# Laser frequency/wavelength measurement

Dienstag, 13. Juni 2023 12:20

Ⓐ Wavemeter

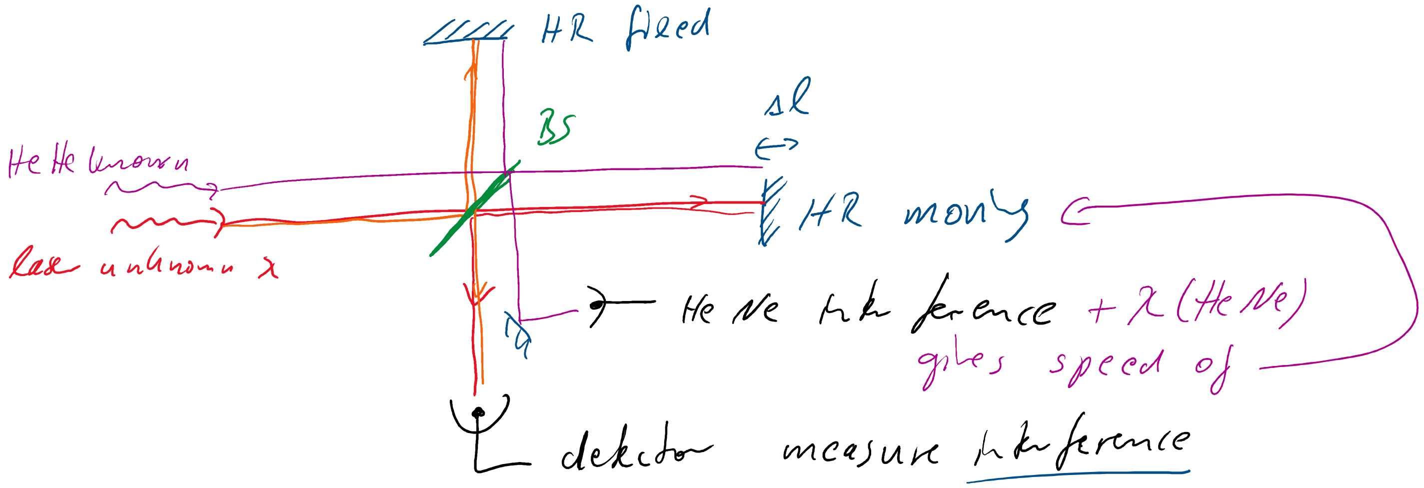
↳ wavelength meter

↳ wavelength $\lambda = \frac{\lambda_0}{n}$ is medium-dependent!

