Grundlagen der Femtochemie
SS 2006

Termin: Donnerstags 7:30 – 8:55

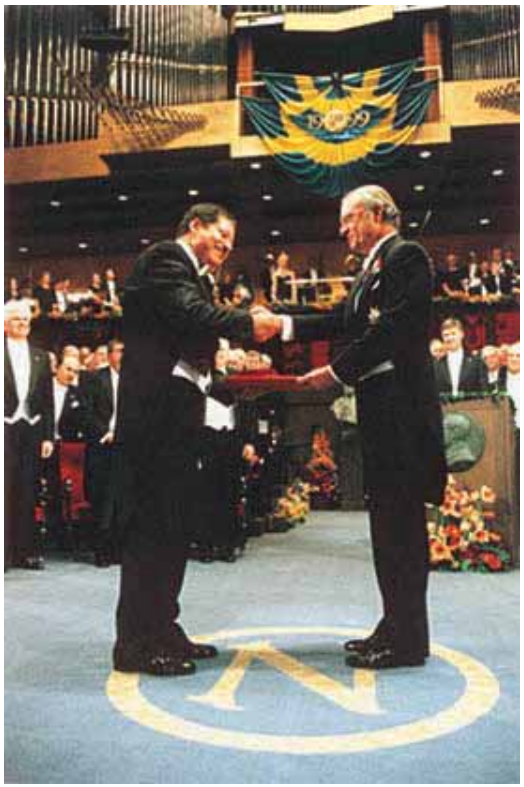
Raum: 1135

Skript

http://www.physik.uni-kassel.de/index.php?id=maschbau

Was ist Femtochemie?

The 1999 Nobel Price in Chemistry



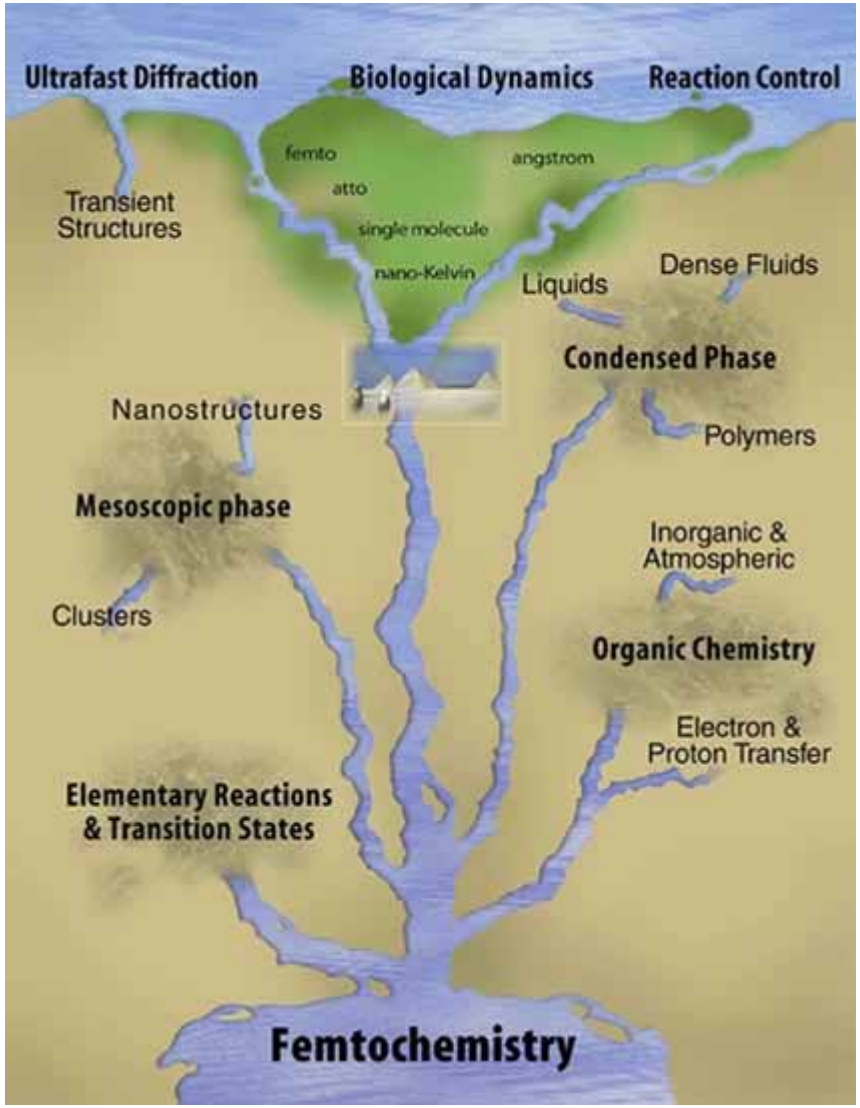
For his studies of the transition states of chemical reactions using femtosecond spectroscopy

