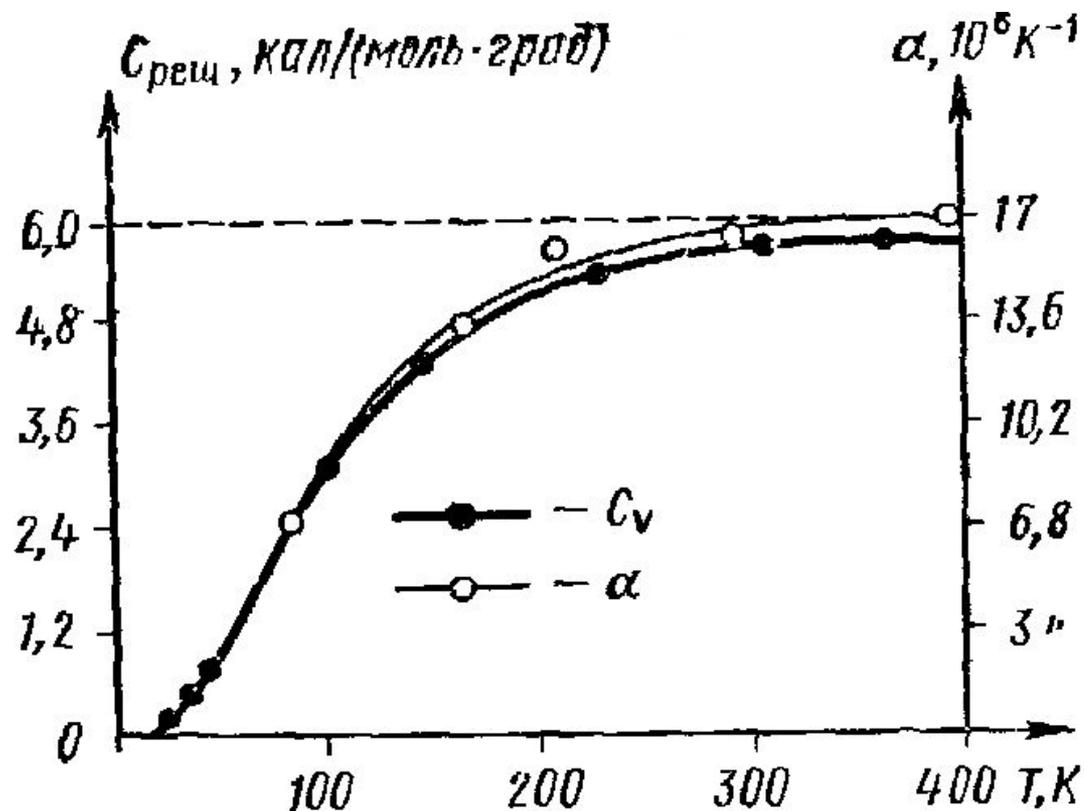


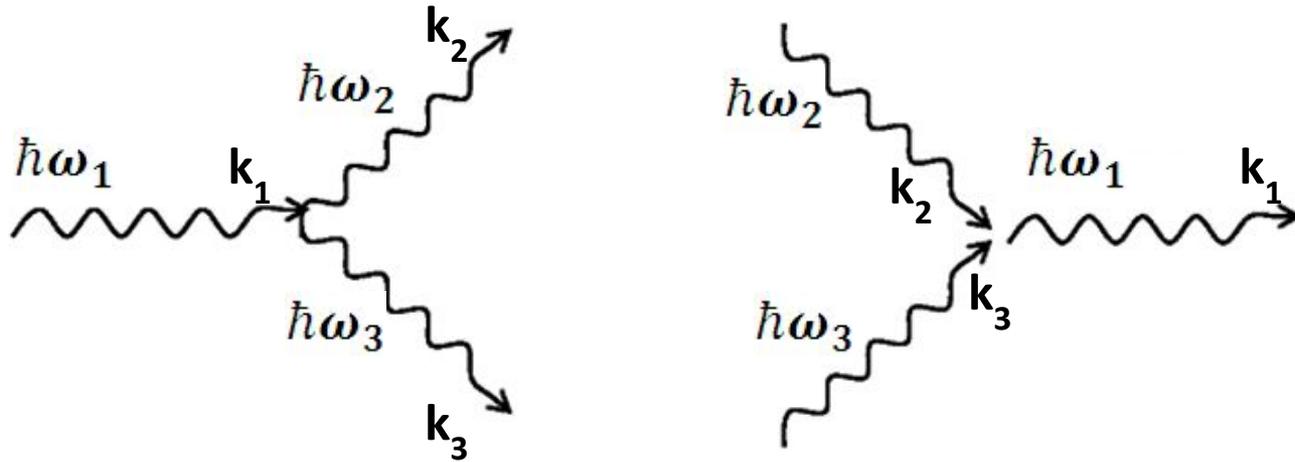
Равновесное положение

Тепловое расширение

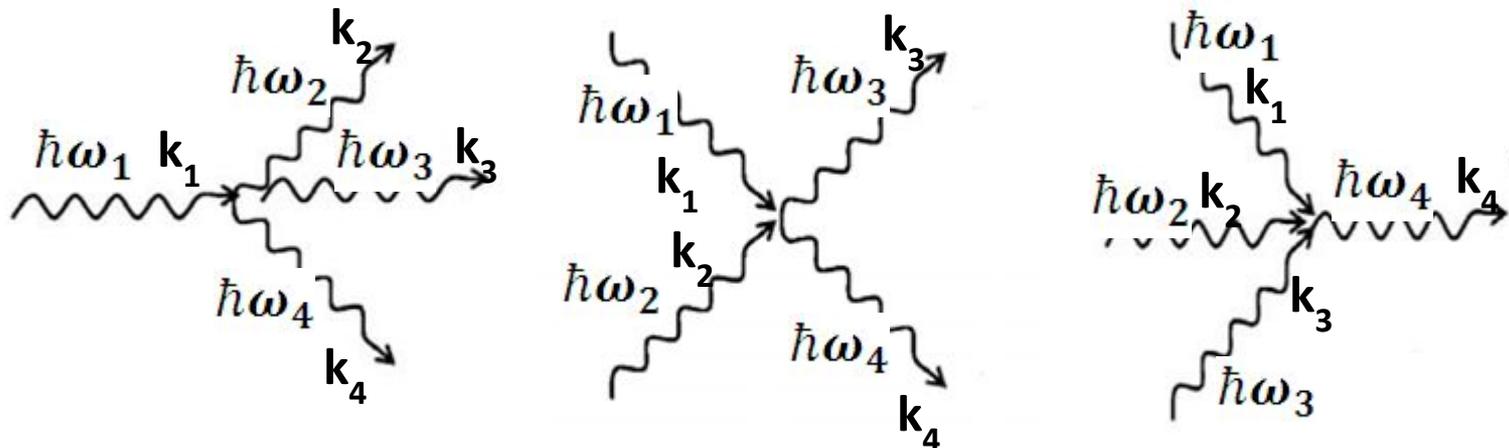


	$\alpha \cdot 10^{-5}, \text{ K}^{-1}$
NaCl	3.96
