

11.3 Masen und Laser

22

11.3.1 Allgemeines

- Masen Molecular amplification by
stimulated emission

- Laser: light

* Induzierte Emission: Einstein
Z. Physik 18 (1917)

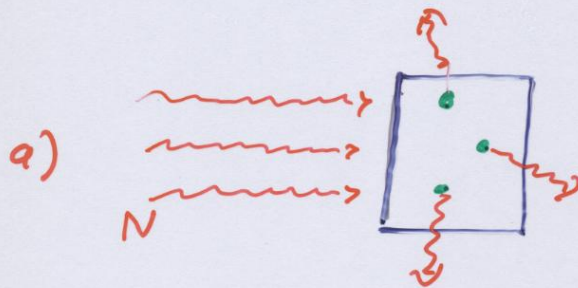
* Masen '53-'54: Gordon, Townes, Zeiger
Phy. Rev 95 (1954)

'54: Basov, Fabrikant, Prokhorov

* Laser '60: T. Maiman

Prinzip: kollektive Deexcitation von
Molekülen od. Atomen nach
Stimulation

• Konventionelle Emission:

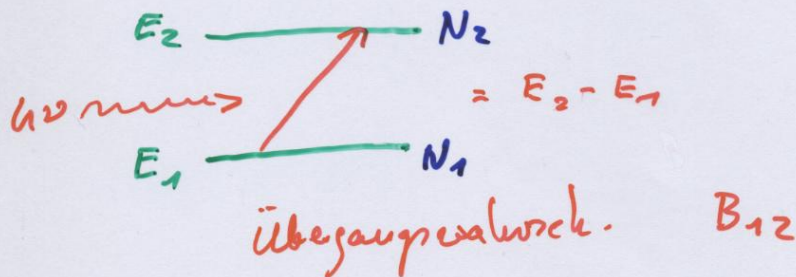


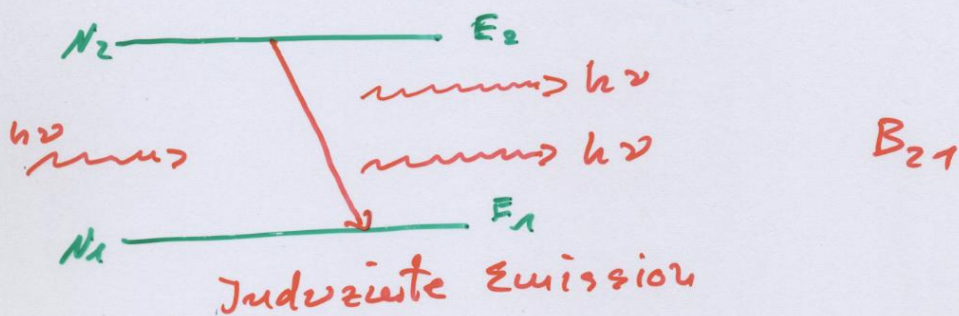
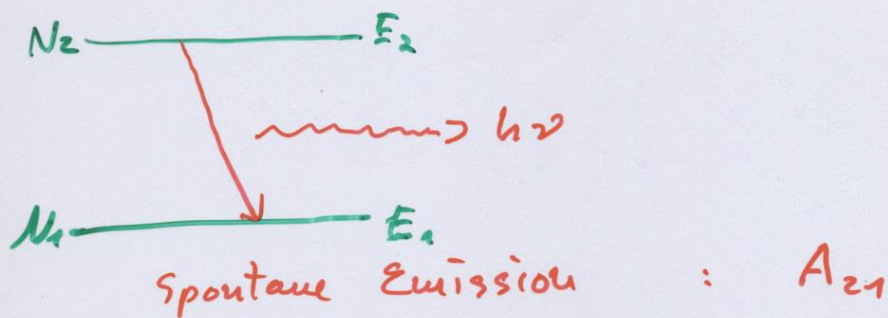
Emission vor
N & nach
Anregung,
diskrete Linien



Strahlung eines
schwarzen Körpers
Anregung durch
therm. Stoffe,
kontinuierl. Spektrum

