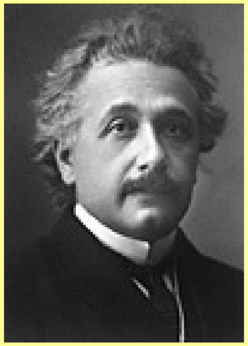
De LASER

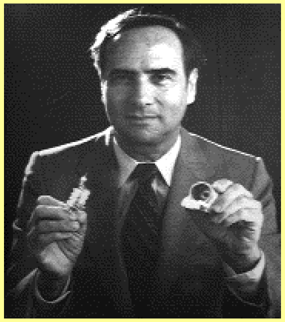
L	Light
A	Amplification (by)
S	Stimulated
E	Emission (of)
R	Radiation

The History



A. Einstein

1916: concept of stimulated emission



Th. Maiman

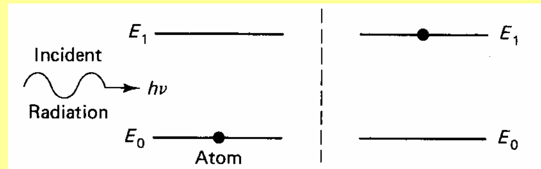
1st Ruby laser

1960: the first laser in operation

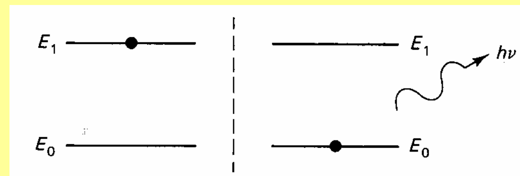
1961 Gas laser (Javan)
1964 YAG laser (Bell Labs)
1964 CO_2 laser (Patel)
1966 Dye laser (Sorokin, IBM)
1970 Excimer laser (Basov)
1977 Free Electron laser (Stanford)
Etc….

Interactie licht en materie

Postulaat van Einstein:
3 fundamentele processen

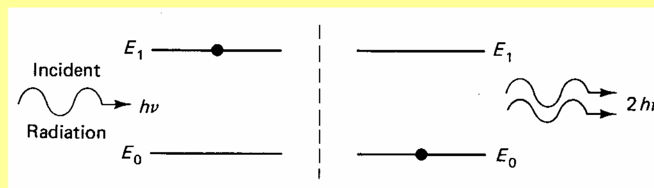


Absorptie



Spontane emissie

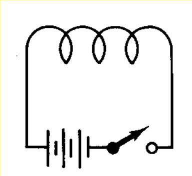
Wet van behoud van energie:
$h\nu = E_1 - E_0$



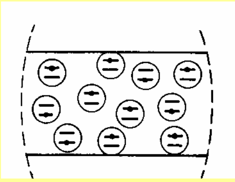
Gestimuleerde emissie: Produktie van *identieke* fotonen

"Populatie-inversie"

