

# 1<sup>st</sup> Order Coherence

- ✓ 1. What's **coherence**?
- ✓ 2. **Spatial Coherence.**
- ✓ 3. **Temporal Coherence.**
- ✓ 4. 1<sup>st</sup> order **correlation function.**
- ✓ 5. **Wiener-Khintchine**
6. **Mode-locked lasers**

# Optical Frequency Combs

A frequency comb is also a pulsed laser:



A *mode-locked laser* produces the shortest possible pulse:

$$\vec{E}_{total}(t) = \sum_{n=1}^N \vec{E}_0 \cos((\omega_0 + n\Delta\omega)t + \phi_n)$$

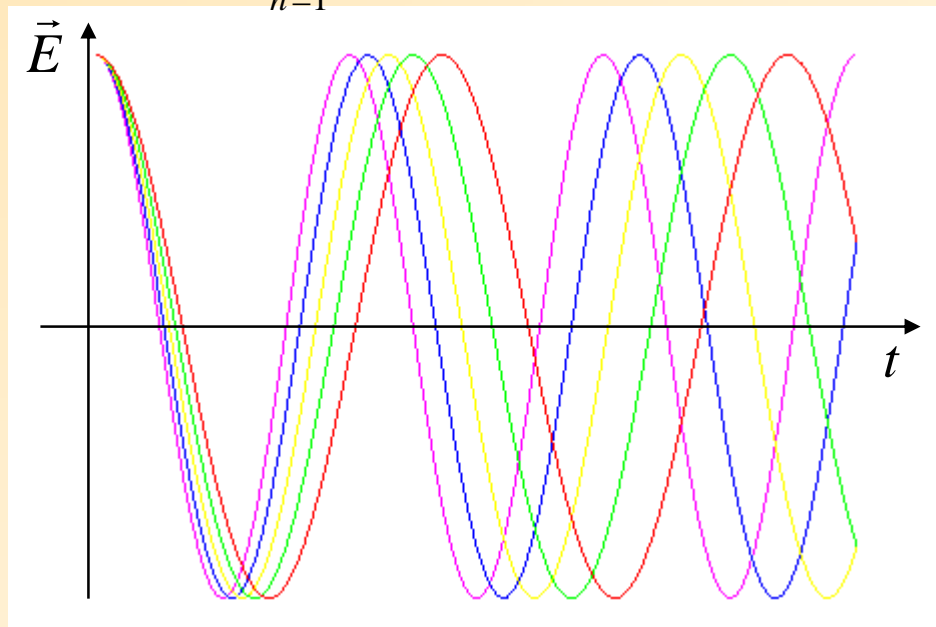
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$$N=5$$

$$\Delta\omega = \omega/10$$

$$\phi_n = 0$$

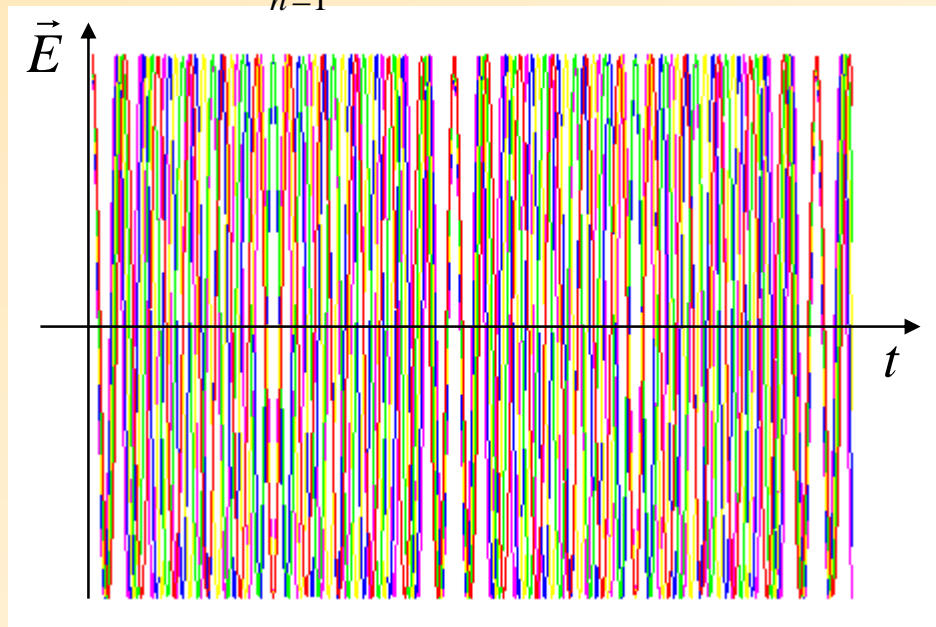
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On a longer time scale, the plot repeats every

