Historical Review on the Maser and Laser Development

Universität Bonn, Institut für Angewandte Physik, 02.09.2025

Dieter Meschede

© MGM HOME ENTERTAINMENT GMBH

Shirley Bassey, Sean Connery, Gert Fröbe

Let us explore the role of
Sean Connery (007)
for laser development …


Filmszene aus Goldfinger 1965

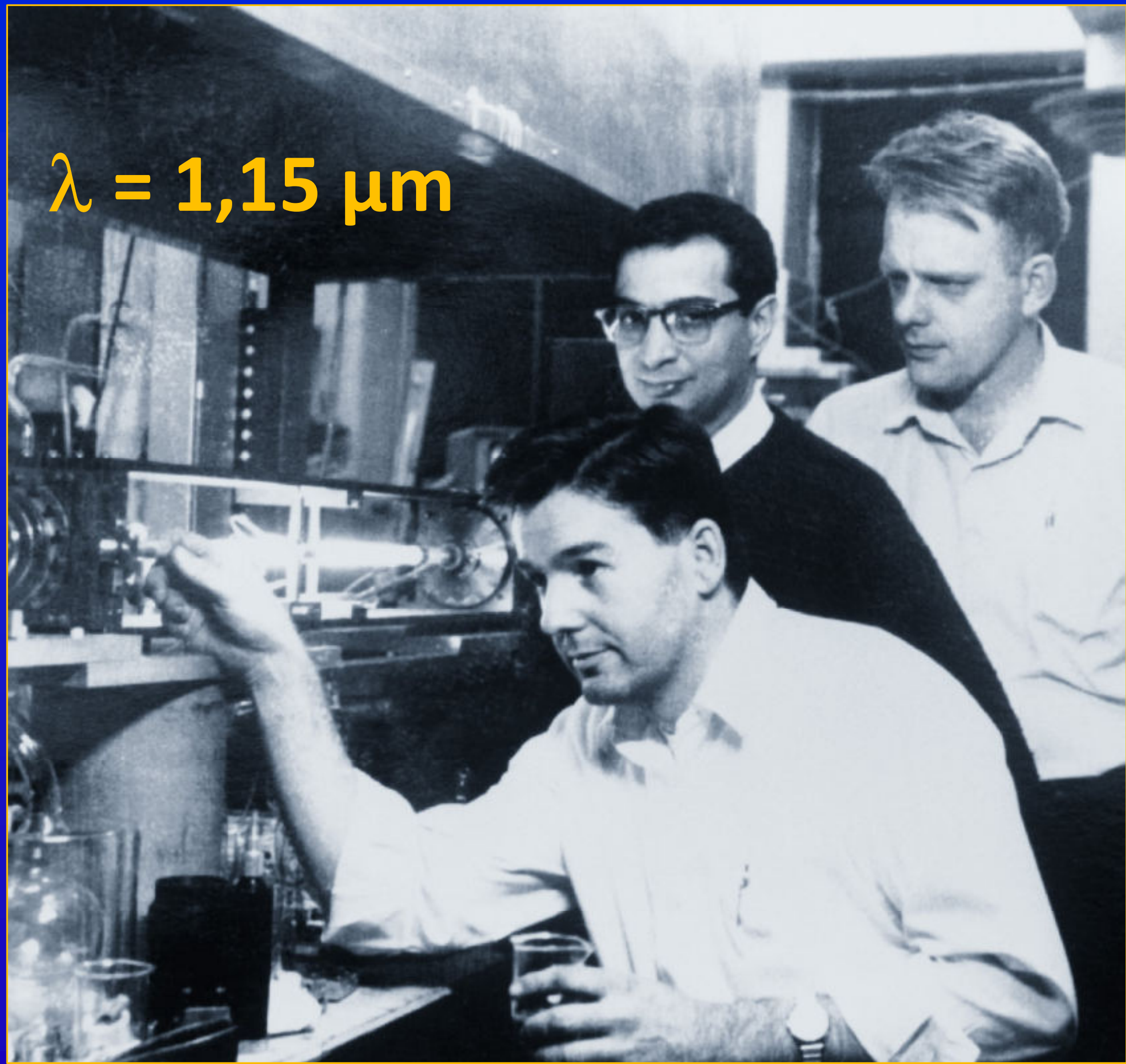
Shirley Bassey, Sean Connery, Gert Fröbe

movie made in 1964!

Short History:

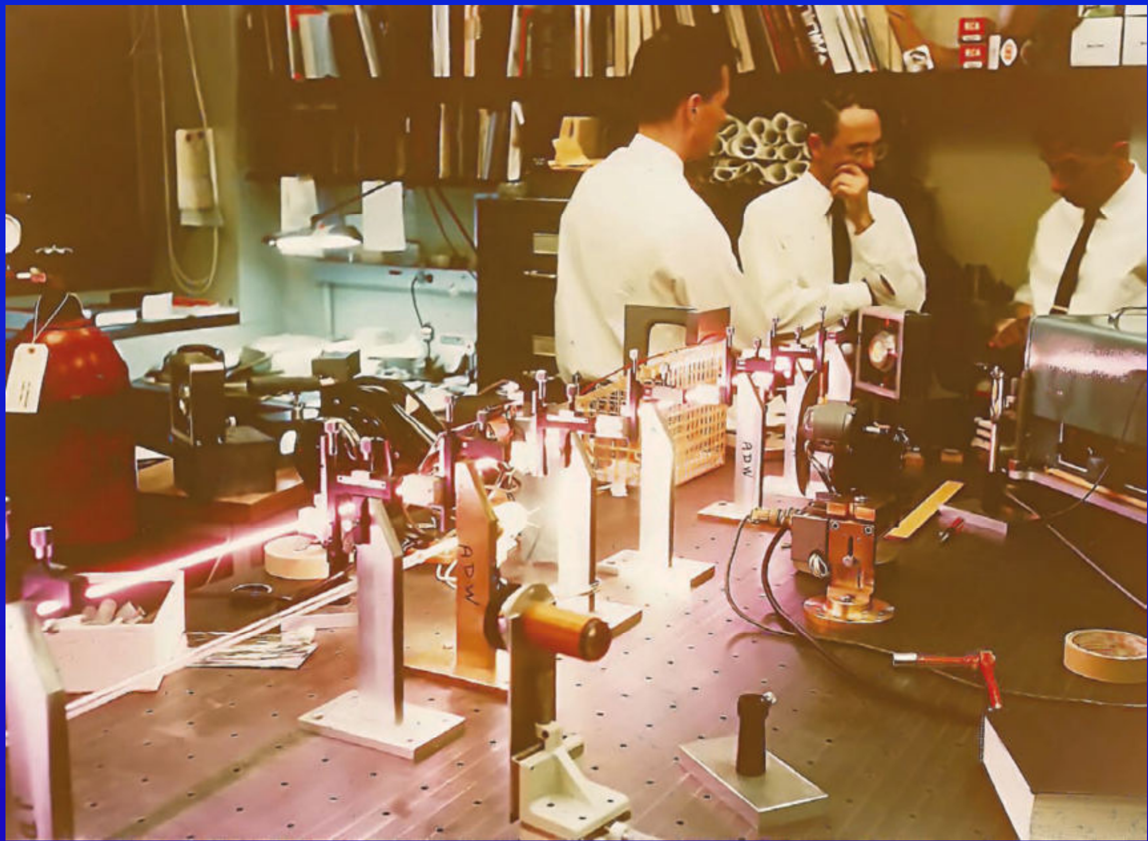
- 14.01.1965: Film debut „Goldfinger“

- 1962 first **cw visible** laser (HeNe)
  .D. White and J.D. Rigden. Proc. IRE 50, 1697 (1962).
- 1961 first **continuous wave** (cw) laser (Helium-Neon)
  A. Javan et al. Phys. Rev. Lett. 6, 106 (1961).
- 1960 **realisation** of a **pulsed** laser (T. Maiman, Ruby)
  T.H. Maiman. Nature 187, 493 (1960).
- 1958 **invention** of the laser (optical maser)
  A.L. Schawlow and C.H. Townes. Phys. Rev. 112, 1940 (1958),
  G. Gould (Patent 1974)



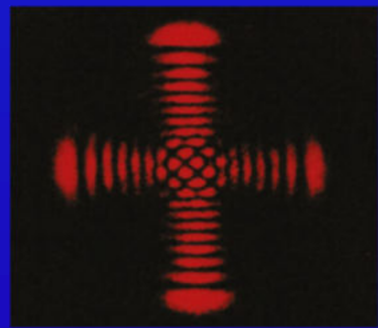
Don Herriott, Ali Javan and William Bennet
(left to right)
with the first ever
Helium-Neon-Laser
(Bell Laboratories)

© Ref: *History of Gas Lasers*, J. Hecht, Optics&Photonics News Jan. 2010



© Ref: *Recollections of the first continuous visible laser*, A. White, Optics&Photonics News, Oct 2011

(Left to right) Dane Rigden, Alan White and Bill Rigrod having a discussion in the laser lab at Bell Labs, 1963. The long HeNe laser on the bench is emitting about **80 milliwatts of power at 632.8 nm.**



What is so fascinating about laser light?

How is laser light different from candle light?

Laser light concentrates energy

in **space**
in **color**
in **time**

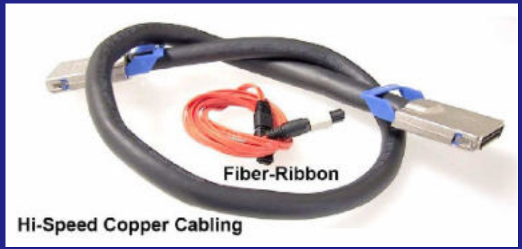
(© D. von der Linde (1941-2024))