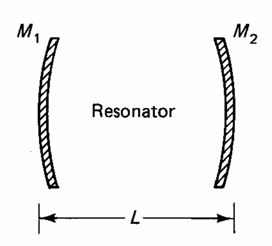
Elementen van een LASER



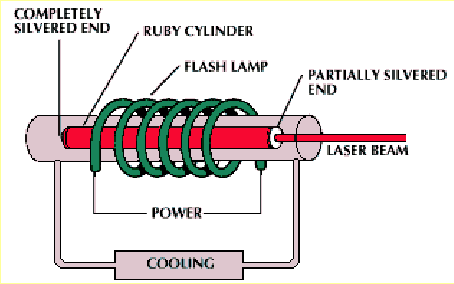
pomp



versterkingsmedium



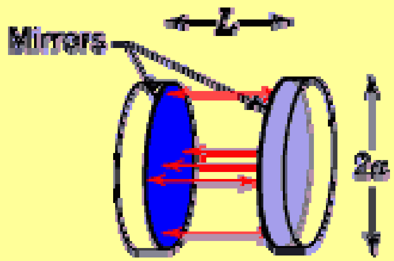
trilholte; caviteit



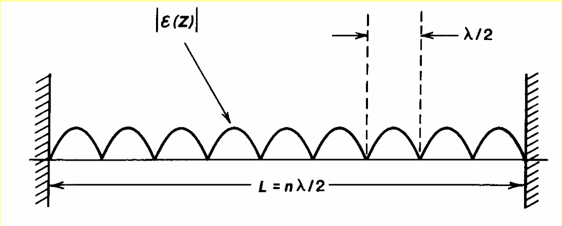
principe van Ruby laser

Laserwerking:
populatie-inversie
versterking > verliezen

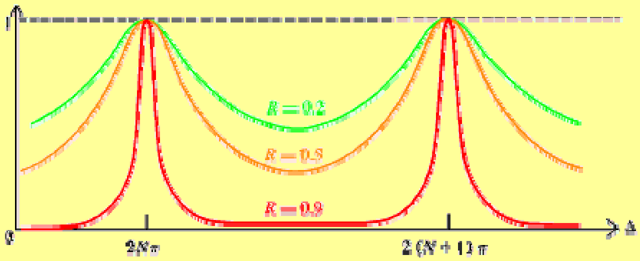
"Modes" van een resonator-trilholte



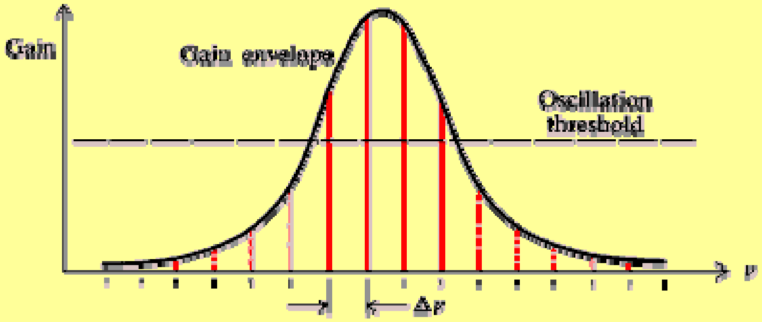
laser trilholte met reflecterende spiegels



staande golf-patroon



modes langs frequentie-as



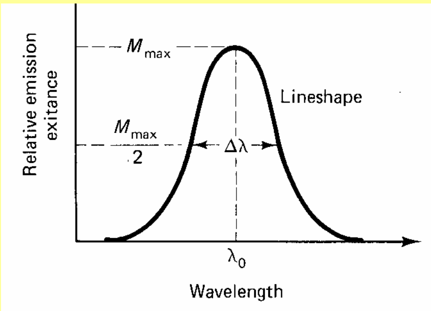
mode-selectie in laser; met mode-competitie