For showing that it is possible with rapid laser technique to see how atoms in a molecule move during a chemical reaction

Ahmed H. Zewail, Caltech

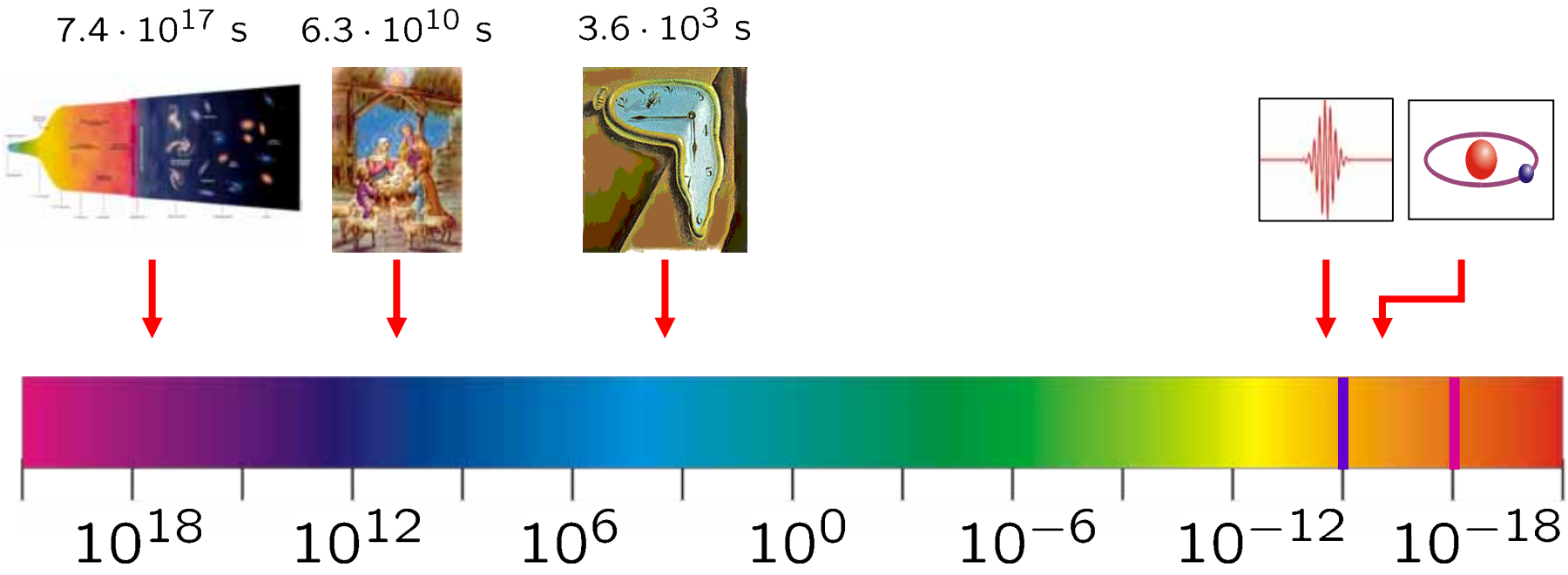
http://nobelprize.org/

Was ist Femtochemie?

