

# Medizinische Biophysik 11. Vorlesung

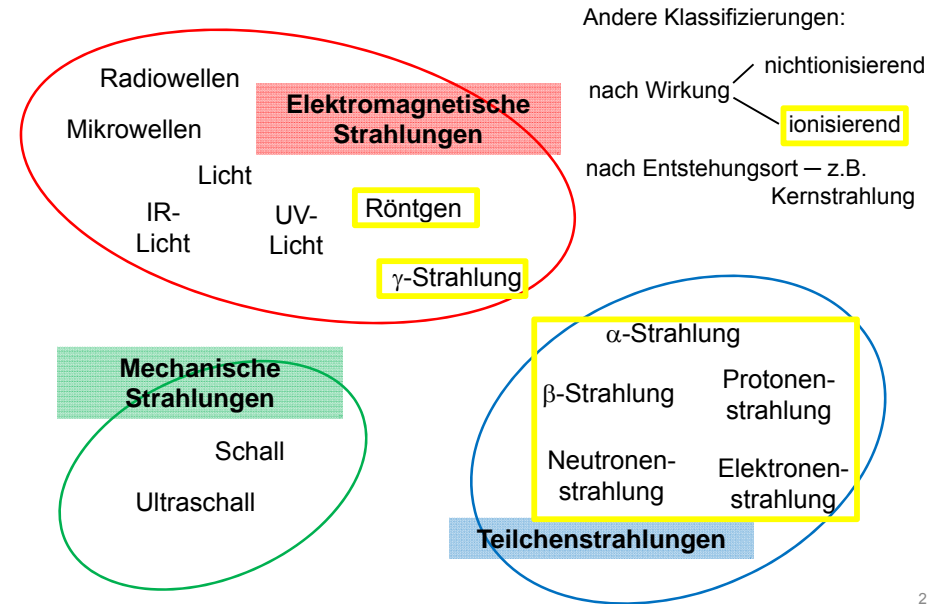
Strahlungen  
Strukturuntersuchungsmethoden in der Medizin

## Strahlungen

1. Gemeinsame Eigenschaften
2. Elektromagnetische Strahlungen
3. Teilchenstrahlungen
4. Mechanische Strahlungen (Schall, Ultraschall, ...)

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## Strahlungen in der medizinischen Praxis



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### 1. Gemeinsame Eigenschaften

- Strahlung = Energietransport ! (Strahlungsintensität (J), ...)
- Doppelcharakter = Wellencharakter & Teilchencharakter

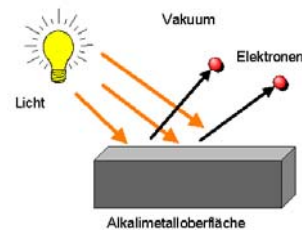
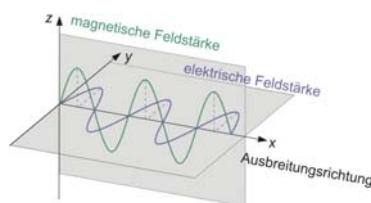
### 2. Elektromagnetische Strahlungen

Elektromagnetische Wellen – Transversalwellen & Teilchen - Photonen

$$c = \lambda \cdot f \quad c = 3 \cdot 10^8 \frac{\text{m}}{\text{s}} \quad (\text{im Vakuum})$$

elektromagnetische Welle

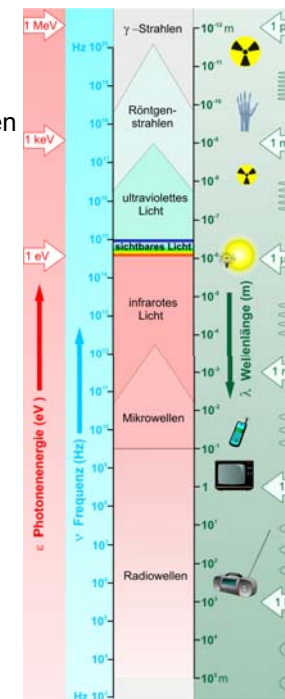
$$\epsilon = h \cdot f$$



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### 7 Bereiche:

