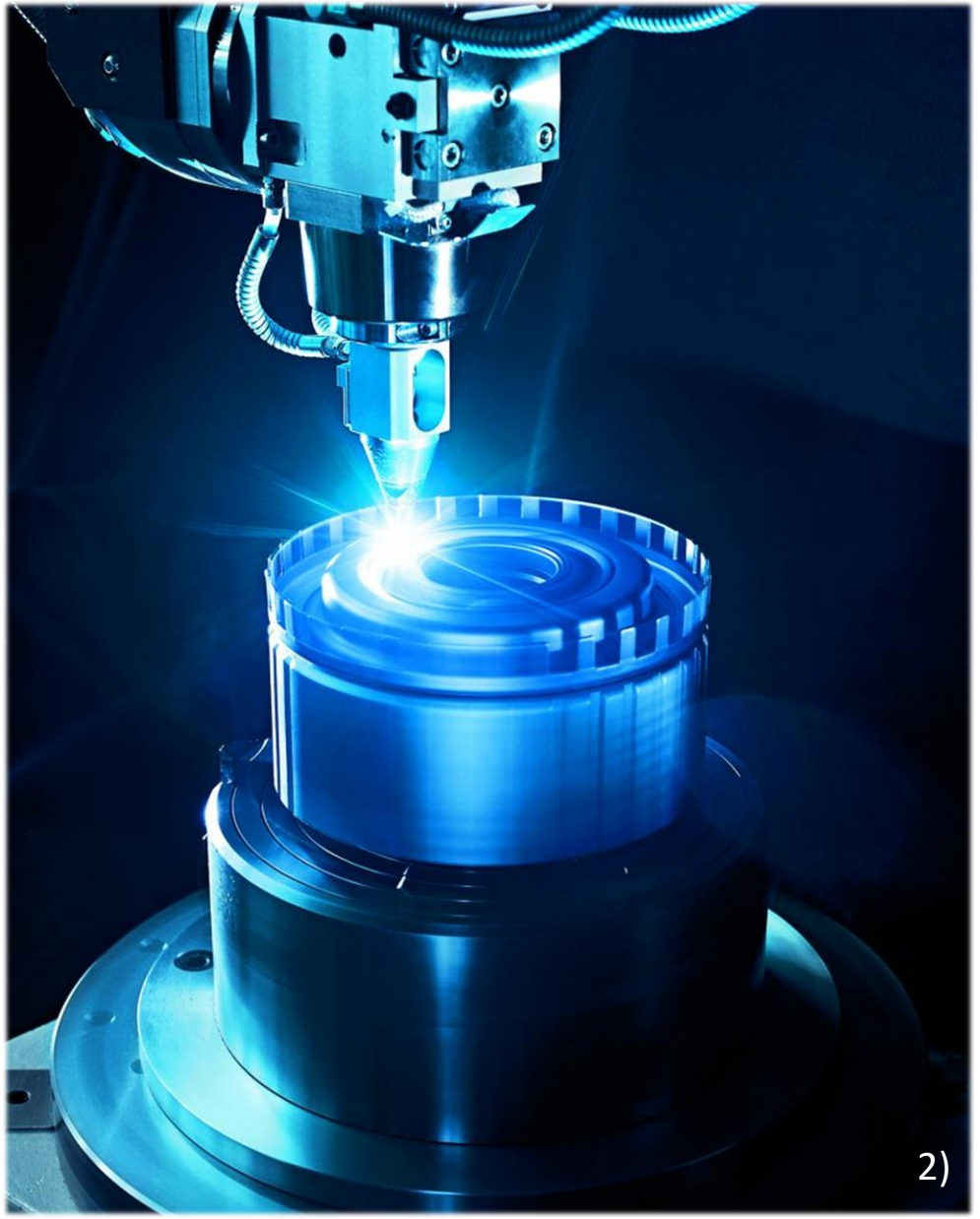
The Invention of the Laser

Morten Will

1)

Lasers: General Characteristics

- Emits coherent light amplified in a laser-amplifier
- LASER = “light amplification by stimulated emission of radiation”
- Spatial coherence allows precise focusing and collimation
- Temporal coherence allows very narrow emission spectra, or ultrashort (~fs) pulses of light