① Lambdameter

compare $\lambda_{unknown}$ with a known $\lambda$, e.g. HeNe laser at 628nm

Michelson Interferometer




detector measure interference

interference pattern (≙ brightness) depends on Δl

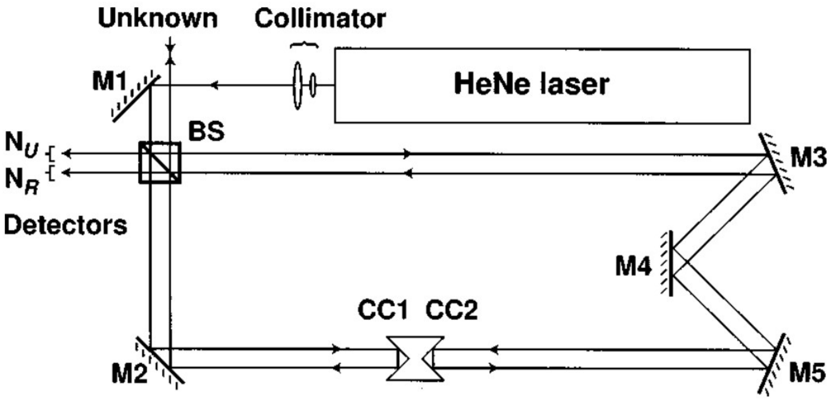
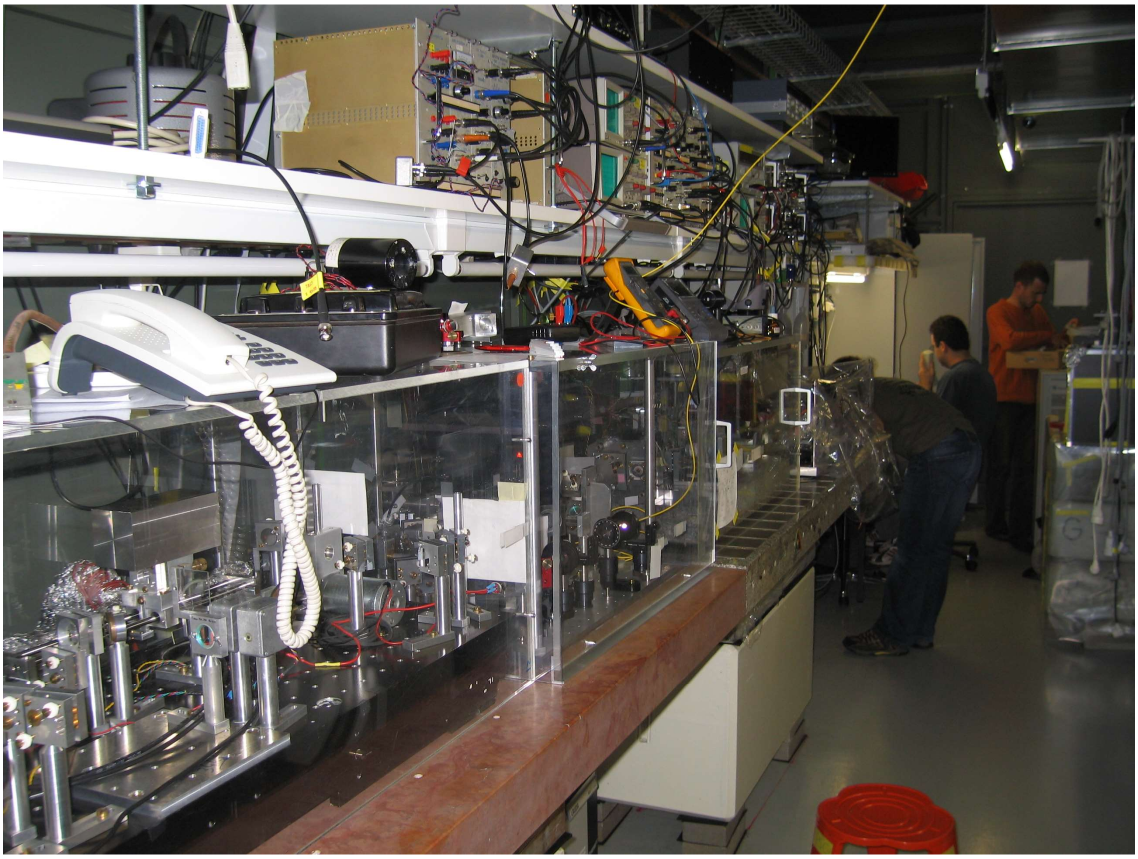


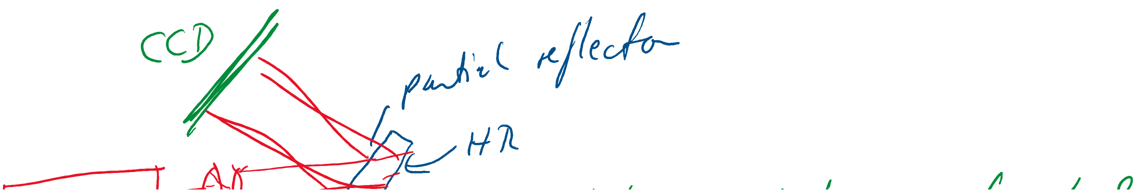

Fig. 2. Wavemeter layout. M1–M5: front-aluminized mirrors, BS: nonpolarizing beamsplitter, plano-convex collimator lenses ($f$=4.5, 19 mm), CC1,2: glass cornercube prisms. The arrows show the beam direction for the reference HeNe laser.