$$T = 2\pi / \Delta\omega$$

# Optical Frequency Combs

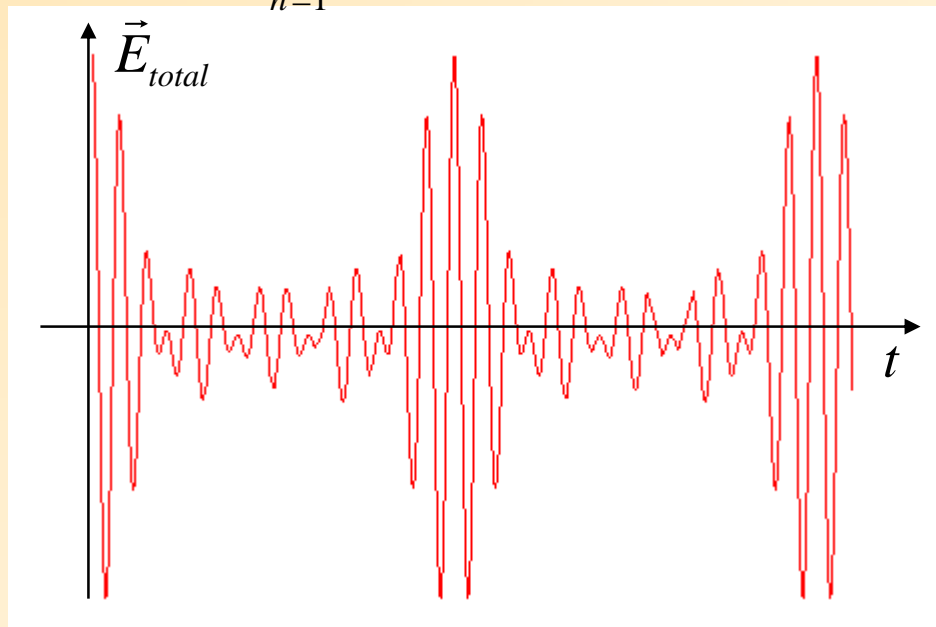
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The total electric field is pulsed!!!



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# Optical Frequency Combs

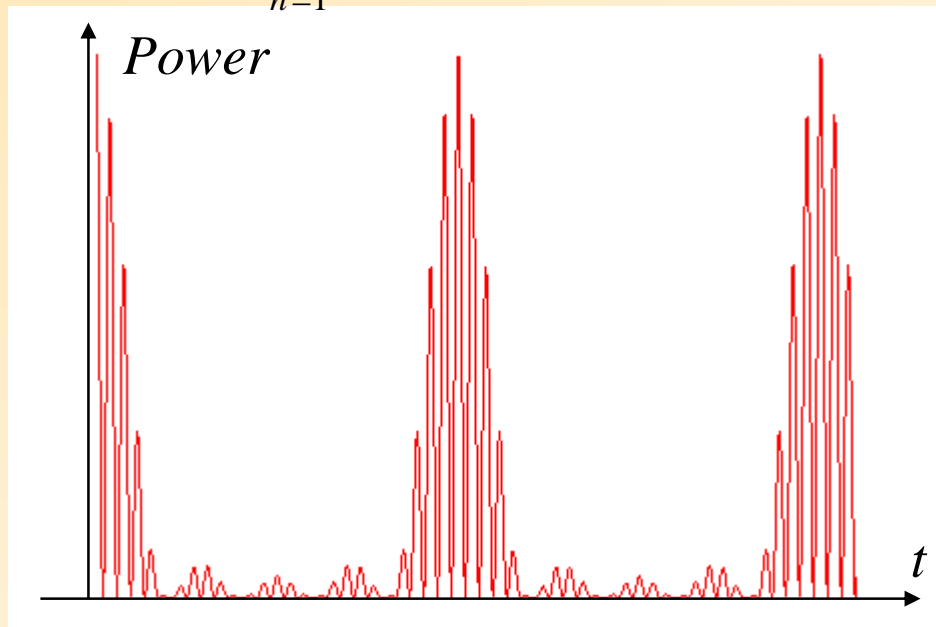
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The total power is pulsed!!!



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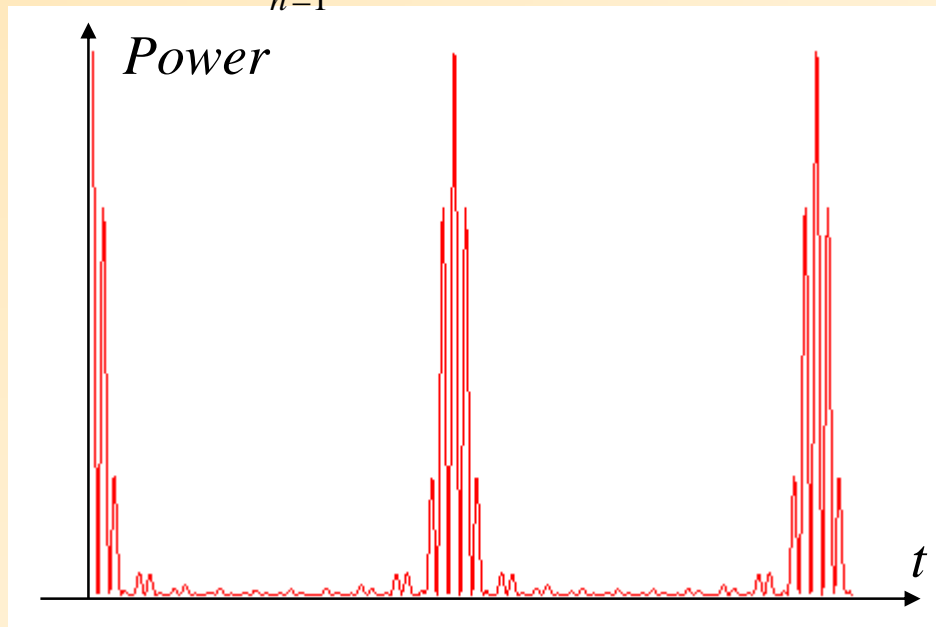