"single-mode" werking mogelijk: smalbandige laser

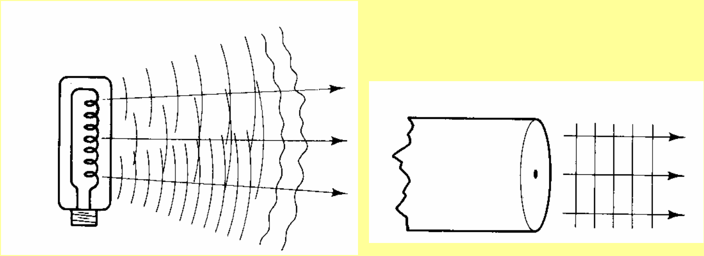
Eigenschappen van laserlicht

Monochromaticiteit/ bandbreedte

temporele coherentie



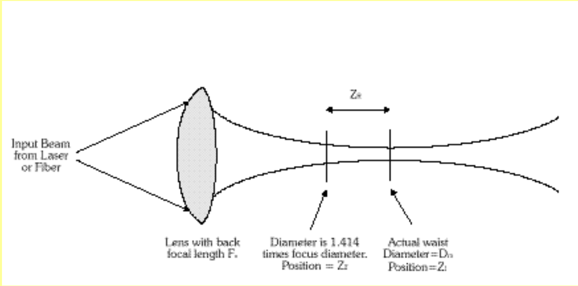
Ruimtelijke coherentie



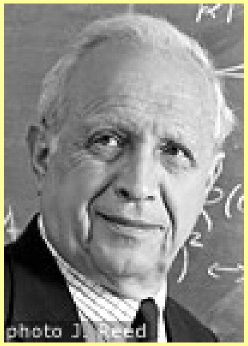
lamp: chaotisch

laser: coherent

Directionaliteit



Maar: vanwege buigingseffecten
- spreiding van bundel
- niet focusseerbaar in punt

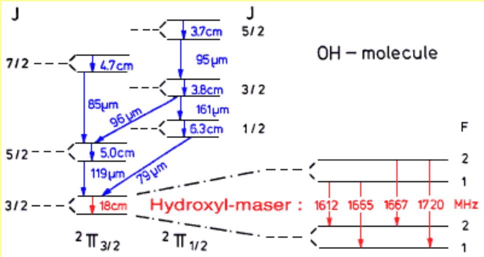


Roy Glauber:
2005 Nobel Prize
"for his contribution to the quantum theory of optical coherence."

Natuurlijke Masers - Lasers

Interstellar hydroxyl radicaal

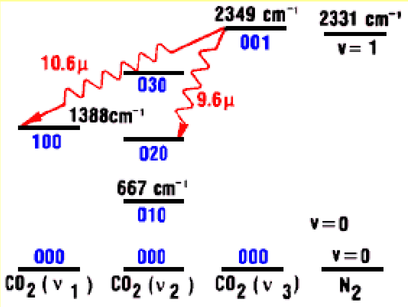
Orion nevel



Niveau schema
OH molecuul

ν = 1.6 GHz

CO_2 laser in de atmosfeer van MARS

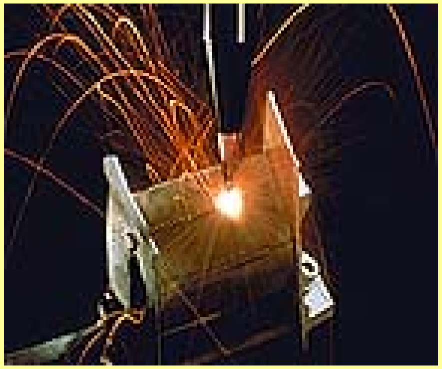


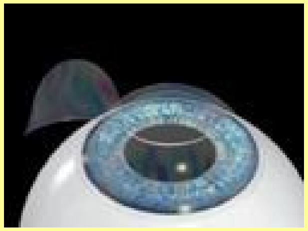
Energieniveau-schema CO_2

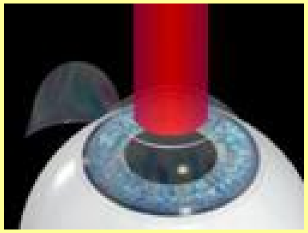
λ = 9.6 en 10.6 mm

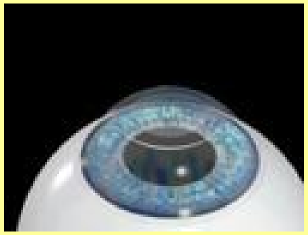
Laser Centre Vrije Universiteit, Amsterdam