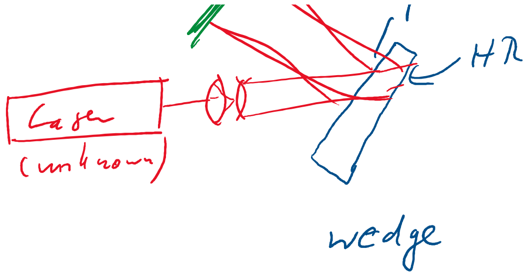
λ-meter



② Fizeau Wavemeter

no moving parts!






interference between front & back side

fringes on CCD tell you the wavelength

typ. more than one wedge

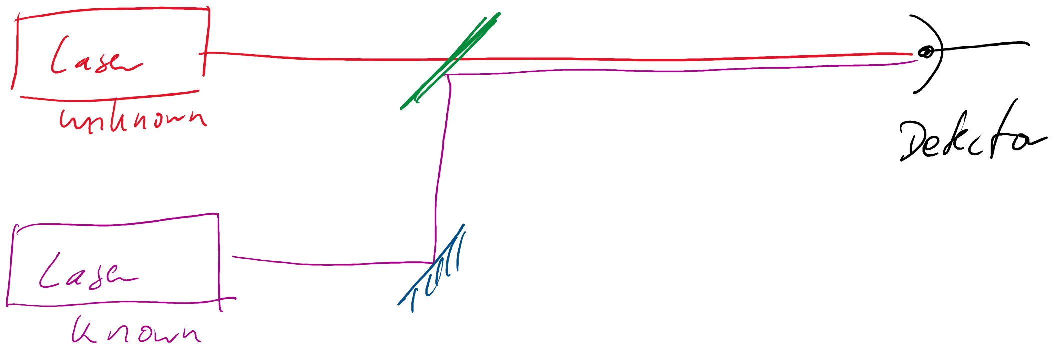
all these measure wavelength
⇒ "bad"

(B) Art Schawlow: "Never measure anything but frequencies!"

BUT: "counting" frequencies works up to maybe 10 GHz

certainly not 100s of THz (= optical frequencies)

Easy to measure: beat frequencies, also in the optical




intensity of 2 lasers superimposed on detector.

$$I \propto E_{tot}^2 \propto \left[E_u \cos(\omega_u t + \varphi) + E_k \cos(\omega_k t)\right]^2 \propto$$

$$\propto \frac{1}{2} E_u^2 + \frac{1}{2} E_k^2 \quad \leftarrow \text{2 DC signals}$$

$$+ 2 E_u E_k \cos(\omega_u t + \varphi) \cdot \cos(\omega_k \cdot t)$$

$$\cos A \cdot \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$$

$$\propto \text{const} + E_u E_k \left\{ \cos\left[(\omega_u + \omega_k) t + \varphi\right] + \cos\left[(\omega_u - \omega_k) t + \varphi\right] \right\}$$

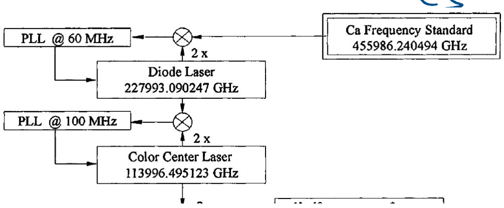
$\omega_u$ and $\omega_k$ are too fast (100s of THz) to be counted, but