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Uses of Lasers


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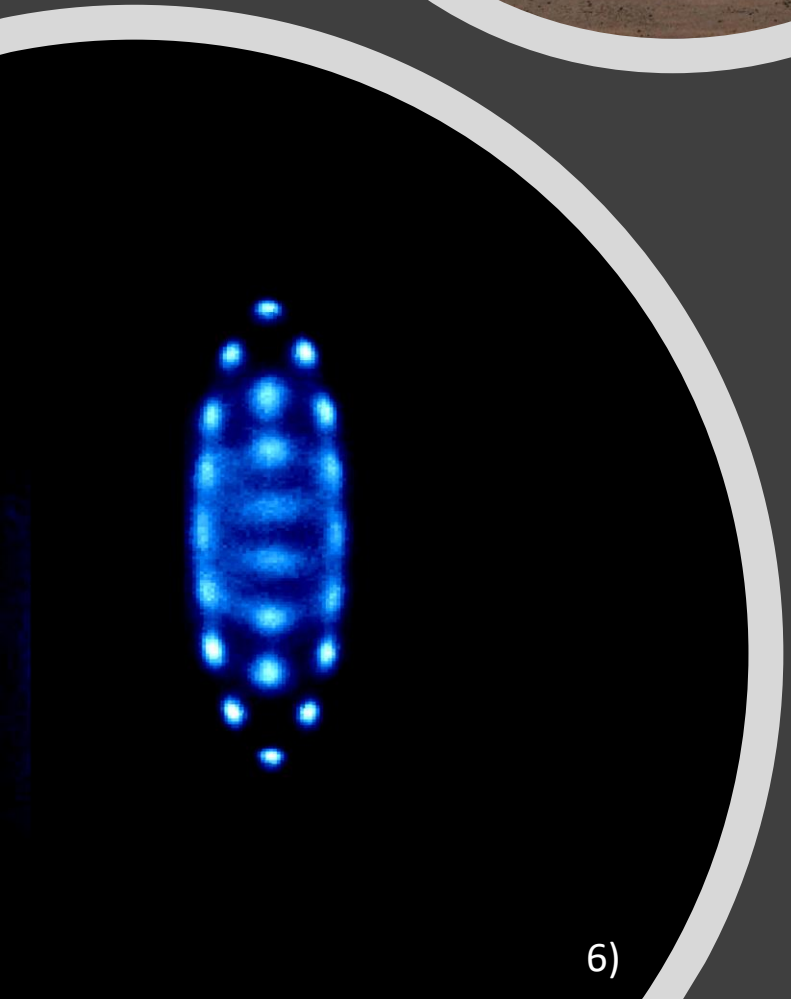
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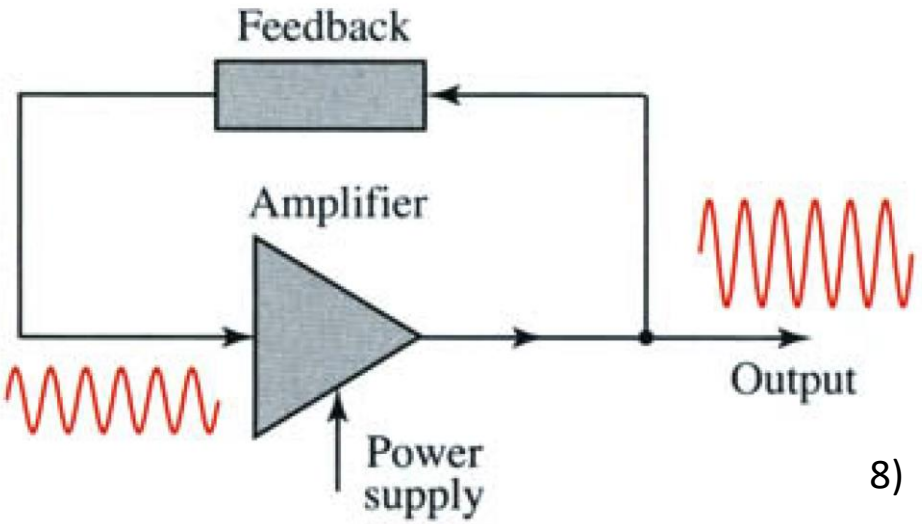
Essential Components

- Amplifier with a gain-saturation mechanism
- Feedback system
- Frequency-selection mechanism
- Output coupling scheme



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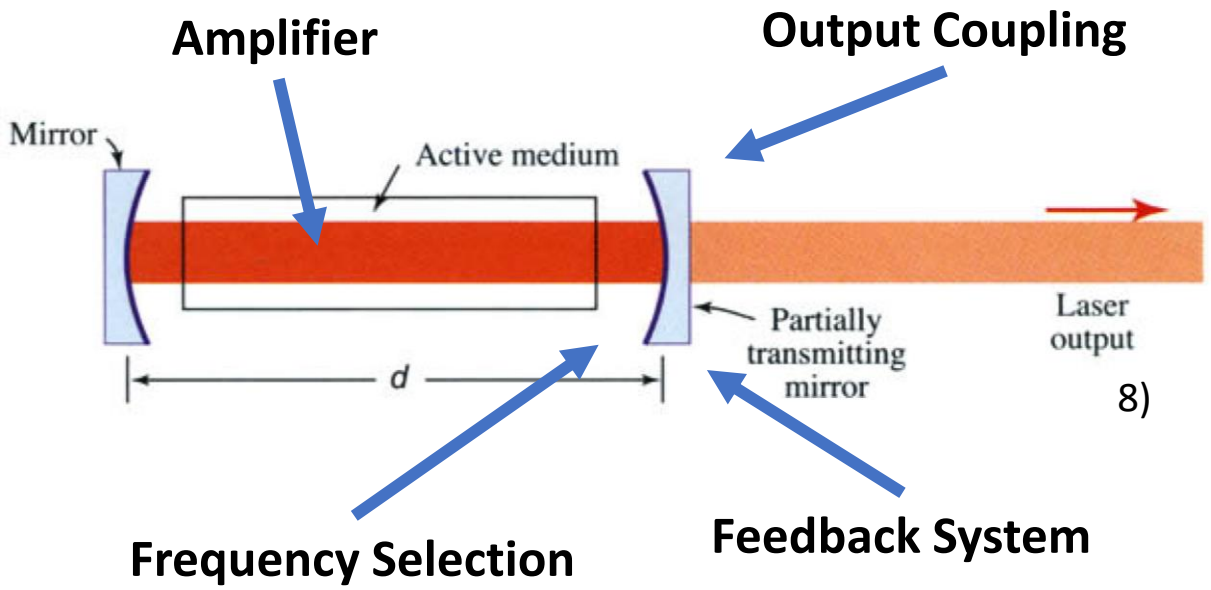

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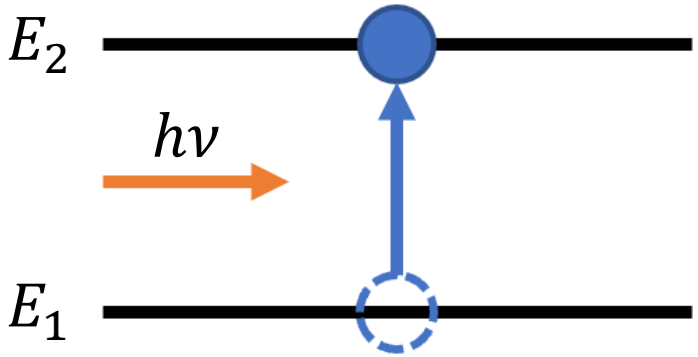
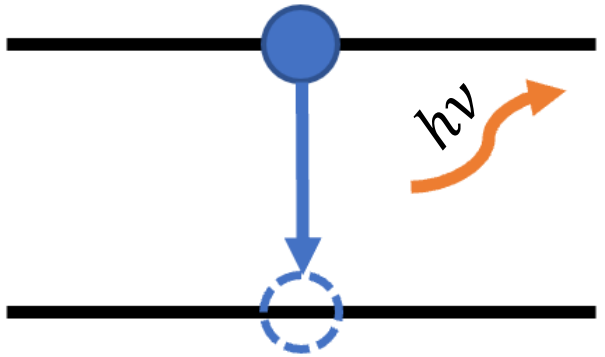
Laser Amplifiers

