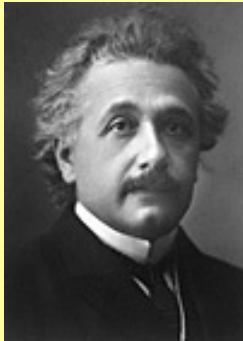


De LASER

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

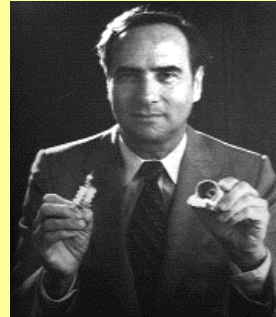
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The History



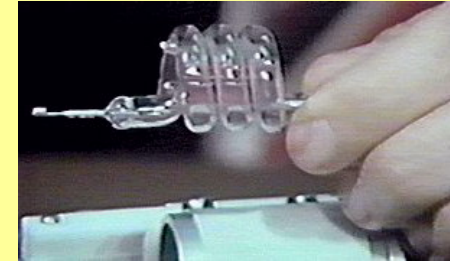
A. Einstein

1916: concept of stimulated emission



Th. Maiman

1960: the first laser in operation



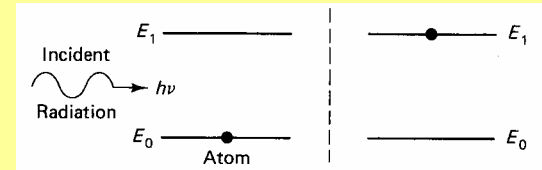
1st Ruby laser

1961 Gas laser (Javan)
1964 YAG laser (Bell Labs)
1964 CO₂ laser (Patel)
1966 Dye laser (Sorokin, IBM)
1970 Excimer laser (Basov)
1977 Free Electron laser (Stanford)
Etc....

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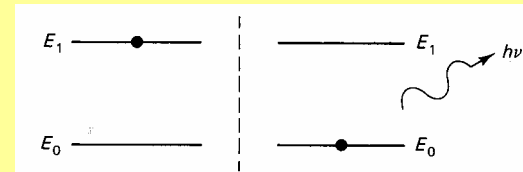
Interactie licht en materie

Postulaat van Einstein:
3 fundamentele processen

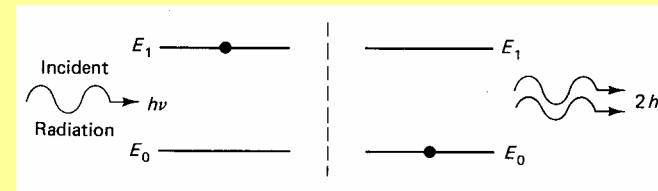


Absorptie

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



Spontane
emissie

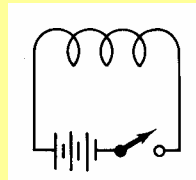


Gestimuleerde
emissie:
Productie van
identieke
fotonen

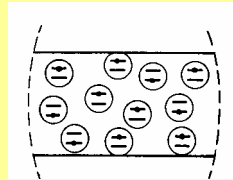
"Populatie-inversie"