• Im thermischen Gleichgewicht:





$$\frac{N_2}{N_1} = e^{-\frac{E_2 - E_1}{k \cdot T}} \quad \text{Boltzmannverteilung}$$

$$= e^{-\frac{h\nu}{kT}}$$

Für $T \rightarrow \infty$: $\frac{N_2}{N_1} \rightarrow 1$

Bsp: Wasserstoff $T = 293 \text{ K}$

$$\frac{N_2}{N_1} = e^{-\frac{10,2 \text{ eV} \cdot 1,6 \cdot 10^{-19} \text{ J/eV}}{293 \text{ K} \cdot 1,38 \cdot 10^{-23} \text{ J/K}}}$$

$$= e^{-404} \approx 0$$

Für $T = 6000 \text{ K}$ (Sonne):

$$\frac{N_2}{N_1} = e^{-20}$$

dh: von außen induzierte
Emission nicht möglich.

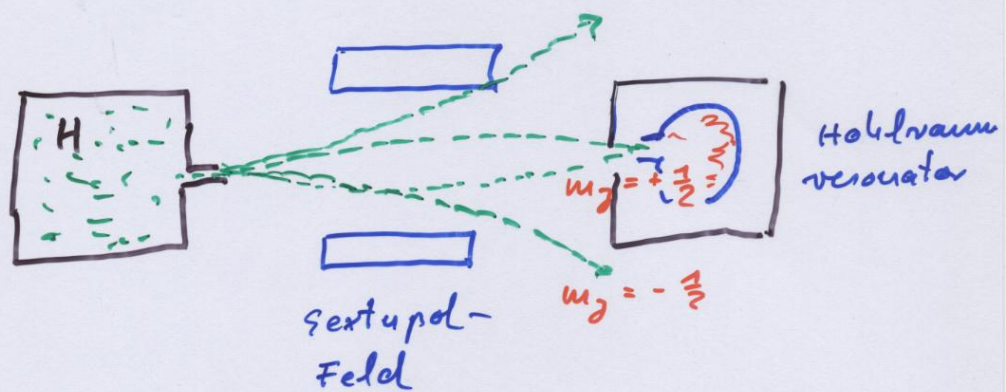
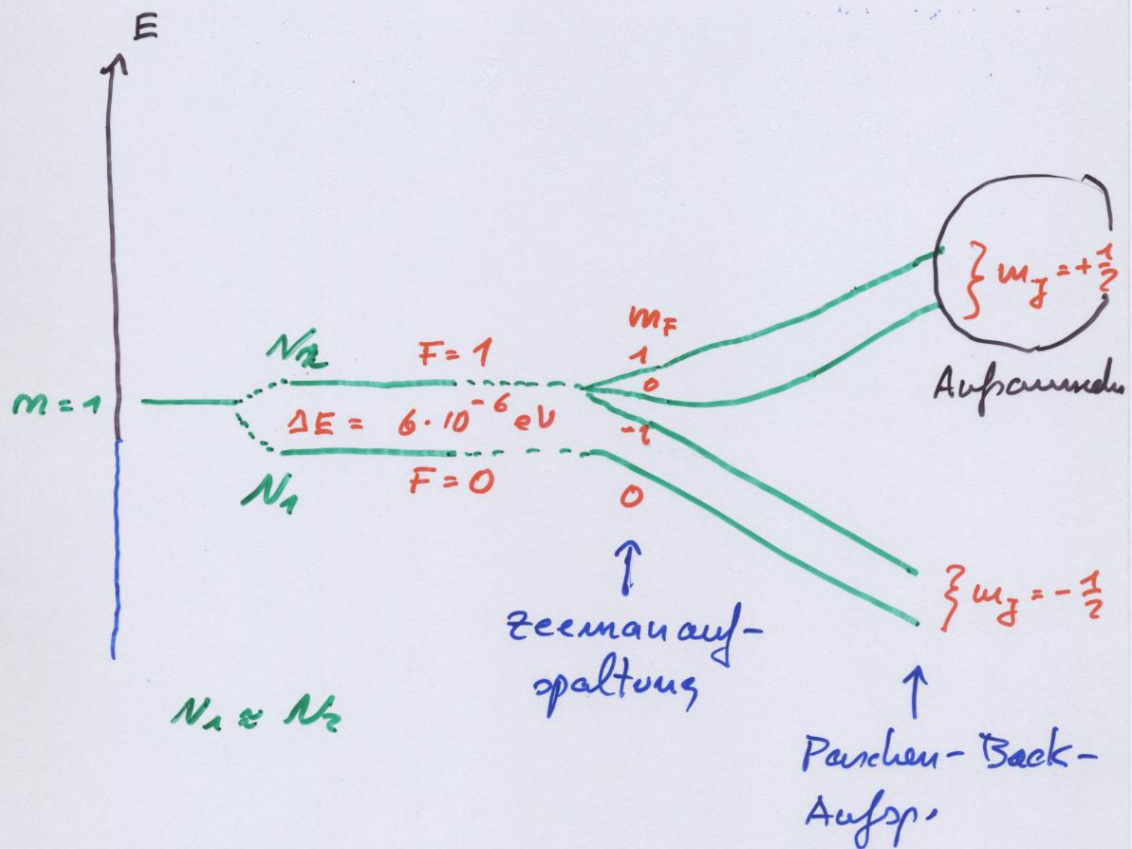
Nötig: $N_2 > N_1$!