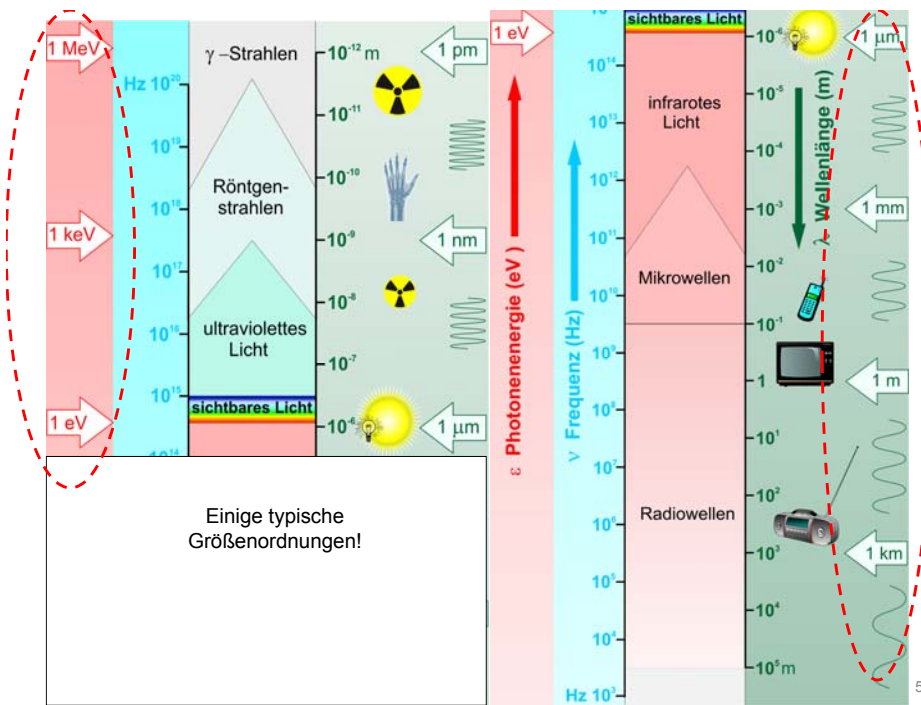
- gamma-Strahlen
- Röntgenstrahlen
- UV-Licht
- VIS-Licht
- IR-Licht
- Mikrowellen
- Radiowellen



### Anwendungsbeispiele:

- Gamma-Messer
- Röntgendiagnostik
- UV-Phototherapie
- Mikroskopie/Sehen
- Infrarotdiagnostik
- MRI

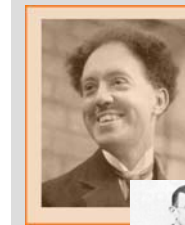
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### 3. Teilchenstrahlungen

- Teilchen ( $\alpha$ ,  $\beta$ ,  $e^-$ ,  $e^+$ ,  $p^+$ ,  $n^0$ , ...)

- Materiewellen



de Broglie (1923): Materiewellen

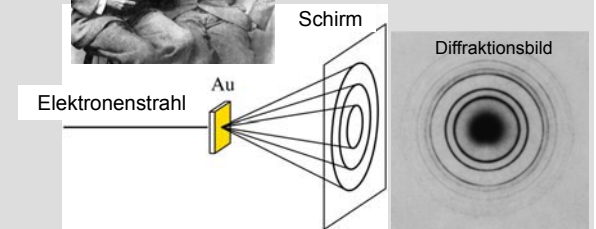
$$\lambda = \frac{h}{m \cdot v}$$



Davisson & Germer (1927): Elektronenbeugungsexperiment

- Anwendungsbeispiele:

- Elektronenmikroskop
- Neutronendiffraktion
- Strahlentherapie



### 4. Mechanische Strahlungen (Schall, Ultraschall, ...)

- Mechanische Wellen

$$c = \lambda \cdot f$$

$$c = 330 \frac{\text{m}}{\text{s}} \quad (\text{in der Luft})$$

$$c = 1500 \frac{\text{m}}{\text{s}} \quad (\text{im Wasser und im Weichteilgewebe})$$



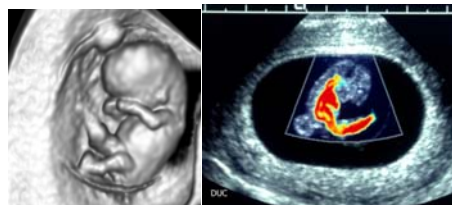
- transversale/longitudinale Wellen

- 3 Bereiche: 

Infraschall	–	Hörschall	–	Ultraschall
< 20 Hz		20 Hz – 20 kHz		20 kHz <

- Anwendungsbeispiele:

- Sonographie
- Ultraschalltherapie
- Hören



## Strukturuntersuchungsmethoden in der medizinischen Forschung

### 1. Spektroskopische Verfahren

- Fluoreszenzspektroskopie ✓
- Absorptionsspektroskopie (UV-VIS) ✓
- Infrarotspektroskopie

### 2. Mikroskopie

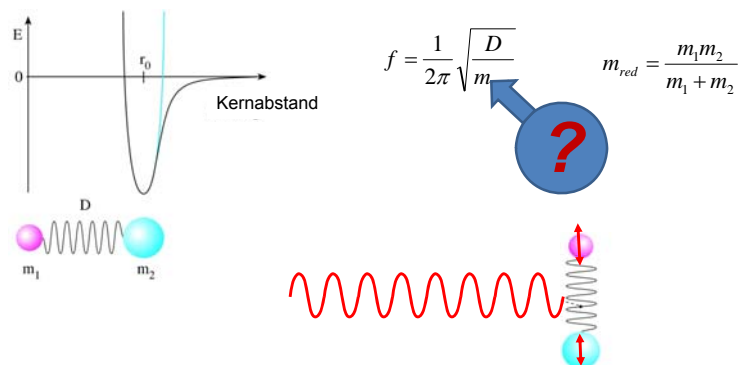
- Lichtmikroskop ✓
- Spezielle Lichtmikroskope (Stereo-, Polarisations-, Phasenkontrast-, Fluoreszenzmikroskop)
- Superresolutionsmikroskope
- Rastersondenmikroskope (SPM; STM, AFM), Piezoelektrizität
- Elektronenmikroskope (TEM, SEM)