Laser Centre Vrije Universiteit, Amsterdam

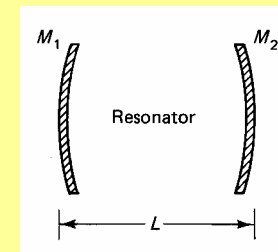
Elementen van een LASER



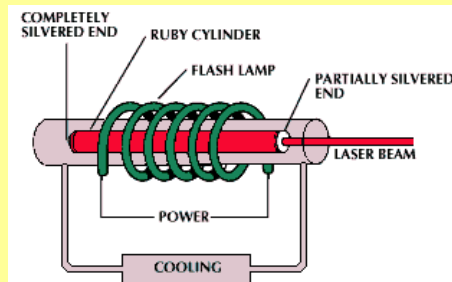
pomp



versterkingsmedium



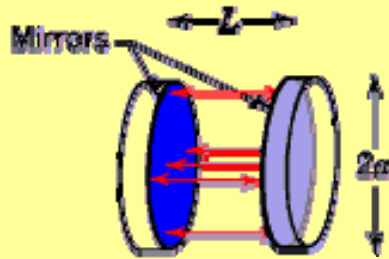
trilholte; caviteit



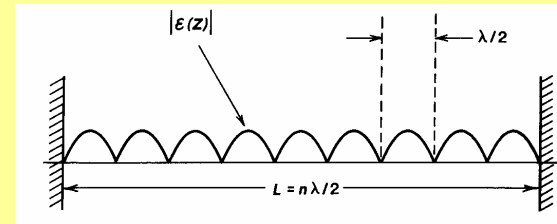
principe van Ruby laser

Laserwerking:
populatie-inversie
versterking > verliezen

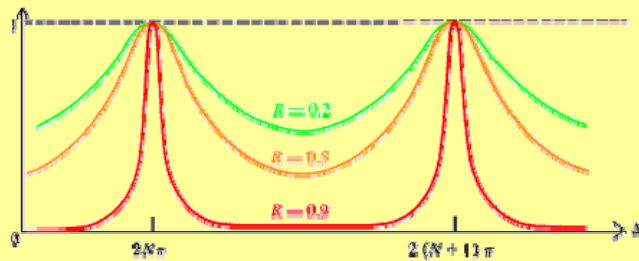
"Modes" van een resonator-trilholte



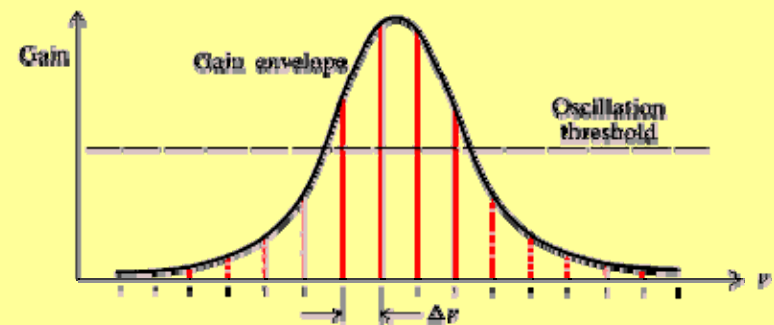
laser trilholte met reflecterende spiegels



staande golf-patroon



modes langs frequentie-as

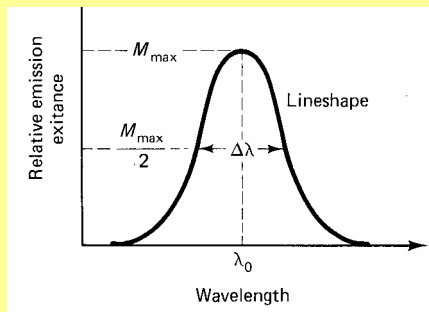


mode-selectie in laser; met mode-competitie

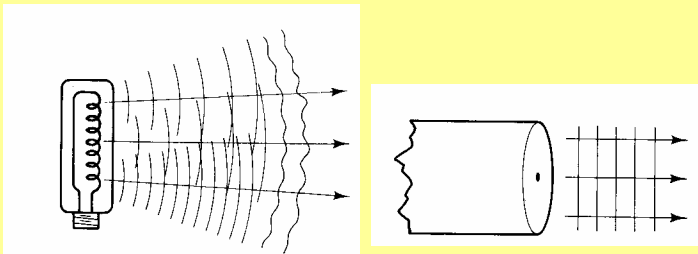
"single-mode" werking mogelijk: smalbandige laser

Eigenschappen van laserlicht

Monochromaticiteit/ bandbreedte temporele coherentie



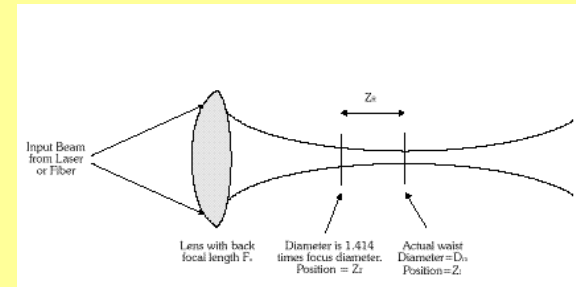
Ruimtelijke coherentie



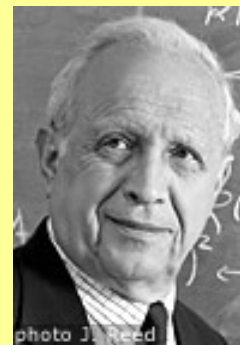
lamp: chaotisch

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."