Lasers: snijden en lassen met hoge precisie





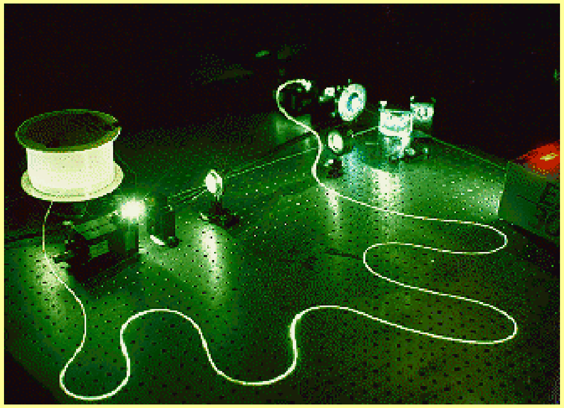




Laser-in-situ Keratomileusis
(LASIK)

Telecommunicatie

"van koper naar optische vezel"



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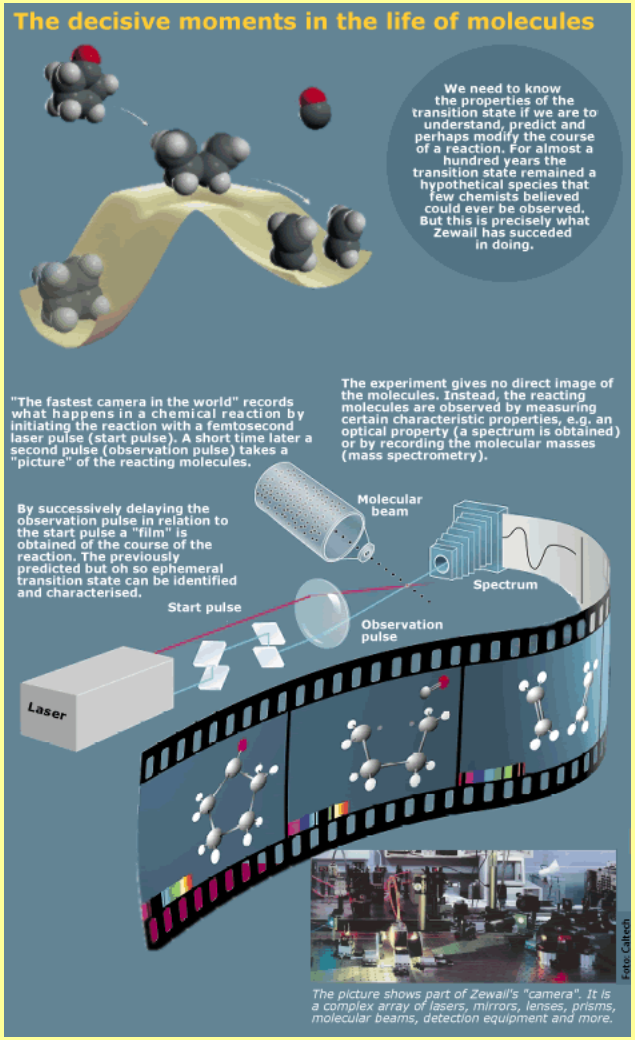
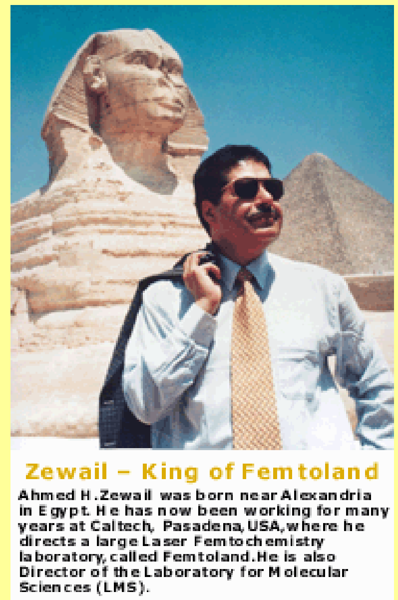
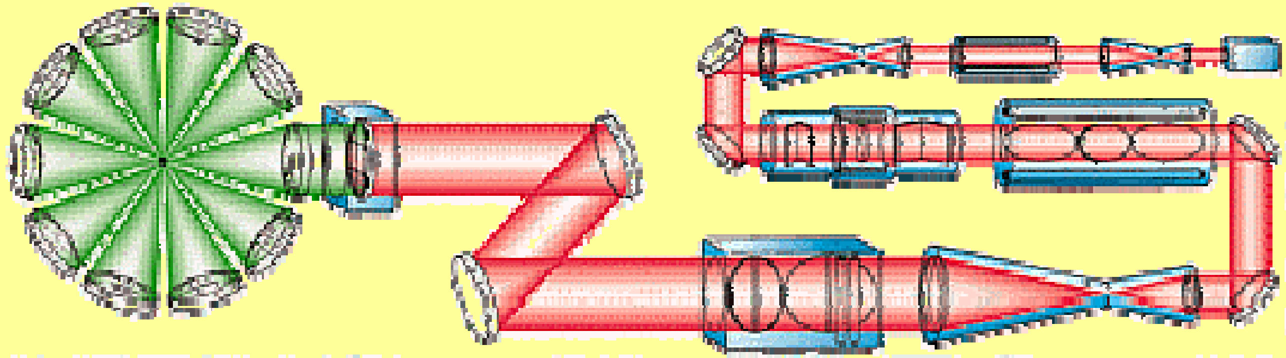
Femto-chemie