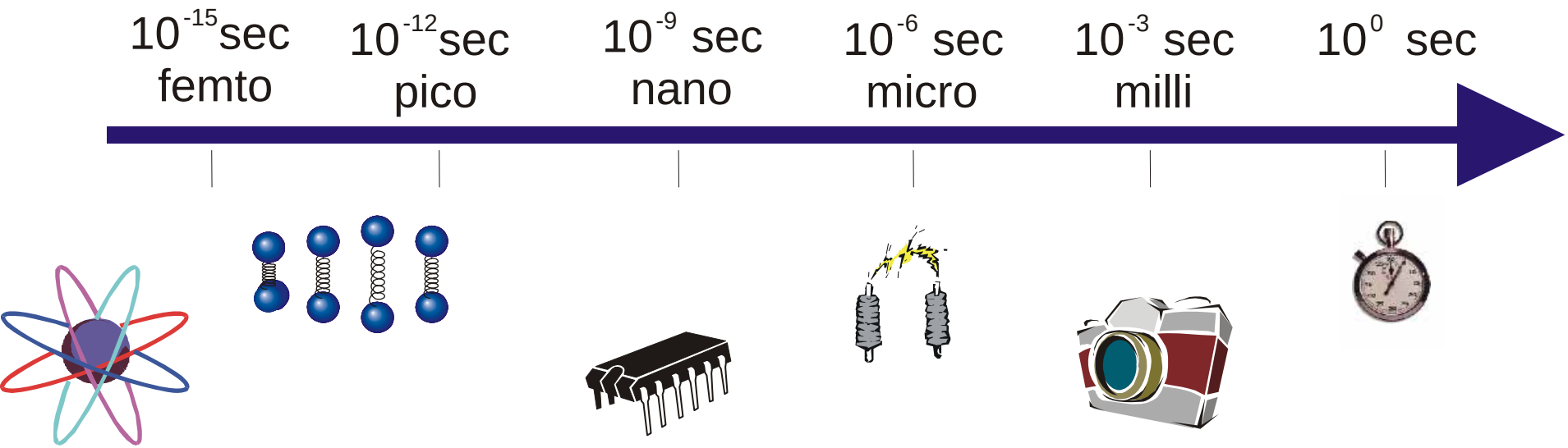


Was ist eine Femtosekunde ?

1 fs = 10^{-15} s = 0. 000 000 000 000 001 s



Zeitskala physikalischer Vorgänge



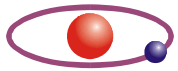
Wie schnell verläuft eine chemische Reaktion?

Beispiel I: Wegstrecken

Lichtgeschwindigkeit: c = 299792458 m/s

• 1 s	300 000 km	Erde - Mond
• 1 ms	300 km	Kassel - Lübeck
• 1 µs	300 m	Hier - Mensa
• 1 ns	30 cm	Lineal
• 1 ps	0.3 mm	(kräftiges) Papier
• 1 fs	0.3 µm	1/200 Haar
• 1 as	3 Å	Molekül

