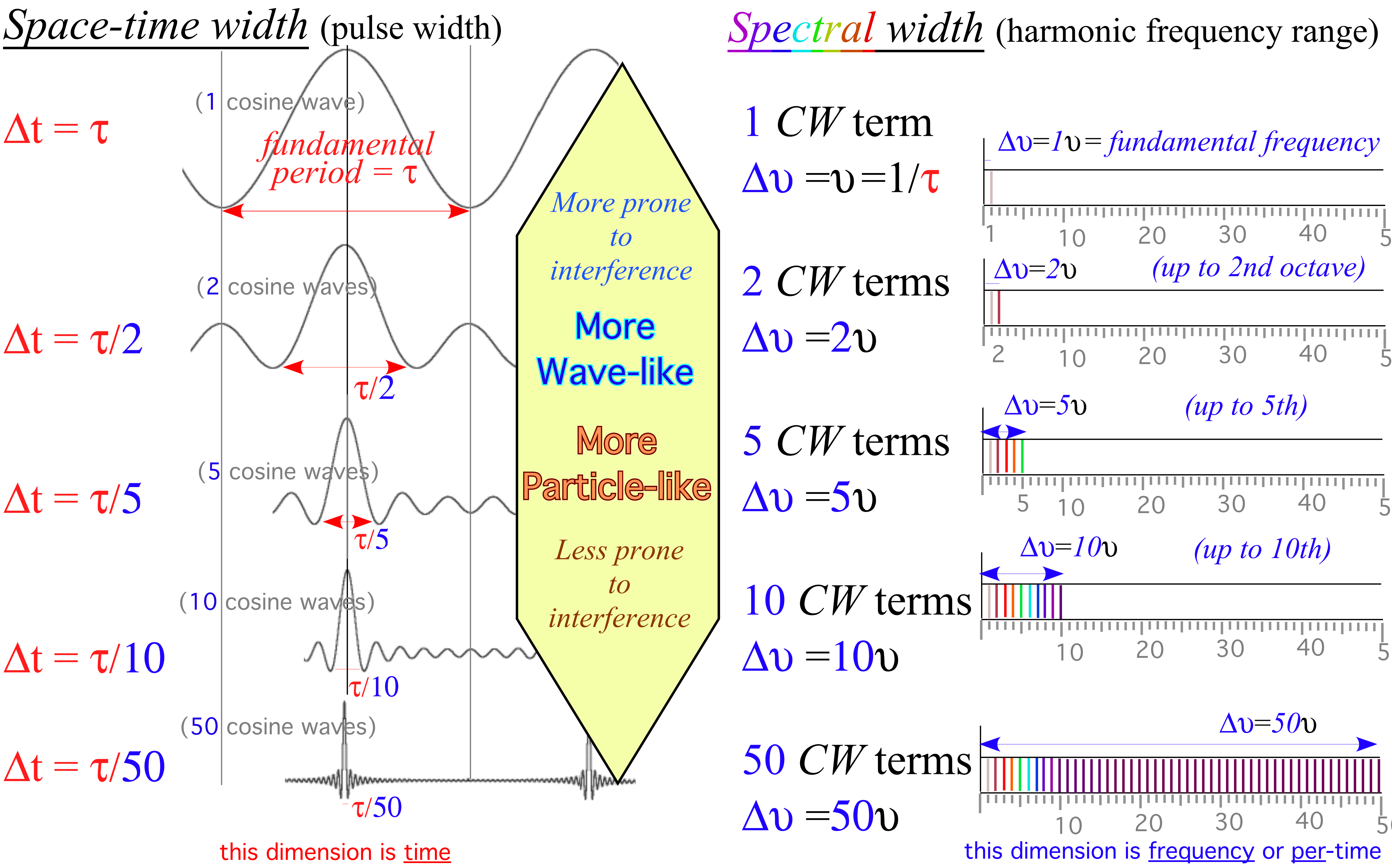
... and *vice-versa* ... *CW* forms can be made *artificially* from *PW* sums ...



(this is digital *sampling* or digital-to-analog *synthesis*.)

http://www.uark.edu/ua/pirelli/php/waves_pw_from_cw_anim.php

PW widths reduce proportionally with more *CW* terms (greater *Spectral* width)



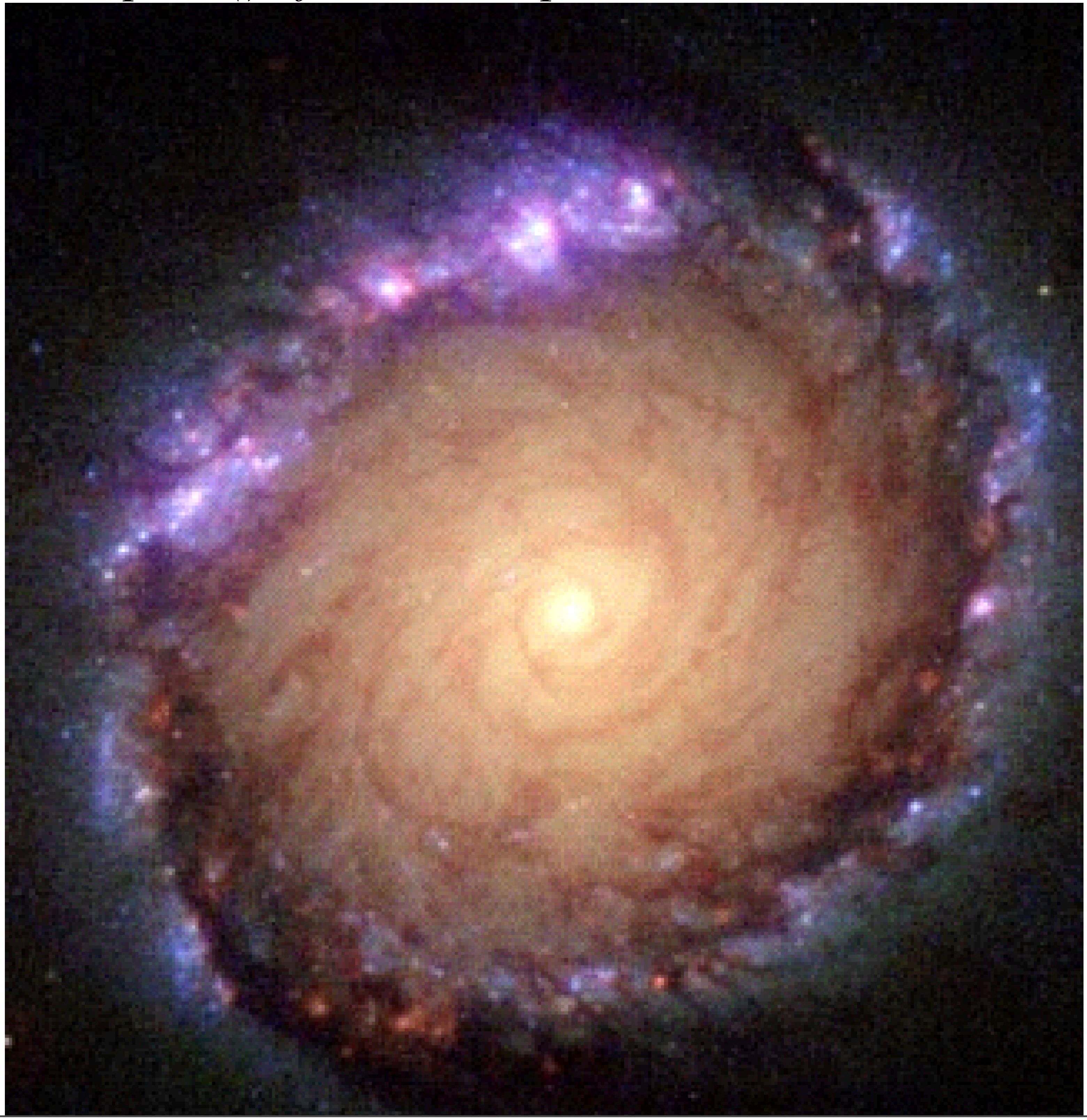
Fourier-Heisenberg product: $\Delta t \cdot \Delta \upsilon = 1$ (time-frequency uncertainty relation)

http://www.uark.edu/ua/pirelli/php/waves_pw_from_cw_width.php

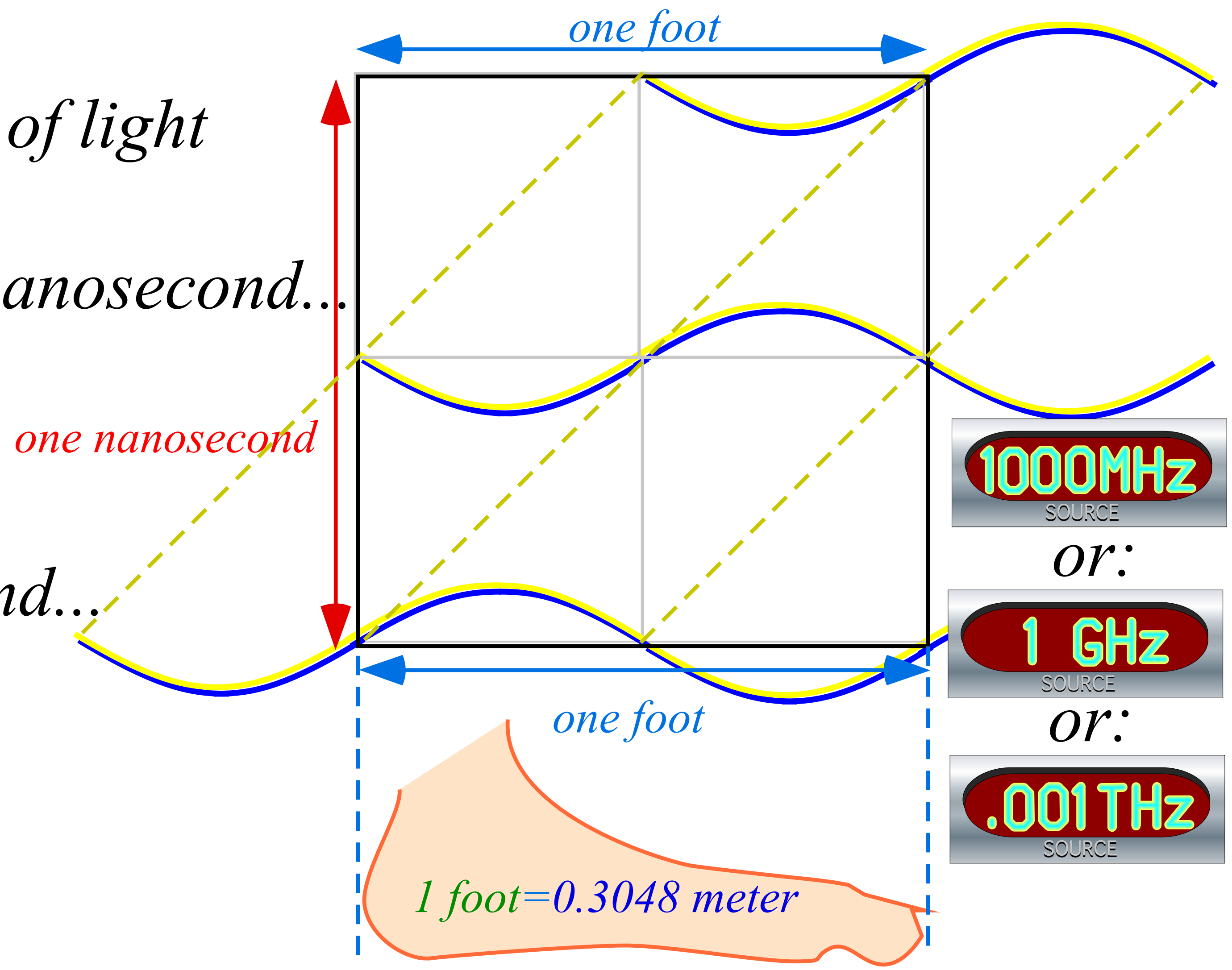
How fast is light? Light goes one foot in a nano-second .

This may seem quite fast to us.

But, on a cosmic scale lightspeed is positively sub-glacial. In your lifetime light cannot cross one pixel (.) of the Hubble photo below.



Ways to recall (roughly) the speed c of light



US-English units

Light travels ~one foot in one nanosecond...

1 foot ~1 light-nanosecond

...or~one billion feet in one second...

1 billion feet ~1 light-second

Metric units

Light travels ~$^{3}/_{10}$ of a meter in one nanosecond...

3/10 meter ~1 light-nanosecond

...or~3 hundred million meters in one second...

300,000,000 meters ~1 light-second

Current Standard c Value

K. M. Evenson - US NIST

c=299,792,458 meters/second

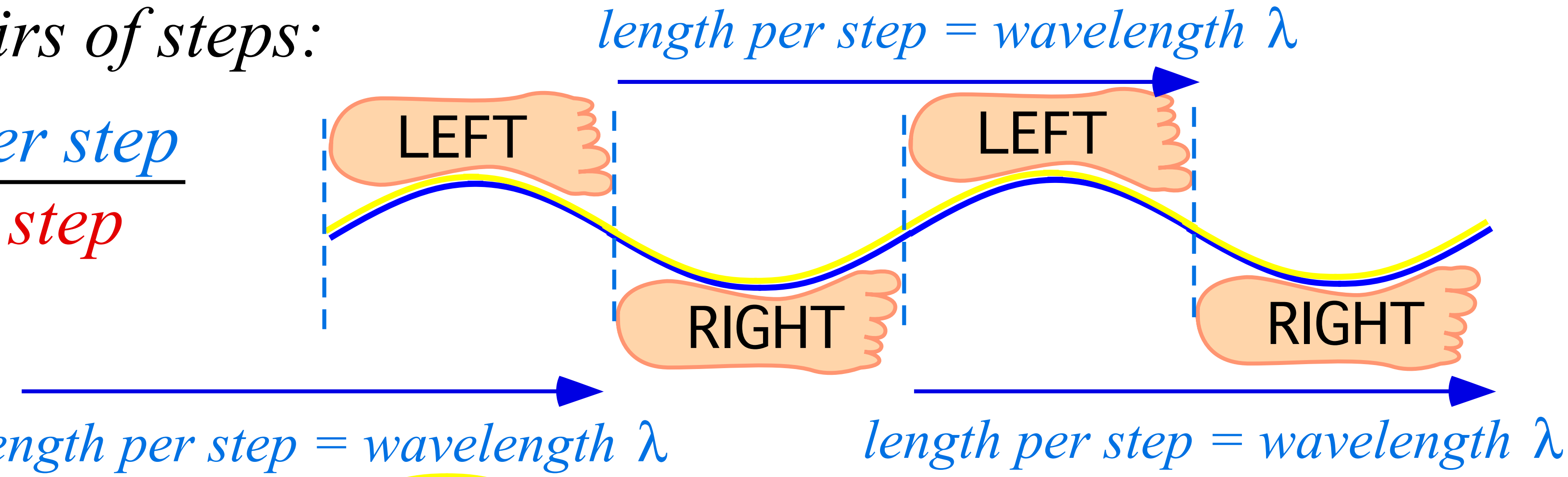
c=186,282.397 miles/second

http://www.uark.edu/ua/pirelli/php/lightspeed_memnonic.php

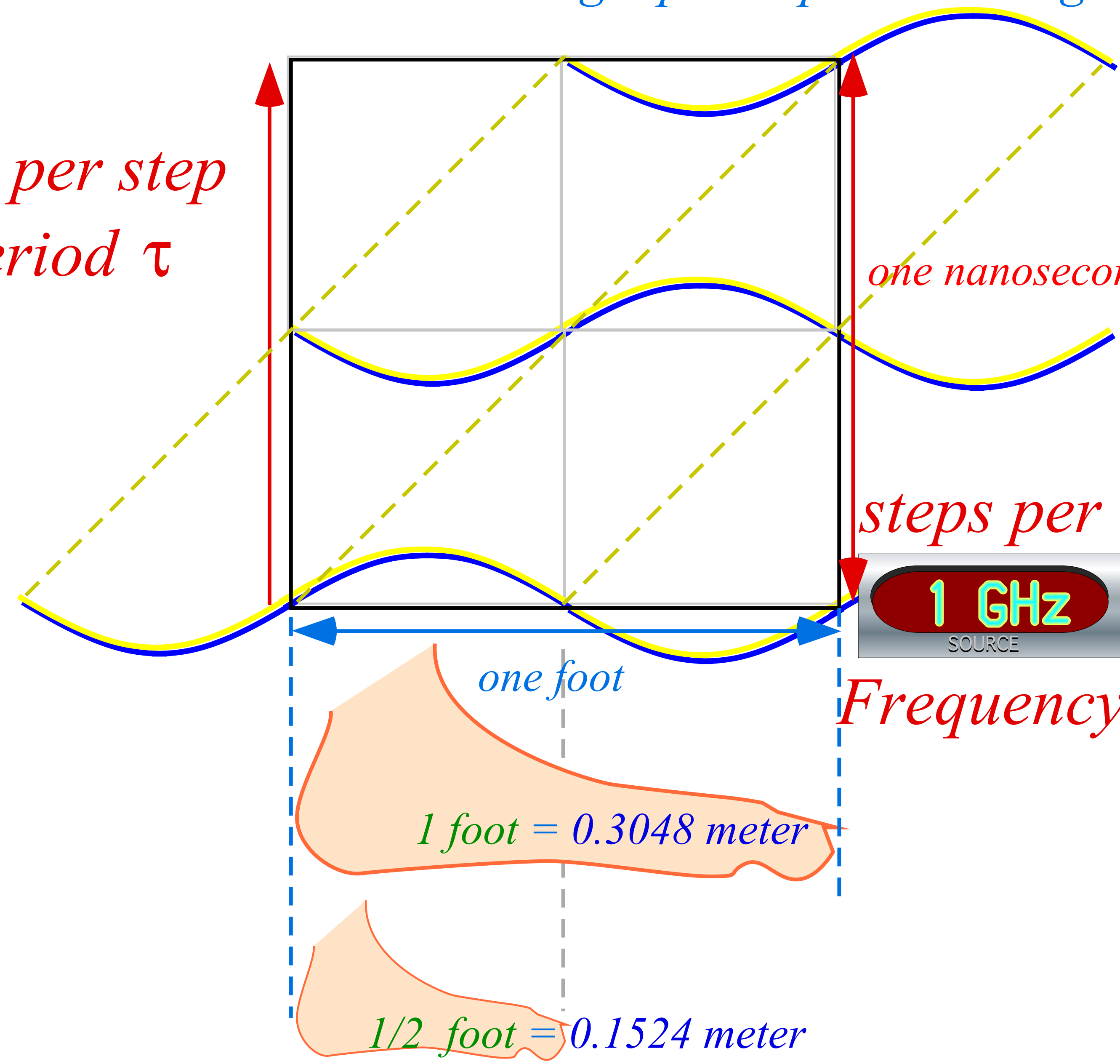
Think of light wave as pairs of steps:

Wave speed c is $\frac{\text{length per step}}{\text{time per step}}$

$$c = \frac{\lambda}{\tau}$$



time per step
= period τ



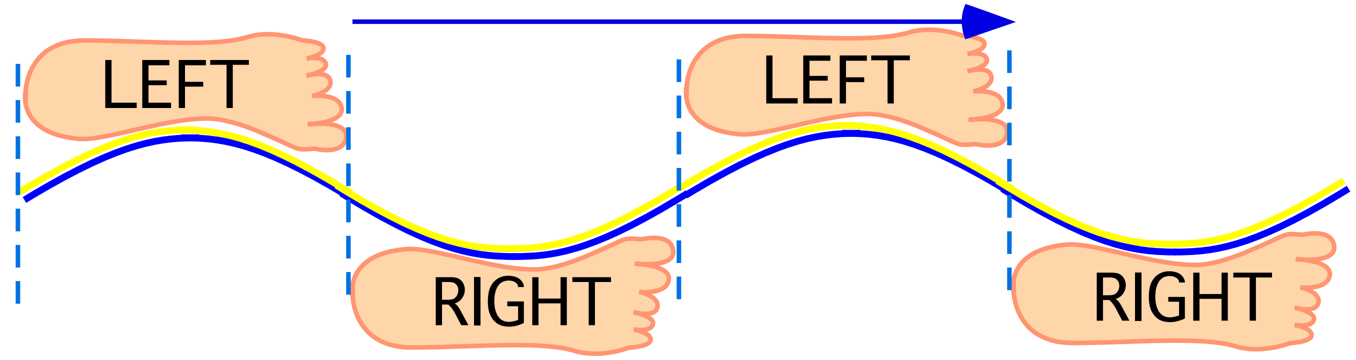
steps per time = Frequency $\upsilon = \frac{1}{\text{time per step}}$

Frequency $\upsilon = \frac{1}{\tau}$

http://www.uark.edu/ua/pirelli/php/wave_pair_steps.php

Light speed using per-space and per-time

meters per step = wavelength λ

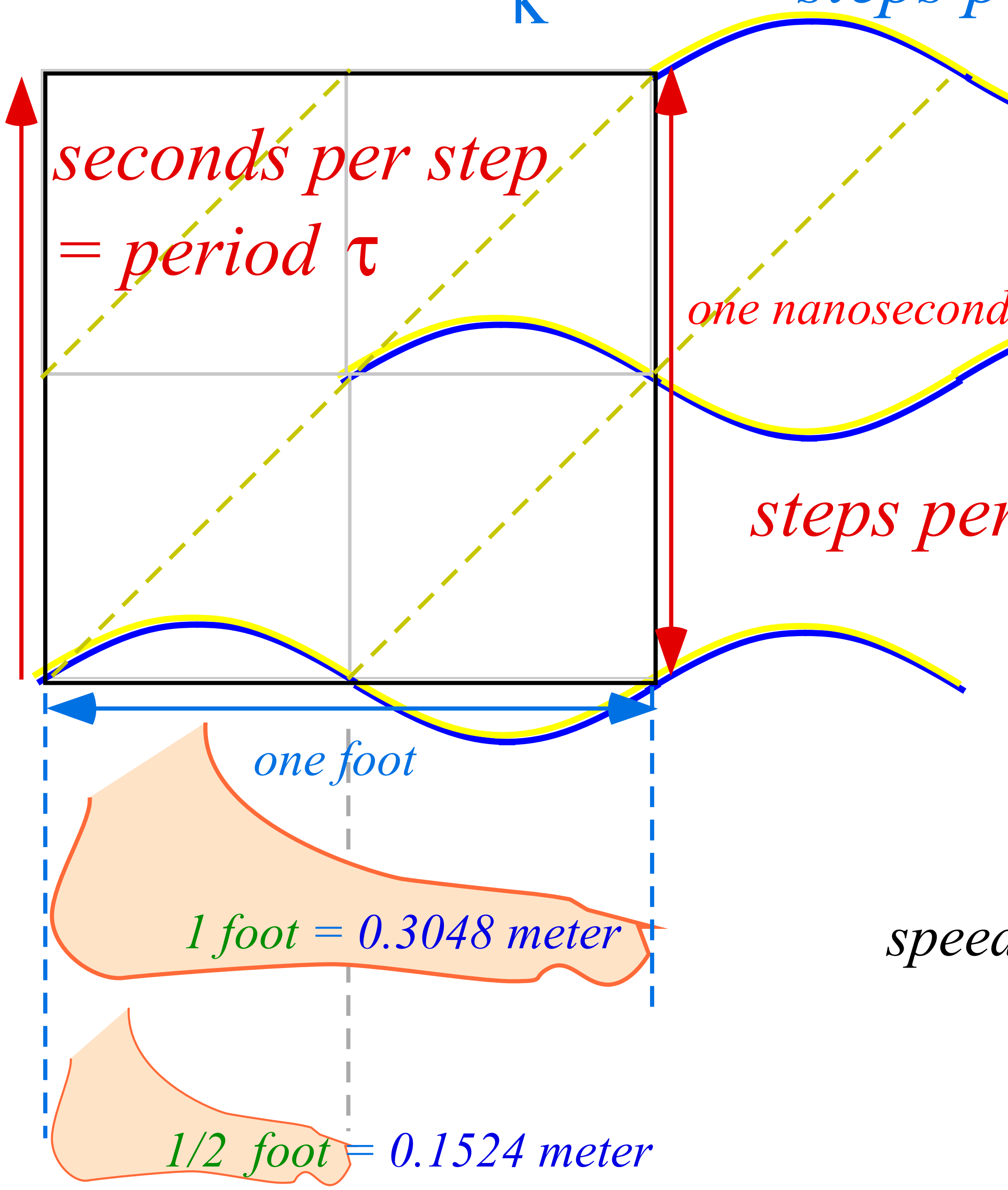


Wave speed c is $\dfrac{\text{steps per second}}{\text{steps per meter}}$

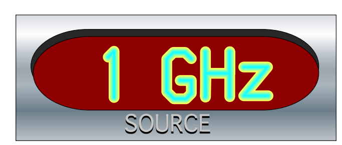
$$c = \frac{\upsilon}{\kappa}$$

steps per meter $=$ *Wave-number* $\kappa = \dfrac{1}{\text{meters per step}}$

Wave-number $\kappa = \dfrac{1}{\lambda}$



steps per second $=$ *Frequency* $\upsilon = \dfrac{1}{\text{seconds per step}}$

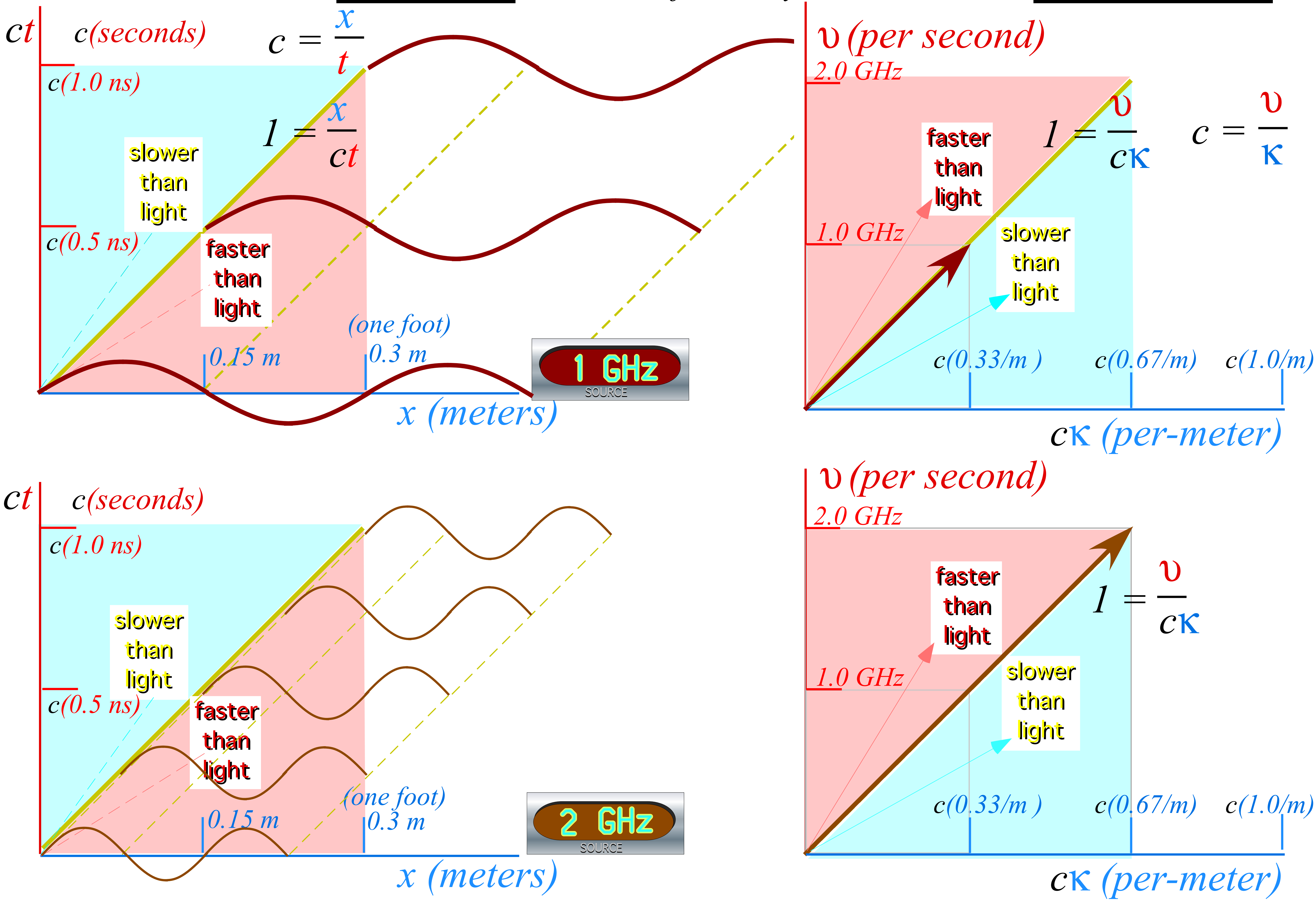


Frequency $\upsilon = \dfrac{1}{\tau}$

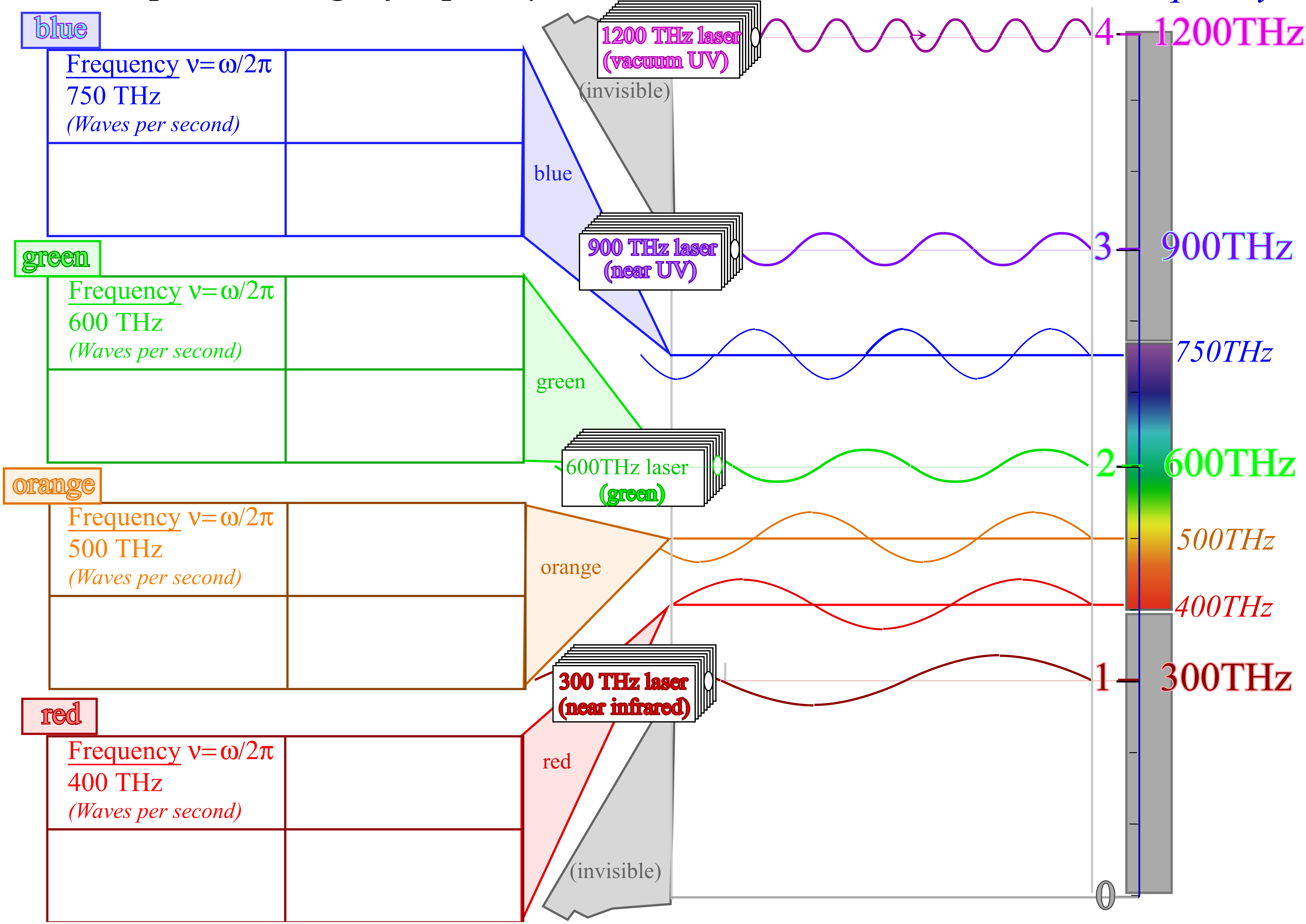
speed formulae:

$c = \dfrac{\upsilon}{\kappa}$	$c = \lambda \cdot \upsilon$	$c = \dfrac{\lambda}{\tau}$

Continuous Wave in **Spacetime** world defined by one vector in **Per-Spacetime**

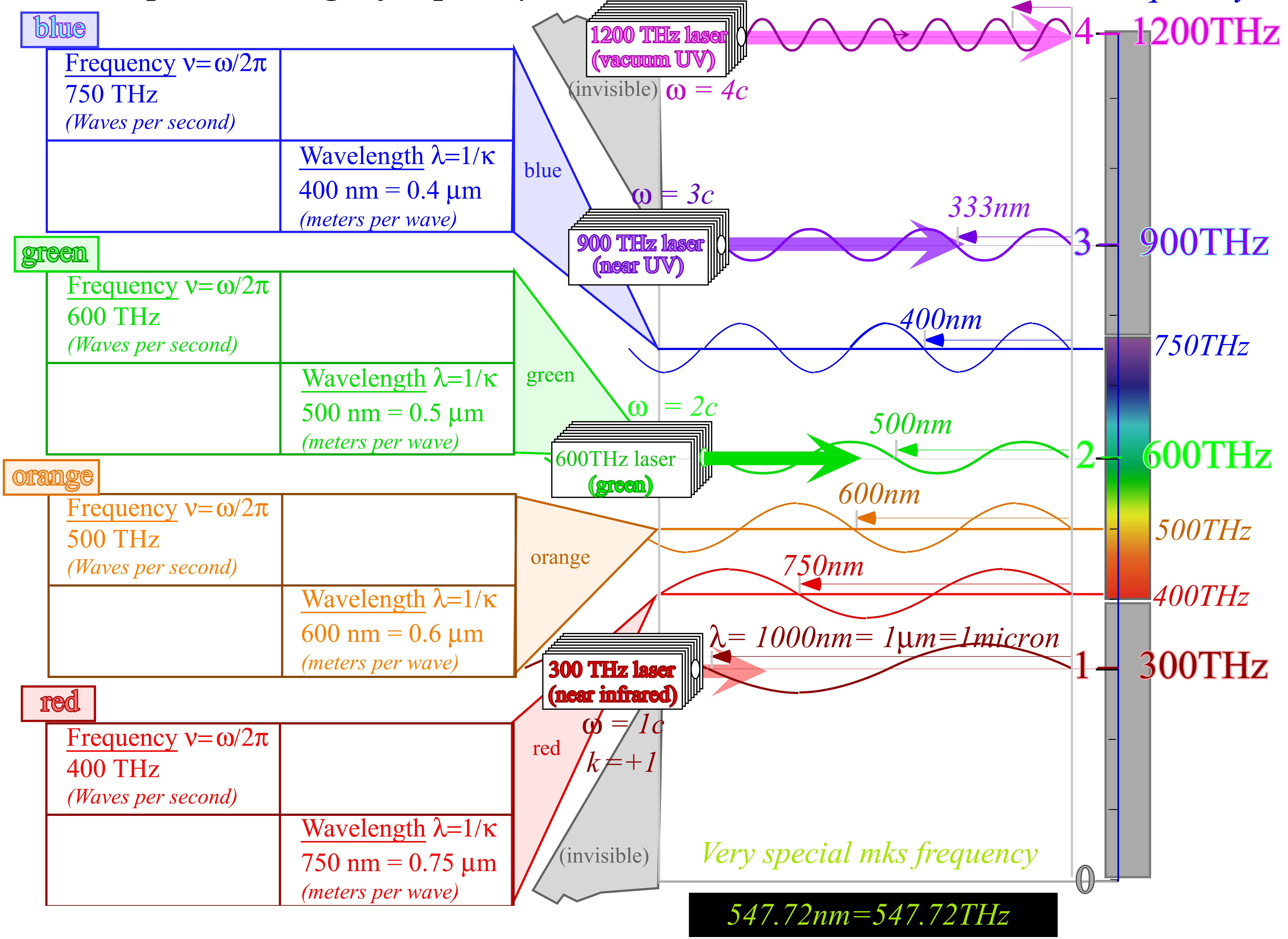


Color depends on light frequency ν ...



http://www.uark.edu/ua/pirelli/php/color_freq.php

Color depends on light frequency ν or wavelenth λ...