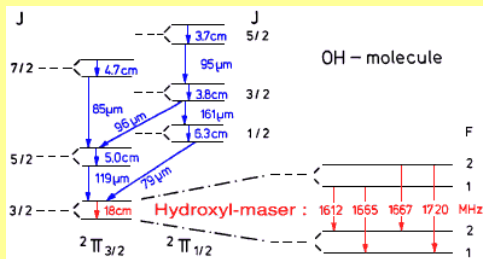
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Natuurlijke Masers - Lasers

Interstellar hydroxyl radicaal



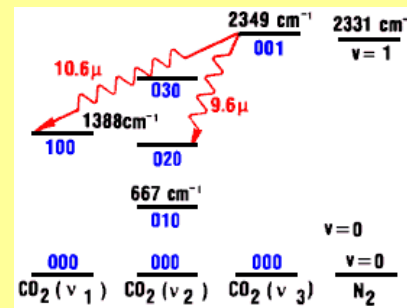
Orion nevel



Niveau schema OH molecuul

$\nu = 1.6 \text{ GHz}$

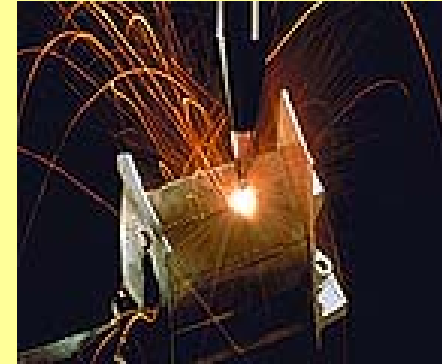
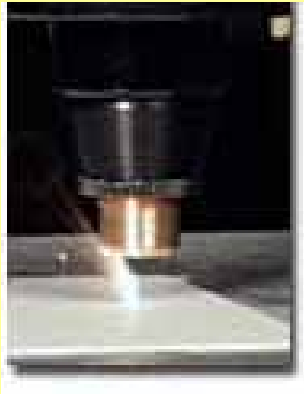
CO₂ laser in de atmosfeer van MARS



Energieniveau-schema CO₂

$\lambda = 9.6 \text{ en } 10.6 \text{ mm}$

Lasers: snijden en lassen met hoge precisie

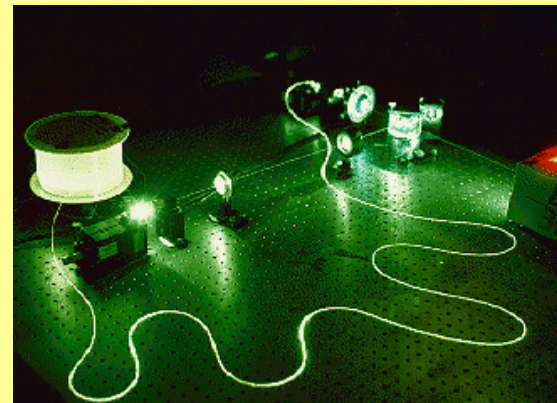


Laser-in-situ Keratomileusis
(LASIK)

Laser Centre Vrije Universiteit, Amsterdam

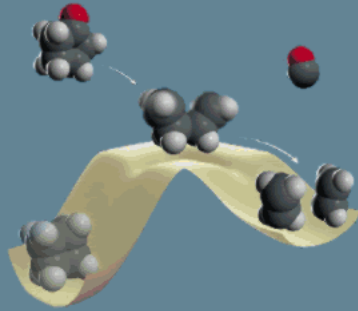
Telecommunicatie

"van koper naar optische vezel"