Lösung

Methode 1] Separation von Atomen
oder Molekülen im Zustand E_2
von denen im Zustand E_1

z.B. Wasserstoff-Maser

Separation der HFS Zustände
[je kleiner ΔE , desto mehr N_2 -Zust.]

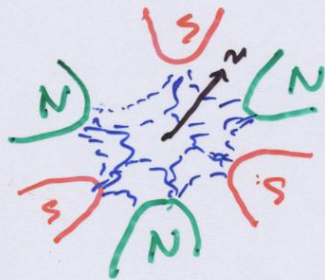


$$\nu = 1420 \text{ MHz}$$

$$\approx 21 \text{ cm}$$

- * Verwendung von Teflon auf Quarz im Hohlraum: Stöße an der Wand führen nicht zur Deexcitation

- * Sextupol



Kraft auf Magn. Momente

$$F = \mu \cdot \frac{dB}{dz} \sim \mu \cdot v$$

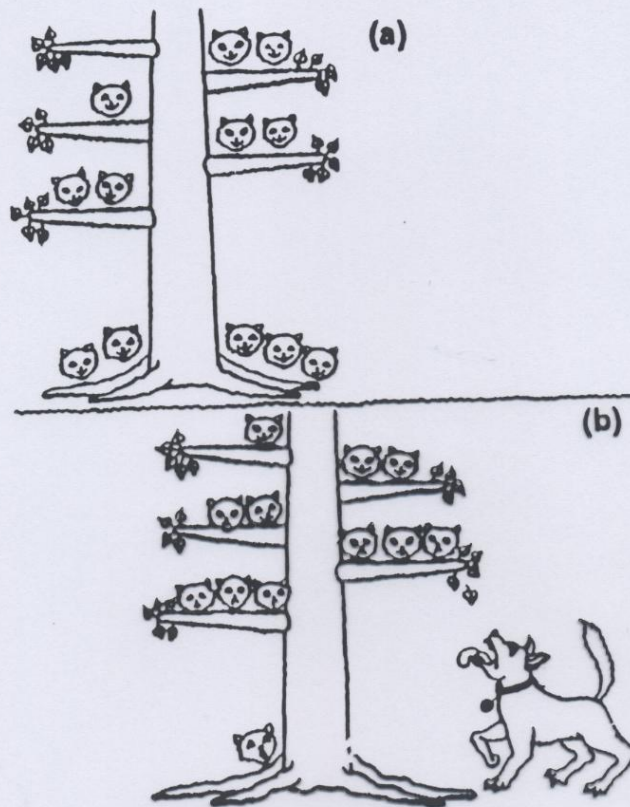
effekt: Fokussierung der angeregten Atome ($m_z = +\frac{1}{2}$)

Methode 2] Anregung von $E_1 \rightarrow E_2$
(Pumpen)

a) Rubin laser (Maiman 1960)