$\omega_u - \omega_k$ may be $\leq 10$ GHz

→ countable

"Bad old days": Frequency chain

connect H(1s−2s) at 2500 THz to Cs at 9.2 GHz



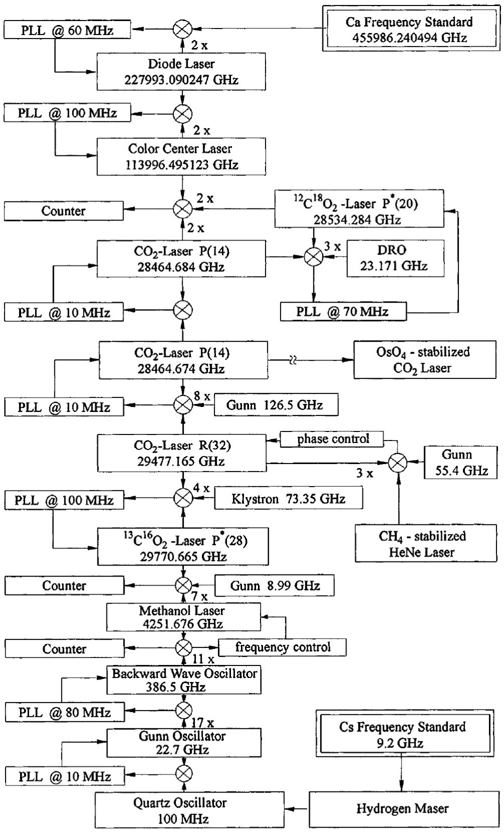
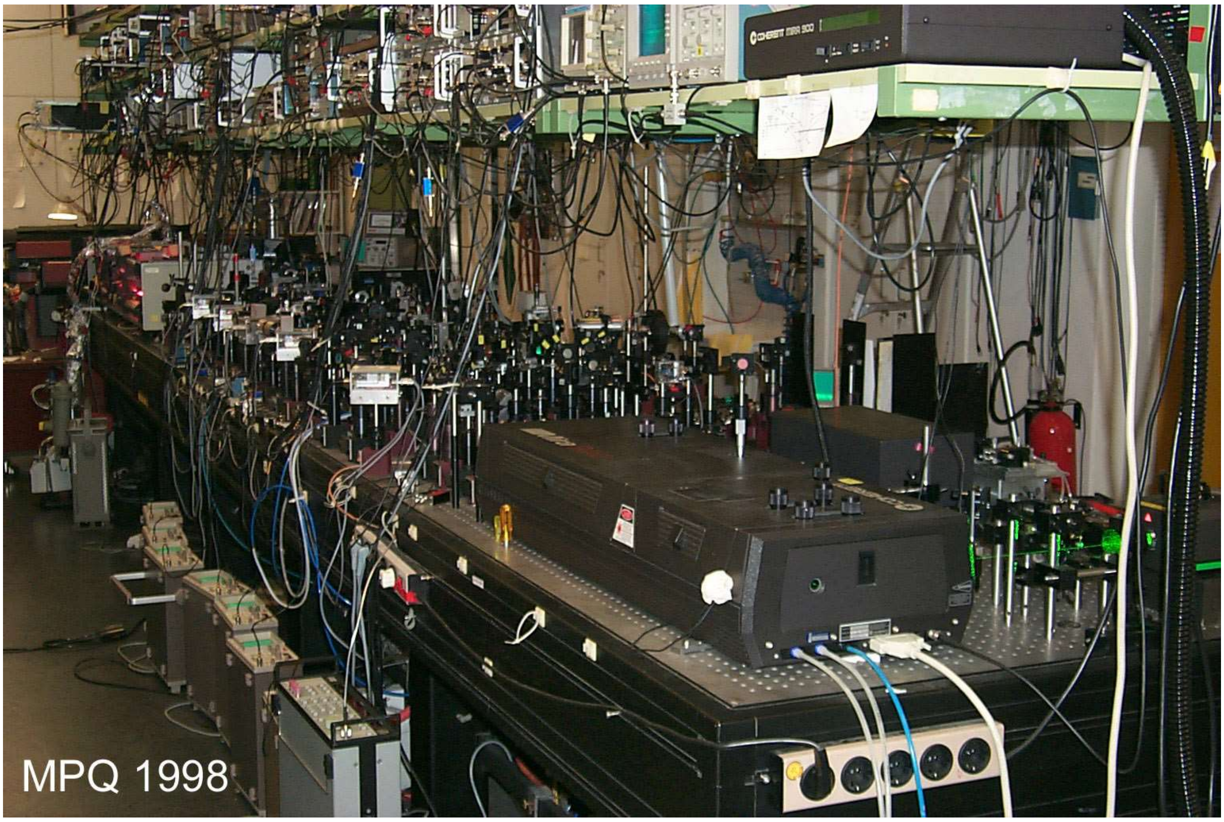
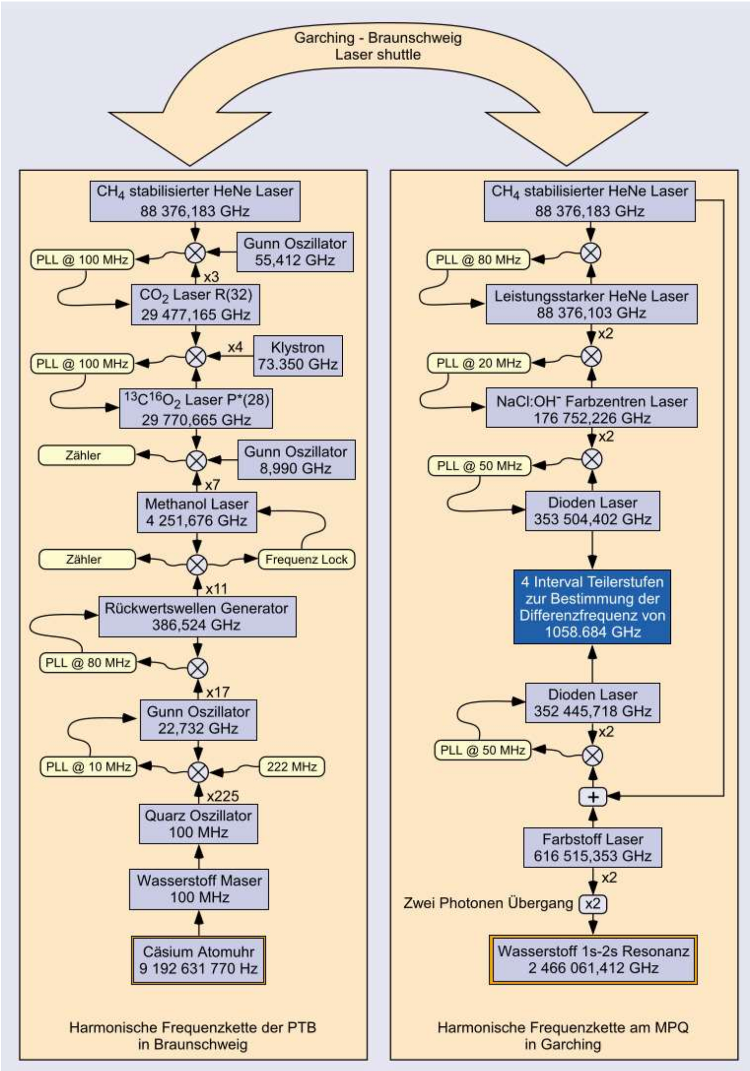