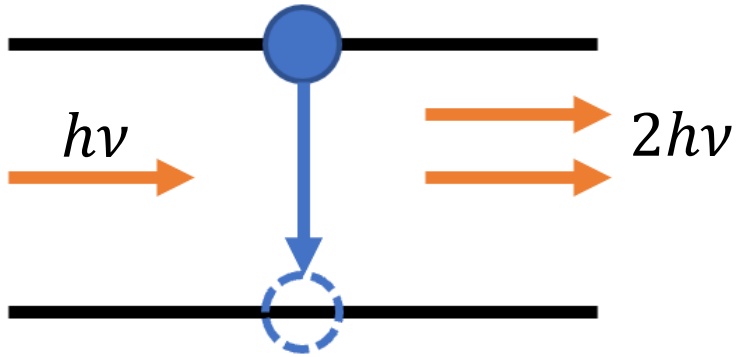
- Coherent light of frequency ν travels through medium with energy levels E_1 and E_2 .
- Given $h\nu \cong E_2 - E_1$, there are three possible interactions:



Absorption



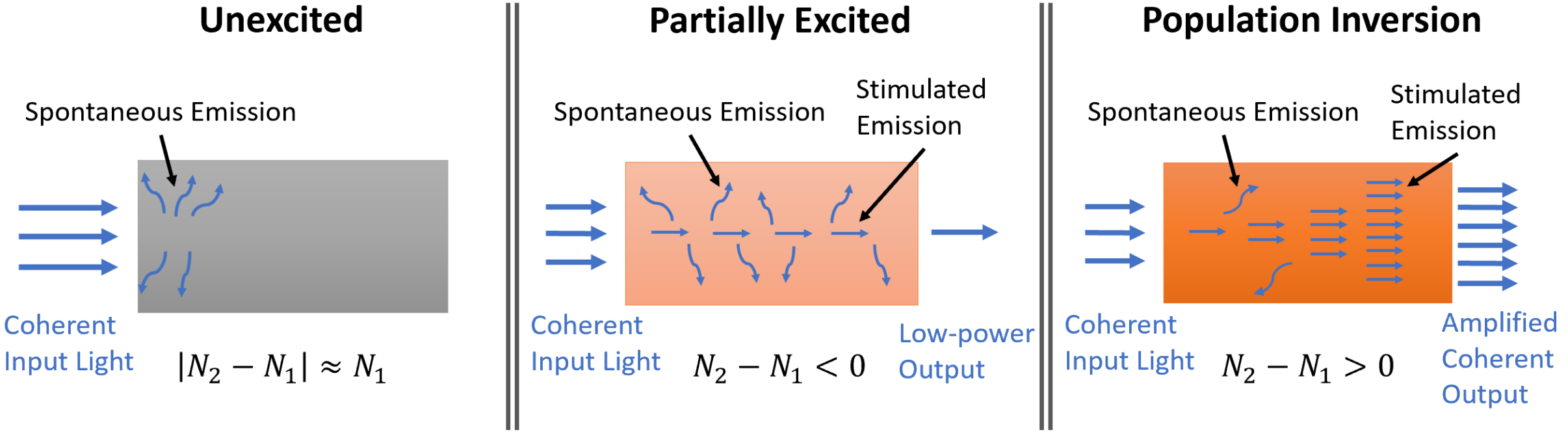
Spontaneous Emission



Stimulated Emission

Laser Amplifiers

- Numbers of atoms per unit volume in the lower and upper energy levels: N_1, N_2
- Exponential amplification with gain coefficient: $\gamma(\nu) = (N_2 - N_1)\,\sigma(\nu)$



1951: Joseph Weber

AMPLIFICATION OF MICROWAVE RADIATION BY SUBSTANCES NOT IN THERMAL EQUILIBRIUM

by

J. Weber

Glenn L. Martin College of Engineering and Aeronautical Sciences
University of Maryland, College Park, Maryland

Introduction

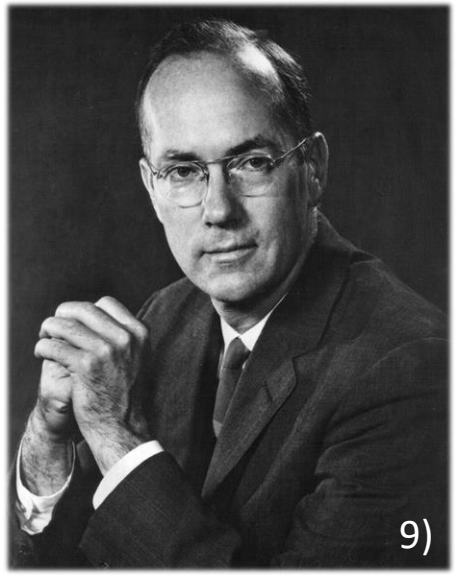
This paper briefly discusses the possibility of obtaining coherent microwave radiation from crystals and gases. It will be shown that it is possible to obtain coherent microwave radiation by such methods, provided that a certain non equilibrium energy distribution is first produced. Methods are discussed for producing such a distribution. The amount of amplification which can be produced by such methods is very small under ordinary circumstances and does not appear to be able to compete with other methods. The method may have certain special applications.

Charles H. Townes

- 1952: Begins work on maser principle, inspired by Weber
- 1953: Townes, Gordon, Zeiger build first maser
- 1958: Patents his theoretical work on the laser
- 1964: Shares Nobel Prize with Nikolay Basov and Alexander Prokhorov

