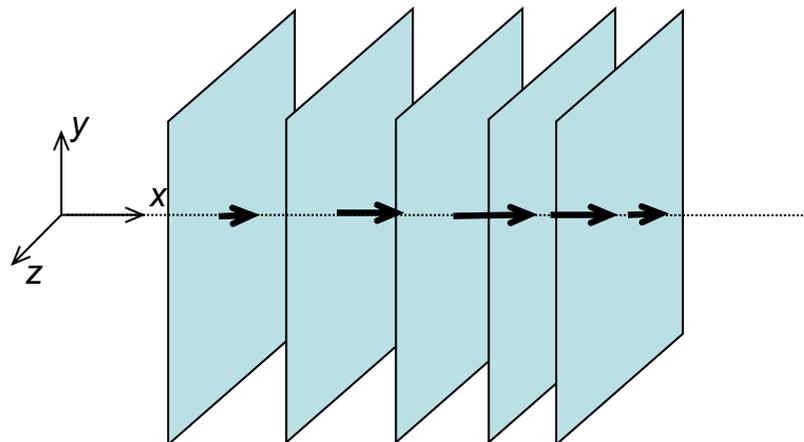
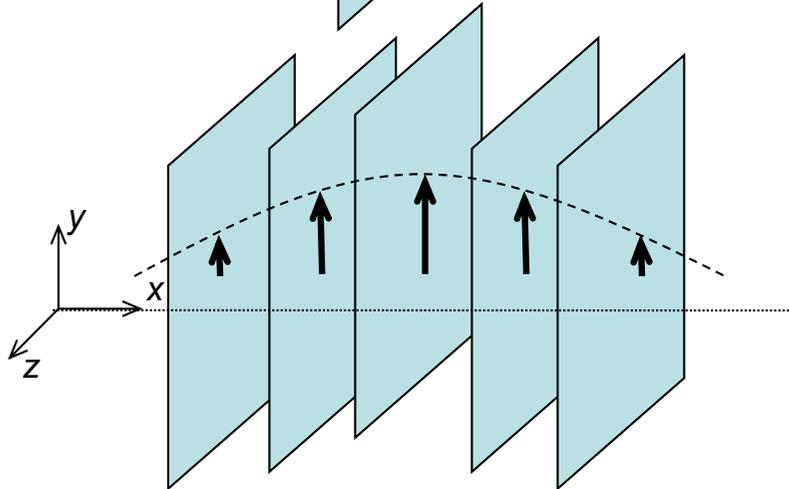
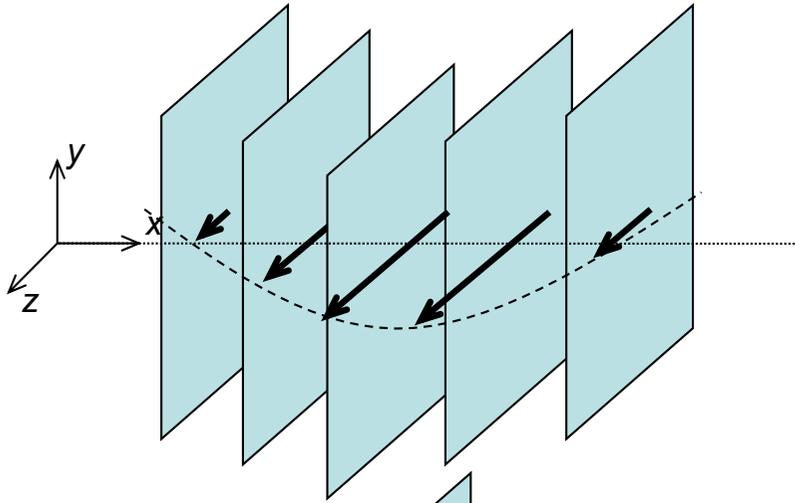


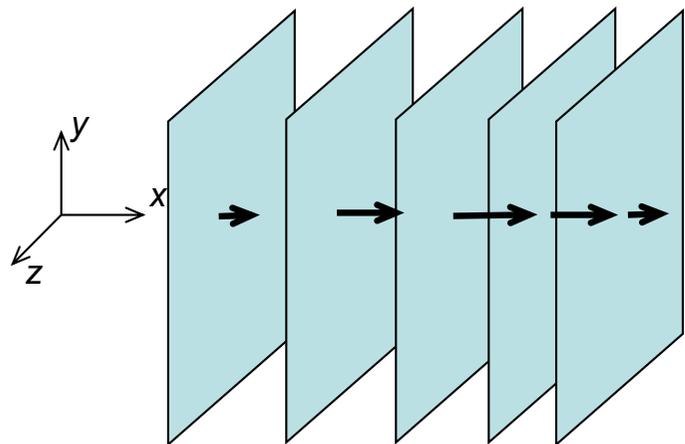
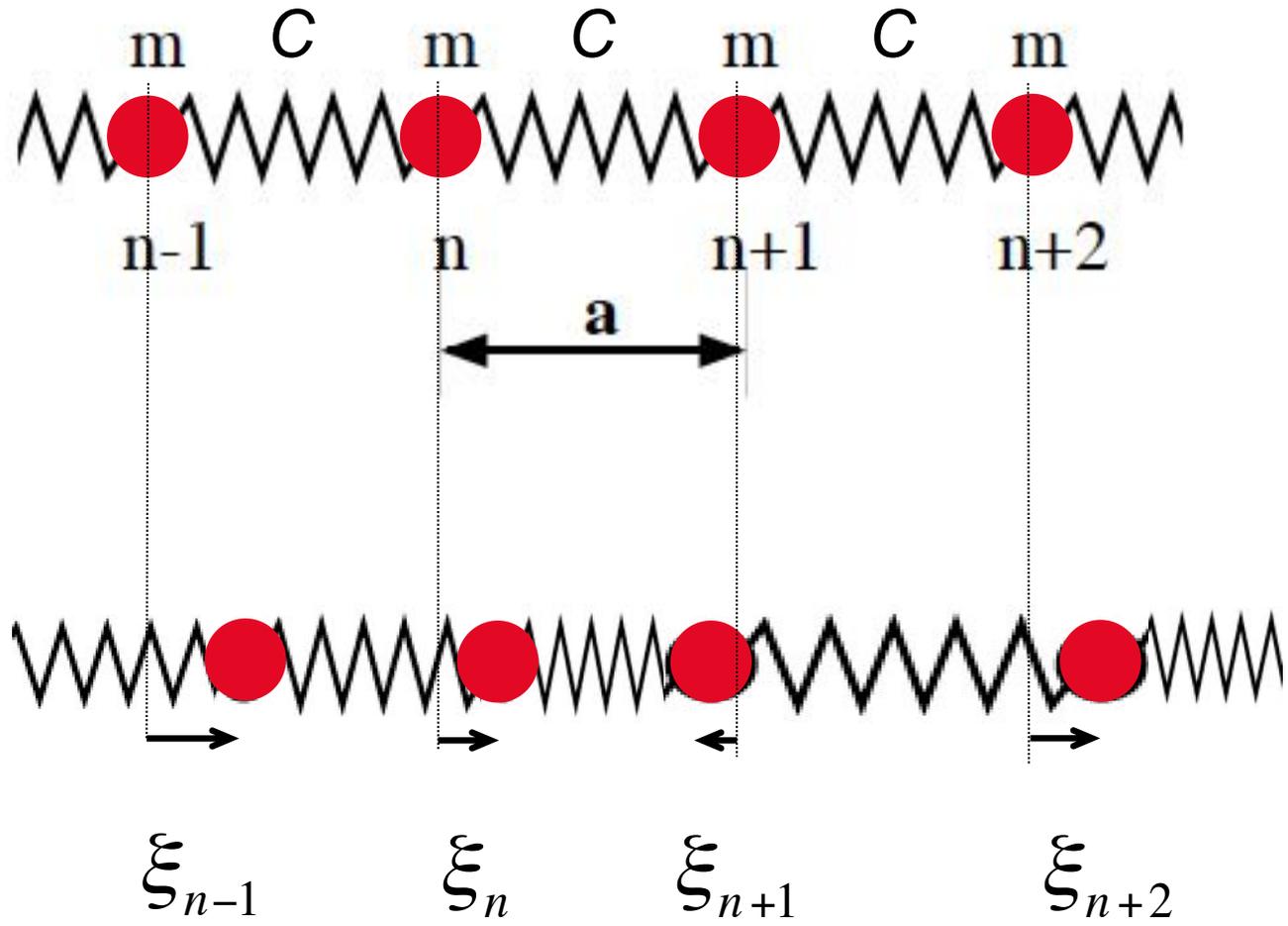
IV. Phononen

Für jeden Wellenvektor \vec{k}
senkrecht zu Netzebenen $(h k l)$
3 Schwingungszustände:

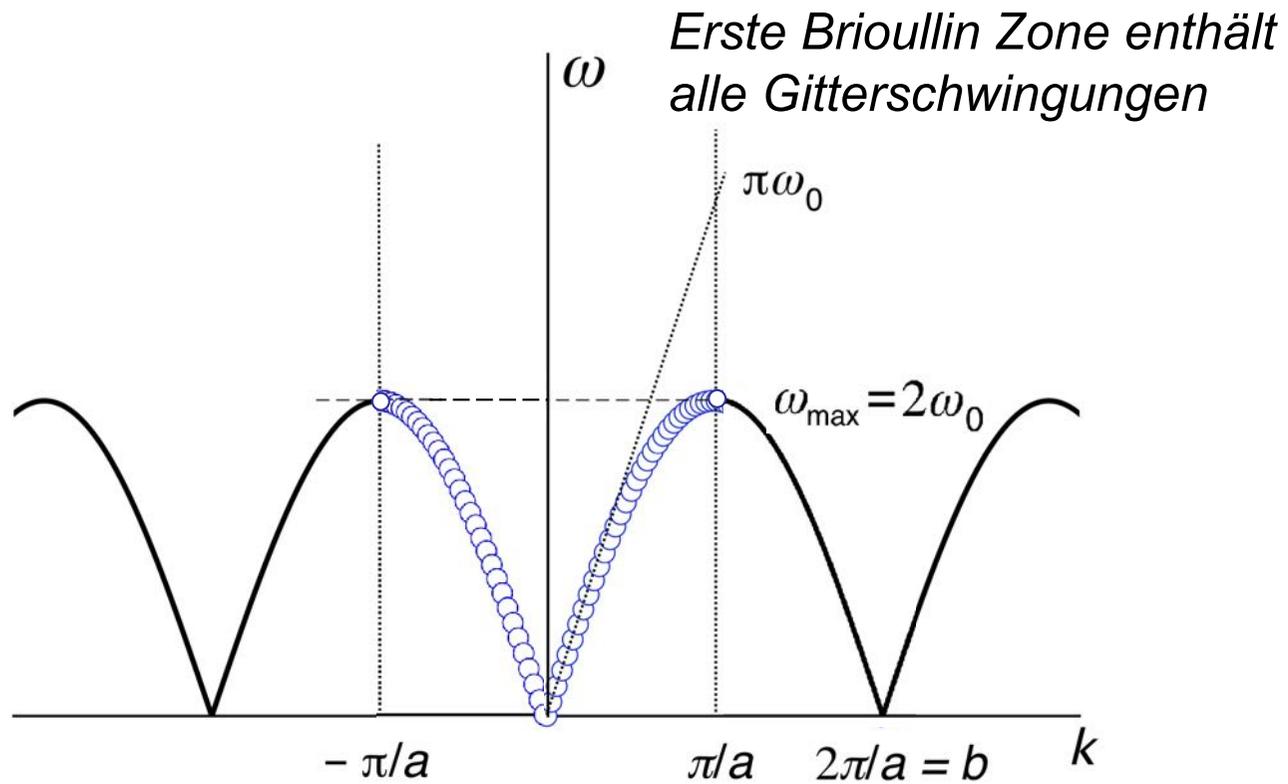
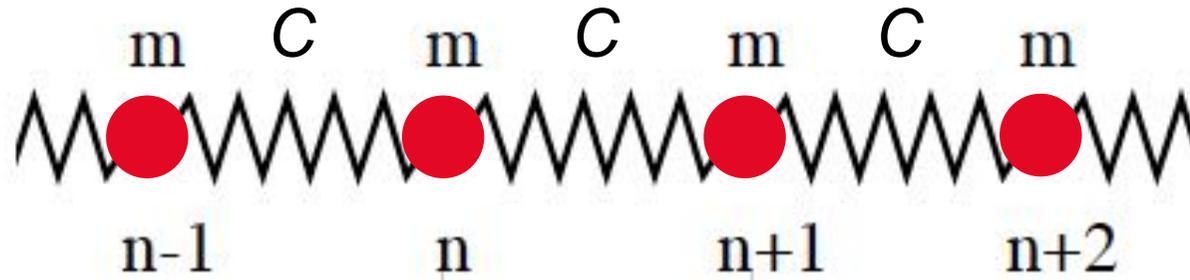
2 x transversal