### 3. Diffraktionsmethoden

- Röntgendiffraktion
- Elektronendiffraktion
- Neutronendiffraktion

## Infrarotspektroskopie

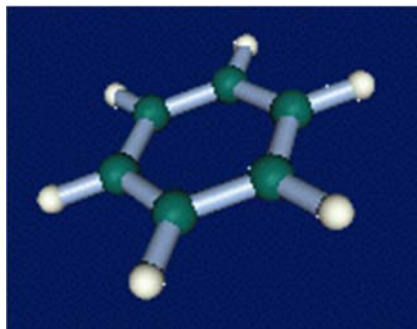
- Infrarotes Licht:  $\lambda=800 \text{ nm} - 1 \text{ mm}$   
Mittleres Infrarot:  $2,5\text{-}50 \mu\text{m}$
- Absorptionsspektroskopie
- Das absorbierte Licht induziert Molekülschwingungen
- Besonders empfindlich für die Molekülstruktur



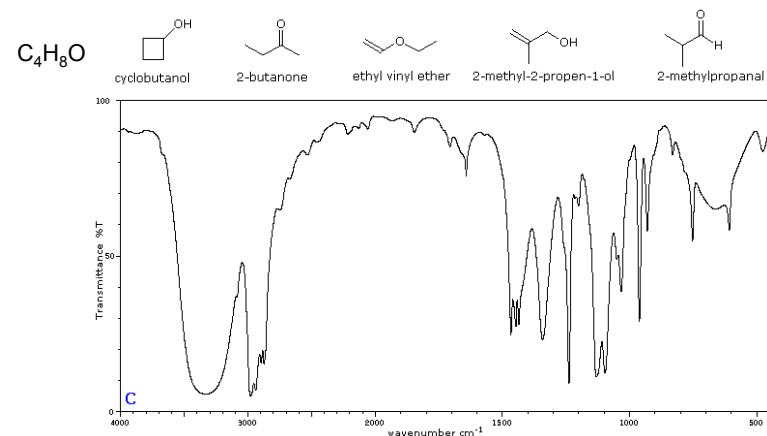
## Mehratomige Moleküle: Die Schwingungen des Wassers



## Weitere Beispiele: Benzol



## Anwendung: Identifizierung der Moleküle, Beweisung des Raumstrukturs

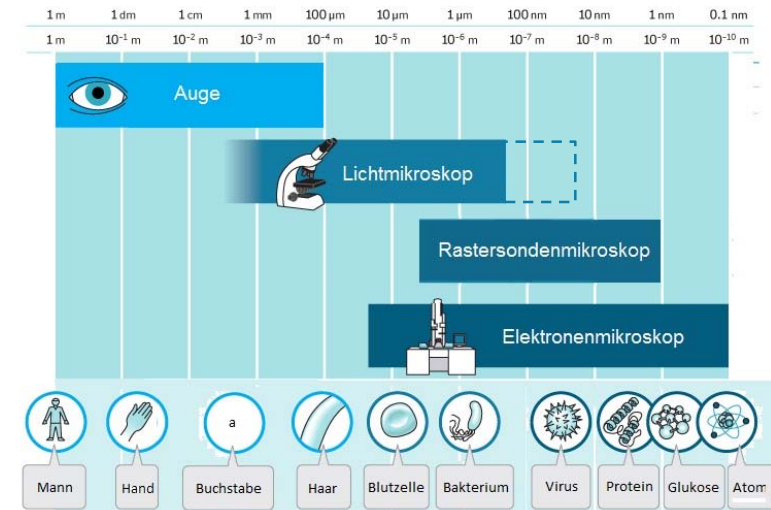


# Mikroskopische Methoden



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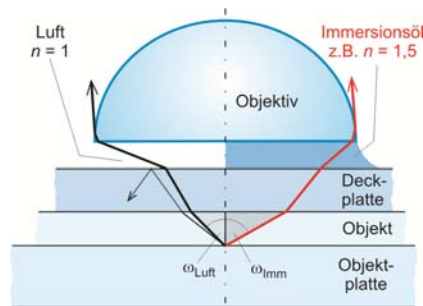
# Typische Abmessungen von einigen Objekten



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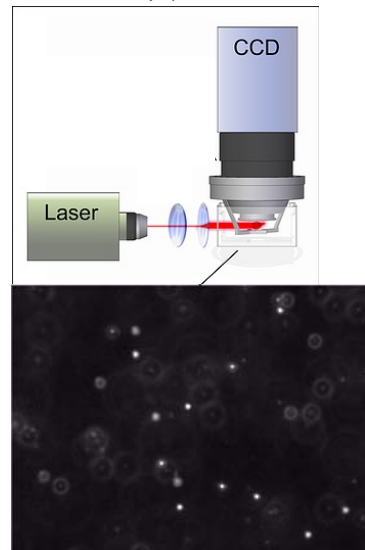
## 2. Mikroskopie