Infrared and Optical Masers

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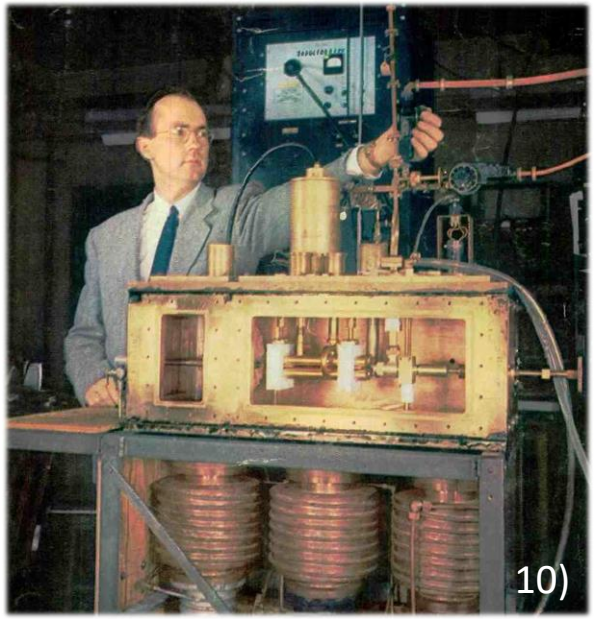
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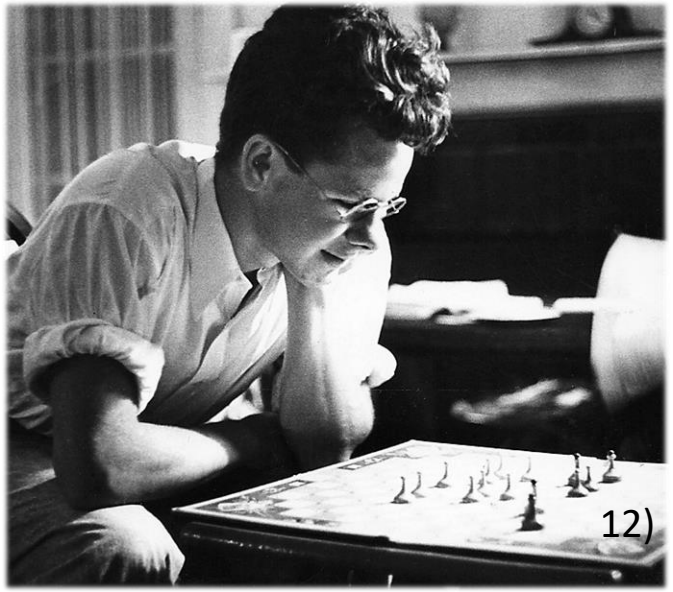
Gordon Gould

- 1957: Writes document on laser theory, but doesn't publish
- 1959: Applies for patent for his work on the laser
- 1987: Awarded 48 patents covering optical pumping, collisional pumping, and applications



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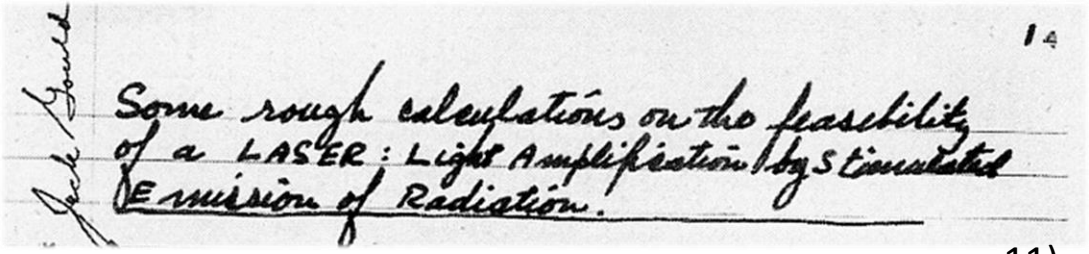

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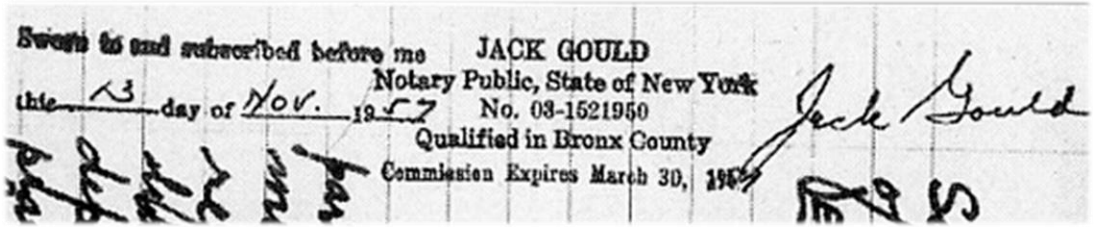
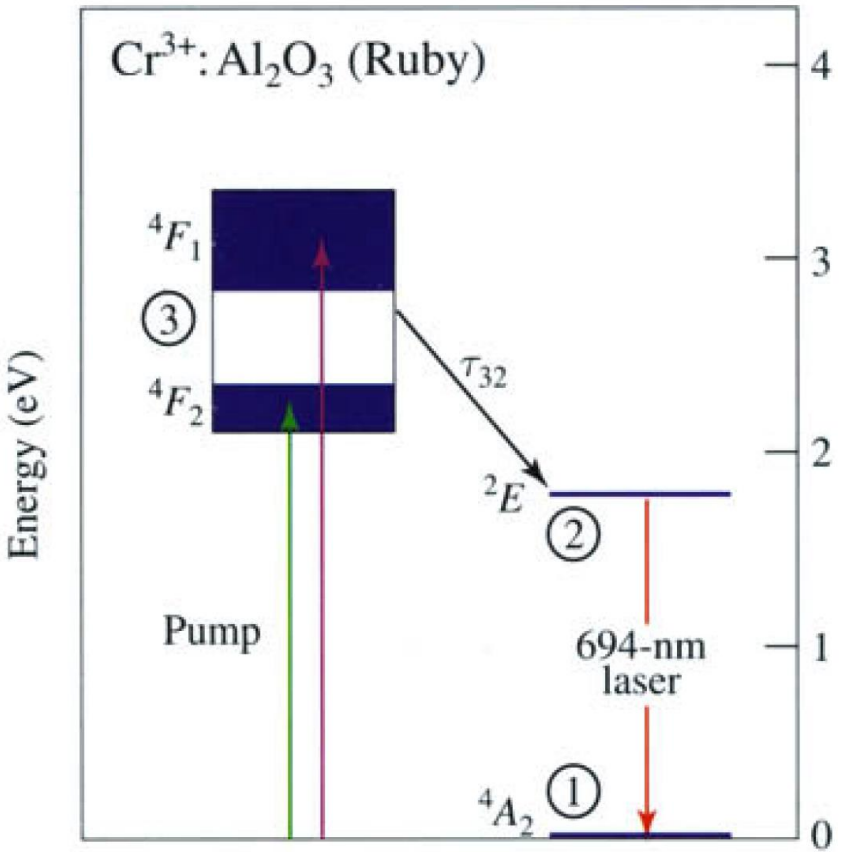