Color depends on light frequency ν or wavelenth λ...

blue

Wavespeed $c = \lambda \cdot \nu = \lambda/\tau = \nu/\kappa = \omega/k$	
Frequency $\nu = \omega/2\pi$ 750 THz *(Waves per meter)*	Wavenumber $\kappa = k/2\pi$ 2.5 Million/meter *(Waves per meter)*
Period $\tau = 1/\nu$ 1/(750 T)sec. *(Seconds per wave)*	Wavelength $\lambda = 1/\kappa$ 400 nm = 0.4 μm *(meters per wave)*

green

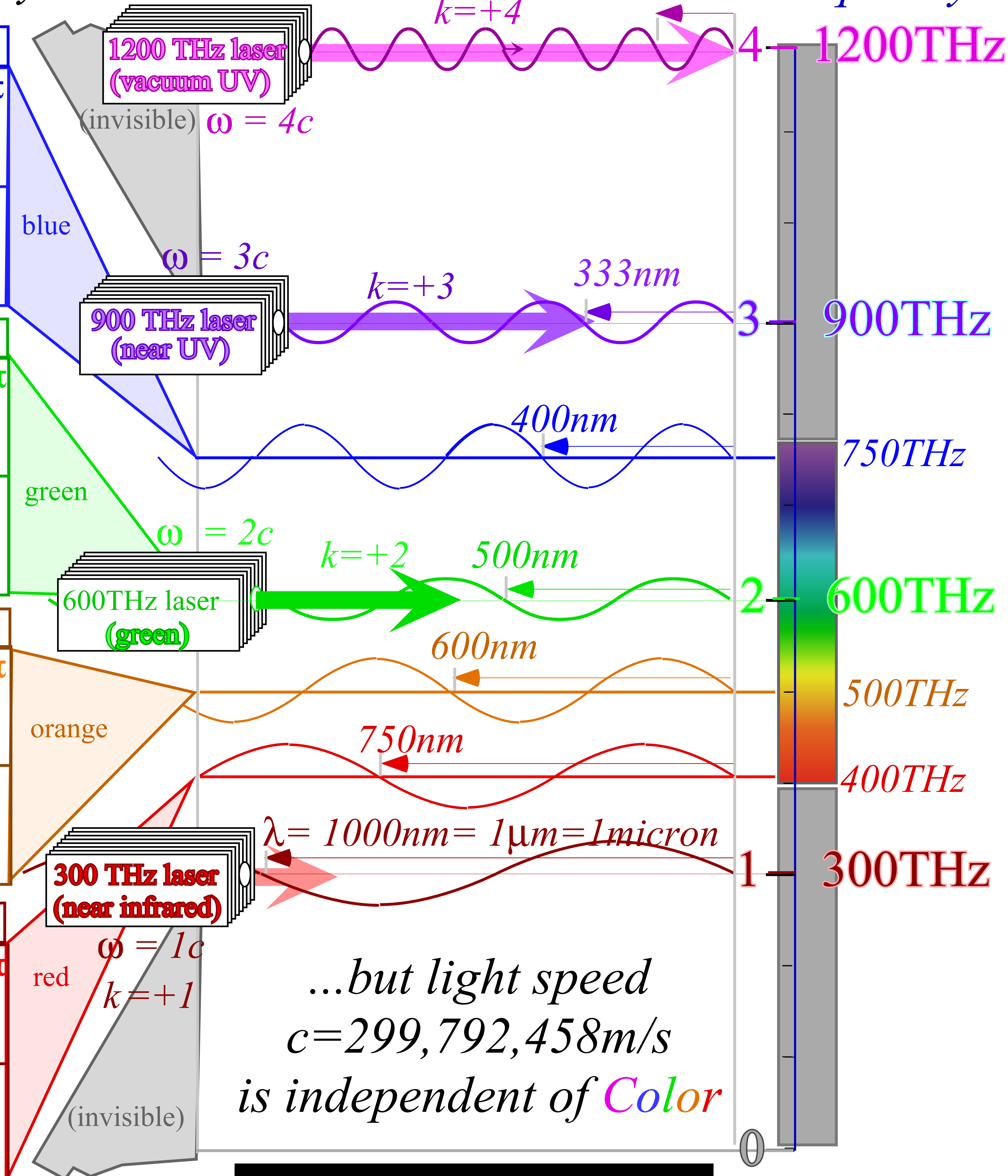
Wavespeed $c = \lambda \cdot \nu = \lambda/\tau = \nu/\kappa = \omega/k$	
Frequency $\nu = \omega/2\pi$ 600 THz *(Waves per second)*	Wavenumber $\kappa = k/2\pi$ 20,000/cm *(Waves per centimeter)*
Period $\tau = 1/\nu$ 1/(600 T)sec. *(Seconds per wave.)*	Wavelength $\lambda = 1/\kappa$ 500 nm = 0.5 μm *(meters per wave)*

orange

Wavespeed $c = \lambda \cdot \nu = \lambda/\tau = \nu/\kappa = \omega/k$	
Frequency $\nu = \omega/2\pi$ 500 THz *(Waves per second)*	Wavenumber $\kappa = k/2\pi$ 16,667/cm *(Waves per centimeter)*
Period $\tau = 1/\nu$ 1/(500 T)sec. *(Seconds per wave.)*	Wavelength $\lambda = 1/\kappa$ 600 nm = 0.6 μm *(meters per wave)*

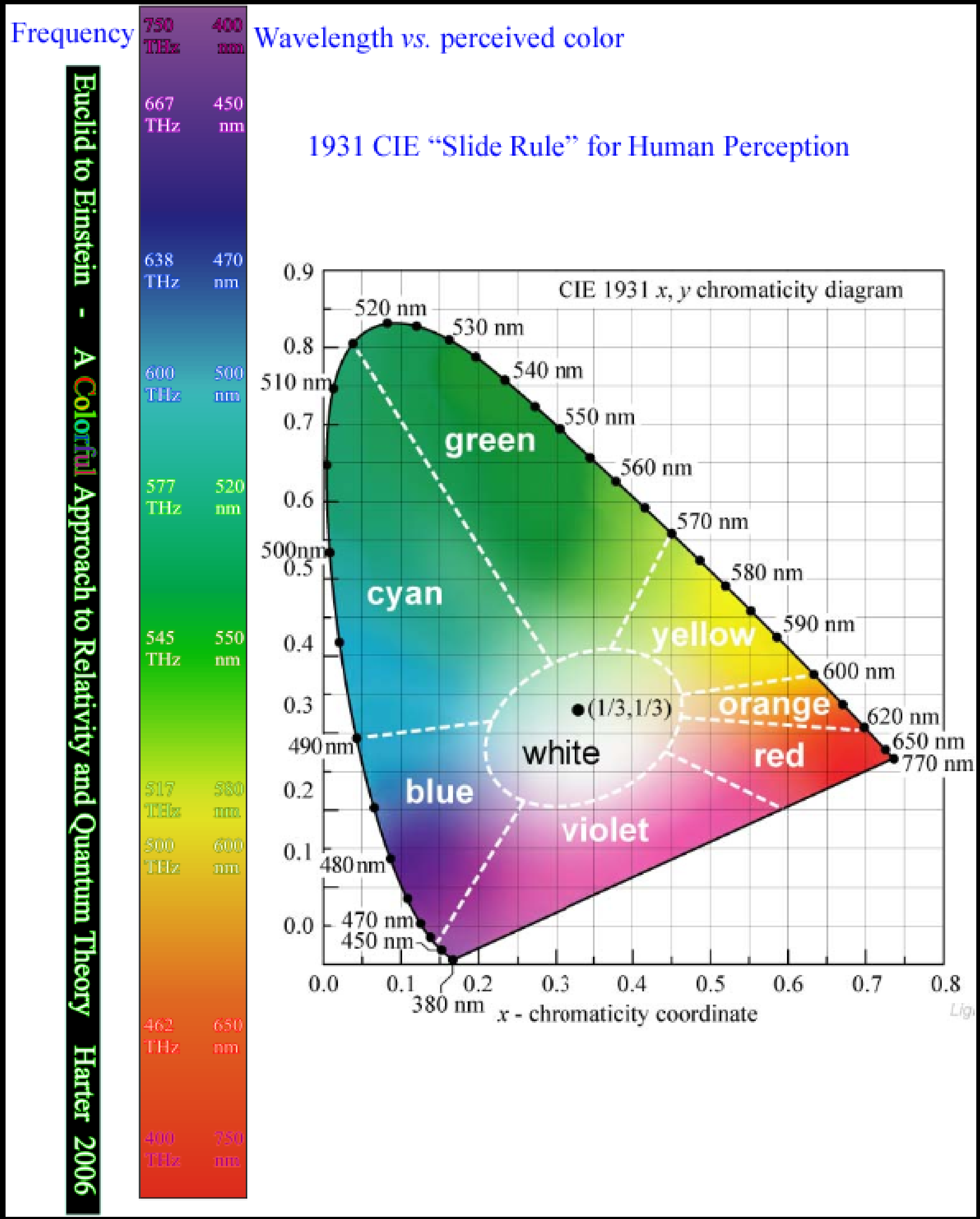
red

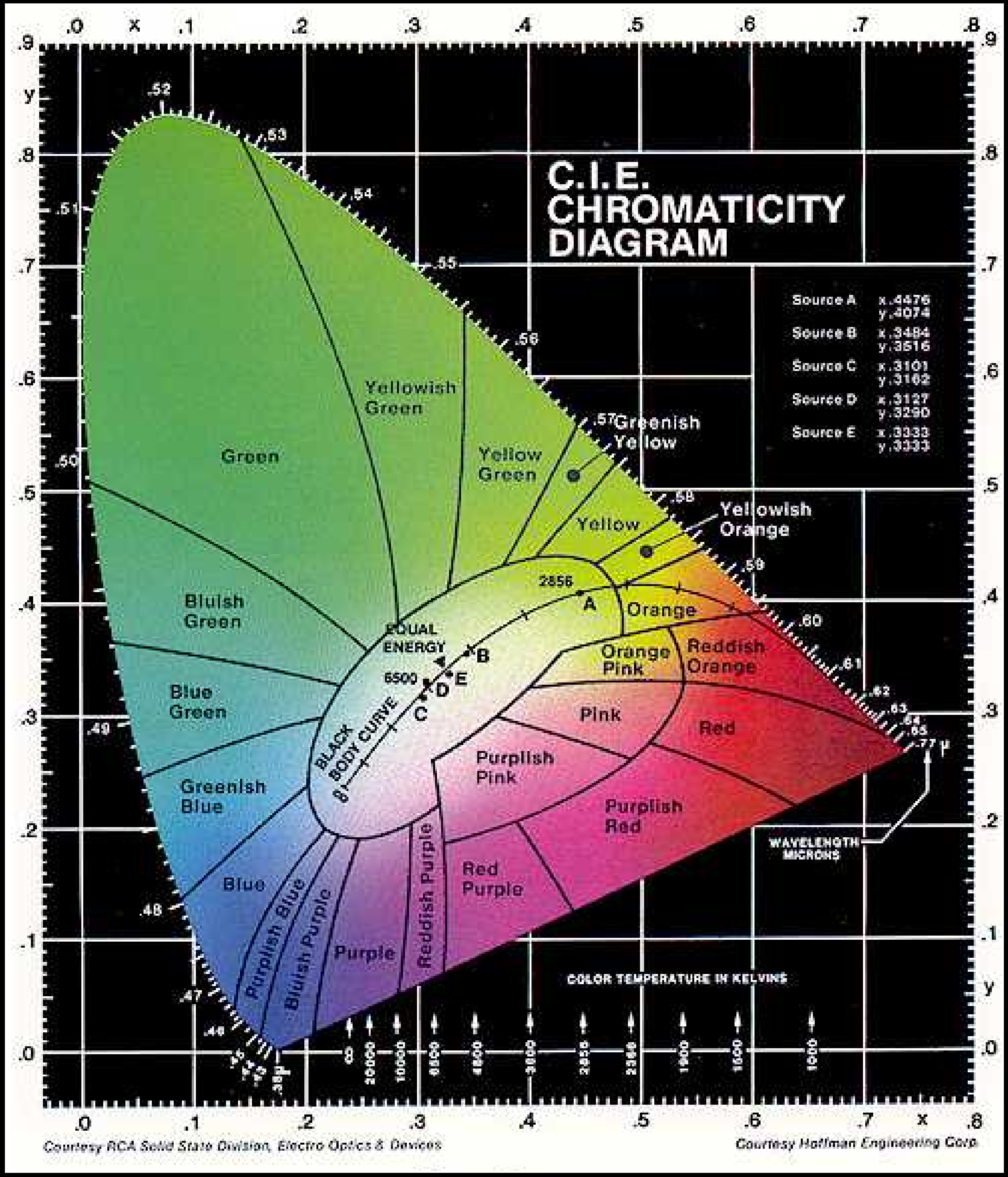
Wavespeed $c = \lambda \cdot \nu = \lambda/\tau = \nu/\kappa = \omega/k$	
Frequency $\nu = \omega/2\pi$ 400 THz *(Waves per second)*	Wavenumber $\kappa = k/2\pi$ 13,333/cm *(Waves per meter)*
Period $\tau = 1/\nu$ 1/(400 T)sec. *(Seconds per wave.)*	Wavelength $\lambda = 1/\kappa$ 750 nm = 0.75 μm *(meters per wave)*



...but light speed
c=299,792,458m/s
is independent of Color

547.72nm=547.72THz


Frequency
Wavelength vs. perceived color
Euclid to Einstein - A Colorful Approach to Relativity and Quantum Theory Harter 2006
750 THz 400 nm
667 THz 450 nm
638 THz 470 nm
600 THz 500 nm
577 THz 520 nm
545 THz 550 nm
517 THz 580 nm
500 THz 600 nm
462 THz 650 nm
400 THz 750 nm
1931 CIE "Slide Rule" for Human Perception
CIE 1931 x, y chromaticity diagram
520 nm
530 nm
540 nm
510 nm
550 nm
560 nm
570 nm
580 nm
590 nm
600 nm
620 nm
650 nm
770 nm
500nm
490 nm
480 nm
470 nm
450 nm
380 nm
green
cyan
yellow
orange
white
red
blue
violet
(1/3,1/3)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
x - chromaticity coordinate


C.I.E.
CHROMATICITY
DIAGRAM
Source A x .4476 y .4074
Source B x .3484 y .3516
Source C x .3101 y .3162
Source D x .3127 y .3290
Source E x .3333 y .3333
Green
Yellowish Green
Yellow Green
Greenish Yellow
Yellow
Yellowish Orange
Orange
Reddish Orange
Orange Pink
Pink
Red
Bluish Green
Blue Green
Greenish Blue
Blue
Purplish Blue
Bluish Purple
Purple
Reddish Purple
Red Purple
Purplish Red
Purplish Pink
EQUAL ENERGY
BLACK BODY CURVE
WAVELENGTH MICRONS
COLOR TEMPERATURE IN KELVINS
Courtesy RCA Solid State Division, Electro Optics & Devices
Courtesy Hoffman Engineering Corp.

2. Applying Occam's razor to relativity axioms

Einstein PW Axioms versus Evenson CW Axioms (Traditional: The "Roadrunner" Axiom)

CW light clearly shows Doppler shifts

Check that red is red is red,...green is green is green,...blue is blue is blue,... etc.

Is dispersion linear?... does astronomy work?... how about spectroscopy?

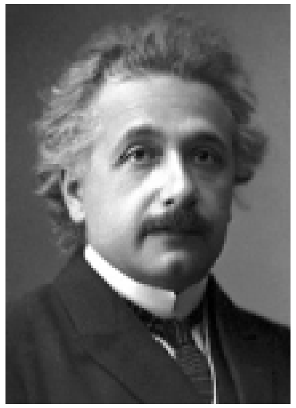
Is Doppler a geometric factor or arithmetic sum?

Introducing rapidity $\rho = \ln b$.

That old Time-Reversal meta-Axiom (that is so-oo-o neglected!)

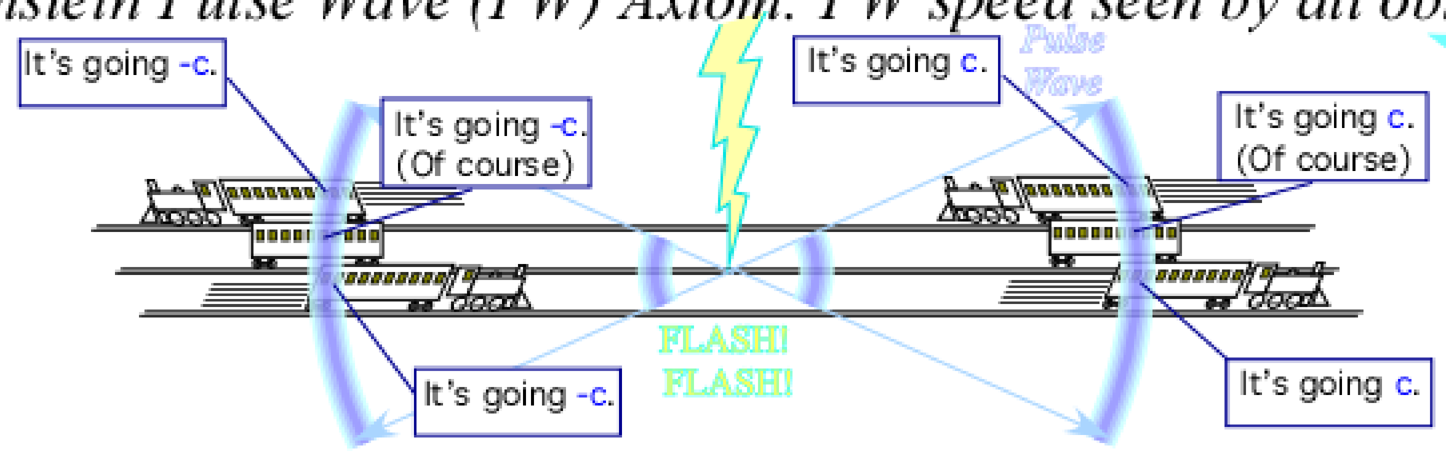
Tradition: Start with the "Roadrunner" Axiom!

Albert Einstein

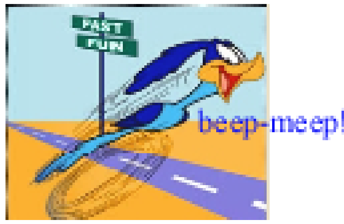


1879-1955

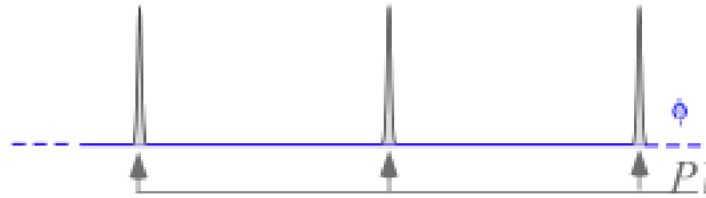
Einstein Pulse Wave (PW) Axiom: PW speed seen by all observers is c



A "road-runner" axiom is a "show-stopper"



Pulse wave (PW) train



$A_1\cos\omega t + A_2\cos 2\omega t + A_3\cos 3\omega t + A_4\cos 4\omega t + \ldots$

Complicated

PW peaks precisely locate places where wave is.

List 1-17 of Roadrunner Episodes Chuck Jones-Wikipedia-2012

#	Release date	Title	Duration	Credits		Pseudo-Latin names given		Acme Corporation devices used	Books Studied
				Story/writing	Direction	For the Road Runner	For the Coyote		
1	1949·9·17	*Fast and Furry-ous*	6:55	Michael Maltese	Chuck Jones	Acceleratii incredibus	Carnivorous vulgaris	ACME Super Outfit	
2	1952·5·24	*Beep, Beep*	6:45	Michael Maltese	Chuck Jones	Accelerati incredibilus	Carnivorous vulgaris	Asprin, Matches, Rocket-Powered Roller Skates	None
3	1952·8·23	*Going! Going! Gosh!*	6:25	Michael Maltese	Chuck Jones	Acceleratti incredibilis	Carnivorous vulgaris	an anvil, a weather balloon, a street cleaner's bin, and a fan	
4	1953·9·19	*Zipping Along*	6:55	Michael Maltese	Chuck Jones	Velocitus tremenjus	Road-Runnerus digestus	Giant Kite Kit, Bomb, Detonator, Nitroglycerin	
5	1954·8·14	*Stop! Look! And Hasten!*	7:00	Michael Maltese	Chuck Jones	Hot-roddicus supersonicus	Eatibus anythingus	Bird Seed, Triple Strength Fortified Leg Muscle Vitamins	"How to Build a Burmese Tiger Trap
6	1955·4·30	*Ready, Set, Zoom!*	6:55	Michael Maltese	Chuck Jones	Speedipus Rex	Famishus-Famishus	Glue	
7	1955·12·10	*Guided Muscle*	6:40	Michael Maltese	Chuck Jones	Velocitus delectiblus	Eatibus almost anythingus	ACME Grease	
8	1956·5·5	*Gee Whiz-z-z-z-z-z-z*	6:35	Michael Maltese	Chuck Jones	Delicius-delicius	Eatius birdius	ACME Triple Strength Battleship Steel Armor Plate, Rubber Band, Jet Bike	
9	1956·11·10	*There They Go-Go-Go!*	6:35	Michael Maltese	Chuck Jones	Dig-outius tid-bittius	Famishius fantasticus		
10	1957·1·26	*Scrambled Aches*	6:50	Michael Maltese	Chuck Jones	Tastyus supersonicus	Eternalii famishiis	ACME Dehydrated Boulders, Outboard Steam Roller	
11	1957·9·14	*Zoom and Bored*	6:15	Michael Maltese	Chuck Jones	Birdibus zippibus	Famishus vulgarus	ACME Bumblebees	
12	1958·4·12	*Whoa, Be-Gone!*	6:10	Michael Maltese	Chuck Jones	Birdius high-ballius	Famishius vulgaris ingeniusi	Tornado Seeds	
13	1958·10·11	*Hook, Line and Stinker*	5:55	Michael Maltese	Chuck Jones	Burnius-roadibus	Famishius-famishius		
14	1958·12·6	*Hip Hip-Hurry!*	6:13	Michael Maltese	Chuck Jones	digoutius-unbelieveablii	eatius-slobbius		
15	1959·5·9	*Hot-Rod and Reel!*	6:25	Michael Maltese	Chuck Jones	Super-sonicus-tastius	Famishius-famishius	Jet-Propelled Pogo Stick, Jet-Propelled Unicycle	None.
16	1959·10·10	*Wild About Hurry*	6:45	Michael Maltese	Chuck Jones	Batoutahelius	Hardheadipus oedipus	Giant Elastic Rubber Band, 5 Miles of Railroad Track, Rocket Sled, Bird Seed, Iron Pellets, Indestructo Steel Ball	None
17	1960·1·9	*Fastest with the Mostest*	7:20	None	Chuck Jones	Velocitus incalcublii	Carnivorous slobbius		

List 17-34 of Roadrunner Episodes
Chuck Jones-Wikipedia-2012

18	1960·10·8	*Hopalong Casualty*	6:05	Chuck Jones	Chuck Jones	speedipus-rex	Hard-headipus ravenus	Christmas Packaging Machine, Earthquake Pills
19	1961·1·21	*Zip 'N Snort*	5:50	Chuck Jones	Chuck Jones	digoutius-hot-rodis	evereadii eatibus	
20	1961·6·3	*Lickety-Splat*	6:20	Chuck Jones	Chuck Jones, Abe Levitow	Fastius tasty-us	Appetitius giganticus	Roller skis, dart bombs
21	1961·11·11	*Beep Prepared*	6:00	John Dunn, Chuck Jones	Chuck Jones, Maurice Noble	Tid-bittius velocitus	Hungrii flea-bagius	ACME Iron Bird Seed
Film	1962·6·2	*Adventures of the Road Runner*	26:00	John Dunn, Chuck Jones, Michael Maltese	Chuck Jones	Super-Sonnicus Idioticus	Desertous-operativus Idioticus	
22	1962·6·30	*Zoom at the Top*	6:30	Chuck Jones	Chuck Jones, Maurice Noble	disappearialis quickius	overconfidentii vulgaris	Bird seed, instant icicle-maker, boomerang
23	1963·12·28	*To Beep or Not to Beep*[1]	6:35	John Dunn, Chuck Jones	Chuck Jones, Maurice Noble	None	None	
24	1964·6·6	*War and Pieces*	6:40	John Dunn	Chuck Jones, Maurice Noble	Burn-em upus asphaltus	Caninus nervous rex	Invisible Paint
25	1965·1·1	*Zip Zip Hooray!*[2]	6:15	John Dunn	Chuck Jones	Super-Sonnicus Idioticus	None	
26	1965·2·1	*Road Runner a Go-Go*[2]	6:05	John Dunn	Chuck Jones	None	None	None
27	1965·2·27	*The Wild Chase*	6:30	None	Friz Freleng, Hawley Pratt	None	None	
28	1965·7·31	*Rushing Roulette*	6:20	David Detiege	Robert McKimson	None	None	
29	1965·8·21	*Run, Run, Sweet Road Runner*	6:00	Rudy Larriva	Rudy Larriva	None	None	
30	1965·9·18	*Tired and Feathered*	6:20	Rudy Larriva	Rudy Larriva	None	None	
31	1965·10·9	*Boulder Wham!*	6:30	Len Janson	Rudy Larriva	None	None	Deluxe Hi-bounce Trampoline Kit
32	1965·10·30	*Just Plane Beep*	6:45	Don Jurwich	Rudy Larriva	None	None	War Surplus Biplane
33	1965·11·13	*Hairied and Hurried*	6:45	Nick Bennion	Rudy Larriva	None	None	Snow Machine, Magnetic Gun, Practice Bombs, Super Bomb, Kit
34	1965·12·11	*Highway Runnery*	6:45	Al Bertino	Rudy Larriva	None	None	

35	1965·12·25	*Chaser on the Rocks*	6:45	Tom Dagenais	Rudy Larriva	None	None		
36	1966·1·8	*Shot and Bothered*	6:30	Nick Bennion	Rudy Larriva	None	None	Suction Cups	N
37	1966·1·29	*Out and Out Rout*	6:00	Dale Hale	Rudy Larriva	None	None	No ACME labeled devices used.	" H "
38	1966·2·19	*The Solid Tin Coyote*	6:15	Don Jurwich	Rudy Larriva	None	None		
39	1966·3·12	*Clippety Clobbered*	6:15	Tom Dagenais	Rudy Larriva	None	None		
40	1966·11·5	*Sugar and Spies*	6:20	Tom Dagenais	Robert McKimson	None	None	Do-it-Yourself Kit Remote Control Missile-Bombs	N
41	1979·11·27	*Freeze Frame*	6:05	John W. Dunn Chuck Jones	Chuck Jones	Semper food-ellus	Grotesques appetitus		
42	1980·5·21	*Soup or Sonic*	9:10	Chuck Jones	Chuck Jones, Phil Monroe	Ultra-sonicus ad infinitum	Nemesis ridiculii		
43	1994·12·21	*Chariots of Fur*[3]	7:00	Chuck Jones	Chuck Jones	Boulevardius-burnupius	Dogius ignoramii		
44	2000·12·30	*Little Go Beep*	7:55	Kathleen Helppie-Shipley, Earl Kress	Spike Brandt	Morselus babyfatius tastius	Poor schnookius		
45	2003·11·1	*The Whizzard of Ow*	7:00	Chris Kelly	Bret Haaland	*Geococcyx californianus*[4]	*Canis latrans*[4]	Book of Magic, Flying Broom, Bomb, Clear Paint	" N
Film	2003·11·14	*Looney Tunes: Back in Action*	91:00	Larry Doyle	Joe Dante	None	Desertus operatus idioticus		
46	2010·7·30	*Coyote Falls*[3]	2:59	Tom Sheppard[10]	Matthew O'Callaghan	None	None	Bird Seed, Bungee Cord	N
47	2010·9·24	*Fur of Flying*[3]	3:03[11]	Tom Sheppard	Matthew O'Callaghan[11]	None	None	Bonnie Bike, Mega-Motor, Football Helmet, Ceiling Fan	N
48	2010·12·17	*Rabid Rider*[3]	3:07	Tom Sheppard	Matthew O'Callaghan	None	None	Hyper-Sonic Transport	N
49	TBA	*Untitled Wile E. Coyote and Road Runner Short Film*	5:38	Tom Sheppard	Matthew O'Callaghan	None	None		

2. Applying Occam's razor to relativity axioms

Einstein PW Axioms versus Evenson CW Axioms (Traditional: The "Roadrunner" Axiom)

CW light clearly shows Doppler shifts

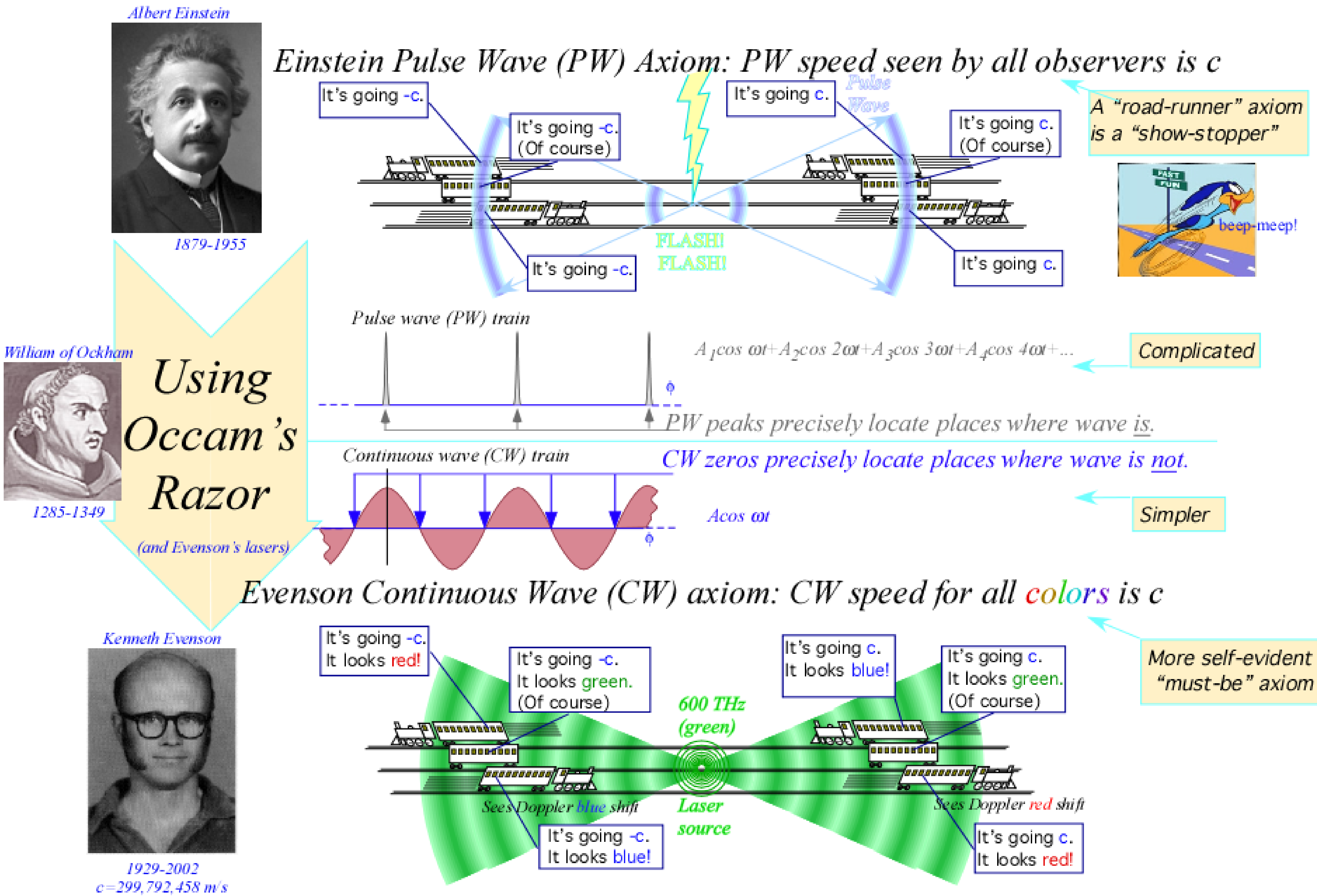
Check that red is red is red,...green is green is green,...blue is blue is blue,... etc.

Is dispersion linear?... does astronomy work?... how about spectroscopy?

Is Doppler a geometric factor or arithmetic sum?

Introducing rapidity $\rho = \ln b$.

That old Time-Reversal meta-Axiom (that is so-oo-o neglected!)


Albert Einstein
1879-1955
Einstein Pulse Wave (PW) Axiom: PW speed seen by all observers is c
It's going -c.
It's going -c.
(Of course)
It's going c.
Pulse Wave
It's going c.
(Of course)
A "road-runner" axiom is a "show-stopper"
beep-meep!
FLASH!
FLASH!
It's going -c.
It's going c.
Pulse wave (PW) train
$A_1 cos\ \omega t + A_2 cos\ 2\omega t + A_3 cos\ 3\omega t + A_4 cos\ 4\omega t + ...$
Complicated
William of Ockham
1285-1349
Using Occam's Razor
(and Evenson's lasers)
PW peaks precisely locate places where wave is.
Continuous wave (CW) train
CW zeros precisely locate places where wave is not.
$A cos\ \omega t$
Simpler
Evenson Continuous Wave (CW) axiom: CW speed for all colors is c
More self-evident "must-be" axiom
Kenneth Evenson
1929-2002
c=299,792,458 m/s
It's going -c.
It looks red!
It's going -c.
It looks green.
(Of course)
600 THz
(green)
It's going c.
It looks blue!
It's going c.
It looks green.
(Of course)
Sees Doppler blue shift
Laser source
Sees Doppler red shift
It's going -c.
It looks blue!
It's going c.
It looks red!