Fe	1.18
Al	2.91
Ag	1.89
Cu	1.65
GaAs	0.54
InSb	0.47
Ge	0.58
Si	0.47
Au	1.42

Трехфононные процессы (ангармонизм 3-го порядка)

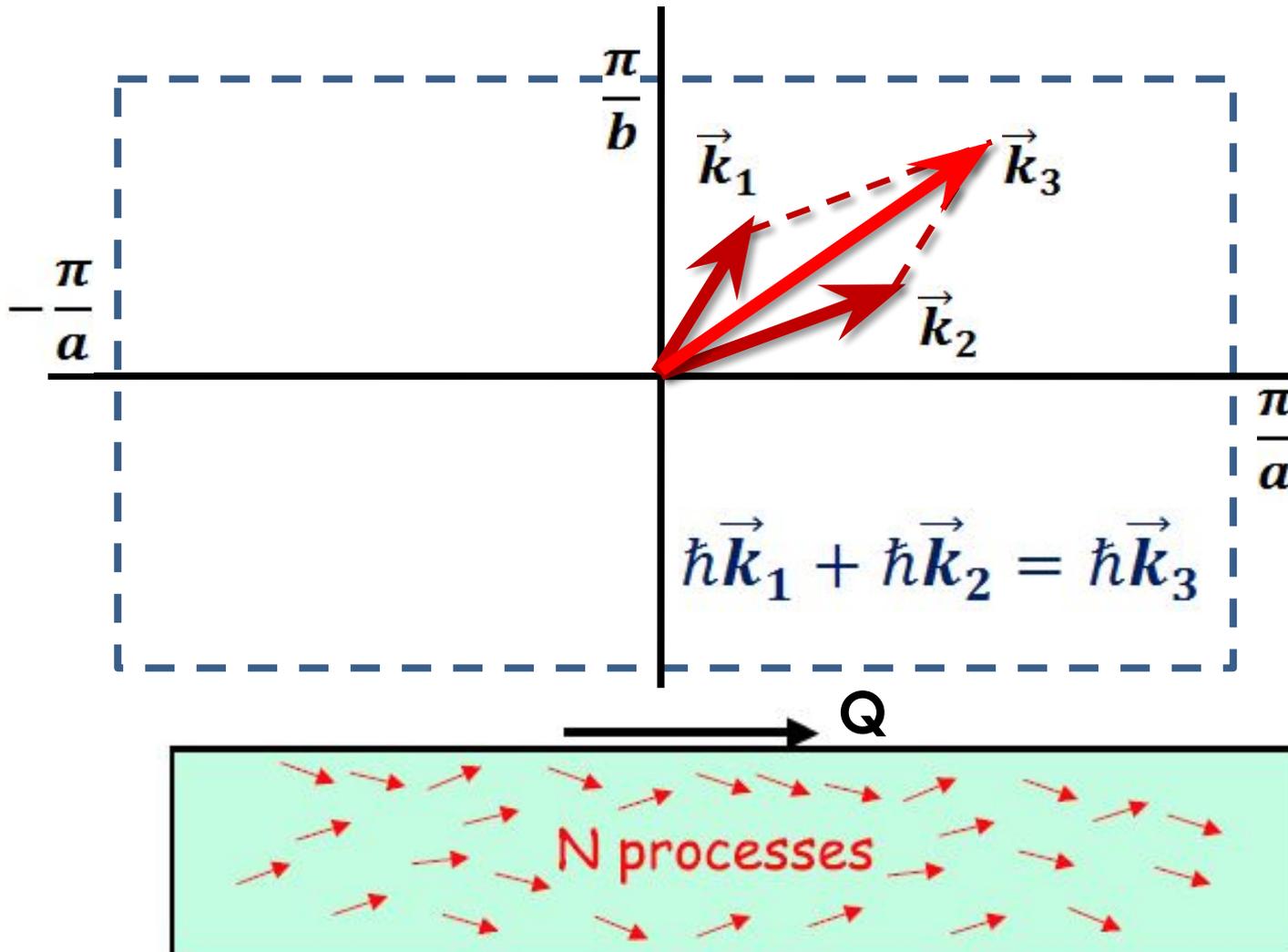


Четырехфононные процессы (ангармонизм 4-го порядка)