The First Laser

- Ruby (Cr^{3+}:Al_2O_3) as active medium
- Level 1: Ground state
- Level 2: Red laser transition at $694.3\ \mathrm{nm}$
- Level 3: Two broad bands centred at about $550\ \mathrm{nm}$ and $400\ \mathrm{nm}$



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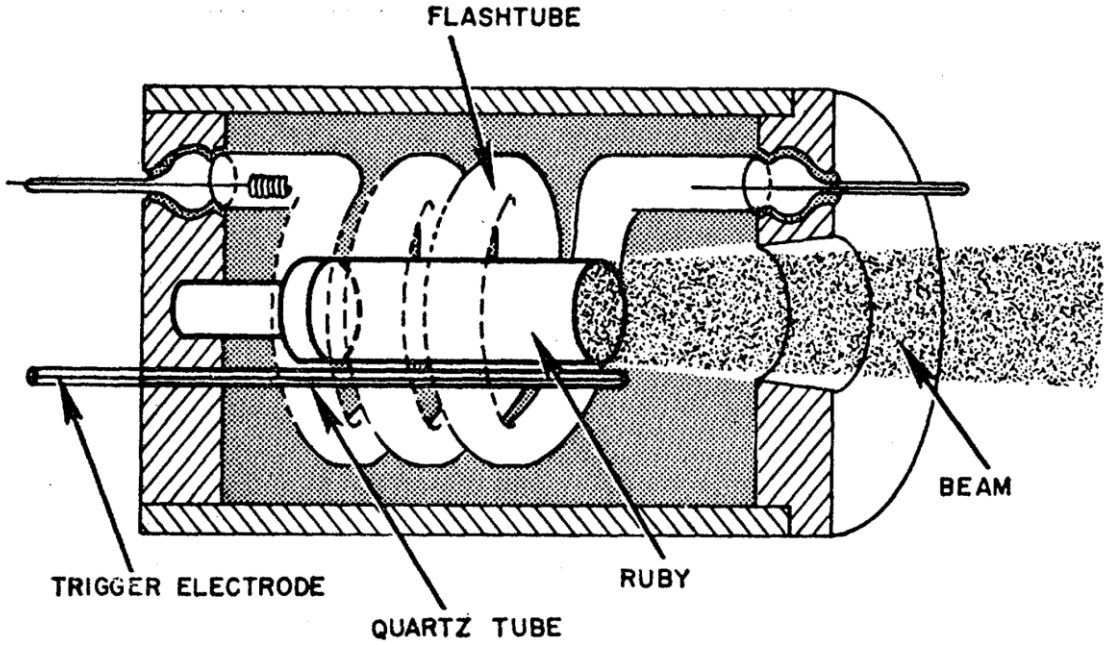
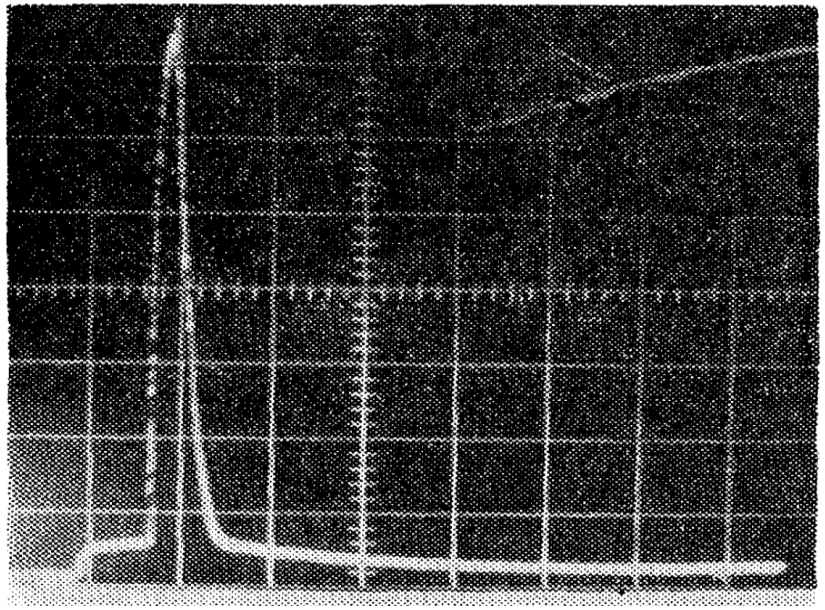
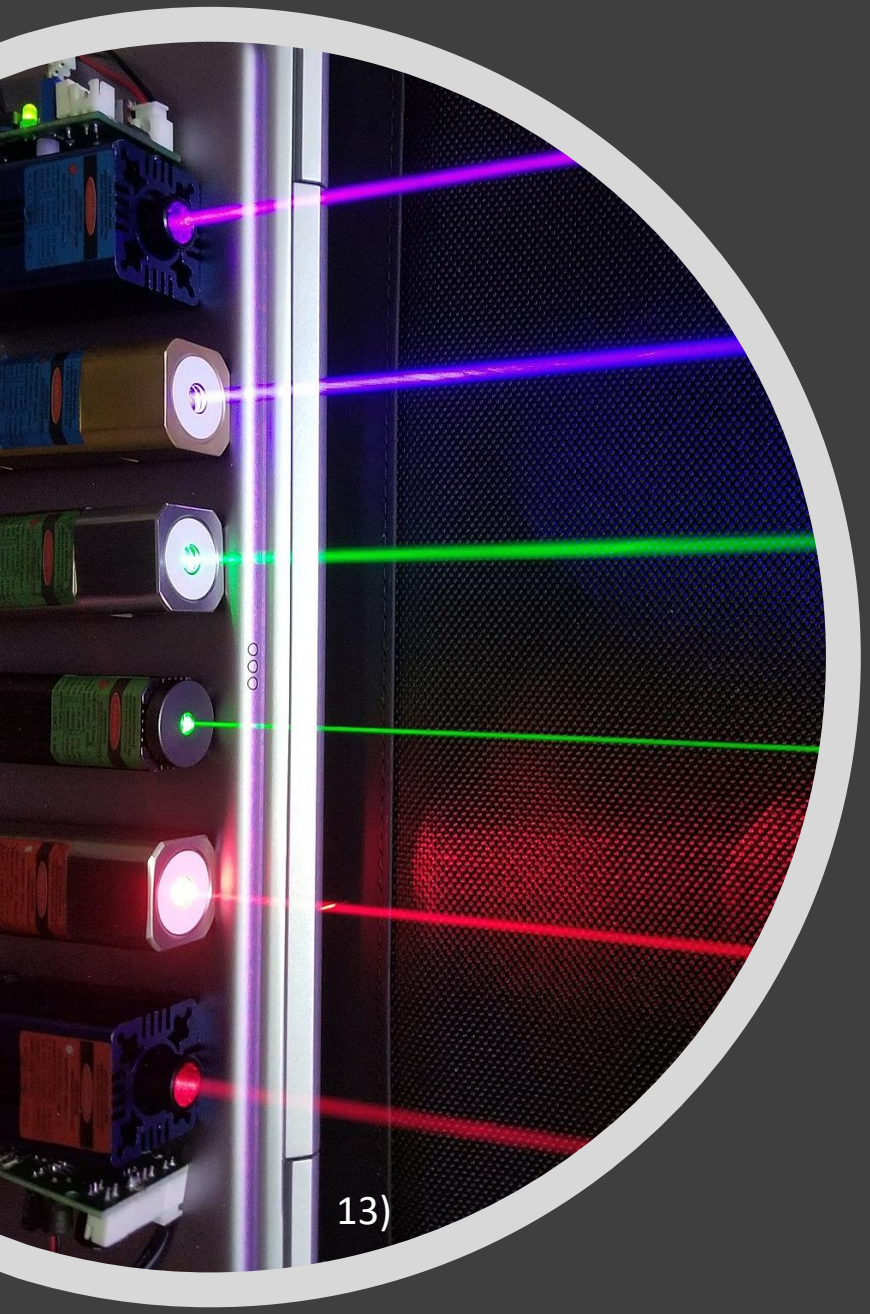
The First Laser