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The total power is pulsed!!!

more comb teeth  
=  
shorter pulses



$$N=10$$

$$\Delta\omega = \omega/10$$

$$\phi_n = 0$$

On a longer time scale, the plot repeats every  
 $T = 2\pi / \Delta\omega$

# Optical Frequency Combs

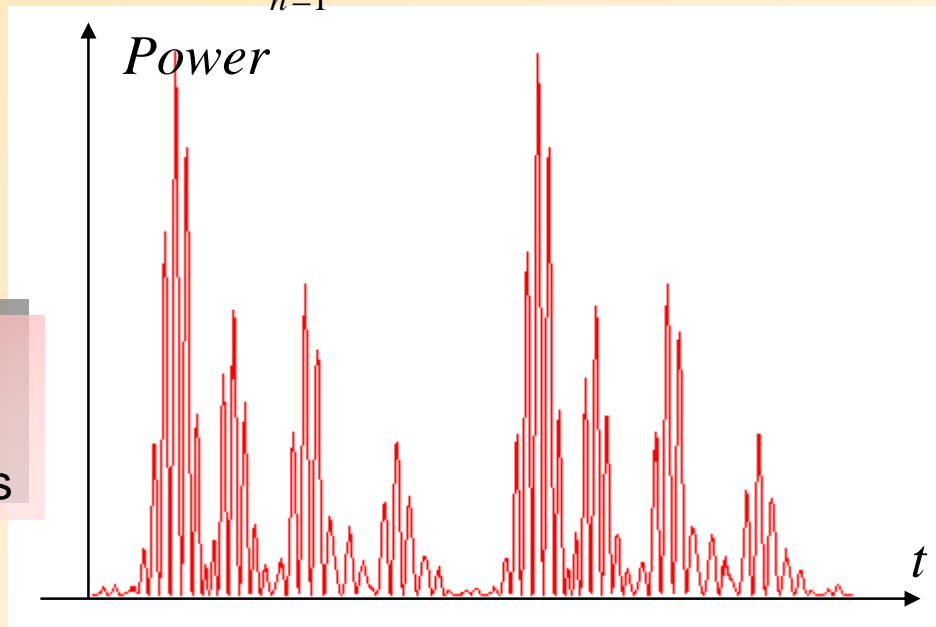
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A *mode-locked laser* produces the shortest possible pulse:

$$\vec{E}_{total}(t) = \sum_{n=1}^N \vec{E}_0 \cos((\omega_0 + n\Delta\omega)t + \phi_n)$$

The total power is pulsed!!!