FIG. 1. PTB's frequency chain to the Ca intercombination line (PLL = phase locked loop, details are given in the text).

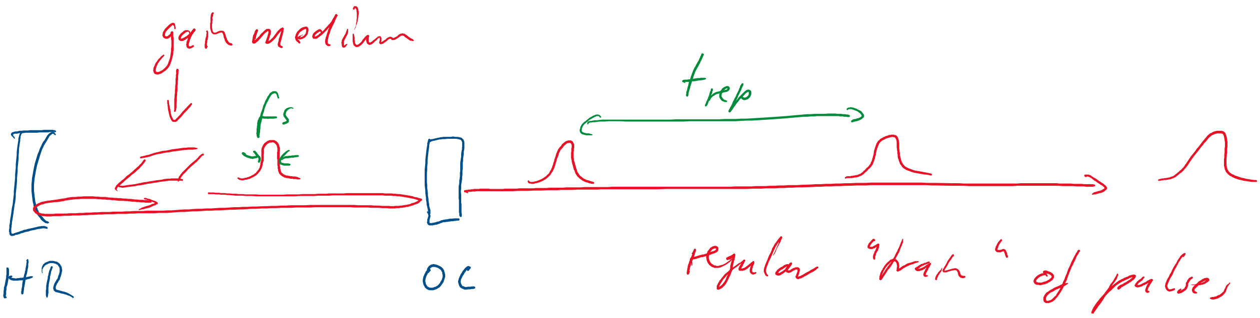





can only measure 1 frequency

different technology for each step

Solution: Frequency comb Hänsch 1999




regular "train" of pulses

FP resonator

convince it to produce pulses