Nobelprijs 1999 Scheikunde

Laser Geïnduceerde Fusie: de NOVA en NIF lasers



principe: D-T pellet
laser-ablatie geeft als reactie naar binnen gerichte schokgolf

National Ignition Facility

In opbouw:
Nd:glass laser (527 nm)
192 bundels
10 MegaJoule in 10 ns

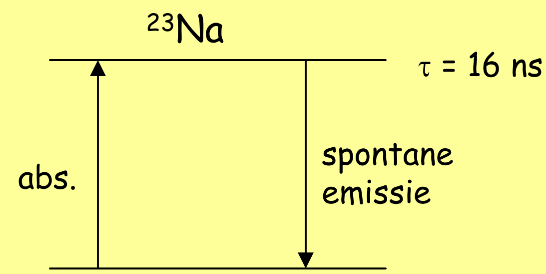
Afremmen van atomen

Impulsoverdracht

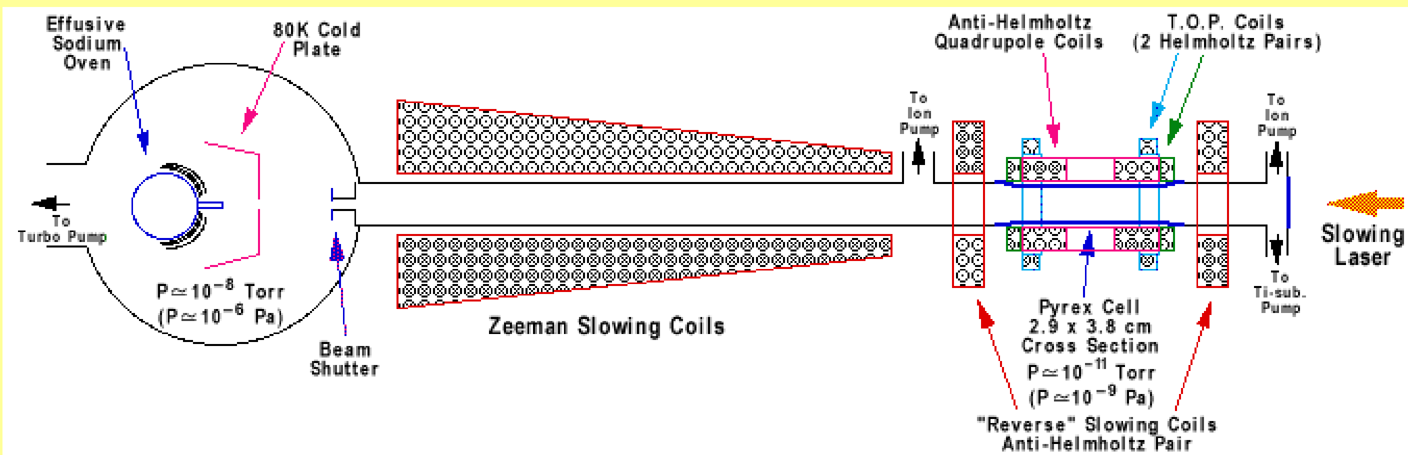
Impuls van fotonen: $p = E/c = h\nu/c = h/\lambda$
voor l = 500 nm : $p = 1.3 \times 10^{-27}$ kgm/s