Beispiel II: Wasserstoffatom



$$F_{Coulomb} = F_{Zentripetal}$$

$$\frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$$

$$L = r \cdot p = n\hbar$$

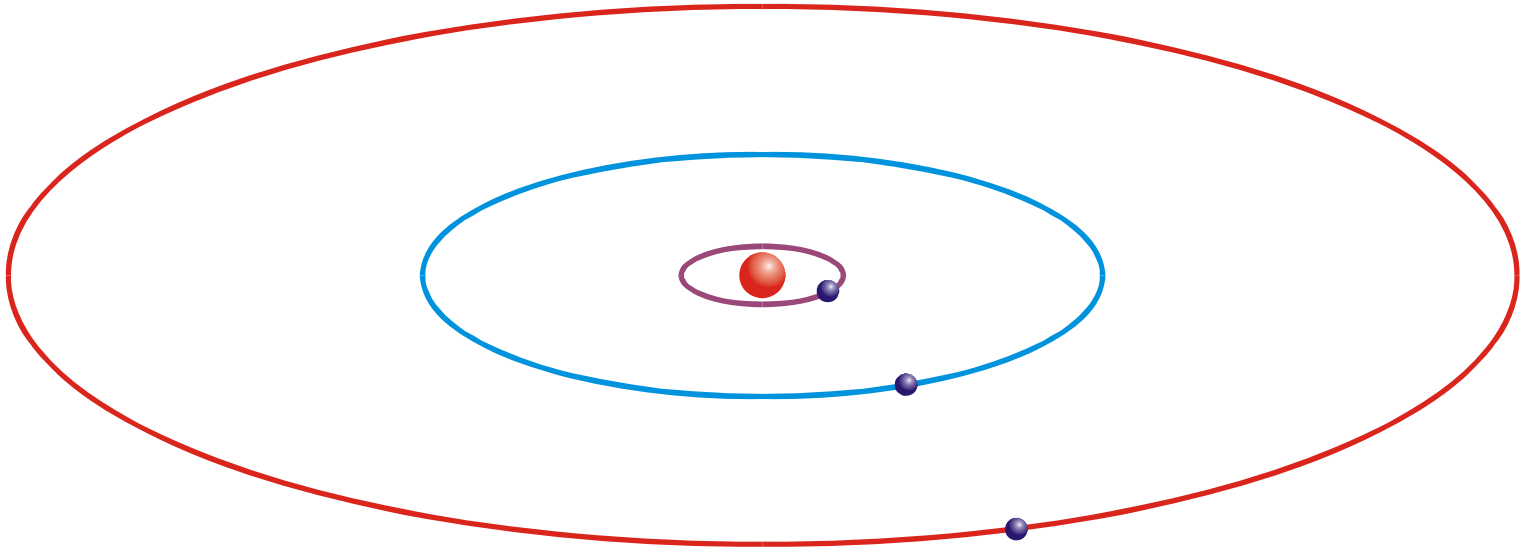
$$r = \frac{4\pi\varepsilon_0 \hbar^2 n^2}{Ze^2 m_e}$$

$$v = \frac{Ze^2}{4\pi\varepsilon_0 \hbar n}$$

$$E_n = -\frac{m}{2\hbar}\left(\frac{Ze^2}{4\pi\varepsilon_0}\right)^2 \frac{1}{n^2}$$