concentration *in space*
→ collimation and focusability

© Ref: TRUMPF Werkzeugmaschinen GmbH

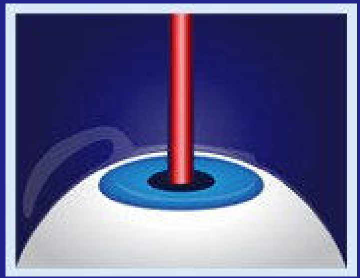
laser cutting, welding …

single color, *monochromasy*
→ interference, diffraction



information transport

concentration *in time*
→ short pulse laser, optical half cycle

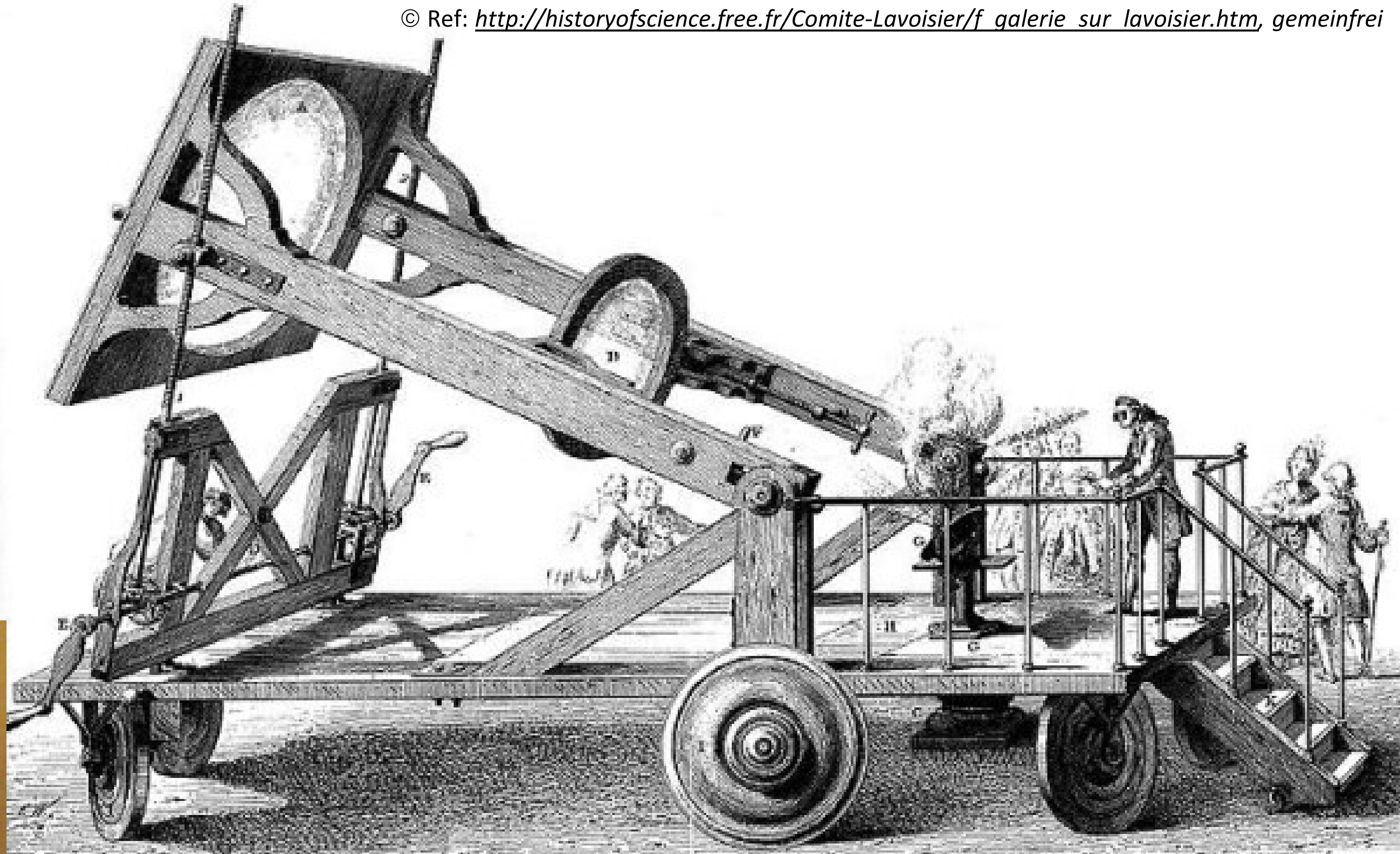


© Ref: myBody.de

laser surgery

focusability

© Ref: http://historyofscience.free.fr/Comite-Lavoisier/f_galerie_sur_lavoisier.htm, gemeinfrei



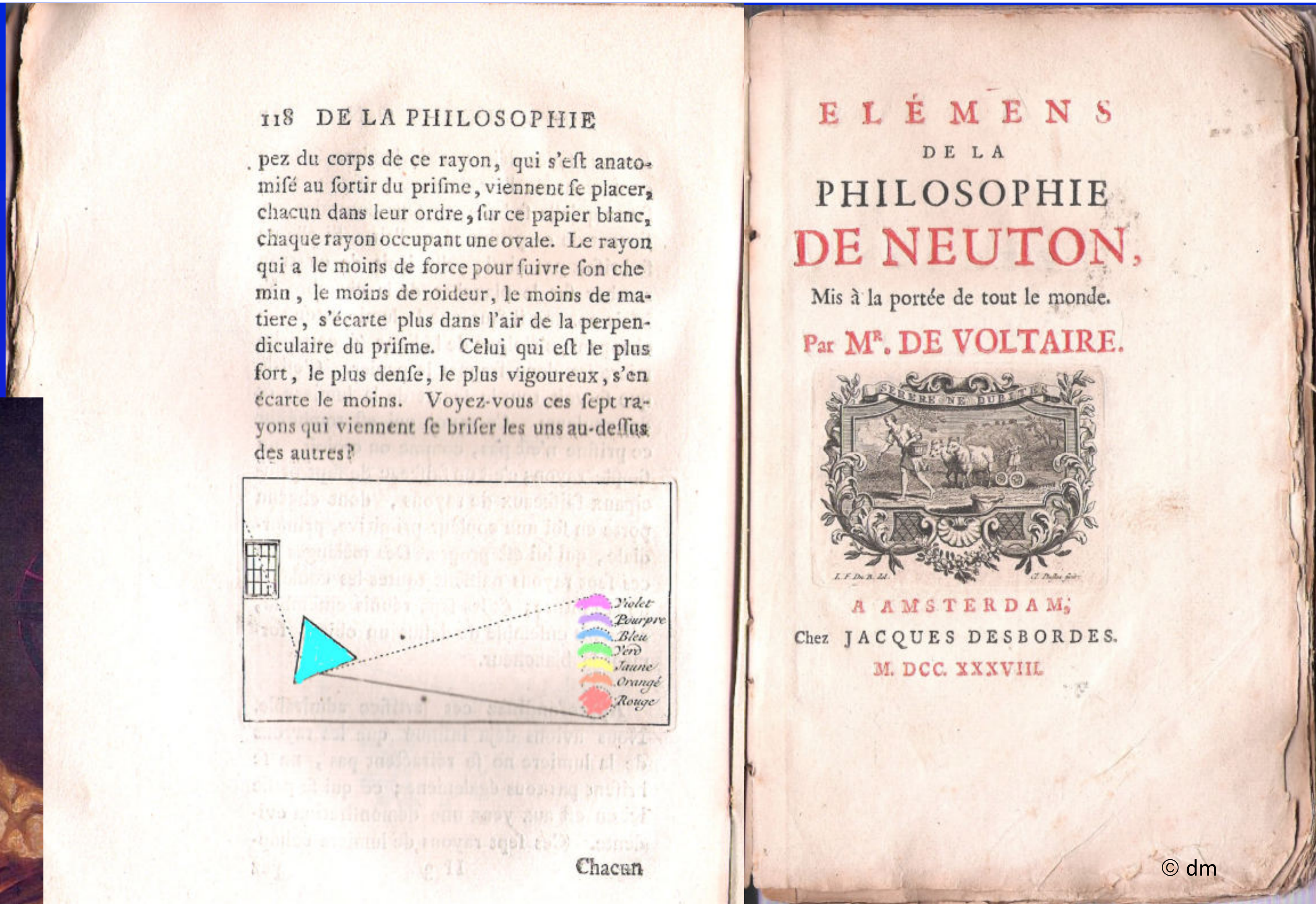
Antoine-Laurent de Lavoisier (1743-1794)

© dm

Musée des Arts et Métiers, Paris

monochromasy

Émilie du Châtelet 1706-1749
Maurice Quentin de La Tour (1704–1788) (Privatsammlung, gemeinfrei)



118 DE LA PHILOSOPHIE

pez du corps de ce rayon, qui s'eſt anatomiſé au ſortir du priſme, viennent ſe placer, chacun dans leur ordre, ſur ce papier blanc, chaque rayon occupant une ovale. Le rayon qui a le moins de force pour ſuivre ſon chemin, le moins de roideur, le moins de matiere, s'écarte plus dans l'air de la perpendiculaire du priſme. Celui qui eſt le plus fort, le plus denſe, le plus vigoureux, s'en écarte le moins. Voyez-vous ces ſept rayons qui viennent ſe briſer les uns au-deſſus des autres?

Chacun

ELÉMENS DE LA PHILOSOPHIE DE NEUTON,

Mis à la portée de tout le monde.

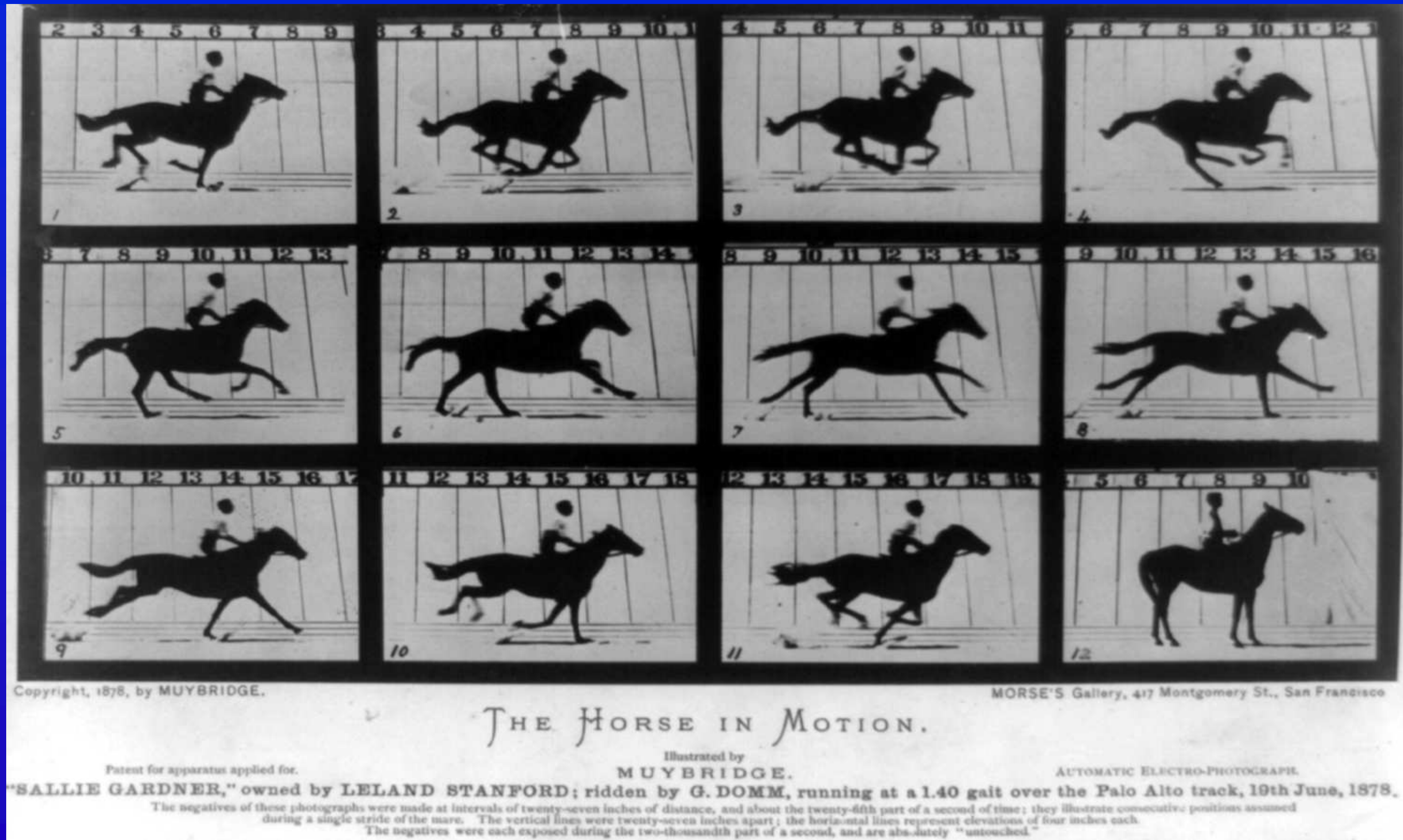
Par Mr. DE VOLTAIRE.