- Active Medium: Ruby
- Pump Method: Xe-Flashtube
- Peak Performance: 5 kW peak power, 1 J pulses







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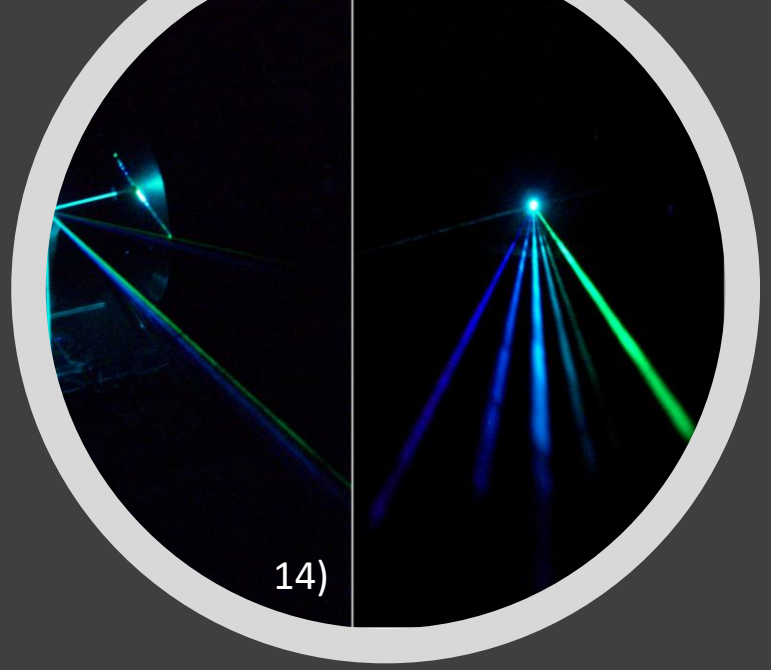

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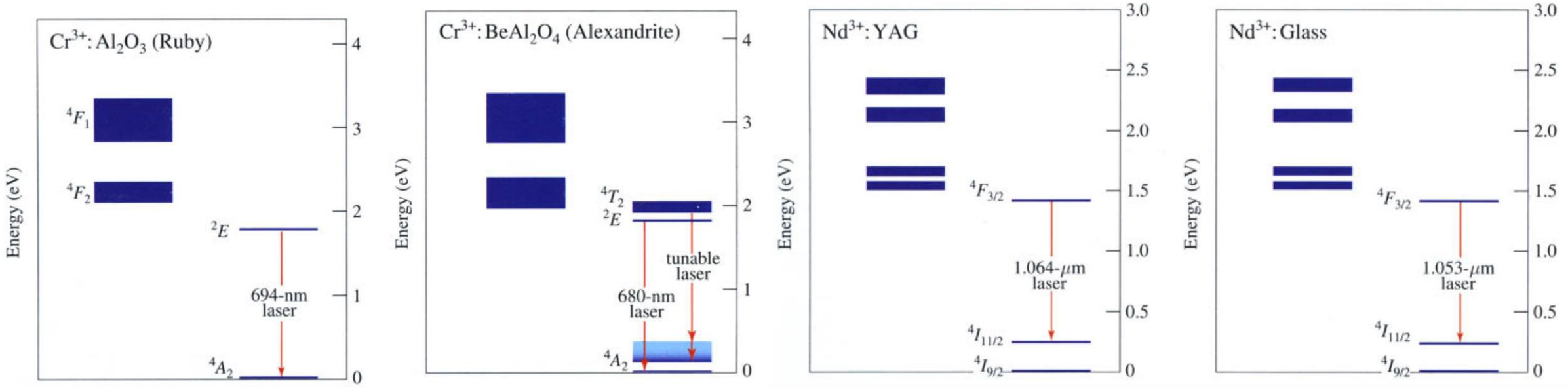
Lasers Today

Solid-State Lasers

- Transparent host materials: Crystalline and glass hosts
- Dopant ions: transition-metals and lanthanide-metals