Bransden and Joachain: „Quantum Mechanics“

Wasserstoffatom II



$$T = \frac{s}{v} = \frac{2\pi r}{v}$$

$$\boxed{T = \frac{32\pi^3 \varepsilon_0^2 \hbar^3}{e^4 m_e Z^2} n^3}$$

$$T(n = 1) = 0.15\,\text{fs}$$

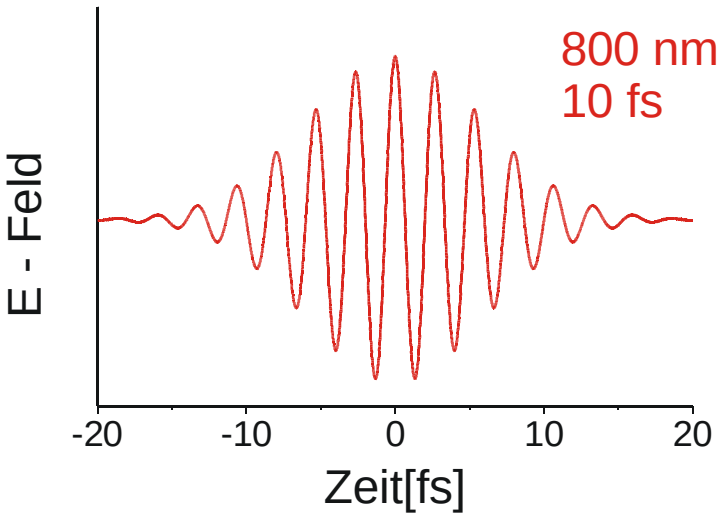
$$T(n = 2) = 1.22\,\text{fs}$$

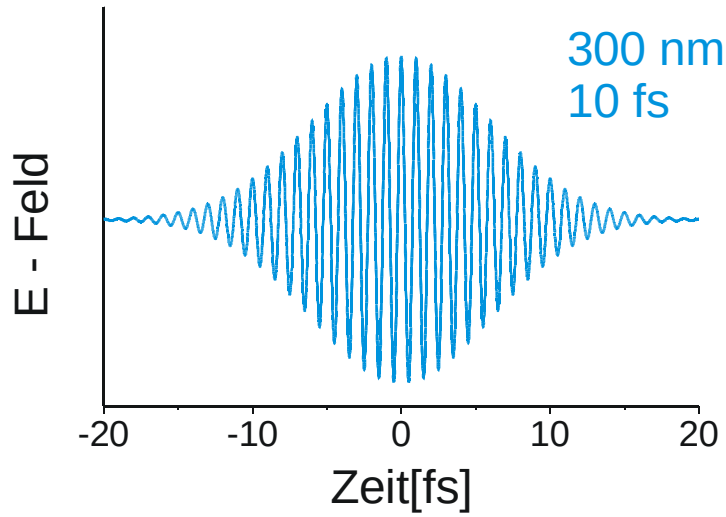
$$T(n = 10) = 151.98\,\text{fs}$$

Beispiel III: Licht

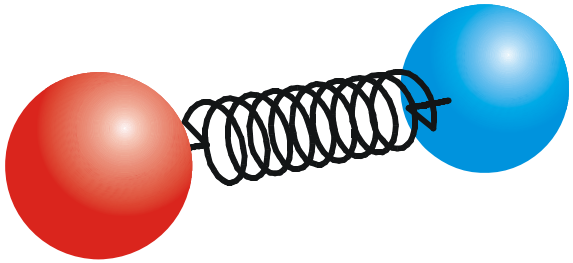
$$T = \frac{1}{f} = \frac{2\pi}{\omega} = \frac{\lambda}{c_0}$$

- 800 nm (IR) $\Rightarrow$ 2.7 fs
- 300 nm (UV) $\Rightarrow$ 1.0 fs





Beispiel IV: molekulare Schwingungen



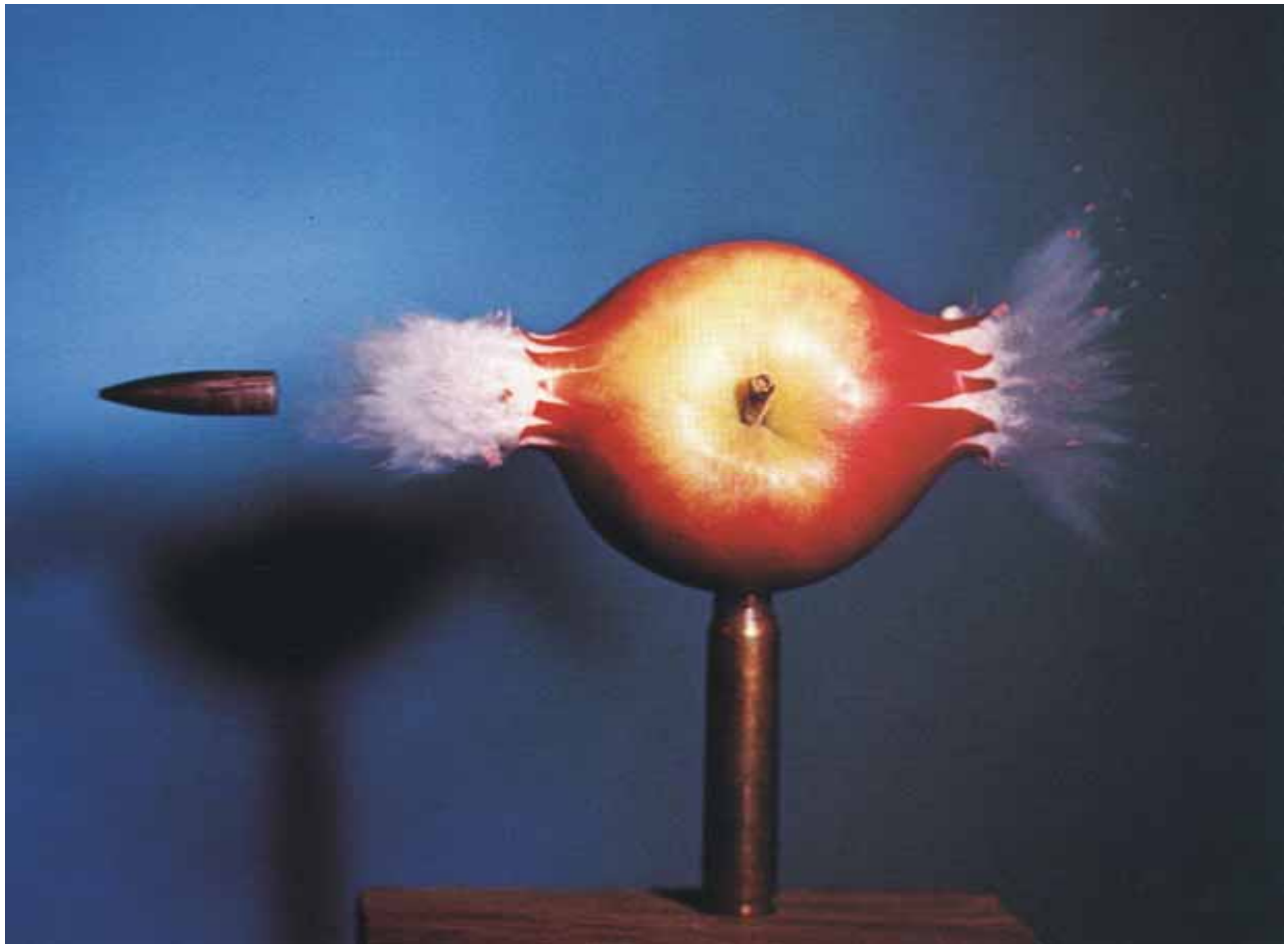
- HI 266 fs
- Na_2 209 fs
- I_2 155 fs
- HCl 11 fs
- OH 8.9 fs