A AMSTERDAM,
Chez JACQUES DESBORDES.
M. DCC. XXXVIII.

© dm

concentration in time

© Library of Congress Prints and Photographs Division; https://www.loc.gov/pictures/item/97502309/



… a generator of ideas …

1912

© ETH-Bibliothek Zürich, Bildarchiv / Fotograf: Langhans, J. F., gemeinfrei

Albert Einstein

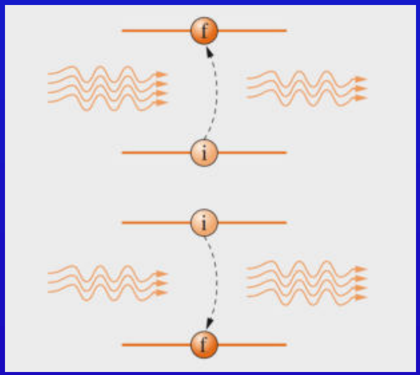
conceived in 1917 the concept of

stimulated emission:

The basic mechanism of light amplificiation leading to the **Laser**

(stimulierte) Absorption

stimulierte Emission



Laser = Light Amplification by Stimulated Emission of Radiation

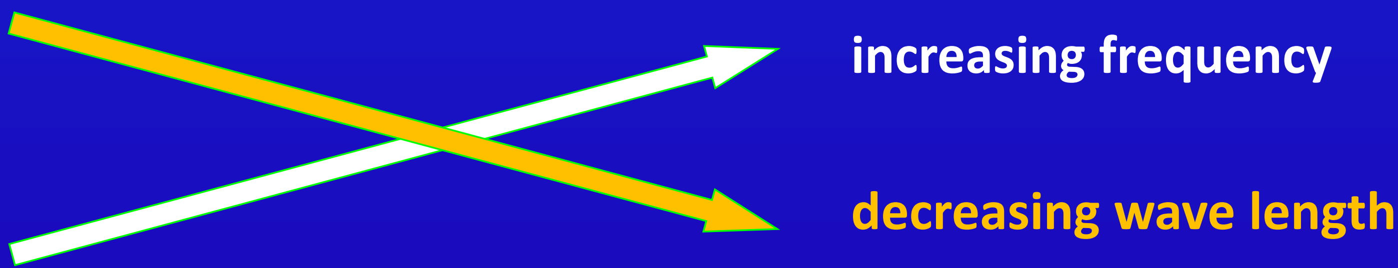
for comparison: LED = Light Emitting Diode

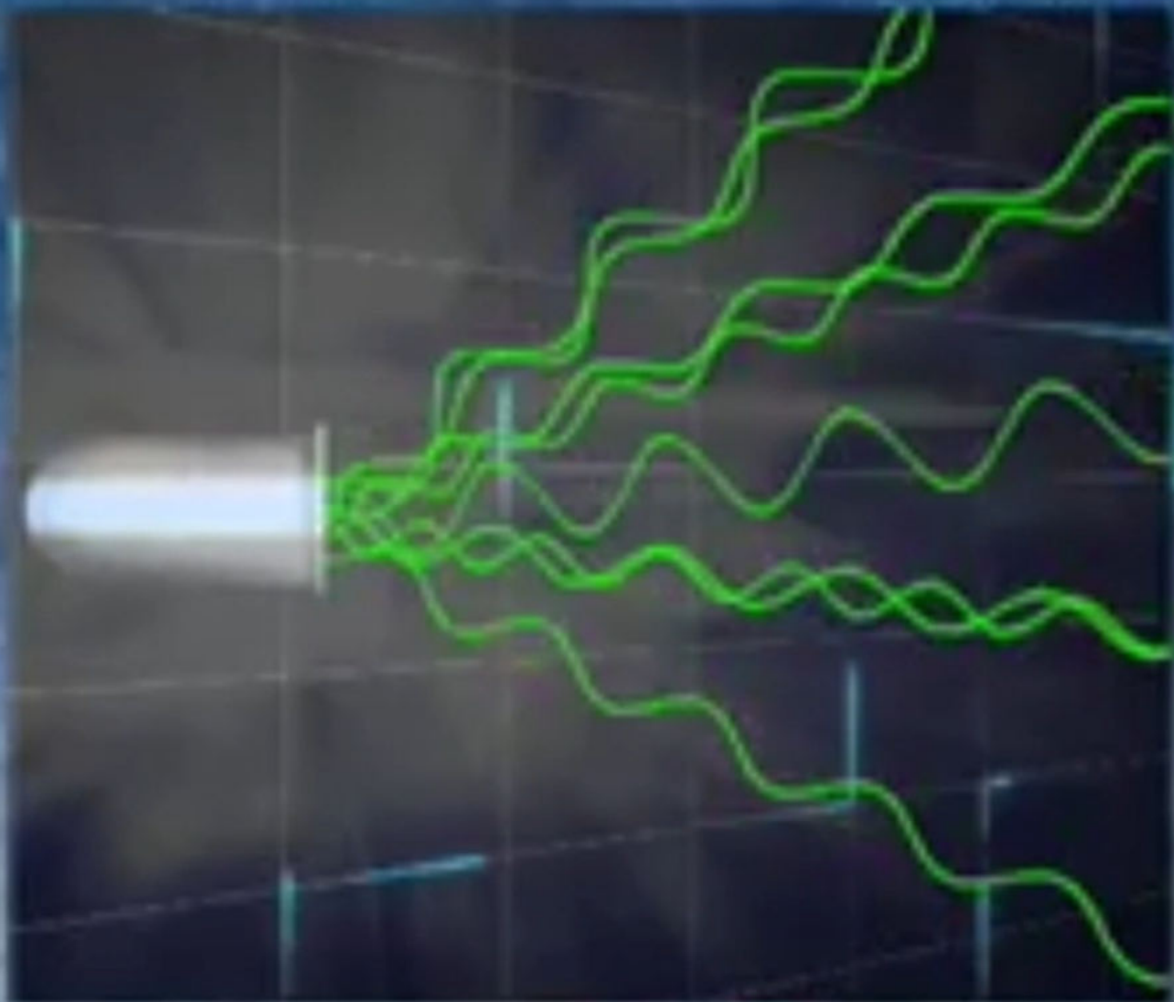
The Laser did **not** result from ***optical research***!

Progress was inspired by

electronic oscillators:

alternating current (AC) → tube oscillator → magnetron → maser → laser





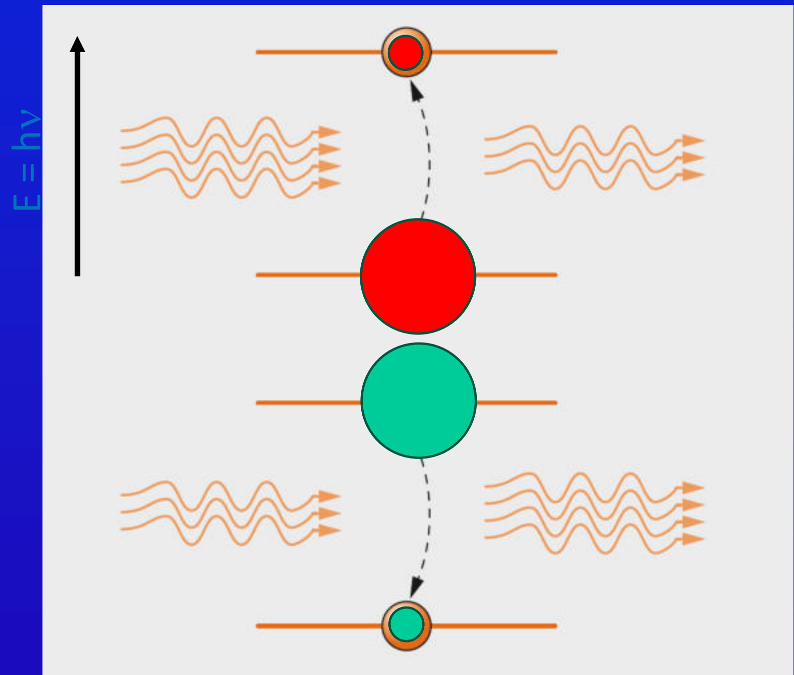
Basov
Prokhorov
Townes

1964

© Video: Laserfest 2010, Optical Society of America

Charles Townes' conclusion (~ 1950):
At high frequencies radiation can only be amplified with atoms and molecules