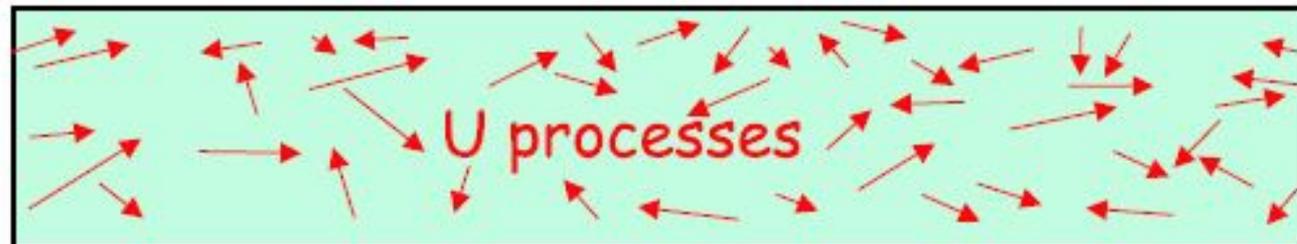
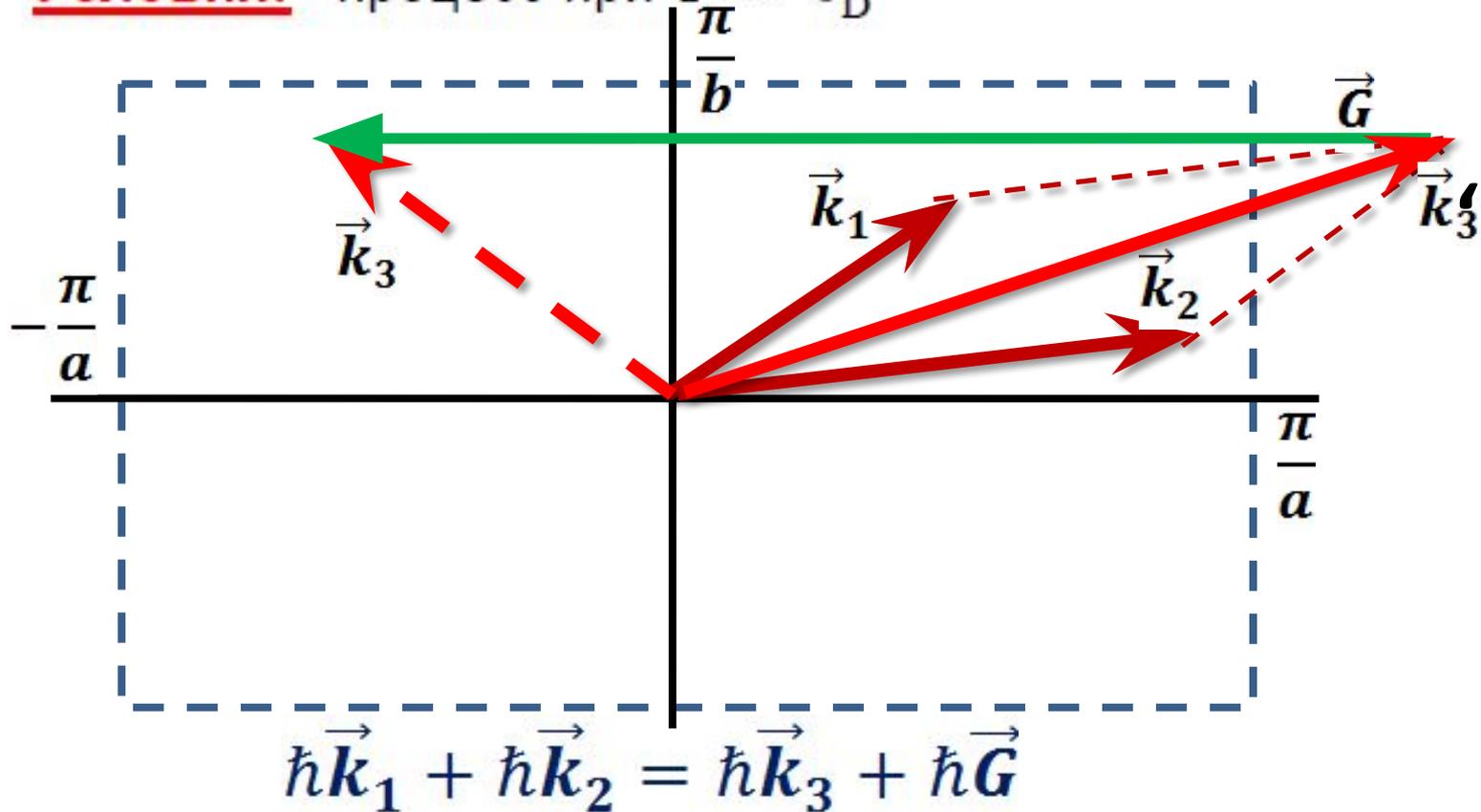
N-процесс