- a) Lichtmikroskop ✓
- b) Spezielle Lichtmikroskope
  - Immersionsobjektiv



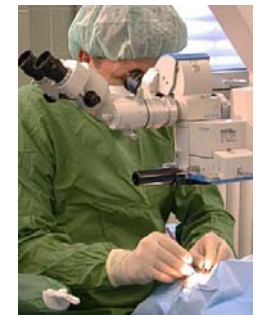
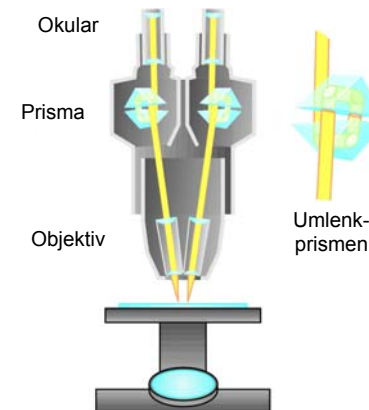
$$\delta = 0,61 \frac{\lambda}{n \sin \omega}$$

- Ultramikroskop (Dunkelfeldmikroskop)



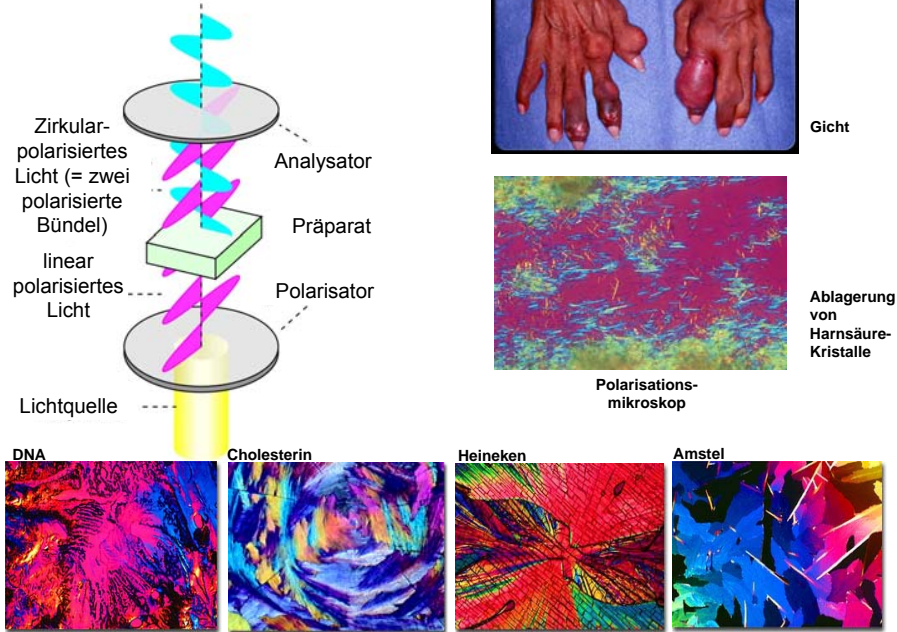
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- Stereomikroskop



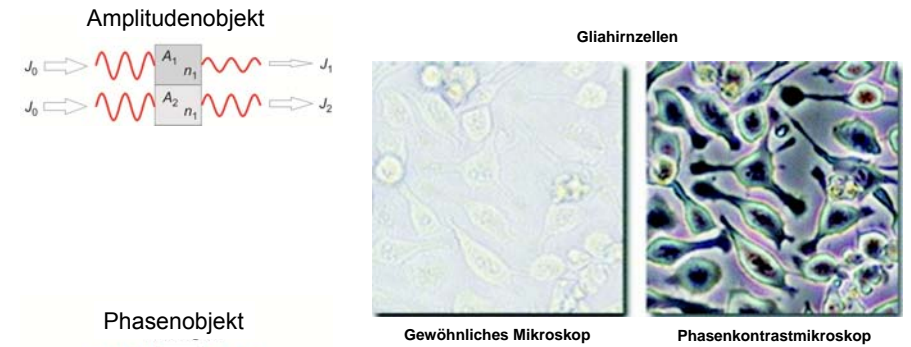
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## ■ Polarisationsmikroskop



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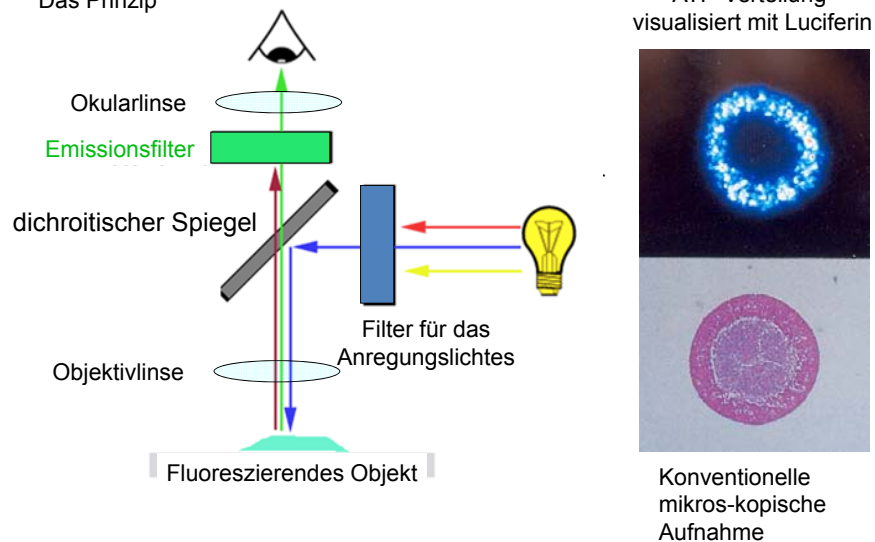
## ■ Phasenkontrastmikroskop