random phases  
=  
broad random pulses

$N=10$

$\Delta\omega = \omega/10$

$\phi_n = \text{random}$

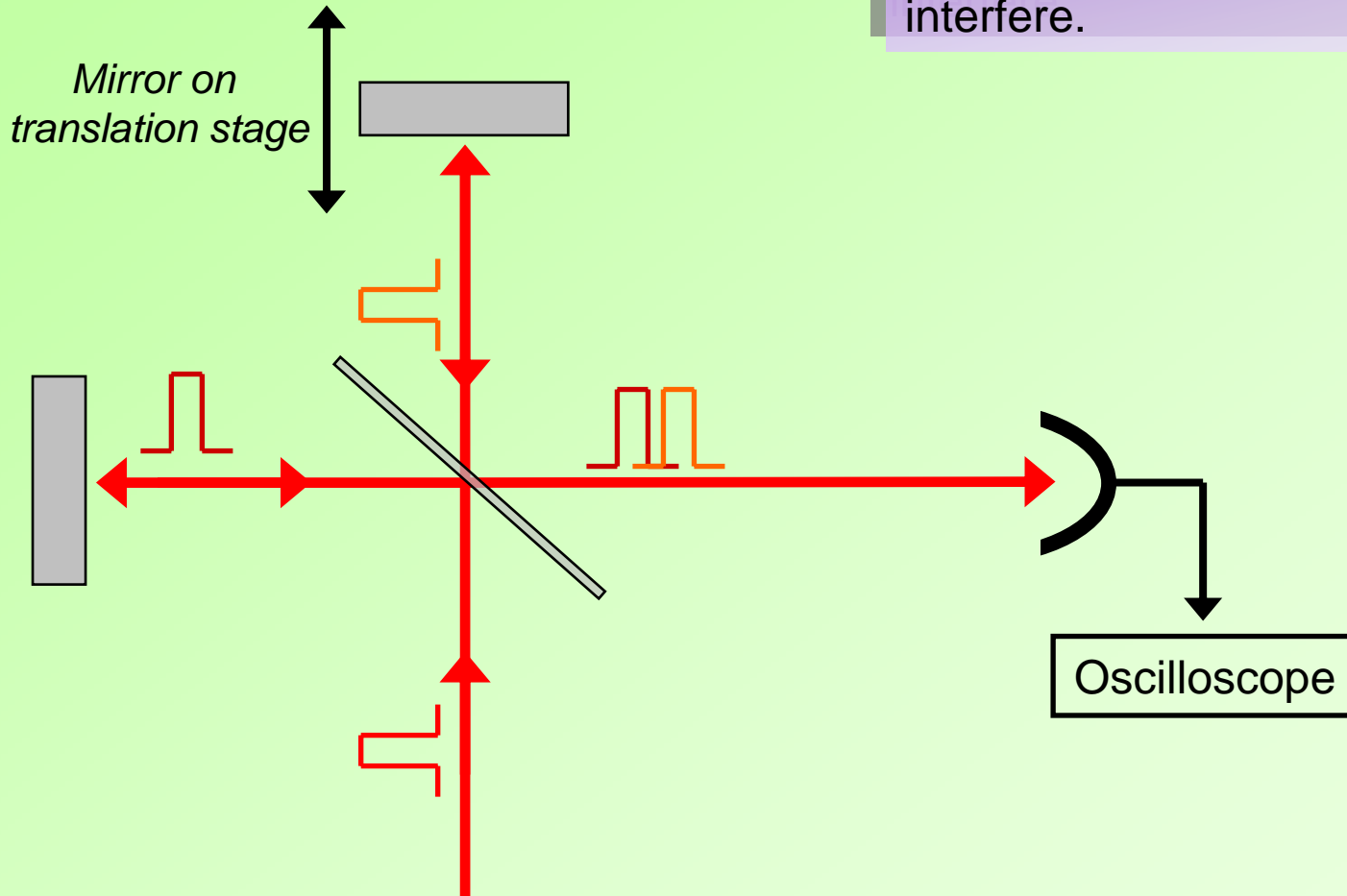
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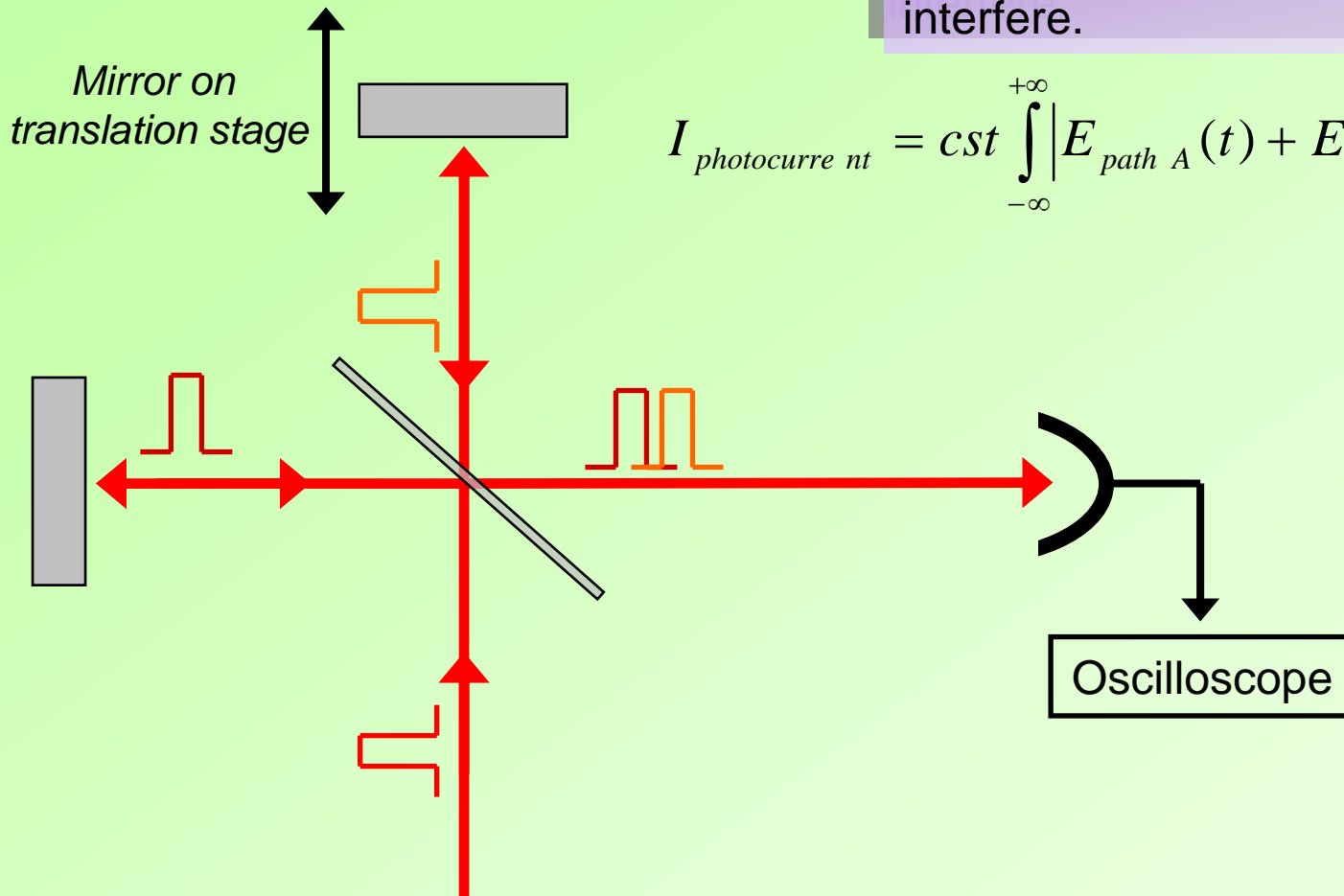
# Can you use a Michelson interferometer to measure the pulse time?