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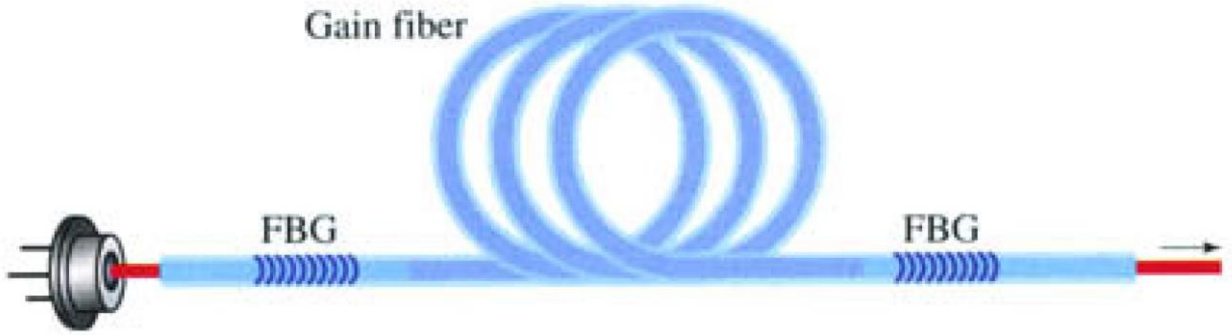
Fibre Lasers

- Lanthanide-Metal doped optical fibres as gain medium
- Feedback from fibre Bragg gratings



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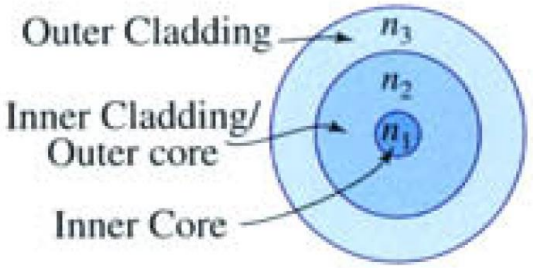

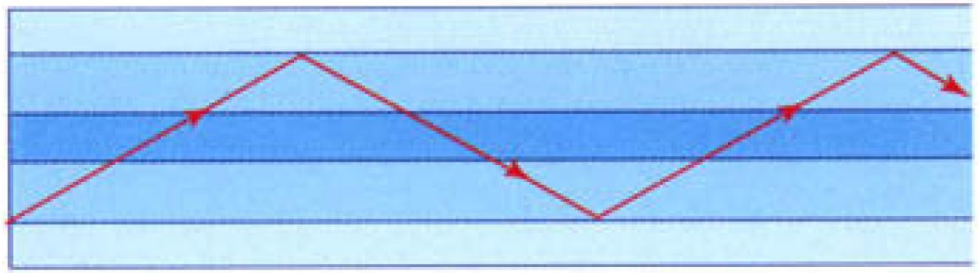

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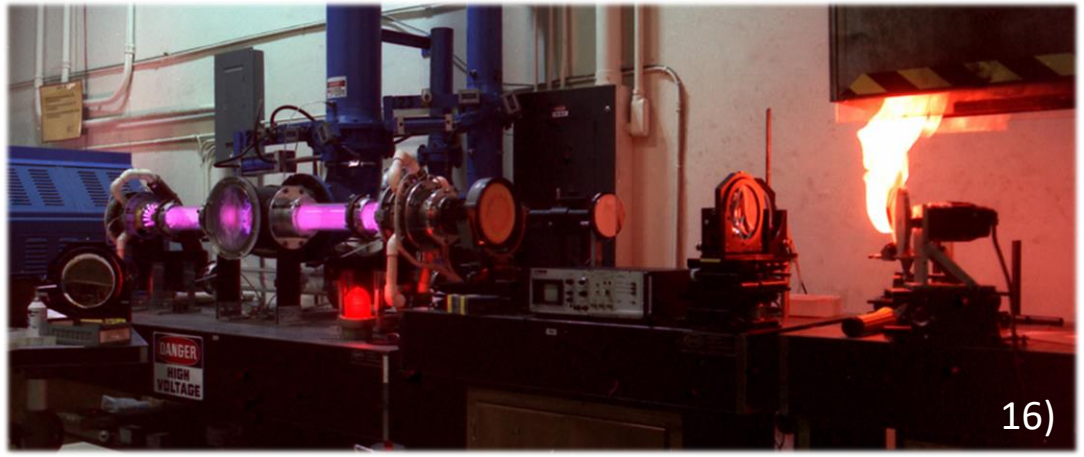
Gas Lasers

- Molecular lasers using electrical pumping: CO_2, $HeNe$, CH_3OH, …
- Large variation in wavelength and power characteristics



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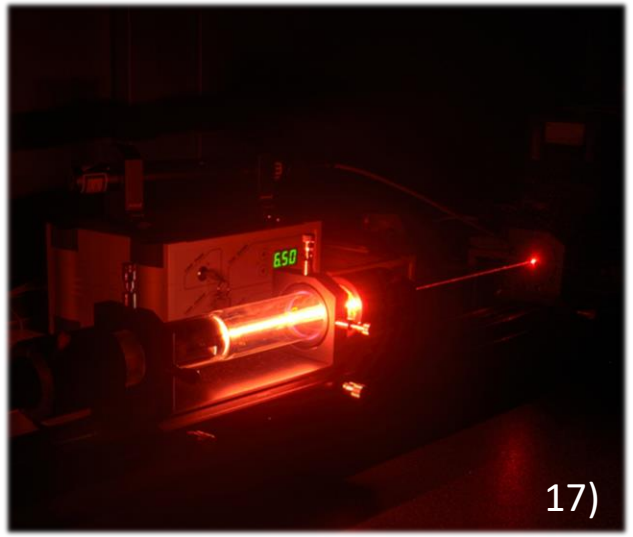