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$

$$T = \frac{1}{c_0\,\omega_e}$$

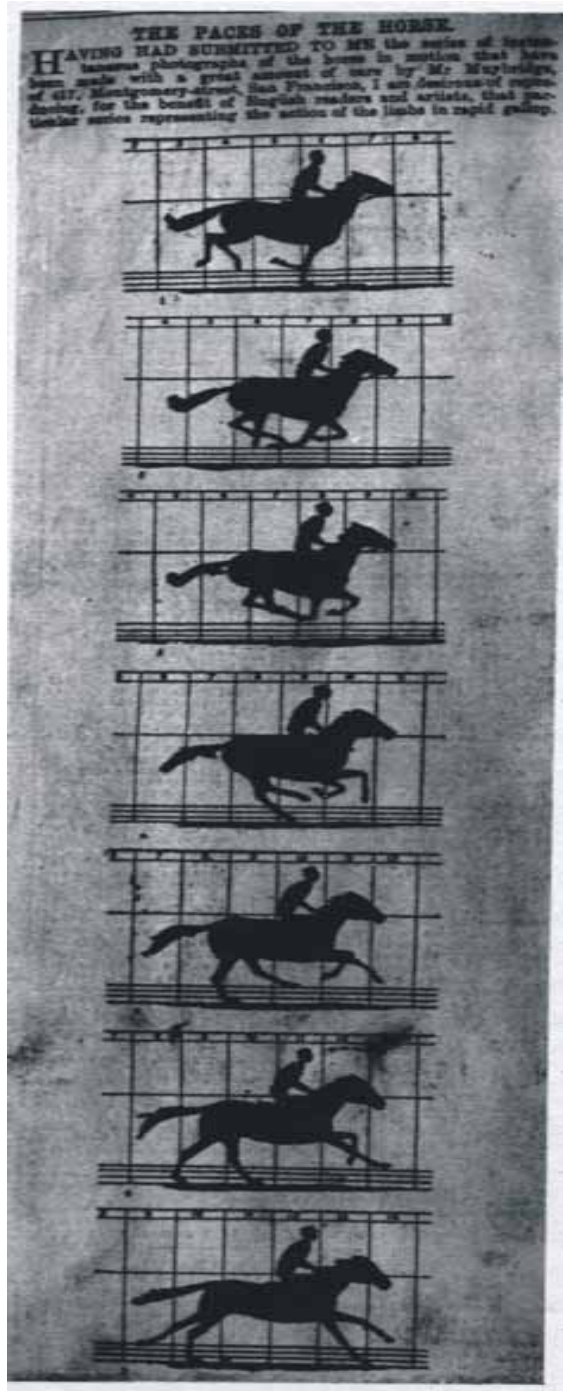
G. Herzberg: „Molecular Spectra and Molecular Structure“