1 x longitudinal

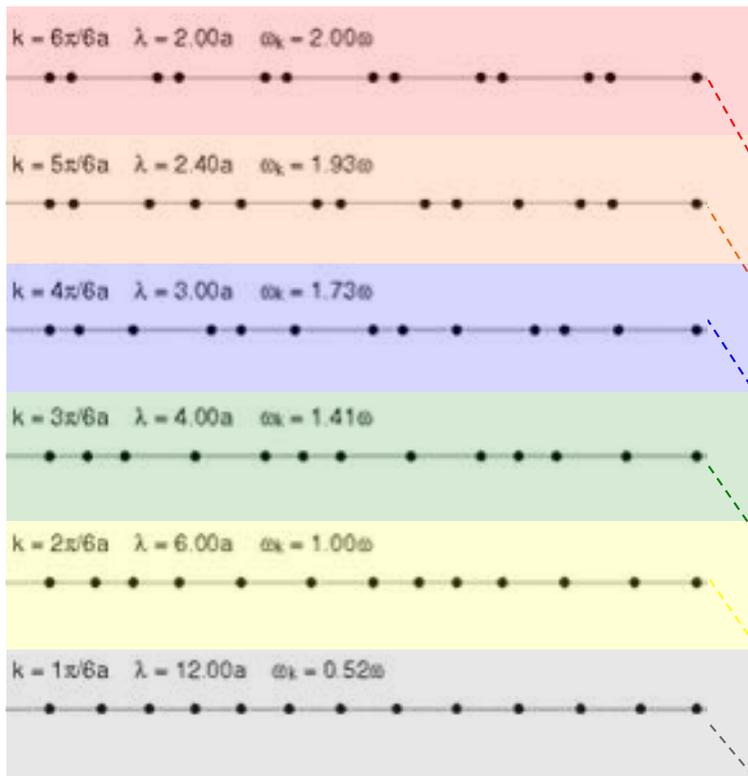




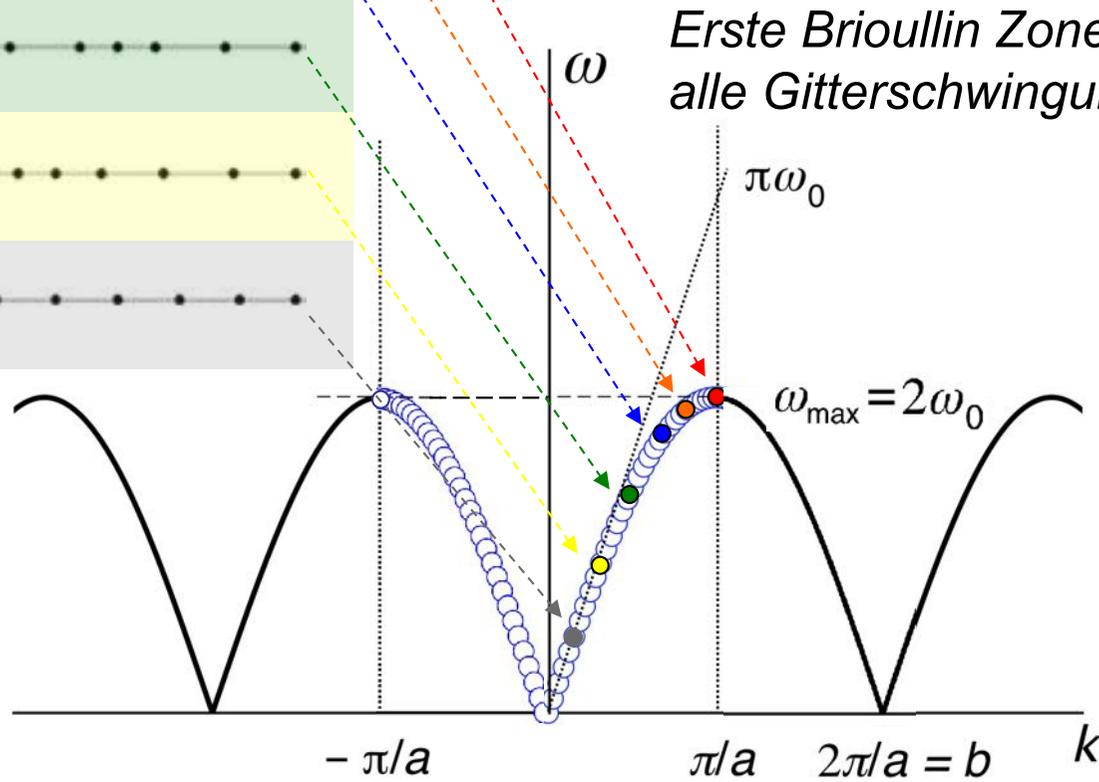
Modell: lineare Federkette



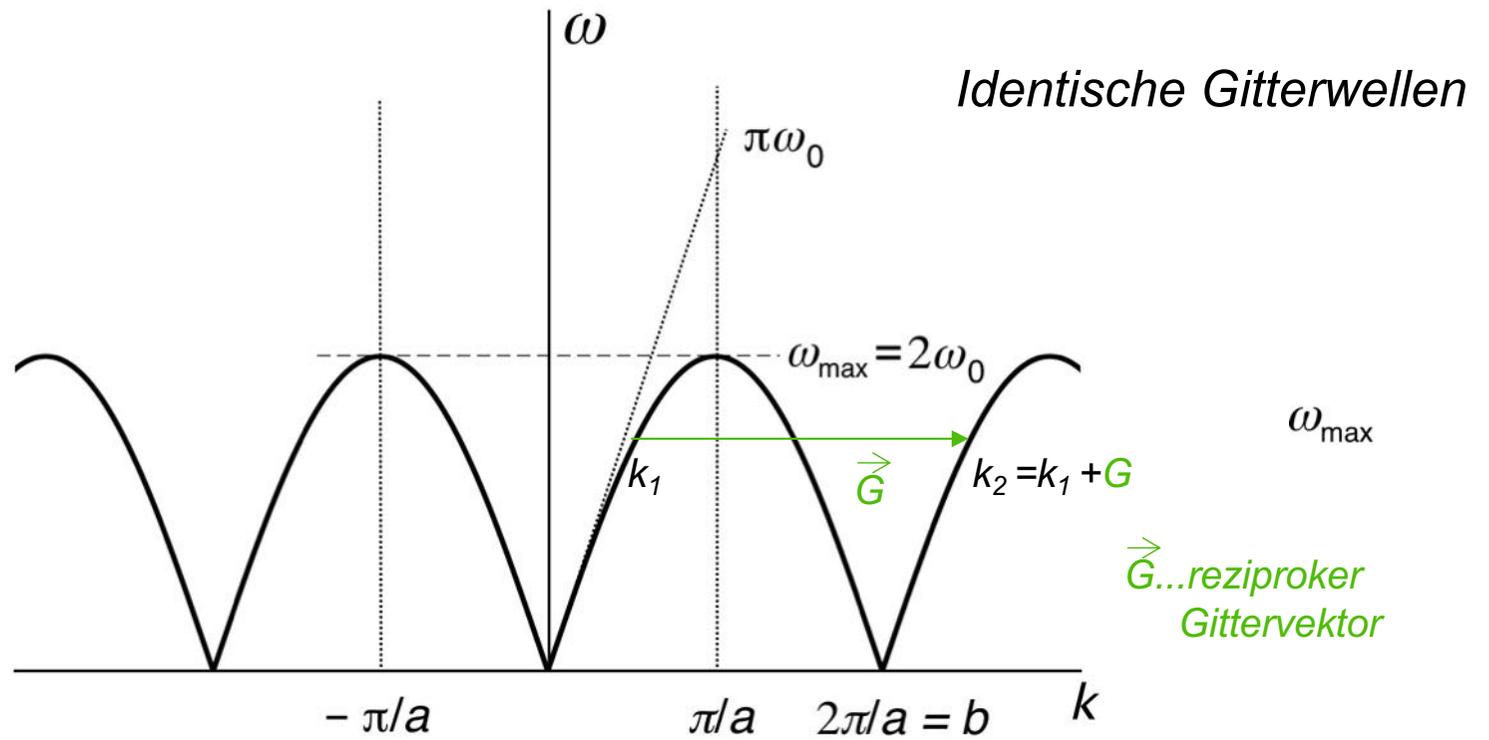
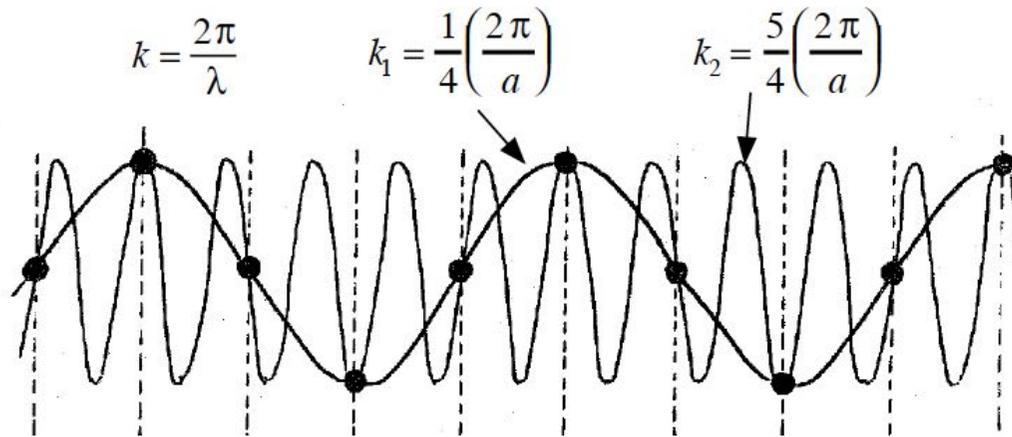
N Atome mit periodischen Randbedingungen

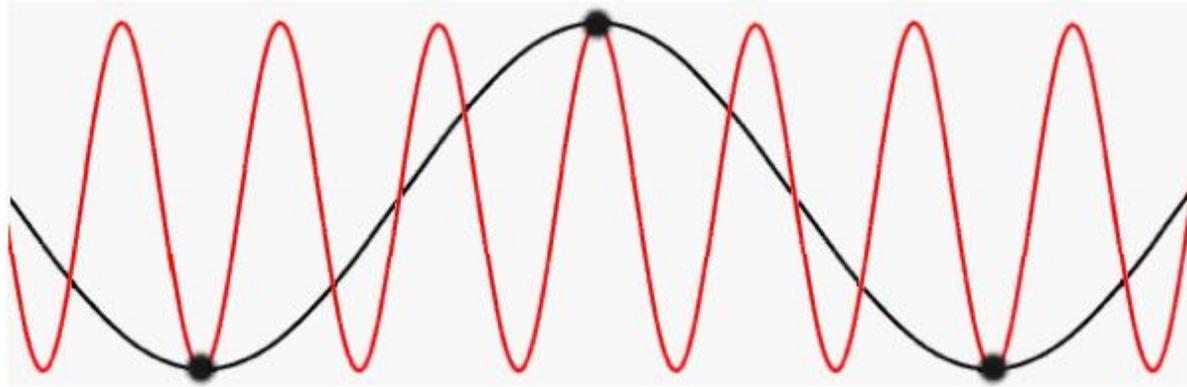


ω_{\max} : stehende Welle; Gruppengeschwindigkeit $d\omega/dk = 0$

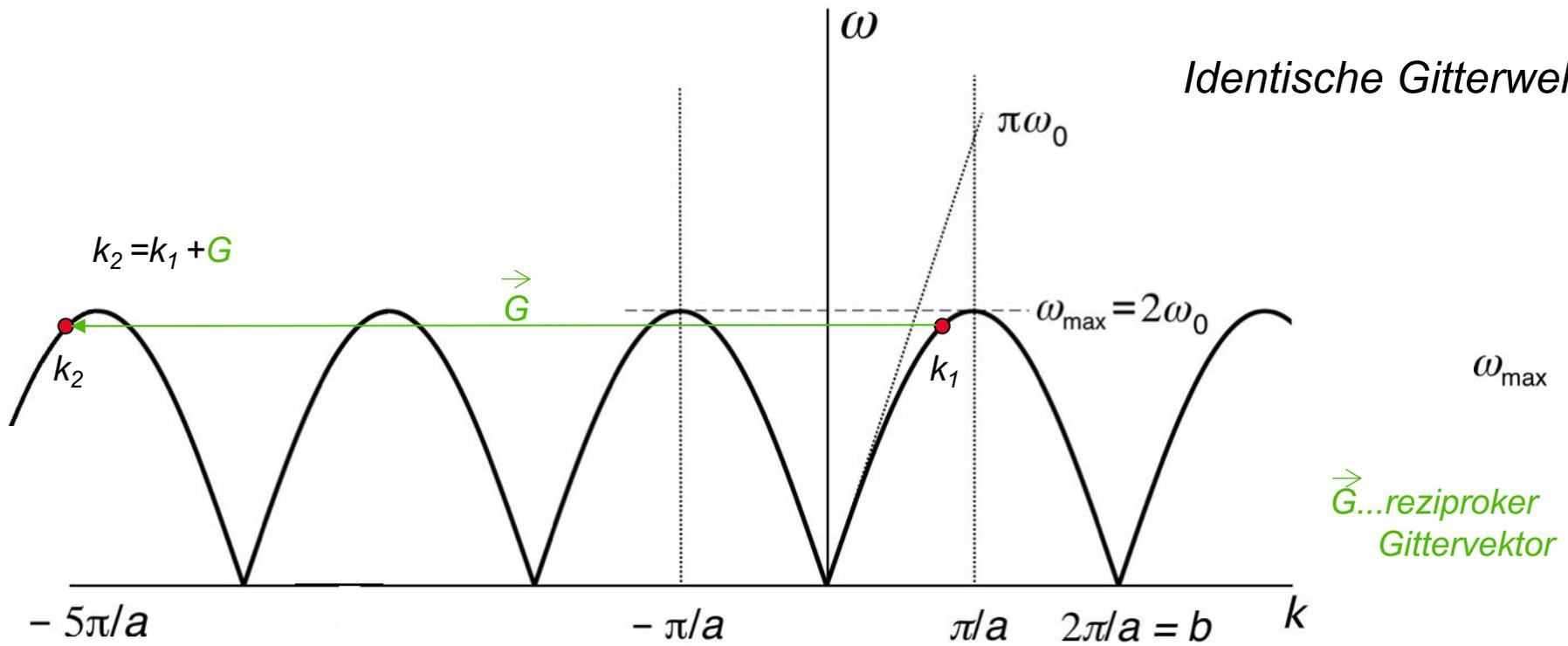


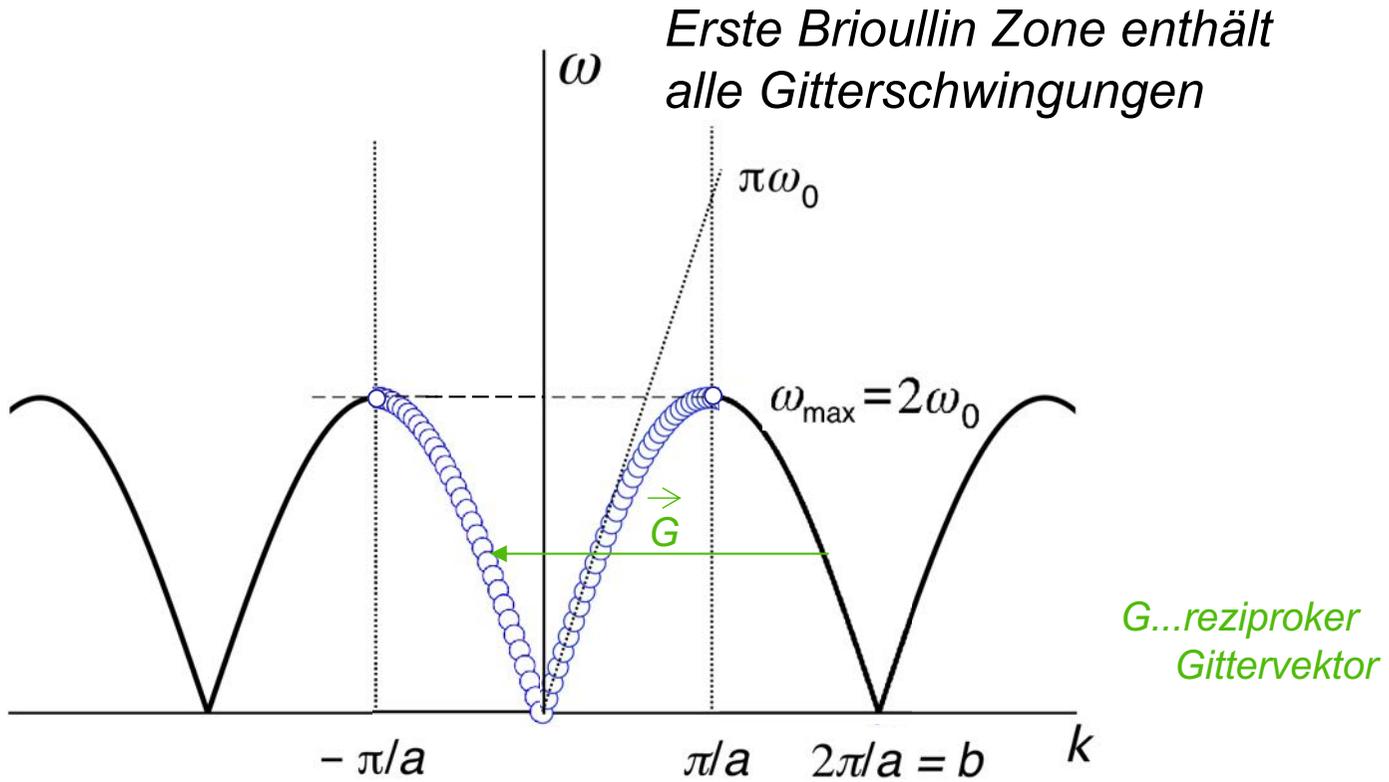
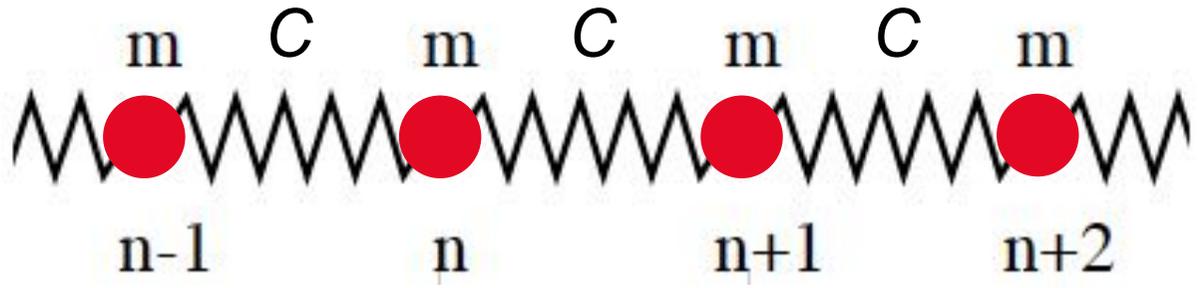
N Atome mit periodischen Randbedingungen