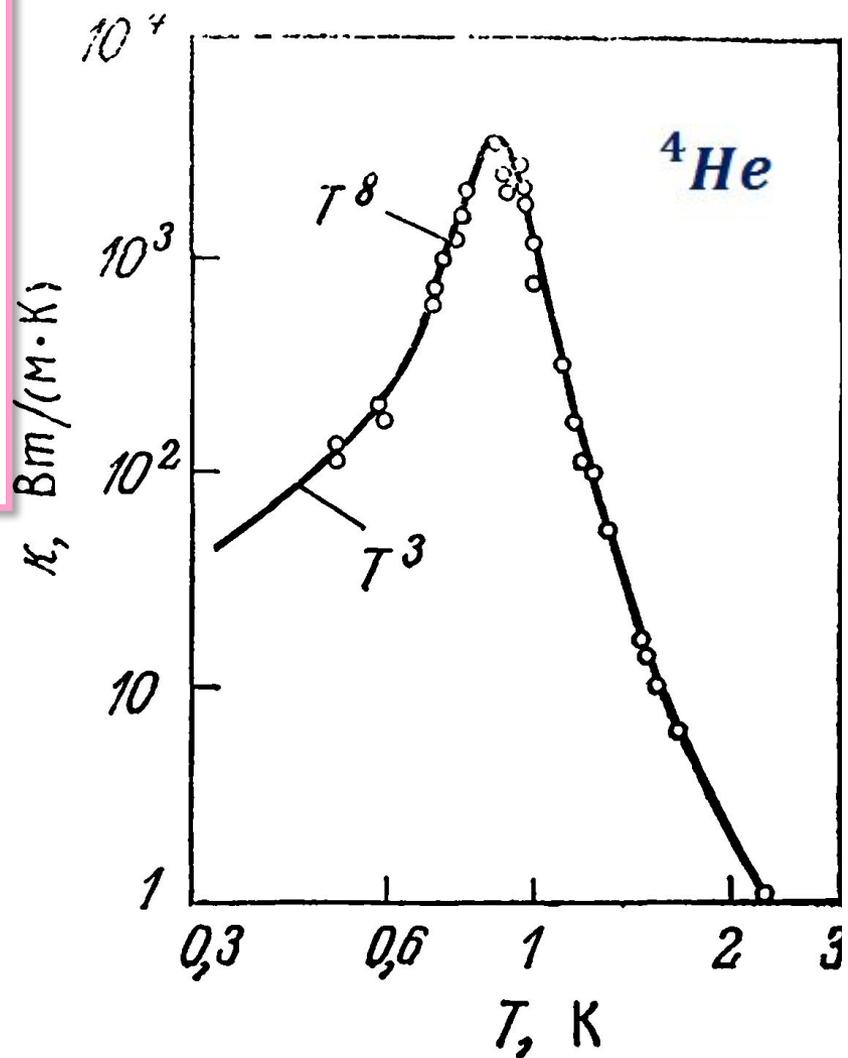
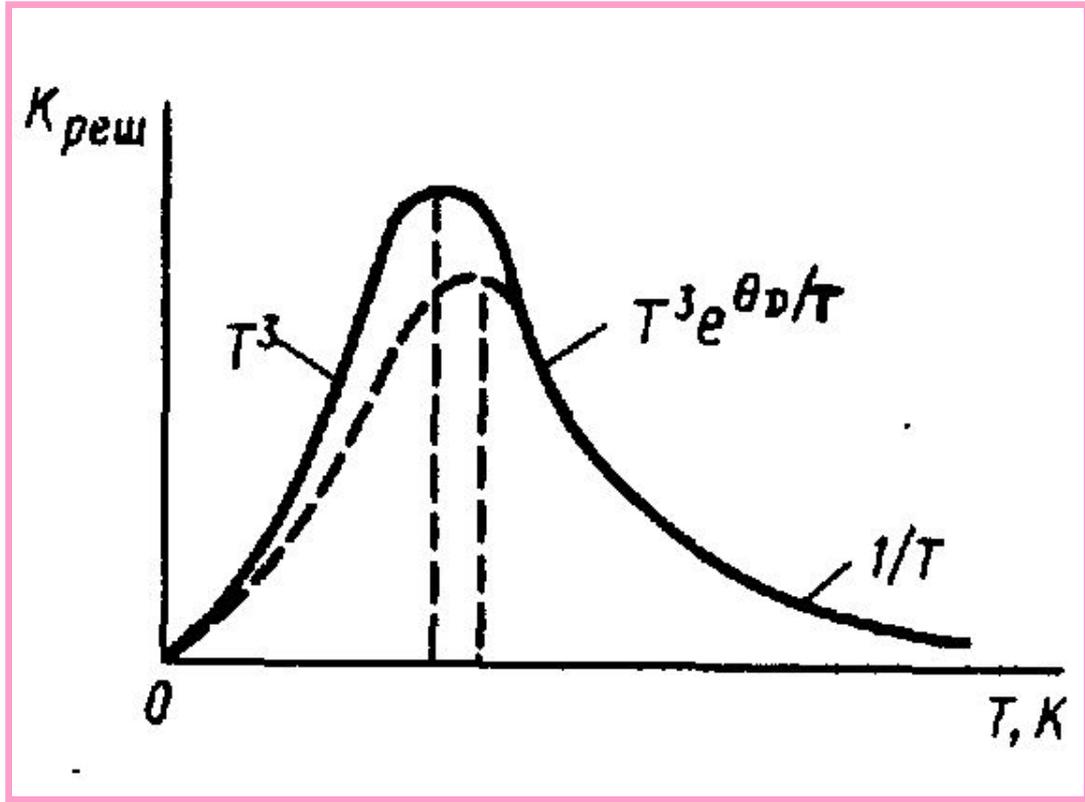
Условия: ω и q малы \rightarrow процесс при $T \ll \theta_D$