Impuls van Atoom: Na (23 a.u.); v = 500 m/s
$p_{Na} = 2 \times 10^{-23}$ kgm/s

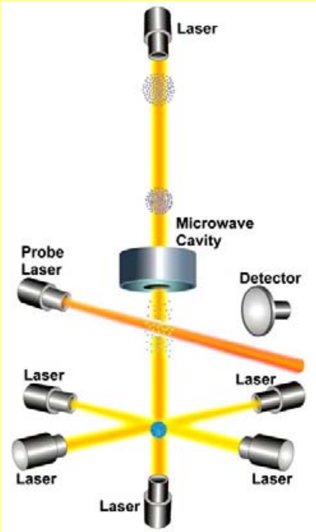
$15000\ p_{foton} = p_{Na}$



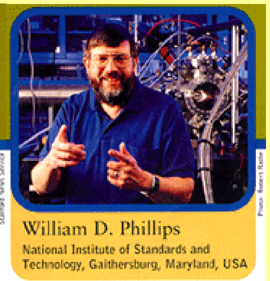
Zeeman slower: Doppler effect ⇔ Zeeman-effect



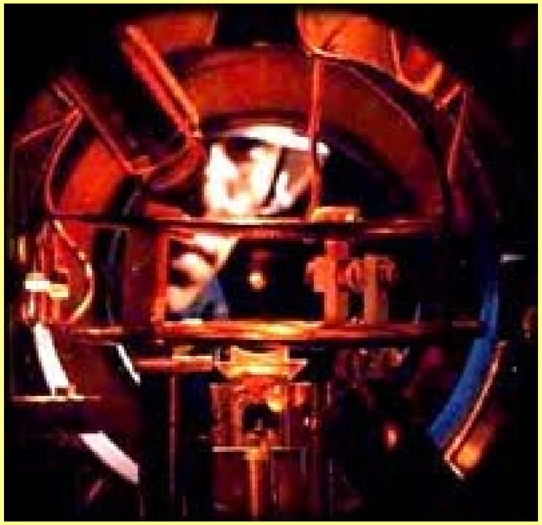
Vangen van atomen en afkoelen



Optische stroop
en atoom fontein



Nobelprijs 1997



Magneto-optical
trap

Extreem koude atomen
Fase-overgang
Bose-Einstein condensatie

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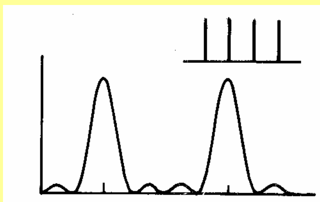
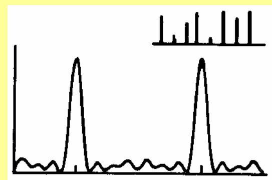
"Mode-locking" van een laser

principe: cavity modes van laser oscilleren "samen"