Laser Centre Vrije Universiteit, Amsterdam

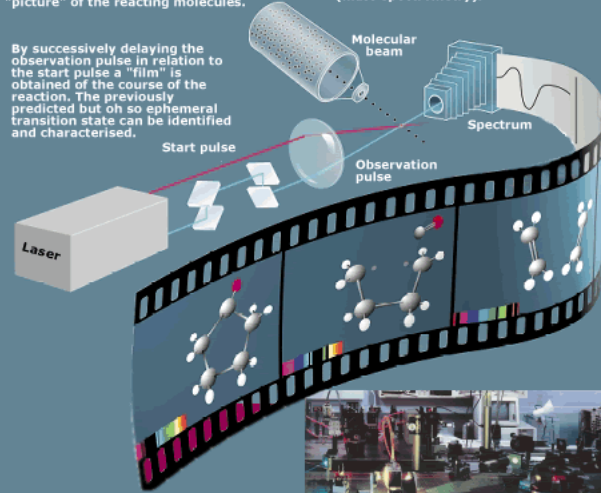
The decisive moments in the life of molecules



We need to know the properties of the transition state if we are to understand, predict and perhaps modify the course of a reaction. For almost a hundred years the transition state remained a hypothetical species that few chemists believed could ever be observed. But this is precisely what Zewail has succeeded in doing.

"The fastest camera in the world" records what happens in a chemical reaction by initiating the reaction with a femtosecond laser pulse (start pulse). A short time later a second pulse (observation pulse) takes a "picture" of the reacting molecules.

The experiment gives no direct image of the molecules. Instead, the reacting molecules are observed by measuring certain characteristic properties, e.g., an optical property (a spectrum is obtained) or by recording the molecular masses (mass spectrometry).



By successively delaying the observation pulse in relation to the start pulse a "film" is obtained of the course of the reaction. The previously predicted but oh so ephemeral transition state can be identified and characterised.

Start pulse

Molecular beam

Spectrum

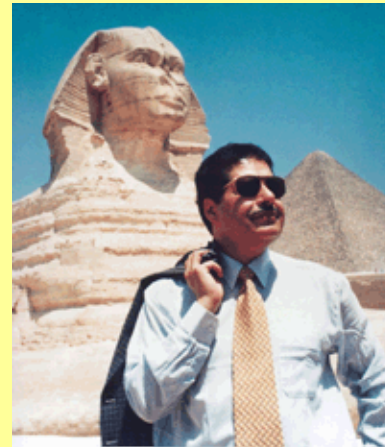
Observation pulse

Laser



The picture shows part of Zewail's "camera". It is a complex array of lasers, mirrors, lenses, prisms, molecular beams, detection equipment and more.

Femto-chemie



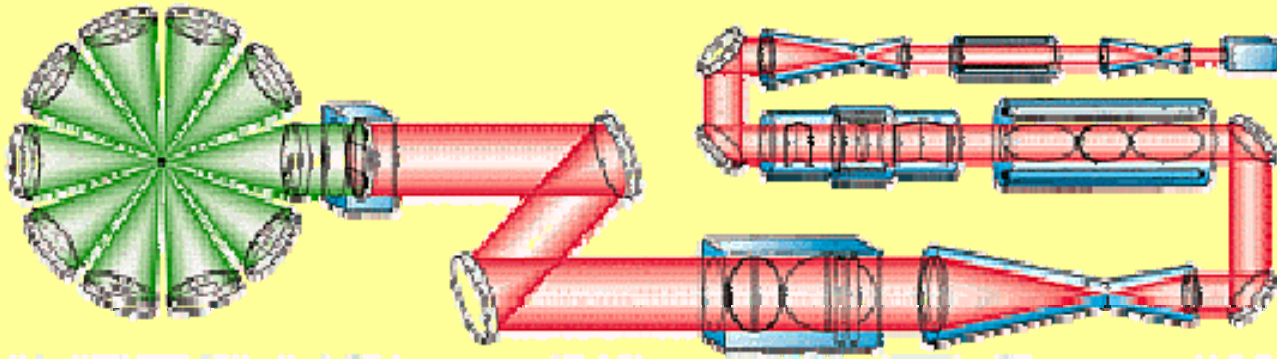
Zewail – King of Femtoland

Ahmed H. Zewail was born near Alexandria in Egypt. He has now been working for many years at Caltech, Pasadena, USA, where he directs a large Laser Femtochemistry laboratory, called Femtoland. He is also Director of the Laboratory for Molecular Sciences (LMS).