2. Applying Occam's razor to relativity axioms

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→ *CW light clearly shows Doppler shifts*

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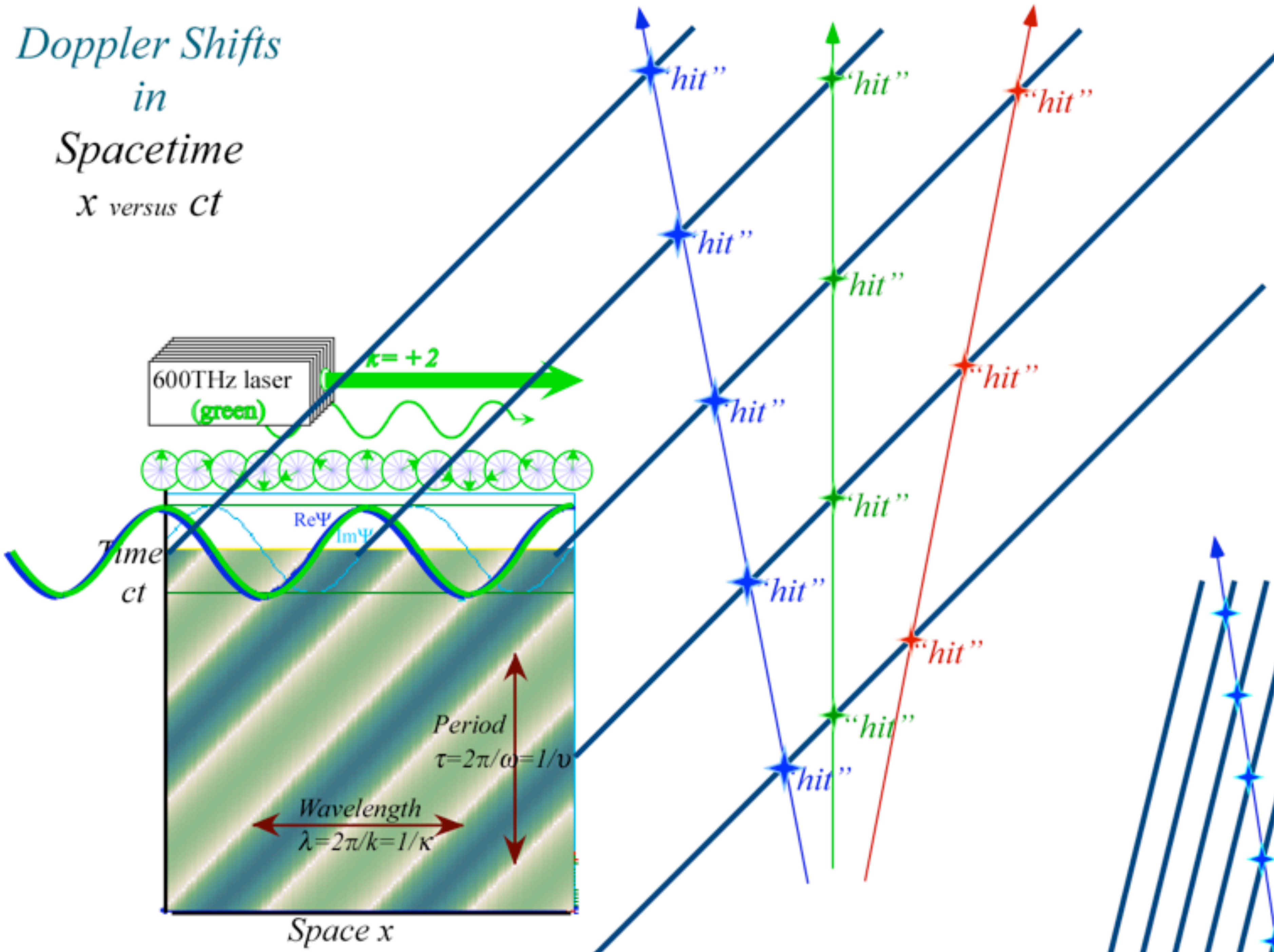
Doppler Shifts in Spacetime
x versus *ct*

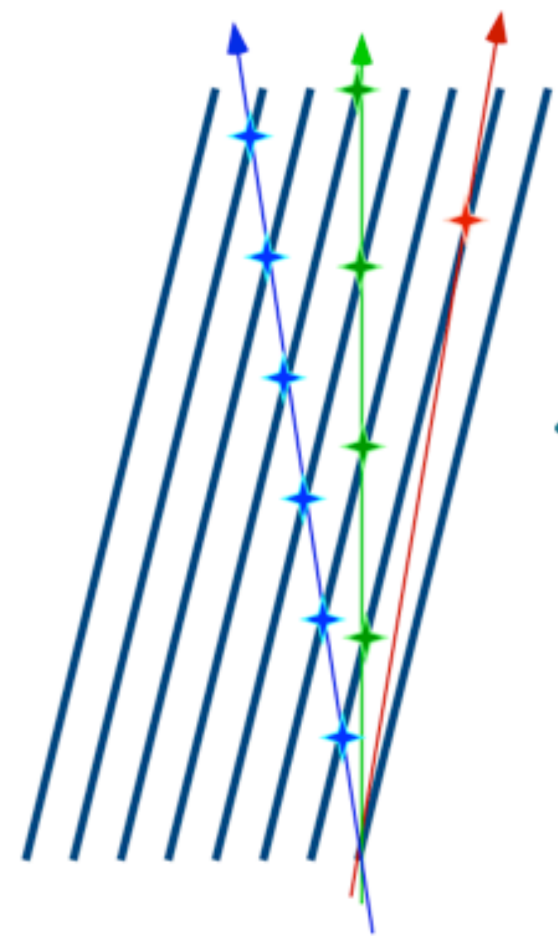
Doppler Blueshift
More "hits" per sec. if moving toward laser source

Doppler Redshift
Fewer "hits" per sec. if moving away from laser source



Doppler's picture needs revision for light whose period *and* wavelength *both* shift.

Why?



...So that *all* colors go the *same* speed!

$$\upsilon \cdot \lambda = \frac{\lambda}{\tau} = \frac{\omega}{k} = c$$

$$\upsilon \cdot \lambda = \frac{\lambda}{\tau} = \frac{\omega}{k} = c \qquad \text{etc.}$$

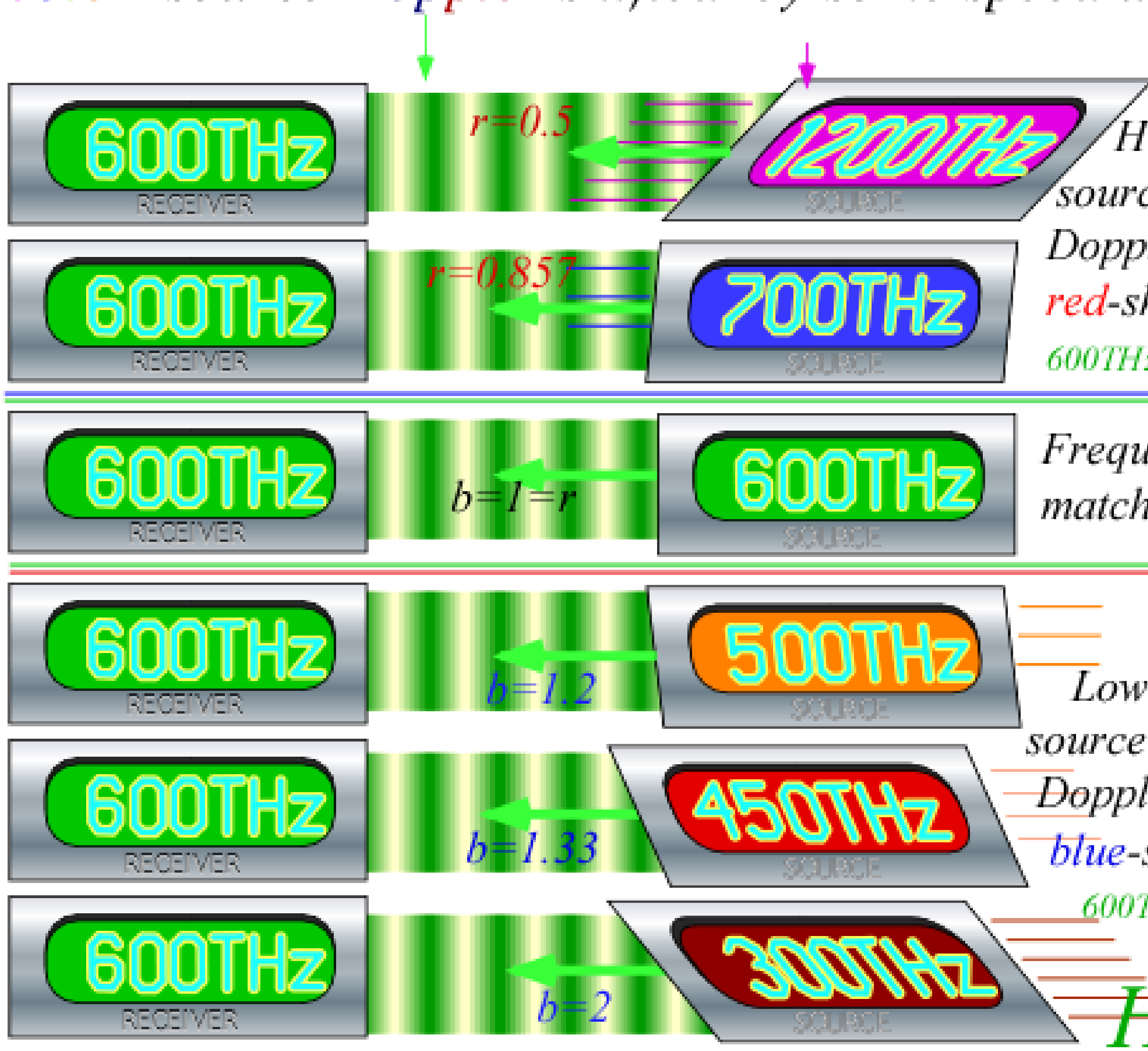
$$\upsilon \cdot \lambda = \frac{\lambda}{\tau} = \frac{\omega}{k} = c$$

Related subject matter at:
http://www.uark.edu/ua/pirelli/php/doppler_segue.php

CW Axiom ("All colors go c.") based on Doppler effects

Showing that Green is Green is Green...(and all the same speed)...

Any color (like 600THz green) may be made by any other color source Doppler shifted by some speed u (less than c)

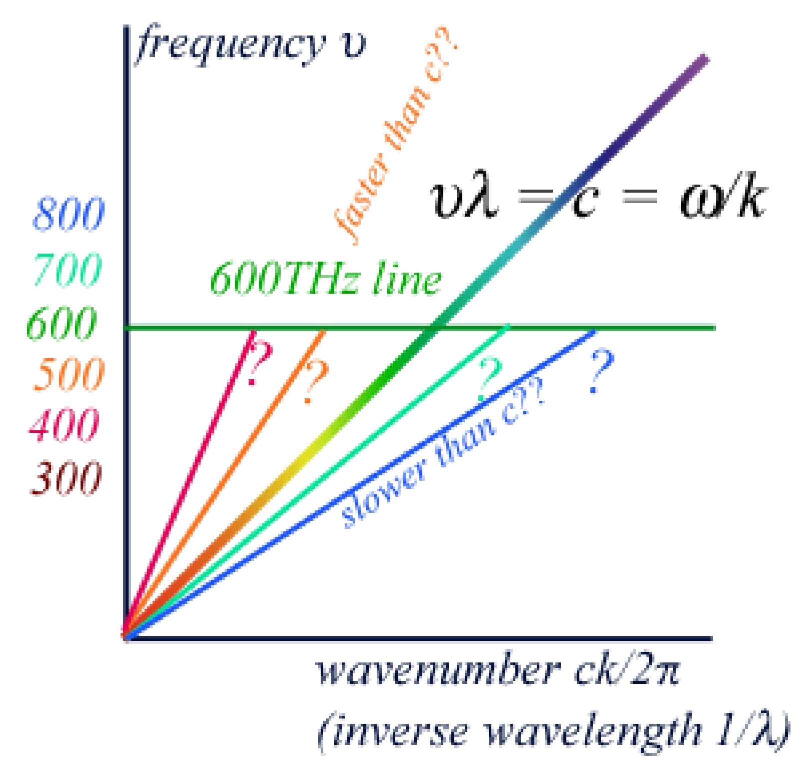


Higher frequency υ source recedes so its Doppler factor (0<r<1) red-shifts υ to match a 600THz-tuned receiver.

Frequency υ=600THz matches receiver.

Lower frequency υ source approaches so its Doppler factor (1<b<∞) blue-shifts υ to match a 600THz-tuned receiver.

How many ways can you make 600THz green?



How many kinds of green exist? (It's either 1 or ∞.)

Related subject matter at:

http://www.uark.edu/ua/pirelli/php/doppler_cw_logic_3.php

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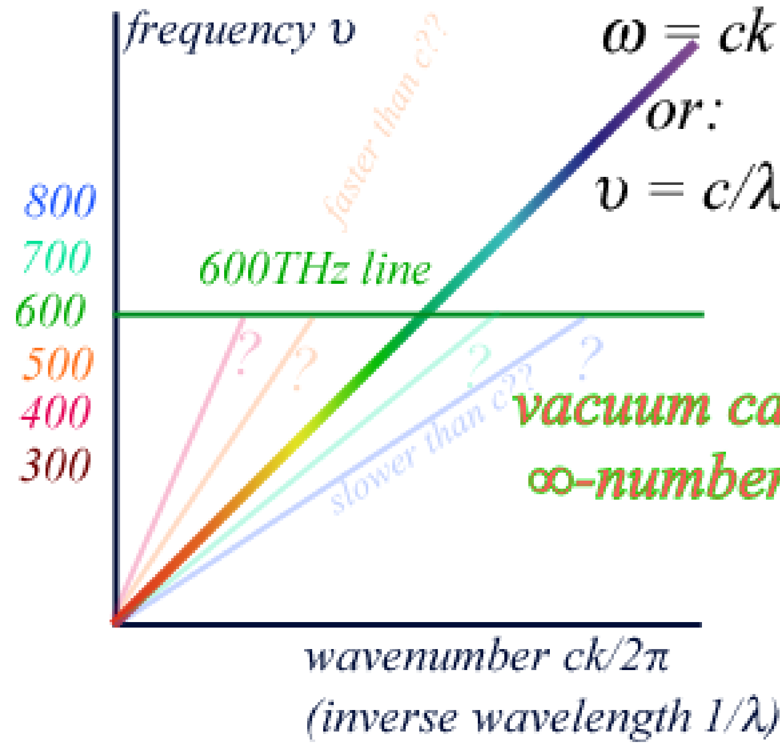
Evenson CW Axiom ("All colors go c.") is only reasonable conclusion:

Linear dispersion: $\omega = ck$

Linear dispersion means NO dispersion

Einstein PW is corollary of Evenson CW



vacuum can't support an ∞-number of "other speeds"

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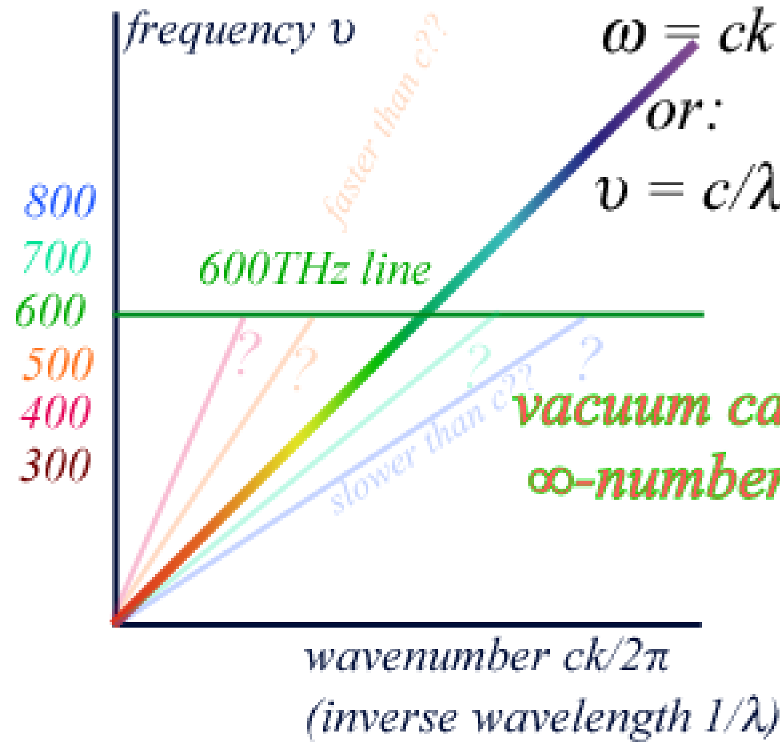

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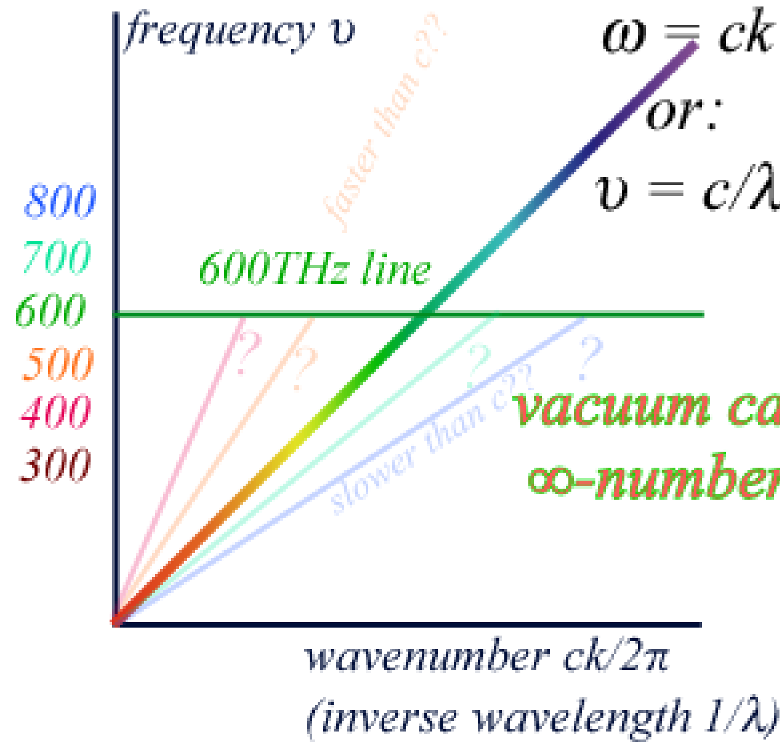
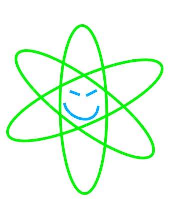


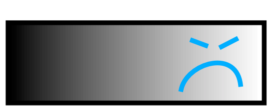
vacuum can't support an ∞-number of "other speeds"

What if blue were to travel 0.001% slower than red from a galaxy 9 billion light years away? (..and show up 10^5 years late)

That would mean Good-Bye Hubble Astronomy!

What if ν=600THz green excited an Ar atom but NOT a λ=0.500μm optical cavity? *(or vice-versa?)*





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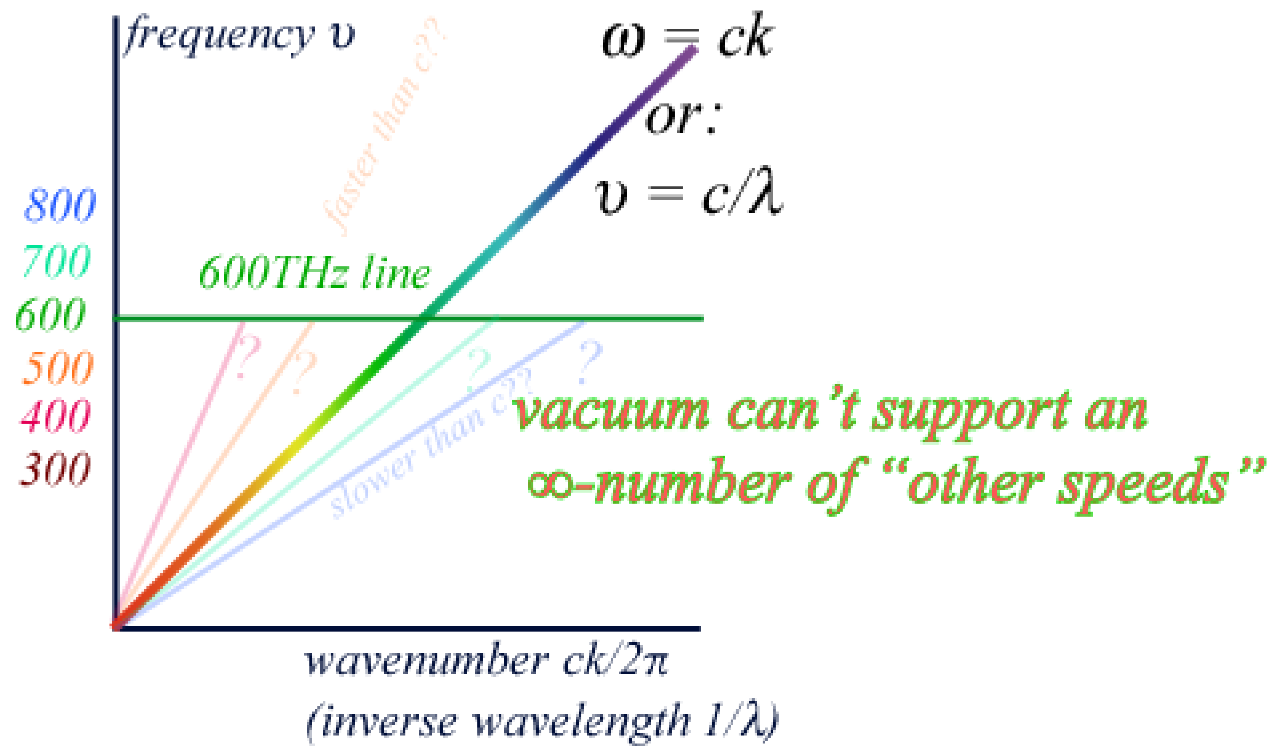

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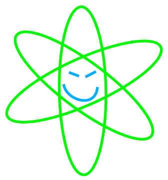

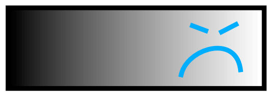

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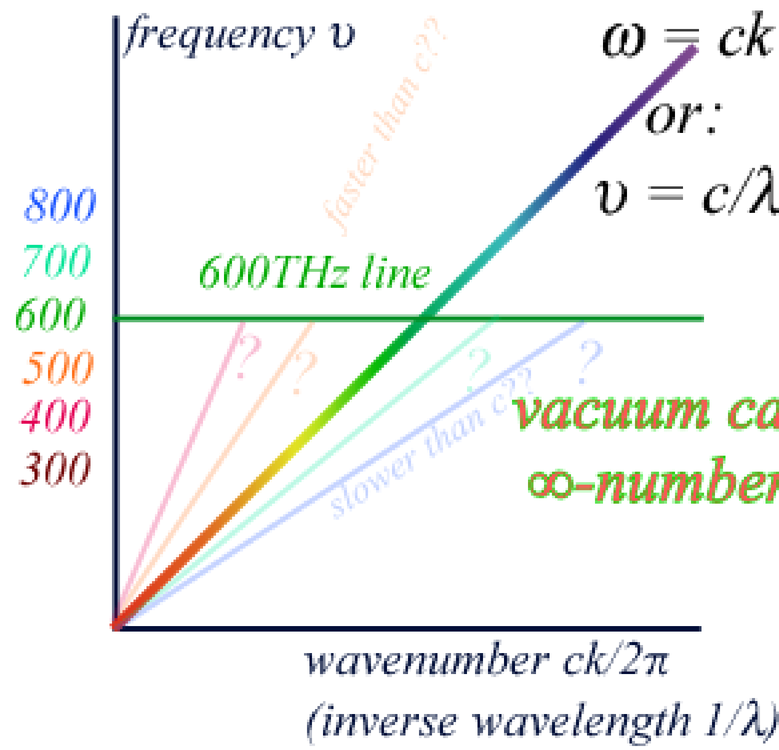

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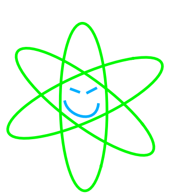
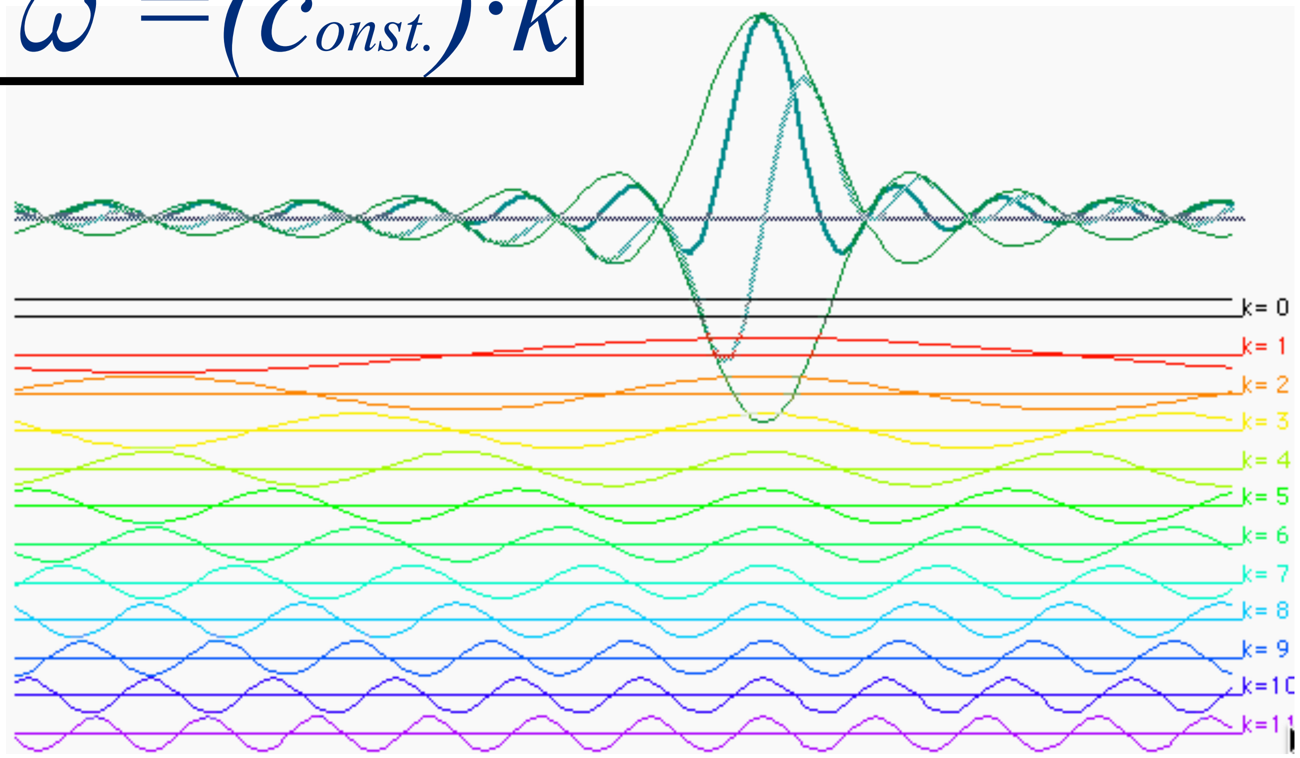
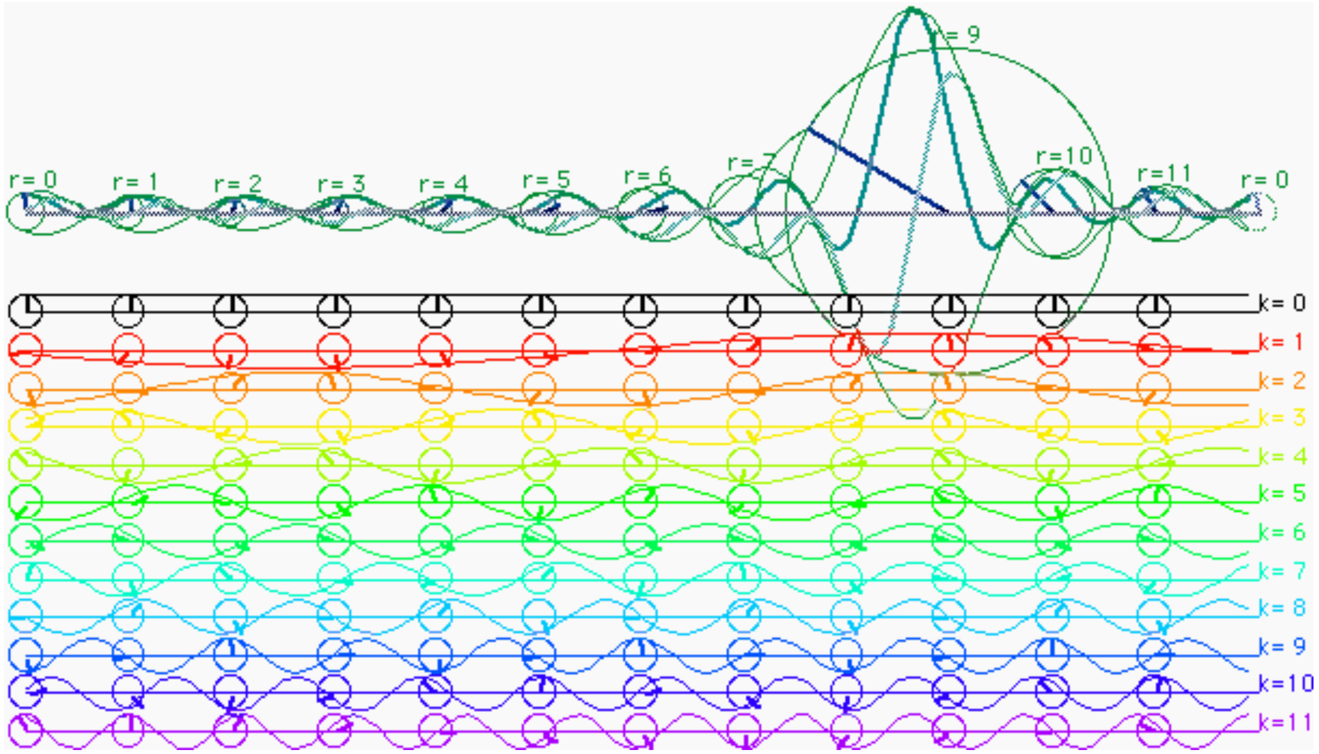


That would mean Good-Bye Light Amplification by Stimulated Emission of Radiation .

Linear Dispersion (means NO dispersion) has all colors (Fourier components) march in "lockstep"

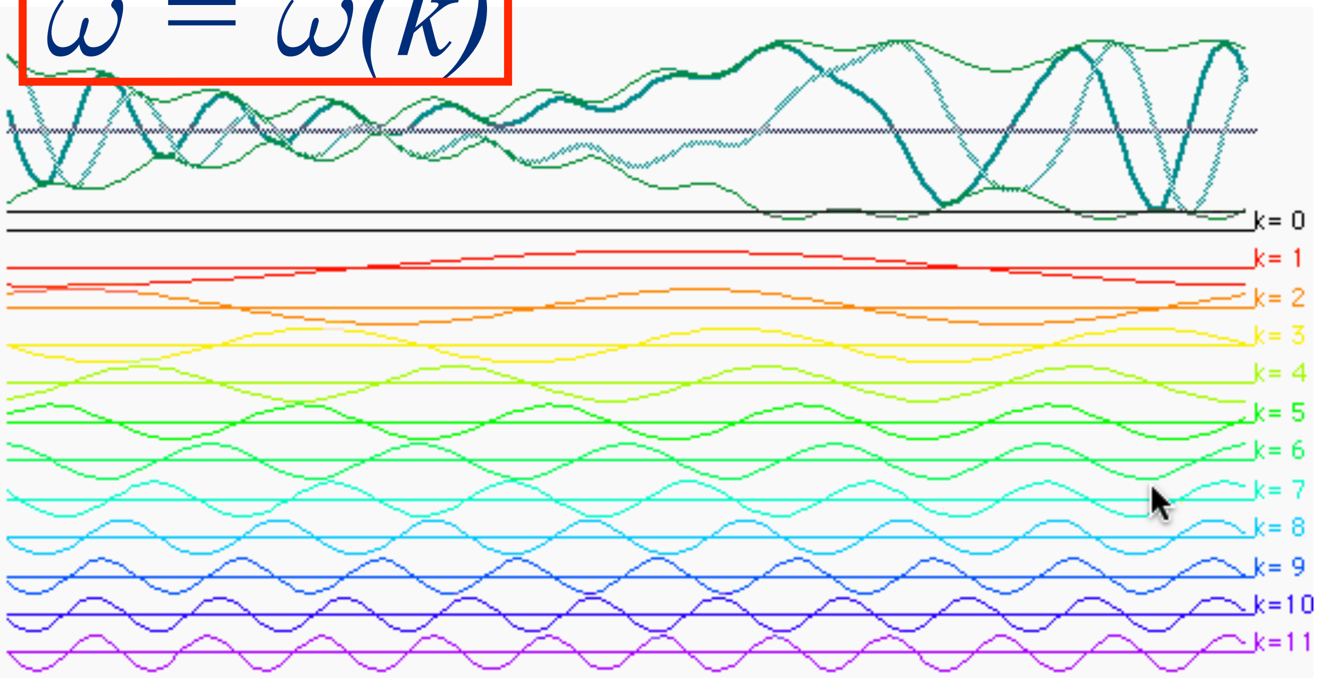
$$\omega = (c_{onst.}) \cdot k$$

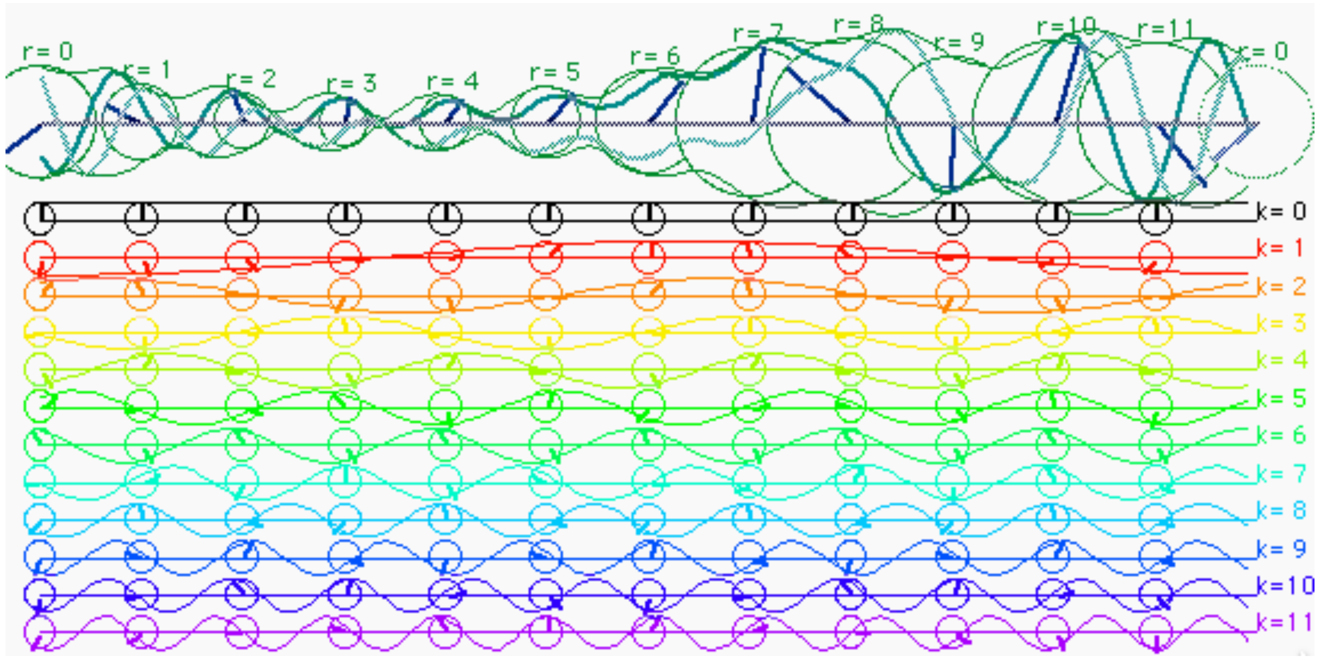




NON-linear Dispersion (has dispersion) so different colors (Fourier components) go different speeds

$$\omega = \omega(k)$$





See animation: www.uark.edu/ua/pirelli/php/train_PW_Occum_Evenson.php

2. Applying Occam's razor to relativity axioms

Einstein PW Axioms versus Evenson CW Axioms (Traditional: The "Roadrunner" Axiom)

CW light clearly shows Doppler shifts

Check that red is red is red,...green is green is green,...blue is blue is blue,... etc.

Is dispersion linear?... does astronomy work?... how about spectroscopy?

Is Doppler a geometric factor or arithmetic sum?

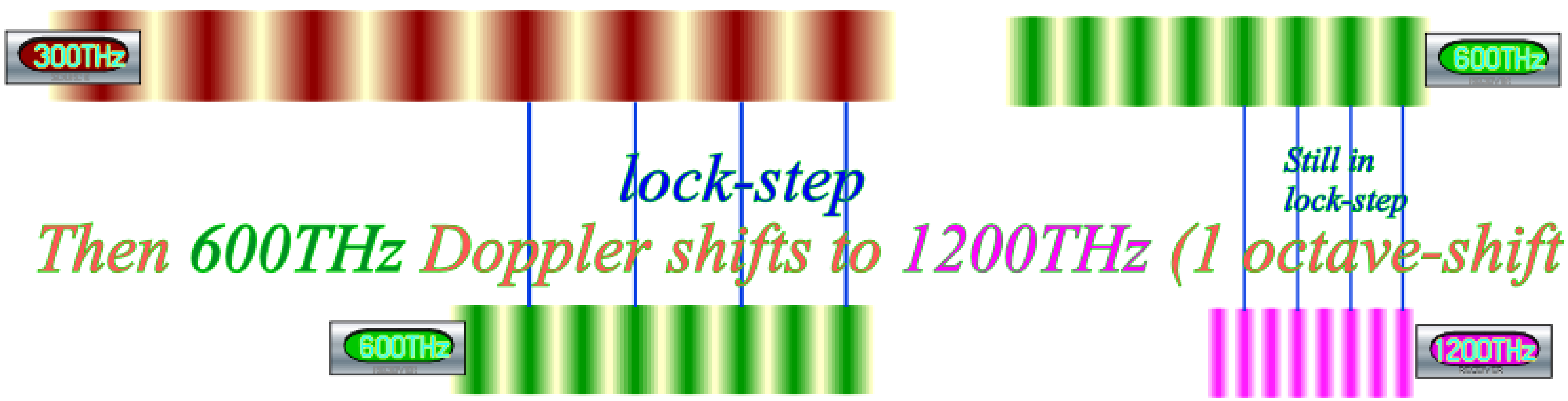
Introducing rapidity $\rho = \ln b$.