The crucial points:



attenuation

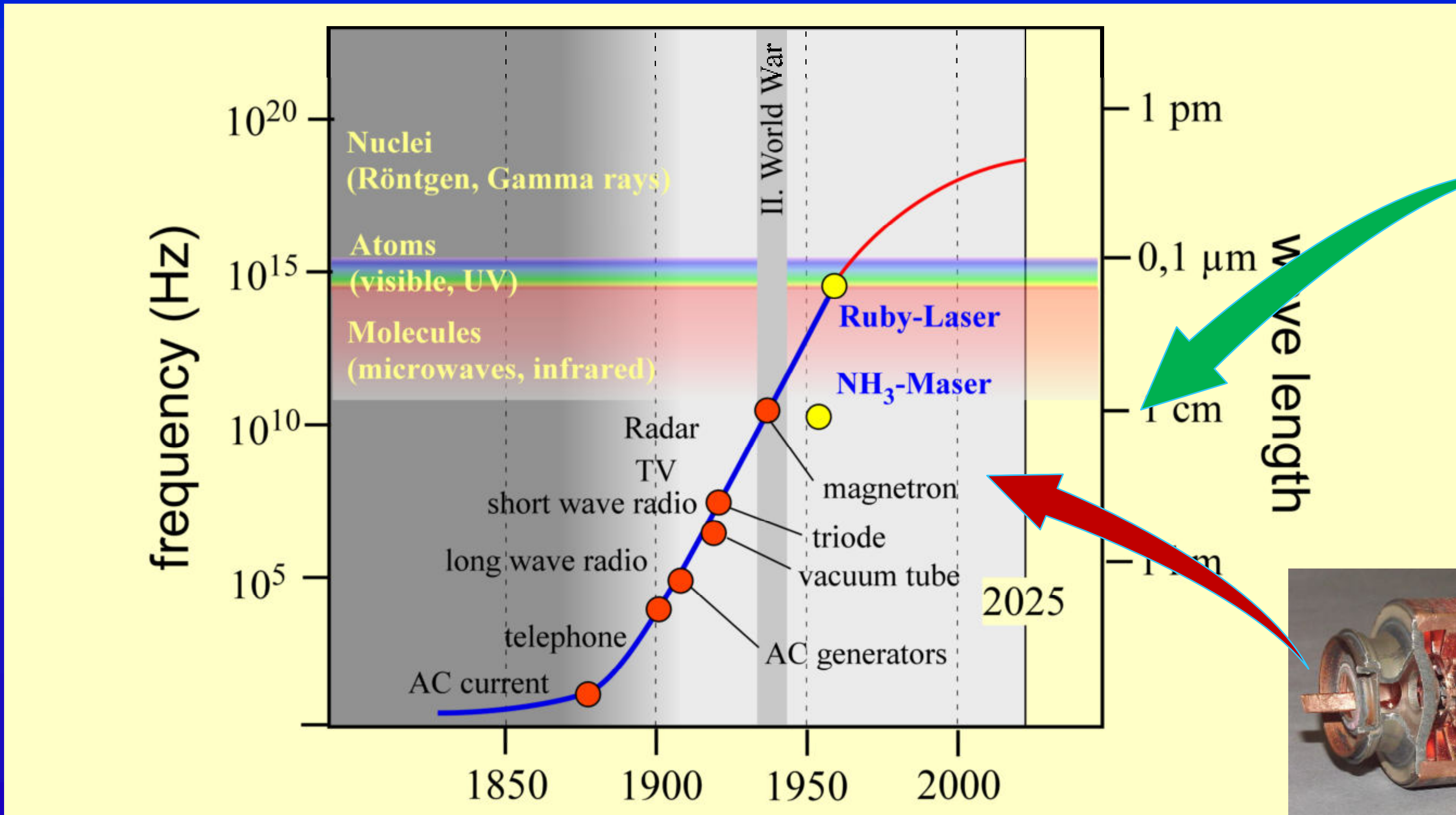
amplification

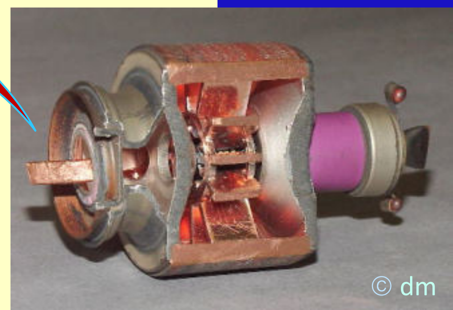
so called
„Inversion"

It was debated for a long time, whether „inversion" could be created in experiments. 1953 Townes and colleagues proved inversion!

The evolution of coherent electromagnetic radiation

5G: ν = 25 GHz
λ = 1,2 cm

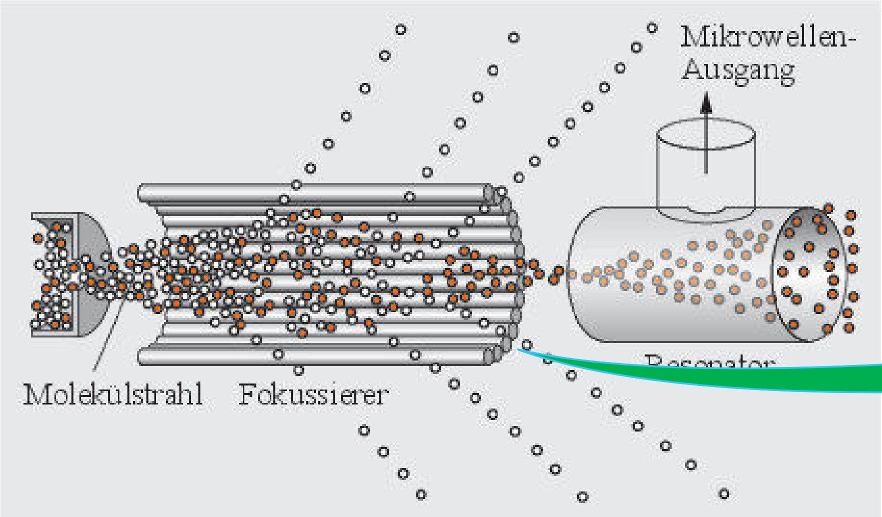




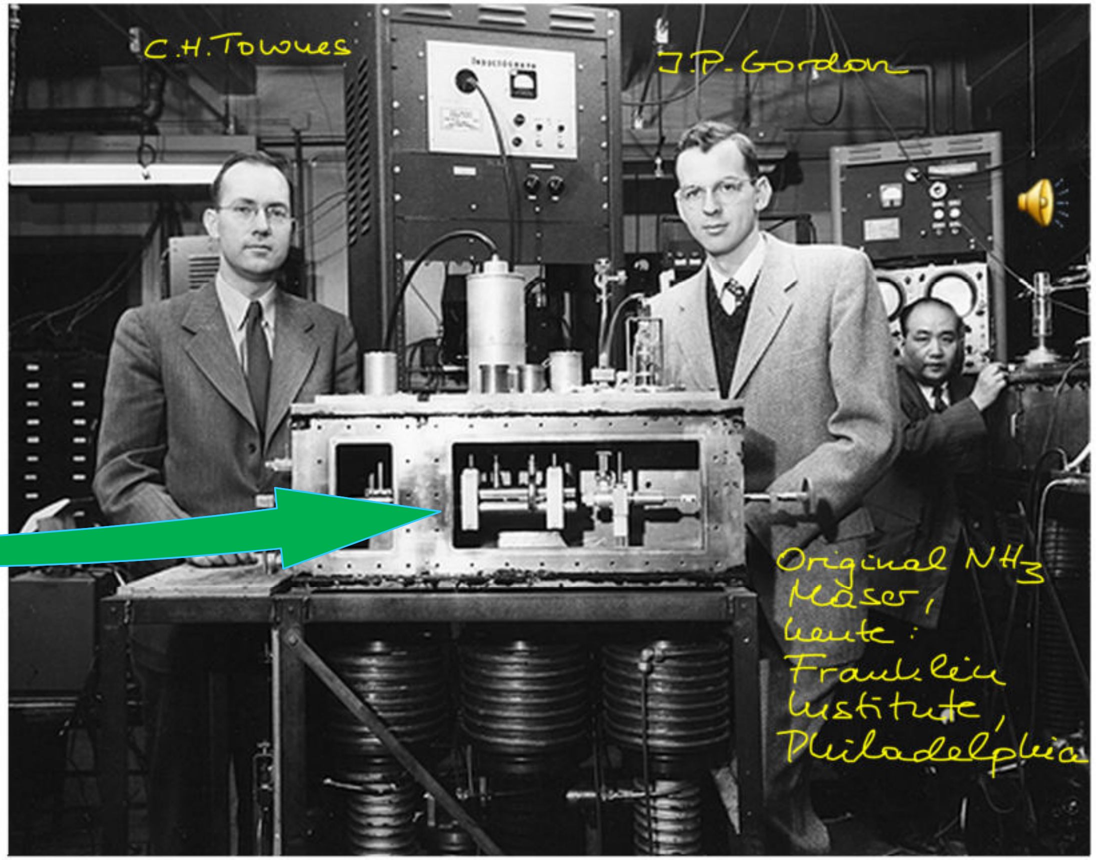
ν = 2,45 GHz, λ = 12,2 cm

Townes **inversion** maker

(adapted from his nobel lecture, © Nobel Foundation)



→Wolfgang Paul's quadrupole



Molecular Microwave Oscillator and New Hyperfine Structure in the Microwave Spectrum of NH_3†

J. P. GORDON, H. J. ZEIGER,* AND C. H. TOWNES
Department of Physics, Columbia University, New York, New York

(Received May 5, 1954)

© Physical Review

inversion line!

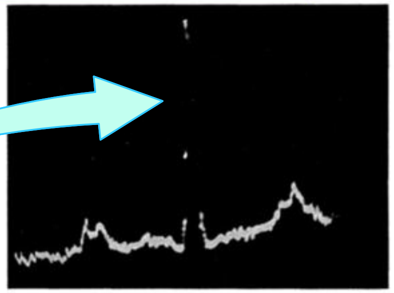


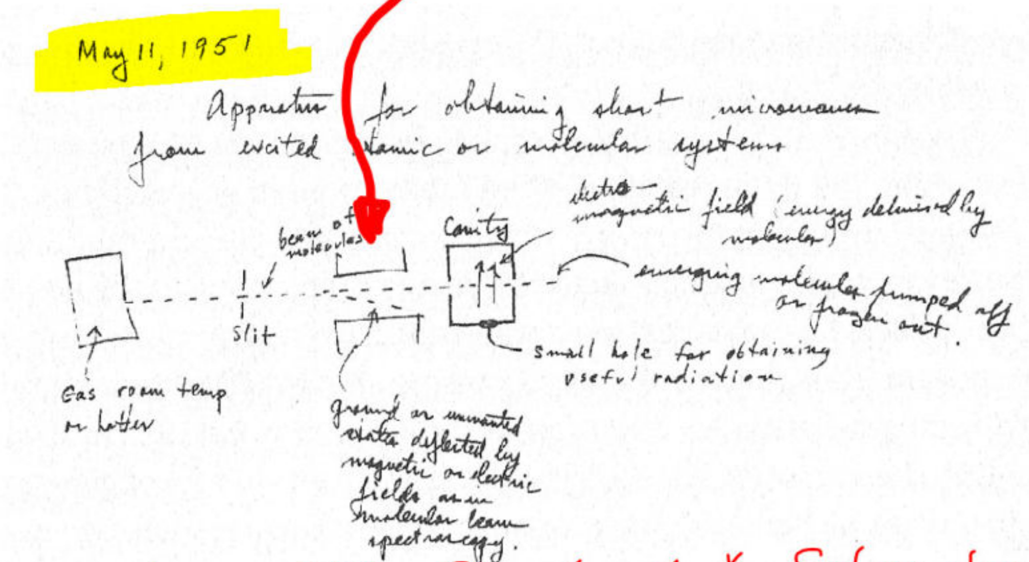
FIG. 2. A typical oscilloscope photograph of the NH_3, $J=K=3$ inversion line at 23 870 Mc/sec, showing the resolved magnetic satellites. Frequency increases to the left.