Nobelprijs 1999 Scheikunde

Laser Centre Vrije Universiteit, Amsterdam

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



Laser Centre Vrije Universiteit, Amsterdam

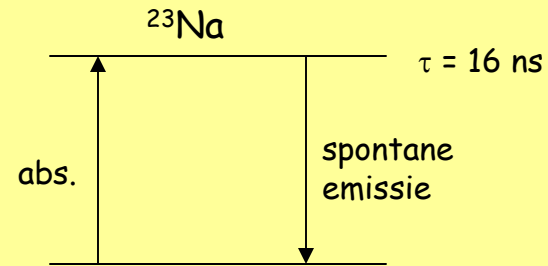
Afremmen van atomen

Impulsoverdracht

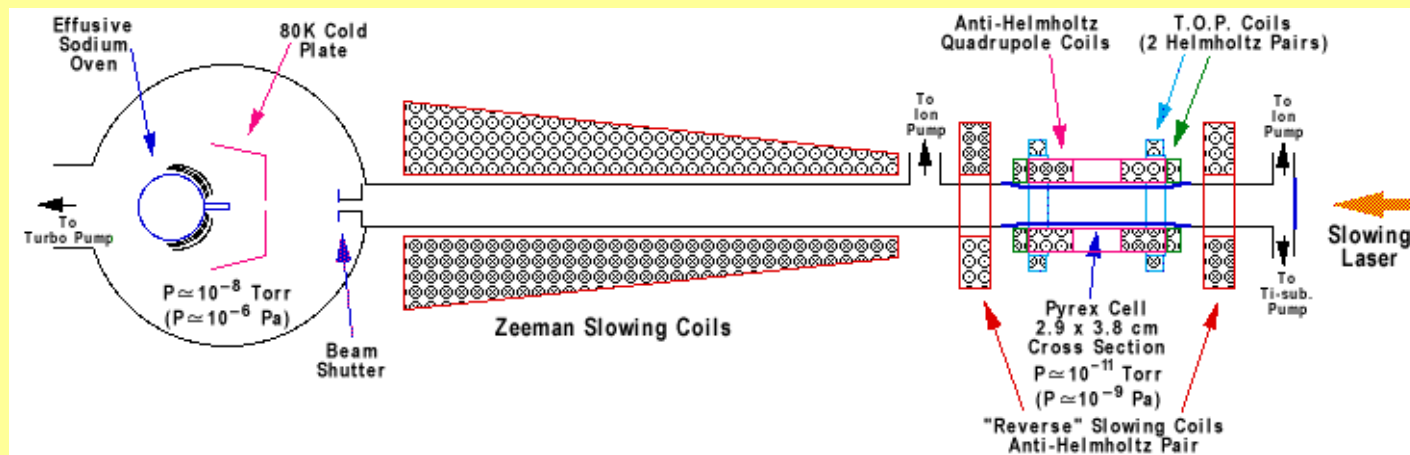
Impuls van fotonen: $p = E/c = hv/c = h/\lambda$
 voor $\lambda = 500 \text{ nm}$: $p = 1.3 \times 10^{-27} \text{ kgm/s}$

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

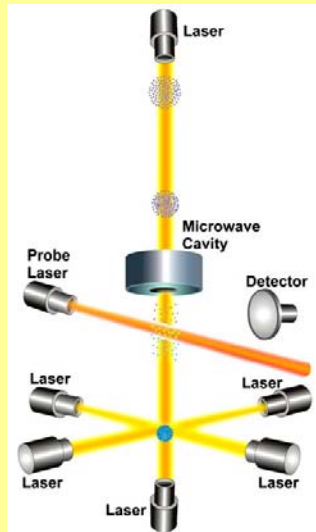
$15000 p_{\text{foton}} = p_{\text{Na}}$