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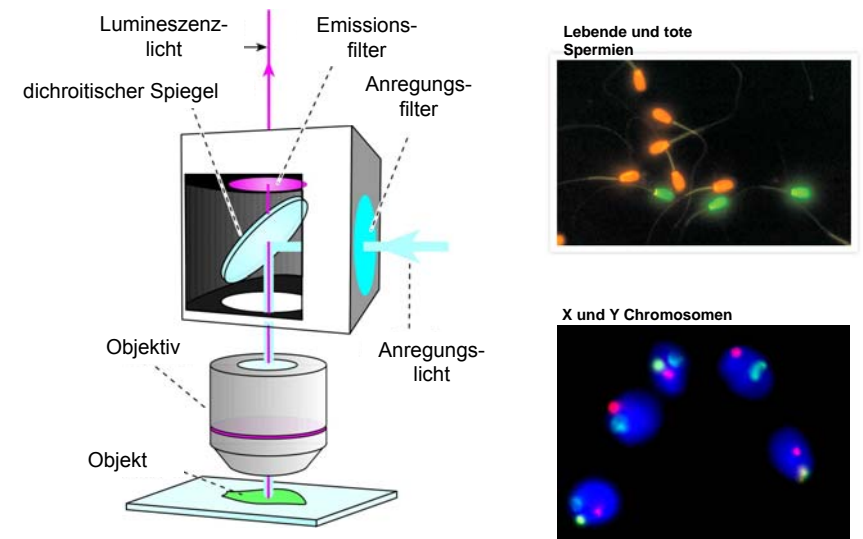
## ■ Fluoreszenzmikroskop

### Epifluoreszenz-Anordnung: Das Prinzip



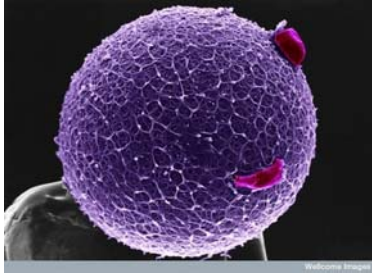
### Epifluoreszenz-Anordnung:

#### Die praktische Realisierung

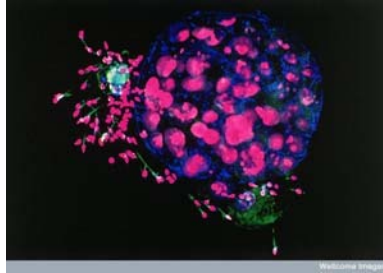


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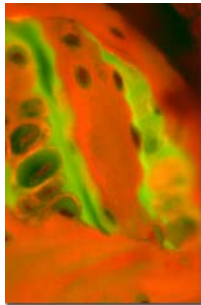
Eizelle



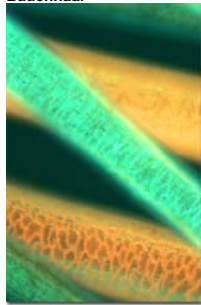
Eizelle nach Befruchtung



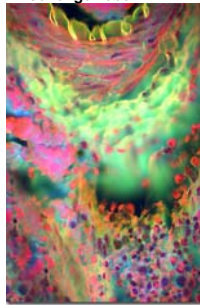
???



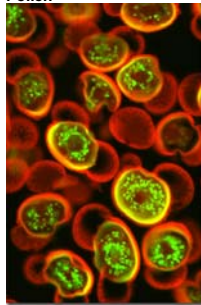
Bauchhaar



Knochengewebe

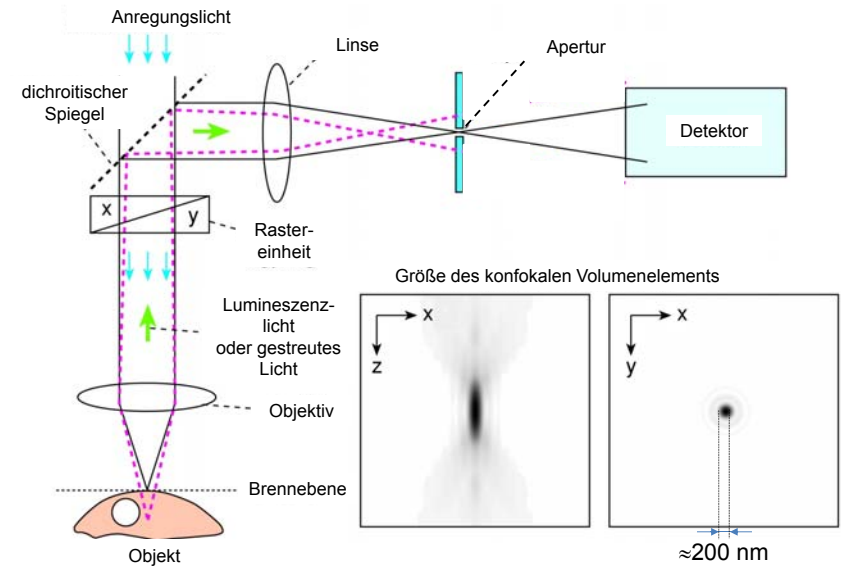


Pollen



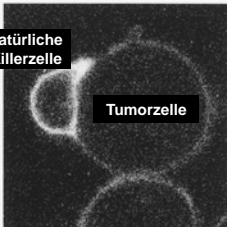
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## Konfokales Laser Rastermikroskop (CLSM)