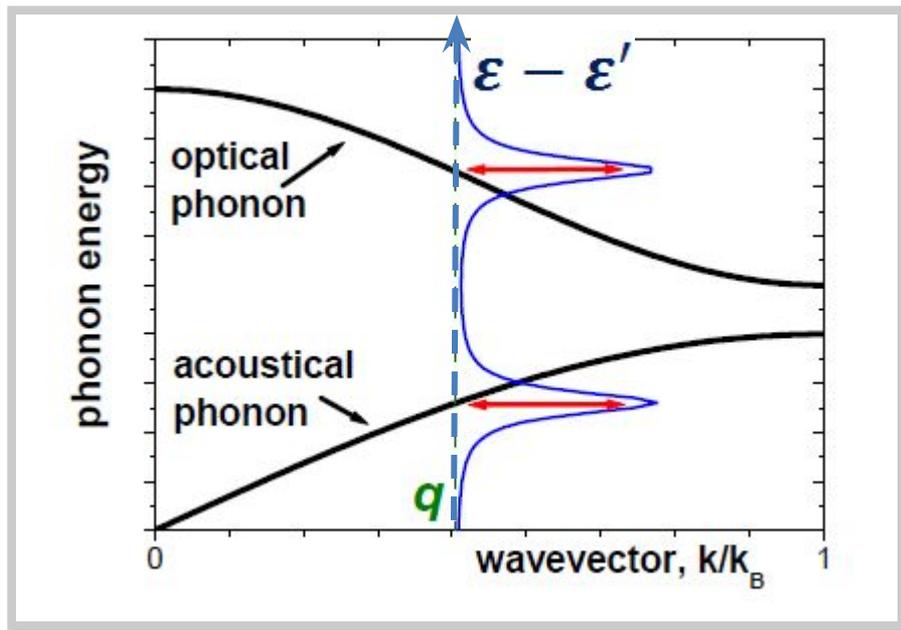
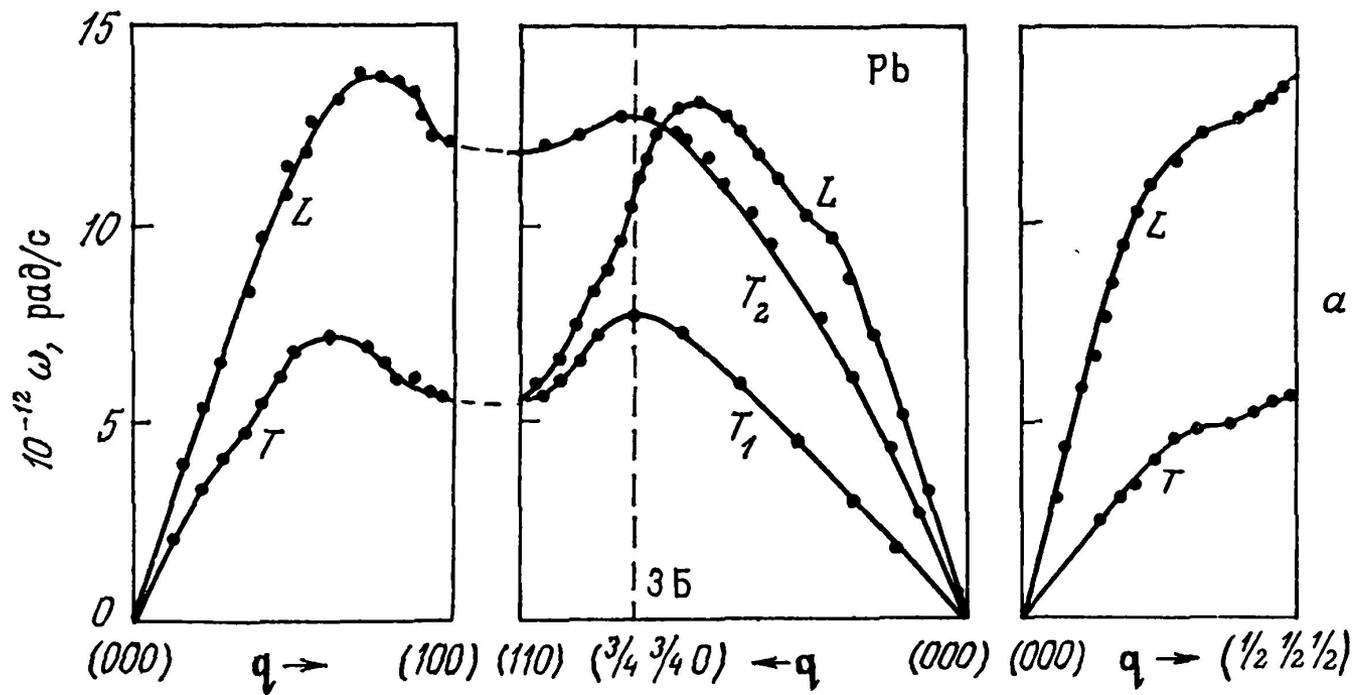


Процесс переброса (U-процесс)