That old Time-Reversal meta-Axiom (that is so-oo-o neglected!)

If all colors always march in lock-step then any Doppler shift must be geometric factor, that is, the same multiplier for all colors.

If 300THz Doppler shifts to 600THz (1 octave-shift = 2.0)

Then 600THz Doppler shifts to 1200THz (1 octave-shift = 2.0)



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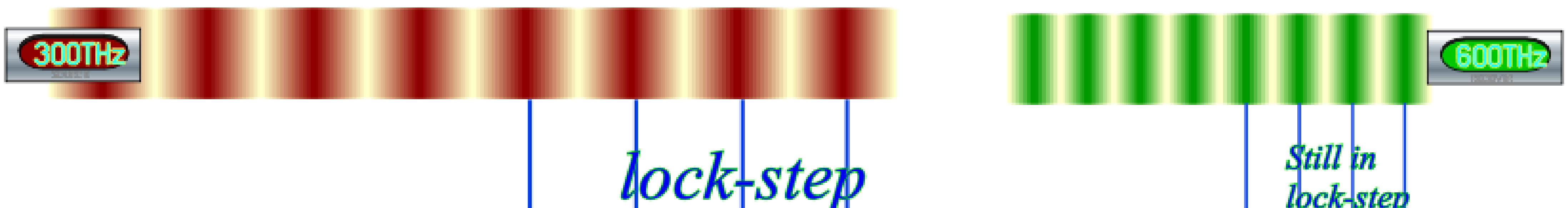

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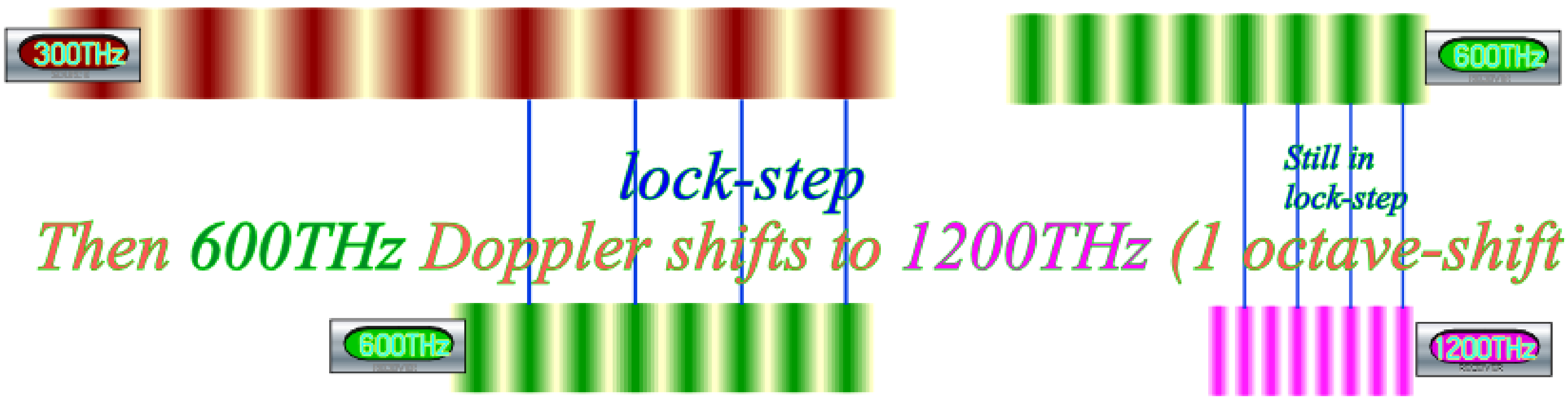

Then 600THz Doppler shifts to 1200THz (1 octave-shift = 2.0)

Doppler shifts maintain frequency ratios (not differences)

1-D Doppler shifts {red $= e^{-\rho}$ ...blue $= e^{+\rho}$} *form a Lie Group*

3-D Doppler shifts are hypercomplex elements of Lorentz Group

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Frequency blue shift b when Source-Receiver interval is >>CLOSING<<

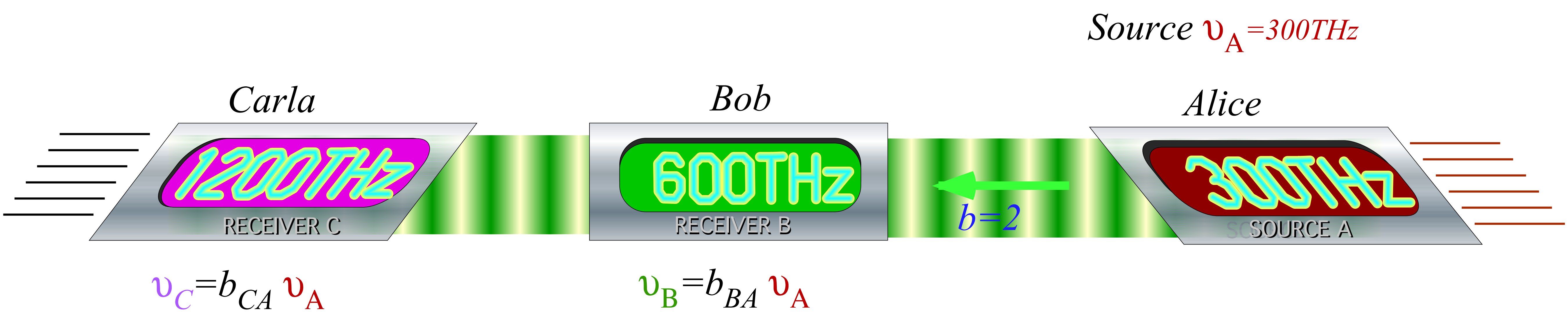
$$\frac{\upsilon_{IN}}{\upsilon_{OUT}} = \frac{\upsilon_{Receiver}}{\upsilon_{Source}} = b = e^{+|\rho|} > 1$$

Frequency red shift r when Source-Receiver interval is <<OPENING>>

$$\frac{\upsilon_{Receiver}}{\upsilon_{Source}} = r = e^{-|\rho|} < 1$$

Defining Rapidity ρ as logarithm of Doppler

$\rho = \ln(b \text{ or } r)$


Source υ_A=300THz
Carla
Bob
Alice
1200THz
RECEIVER C
600THz
RECEIVER B
b=2
300THz
SOURCE A
$\upsilon_C = b_{CA}\, \upsilon_A$
$\upsilon_B = b_{BA}\, \upsilon_A$

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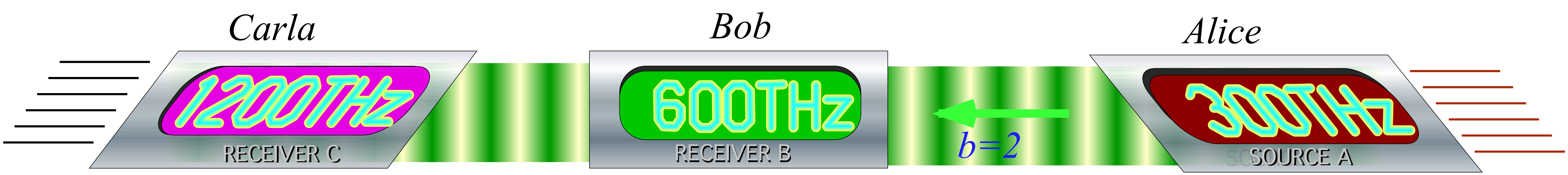
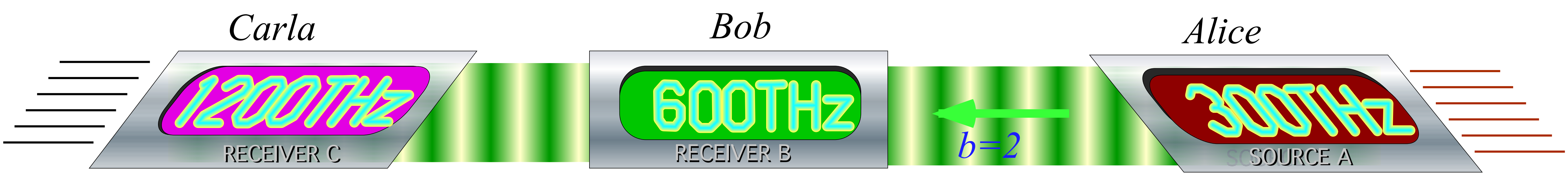


$\upsilon_C = b_{CA}\ \upsilon_A$ $\qquad$ $\upsilon_B = b_{BA}\ \upsilon_A$

Source υ_A=300THz



$\upsilon_C = b_{CA}\, \upsilon_A = b_{CB}\, \upsilon_B$

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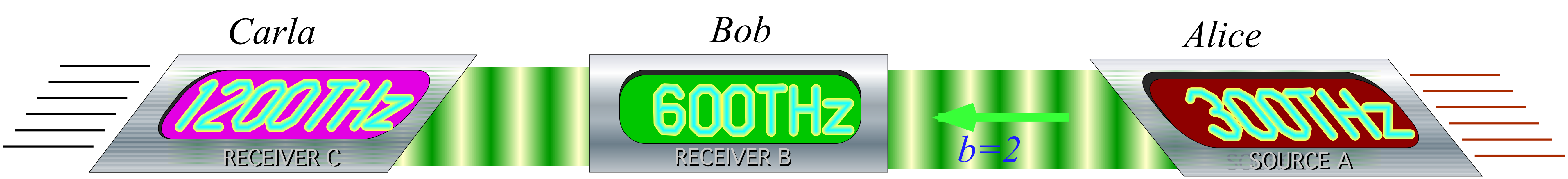

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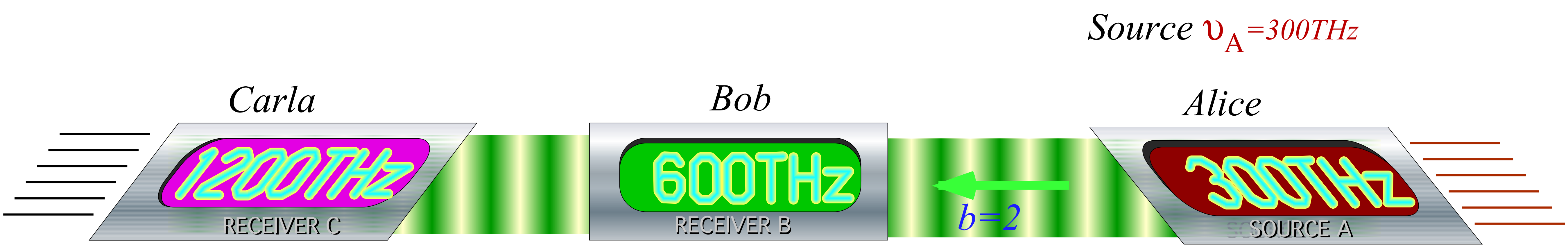

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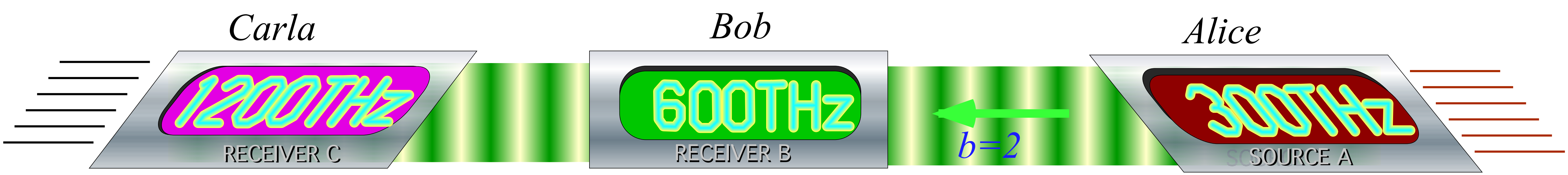
Source $\upsilon_A = 300THz$



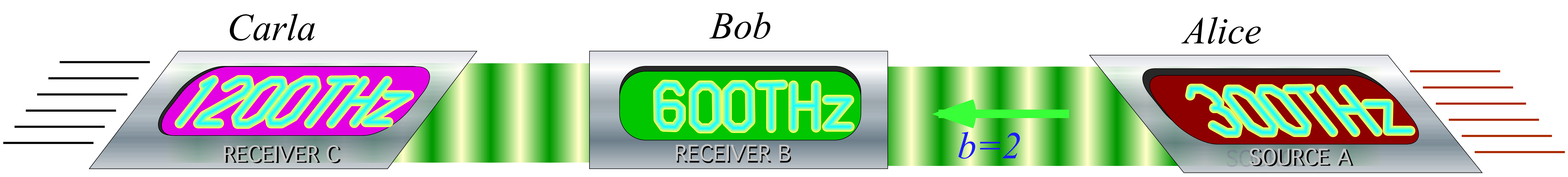
$\upsilon_C = b_{CA}\,\upsilon_A = b_{CB}\,\upsilon_B$

$= b_{CB}\, b_{BA}\, \upsilon_A$

$\upsilon_B = b_{BA}\,\upsilon_A$

2 times 2 = 4 Doppler arithmetic

Source υ_A *=300THz*



$\upsilon_C = b_{CA}\, \upsilon_A = b_{CB}\, \upsilon_B$

$= b_{CB}\, b_{BA}\, \upsilon_A$

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This implies:

$b_{CA} = b_{CB}\, b_{BA}$

b-Product rule

Frequency blue shift *b* when Source-Receiver interval is >>CLOSING<<

Frequency red shift *r* when Source-Receiver interval is <<OPENING>>

$$\frac{\upsilon_{IN}}{\upsilon_{OUT}}=\frac{\upsilon_{Receiver}}{\upsilon_{Source}}=b=e^{+|\rho|}>1$$

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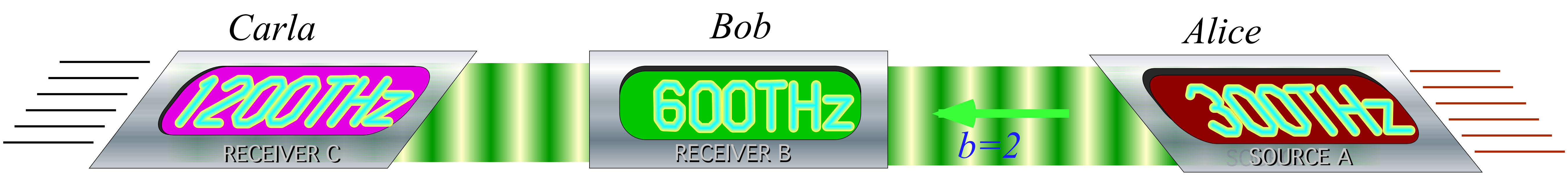
$$\frac{\upsilon_{Receiver}}{\upsilon_{Source}}=r=e^{-|\rho|}<1$$

2 times 2 = 4 Doppler arithmetic

Source υ_A=300THz



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Examples:

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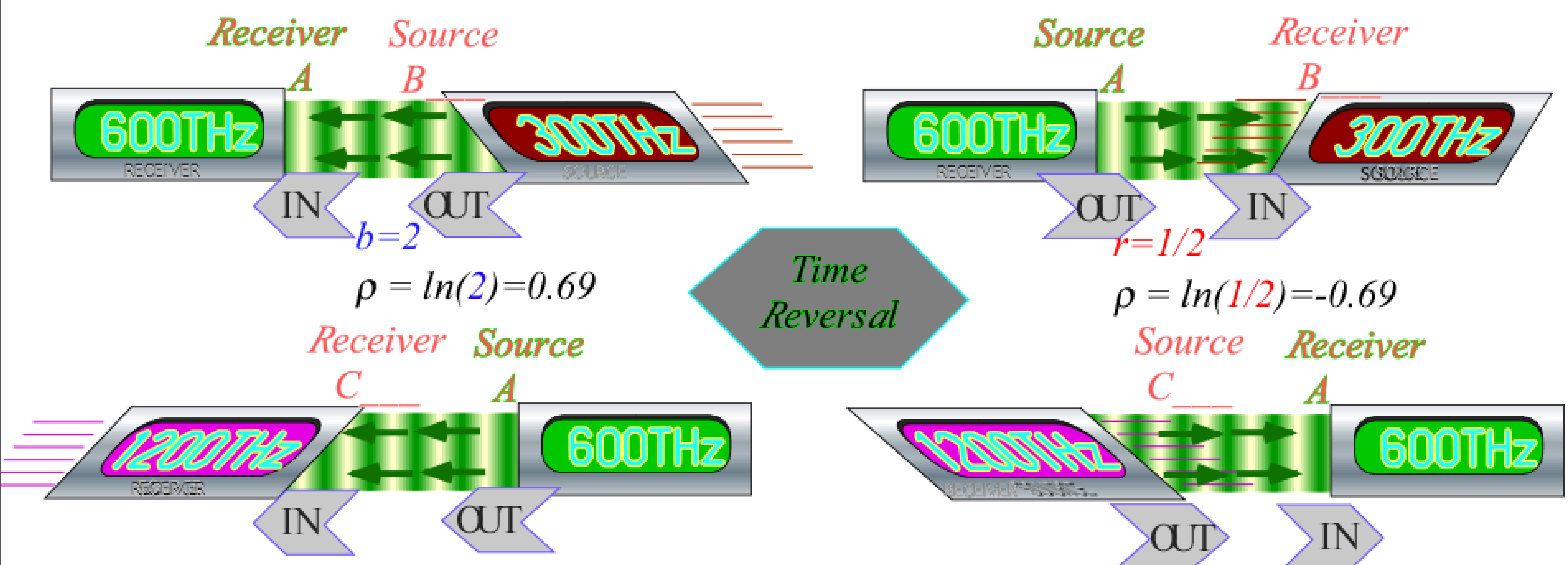
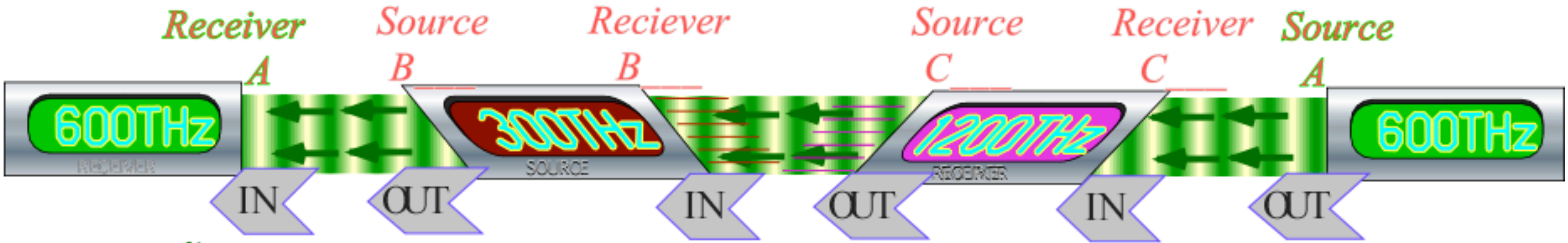


Each Doppler shift $\frac{\upsilon_A}{\upsilon_B}$ maps to a Lorentz transformation T_{AB}



$$\frac{\upsilon_A}{\upsilon_B} = b_{AB} = e^{\rho_{AB}} = 2$$

$$\rho_{AB} = \ln(2) = 0.69$$

$$\frac{\upsilon_B}{\upsilon_C} = b_{BC} = e^{\rho_{BC}} = 1/4$$

$$\rho_{BC} = \ln(1/4) = -1.38$$

$$\frac{\upsilon_C}{\upsilon_A} = b_{CA} = e^{\rho_{CA}} = 2$$

$$\rho_{CA} = \ln(2) = 0.69$$

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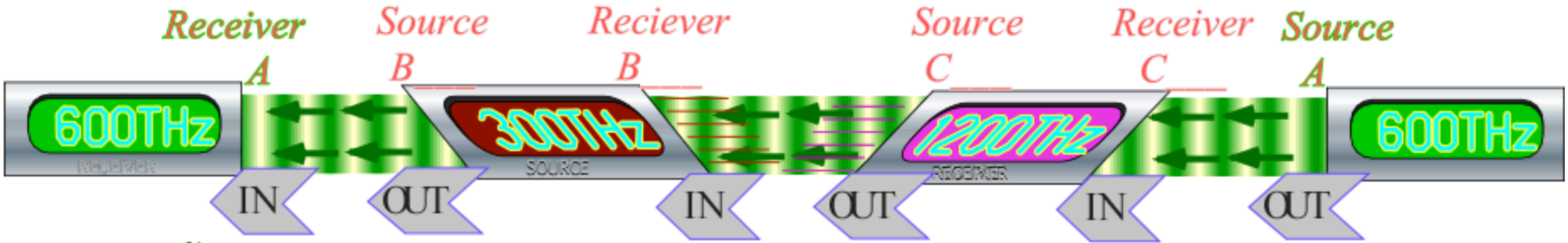

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$\frac{\upsilon_C}{\upsilon_A} = b_{CA} = e^{\rho_{CA}} = 2$ $\rho_{CA} = \ln(2) = 0.69$

Group product is represented:
(by IN-OUT "nematodes")

$$T_{AB} \cdot T_{BC} = T_{CA}$$

$$\frac{\upsilon_A}{\upsilon_B} \frac{\upsilon_B}{\upsilon_C} = \frac{\upsilon_A}{\upsilon_C}$$

$$e^{\rho_{AB}} e^{\rho_{BC}} = e^{\rho_{AC}} = e^{(\rho_{AB} + \rho_{BC})}$$

...and rapidity ρ_{AB} is a Galilean (arithmetic) parameter

To be shown: $\rho_{AB} = \mathrm{atanh}(u_{AB}/c)$ approaches (u_{AB}/c) for: $\rho_{AB} << 1$

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That old Time-Reversal meta-Axiom (that is so-oo-o neglected!)

Inverse to Lorentz transformation T_{AB} *is* T_{BA}

..just as the arithmetic inverse of $\frac{\upsilon_A}{\upsilon_B}$ *is* $\frac{\upsilon_B}{\upsilon_A}$

..just as the arithmetic inver... of $e^{\rho_{AB}}$ *is* $e^{\rho_{BA}} = e^{-\rho_{AB}}$

..just as the arithmetic inver... of ρ_{AB} *is* $\rho_{BA} = -\rho_{AB}$

See animation: www.uark.edu/ua/pirelli/php/time_rev_sym.php

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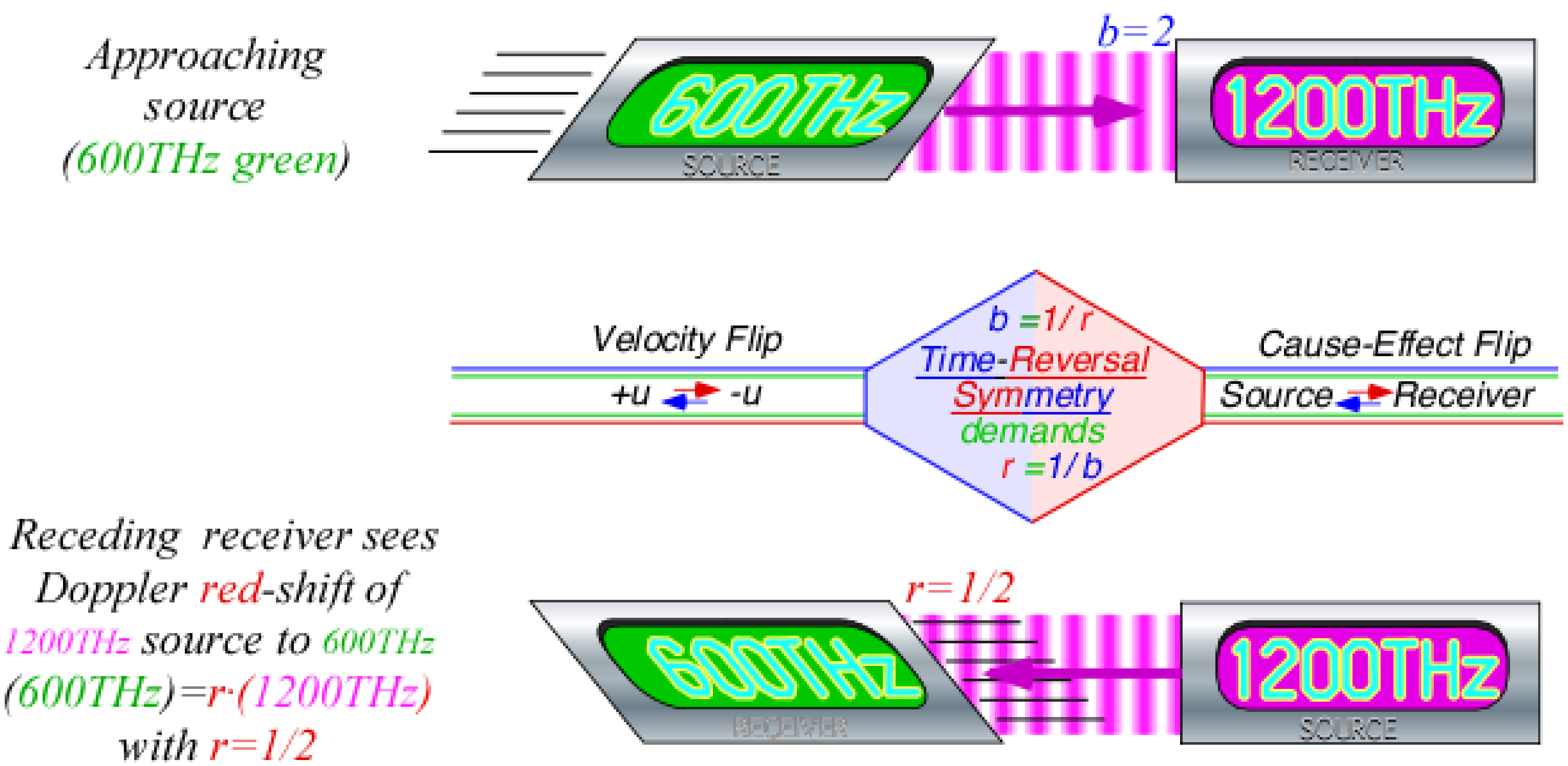
Detailed time reversal symmetry implies r=1/b.



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3. Spectral theory of Einstein-Lorentz relativity

- Applying Doppler Shifts to per-space-time (ck,ω) graph
- CW Minkowski space-time coordinates (x,ct) and PW grids
- Relating Doppler Shifts b or $r=1/b$ to velocity u/c or rapidity ρ
- Lorentz transformation

Connection: Conventional approach to relativity and old-fashioned formulas

Deriving Spacetime and per-spacetime coordinate geometry by:

(1) *Evenson* CW axiom *"All colors go c"* keeps K_A and K_B *on their baselines.*

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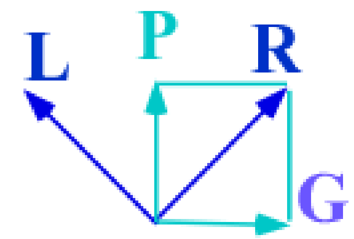
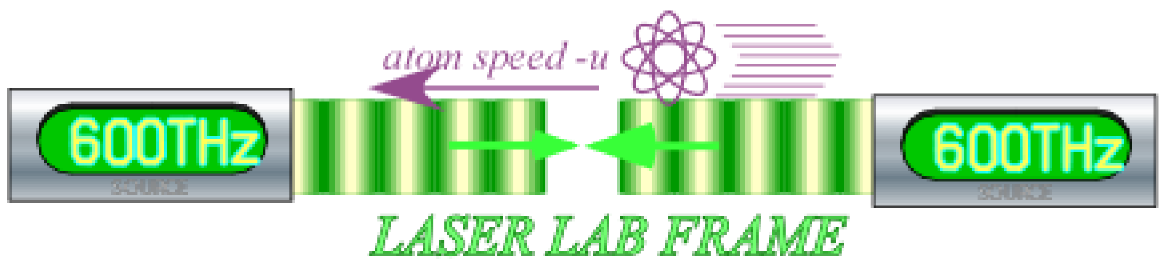
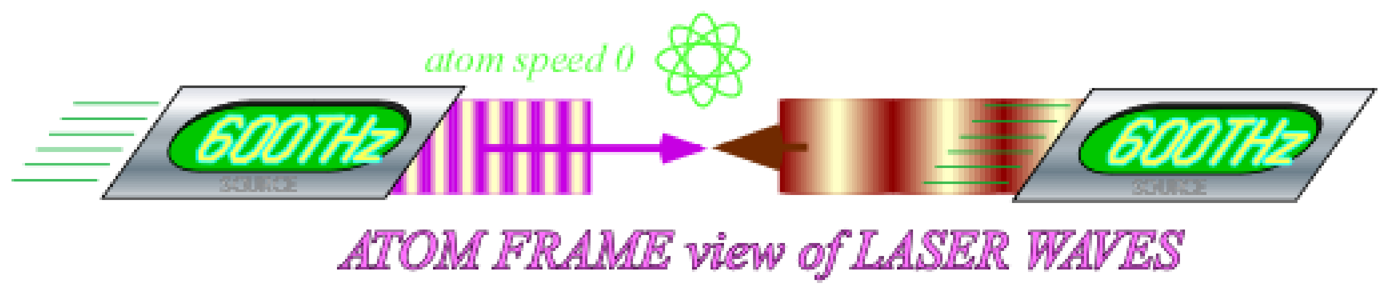
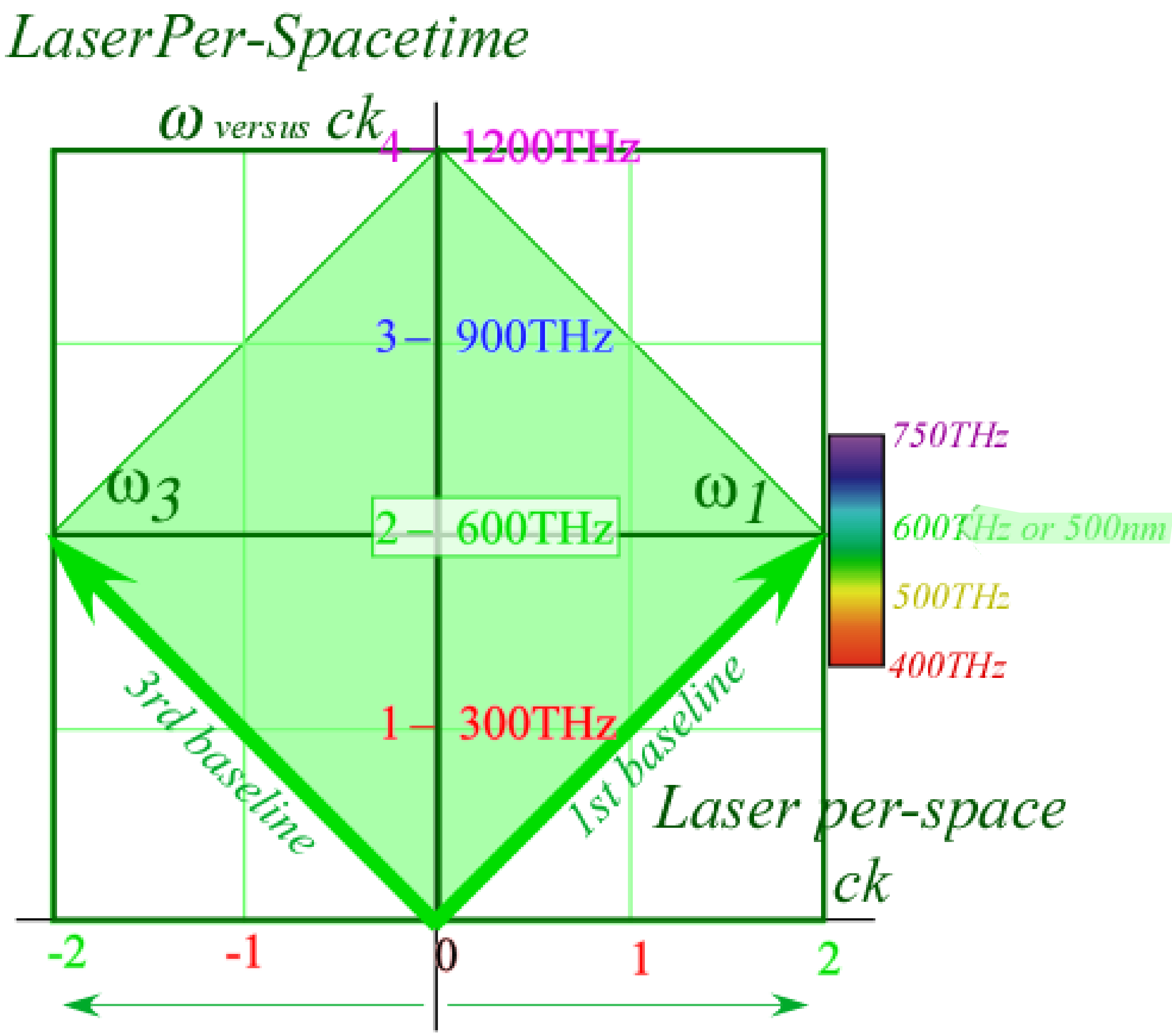
(3) Half-Sum Phase **P=(R+L)/2** and Half-Difference Group **G=(R–L)/2**