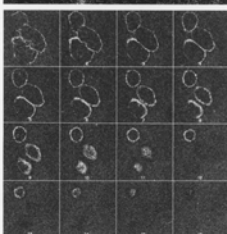


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natürliche  
Killerzelle



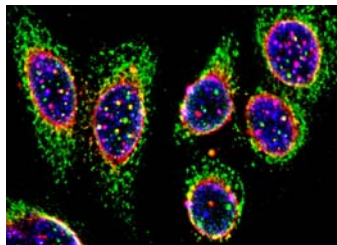
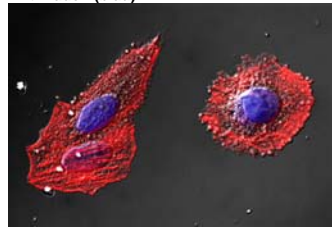
Tumorzelle



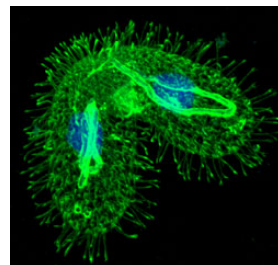
Aktinfaden (grün)



Aktinfaden (blau)



DNA



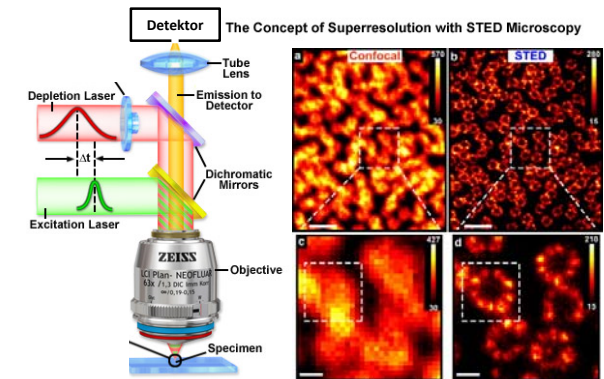
Mikrotubuli (grün)

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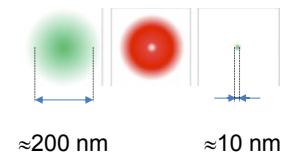
## c) Superresolutionsmikroskopie. Beispiel: STED



Stefan W. Hell



STED: Stimulierte Emission Depletion

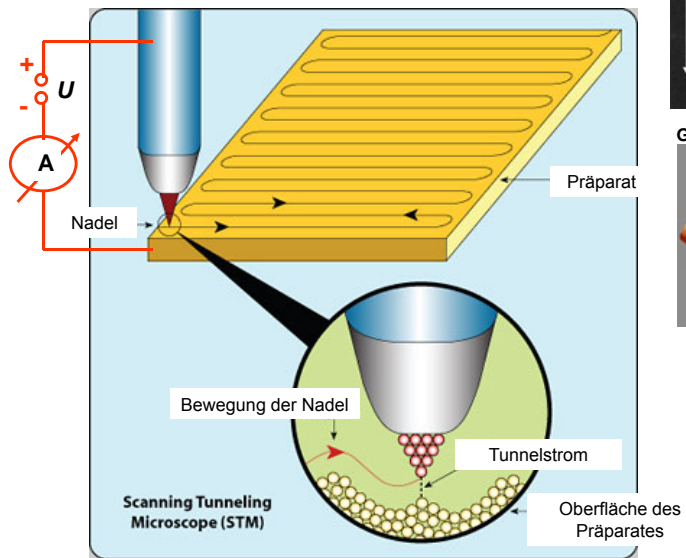


- Anregung
- Stimulierte Emission
- Fluorophore nur in sehr kleinen Raumteil Emittieren
- Abtastung

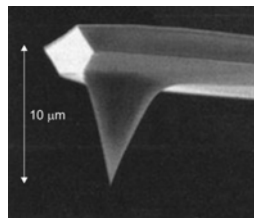
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#### d) Rastersondenmikroskope (SPM)

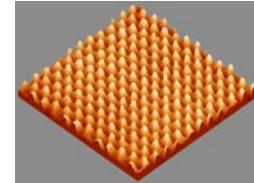
##### ▪ Rastertunnelmikroskop (STM)