**Basic principle:** When the recombined pulses from both arms overlap, they interfere.



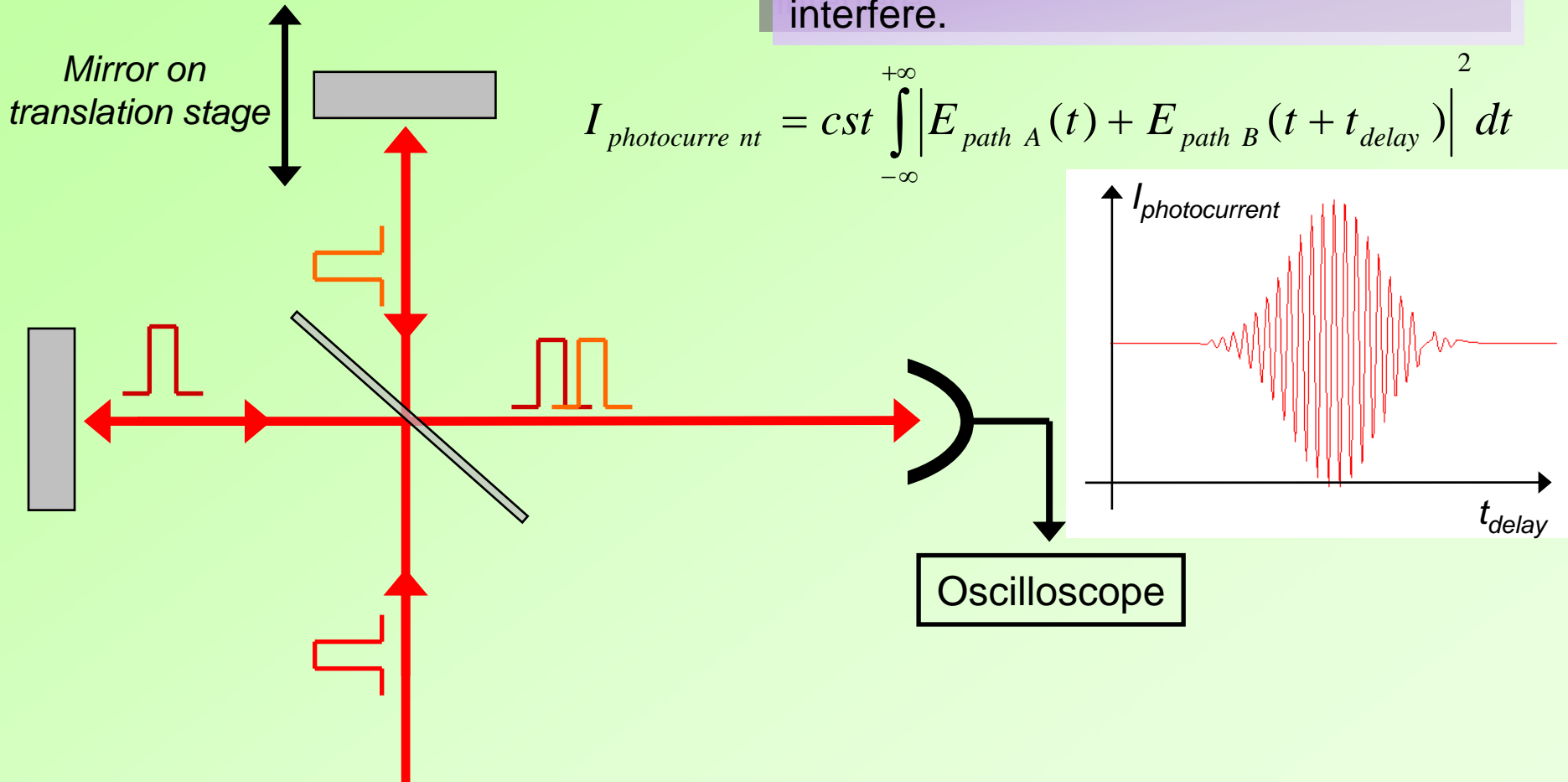
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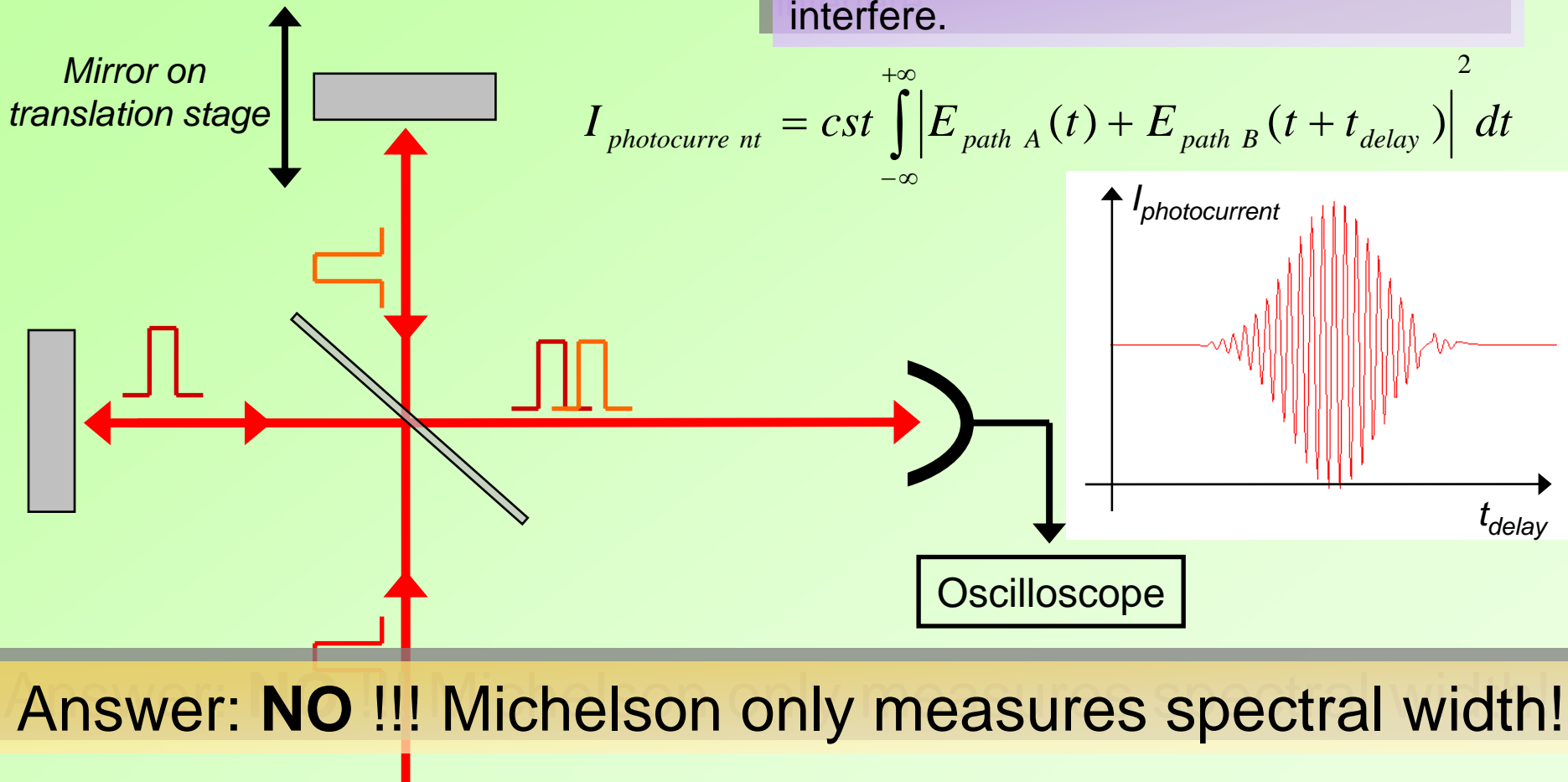