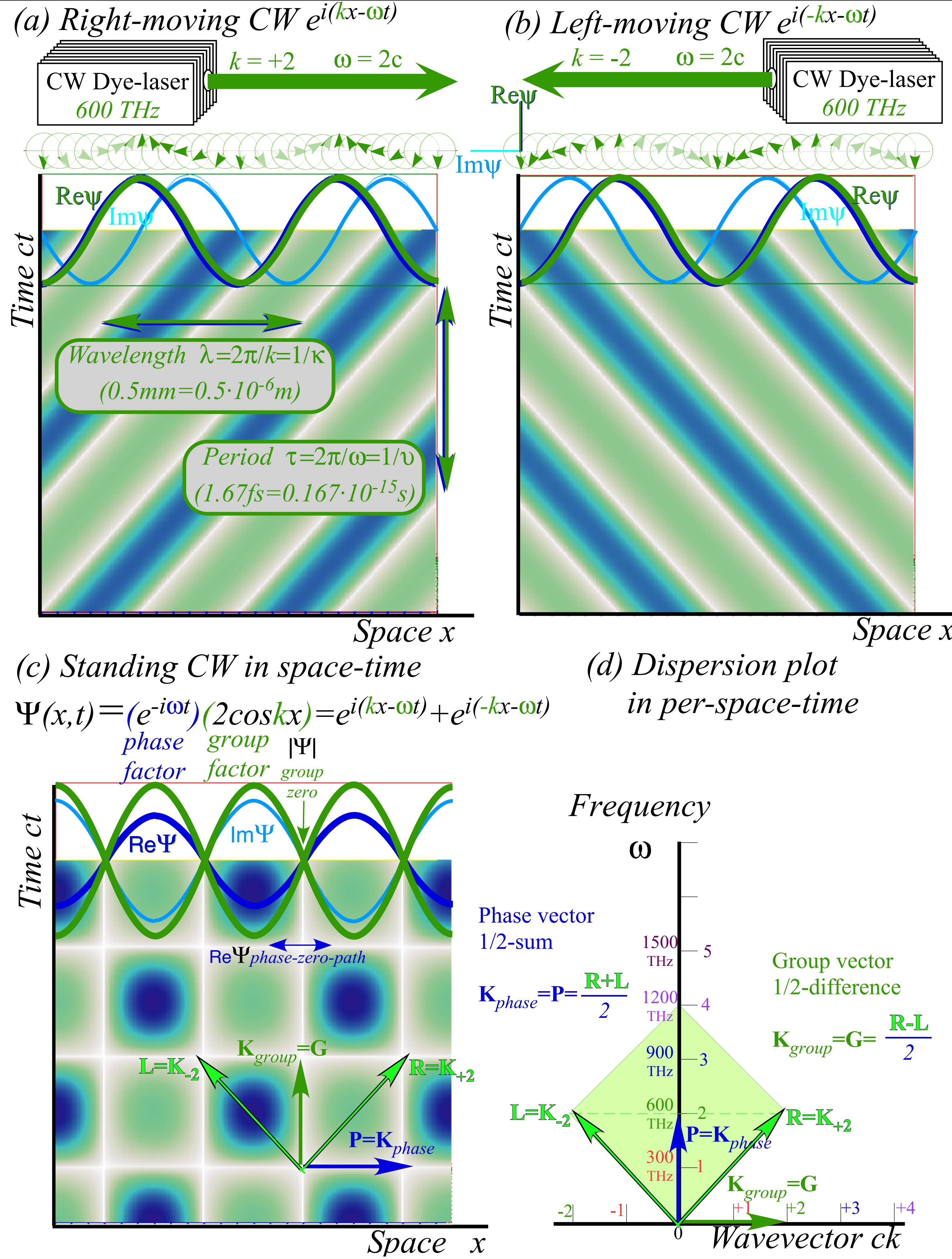


Fig. 5 in SR&QM

recall also:
p. 3-11 of Lect.1

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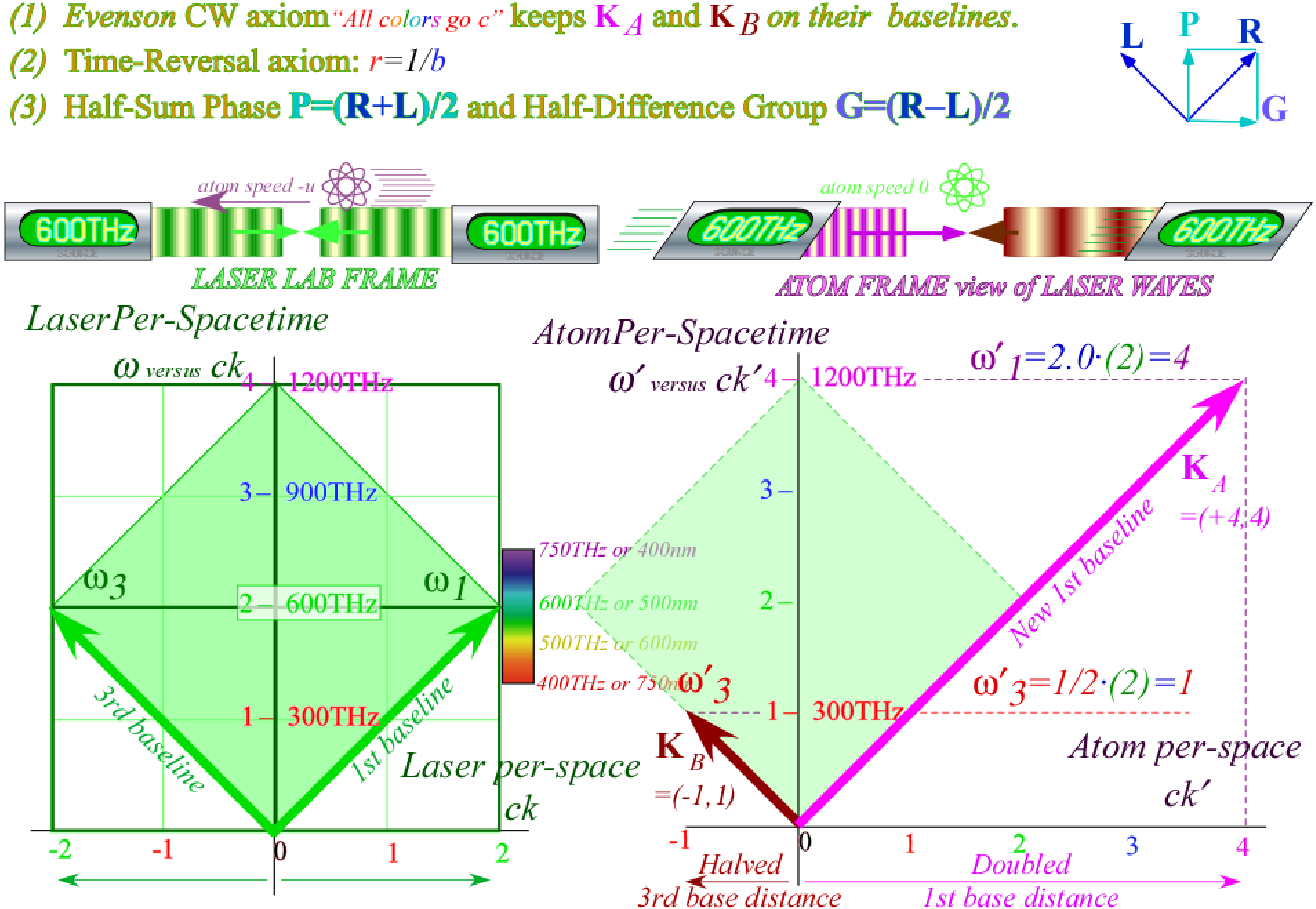

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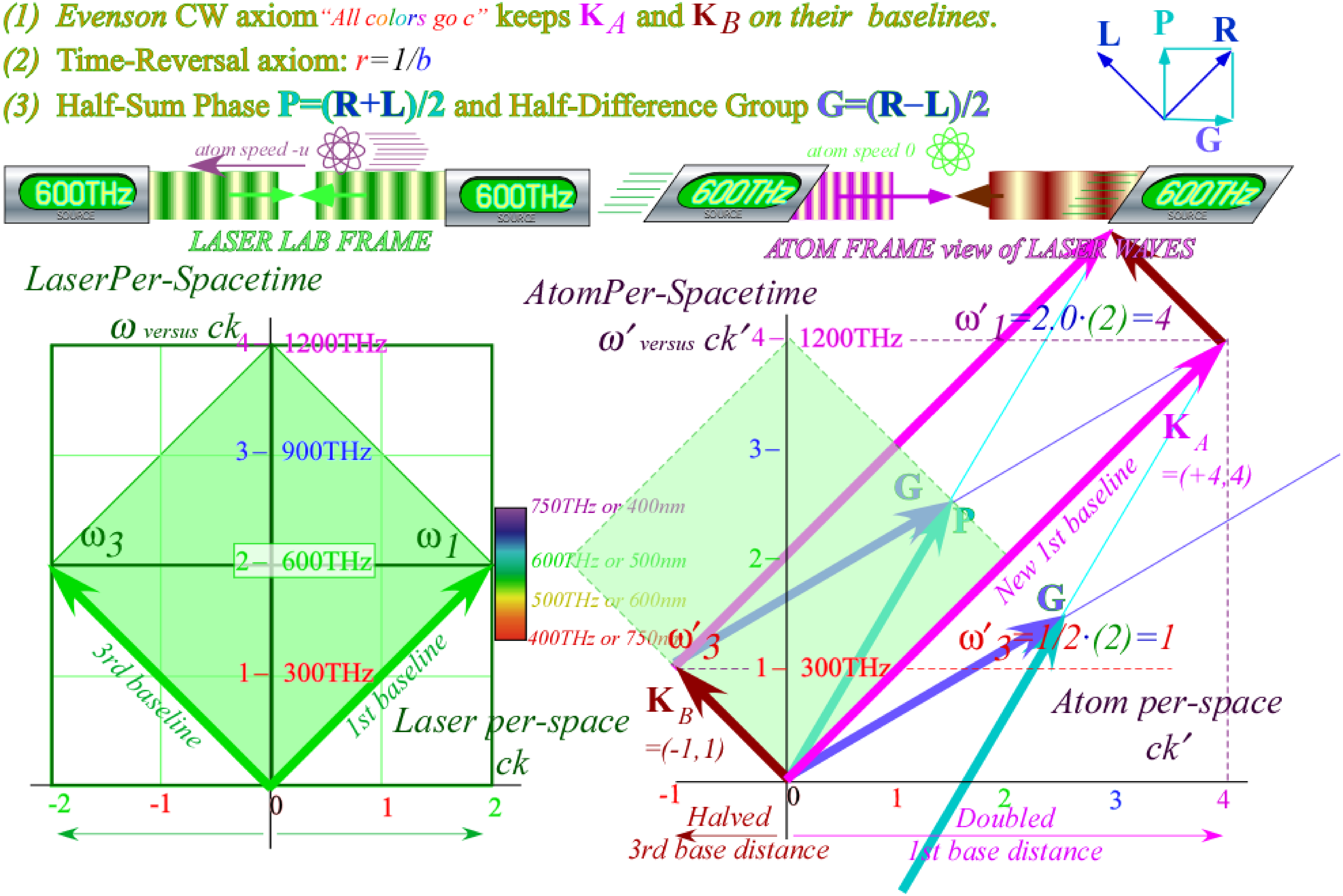

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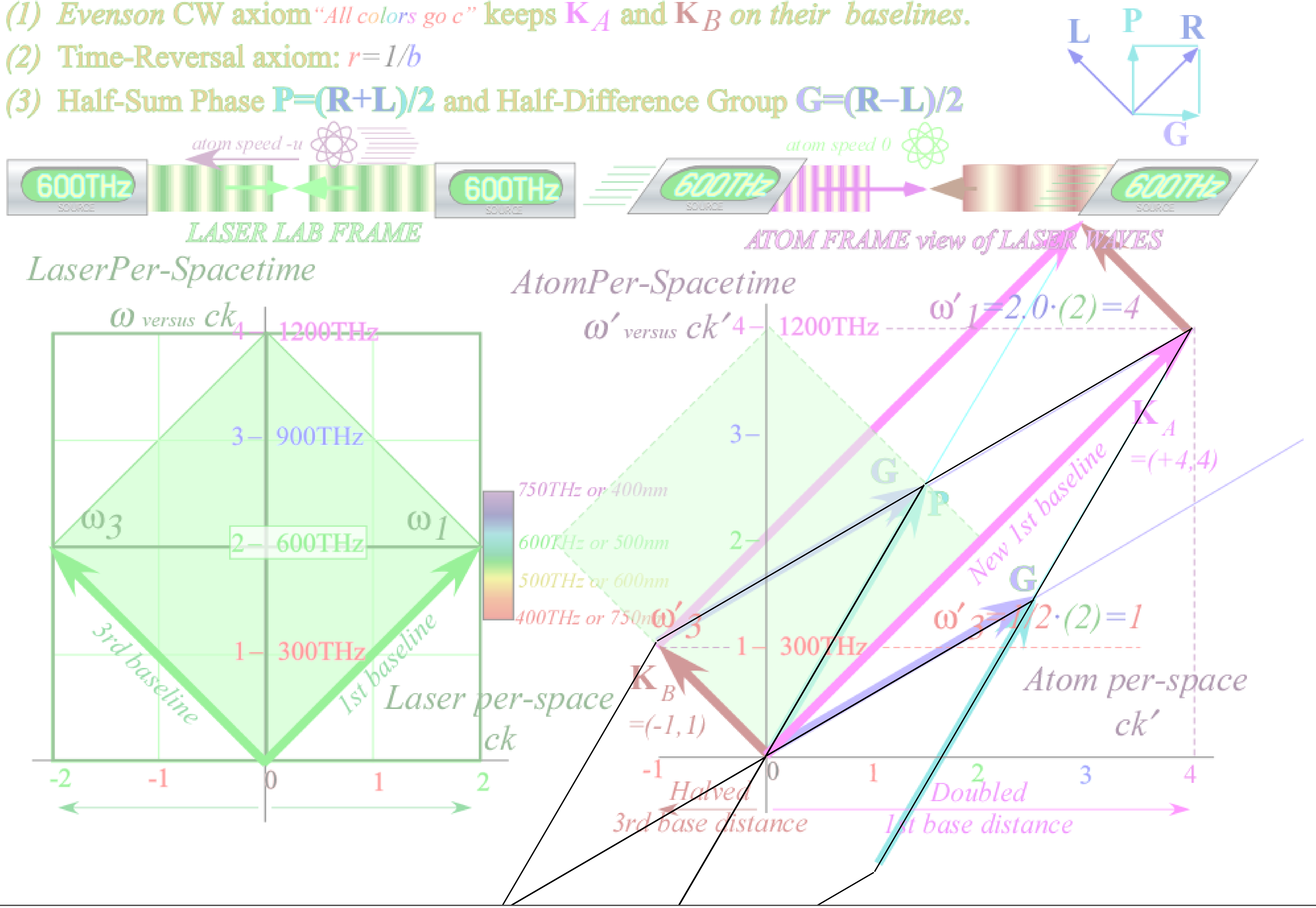

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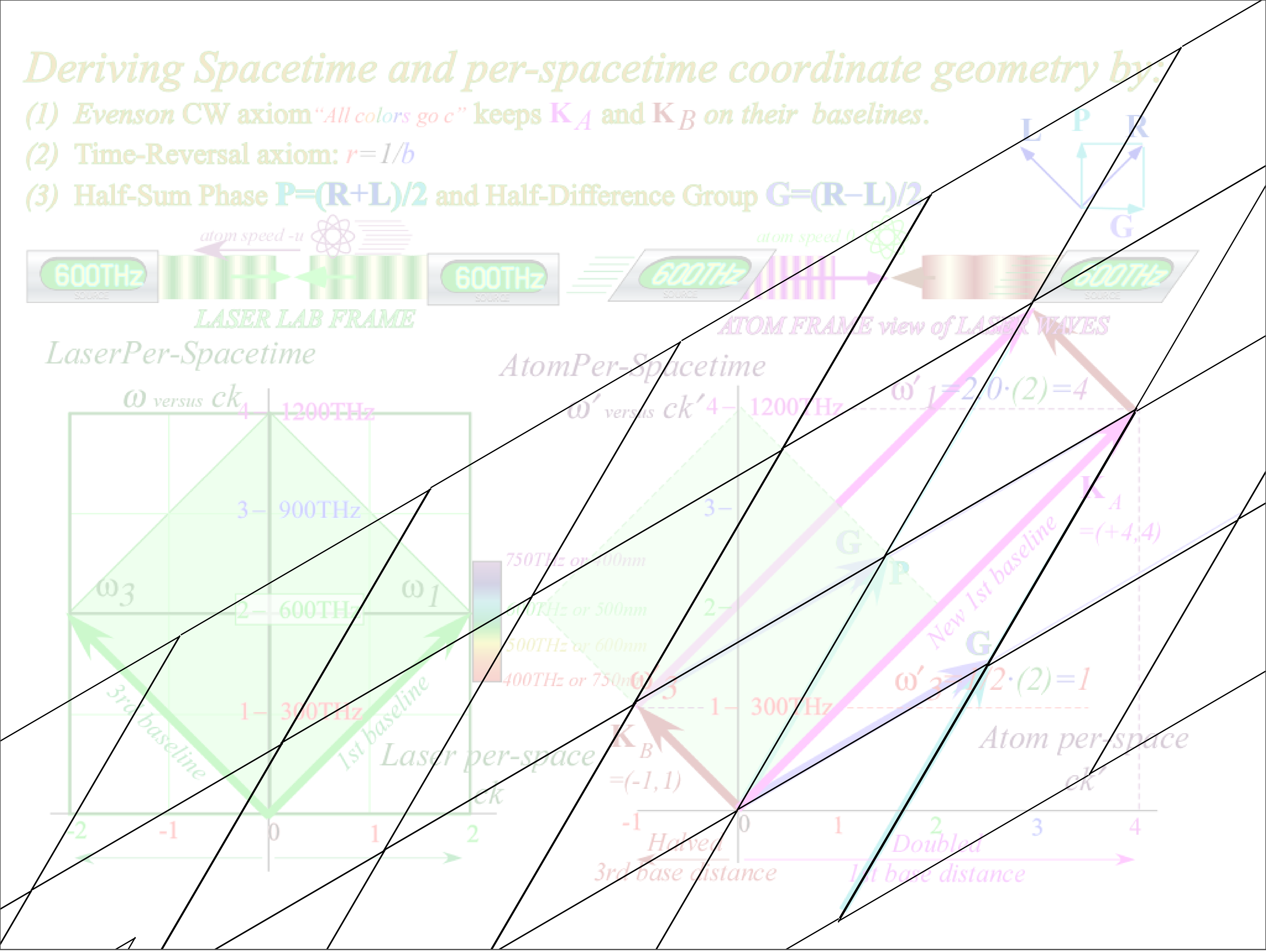

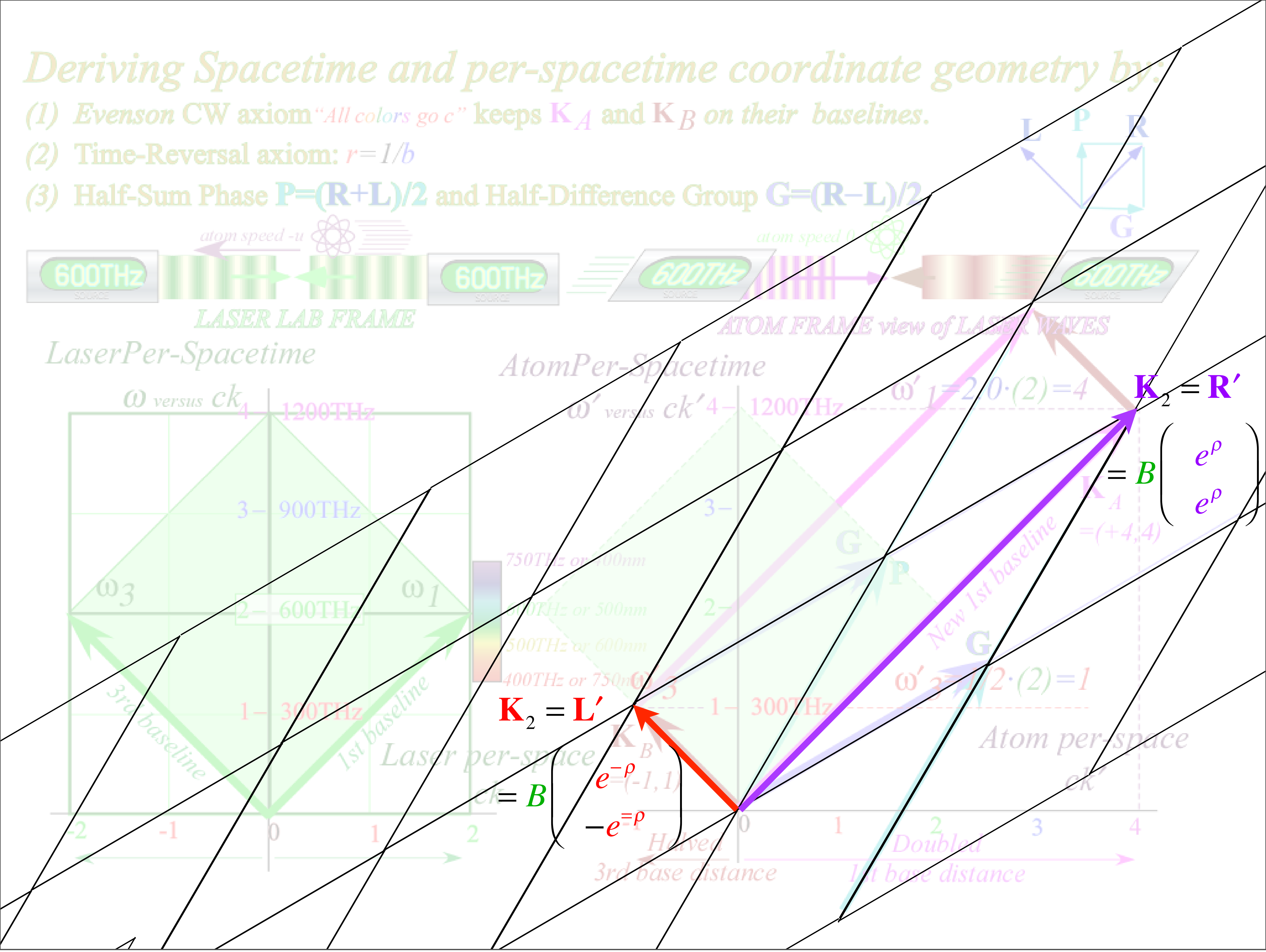

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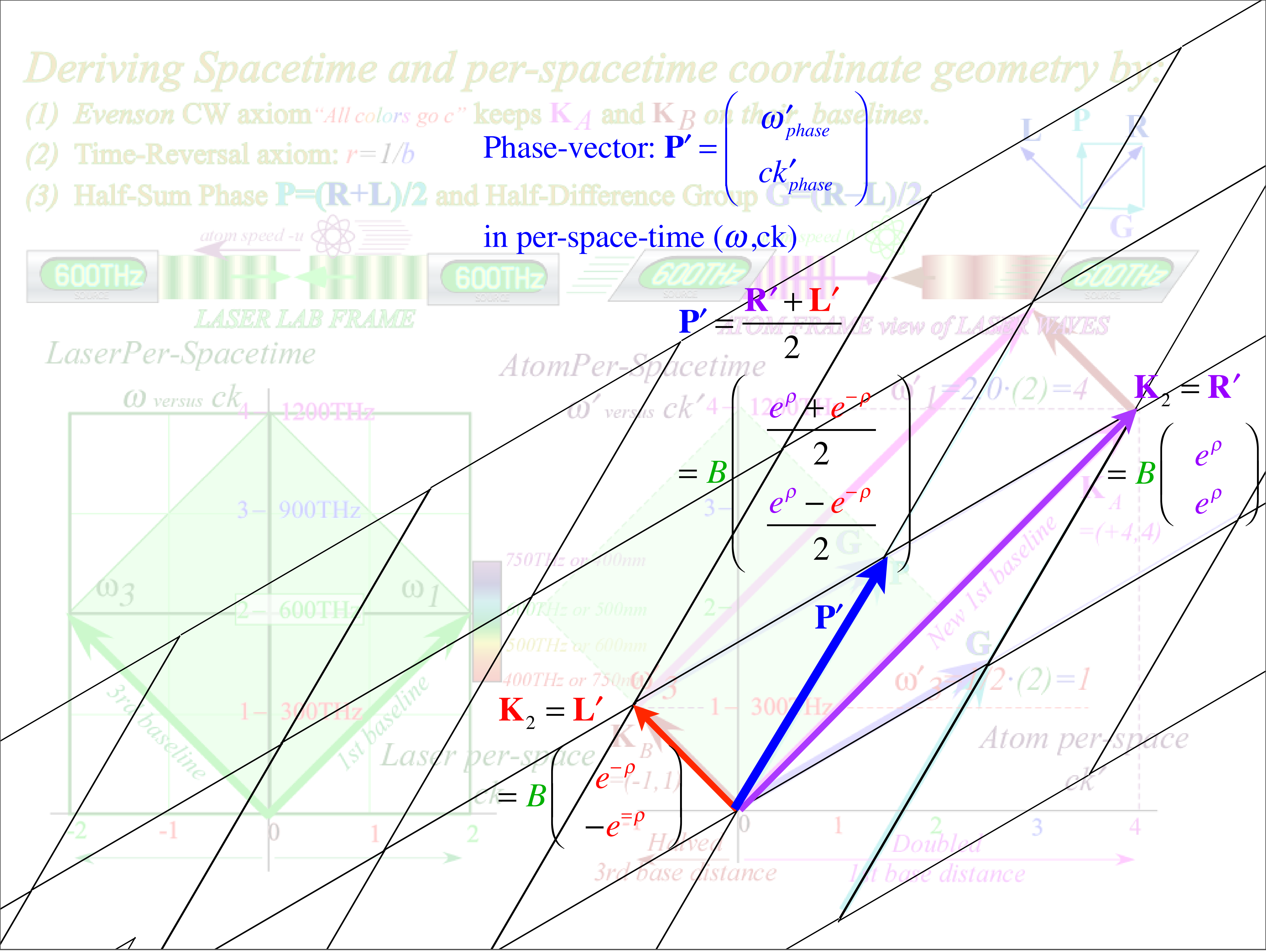
L P R G
atom speed -u
atom speed 0
600THz
LASER LAB FRAME
ATOM FRAME view of LASER WAVES
LaserPer-Spacetime
ω versus ck
1200THz
900THz
600THz
300THz
ω3
ω1
3rd baseline
1st baseline
Laser per-space
ck
AtomPer-Spacetime
ω′ versus ck′
750THz or 400nm
600THz or 500nm
500THz or 600nm
400THz or 750nm
K₂ = R′
= B (e^ρ, e^ρ)
K_A =(+4,4)
New 1st baseline
G
P
K₂ = L′
= B (e^−ρ, −e^−ρ)
K_B =(-1,1)
Atom per-space
ck′
Halved 3rd base distance
Doubled 1st base distance



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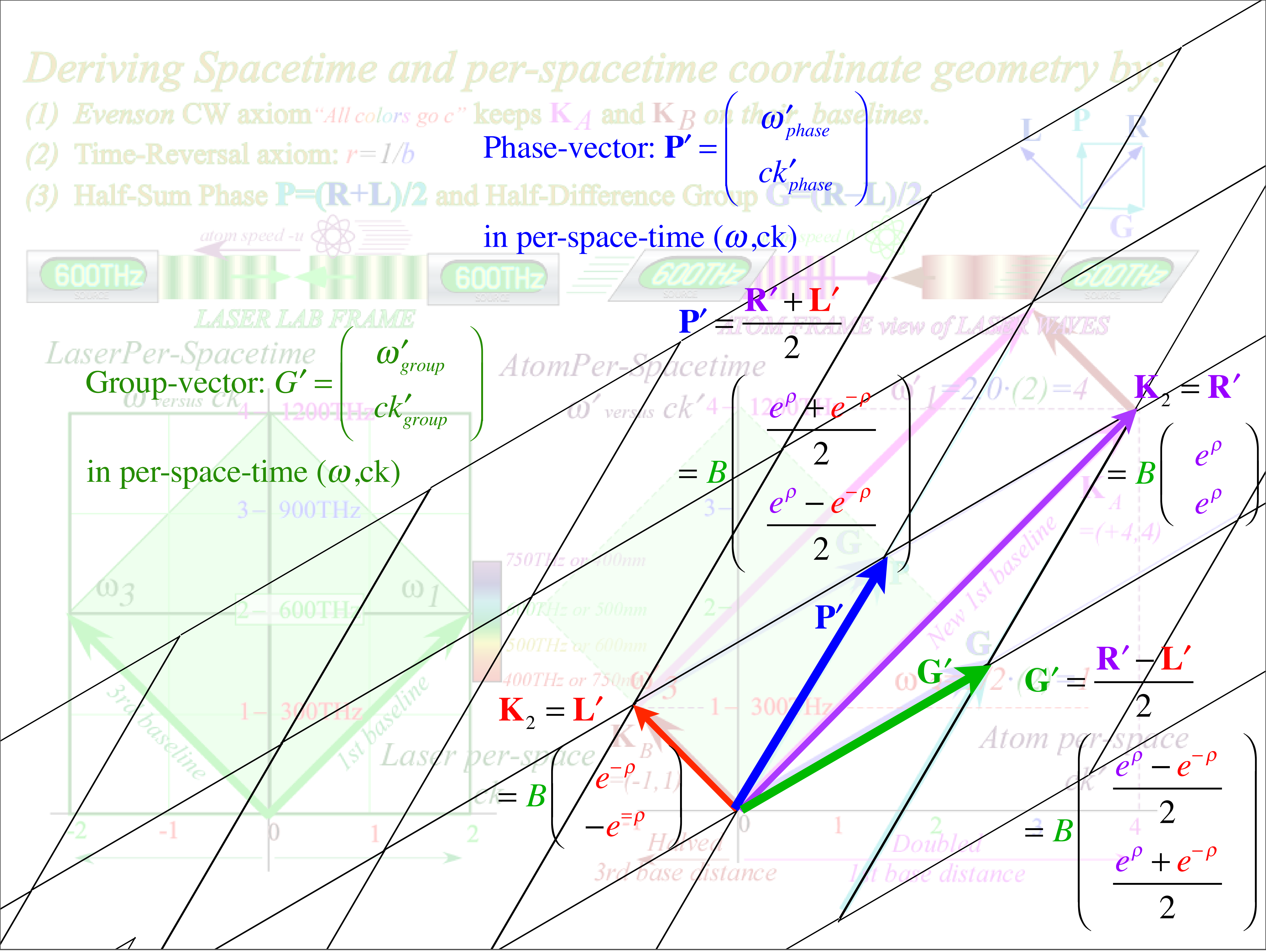
Phase-vector: P′ = (ω′_phase, ck′_phase)
in per-space-time (ω,ck)
P′ = (R′ + L′)/2
= B ((e^ρ + e^−ρ)/2, (e^ρ − e^−ρ)/2)
K_2 = R′
= B (e^ρ, e^ρ)
K_2 = L′
= B (e^−ρ, −e^=ρ)
P′
LASER LAB FRAME
ATOM FRAME view of LASER WAVES
LaserPer-Spacetime
AtomPer-Spacetime
600THz
New 1st baseline
Halved 3rd base distance
Doubled 1st base distance
Atom per-space
Laser per-space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Phase-vector: $\mathbf{P}' = \begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix}$
in per-space-time (ω,ck)
Group-vector: $G' = \begin{pmatrix} \omega'_{group} \\ ck'_{group} \end{pmatrix}$
in per-space-time (ω,ck)
$\mathbf{P}' = \dfrac{\mathbf{R}' + \mathbf{L}'}{2} = B \begin{pmatrix} \dfrac{e^{\rho} + e^{-\rho}}{2} \\ \dfrac{e^{\rho} - e^{-\rho}}{2} \end{pmatrix}$
$\mathbf{K}_2 = \mathbf{R}' = B \begin{pmatrix} e^{\rho} \\ e^{\rho} \end{pmatrix}$
$\mathbf{K}_2 = \mathbf{L}' = B \begin{pmatrix} e^{-\rho} \\ -e^{-\rho} \end{pmatrix}$
$\mathbf{G}' = \dfrac{\mathbf{R}' - \mathbf{L}'}{2} = B \begin{pmatrix} \dfrac{e^{\rho} - e^{-\rho}}{2} \\ \dfrac{e^{\rho} + e^{-\rho}}{2} \end{pmatrix}$
P′
G′
LASER LAB FRAME
ATOM FRAME view of LASER WAVES
LaserPer-Spacetime
AtomPer-Spacetime
New 1st baseline
Atom per-space
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Doubled 1st base distance

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in per-space-time (ω,ck)

Group-vector: $G' = \begin{pmatrix} \omega'_{group} \\ ck'_{group} \end{pmatrix}$

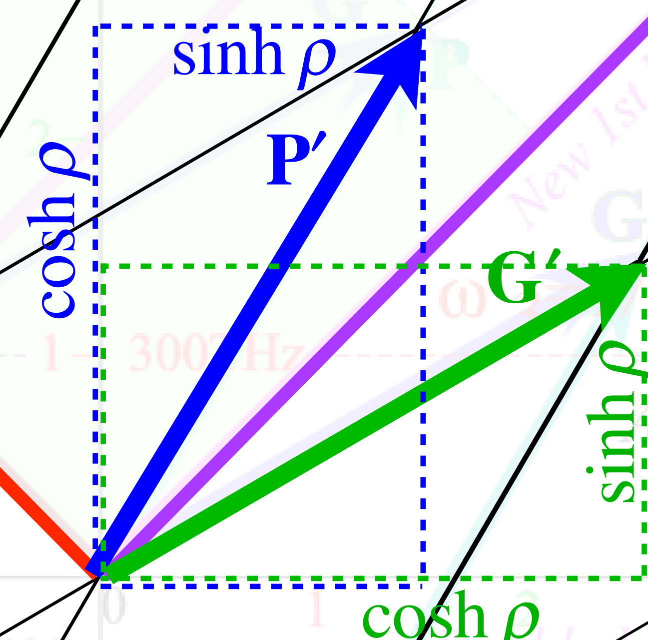
in per-space-time (ω,ck)

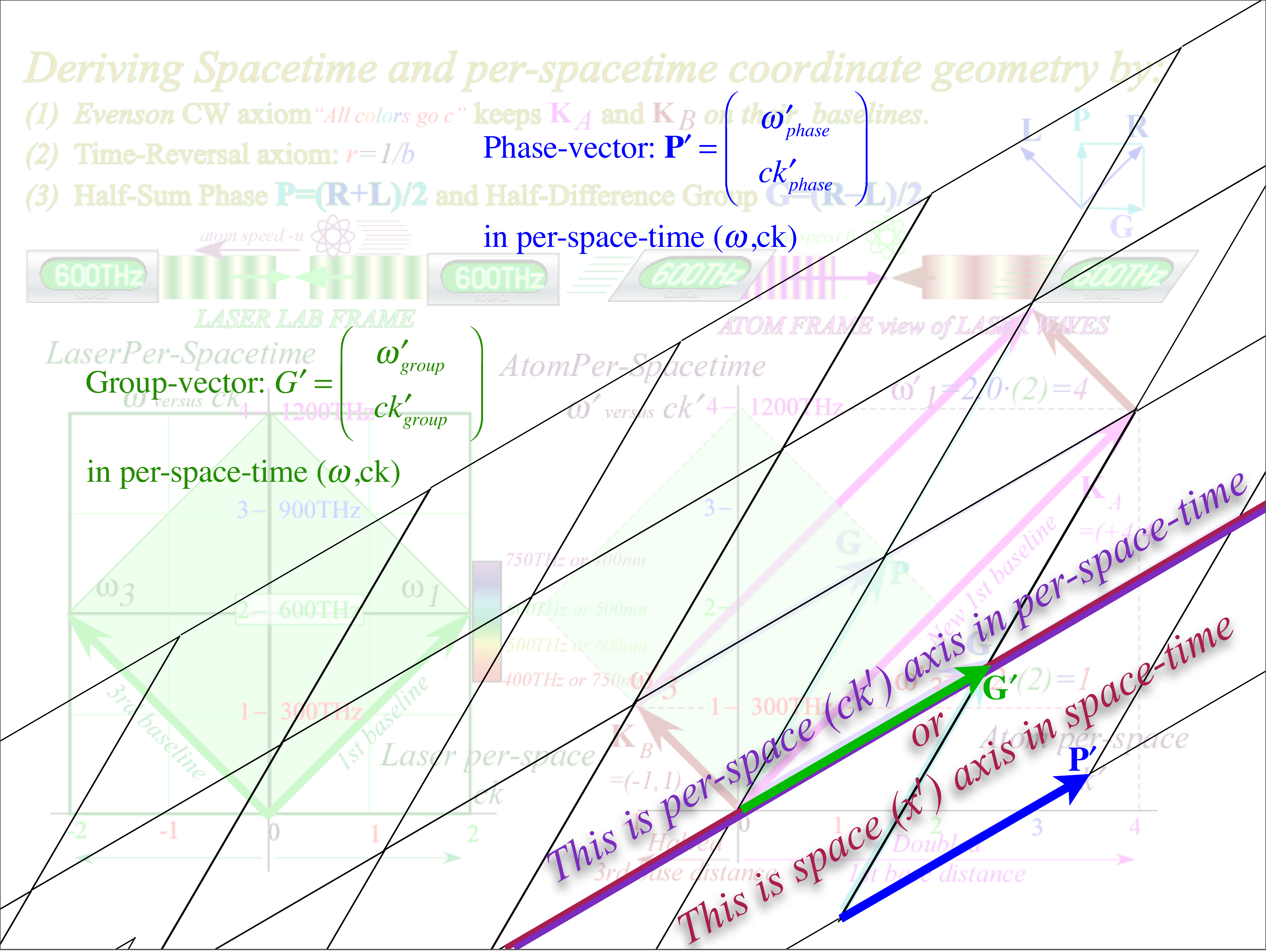
$$\mathbf{P}' = \frac{\mathbf{R}' + \mathbf{L}'}{2} = B \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix}$$

$$\mathbf{K}_2 = \mathbf{R}' = B \begin{pmatrix} e^{\rho} \\ e^{\rho} \end{pmatrix}$$