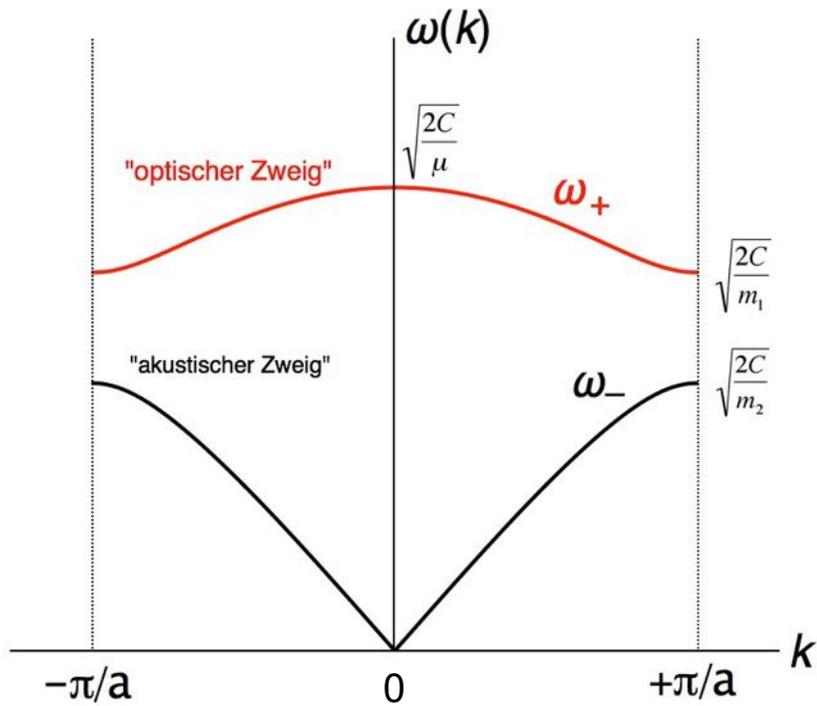
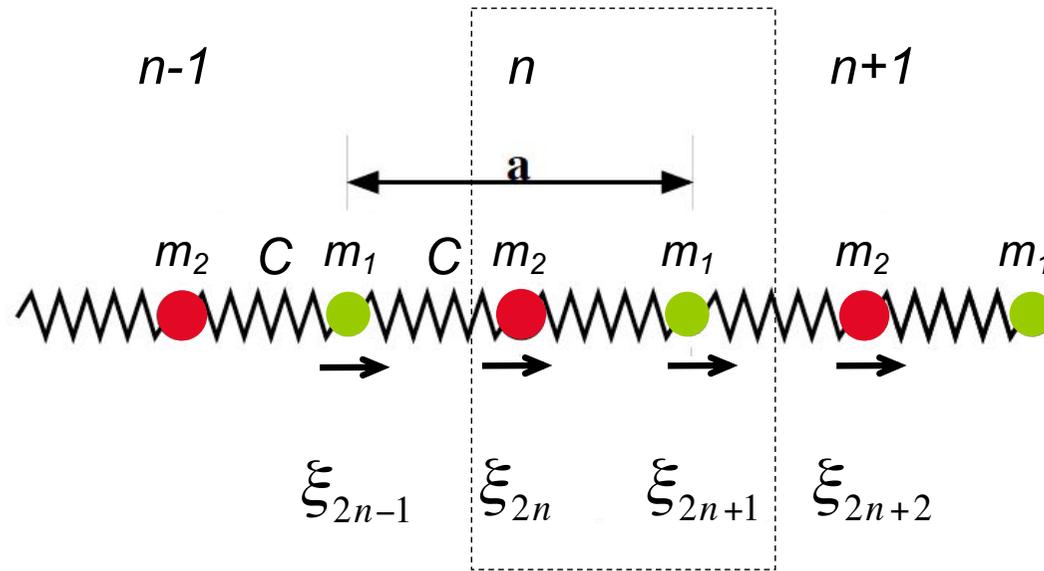


Identische Gitterwellen

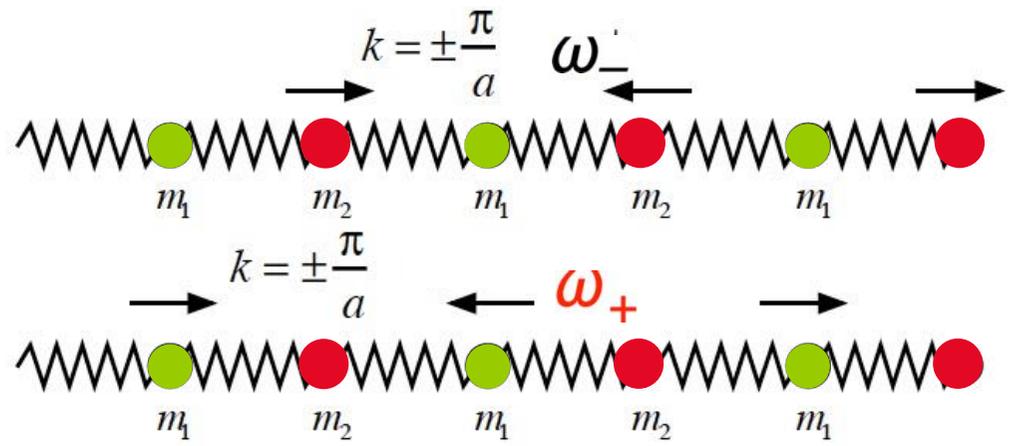
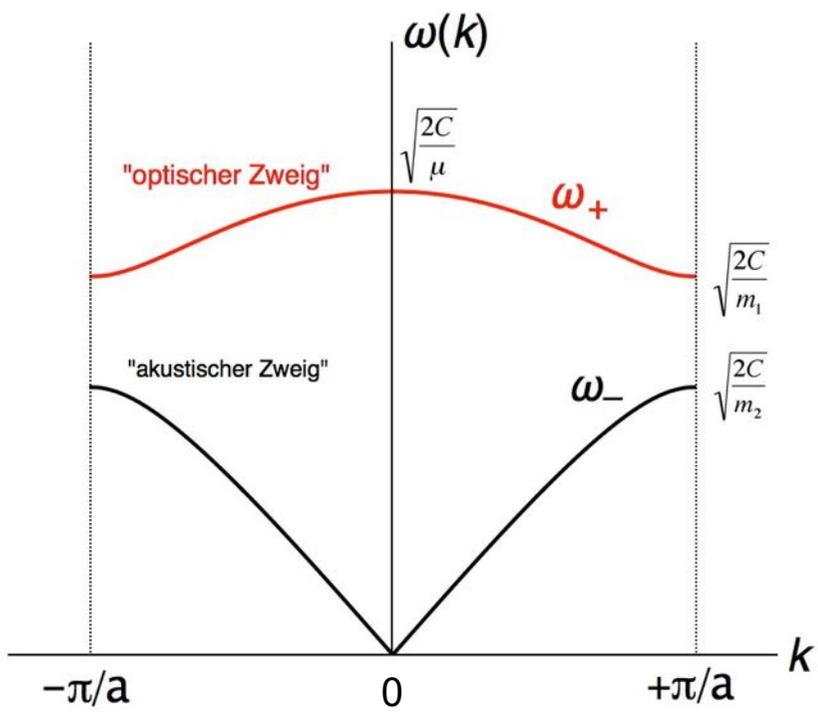
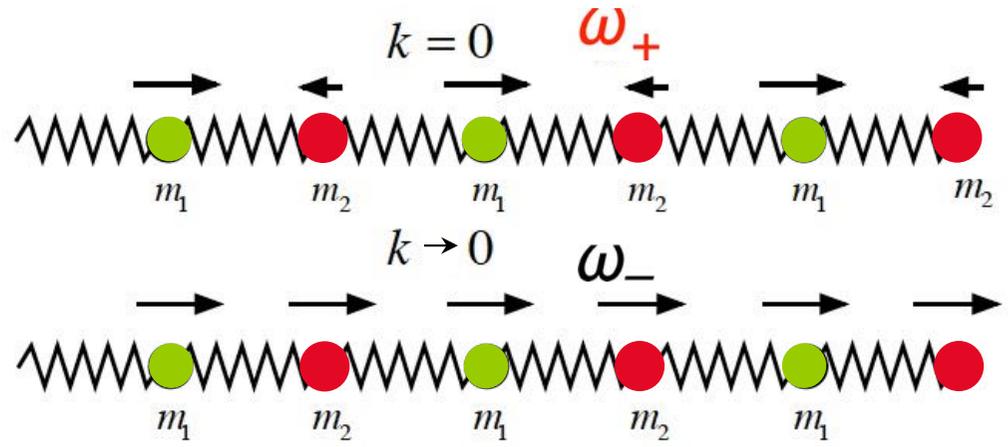




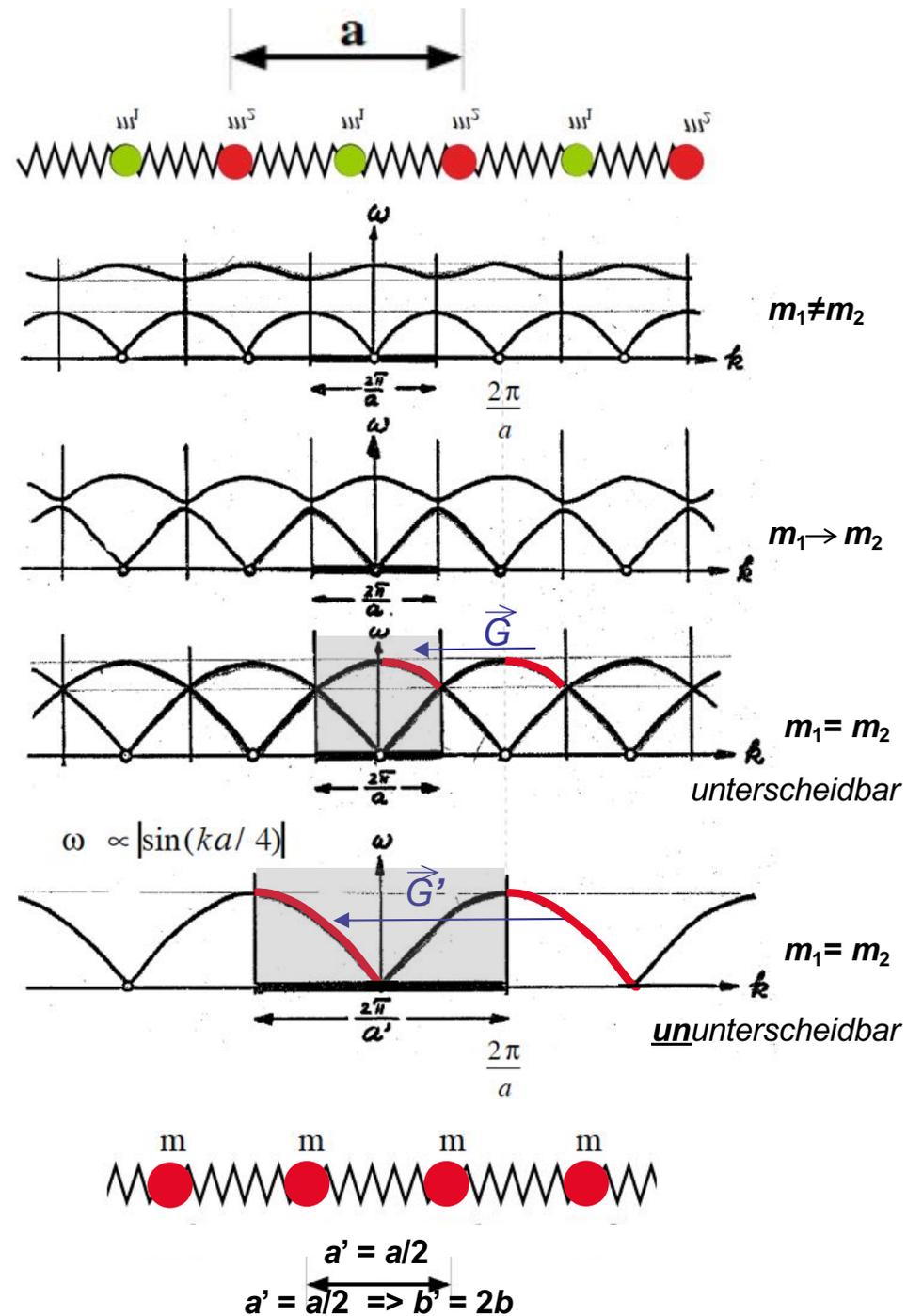
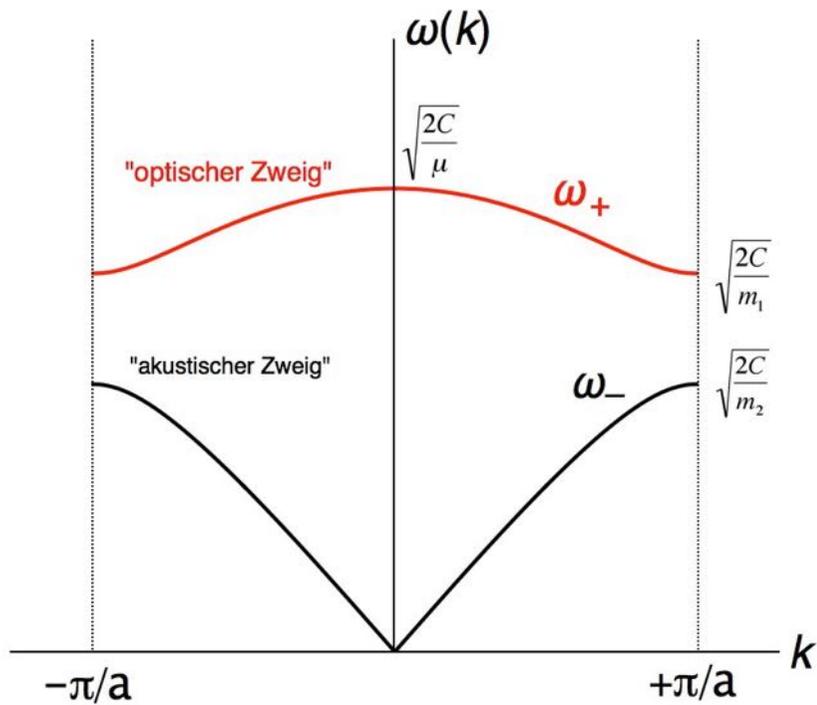
N Atome mit periodischen Randbedingungen