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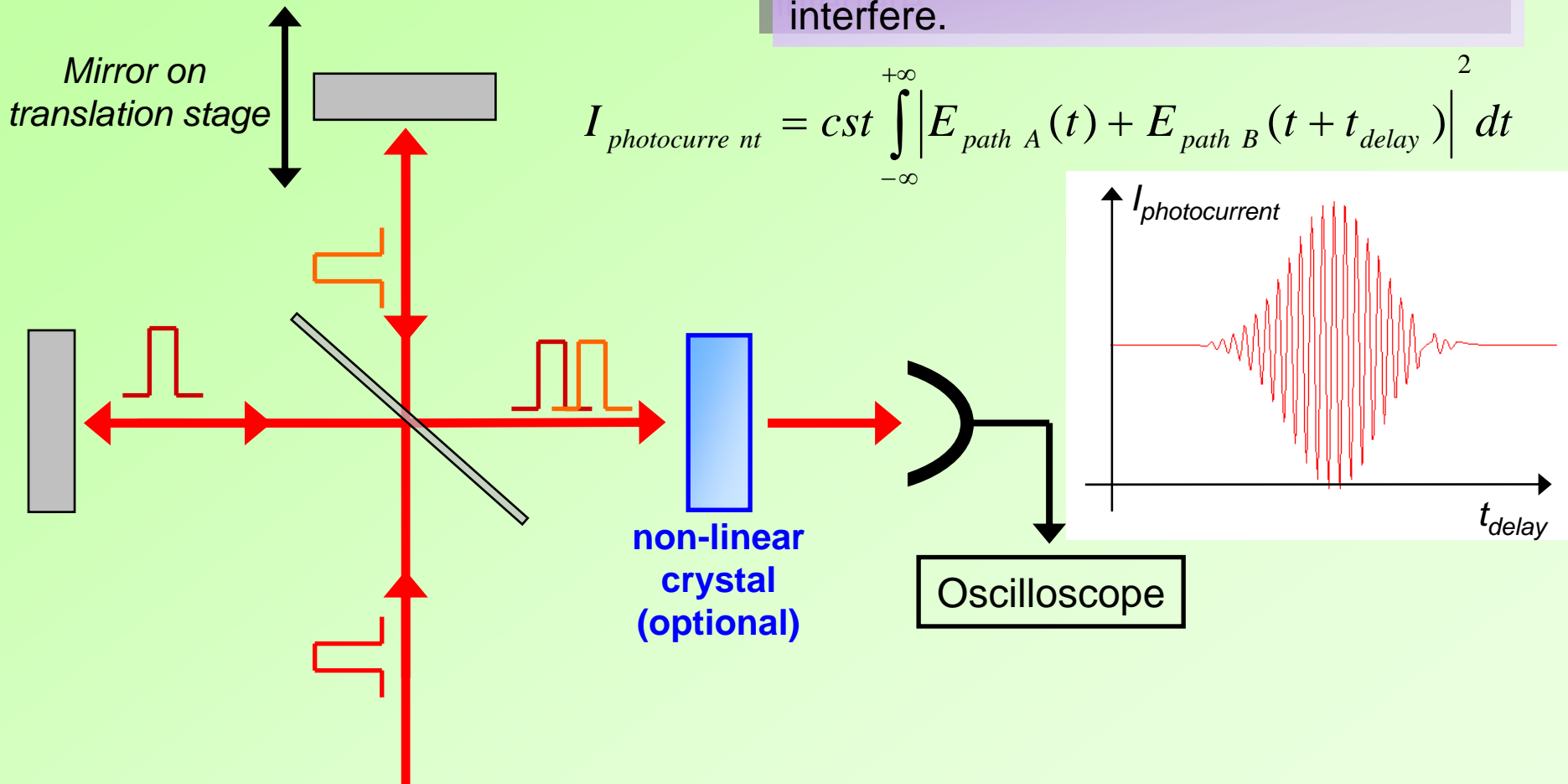
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Answer: **NO !!!** Michelson only measures spectral width!