Rubin $Al_2O_3 + 0,05\% Cr^{3+}$ - Ionen

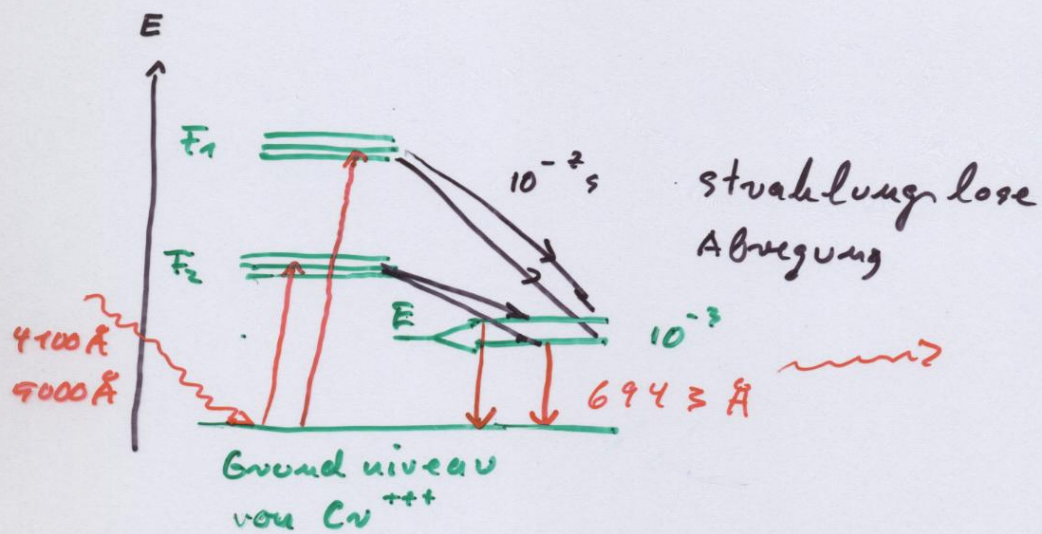
[Cr ersetzt Al $\Rightarrow$ rote Emission]



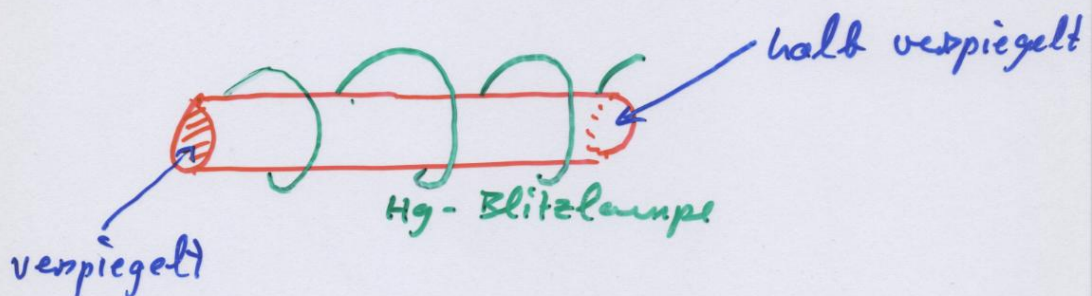
"Schematic of a population inversion. (a) Without an external driving force, the particles (cats) are distributed in the lower-lying energy levels (branches) according to the Boltzmann distributions. (b) With external pumping of energy (dog), the particles populate higher energy states (higher branches) more than lower ones. Lasing action may be likened to an upper branch breaking, returning its occupants to their ground state in a coherent pulse."

S. 270.1513

Science (1996)