A month earlier, I had coincidentally heard the German physicist Wolfgang Paul give a colloquium at Columbia. He described a new way to focus molecular beams, by using four electrically charged rods to form a quadrupole field—a field with four-fold symmetry. This system focused and intensified the beam better than Rabi's system with two flat plates, which had only a two-fold symmetry. Sitting on that bench, I calculated just how lossy the cavity resonator could be and still have oscillations produced by a beam of ammonia focused by Paul's method. That is, at what rate could the cavity lose energy because of imperfect conductivity and still allow an energy build up? The results indicated that it was just marginally possible the idea would work with ammonia. Using Paul's technique, one should be able to put enough excited ammonia molecules through a cavity to produce an oscillator that would operate at shorter wavelengths than could be achieved by any other known means. My calculations

aus:
C.T., How the laser happened

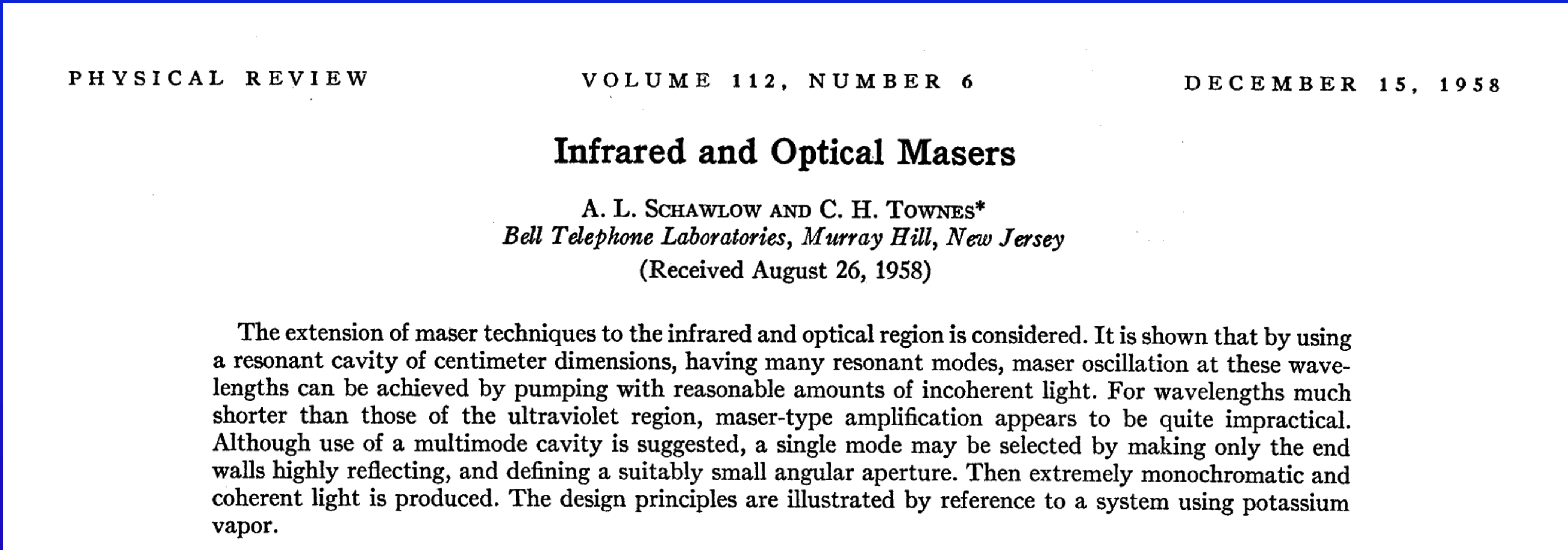
Mit dieser Idee findet die Inversionserzeugung hier statt:

Die Genese einer Idee ...



bezeugt von C.T.s Student A. Schawlow

The race for the laser was ignited in 1958:



PHYSICAL REVIEW VOLUME 112, NUMBER 6 DECEMBER 15, 1958

Infrared and Optical Masers

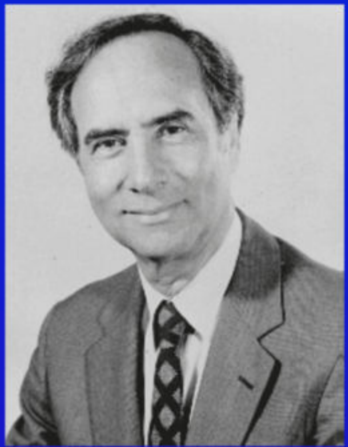
A. L. SCHAWLOW AND C. H. TOWNES*
Bell Telephone Laboratories, Murray Hill, New Jersey

(Received August 26, 1958)

The extension of maser techniques to the infrared and optical region is considered. It is shown that by using a resonant cavity of centimeter dimensions, having many resonant modes, maser oscillation at these wavelengths can be achieved by pumping with reasonable amounts of incoherent light. For wavelengths much shorter than those of the ultraviolet region, maser-type amplification appears to be quite impractical. Although use of a multimode cavity is suggested, a single mode may be selected by making only the end walls highly reflecting, and defining a suitably small angular aperture. Then extremely monochromatic and coherent light is produced. The design principles are illustrated by reference to a system using potassium vapor.

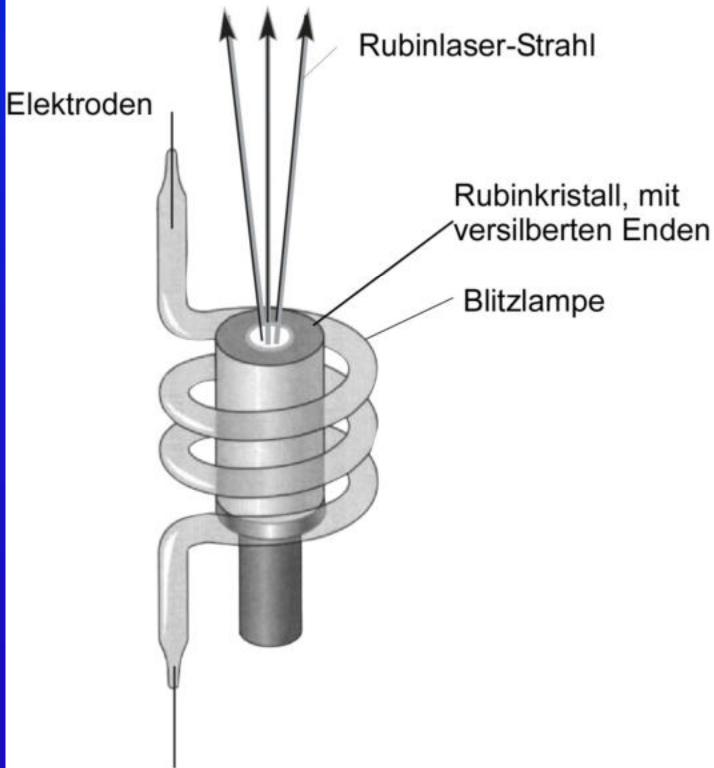
The **winner** wrt the „optical maser“:

© OPTICA, https://www.optica.org/History/Biographies/bios/Theodore_H_Maiman



1927 - 2007

Der erste Laser der Welt, 1960 (Theodore Maiman)



© Ref: *Beam. The Race to Make the Laser*, J. Hecht, Optics&Photonics News Jul. 2005

Laser:
Arthur Schawlow, einer der Erfinder

Arthur Schawlow
1921-1999
Nobelpreis 1981

"for their contribution to the development of laser spectroscopy"

A.S. hält eine Spielzeugpistole mit einem eingebauten frühen Rubin-Laser in der Hand. Auf Knopfdruck wurde ein Laserpuls erzeugt, der durch die transparente Hülle des äußeren Luftballons den inneren, absorbierenden Luftballon zum Platzen brachte. Die Kamera wurde durch den Knall ausgelöst.

© 2005 B.G. Teubner / GWV Fachverlage Wiesbaden

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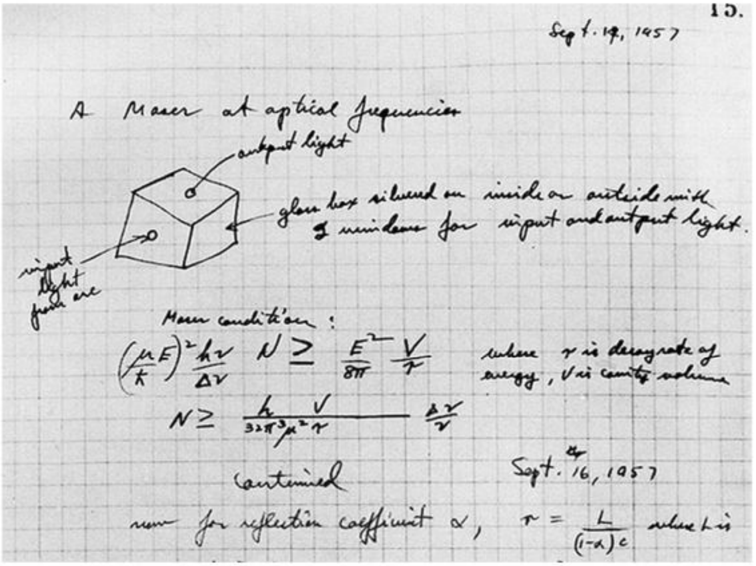
Patent Fight



VOLUME 112, NUMBER 6

Infrared and Optical Masers

A. L. SCHAWLOW AND C. H. TOWNES*
Bell Telephone Laboratories, Murray Hill, New Jersey
(Received August 26, 1958)

United States Patent Office

2,929,922
Patented Mar. 22, 1960

2,929,922

MASERS AND MASER COMMUNICATIONS SYSTEM

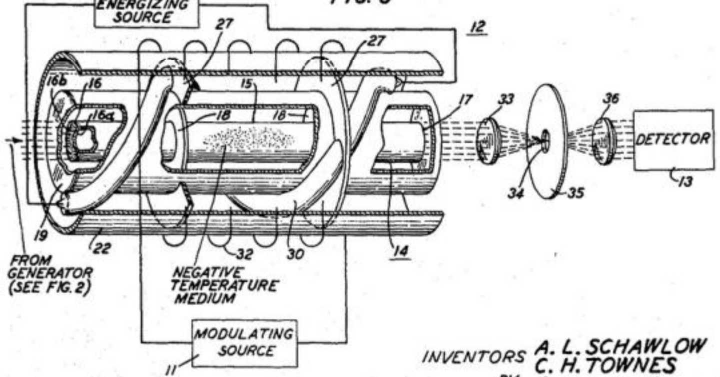
Arthur L. Schawlow, Madison, N.J., and Charles H. Townes, New York, N.Y., assignors to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Application July 30, 1958, Serial No. 752,137

11 Claims. (Cl. 250—7)

This invention relates to the generation and amplification of infrared, visible, and ultraviolet waves, and more particularly to the generation and amplification of such waves by means of devices including media in which the stimulated emission of radiation occurs; devices of this type are now generally termed "masers."