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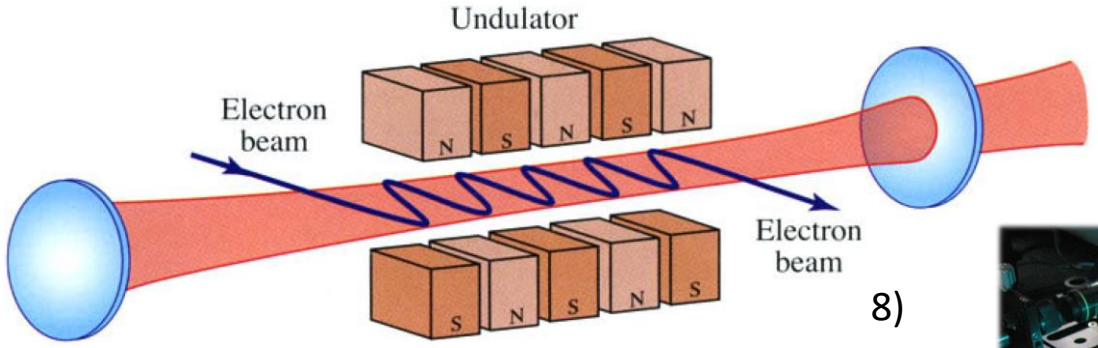
And So On…

- Chemical Lasers, Excimer Lasers, Dye Lasers, Free Electron Lasers



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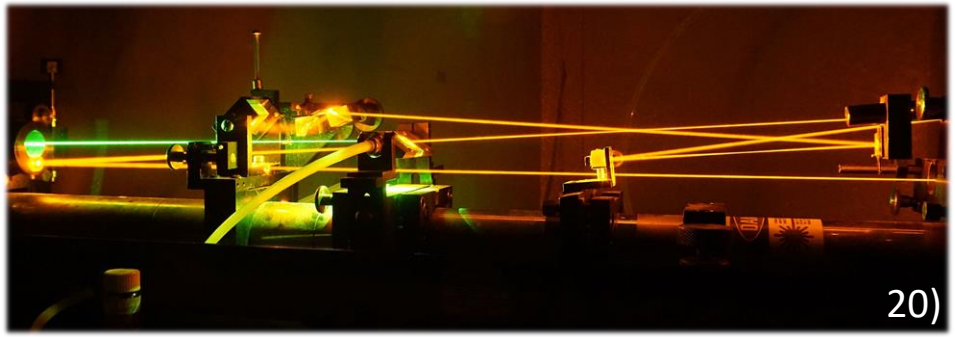
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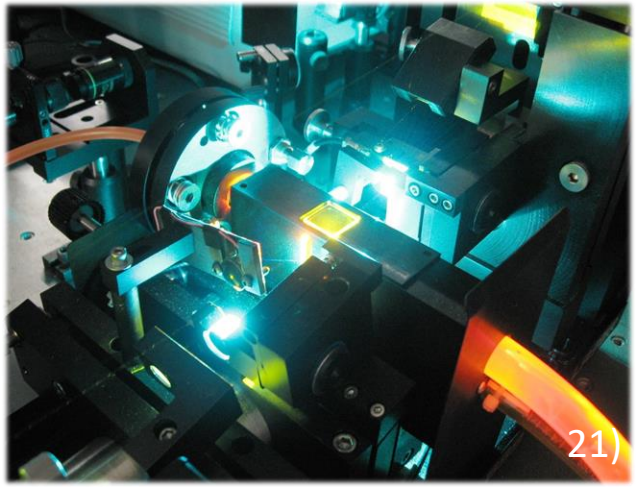
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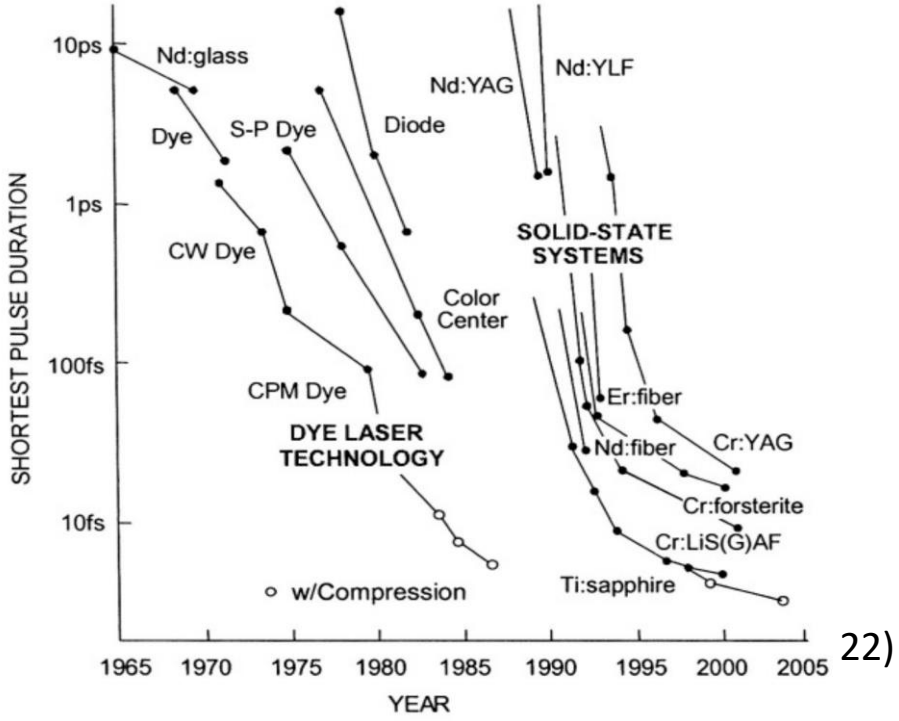
Ongoing Research

- Lasers ubiquitous in atomic physics
- 71.100 results on Google Scholar with „laser“ in title in 2021



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Thank you for your Attention!

Any Questions?

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Images

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6) Beryllium Coulomb Crystal: Adapted from: J. Stark, C. Warnecke, S. Bogen, S. Chen, E. A. Dijck, S. Kühn, M. K. Rosner, A. Graf,J. Nauta, J.-H. Oelmann, L. Schmöger, M. Schwarz, D. Liebert, L. J. Spieß, S. A. King,T. Leopold, P. Micke, P. O. Schmidt, T. Pfeifer, and J. R. Crespo López-Urrutia, “An ultralow-noise superconducting radio-frequency ion trap for frequency metrology withhighly charged ions,” Review of Scientific Instruments, vol. 92, no. 8, p. 083203, 2021

Images

7) LaserJet Printer: By Joydeep - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=46965764

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21) Dye Laser: CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=913343

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