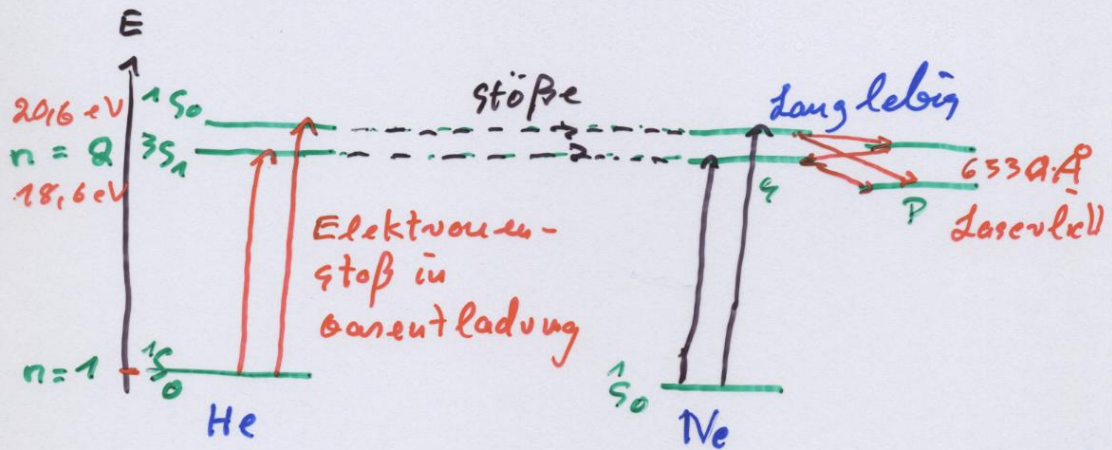


- * Hg - Blitzlicht = Pumpen in die F_1, F_2 - Bänder des Cu^{3+}
- * Schneller Übergang in das E - Niveau
- * Hohe Lebensdauer des E - Zustandes erlaubt induzierte Emission



b) He - Ne - Laser

(Ähnlich auch
CO₂ - N - Laser)



- * Anregung des He durch Gasentladung
- * Stoßanregung des Ne durch angeregtes He : ähnl. Energieniveaus
- * Emission von γ , Übergang in P-Zustand

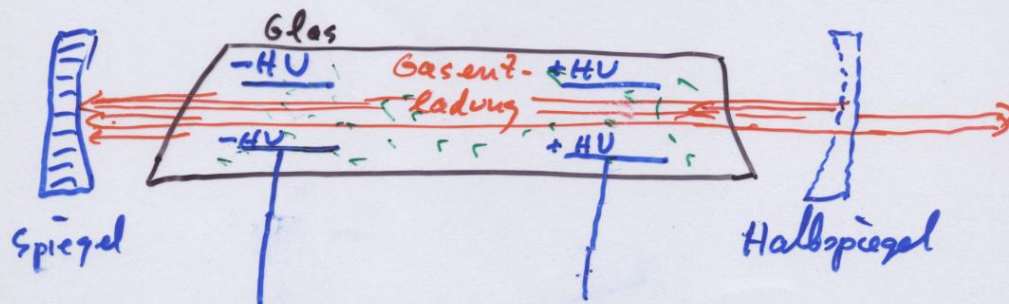
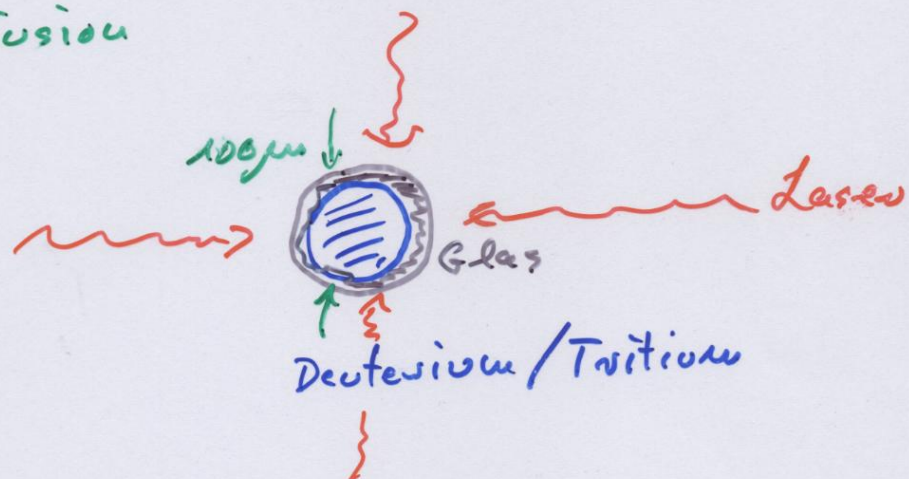