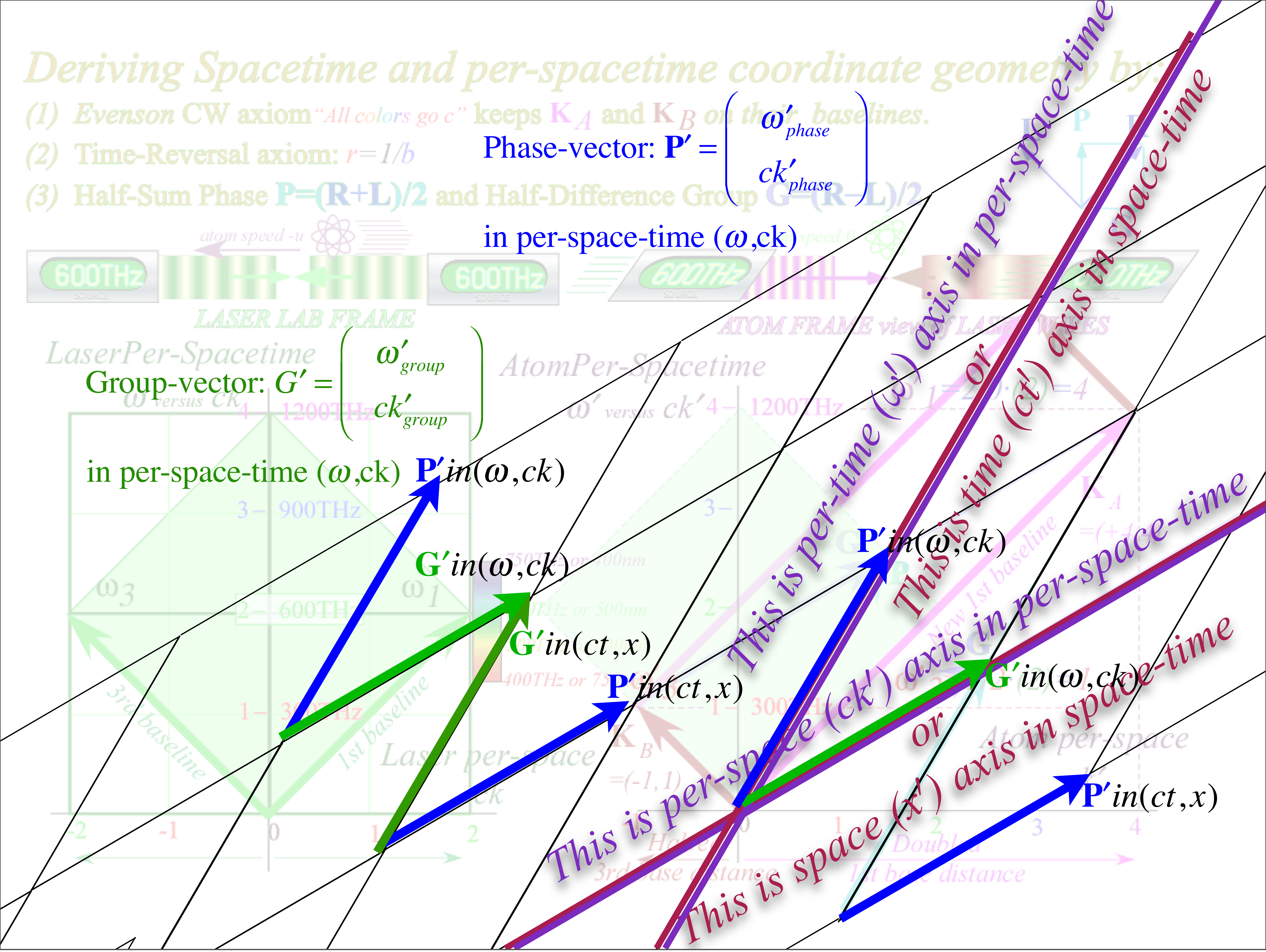
$$\mathbf{G}' = \frac{\mathbf{R}' - \mathbf{L}'}{2} = B \begin{pmatrix} \sinh\rho \\ \cosh\rho \end{pmatrix}$$

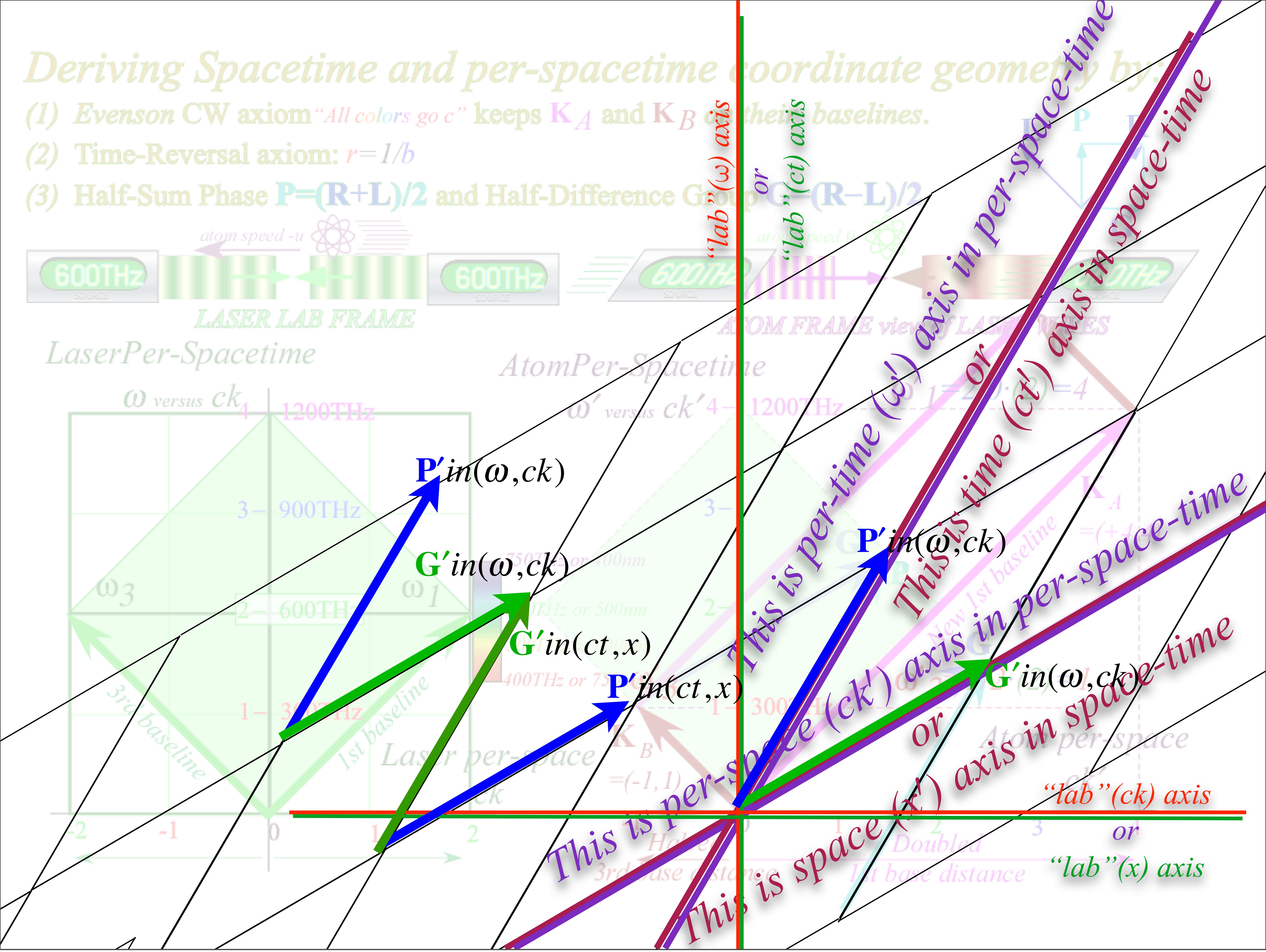
$$\mathbf{K}_2 = \mathbf{L}' = B \begin{pmatrix} e^{-\rho} \\ -e^{=\rho} \end{pmatrix}$$





Deriving Spacetime and per-spacetime coordinate geometry by:
(1) Evenson CW axiom "All colors go c" keeps K_A and K_B on their baselines.
(2) Time-Reversal axiom: r=1/b
(3) Half-Sum Phase P=(R+L)/2 and Half-Difference Group G=(R−L)/2
Phase-vector: $\mathbf{P}' = \begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix}$
in per-space-time (ω,ck)
Group-vector: $G' = \begin{pmatrix} \omega'_{group} \\ ck'_{group} \end{pmatrix}$
in per-space-time (ω,ck)
LASER LAB FRAME
ATOM FRAME view of LASER WAVES
LaserPer-Spacetime
AtomPer-Spacetime
600THz
1200THz
900THz
600THz
300THz
750THz or 400nm
600THz or 500nm
500THz or 600nm
400THz or 750nm
3rd baseline
1st baseline
New 1st baseline
Laser per-space
Atom per-space
This is per-space (ck′) axis in per-space-time
or
This is space (x′) axis in space-time
G′
P′


Deriving Spacetime and per-spacetime coordinate geometry by:
(1) Evenson CW axiom "All colors go c" keeps K_A and K_B on their baselines.
(2) Time-Reversal axiom: r=1/b
(3) Half-Sum Phase P=(R+L)/2 and Half-Difference Group G=(R-L)/2
Phase-vector: P′ = (ω′_phase, ck′_phase)
in per-space-time (ω,ck)
Group-vector: G′ = (ω′_group, ck′_group)
in per-space-time (ω,ck)
LASER LAB FRAME
ATOM FRAME view of LASER WAVES
LaserPer-Spacetime
AtomPer-Spacetime
P′ in(ω,ck)
G′ in(ω,ck)
G′ in(ct,x)
P′ in(ct,x)
This is per-time (ω′) axis in per-space-time
or
This is time (ct′) axis in space-time
This is per-space (ck′) axis in per-space-time
or
This is space (x′) axis in space-time
Laser per-space
Atom per-space
3rd baseline
1st baseline
New 1st baseline
600THz
1200THz
900THz
300THz



P′in(ω,ck)
G′in(ω,ck)
G′in(ct,x)
P′in(ct,x)
P′in(ω,ck)
G′in(ω,ck)
"lab"(ω) axis
or
"lab"(ct) axis
"lab"(ck) axis
or
"lab"(x) axis
This is per-time (ω′) axis in per-space-time
or
This is time (ct′) axis in space-time
This is per-space (ck′) axis in per-space-time
or
This is space (x′) axis in space-time
LaserPer-Spacetime
AtomPer-Spacetime
LASER LAB FRAME
Laser per-space
Atom per-space

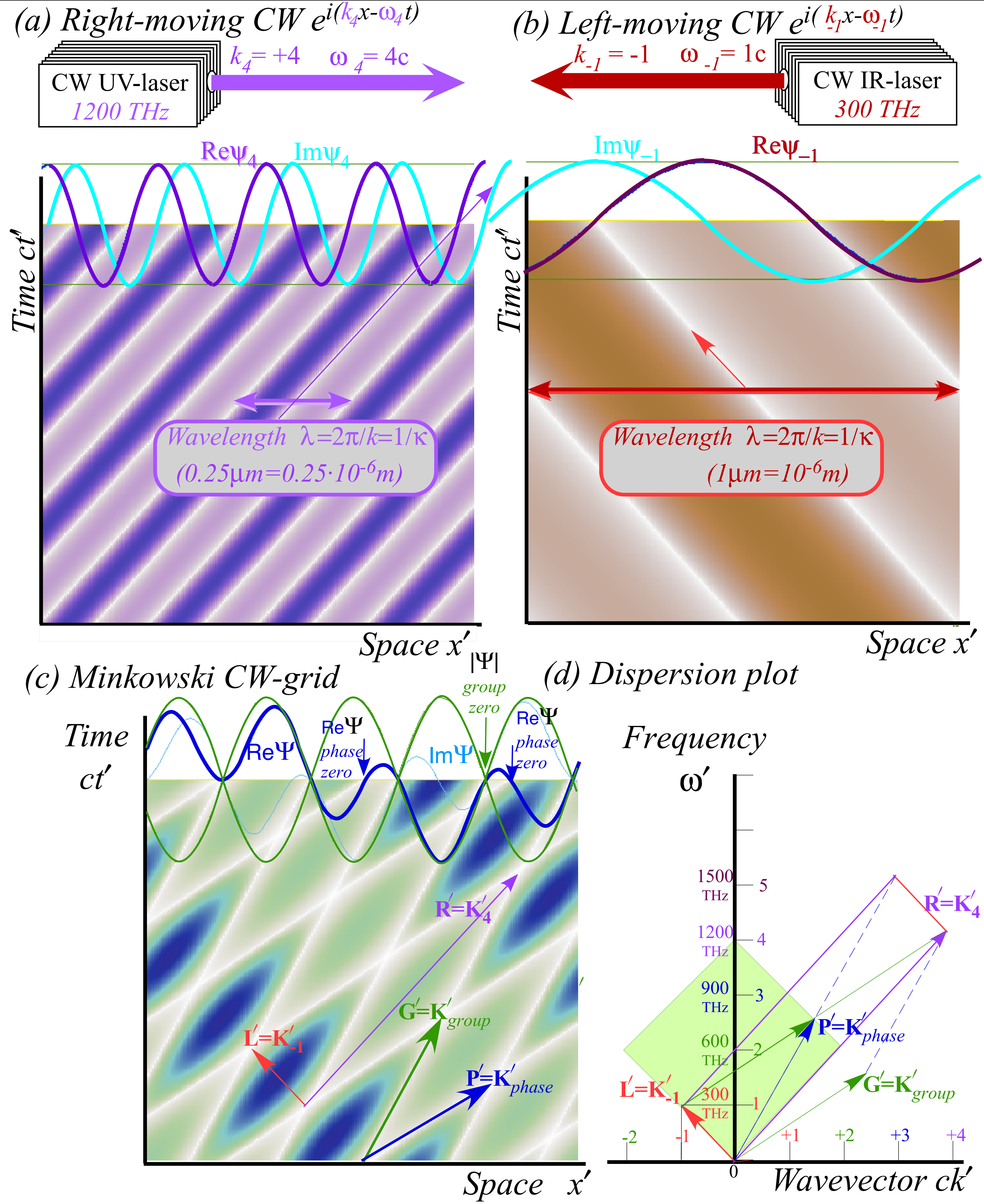
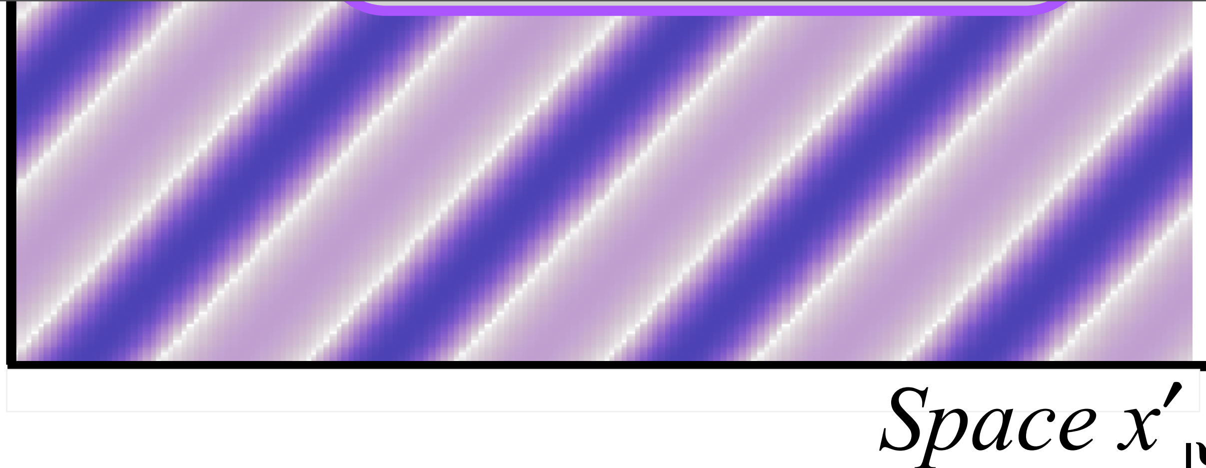
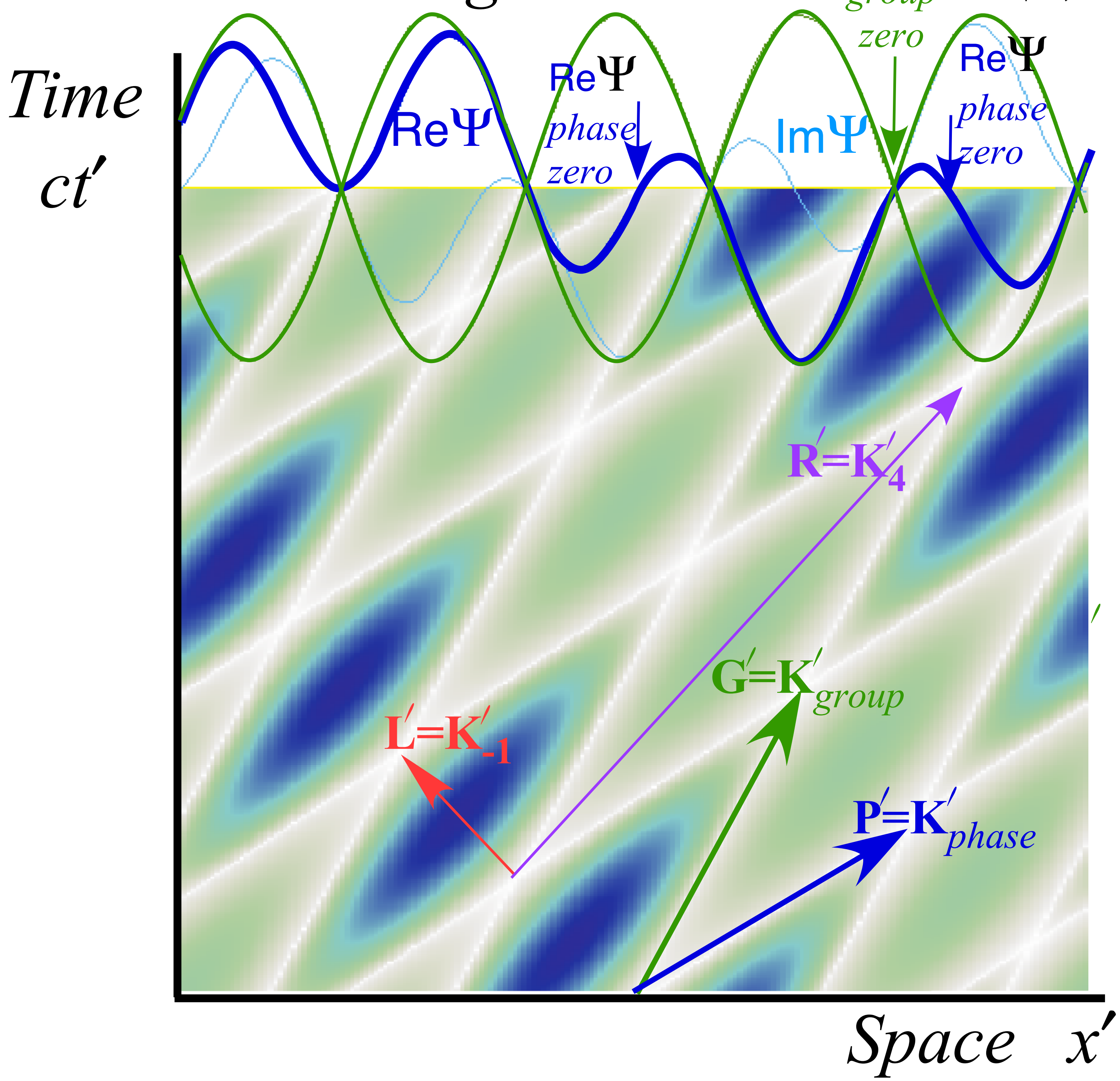


Fig. 9 in SR&QM

recall also:
p. 3-11 of Lect.1



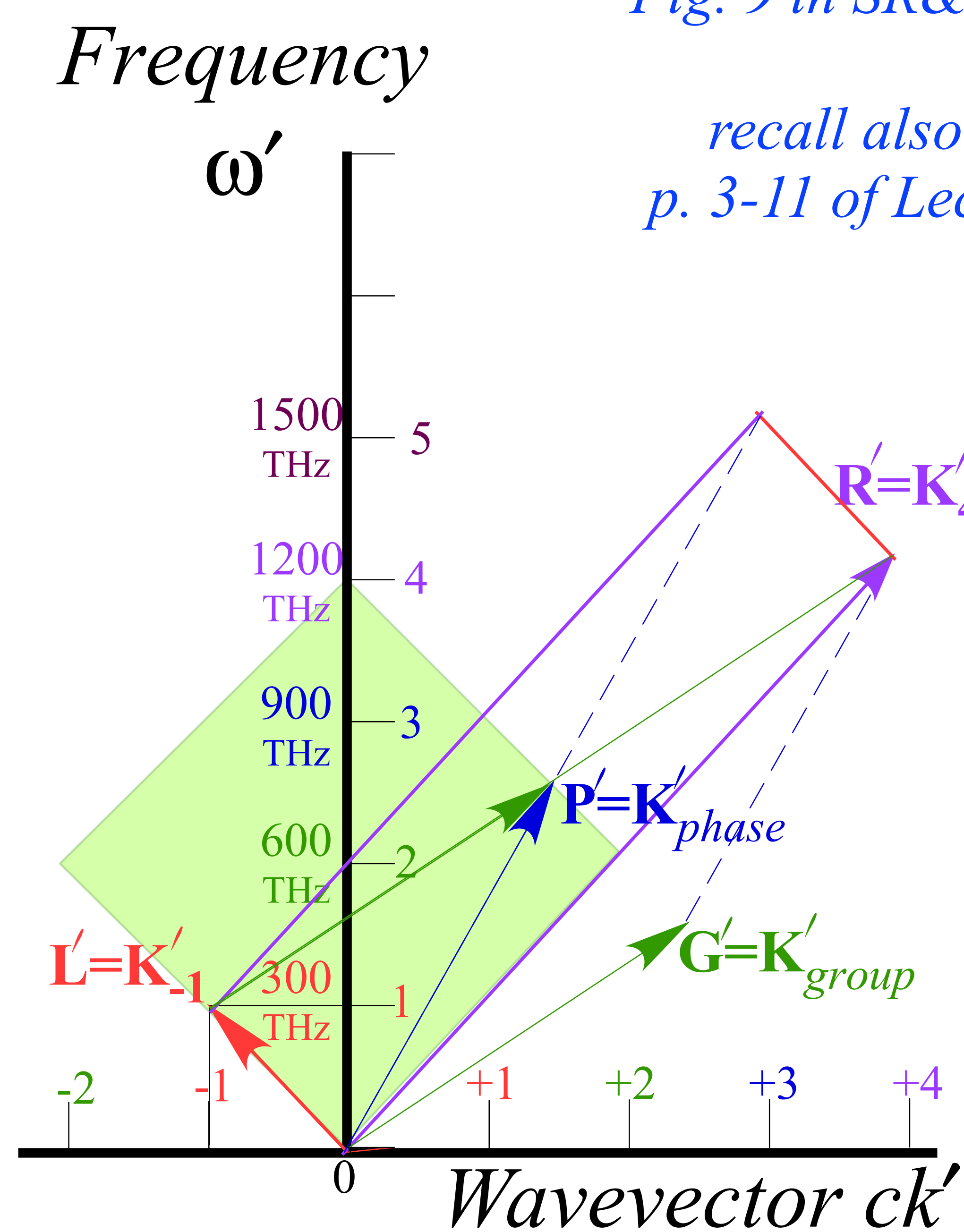
(c) Minkowski CW-grid



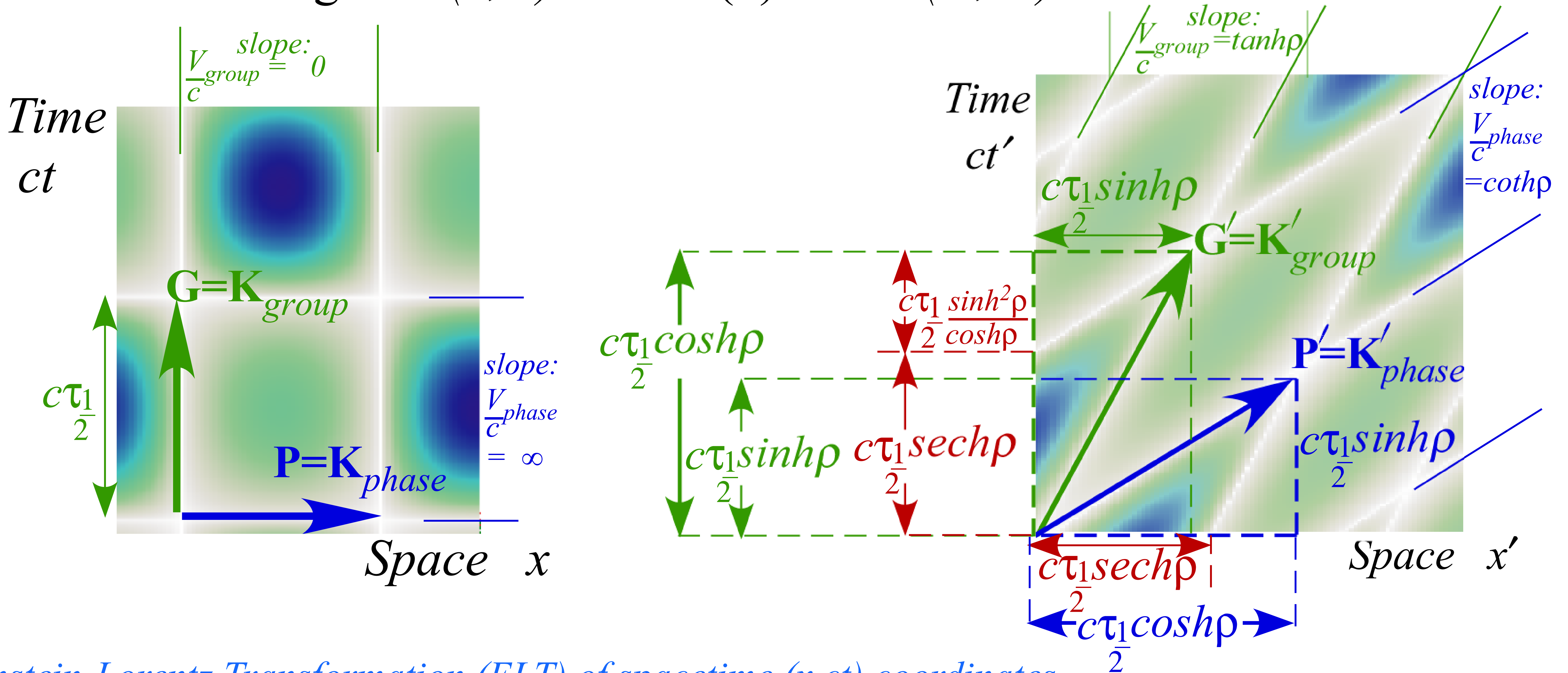
(d) Dispersion plot

Fig. 9 in SR&QM

recall also:
p. 3-11 of Lect.1



(a) Alice's standing CW *(x,ct)* frame (b) Bob's *(x′,ct′)* view



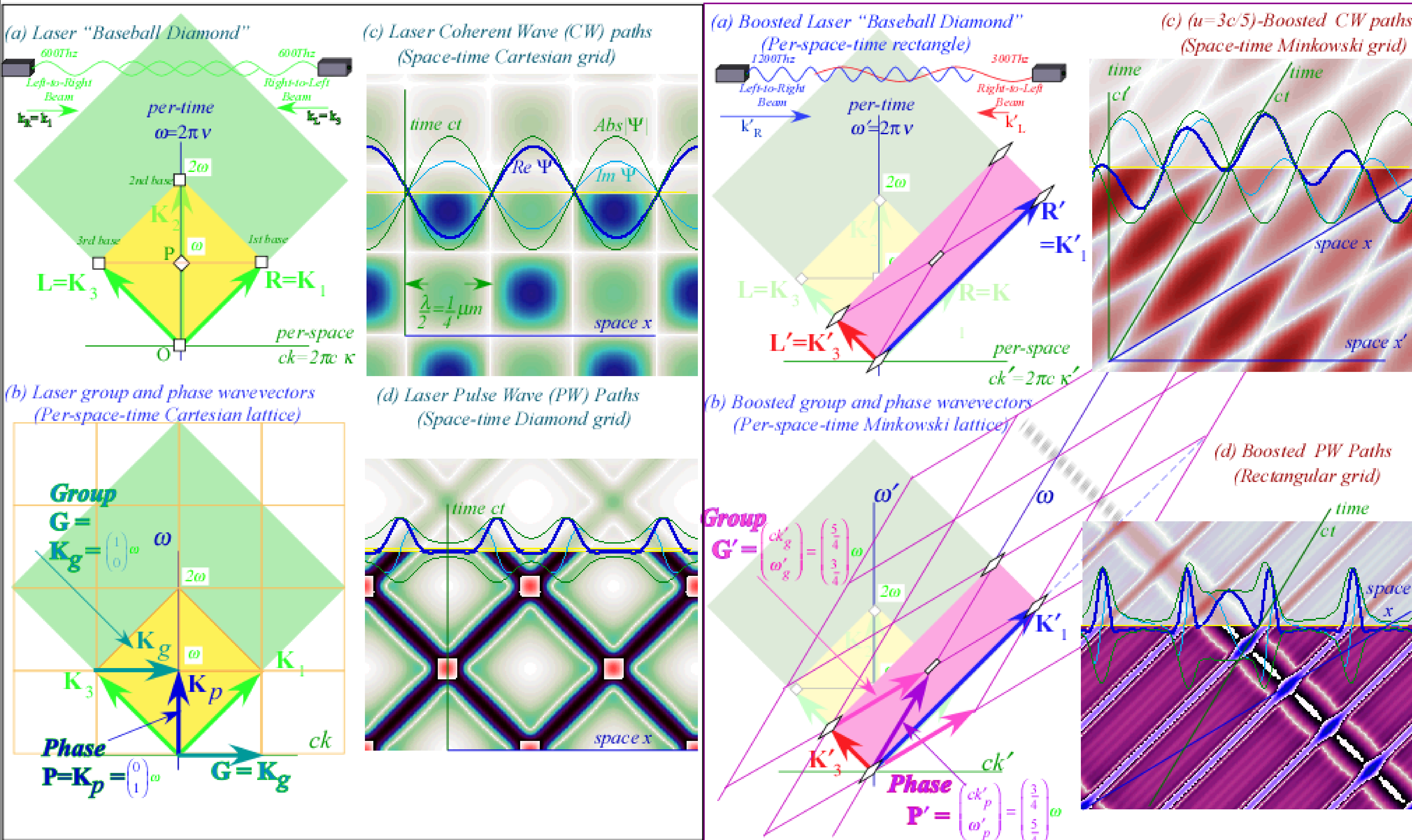
Einstein-Lorentz Transformation (ELT) of spacetime (x,ct) coordinates...

$$\begin{pmatrix} x'_{(any)} \\ ct'_{(any)} \end{pmatrix}_B = \begin{pmatrix} \cosh\rho & \sinh\rho \\ \sinh\rho & \cosh\rho \end{pmatrix} \begin{pmatrix} x_{(any)} \\ ct_{(any)} \end{pmatrix}_A \Leftrightarrow \begin{pmatrix} x_{(any)} \\ ct_{(any)} \end{pmatrix}_A = \begin{pmatrix} \cosh\rho & -\sinh\rho \\ -\sinh\rho & \cosh\rho \end{pmatrix} \begin{pmatrix} x'_{(any)} \\ ct'_{(any)} \end{pmatrix}_B$$

...is based upon the same ELT of per-spacetime (ck,ω) coordinates...

Old-fashioned notation (discussed below)

$$\begin{pmatrix} \omega'_{(any)} \\ ck'_{(any)} \end{pmatrix}_B = \begin{pmatrix} \cosh\rho & \sinh\rho \\ \sinh\rho & \cosh\rho \end{pmatrix} \begin{pmatrix} \omega_{(any)} \\ ck_{(any)} \end{pmatrix}_A \quad \text{where:} \begin{pmatrix} \cosh\rho & \sinh\rho \\ \sinh\rho & \cosh\rho \end{pmatrix} = \begin{pmatrix} \gamma & \beta\cdot\gamma \\ \beta\cdot\gamma & \gamma \end{pmatrix}$$



Laser lab views

atom speed $-u=-\frac{3}{5}c$

Atom views (sees lab going $+u=\frac{3}{5}c$)

3. Spectral theory of Einstein-Lorentz relativity

Applying Doppler Shifts to per-space-time (ck,ω) graph

CW Minkowski space-time coordinates (x,ct) and PW grids

Relating Doppler Shifts b or $r=1/b$ to velocity u/c or rapidity ρ

Lorentz transformation

Connection: Conventional approach to relativity and old-fashioned formulas

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix} = \mathbf{P}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}+e^{-\rho}}{2} \\ \frac{e^{\rho}-e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{5}{4} \\ \frac{3}{4} \end{pmatrix}$$

$$\begin{pmatrix} \omega'_{group} \\ ck'_{group} \end{pmatrix} = \mathbf{G}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}-e^{-\rho}}{2} \\ \frac{e^{\rho}+e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \sinh\rho \\ \cosh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{3}{4} \\ \frac{5}{4} \end{pmatrix}$$

Connection to conventional approach to relativity and old-fashioned formulas

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Calculate phase velocity and group velocity of coordinate waves:

$$\frac{V_{phase}}{c} = \frac{\omega'_{phase}}{ck'_{phase}} = \frac{\cosh\rho}{\sinh\rho} = \frac{5}{3} = \coth\rho$$

$$\frac{V_{group}}{c} = \frac{\omega'_{group}}{ck'_{group}} = \frac{\sinh\rho}{\cosh\rho} = \frac{3}{5} = \tanh\rho$$

$$\frac{V'_{group}}{c} = \frac{u}{c} = \tanh\rho = \frac{e^{\rho}-e^{-\rho}}{e^{\rho}+e^{-\rho}} = \frac{b-b^{-1}}{b+b^{-1}} = \frac{b^2-1}{b^2+1} \equiv \beta$$

old-fashioned relativity parameter $\beta = u/c$

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix}\omega'_{phase}\\ ck'_{phase}\end{pmatrix}=\mathbf{P}'=\frac{\mathbf{R}'+\mathbf{L}'}{2}=\omega_A\begin{pmatrix}\frac{e^{\rho}+e^{-\rho}}{2}\\ \frac{e^{\rho}-e^{-\rho}}{2}\end{pmatrix}=\omega_A\begin{pmatrix}\cosh\rho\\ \sinh\rho\end{pmatrix}=\omega_A\begin{pmatrix}\frac{5}{4}\\ \frac{3}{4}\end{pmatrix}$$

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$$\frac{V_{phase}}{c}=\frac{\omega'_{phase}}{ck'_{phase}}=\frac{\cosh\rho}{\sinh\rho}=\frac{5}{3}=\coth\rho$$

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old-fashioned relativity parameter β=u/c

Solve $\frac{b^2-1}{b^2+1}\equiv\beta$ *for Doppler-blue factor:*

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix} = \mathbf{P}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}+e^{-\rho}}{2} \\ \frac{e^{\rho}-e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{5}{4} \\ \frac{3}{4} \end{pmatrix}$$

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Calculate phase velocity *and* *group velocity of coordinate waves:*

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old-fashioned relativity parameter $\beta = u/c$

$$b^2 - 1 = \beta b^2 + \beta$$

$$b^2 - \beta b^2 = 1 + \beta$$

Solve $\frac{b^2-1}{b^2+1} \equiv \beta$ *for Doppler-blue factor:*

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix} = \mathbf{P}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}+e^{-\rho}}{2} \\ \frac{e^{\rho}-e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{5}{4} \\ \frac{3}{4} \end{pmatrix}$$

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old-fashioned relativity parameter $\beta = u/c$

$$b^2-1=\beta b^2+\beta$$

$$b^2-\beta b^2=1+\beta$$

$$b^2=\frac{1+\beta}{1-\beta}$$

Solve $\frac{b^2-1}{b^2+1}\equiv\beta$ *for Doppler-blue factor:*

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix} = \mathbf{P}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}+e^{-\rho}}{2} \\ \frac{e^{\rho}-e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{5}{4} \\ \frac{3}{4} \end{pmatrix}$$

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$$\frac{V'_{group}}{c} = \frac{u}{c} = \tanh\rho = \frac{e^{\rho}-e^{-\rho}}{e^{\rho}+e^{-\rho}} = \frac{b-b^{-1}}{b+b^{-1}} = \frac{b^2-1}{b^2+1} \equiv \beta$$

old-fashioned relativity parameter $\beta = u/c$

$$b^2-1=\beta b^2+\beta$$

$$b^2-\beta b^2=1+\beta \qquad b^2=\frac{1+\beta}{1-\beta}$$

Solve $\frac{b^2-1}{b^2+1}\equiv\beta$ *for Doppler-blue factor:* $b=\sqrt{\frac{1+\beta}{1-\beta}}=\sqrt{\frac{1+u/c}{1-u/c}}=\frac{1+u/c}{\sqrt{1-u^2/c^2}}\equiv\frac{1+\beta}{\lambda}$

old-fashioned Lorentz x-contraction parameter $\lambda=\sqrt{1-u^2/c^2}$

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix} = \mathbf{P}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}+e^{-\rho}}{2} \\ \frac{e^{\rho}-e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{5}{4} \\ \frac{3}{4} \end{pmatrix}$$

$$\begin{pmatrix} \omega'_{group} \\ ck'_{group} \end{pmatrix} = \mathbf{G}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}-e^{-\rho}}{2} \\ \frac{e^{\rho}+e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \sinh\rho \\ \cosh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{3}{4} \\ \frac{5}{4} \end{pmatrix}$$