lineare Federkette mit 2-atomiger Basis



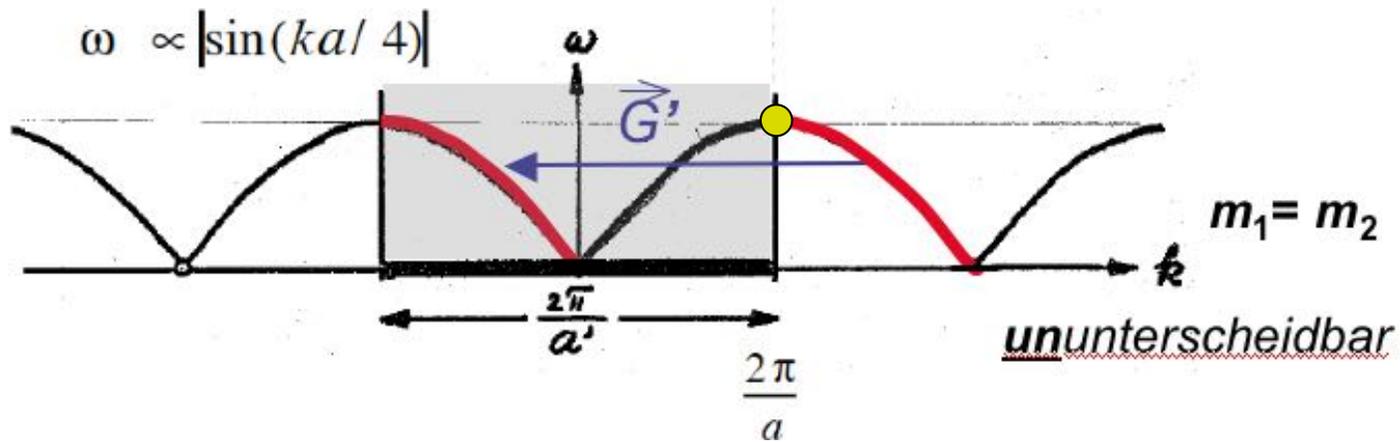
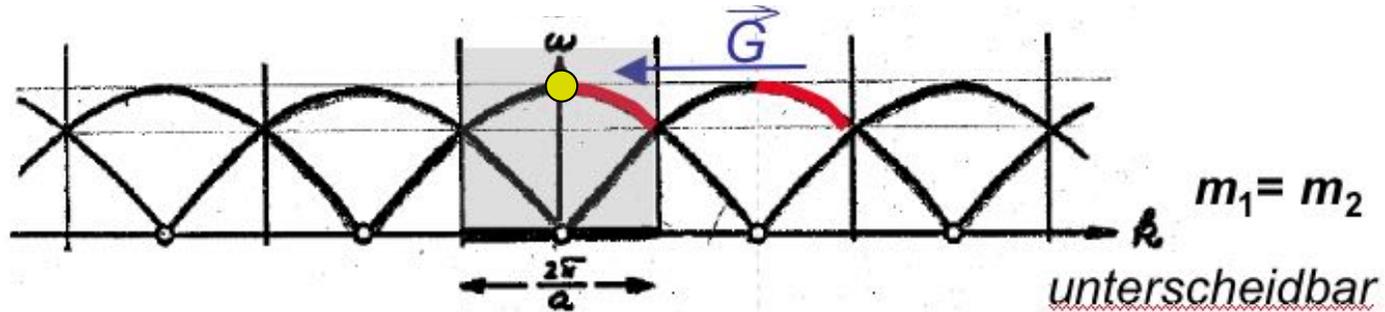
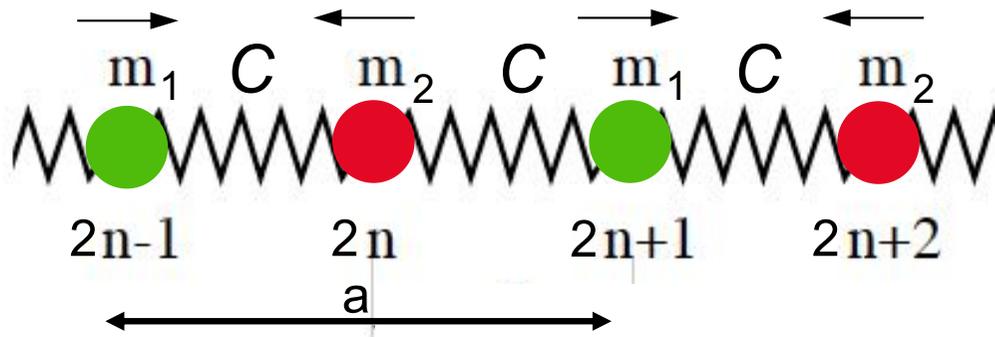
lineare Federkette mit 2-atomiger Basis



lineare Federkette mit 2-atomiger Basis

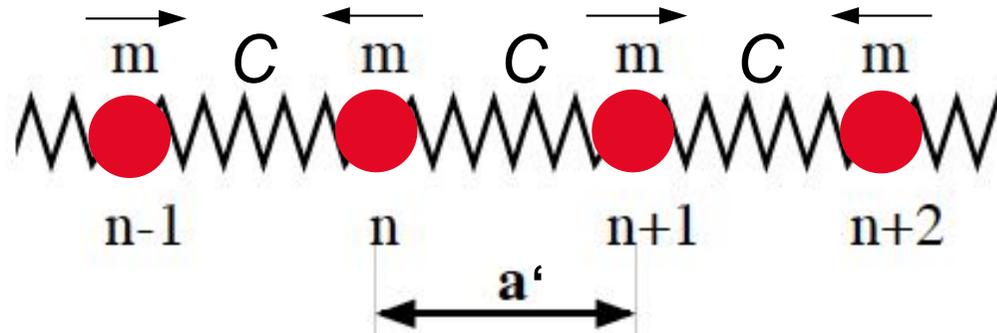
$$\lambda = \infty$$

$$k = 0$$



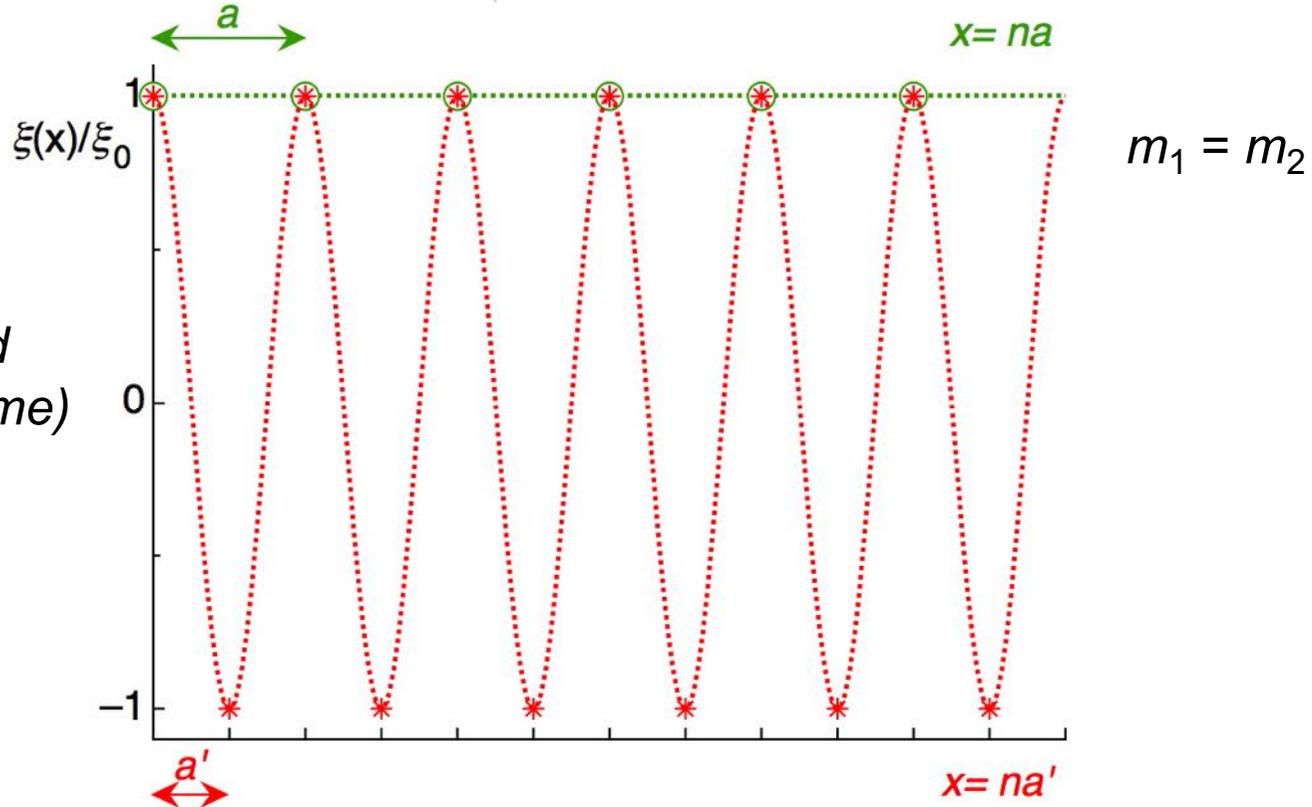
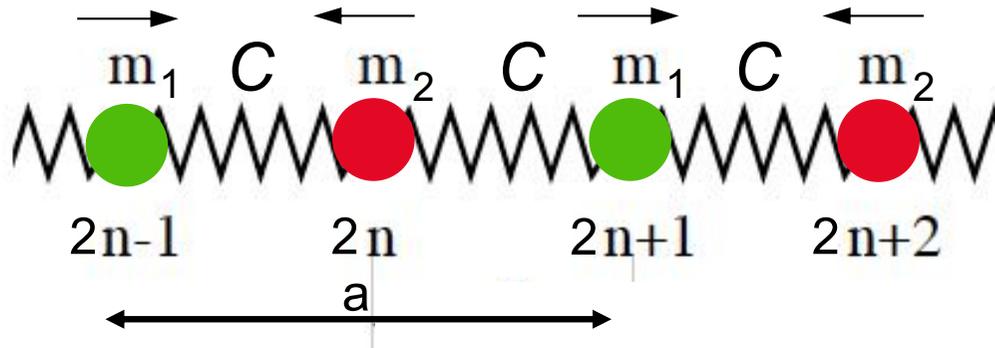
$$\lambda = 2a'$$

$$k = 2\pi / \lambda = \pi / a'$$



$$\lambda = \infty$$

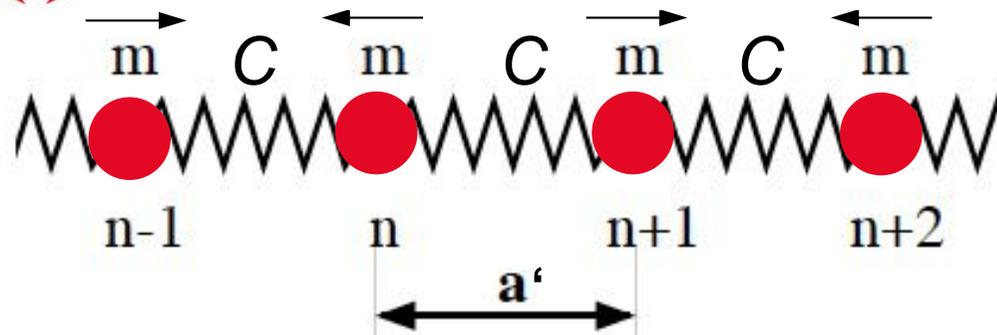
$$k = 0$$



Schwingungsbild
(Momentaufnahme)