Warum Femtosekundenspektroskopie ?



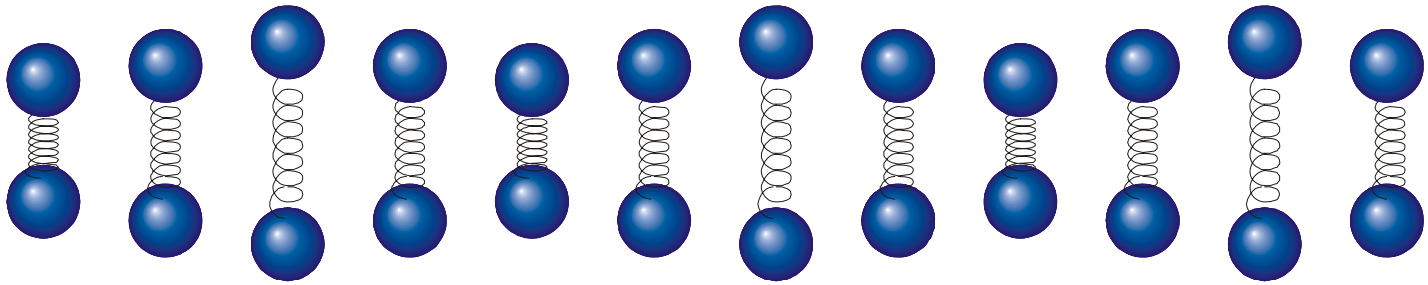
Warum Femtosekunden-spektroskopie ?