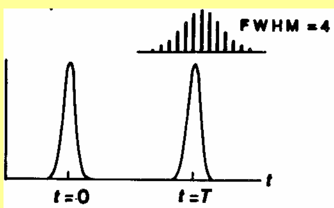
4 modes in fase



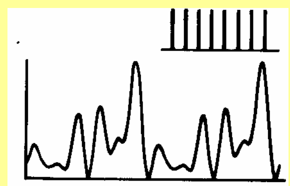
veel modes in fase
random amplitude

$$I(t) = I_0 \sin(2\pi f t + \phi)$$

$$I(t) = \sum_n I_n \sin(2\pi_n f t + \phi_n)$$



veel modes in fase

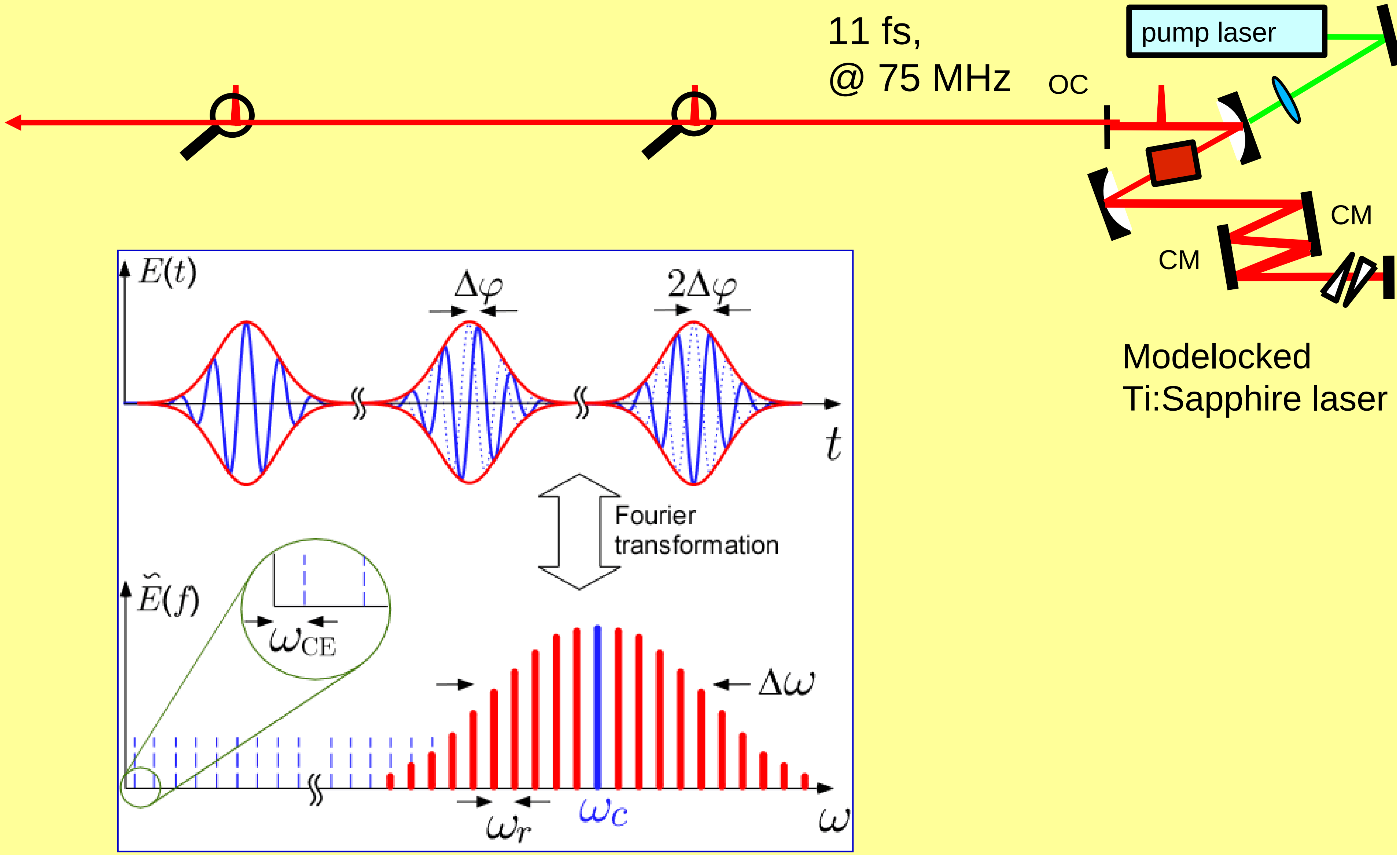


modes random fase

Fourier principe voor golfverschijnselen

$$\Delta\omega \cdot \Delta\tau \geq 1$$

Frekwentiekamlaser