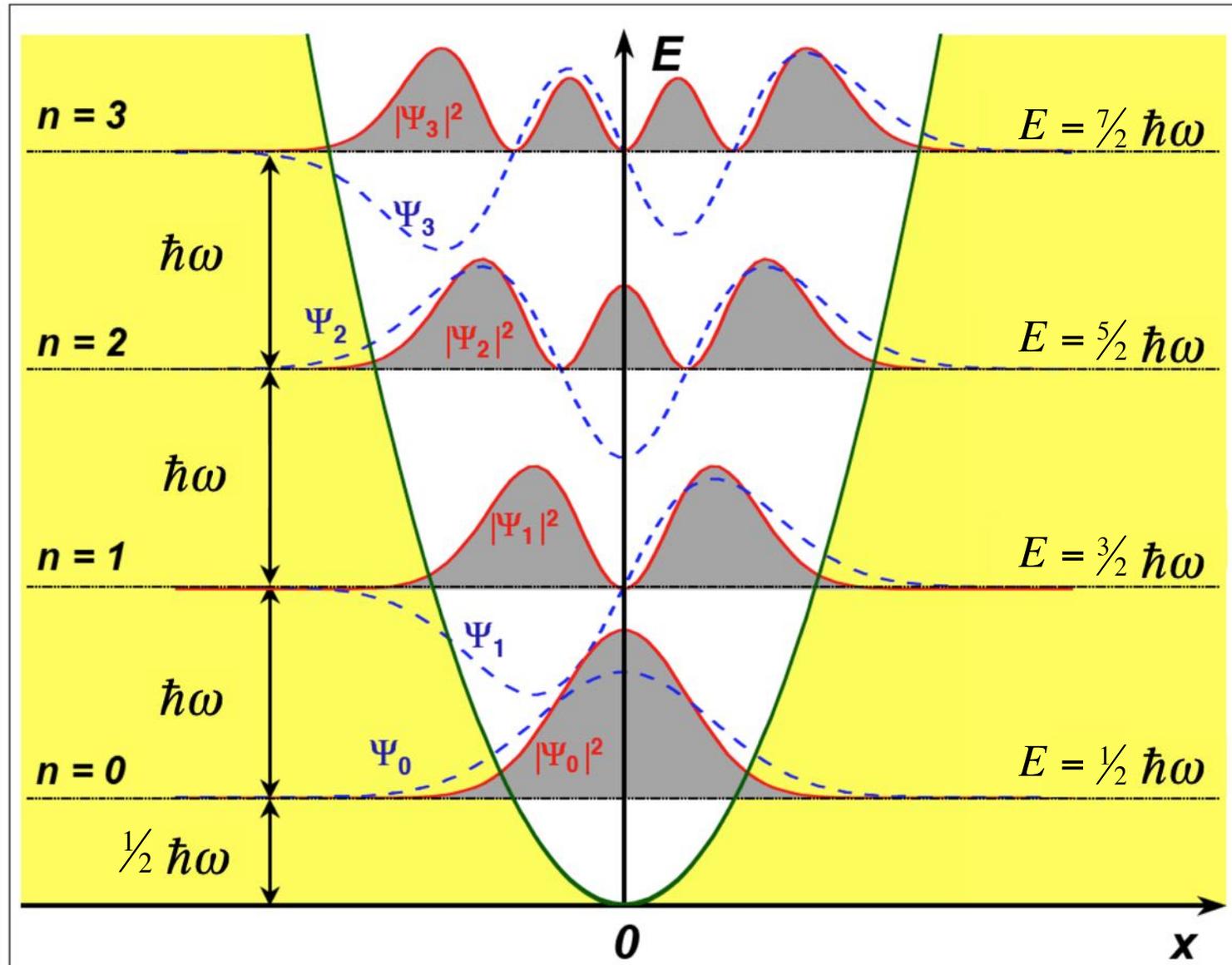
$$\lambda = 2a'$$

$$k = 2\pi / \lambda = \pi / a'$$



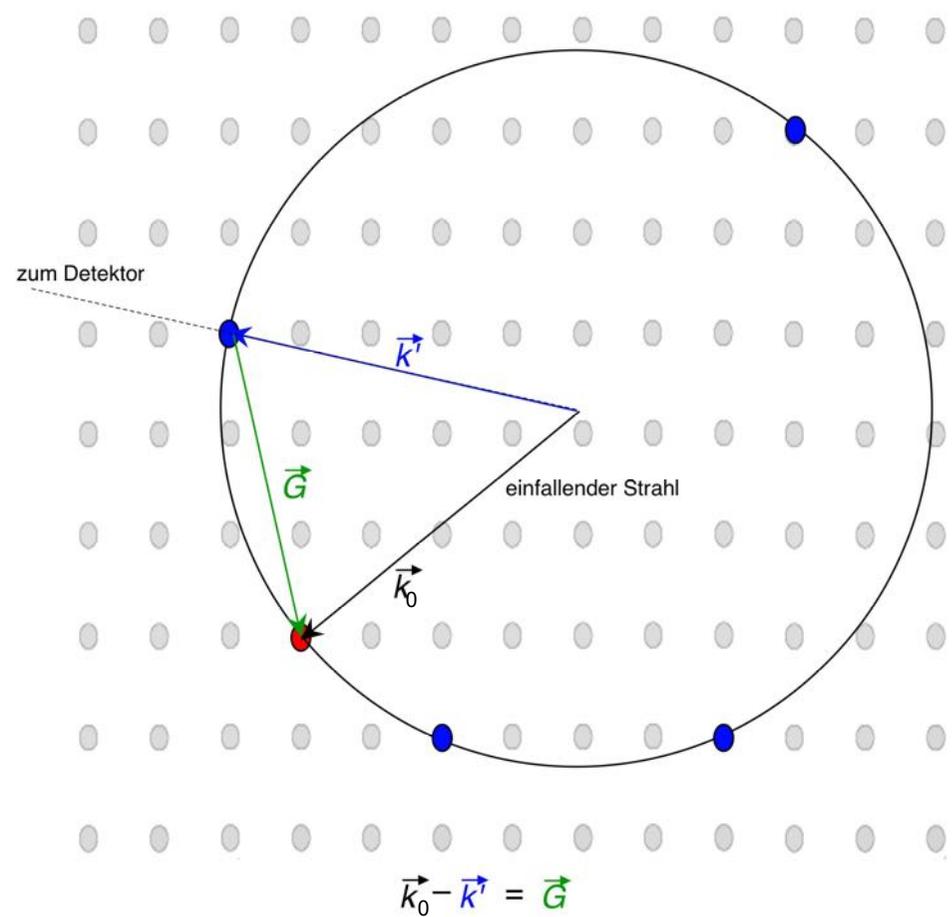
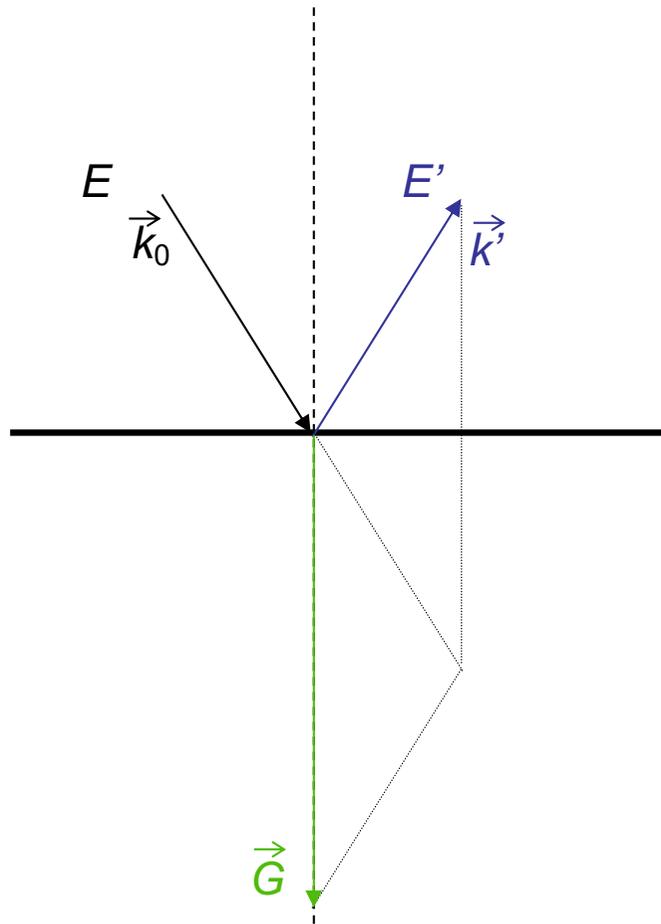
Erzeugung
von Phononen
durch
Energiezufuhr

1D- quantenmechanischer harmonischer Oszillator mit ω



Vernichtung von
Phononen
durch
Energieabgabe

Elastische Streuung von Licht/Neutronen:

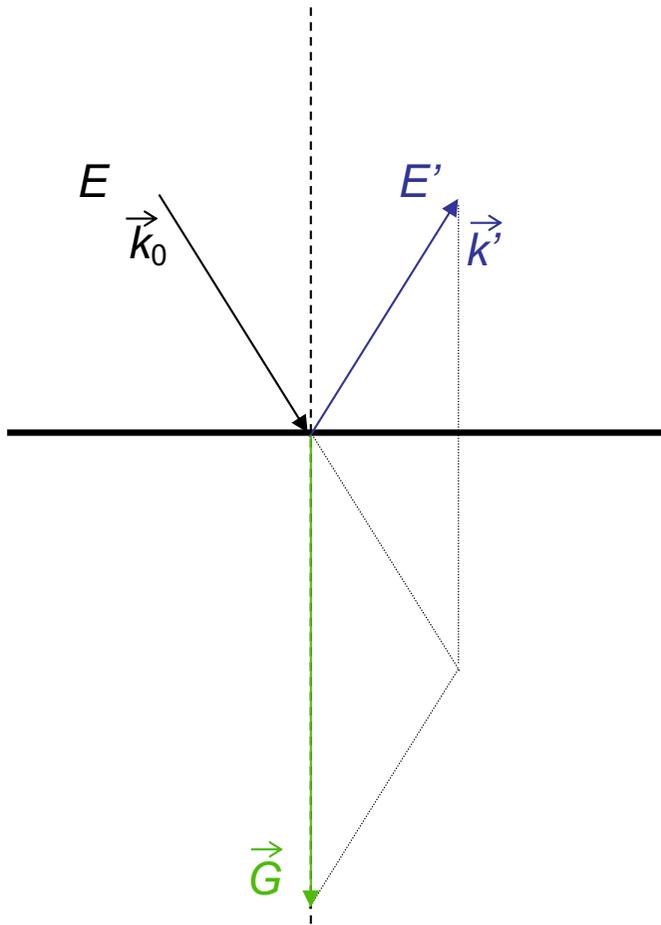


$$\vec{k}_0 - \vec{k}' = \vec{G} \quad (\text{Reziproker Gittervektor})$$

$$E - E' = 0$$

\vec{k}' auf der Ewald-Kugel;
keine Erzeugung von Phononen!

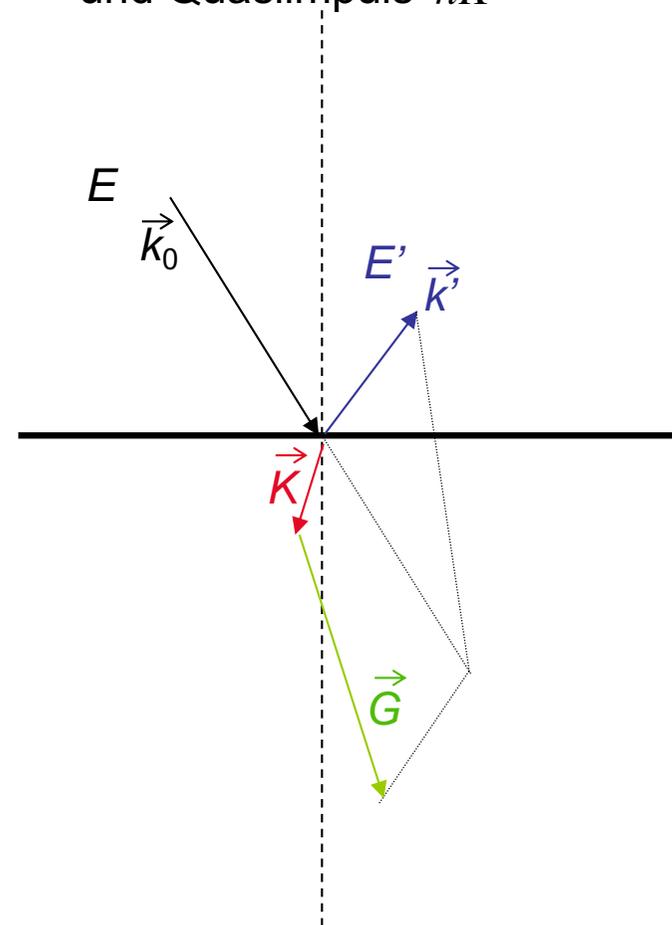
Elastische Streuung von Licht/Neutronen:



$$\vec{k}_0 - \vec{k}' = \vec{G} \quad (\text{Reziproker Gittervektor})$$

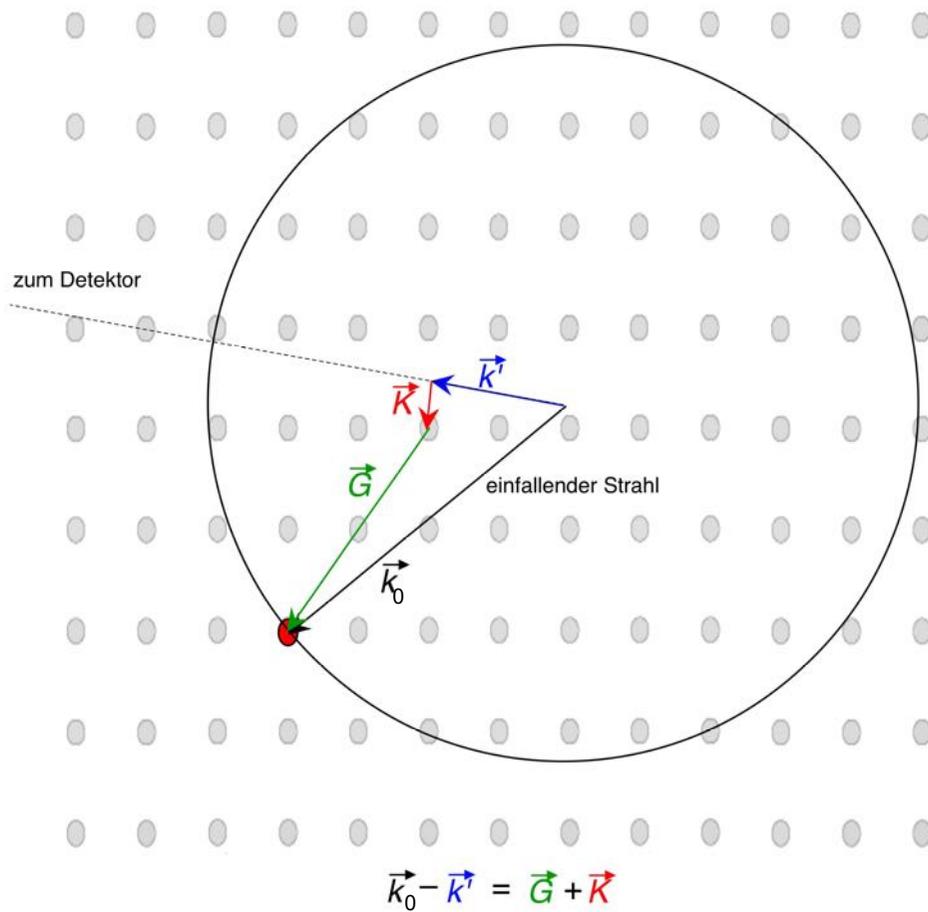
$$E - E' = 0$$

Inelastische Streuung:
Erzeugung eines Phonons
mit Energie $\hbar\omega(\vec{K})$
und Quasiimpuls $\hbar\vec{K}$

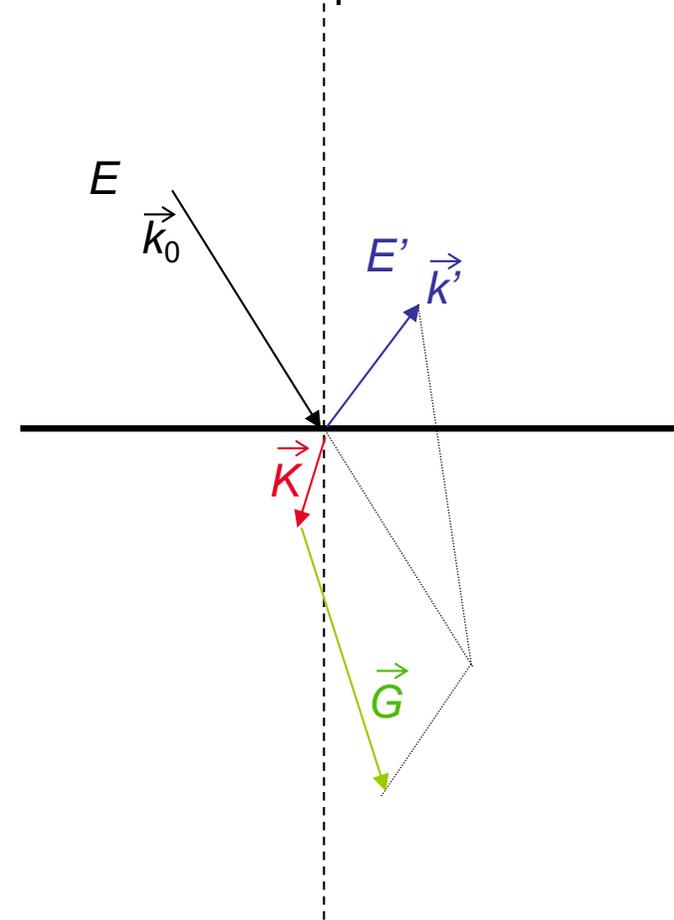


$$\vec{k}_0 - \vec{k}' = \vec{K} + \vec{G}$$

$$|E - E'| = \hbar\omega(\vec{K})$$



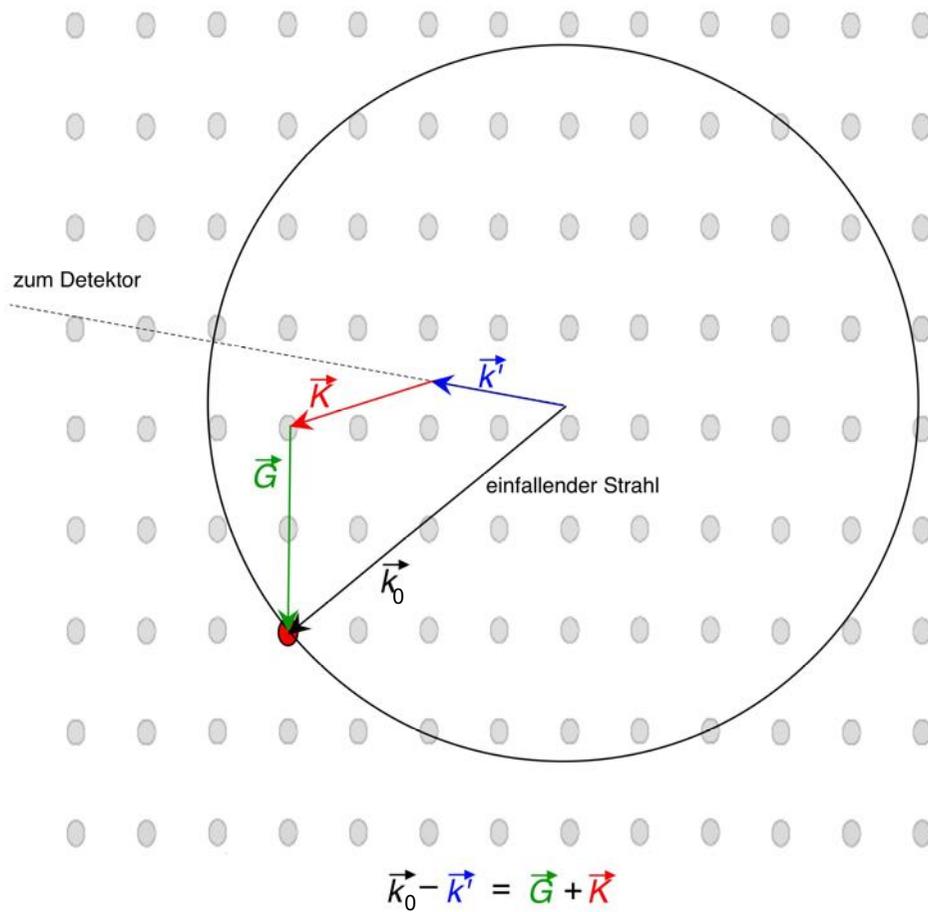
Inelastische Streuung:
Erzeugung eines Phonons
mit Energie $\hbar\omega(\vec{K})$
und Quasiimpuls $\hbar\vec{K}$