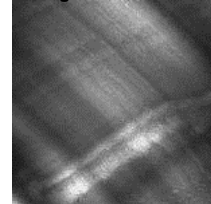
Sonde



Grafit



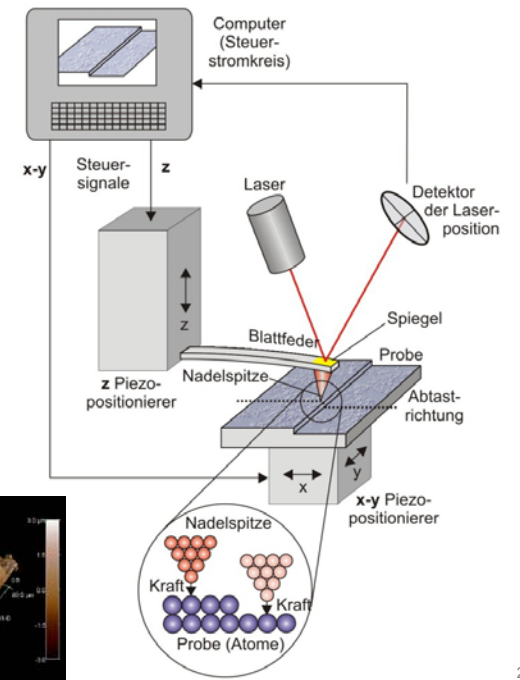
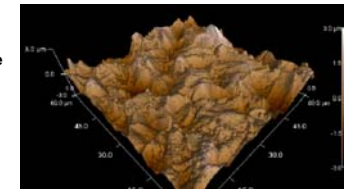
Kollagen



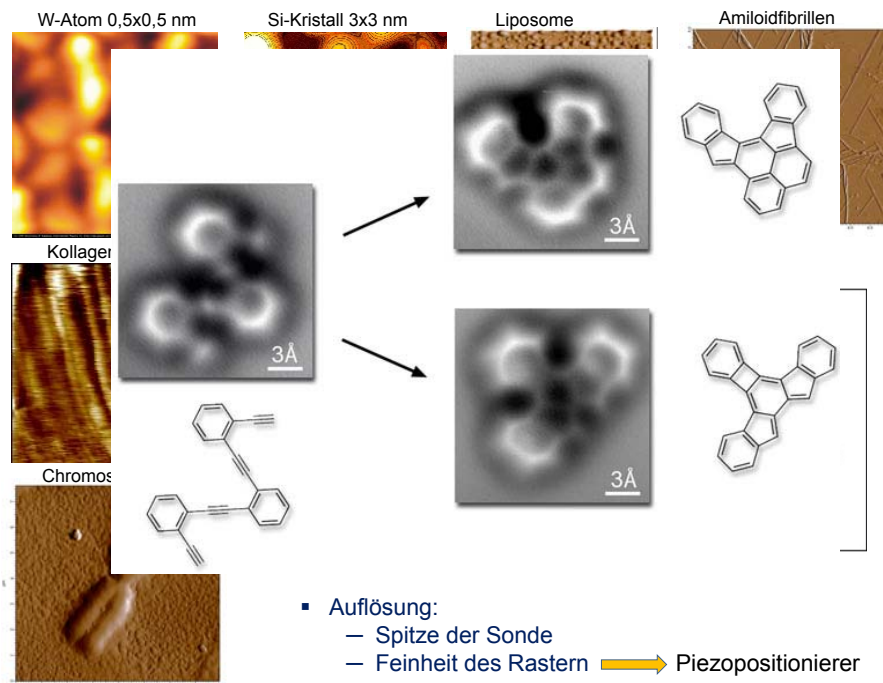
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##### ▪ Rasterkraftmikroskop (AFM)

Titan-Oberfläche



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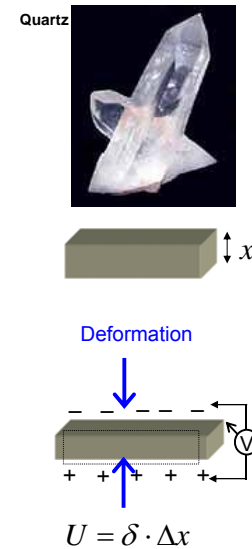


- Auflösung:
  - Spitze der Sonde
  - Feinheit des Rastern → Piezopositionierer

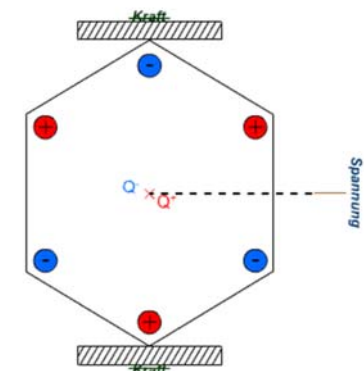
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##### ▪ Piezoelektrizität (piezoelektrischer Effekt)

(s. später Sonographie)



z.B für Quarz:  $\delta \approx 10^{12} \text{ V/m}$



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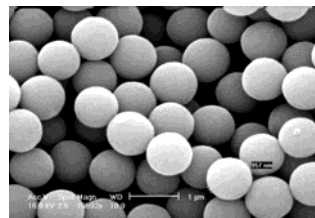
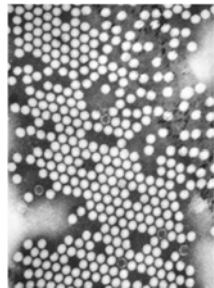
- Inverser piezoelektrischer E



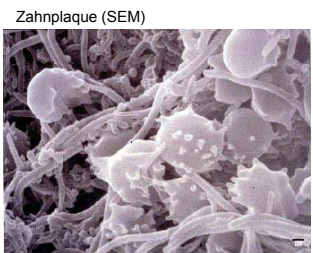
- Rasterelektronenmikroskop (SEM)


$$\delta \approx \frac{\lambda}{\text{NA}}$$

$$\lambda \approx 0,005 \text{ nm}$$
$$\text{NA} \approx 0,03$$

$$\delta \approx 0,2 \text{ nm}$$


TiO-Kugeln  
(SEM)