trep = repetition rate

= pulse round-trip

pulses

fs-laser

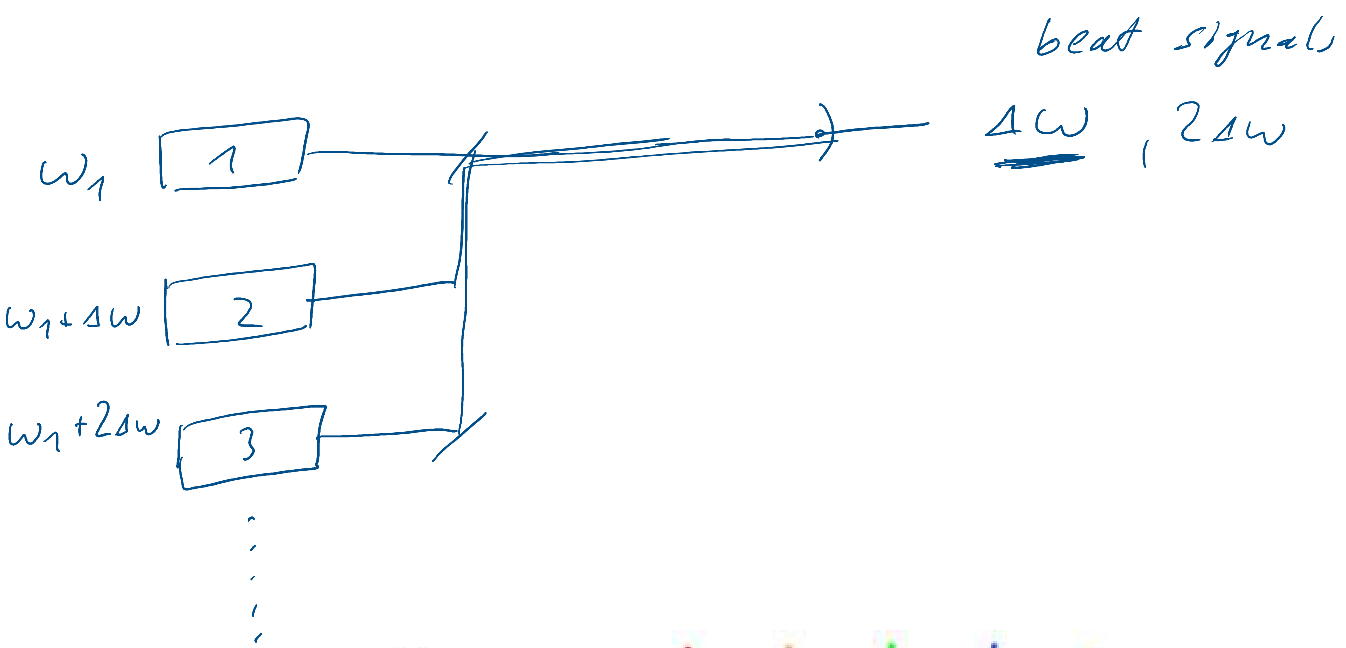
= pulse round-trip time

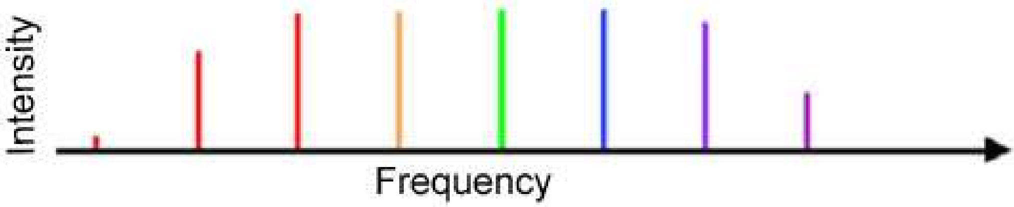
a regular "train" of pulses

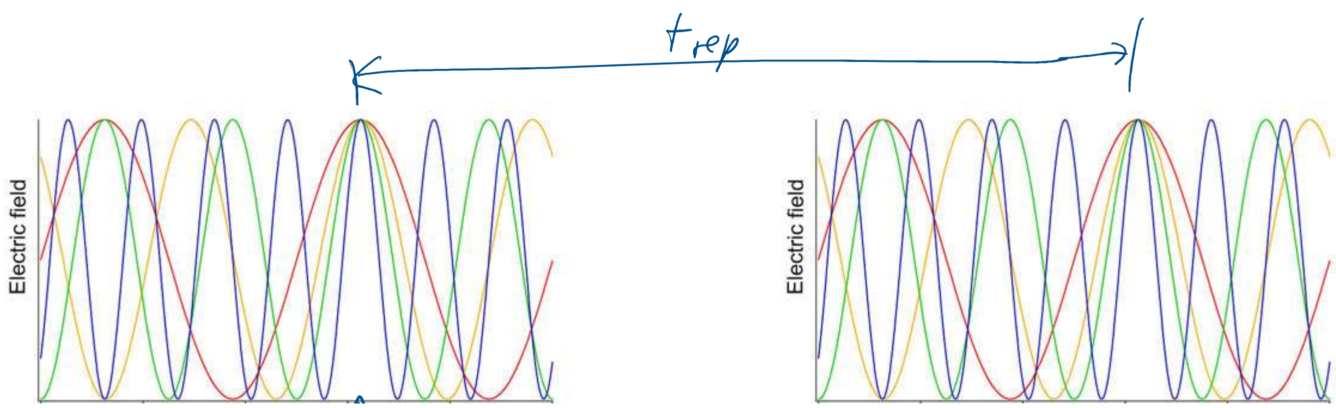
is THE SAME

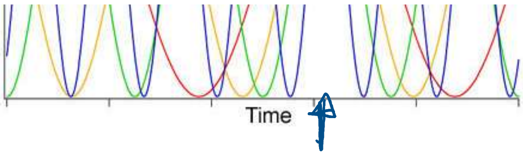
as a superposition of many continuous lasers (cw)