# Can you use a Michelson interferometer to measure the pulse time?

**Basic principle:** When the recombined pulses from both arms overlap, they interfere.



# 2nd Order Coherence

1. Degree of second order coherence
2. Classical view: Time-domain
3. Quantum view: Coincidence measurements
4. Thermal Light vs. Laser Light
5. Coherence of atomic sources

# $g^{(2)}(\tau)$

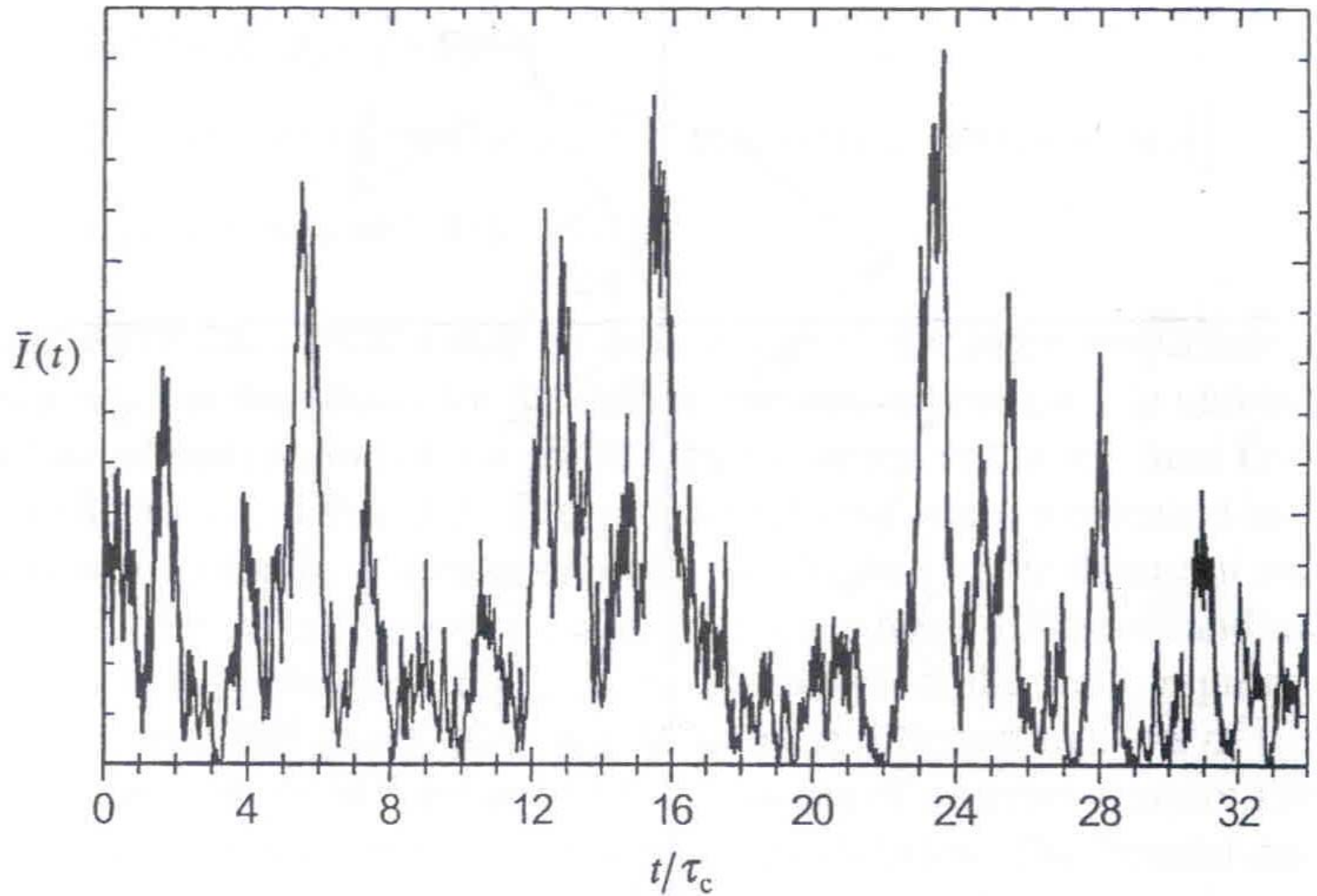
## **2<sup>nd</sup> order correlation function**