Zeeman slower: Doppler effect \Leftrightarrow Zeeman-effect



Vangen van atomen en afkoelen



Optische stroop
en atoom fontein



Magneto-optical
trap



Steven Chu
Stanford University, Stanford,
California, USA



William D. Phillips
National Institute of Standards and
Technology, Gaithersburg, Maryland, USA



Claude Cohen-Tannoudji
Collège de France and École Normale
Supérieure, Paris, France

Nobelprijs 1997

Extreem koude atomen
Fase-overgang
Bose-Einstein condensatie

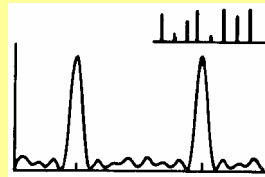
Laser Centre Vrije Universiteit, Amsterdam

"Mode-locking" van een laser

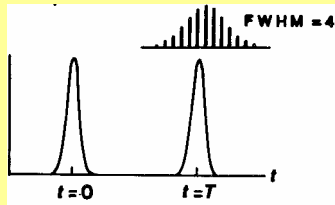
principe: cavity modes van laser oscilleren "samen"



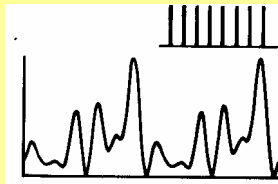
4 modes in fase



veel modes in fase
random amplitude



veel modes in fase



modes random fase

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

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

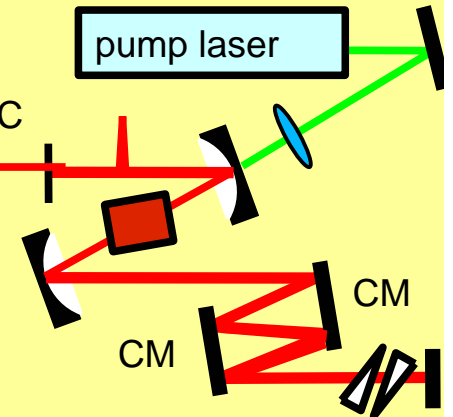
Fourier principe voor golfverschijnselen

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

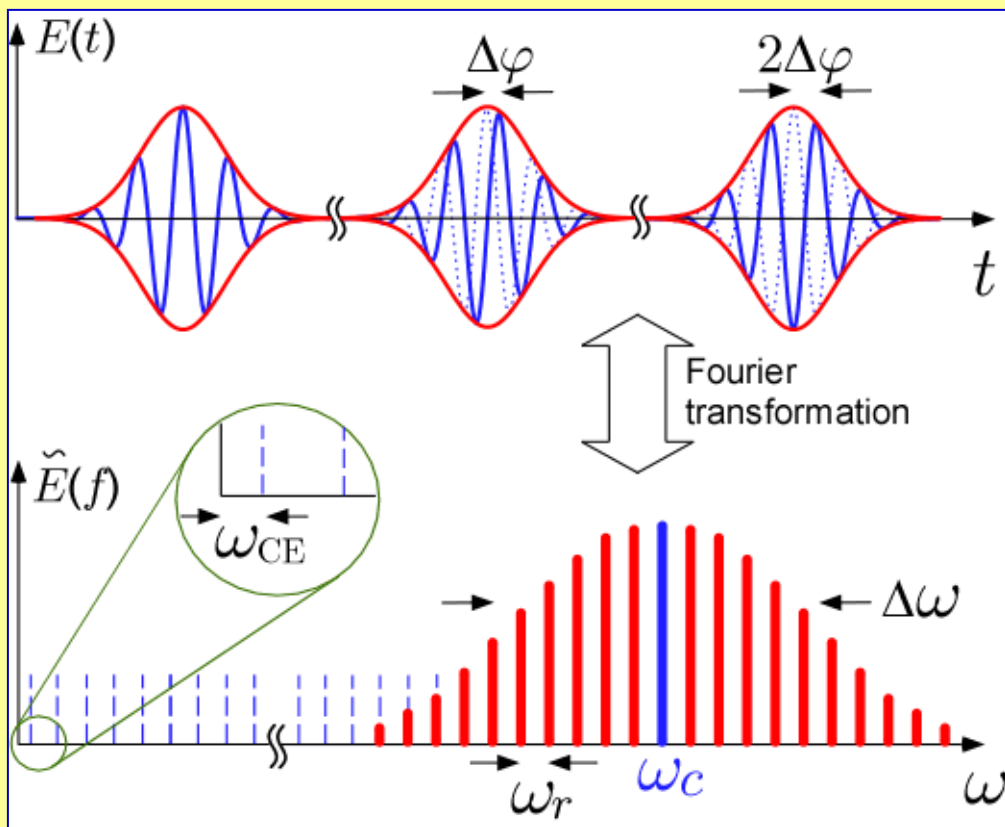
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Frekwentiekamlaser