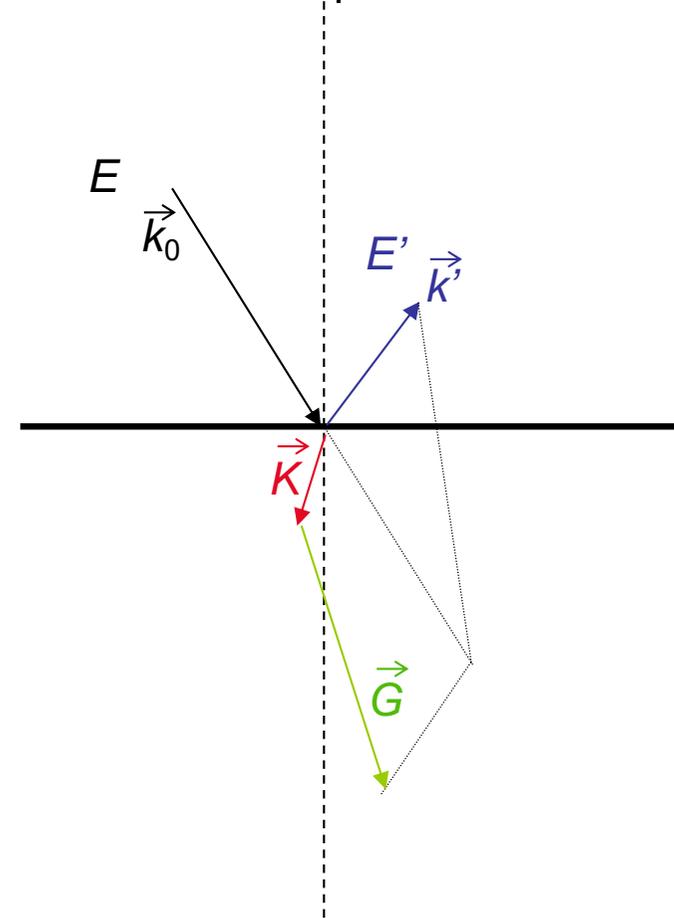
Der Quasiimpuls ist nicht eindeutig: bei gegebenen \vec{k}_0, \vec{k}' gibt es mehrere Streumöglichkeiten!

$$\vec{k}_0 - \vec{k}' = \vec{K} + \vec{G}$$

$$|E - E'| = \hbar\omega(\vec{K})$$



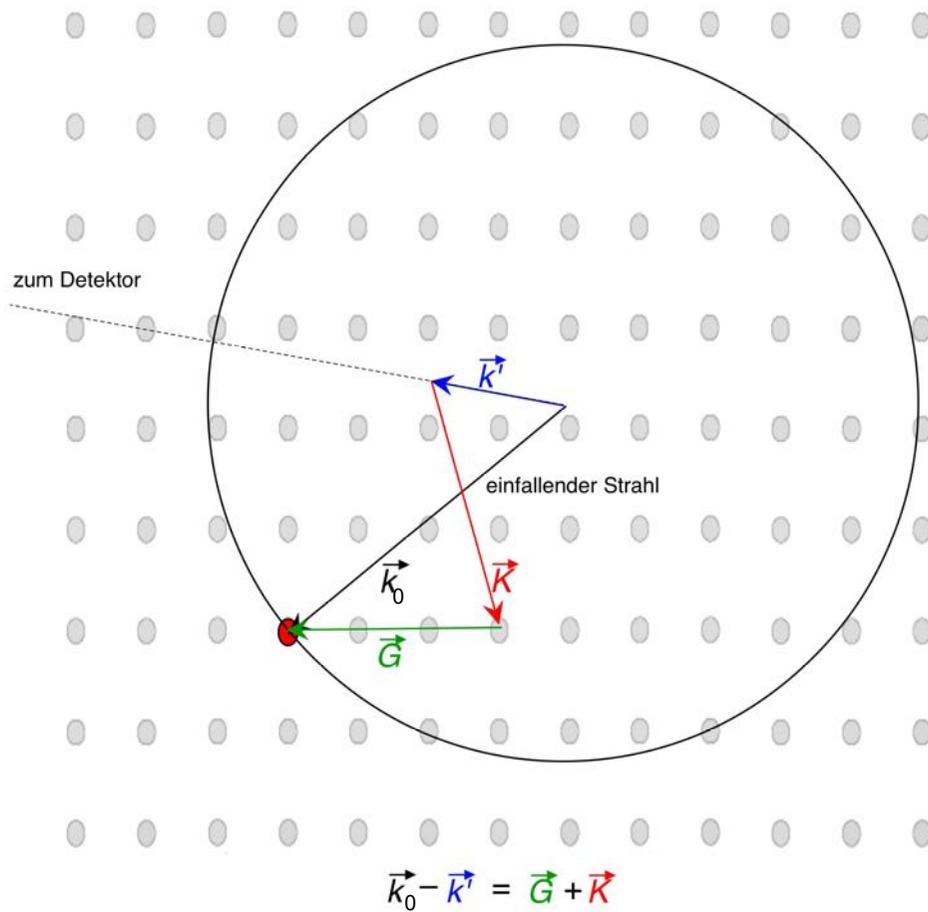
Inelastische Streuung:
Erzeugung eines Phonons
mit Energie $\hbar\omega(\vec{K})$
und Quasiimpuls $\hbar\vec{K}$



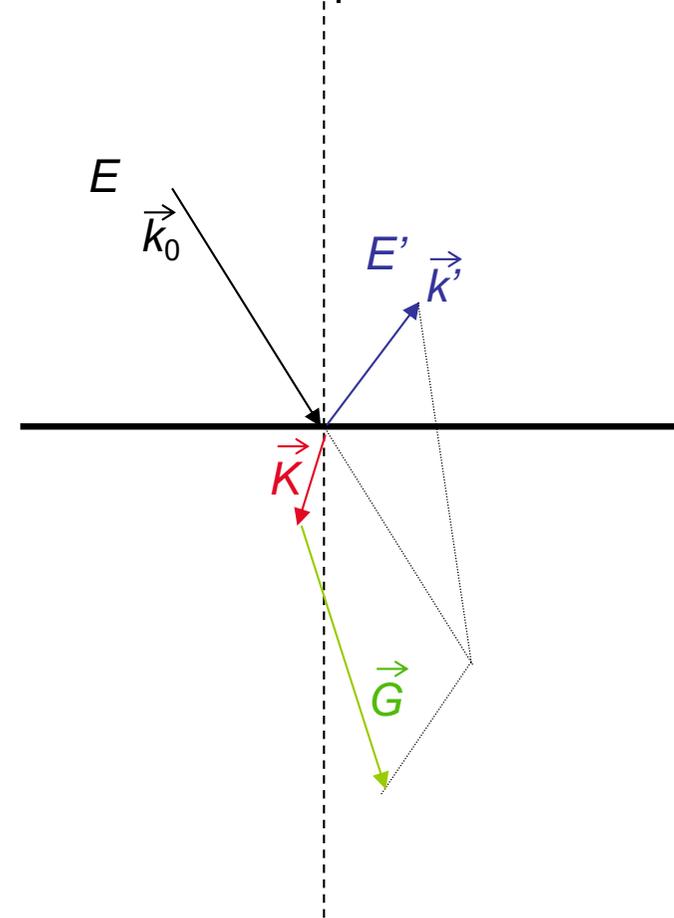
Der Quasiimpuls ist nicht eindeutig: bei gegebenen \vec{k}_0, \vec{k}' gibt es mehrere Streumöglichkeiten!

$$\vec{k}_0 - \vec{k}' = \vec{K} + \vec{G}$$

$$|E - E'| = \hbar\omega(\vec{K})$$



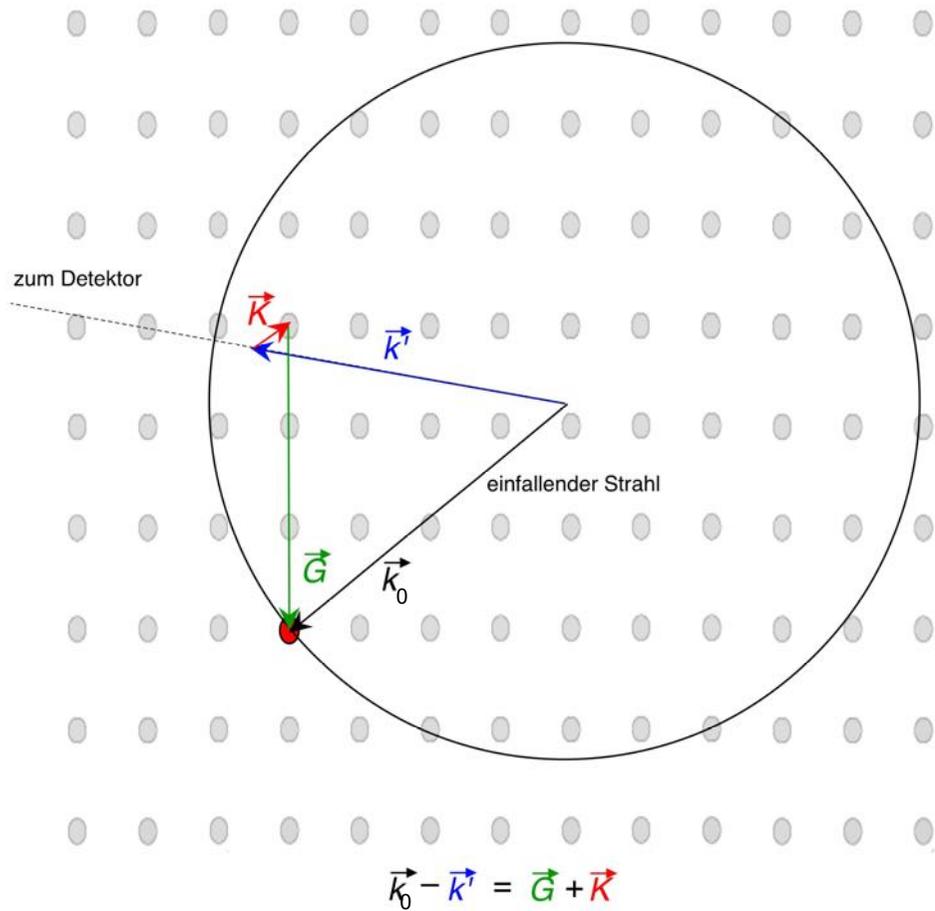
Inelastische Streuung:
Erzeugung eines Phonons
mit Energie $\hbar\omega(\vec{K})$
und Quasiimpuls $\hbar\vec{K}$



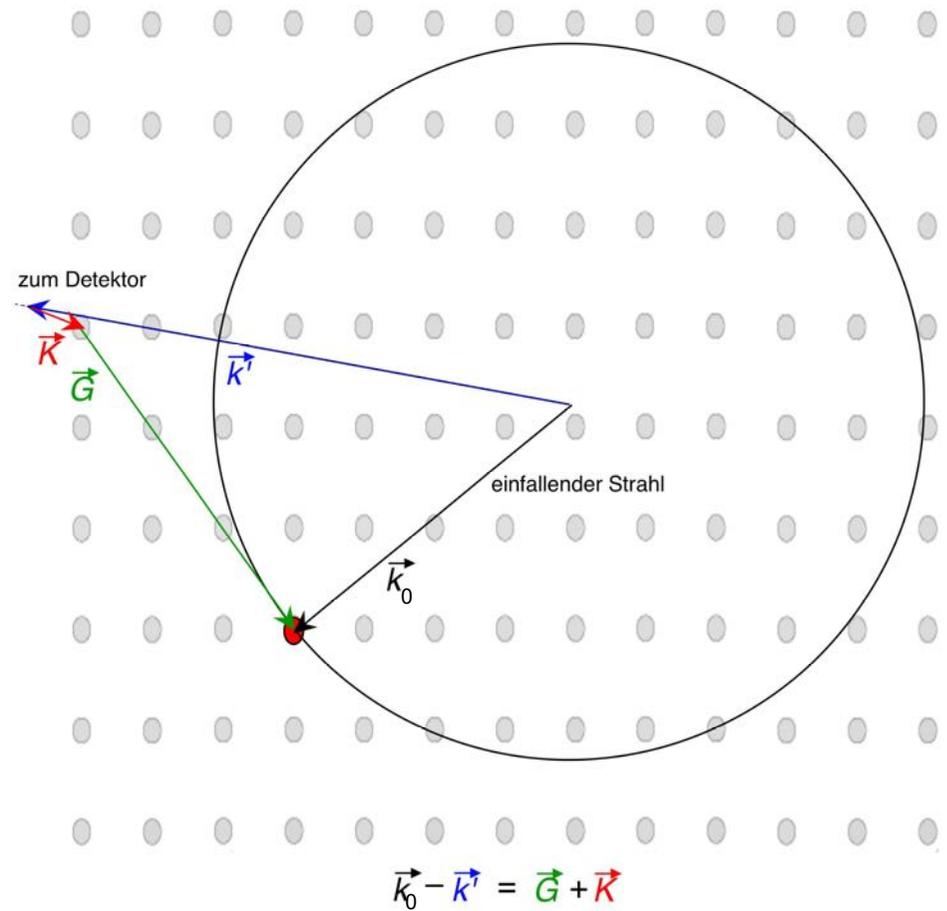
Der Quasiimpuls ist nicht eindeutig: bei gegebenen \vec{k}_0, \vec{k}' gibt es mehrere Streumöglichkeiten!