Условия: процесс при $\Gamma \gg \theta_D$

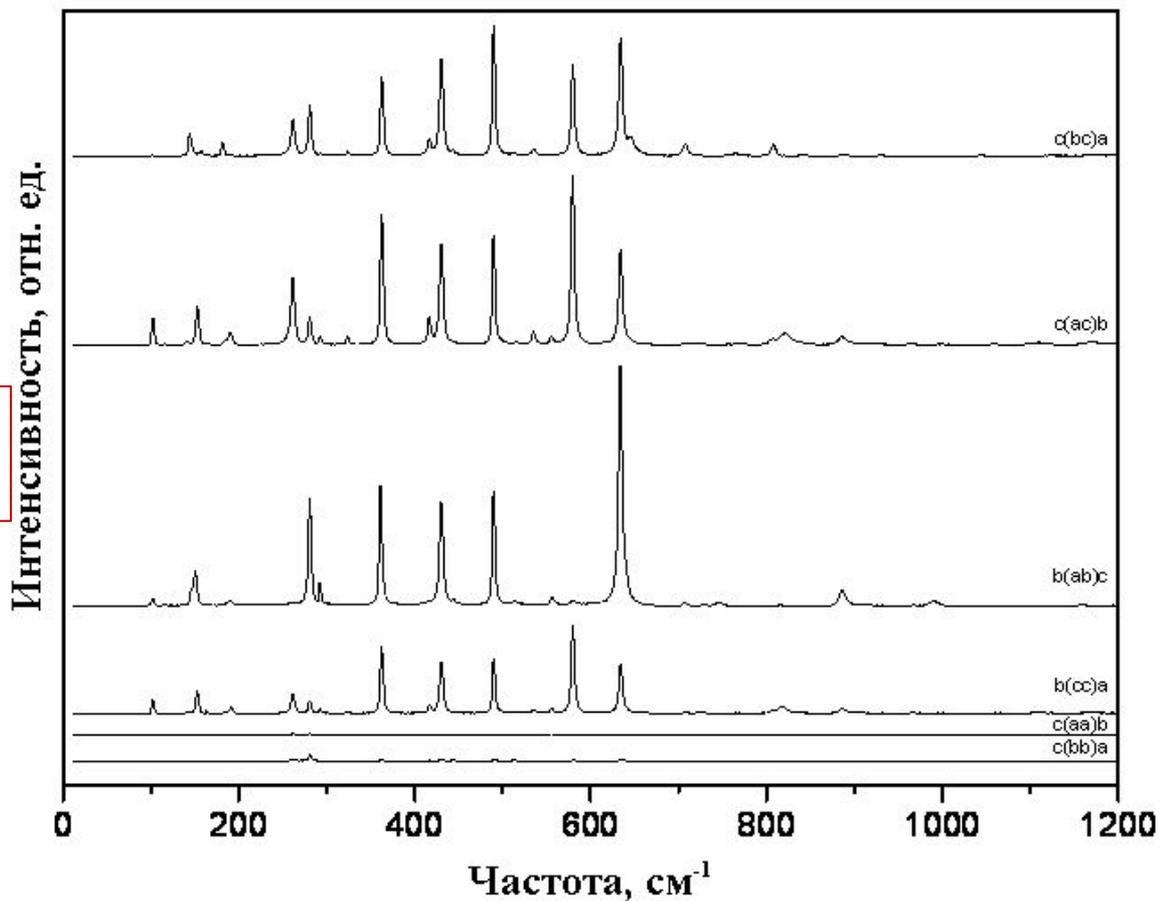
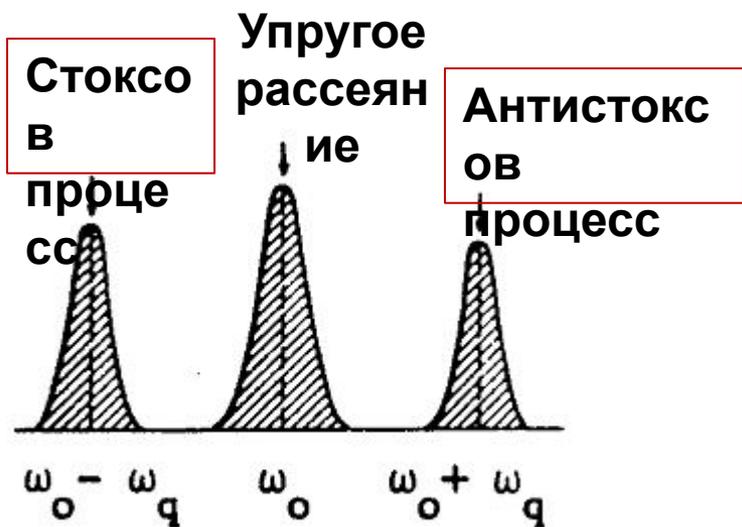
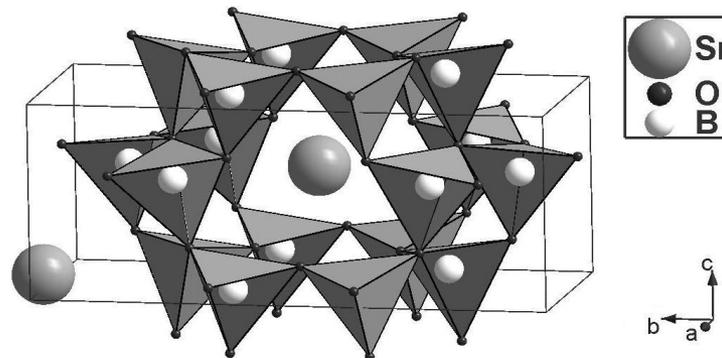
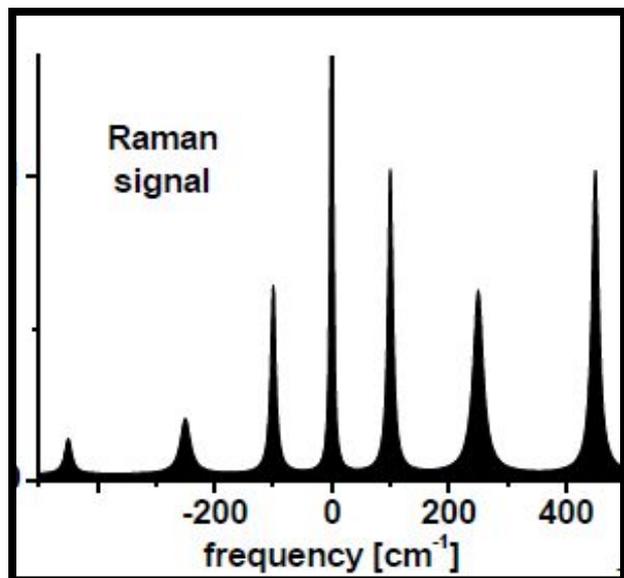