Calculate phase velocity and group velocity of coordinate waves:

$$\frac{V_{phase}}{c} = \frac{\omega'_{phase}}{ck'_{phase}} = \frac{\cosh\rho}{\sinh\rho} = \frac{5}{3} = \coth\rho$$

$$\frac{V_{group}}{c} = \frac{\omega'_{group}}{ck'_{group}} = \frac{\sinh\rho}{\cosh\rho} = \frac{3}{5} = \tanh\rho$$

$$b^2 = \frac{1+\beta}{1-\beta}$$

$$\frac{V'_{group}}{c} = \frac{u}{c} = \tanh\rho = \frac{e^{\rho}-e^{-\rho}}{e^{\rho}+e^{-\rho}} = \frac{b-b^{-1}}{b+b^{-1}} = \frac{b^2-1}{b^2+1} \equiv \beta$$

old-fashioned relativity parameter
$\beta = u/c$

Solve $\frac{b^2-1}{b^2+1} \equiv \beta$ *for Doppler-blue factor:*

$$b = \sqrt{\frac{1+\beta}{1-\beta}} = \sqrt{\frac{1+u/c}{1-u/c}} = \frac{1+u/c}{\sqrt{1-u^2/c^2}} \equiv \frac{1+\beta}{\lambda}$$

old-fashioned Lorentz x-contraction parameter
$\lambda = \sqrt{1-u^2/c^2}$

Convert Lorentz parameter to hyper-function: $\lambda \equiv \sqrt{1-u^2/c^2}$

$$= \sqrt{1-\tanh^2\rho} = \operatorname{sech}\rho = \frac{1}{\cosh\rho} \equiv \frac{1}{\gamma}$$

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix} = \mathbf{P}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}+e^{-\rho}}{2} \\ \frac{e^{\rho}-e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{5}{4} \\ \frac{3}{4} \end{pmatrix}$$

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Calculate phase velocity and group velocity of coordinate waves:

$$\frac{V_{phase}}{c} = \frac{\omega'_{phase}}{ck'_{phase}} = \frac{\cosh\rho}{\sinh\rho} = \frac{5}{3} = \coth\rho$$

$$\frac{V_{group}}{c} = \frac{\omega'_{group}}{ck'_{group}} = \frac{\sinh\rho}{\cosh\rho} = \frac{3}{5} = \tanh\rho$$

$$b^2 = \frac{1+\beta}{1-\beta}$$

$$\frac{V'_{group}}{c} = \frac{u}{c} = \tanh\rho = \frac{e^{\rho}-e^{-\rho}}{e^{\rho}+e^{-\rho}} = \frac{b-b^{-1}}{b+b^{-1}} = \frac{b^2-1}{b^2+1} \equiv \beta$$

old-fashioned relativity parameter
β=u/c

Solve $\frac{b^2-1}{b^2+1} \equiv \beta$ *for Doppler-blue factor:* $b = \sqrt{\frac{1+\beta}{1-\beta}} = \sqrt{\frac{1+u/c}{1-u/c}} = \frac{1+u/c}{\sqrt{1-u^2/c^2}} \equiv \frac{1+\beta}{\lambda}$

old-fashioned Lorentz x-contraction parameter
$\lambda = \sqrt{1-u^2/c^2}$

Convert Lorentz parameter to hyper-function: $\lambda \equiv \sqrt{1-u^2/c^2}$

$$= \sqrt{1-\tanh^2\rho} = \operatorname{sech}\rho = \frac{1}{\cosh\rho} \equiv \frac{1}{\gamma}$$

old-fashioned Einstein t-dilation parameter
$\gamma = \frac{1}{\sqrt{1-u^2/c^2}}$

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix} = \mathbf{P}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}+e^{-\rho}}{2} \\ \frac{e^{\rho}-e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{5}{4} \\ \frac{3}{4} \end{pmatrix}$$

$$\begin{pmatrix} \omega'_{group} \\ ck'_{group} \end{pmatrix} = \mathbf{G}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}-e^{-\rho}}{2} \\ \frac{e^{\rho}+e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \sinh\rho \\ \cosh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{3}{4} \\ \frac{5}{4} \end{pmatrix}$$

Calculate phase velocity and group velocity of coordinate waves:

$$\frac{V_{phase}}{c} = \frac{\omega'_{phase}}{ck'_{phase}} = \frac{\cosh\rho}{\sinh\rho} = \frac{5}{3} = \coth\rho$$

$$\frac{V_{group}}{c} = \frac{\omega'_{group}}{ck'_{group}} = \frac{\sinh\rho}{\cosh\rho} = \frac{3}{5} = \tanh\rho$$

$$b^2 = \frac{1+\beta}{1-\beta}$$

$$\frac{V'_{group}}{c} = \frac{u}{c} = \tanh\rho = \frac{e^{\rho}-e^{-\rho}}{e^{\rho}+e^{-\rho}} = \frac{b-b^{-1}}{b+b^{-1}} = \frac{b^2-1}{b^2+1} \equiv \beta$$

old-fashioned relativity parameter
$\beta = u/c = \tanh\rho$

Solve $\frac{b^2-1}{b^2+1} \equiv \beta$ *for Doppler-blue factor:*

$$b = \sqrt{\frac{1+\beta}{1-\beta}} = \sqrt{\frac{1+u/c}{1-u/c}} = \frac{1+u/c}{\sqrt{1-u^2/c^2}} \equiv \frac{1+\beta}{\lambda}$$

old-fashioned Lorentz x-contraction parameter
$\lambda = \sqrt{1-u^2/c^2} = \operatorname{sech}\rho$

Convert Lorentz parameter to hyper-function: $\lambda \equiv \sqrt{1-u^2/c^2}$

$$= \sqrt{1-\tanh^2\rho} = \operatorname{sech}\rho = \frac{1}{\cosh\rho} \equiv \frac{1}{\gamma}$$

old-fashioned Einstein t-dilation parameter
$\frac{1}{\lambda} = \gamma = \frac{1}{\sqrt{1-u^2/c^2}} = \cosh\rho$

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix}\omega'_{phase}\\ ck'_{phase}\end{pmatrix}=\mathbf{P}'=\frac{\mathbf{R}'+\mathbf{L}'}{2}=\omega_A\begin{pmatrix}\frac{e^{\rho}+e^{-\rho}}{2}\\ \frac{e^{\rho}-e^{-\rho}}{2}\end{pmatrix}=\omega_A\begin{pmatrix}\cosh\rho\\ \sinh\rho\end{pmatrix}=\omega_A\begin{pmatrix}\frac{5}{4}\\ \frac{3}{4}\end{pmatrix}$$

$$\begin{pmatrix}\omega'_{group}\\ ck'_{group}\end{pmatrix}=\mathbf{G}'=\frac{\mathbf{R}'+\mathbf{L}'}{2}=\omega_A\begin{pmatrix}\frac{e^{\rho}-e^{-\rho}}{2}\\ \frac{e^{\rho}+e^{-\rho}}{2}\end{pmatrix}=\omega_A\begin{pmatrix}\sinh\rho\\ \cosh\rho\end{pmatrix}=\omega_A\begin{pmatrix}\frac{3}{4}\\ \frac{5}{4}\end{pmatrix}$$

Calculate phase velocity and group velocity of coordinate waves:

$$\frac{V_{phase}}{c}=\frac{\omega'_{phase}}{ck'_{phase}}=\frac{\cosh\rho}{\sinh\rho}=\frac{5}{3}=\coth\rho$$

$$\frac{V_{group}}{c}=\frac{\omega'_{group}}{ck'_{group}}=\frac{\sinh\rho}{\cosh\rho}=\frac{3}{5}=\tanh\rho$$

$$b^2=\frac{1+\beta}{1-\beta}$$

$$\frac{V'_{group}}{c}=\frac{u}{c}=\tanh\rho=\frac{e^{\rho}-e^{-\rho}}{e^{\rho}+e^{-\rho}}=\frac{b-b^{-1}}{b+b^{-1}}=\frac{b^2-1}{b^2+1}\equiv\beta$$

old-fashioned relativity parameter $\beta=u/c=\tanh\rho$

Solve $\frac{b^2-1}{b^2+1}\equiv\beta$ *for Doppler-blue factor:* $b=\sqrt{\frac{1+\beta}{1-\beta}}=\sqrt{\frac{1+u/c}{1-u/c}}=\frac{1+u/c}{\sqrt{1-u^2/c^2}}\equiv\frac{1+\beta}{\lambda}$

old-fashioned Lorentz x-contraction parameter $\lambda=\sqrt{1-u^2/c^2}=\operatorname{sech}\rho$

Convert Lorentz parameter to hyper-function: $\lambda\equiv\sqrt{1-u^2/c^2}$

$$=\sqrt{1-\tanh^2\rho}=\operatorname{sech}\rho=\frac{1}{\cosh\rho}\equiv\frac{1}{\gamma}$$

Doppler-blue (again)

$$b=e^{\rho}=\cosh\rho+\sinh\rho=\frac{1+u/c}{\sqrt{1-u^2/c^2}}\equiv\frac{1+\beta}{\lambda}$$

old-fashioned Einstein t-dilation parameter $\frac{1}{\lambda}=\gamma=\frac{1}{\sqrt{1-u^2/c^2}}=\cosh\rho$

Connection to conventional approach to relativity and old-fashioned formulas

Given phase and group wave formulas:

$$\begin{pmatrix} \omega'_{phase} \\ ck'_{phase} \end{pmatrix} = \mathbf{P}' = \frac{\mathbf{R}'+\mathbf{L}'}{2} = \omega_A \begin{pmatrix} \frac{e^{\rho}+e^{-\rho}}{2} \\ \frac{e^{\rho}-e^{-\rho}}{2} \end{pmatrix} = \omega_A \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix} = \omega_A \begin{pmatrix} \frac{5}{4} \\ \frac{3}{4} \end{pmatrix}$$

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Calculate phase velocity and group velocity of coordinate waves:

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$$= \frac{1}{\lambda} + \frac{\beta}{\lambda} = \frac{1}{\sqrt{1-u^2/c^2}} + \frac{u/c}{\sqrt{1-u^2/c^2}}$$

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$\frac{1}{\lambda} = \gamma = \frac{1}{\sqrt{1-u^2/c^2}} = \cosh\rho$

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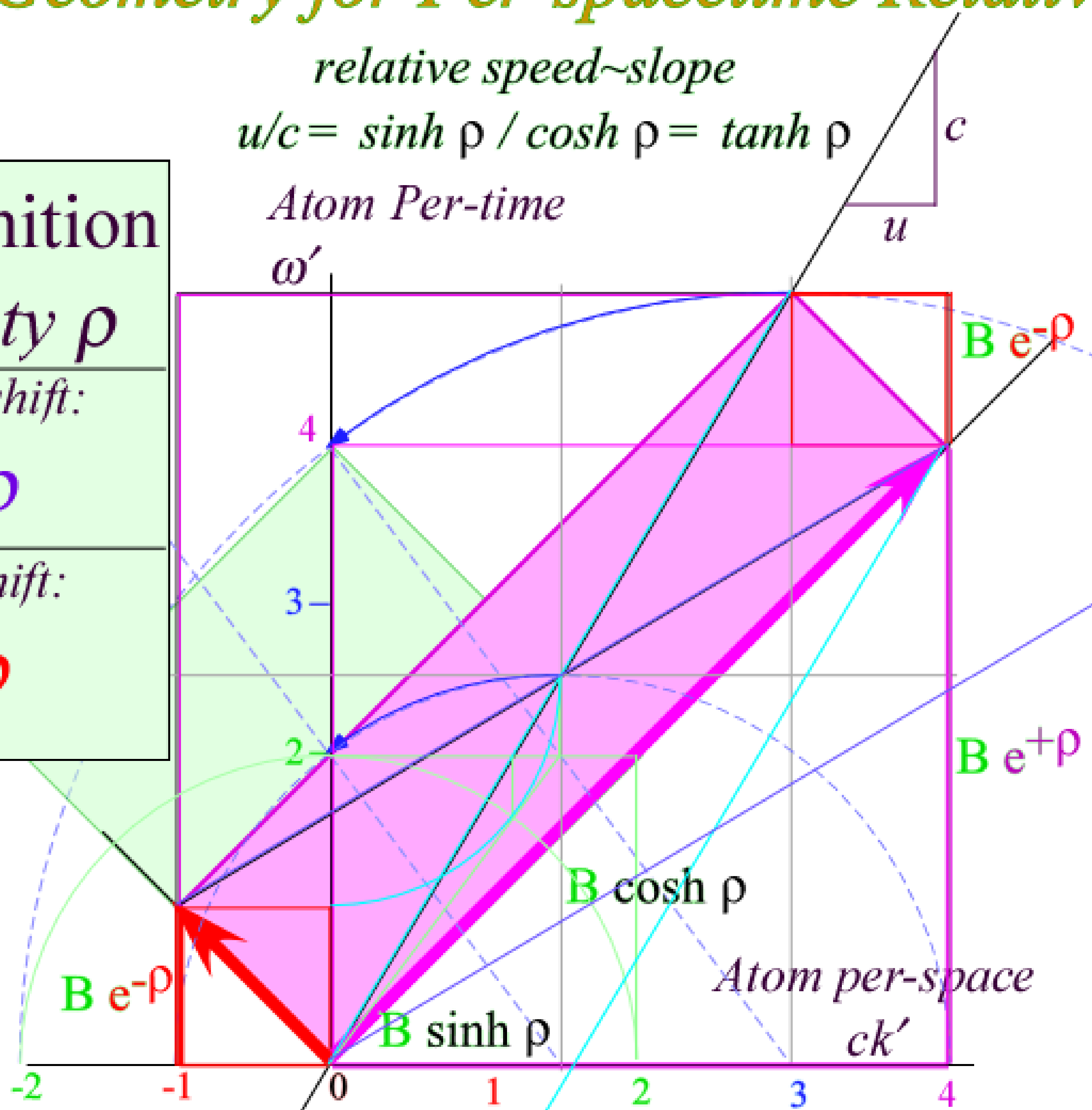
$$b = e^{\rho} = \cosh\rho + \sinh\rho = \frac{1+u/c}{\sqrt{1-u^2/c^2}} \equiv \frac{1+\beta}{\lambda}$$

$$= \frac{1}{\lambda} + \frac{\beta}{\lambda} = \frac{1}{\sqrt{1-u^2/c^2}} + \frac{u/c}{\sqrt{1-u^2/c^2}}$$

old-fashioned asimultaneity coeff. $\frac{u/c}{\sqrt{1-u^2/c^2}} = \sinh\rho$

old-fashioned Einstein t-dilation parameter $\frac{1}{\lambda} = \gamma = \frac{1}{\sqrt{1-u^2/c^2}} = \cosh\rho$

Euclidian Geometry for Per-spacetime Relativity



Key Definition of *Rapidity ρ*

Doppler blue shift:

$$Bb = Be^{+\rho}$$

Doppler red shift:

$$Br = Be^{-\rho}$$

Key Results:

ω *vs.* ck

"winks" vs. "kinks"

$$\omega = B \cosh\rho$$

$$ck = B \sinh\rho$$

group velocity:

$$\frac{\omega}{ck} = \frac{u}{c} = \tanh\rho$$

phase velocity:

$$\frac{ck}{\omega} = \frac{c}{u} = \coth\rho$$

$$B \sinh\rho = (B e^{+\rho} - B e^{-\rho})/2 \qquad B \cosh\rho = (B e^{+\rho} + B e^{-\rho})/2$$

$\sinh\rho = \dfrac{\frac{u}{c}}{\sqrt{1-\frac{u^2}{c^2}}}$	**Key Quantities** *Lorentz-Einstein factors*	$\cosh\rho = \dfrac{1}{\sqrt{1-\frac{u^2}{c^2}}}$

Related material at "per space-per-time" setting of: http://www.uark.edu/ua/modphys/testing/markup/RelaWavityWeb.html

Euclidian wave geometry with time-reversal symmetry imply

Lab frame area...

equals

r *Atom frame area...*

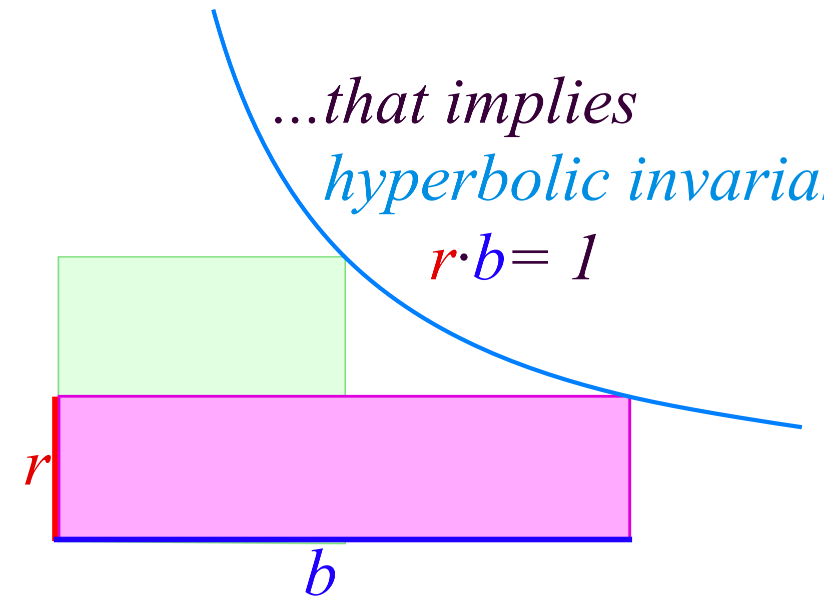
b

by time-reversal axiom: $r = 1/b$

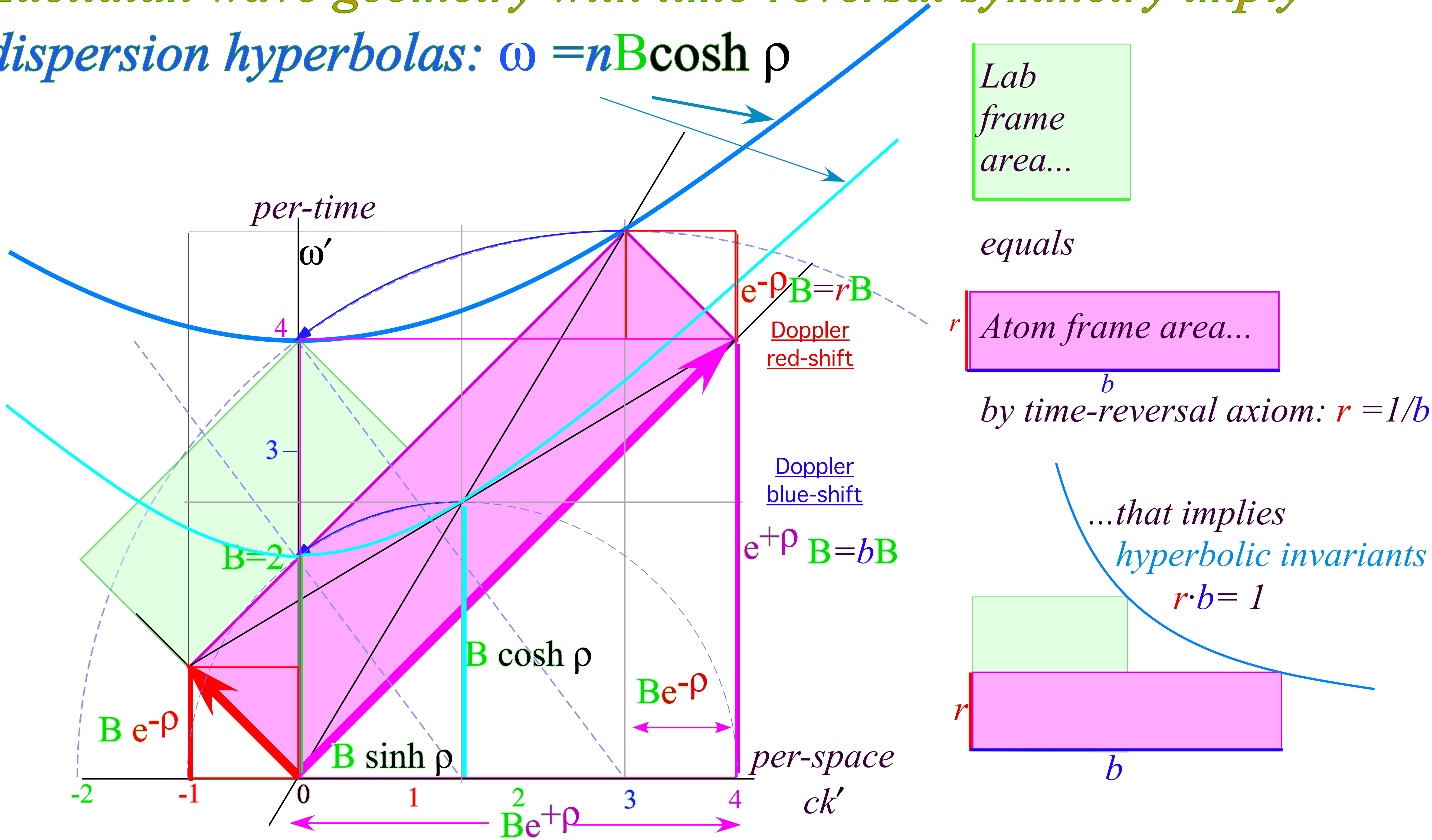
...that implies

hyperbolic invariants

$r \cdot b = 1$

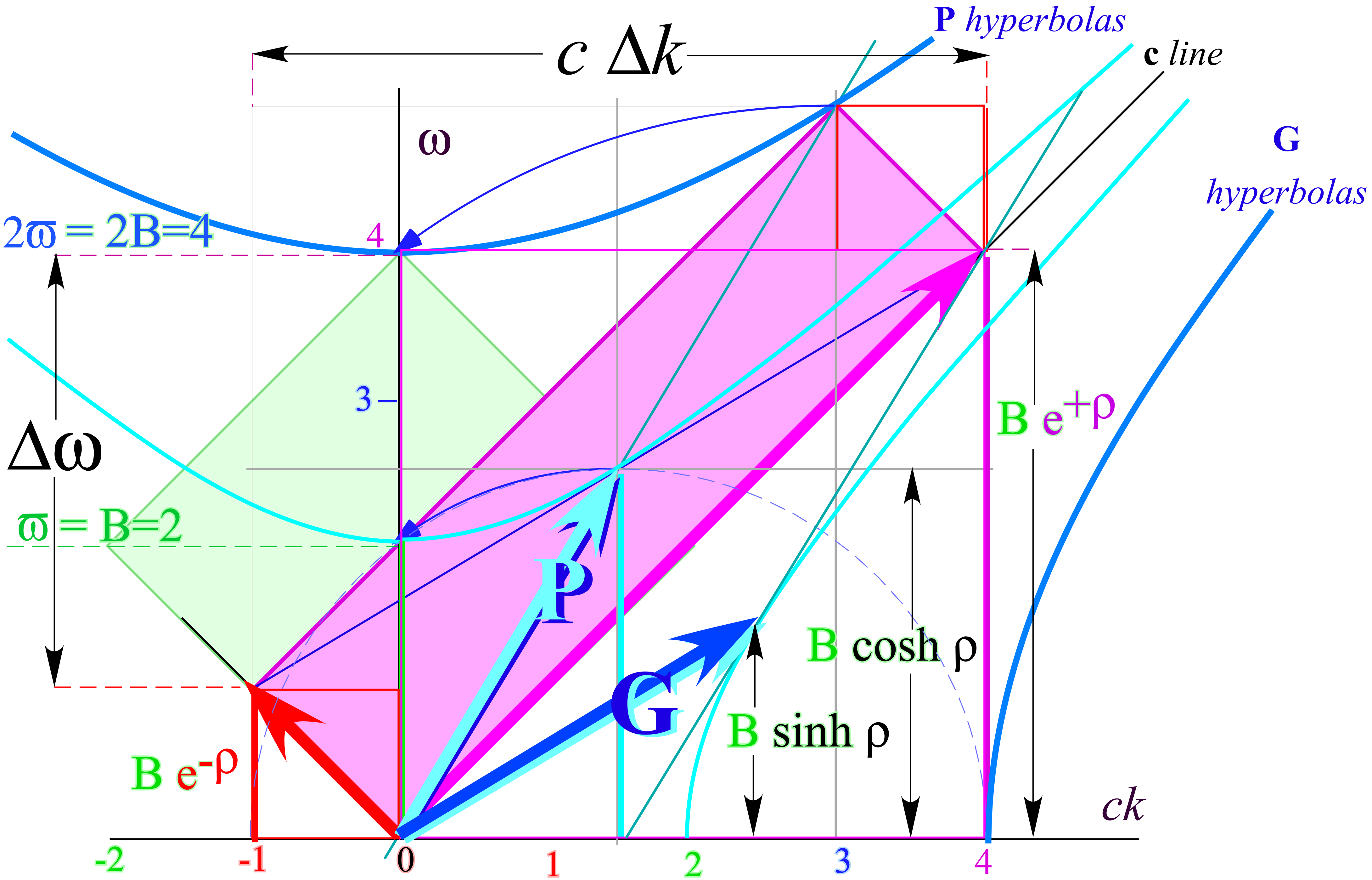


Euclidian wave geometry with time-reversal symmetry imply dispersion hyperbolas: $\omega = nB\cosh\rho$



$B\sinh\rho = (Be^{+\rho} - Be^{-\rho})/2$ $\qquad$ $B\cosh\rho = (Be^{+\rho} + Be^{-\rho})/2$

Group velocity u and phase velocity c^2/u are hyperbolic tangent slopes



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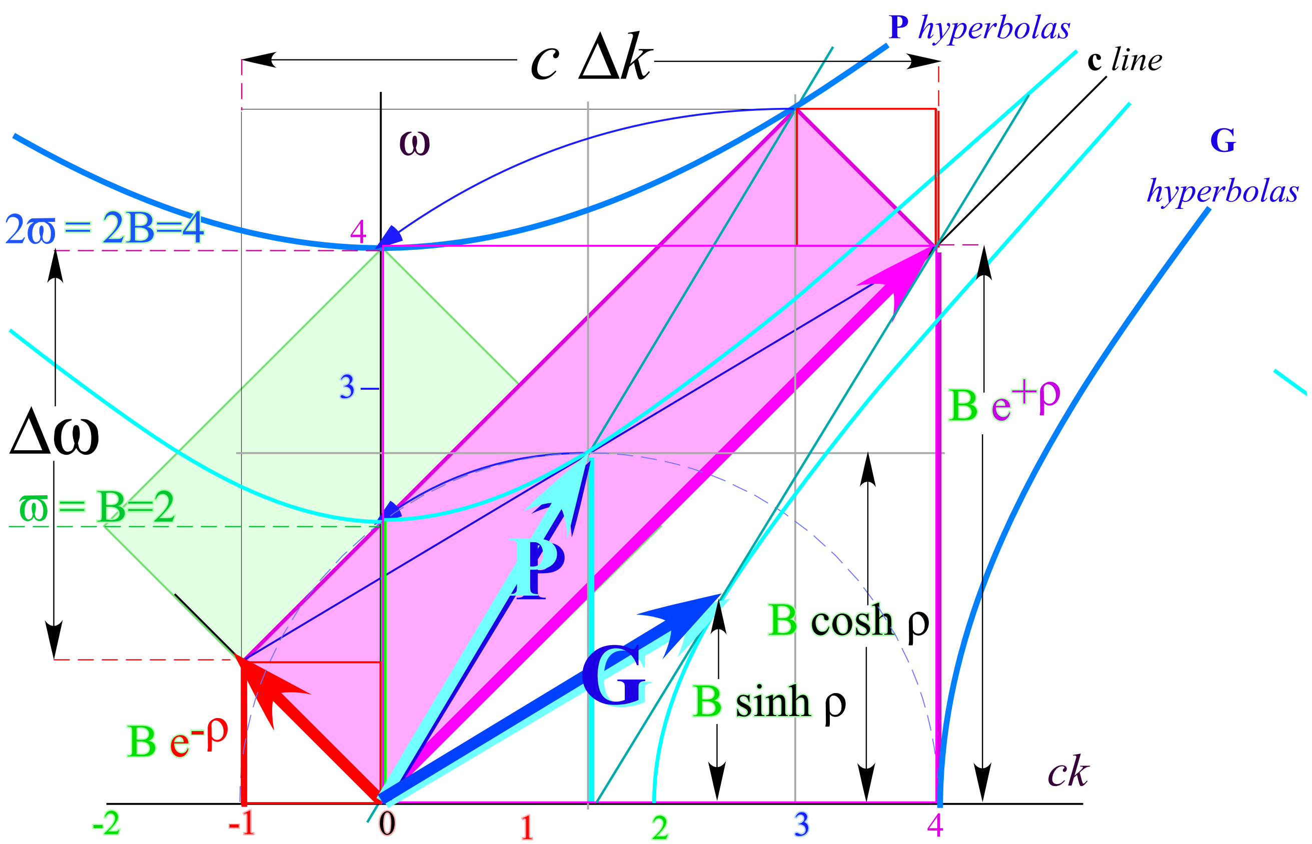


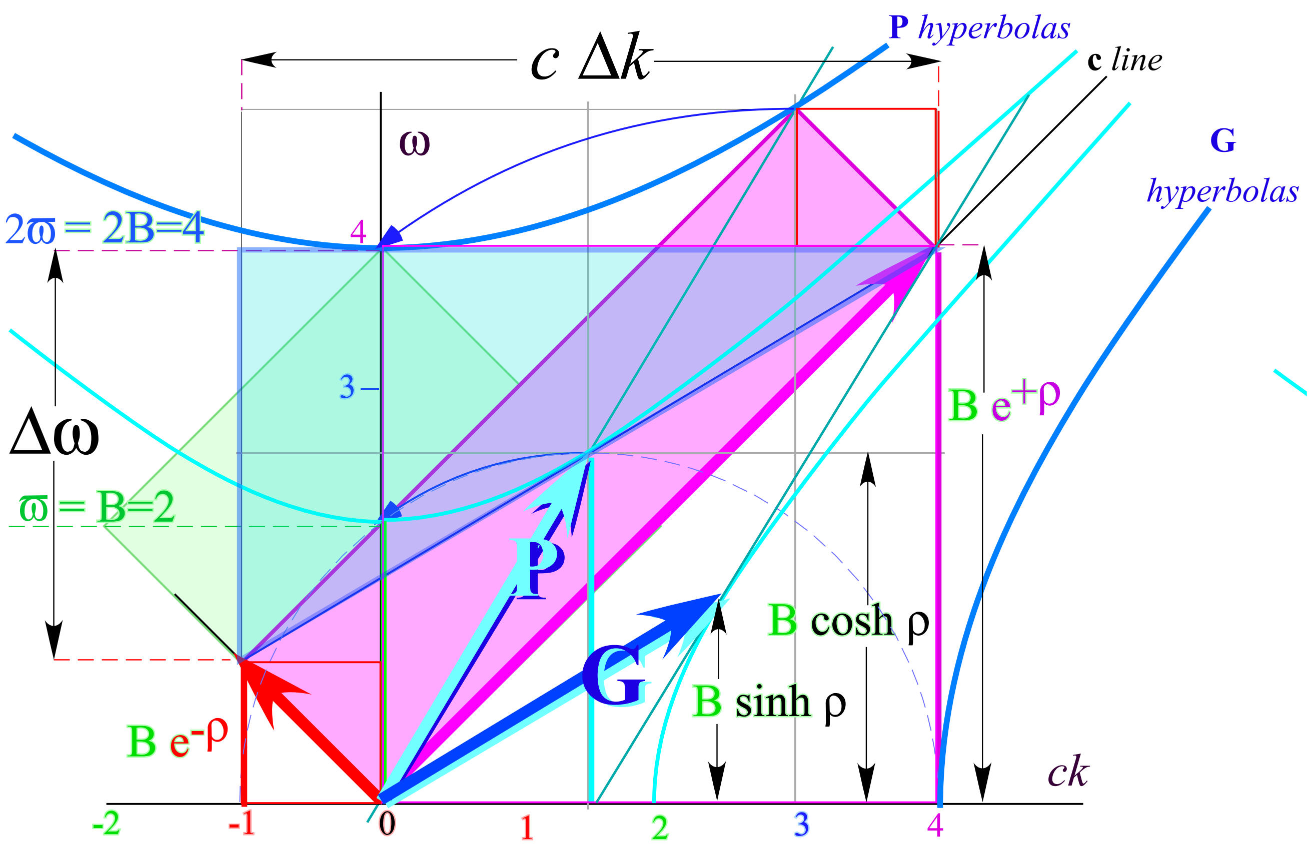
Rare but important case where

$$\frac{d\omega}{dk} = \frac{\Delta\omega}{\Delta k}$$

with LARGE Δk
(not infinitesimal)

Relativistic
group wave
speed u=c tanh ρ

Group velocity u and phase velocity c^2/u are hyperbolic tangent slopes



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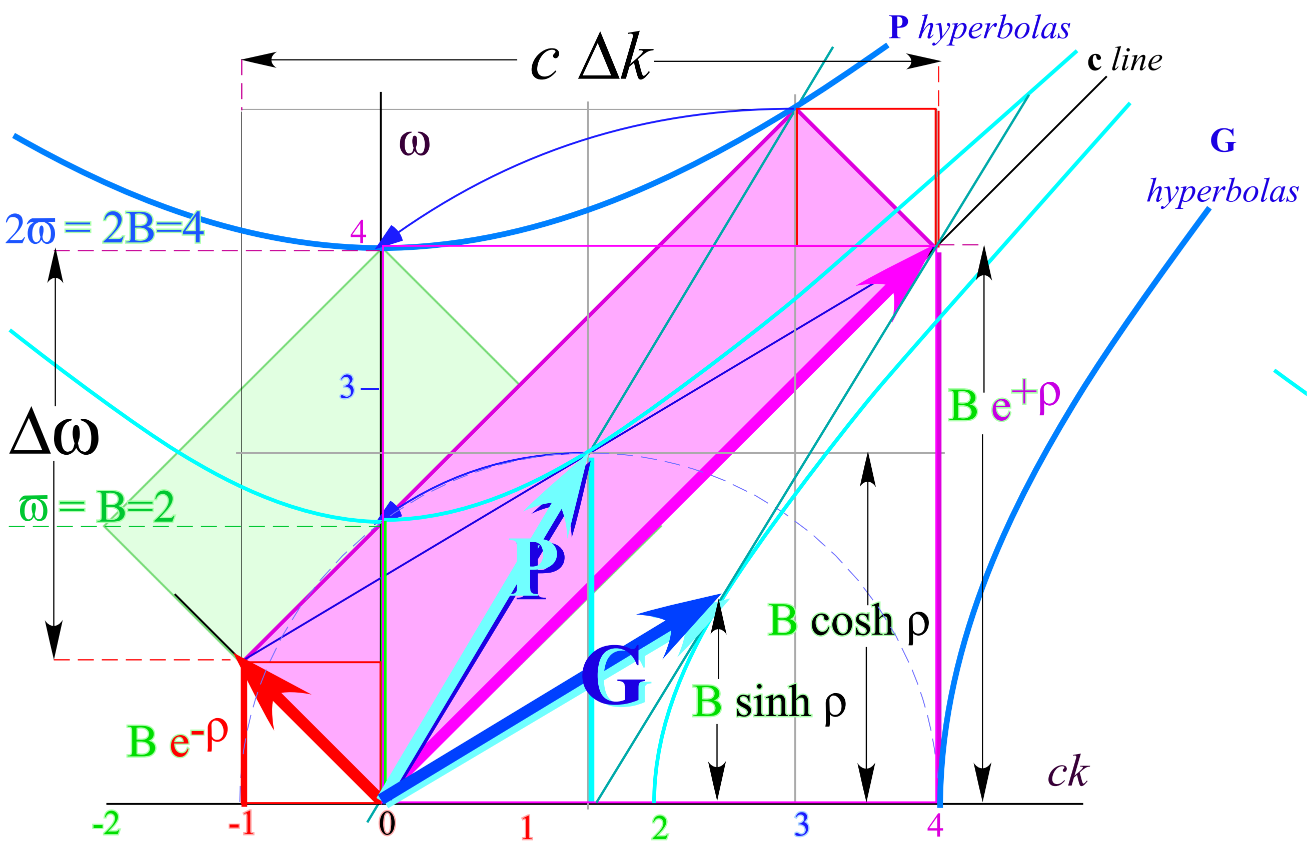