FIG. 3



INVENTORS A. L. SCHAWLOW
C. H. TOWNES
BY Lucian C. Canepa
ATTORNEY

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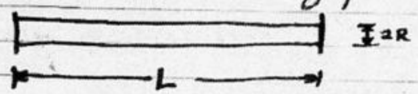
Some rough calculations on the feasibility of a LASER: Light Amplification by Stimulated Emission of Radiation.

Conceive a tube terminated by optically flat



partially reflecting parallel mirrors. The mirrors might be silvered or multilayer interference reflectors. The latter are almost lossless and may have an arbitrarily high reflectance depending on the number of layers. A practical achievement is 98% in the visible for a 7-layer reflector.① Flats with closer tolerance than 1/100 λ are not available so if a resonant system is desired, higher reflectance would not be useful. However for a nonresonant system, the 99.9% reflectances which are possible might be useful.

Consider a plane standing wave in the tube. There is the effect of a closed cavity; since the wavelength is small the diffraction and hence the lateral loss is negligable.

① O.S. Heavens, "Optical Properties of Thin Solid Films" (Butterworths Scientific Publications, London, 1955), P320.

Sworn to and subscribed before me the 13 day of Nov. 1957
JACK GOULD
Notary Public, State of New York
No. 03-1621950
Qualified in Bronx County
Commission Expires March 30, 19..

Jack Gould

Gordon Gould

United States Patent [19] Gould

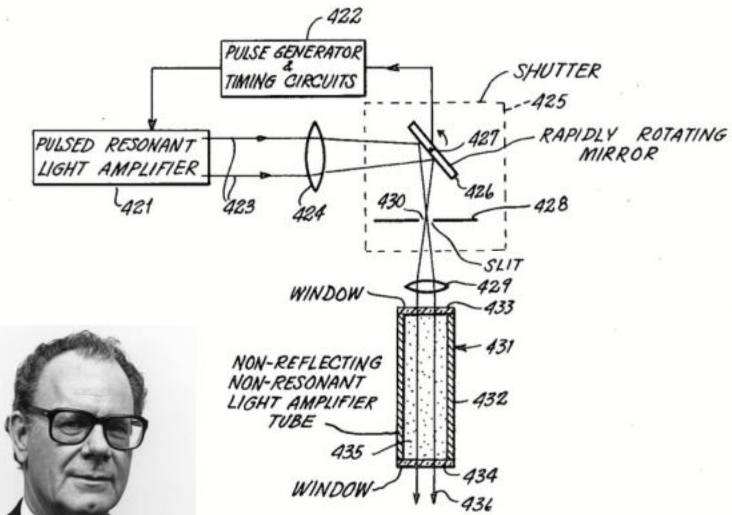
[11] 4,053,845
[45] Oct. 11, 1977

[54] OPTICALLY PUMPED LASER AMPLIFIERS

[76] Inventor: Gordon Gould, 329 E. 82 St., New York, N.Y. 10028

[21] Appl. No.: 498,065

[22] Filed: Aug. 16, 1974



Gordon Gould (1920 - 2005)

- Schawlow-Townes-Patent 1959-1976

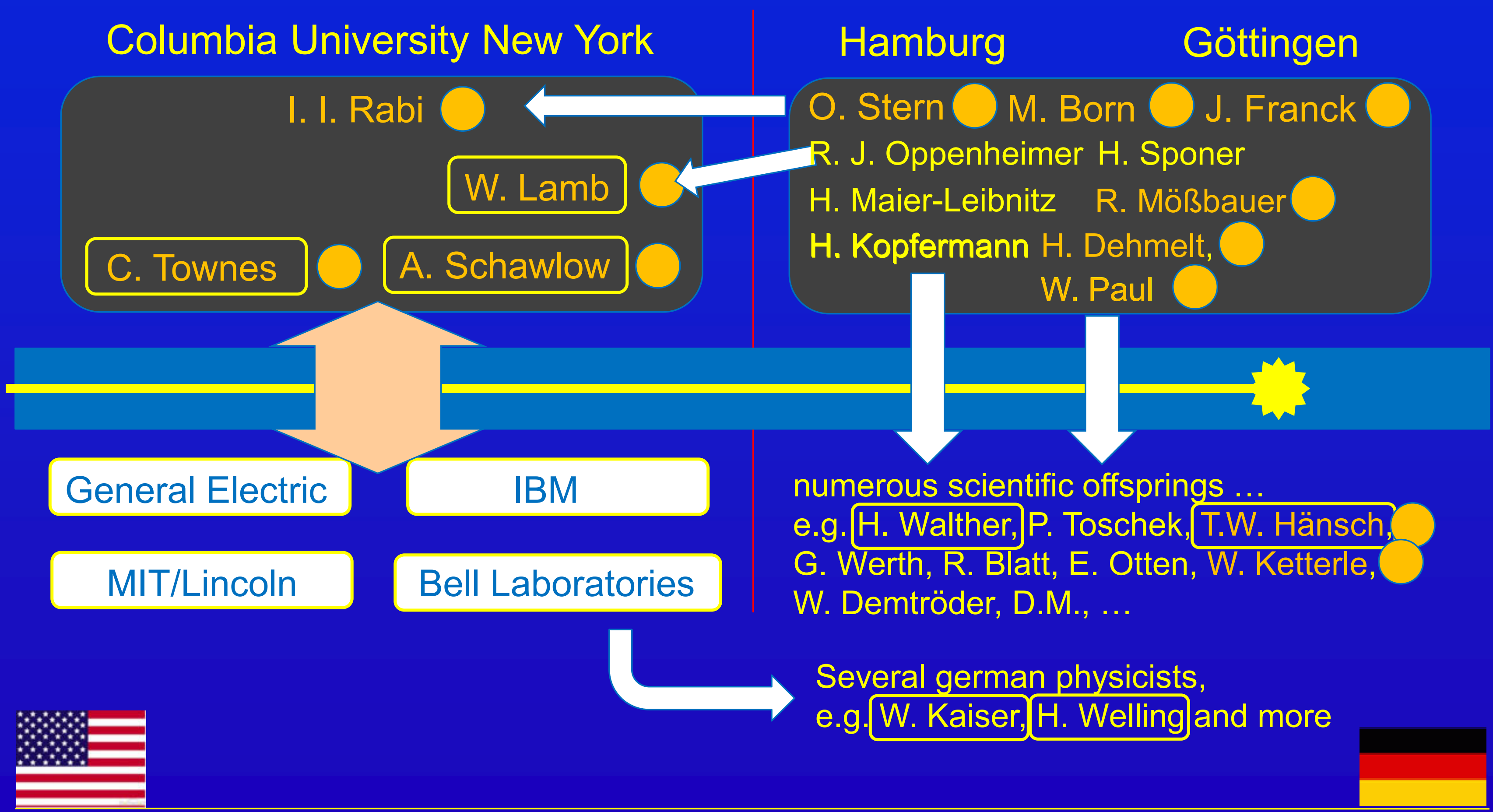
Townes: Income occasionally 2-3-fold of
his annual salary as a professor,
but predomimantly for the „Research Foundation“

- Gould-Patent 1976 – 1993

Income in its last year 7,5 Mio $
(late award made it lucrative!)

The scientific advent of the lasers is a matter of „schools“, too:

(Example: USA and Germany)



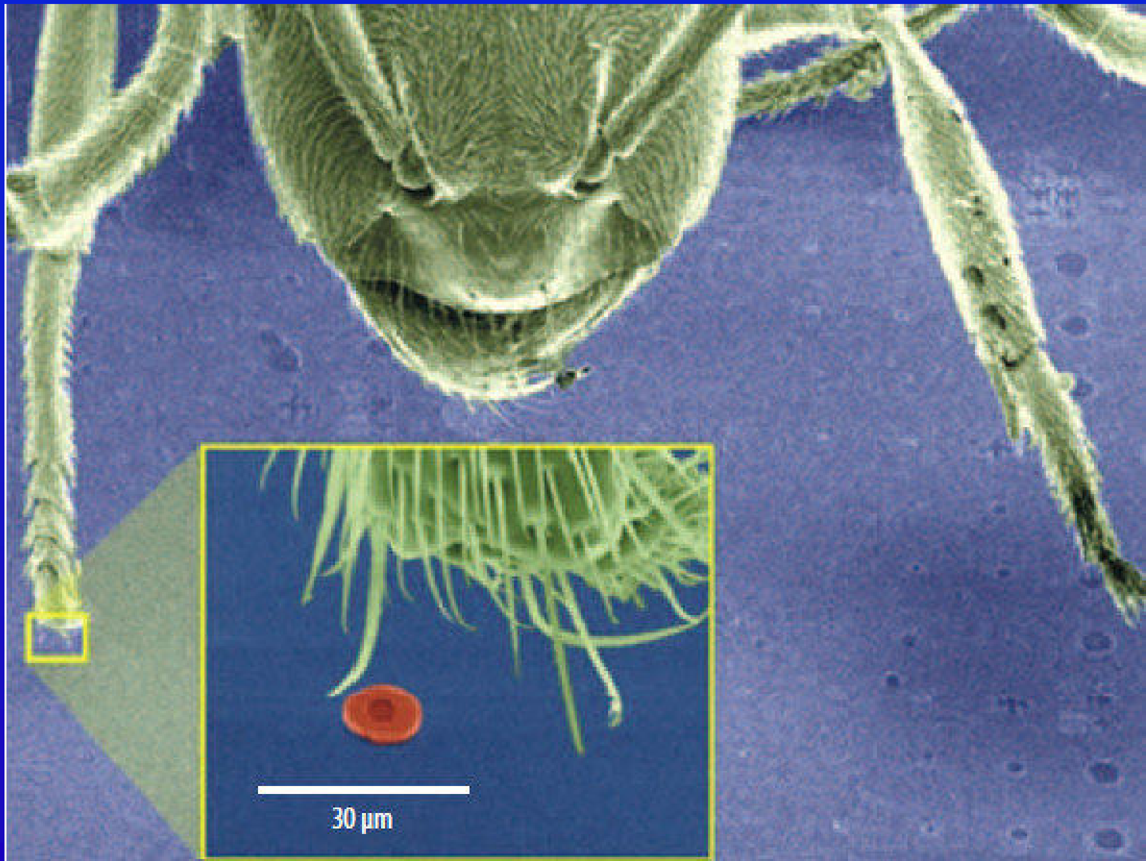
= Nobelpreis

= Laserpionier

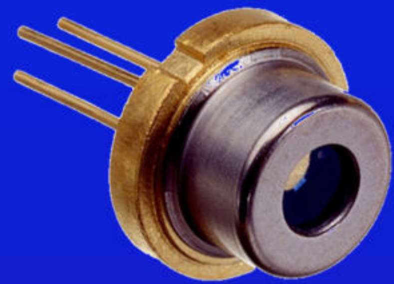
Selected aspects of laser evolution (I):

Miniaturisation: the most crucial laser for economy!
(in the end for science, too!)