TABLE I
CHARACTERISTICS OF TYPICAL LASERS

GAIN MEDIUM	PEAK POWER	PULSE LENGTH	WAVELENGTH	USES
Gas				
HeNe	1 mW	cw	633 nm	Supermarket scanners
Argon	10 W	cw	488 nm	Entertainment, medical
CO ₂	200 W	cw	10.6 μ m	Cutting and welding
CO ₂ TEA	5 MW	20 ns	10.6 μ m	Heat treating
Semiconductor				
GaAs	5 mW	cw	840 nm	CD players
AlGaAs	50 mW	Modulated	760 nm	Laser printers
GaInAsP	20 mW	Modulated	1.3 μ m	Fiber communications
Solid state				
Ruby	100 MW	10 ns	694 nm	Live holography
Nd:YAG	50 W	cw	1.06 μ m	Semiconductor processing
Nd:YAG (QS)	50 MW	20 ns	1.06 μ m	Medical applications
Nd:YAG (ML)	2 kW	60 ps	1.06 μ m	Short-pulse studies
Nd:Glass	100 TW	11 ps	1.06 μ m	Laser fusion
Dye				
Ring dye	100 mW	Continuous	Tunable	Spectroscopy
Rh6G (ML)	10 kW	10 fs	600 nm	Scientific studies
Chemical				
HF	50 MW	50 ns	3 μ m	Weapons
Excimer				
ArF	10 MW	20 ns	193 nm	Materials processing
XeCl	50 kW	10 ns	375 nm	Medical applications

11.3.3 Anwendungen des Lasers

- Vermessungswesen
[Bsp.: Δd (Erde - Mond) $\sim 15\text{cm}$]
- Opt. Kommunikation
- Schneiden [Bsp.: Automobilindustrie
Beleuchtungsind.
Medizin]
- Holographie
- Fusion



Kompression um $\times 1000$

$T \sim 10^7 - 10^8 \text{ K}$

Für 1 Kugel / Pellet:

Fusionsenergie $\hat{=}$ 1 Fass Öl

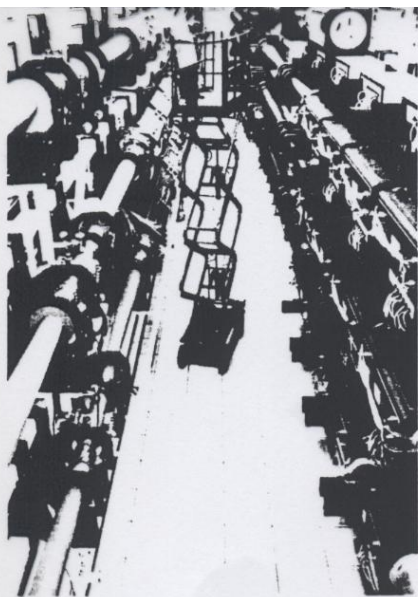


Fig. L.14 Neodymium lasers at Lawrence Livermore Laboratory.

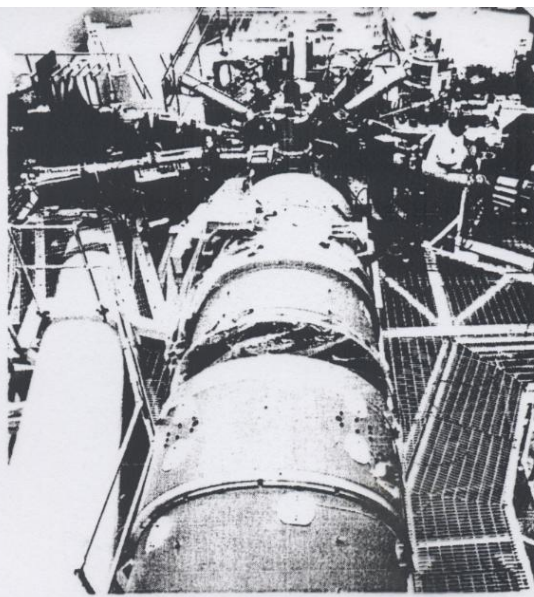


Fig. L.15 Target chamber at Lawrence Livermore Laboratory. Laser beams, within tubes, converge toward the center of this chamber.



Fig. L.16 Small glass balloons, or microballoons, filled with a mixture of deuterium and tritium.