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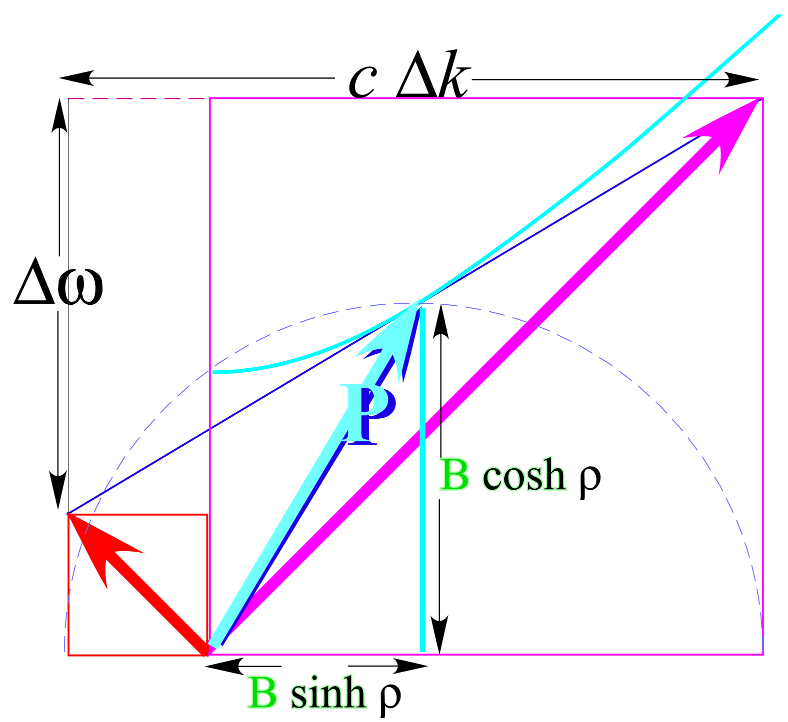
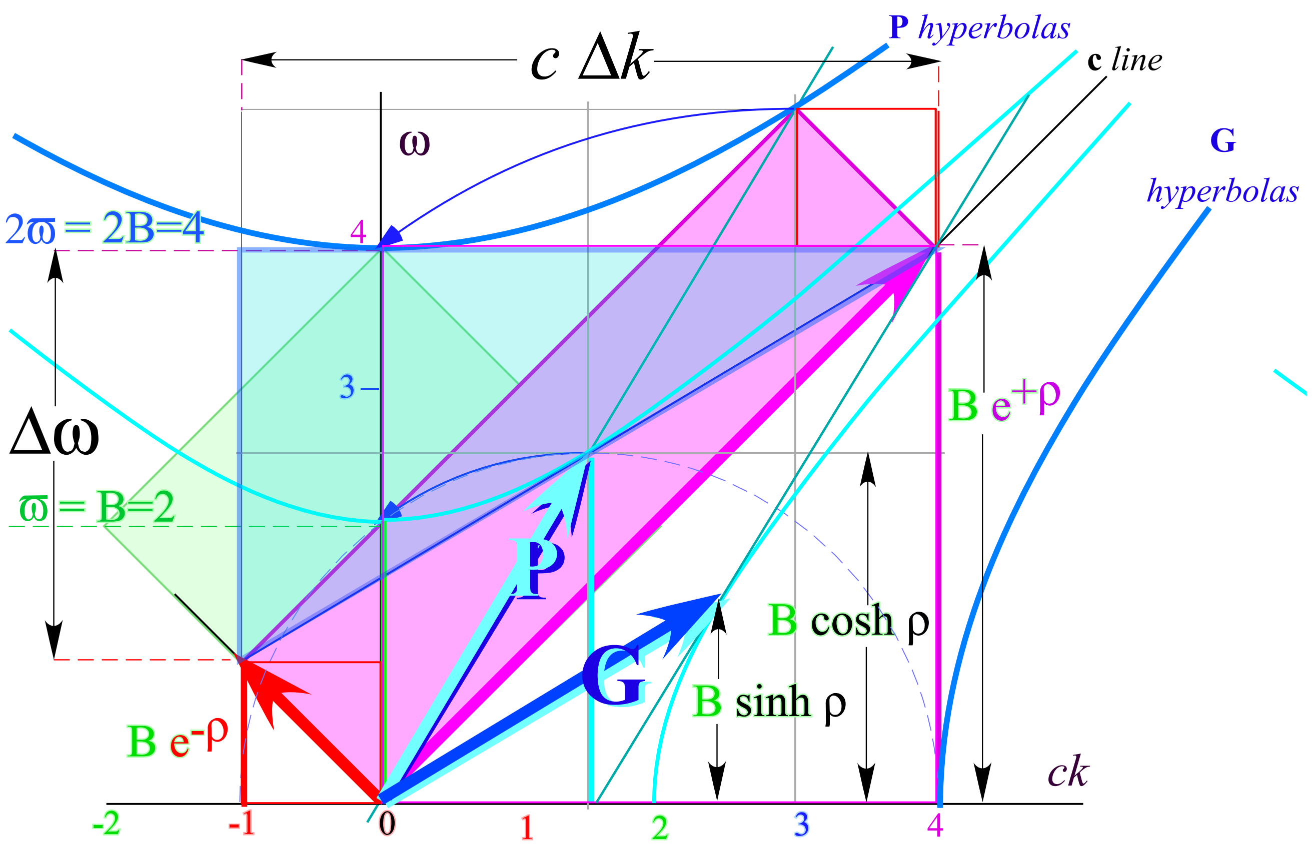


Relativistic group wave speed u=c tanh ρ

Group velocity u *and phase velocity* c^2/u *are hyperbolic tangent slopes*



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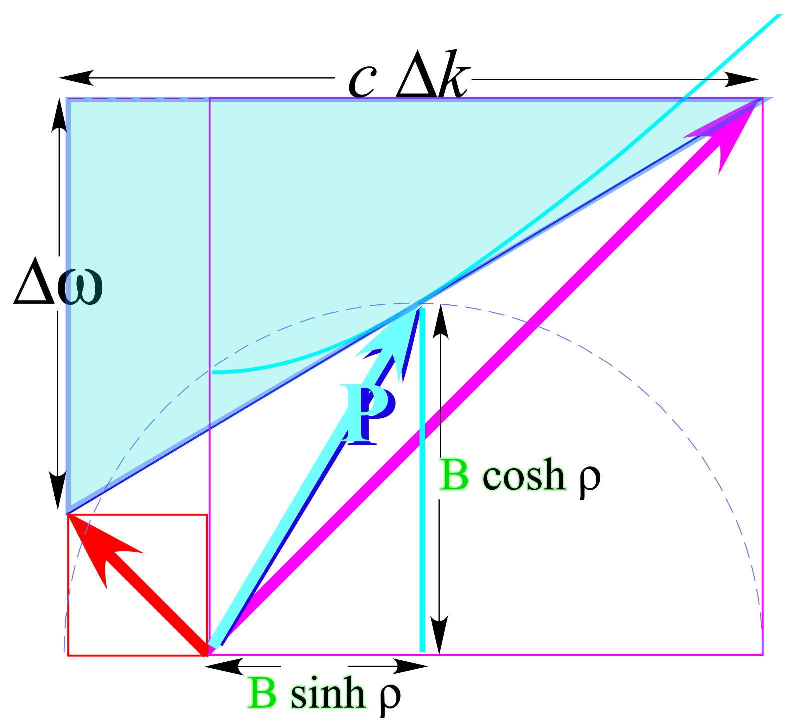
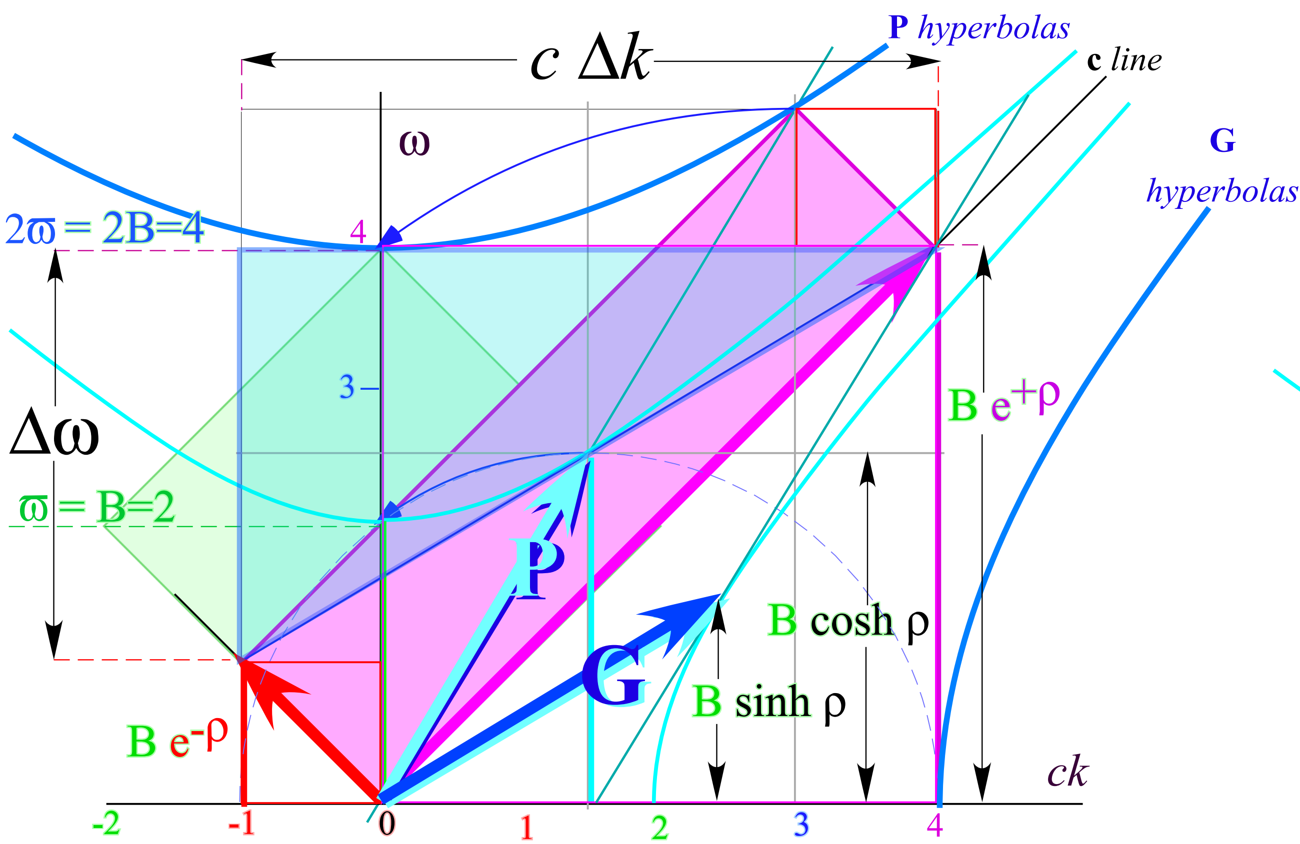
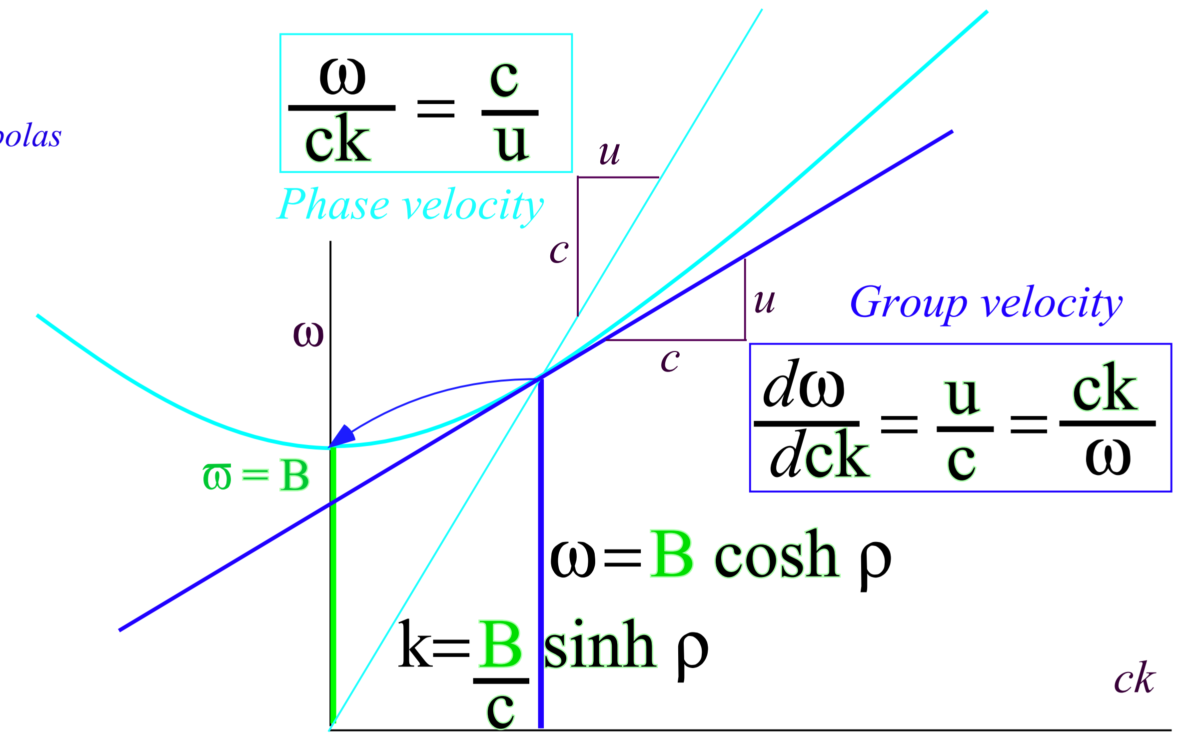


Relativistic group wave speed $u = c \tanh \rho$

Group velocity u and phase velocity c^2/u are hyperbolic tangent slopes





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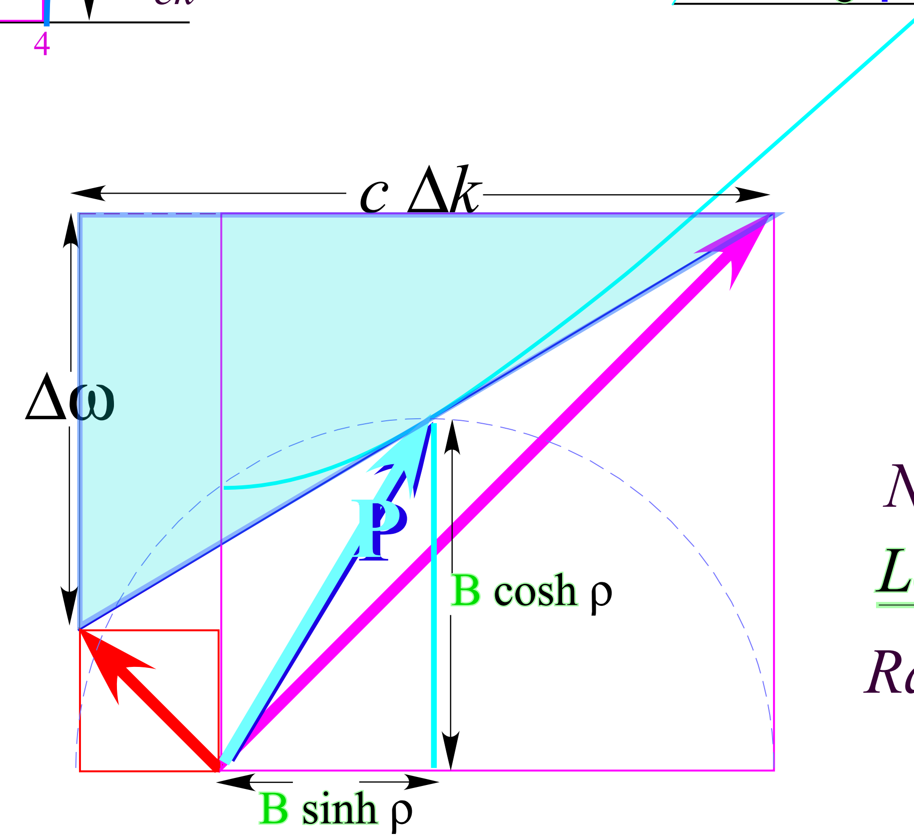


Newtonian speed $u \sim c\rho$

Low speed approximation

Rapidity ρ approaches u/c

Connection to conventional approach to relativity and old-fashioned formulas

The most old-fashioned form(ula) of all: Thales & Euclid means

Connection to conventional approach to relativity and old-fashioned formulas

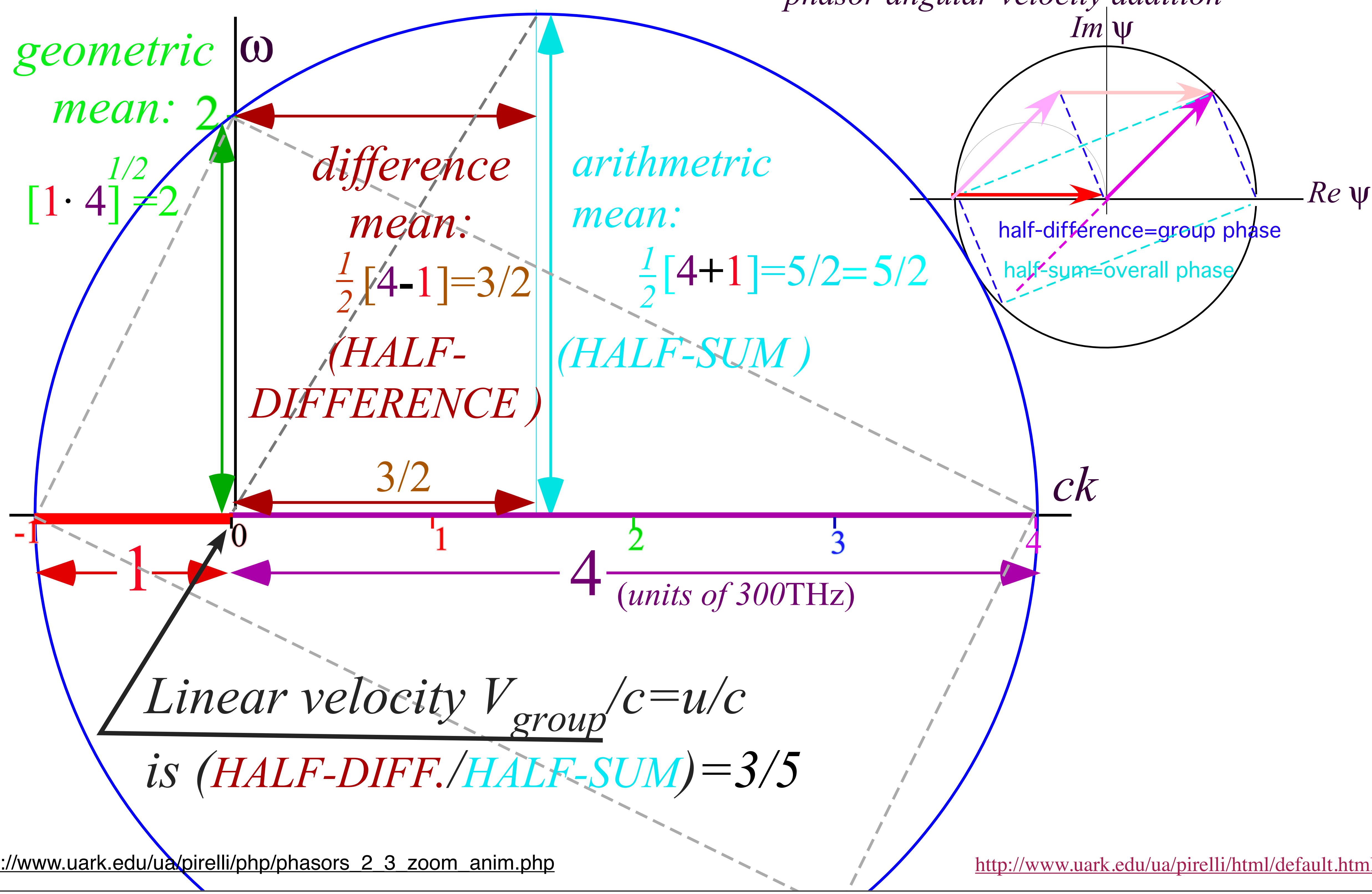
The most old-fashioned form(ula) of all: Thales & Euclid means

Euclid's 3-means (300 BC)

Geometric "heart" of wave mechanics

Thales (580BC) rectangle-in-circle

Relates to wave interference by (Galilean) phasor angular velocity addition



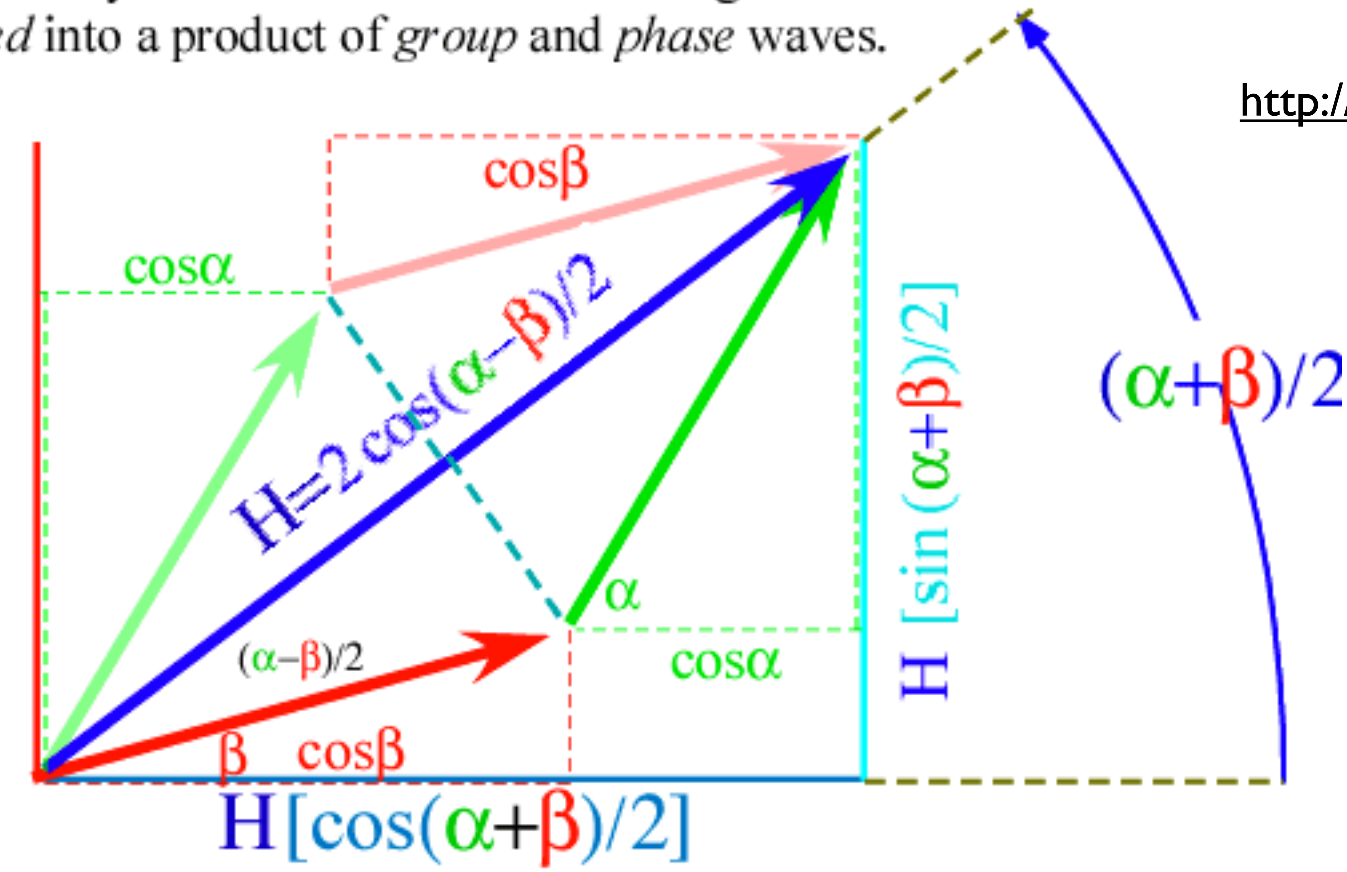
http://www.uark.edu/ua/pirelli/php/phasors_2_3_zoom_anim.php

http://www.uark.edu/ua/pirelli/html/default.html

Connection to conventional approach to relativity and old-fashioned formulas
The most old-fashioned form(ula) of all: Thales & Euclid means

The detailed trigonometry of half-sum & difference angles is shown below.
The wave is *factored* into a product of *group* and *phase* waves.

http://www.uark.edu/ua/pirelli/php/half_sum_5.php



Main Result: Factoring algebraic sums helps to locate *wave zeros.*

$\cos\alpha + \cos\beta \;=\; 2\cos(\alpha-\beta)/2 \;\bullet\; [\cos(\alpha+\beta)/2]$

$\sin\alpha + \sin\beta \;=\; 2\cos(\alpha-\beta)/2 \;\bullet\; [\sin(\alpha+\beta)/2]$

Sum is zeroed by *either* factor. Each factor's zero line is a *spacetime coordinate line*.

The most old-fashioned form(ula) of all: Thales & Euclid means

The detailed trigonometry of half-sum & difference angles is shown below.
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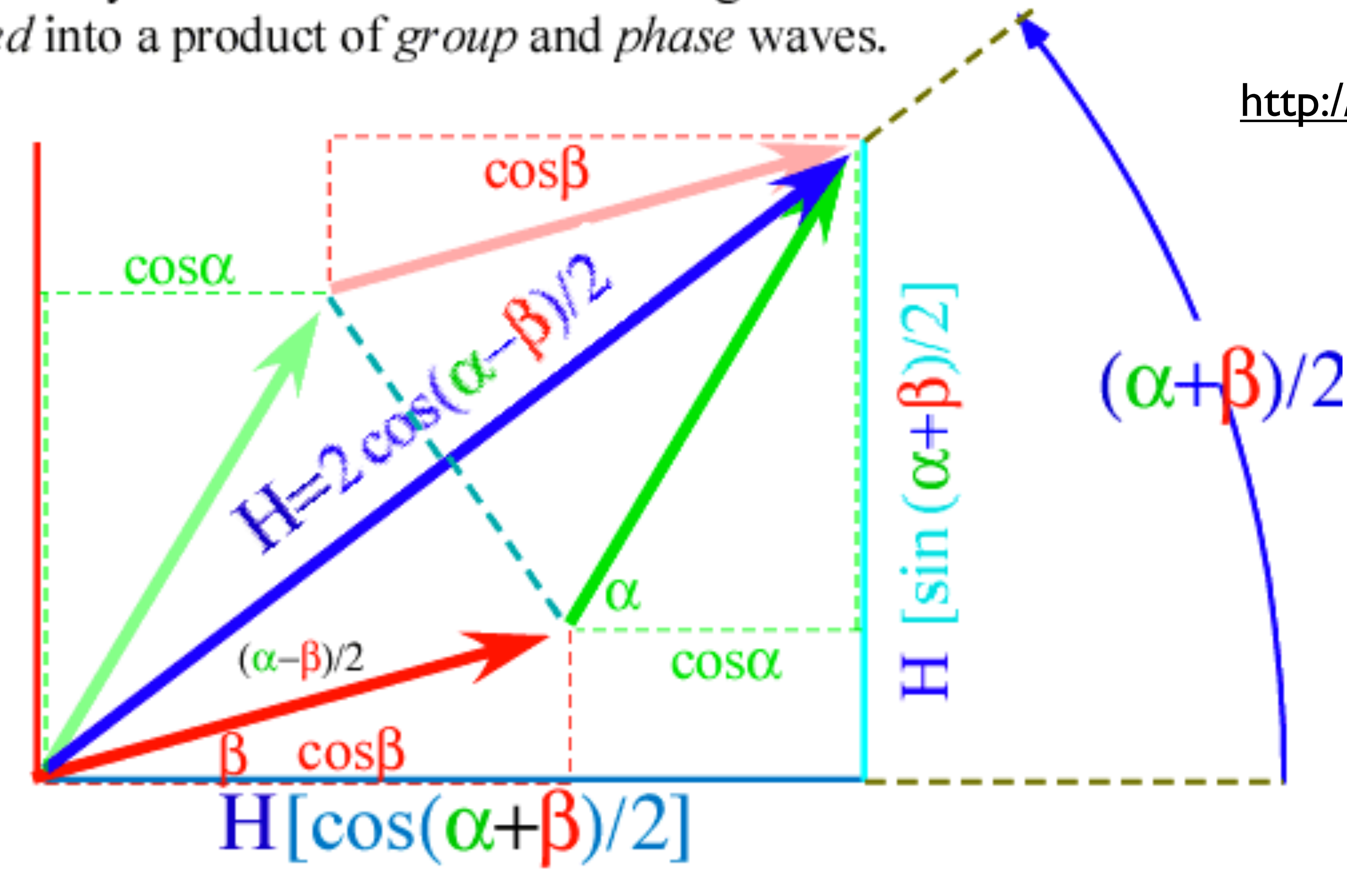

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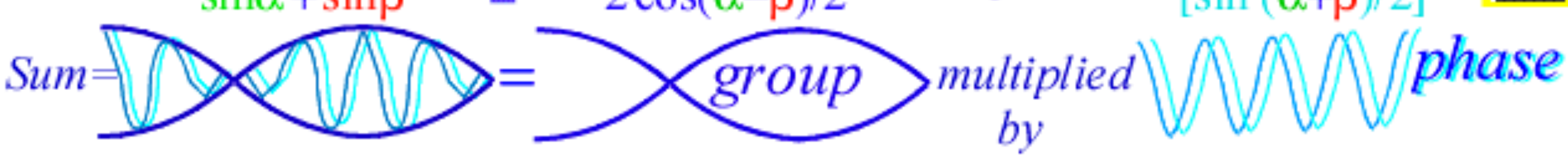

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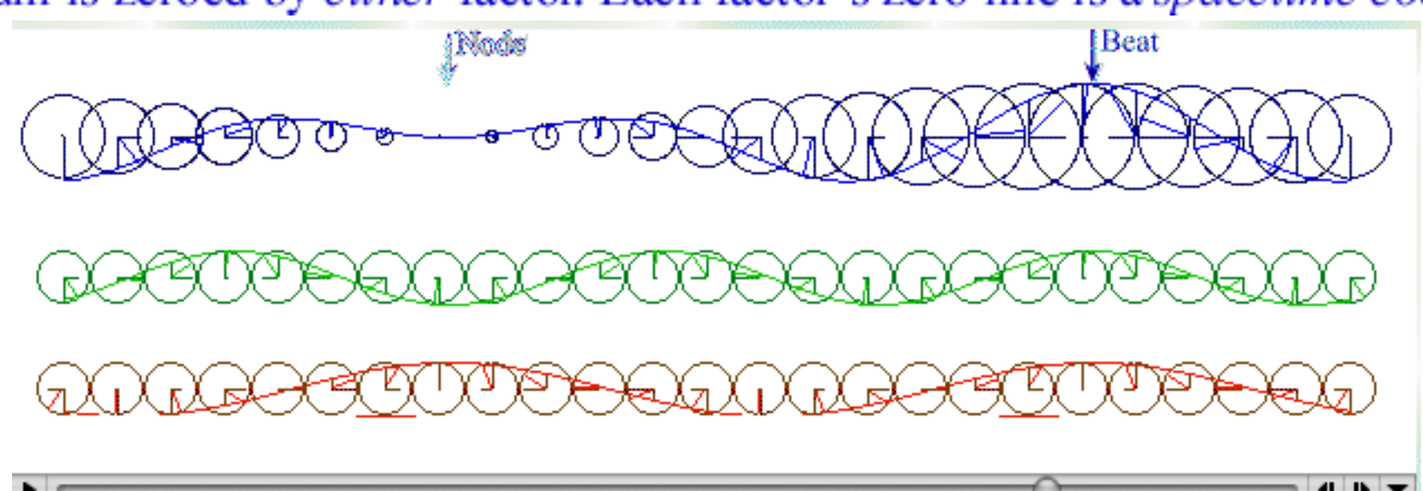
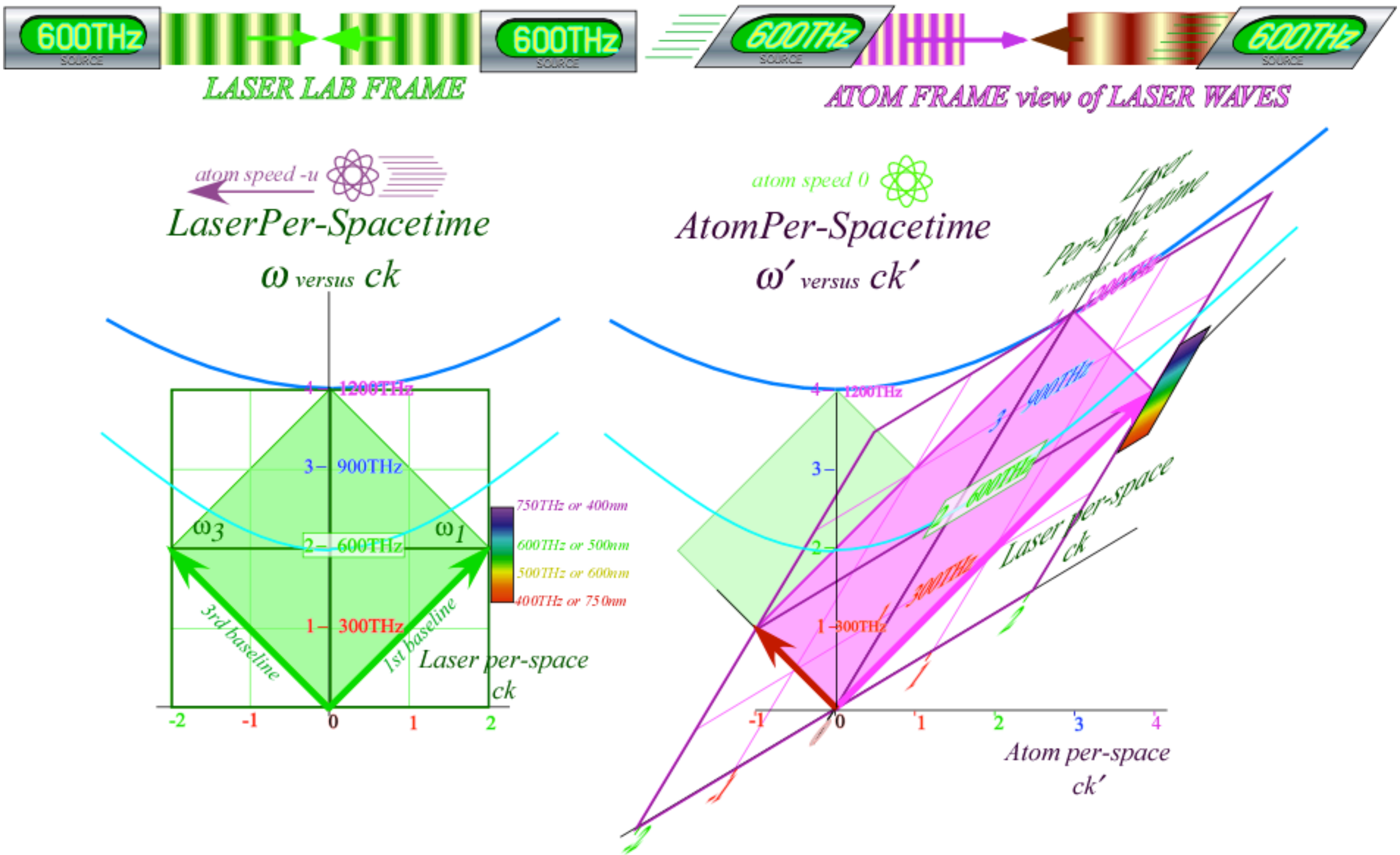


http://www.uark.edu/ua/pirelli/php/phasors_2_3_anim.php



600THz
SOURCE
LASER LAB FRAME
ATOM FRAME view of LASER WAVES
atom speed -u
LaserPer-Spacetime
ω versus ck
atom speed 0
AtomPer-Spacetime
ω′ versus ck′
1200THz
900THz
600THz
300THz
3rd baseline
1st baseline
Laser per-space
ck
750THz or 400nm
600THz or 500nm
500THz or 600nm
400THz or 750nm
Atom per-space
ck′
Laser
Per-Spacetime
ω versus ck