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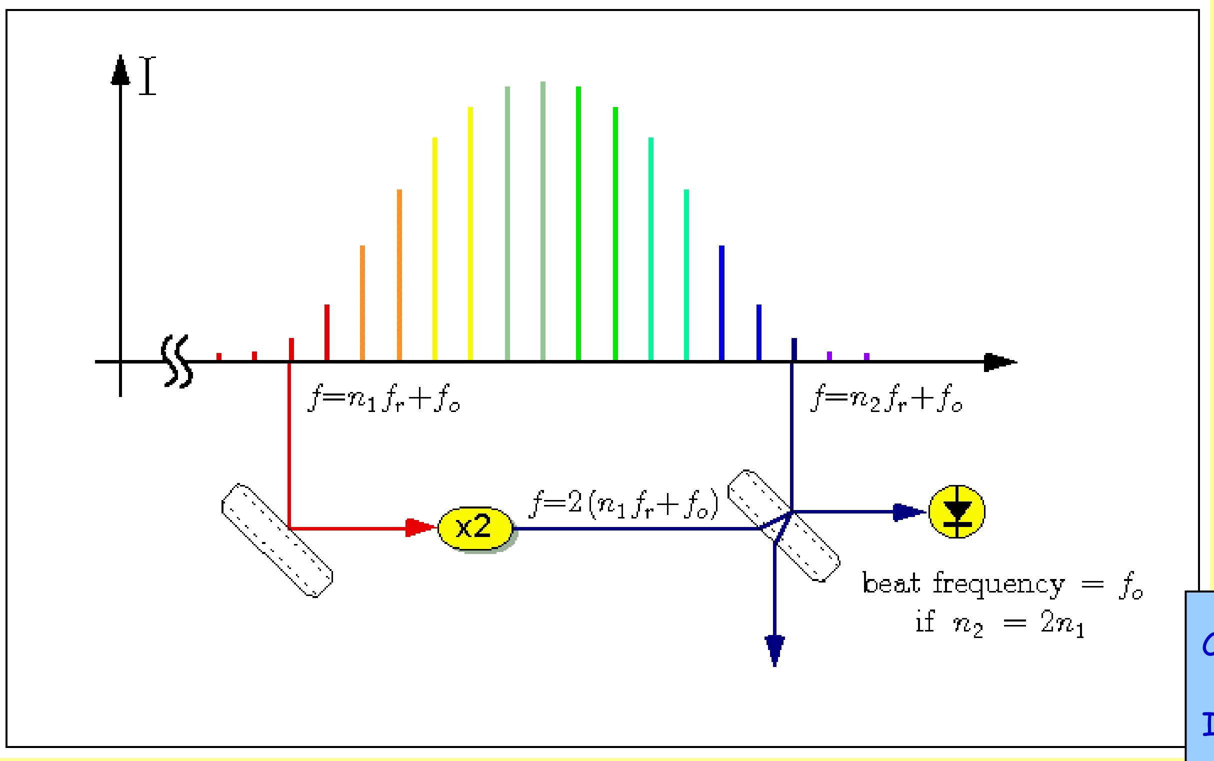
Toekomstige atoomklok; terug naar de laser

Tellen van pulsen uit een
"ge-mode-lockte" laser



Toepassingen in
Hoge resolutie spectroscopie

Cs-lijn: f = 335 116 048 807 (41) kHz

In-lijn: f = 1 267 402 452 899.92 (23) kHz

H-lijn(1s2s) = 2 466 061 413 187 103 (46) Hz

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The Nobel Prize in Physics 2005