$$\vec{k}_0 - \vec{k}' = \vec{K} + \vec{G}$$

$$|E - E'| = \hbar\omega(\vec{K})$$

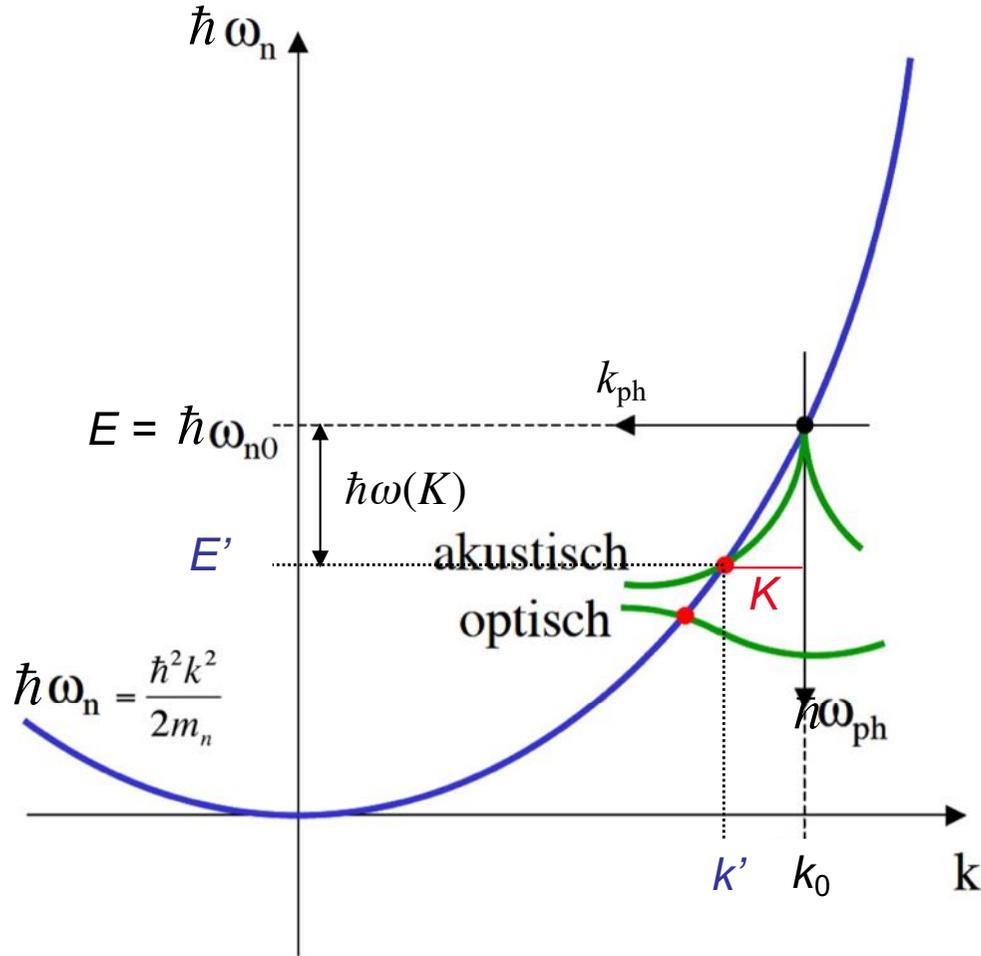


$E - E' > 0$: \vec{k}' innerhalb der Ewald-Kugel
 = **Phononen-Erzeugung**

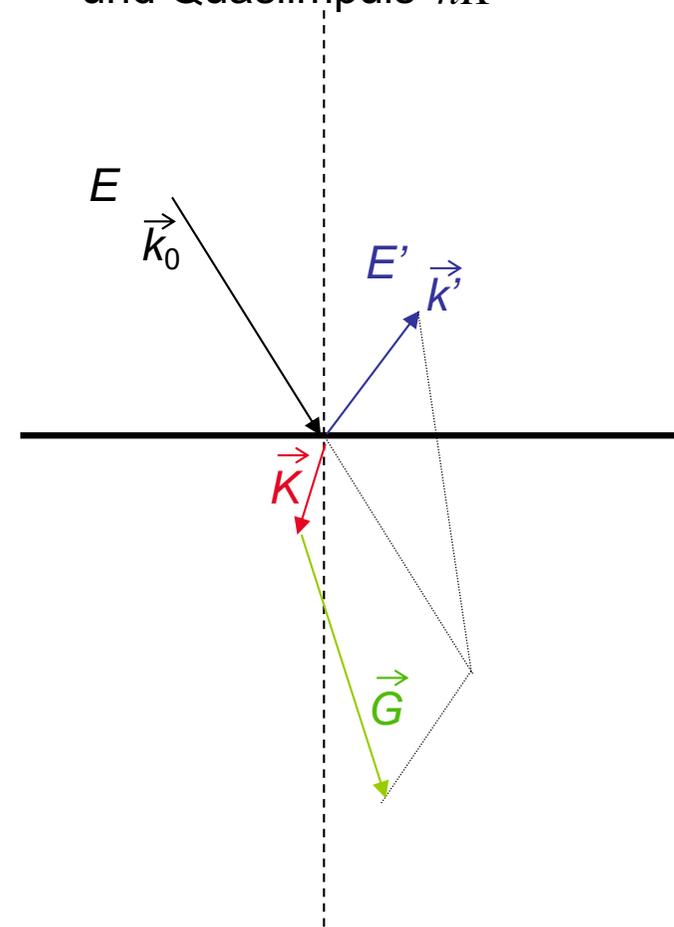


$E - E' < 0$: \vec{k}' ausserhalb der Ewald-Kugel
 = **Phononen-Vernichtung**

Phononen-Erzeugung durch Neutronen
(1D-Veranschaulichung)



Inelastische Streuung:
Erzeugung eines Phonons
mit Energie $\hbar\omega(\vec{K})$
und Quasiimpuls $\hbar\vec{K}$

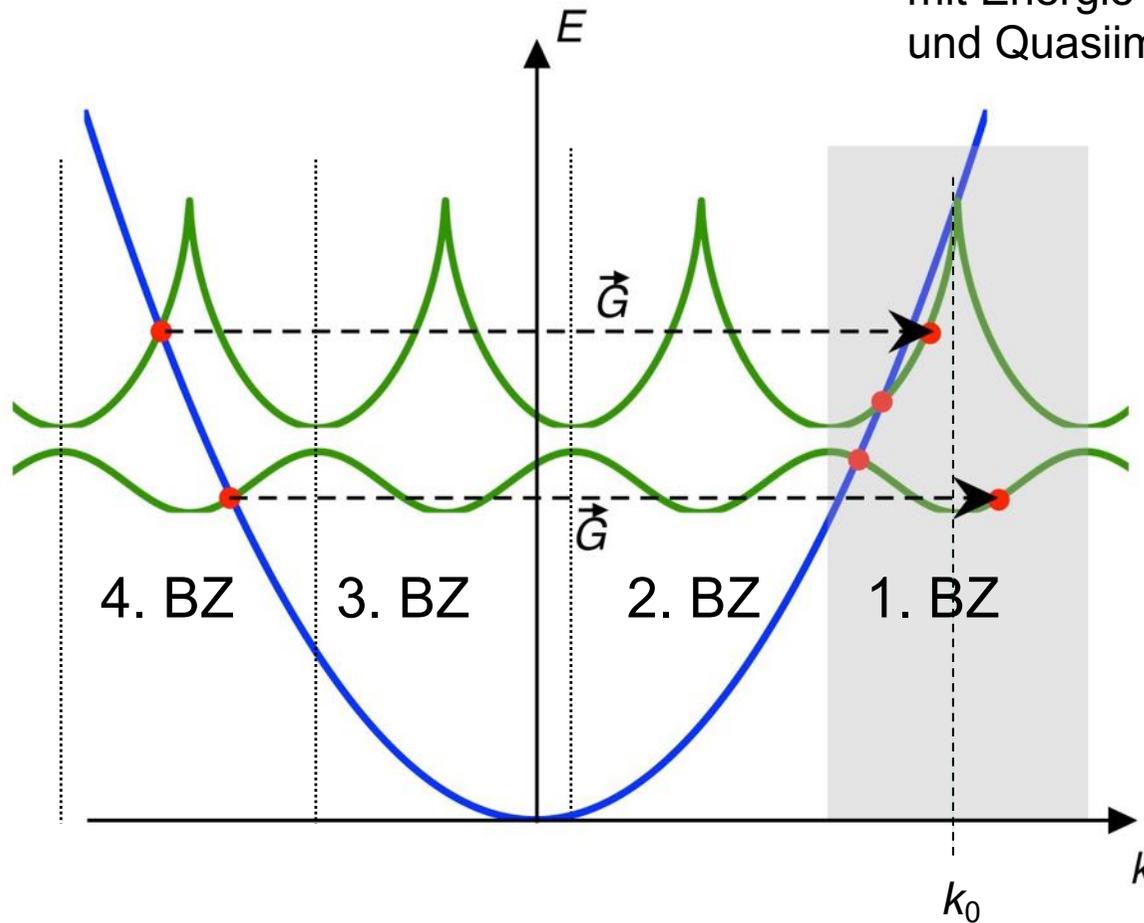


$$\vec{k}_0 - \vec{k}' = \vec{K} + \vec{G}$$

$$|E - E'| = \hbar\omega(\vec{K})$$

Phononen-Erzeugung durch Neutronen
(1D-Veranschaulichung)

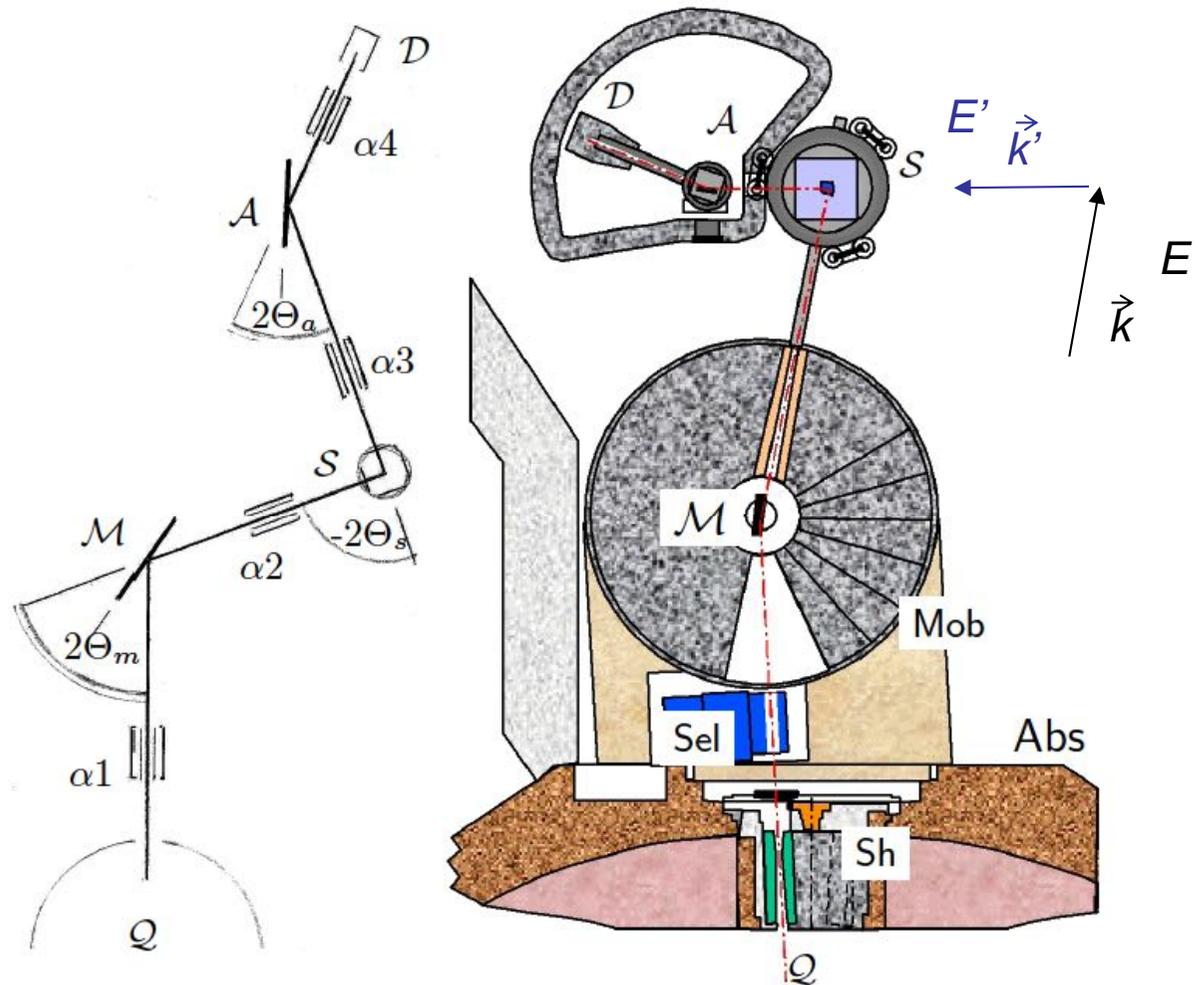
Inelastische Streuung:
Erzeugung eines Phonons
mit Energie $\hbar\omega(\vec{K})$
und Quasiimpuls $\hbar\vec{K}$



$$\vec{k}_0 - \vec{k}' = \vec{K} + \vec{G}$$

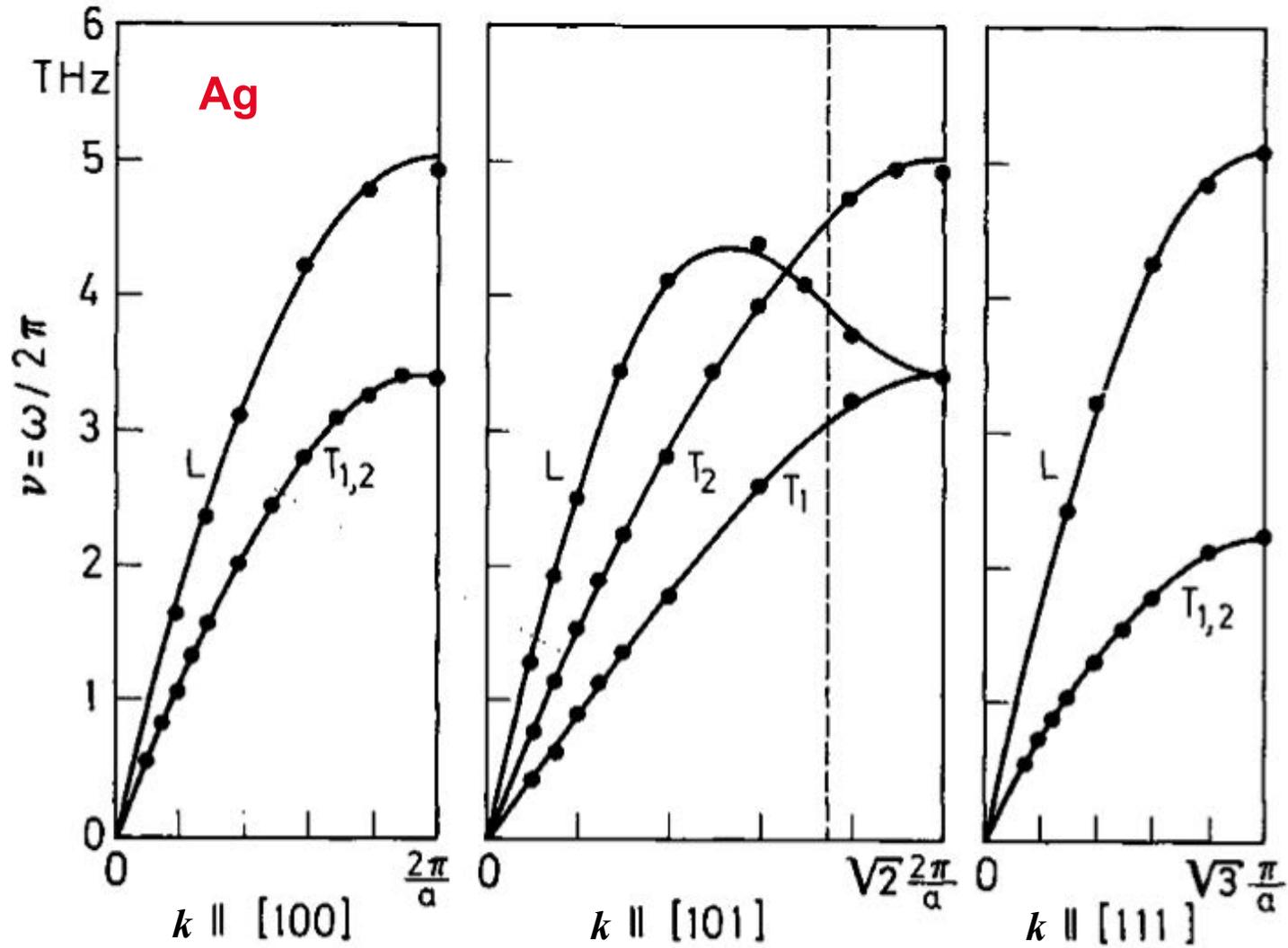
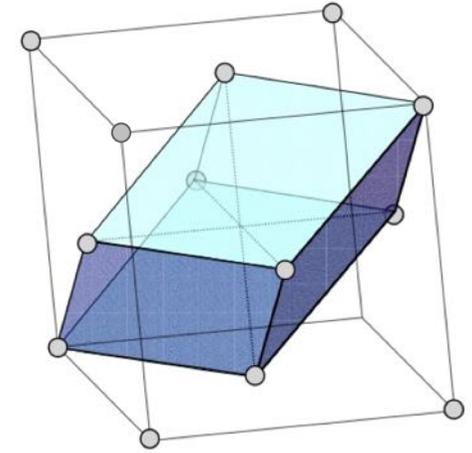
$$|E - E'| = \hbar\omega(\vec{K})$$

Q	Neutronenquelle
M	Monochromator
S	Probentisch
A	Analysator
D	Detektor
α_1 α_2 α_3 α_4	Kollimatoren
$2\theta_m$ $2\theta_s$ $2\theta_a$	Winkel der Spektrometer- achsen
Abs Sel Mob Sh	Abschirmburg Selektor Mobilblöcke Primärshutter