Let's combine several cw lasers

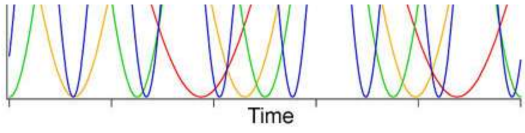


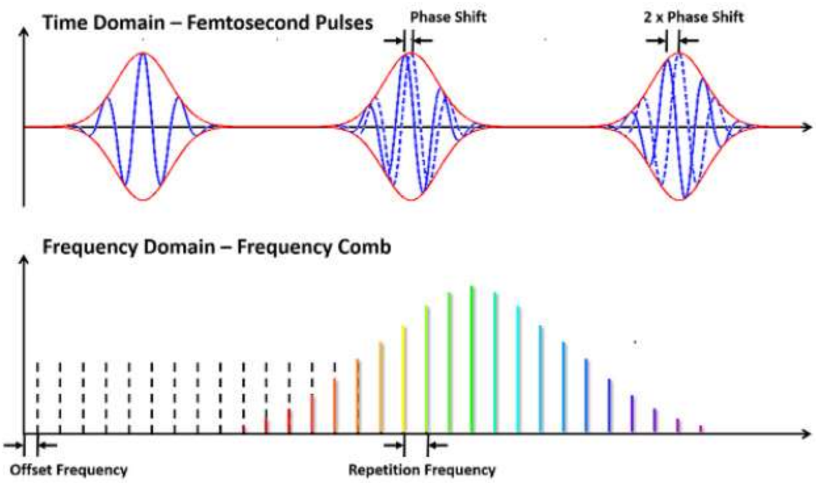



constructive interference



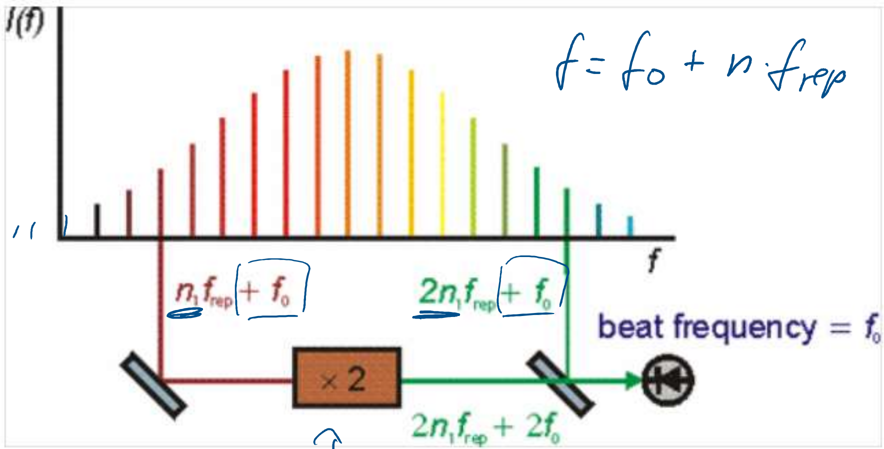

2nd pulse

# Fourier transform




https://www.laserfocusworld.com/articles/2015/03/cornell-cmos-compatible-mid-ir-optical-frequency-comb-fits-on-1-mm-chip.html

# Self-referenced comb




$f = f_0 + n \cdot f_{rep}$

$f_0$

http://www.npl.co.uk/science-technology/time-frequency/optical-frequency-standards-and-metrology/research/self-referencing-of-an-optical-frequency-comb

$f_{total}$

$$E(t) = E_0 \cos(\overbrace{\underbrace{\omega t}_{\text{time-dependent phase}} + \underbrace{\varphi}_{\to\ \varphi(t)}}^{\varphi_{total}})$$