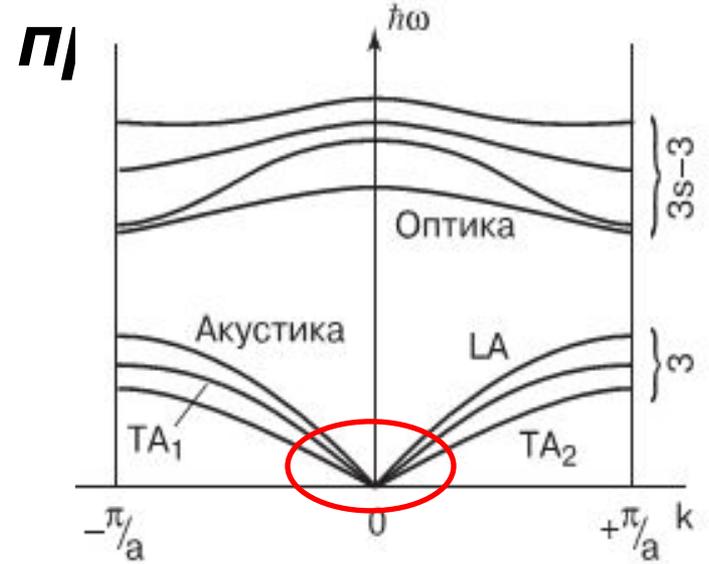
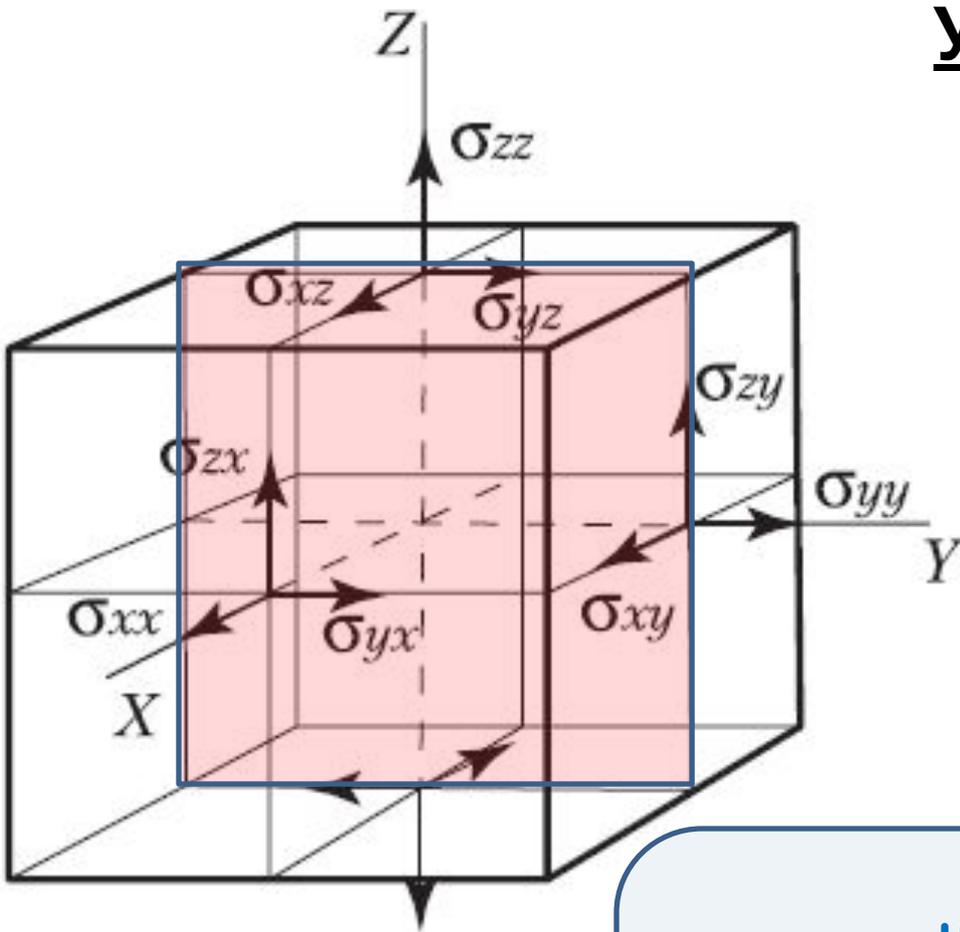