Definition:

$$g^{(2)}(\tau) = \frac{\langle I(t) \cdot I(t + \tau) \rangle}{\langle I(t) \rangle \langle I(t + \tau) \rangle} = \frac{\langle I(t) \cdot I(t + \tau) \rangle}{\langle I(t) \rangle^2}$$

It measures **correlations in the intensity** of the light, instead of correlations in the electric field.

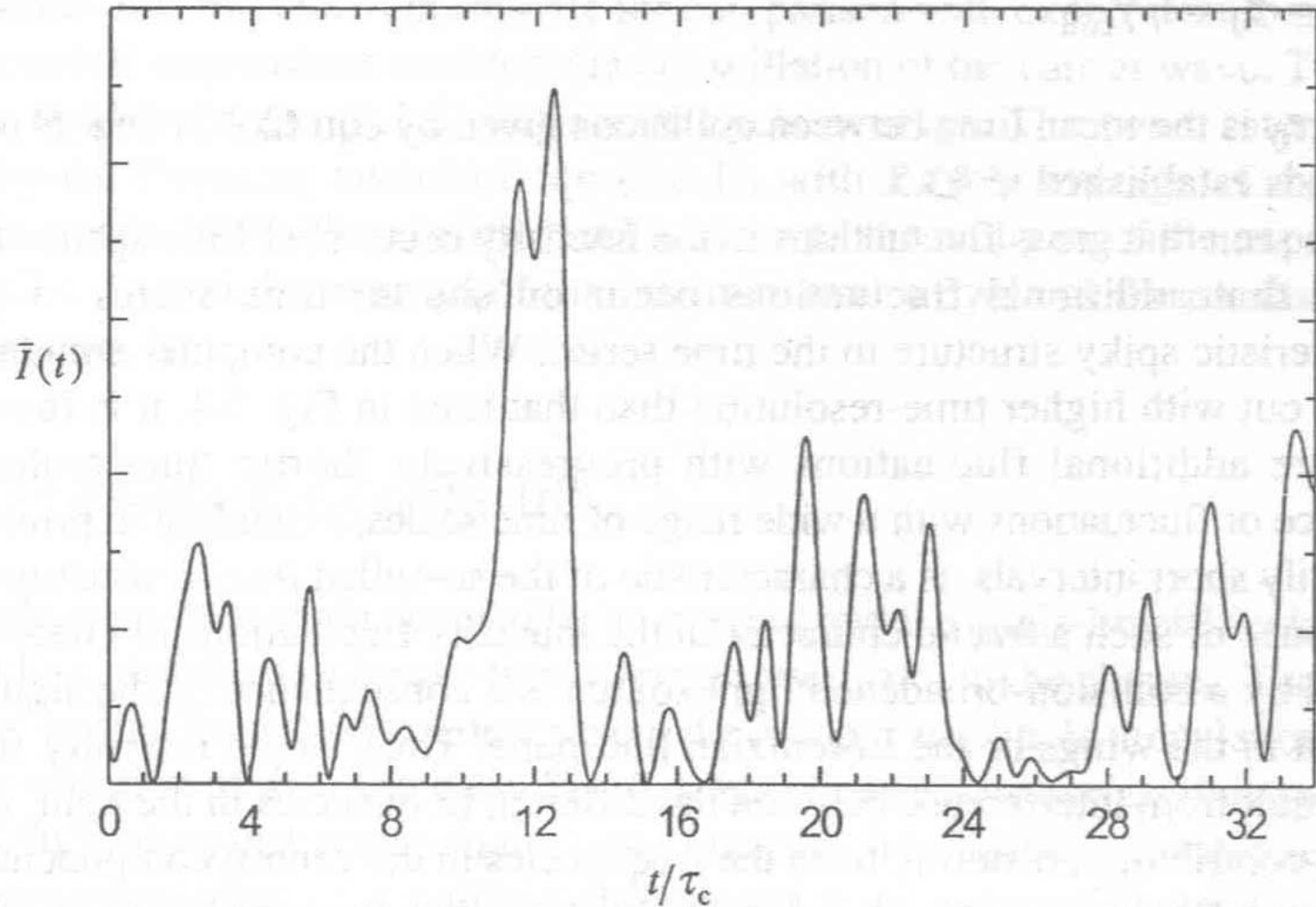
# Random Phase Chaotic Light Source (*Lorentzian*)



[computer simulation, from Quantum Theory of Light, by R. Loudon (2000)]



# Gaussian Spectrum Chaotic Light Source



[computer simulation, from Quantum Theory of Light, by R. Loudon (2000)]