11 fs,
@ 75 MHz oc



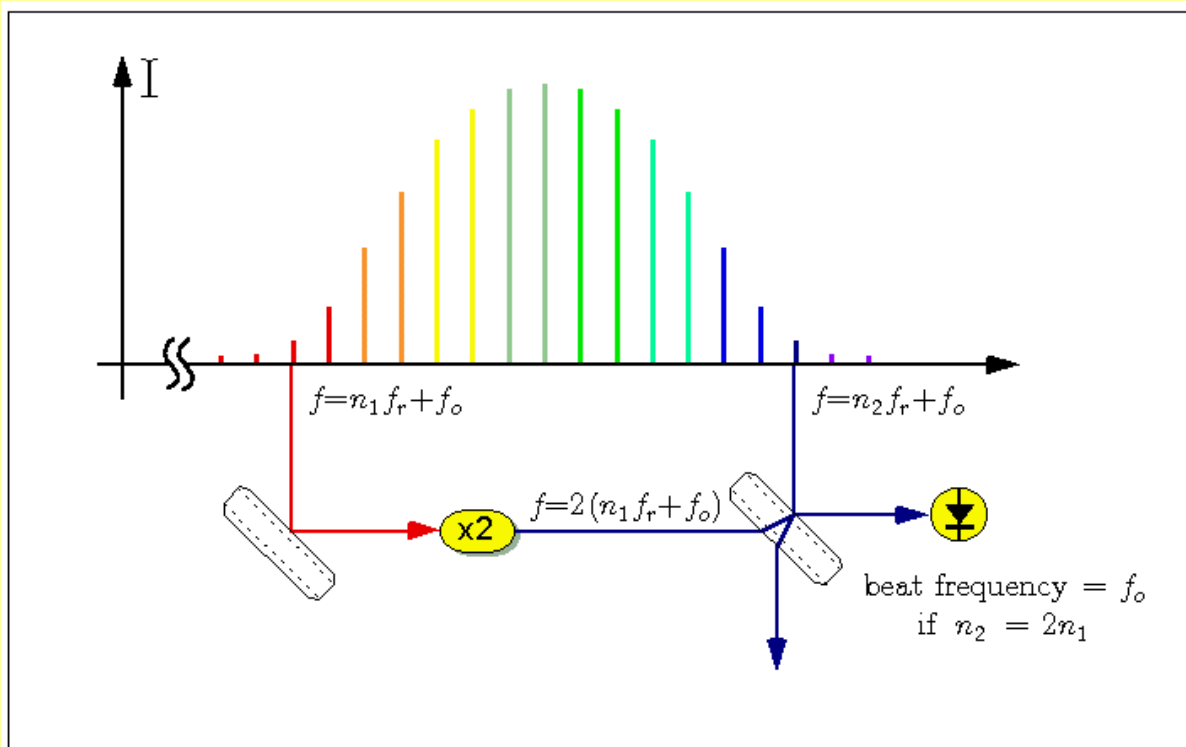
Modelocked
Ti:Sapphire laser



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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: $f = 335\,116\,048\,807\,(41)\text{ kHz}$

In-lijn: $f = 1\,267\,402\,452\,899.92\,(23)\text{ kHz}$

H-lijn(1s2s) = $2\,466\,061\,413\,187\,103\,(46)\text{ Hz}$

Laser Centre Vrije Universiteit, Amsterdam



The Nobel Prize in Physics 2005



Laser Centre Vrije Universiteit, Amsterdam