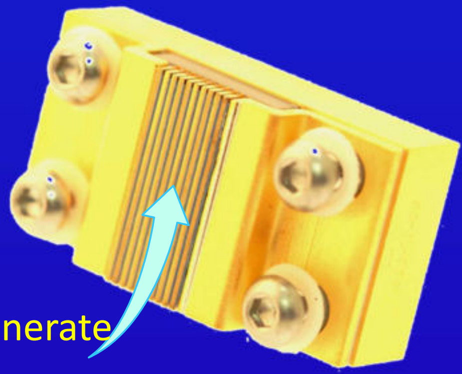
2025: 63 years of diode lasers …



diode laser =
LED with integrated mirrors



High power diode lasers



Multi stripes generate
up to 100 kW !

applications: welding, 3D-printing, …

© Ref: *Vom hässlichen Entlein zum Schwan*, D. Bimberg, Physik Journal 11 (2012)

Robert N. Hall (far right) and his team at General Electric 1962

R. N. Hall, M. Fenner, J. D. Kingsley, T. J. Soltys, and R. O. Carlson, *Coherent Light Emission From GaAs Junctions*, Physical Review Letters 9, 366 (1962).

© Ref: *The Diode Laser*, R. Dupuis, Optics&Photonics News April 2004

The blue miracle

author of a scientific.
fairy tale (~ 1990)

© The Franklin Institute Philadelphia

Shuji Nakamura,
UC Santa Barbara
vorher Nichia Chemicals, Japan

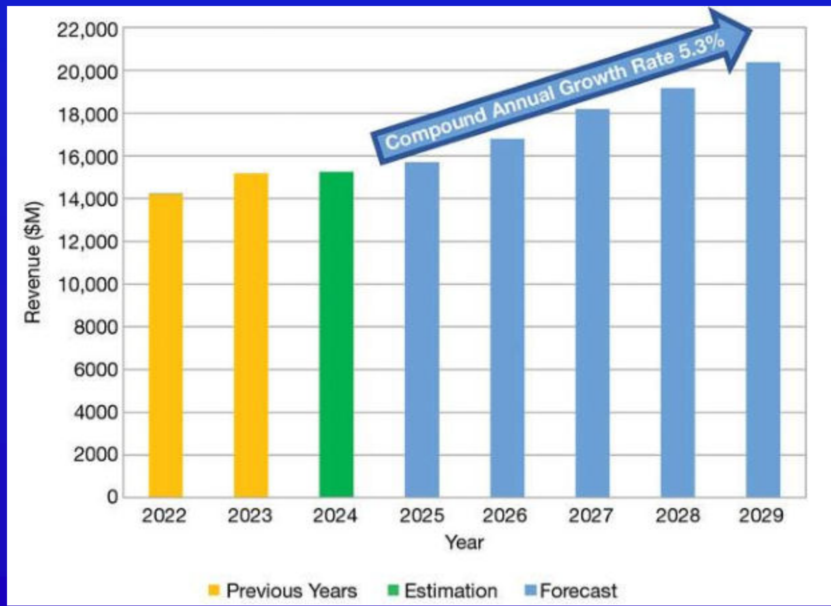
Nobel Prize 2014

Times Square 1998

GaN shines blue!

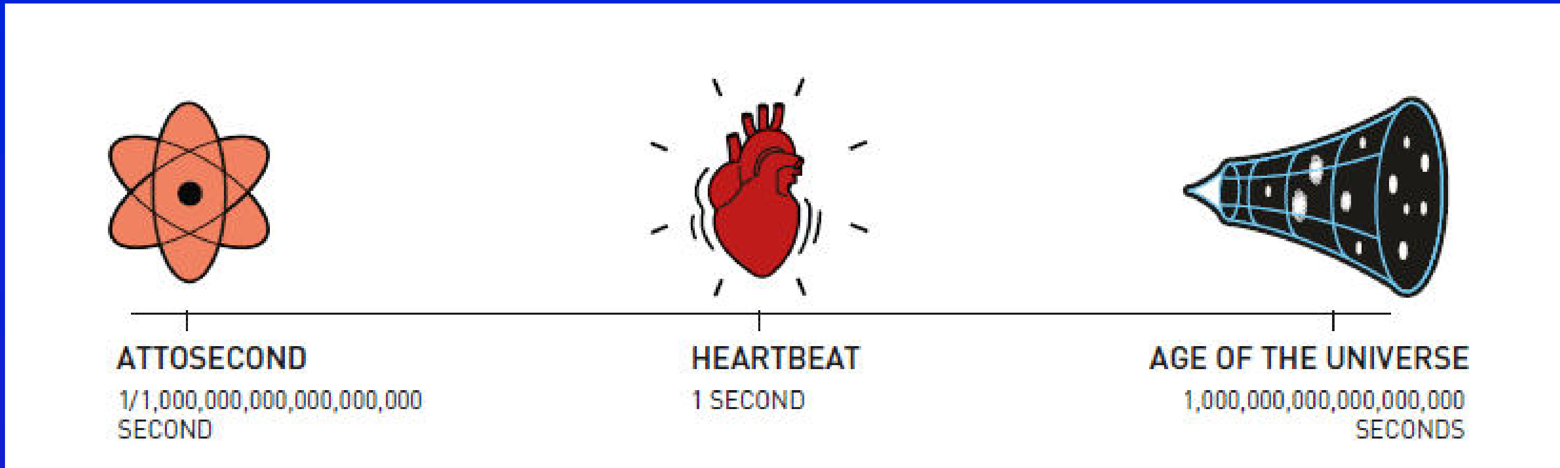
The success of diode laser/leds:

- **Direct conversion of electrical into light energy**
  (~ 50% efficiency)
- **Connects the worlds of electronics and photonics**
- **The color can (almost) be „dialed“.**



Selected aspects of laser evolution (II):

Optical half cycles (~ 1 fs!)



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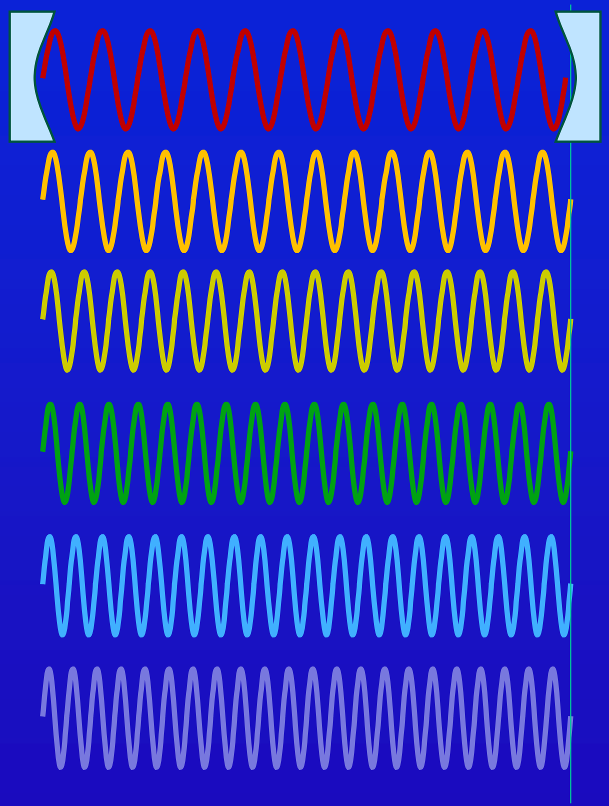
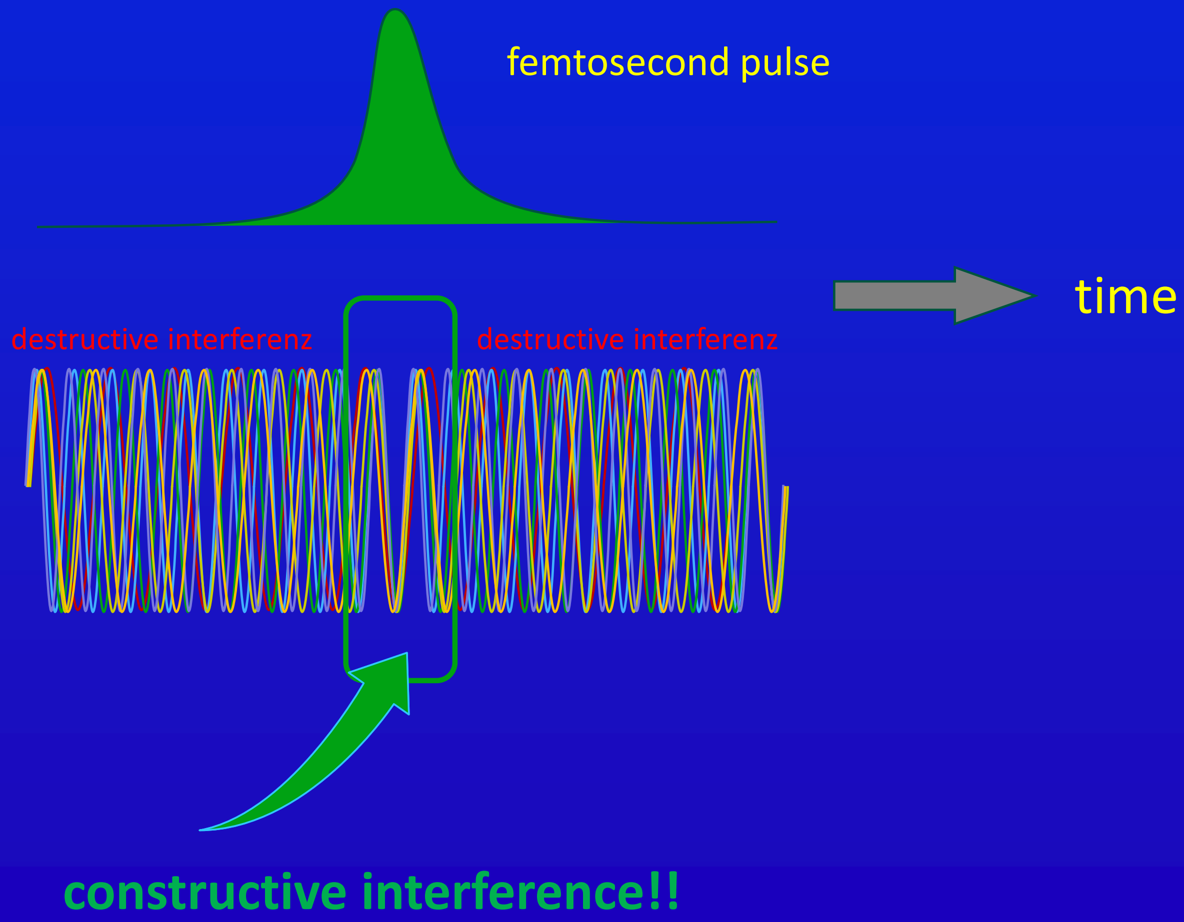
Scientific applications:
Dynamics of chemical and biologal processes

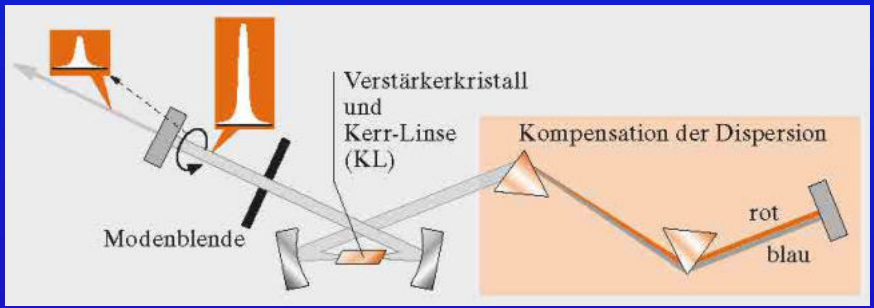
Practical relevance:
Material processing with high quality
(e.g. eye surgery!)