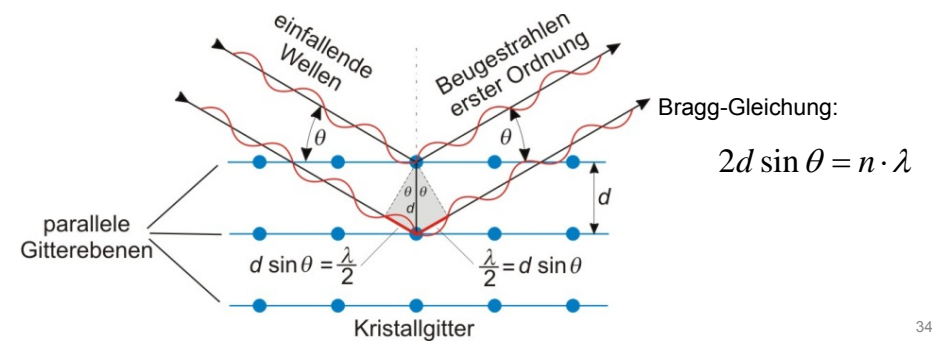
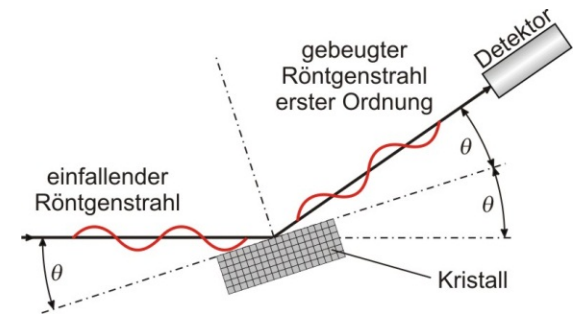
Zahnplaque (SEM)



### Zahnschmelzprismen mit den Apatitkristallen (SEM)



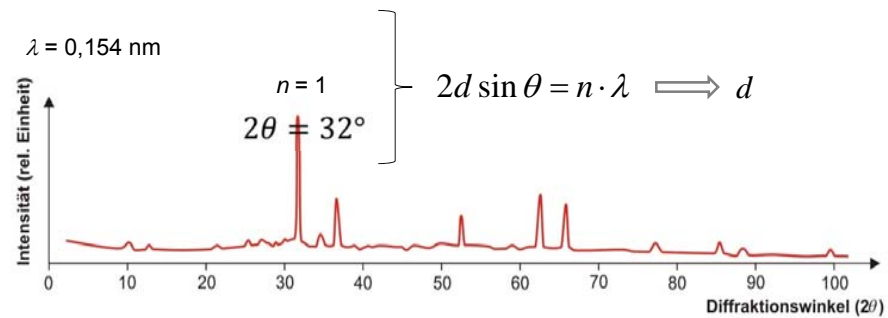
Dentin mit den Odontoblasten (SEM)

$$\lambda \approx 0,01-0,1 \text{ nm}$$


$$2d \sin \theta = n \cdot \lambda$$

Beispiel:

Röntgendiffraktionsspektrum von Blei (Pb)

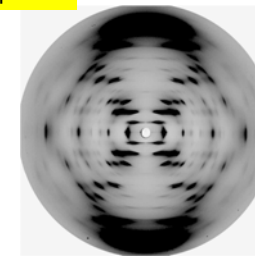


b) Elektronendiffraktion  $\lambda \approx 0,1 \text{ nm}$

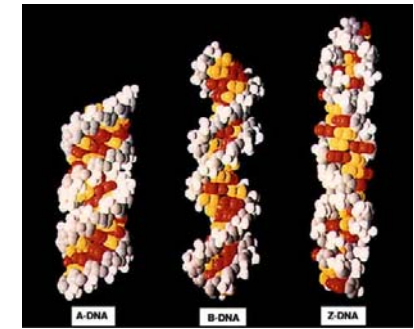
c) Neutronendiffraktion  $\approx 0,01 \text{ nm}$

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Beispiele:

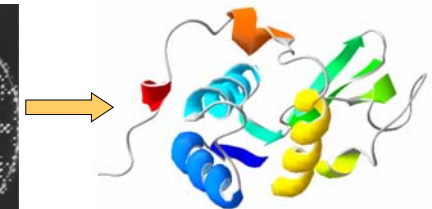
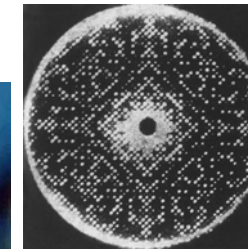
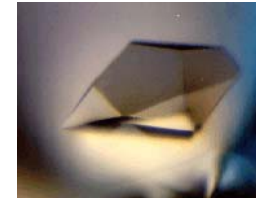


DNA



Lysozyme

Protein-Kristall



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PDB Database: 3D Makromolekülstrukturen  
meistens mit Hilfe der Rtgdiffraktion bestimmt

RCSB PDB - Mozilla Firefox

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10.1-3 und 9-10



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