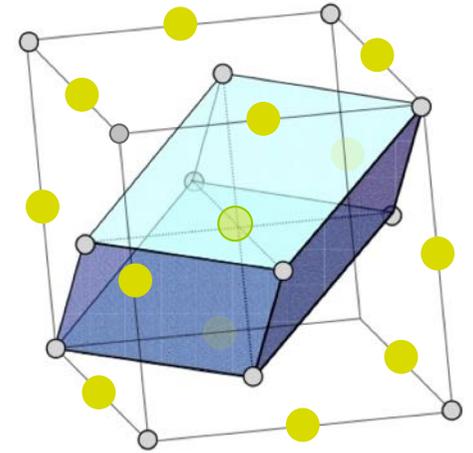
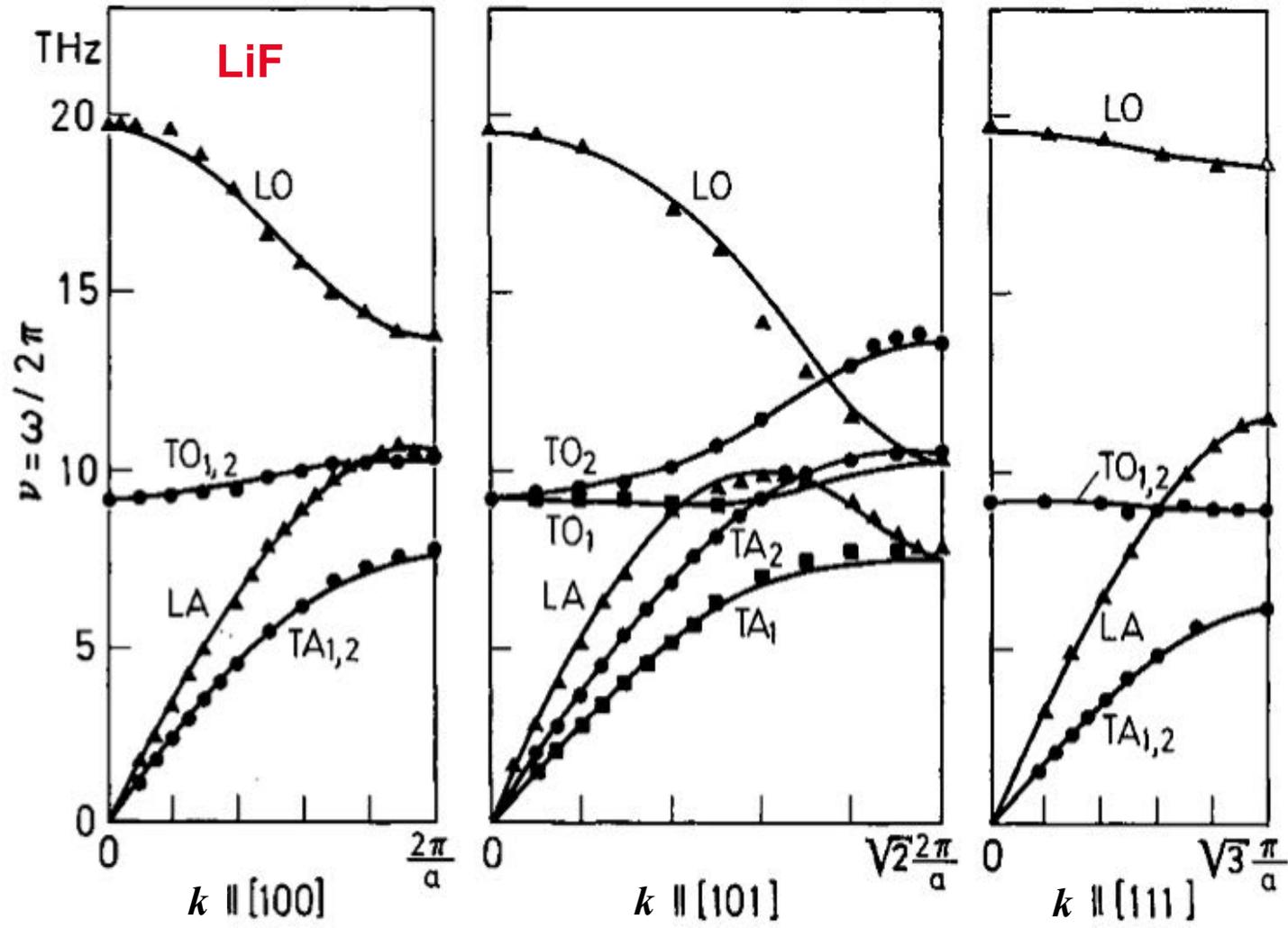


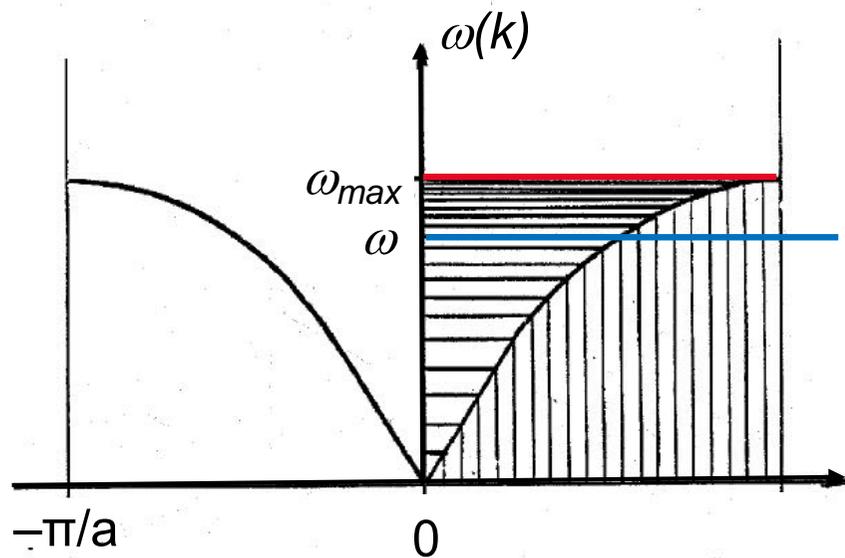
Schematischer Aufbau eines Dreiachsenspektrometers.

1-atomige Basis



2-atomige Basis

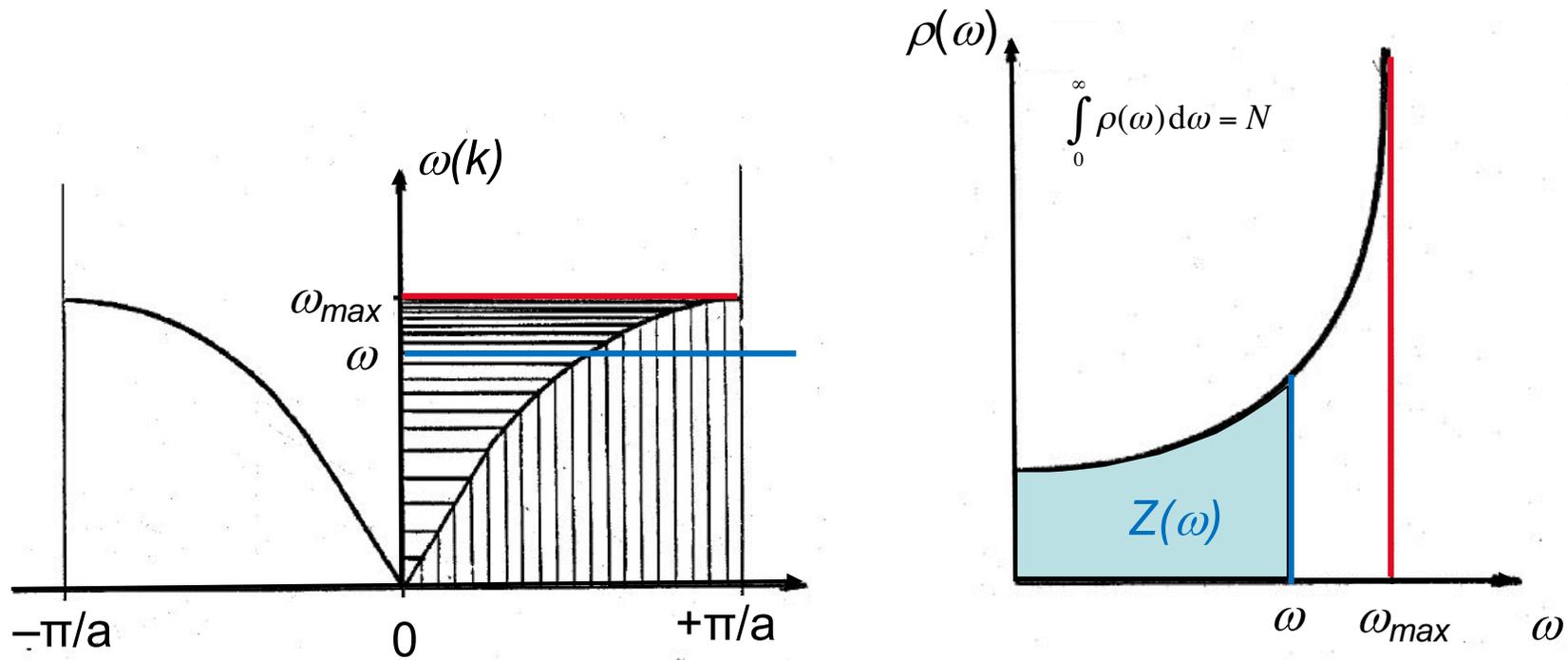




Zustandsdichte $\rho(\omega) = dZ/d\omega$:

Anzahl Eigenschwingungen pro Frequenzintervall $d\omega$

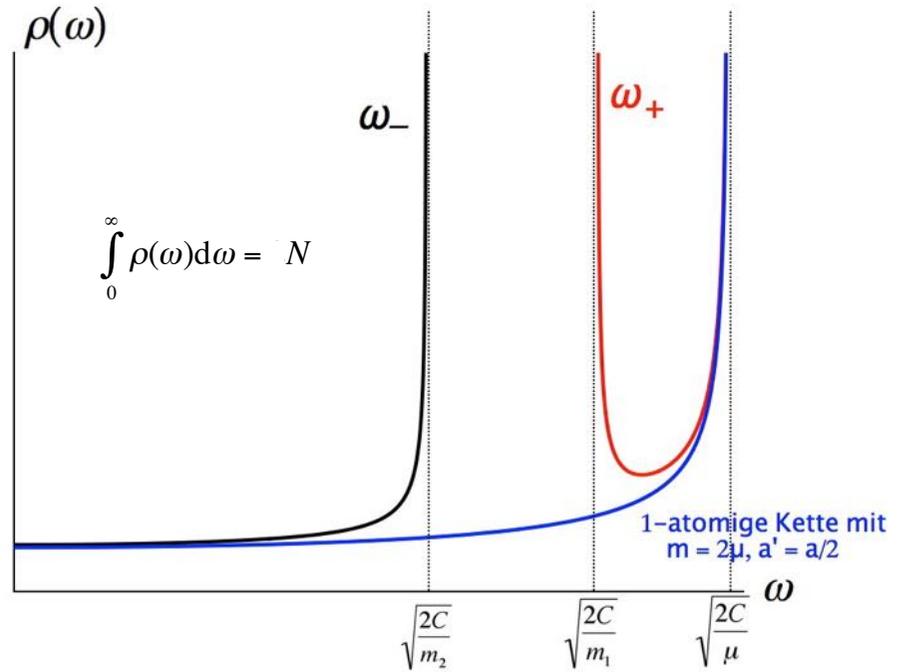
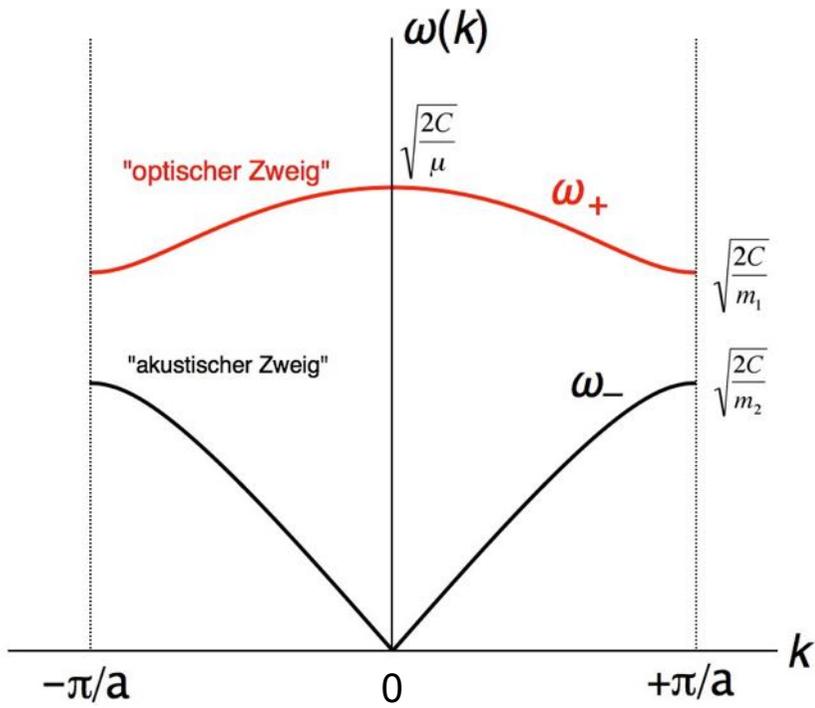
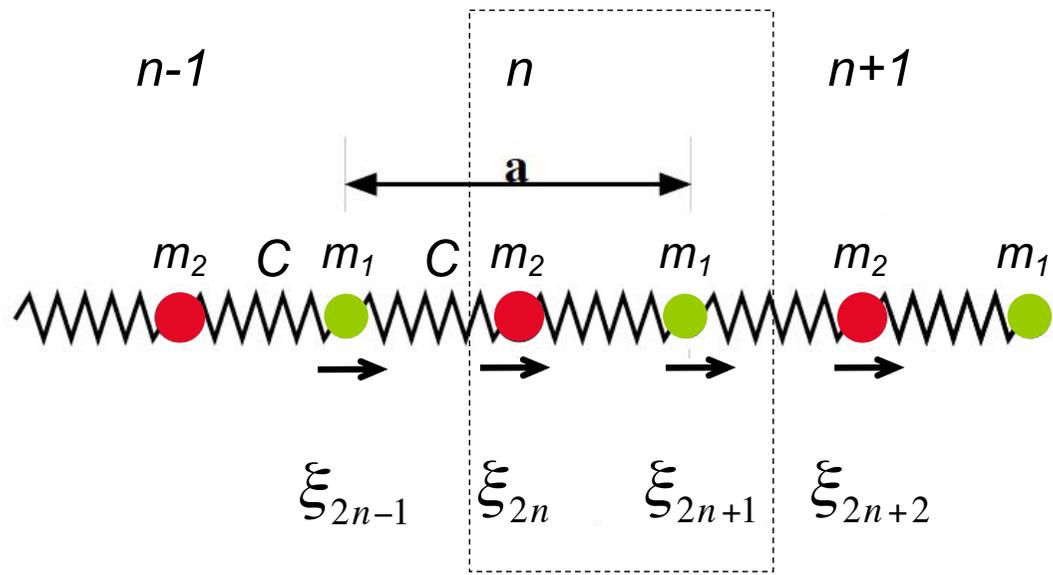
lineare Federkette mit 1-atomiger Basis



Zustandsdichte $\rho(\omega) = dZ/d\omega$:

Anzahl Eigenschwingungen pro Frequenzintervall $d\omega$

lineare Federkette mit 1-atomiger Basis



lineare Federkette mit 2-atomiger Basis