Muybridge und die 25000 Dollar Wette



La Nature, 14. Dez. 1878

Pump - Probe Techniken



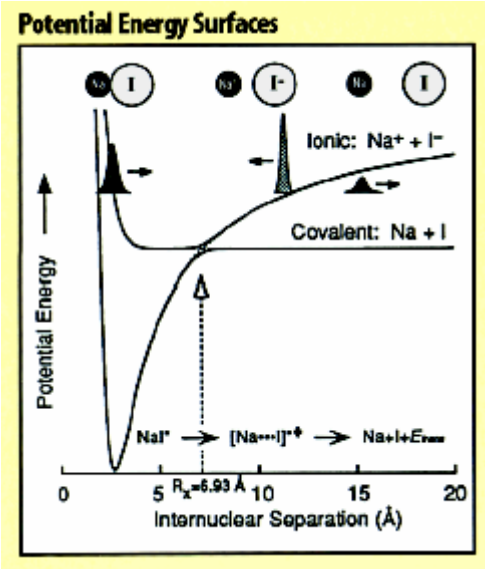
Zeitverzögerung

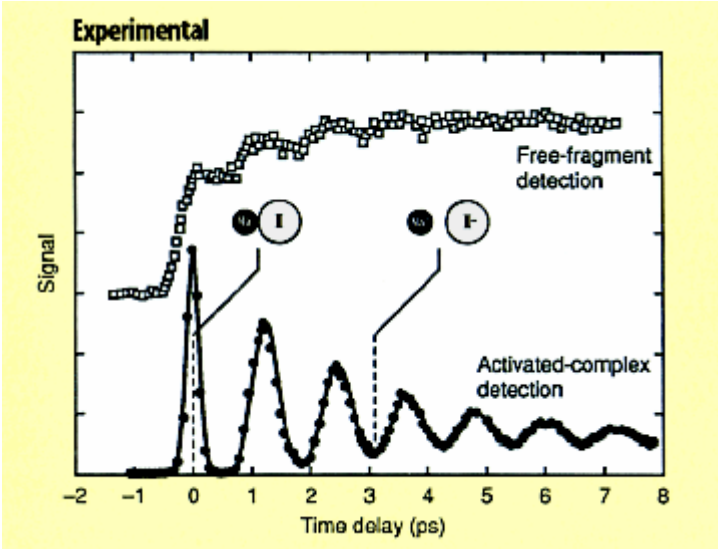
Pump-Puls

Probe-Puls

„Slow motion“

Beobachtung ultraschneller Prozesse





J. Phys. Chem A, ***104****, 5660-5694 (2000)*

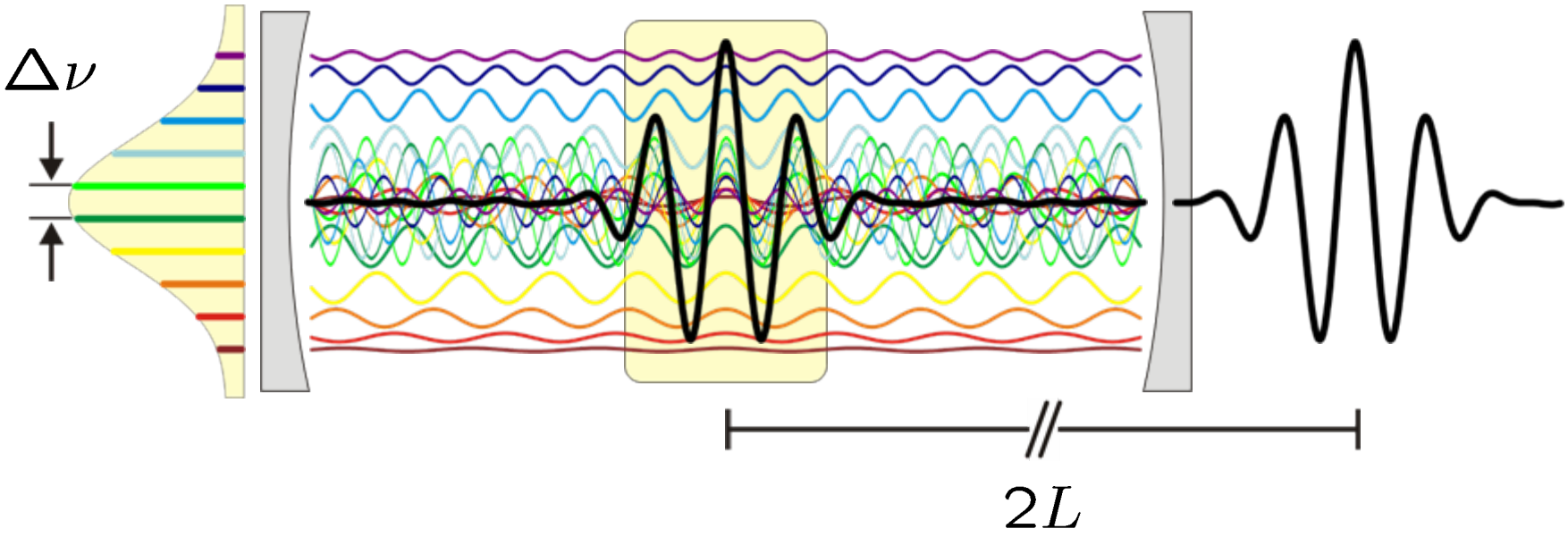
Programm

- Licht
- Materie
- Licht & Materie

Licht

- Erzeugung von femtosekunden Pulsen
- Pulsformung
- Charakterisierung (Messung)

Erzeugung von femtosekunden Laserpulsen I



Pulsbreite: $\Delta T \propto \frac{1}{N\,\Delta\nu}$

Intensität: $I \propto N^2$

Erzeugung von femtosekunden Laserpulsen II