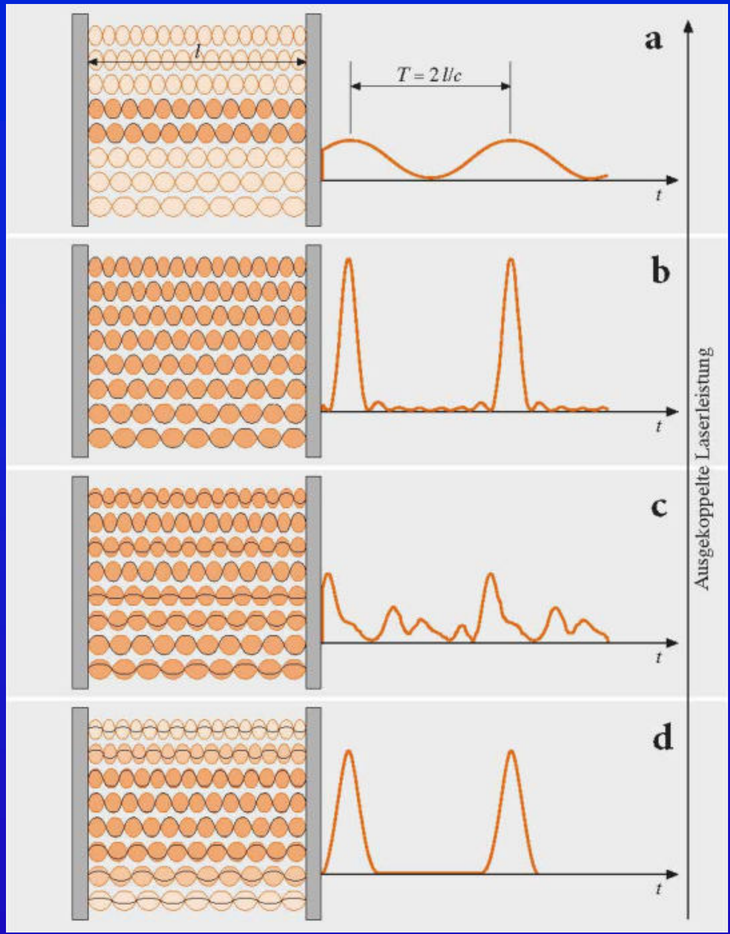
Short pulses are a consequence of laser coherence !!





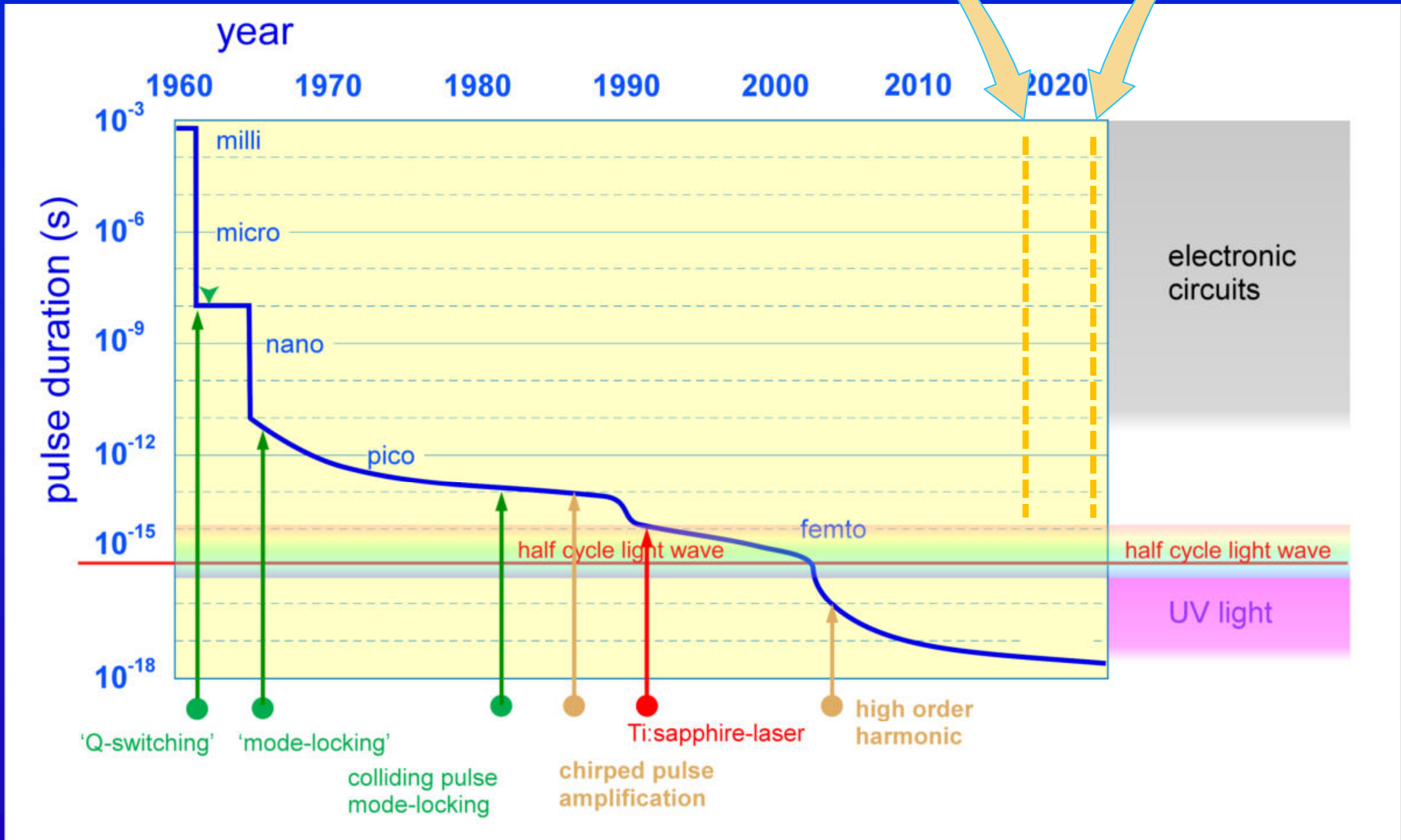
W. Sibbett‘s Ti-Sapphire Laser



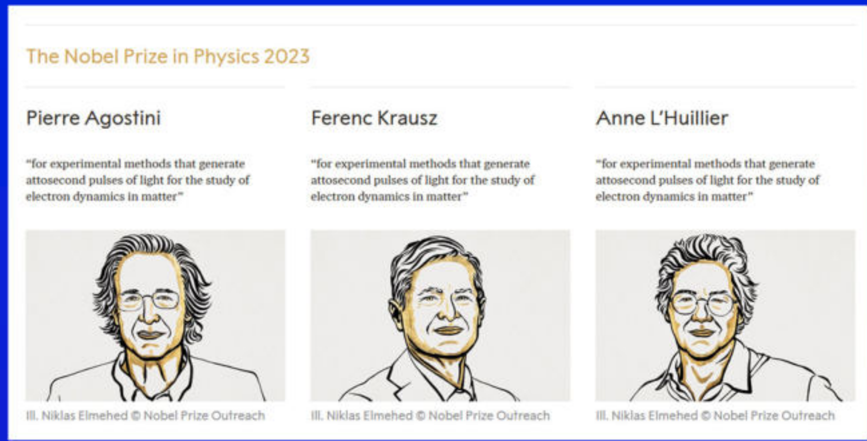


Strickland
Mourou

Agostini
l'Huillier
Krausz



 Dank an D. v. d. Linde, Essen



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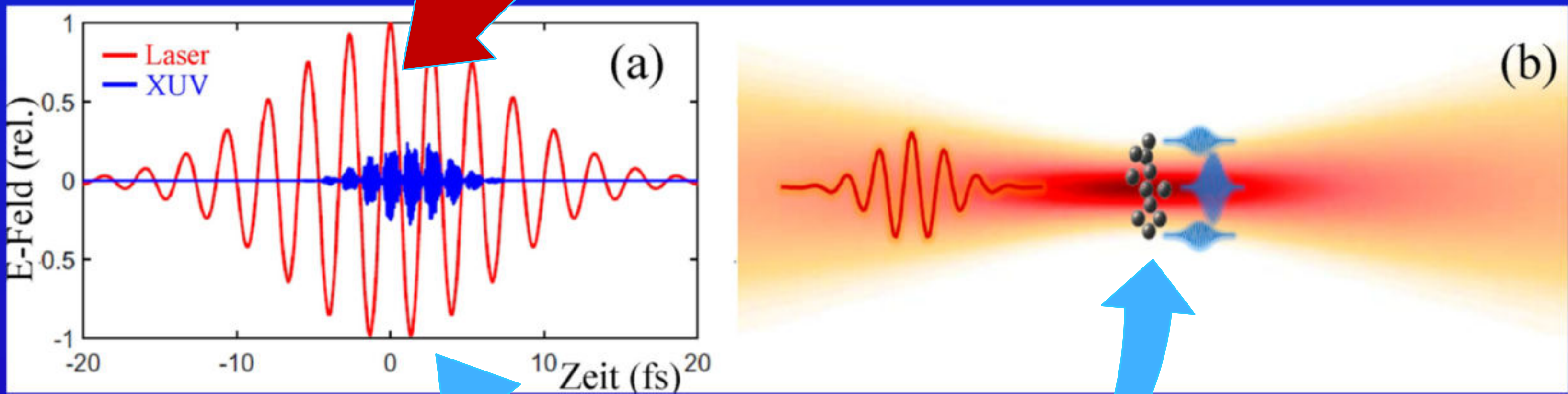
This is our femto-
second flash



This interaction generated
attosecond xray flashes

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