**Неупругое
рассеяние
нейтронов**

Рамановские

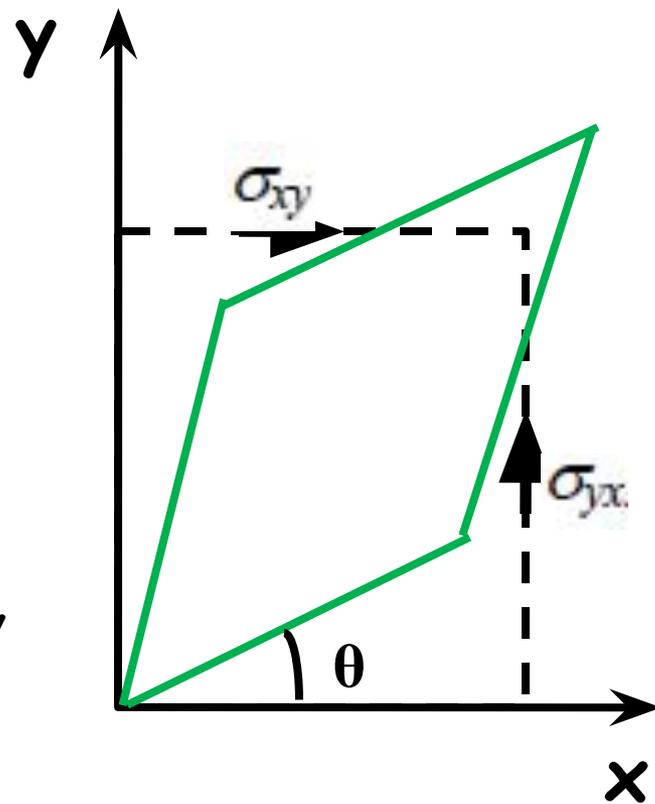
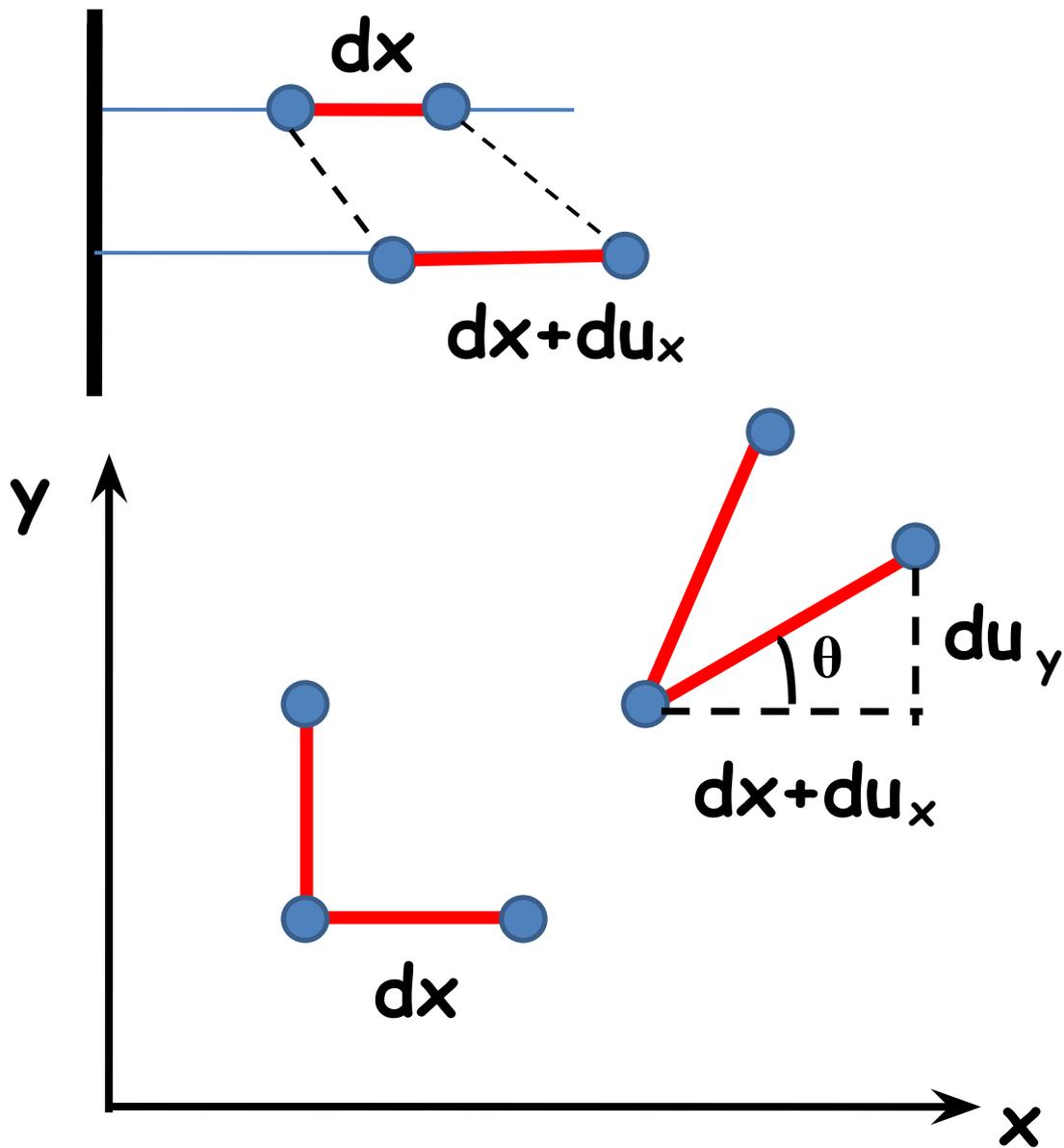


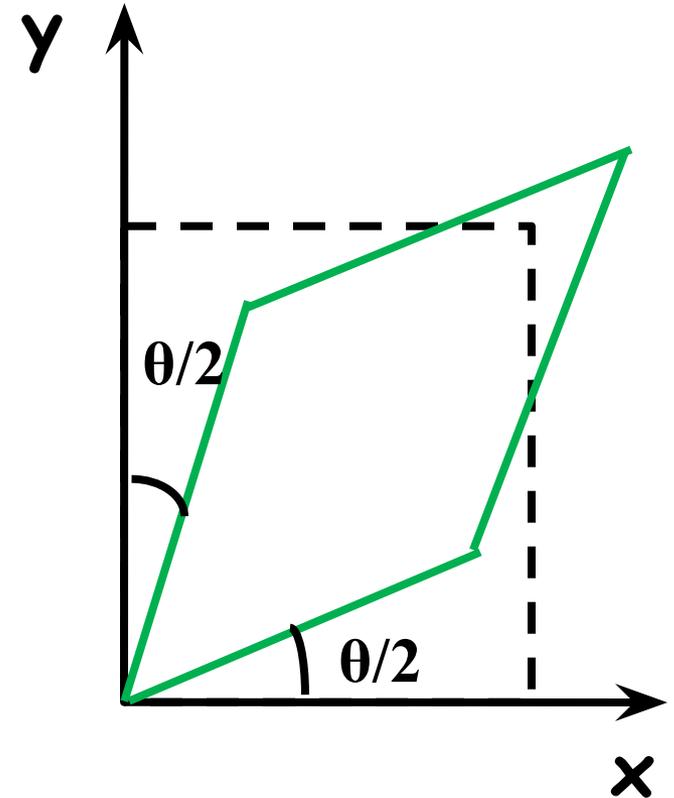
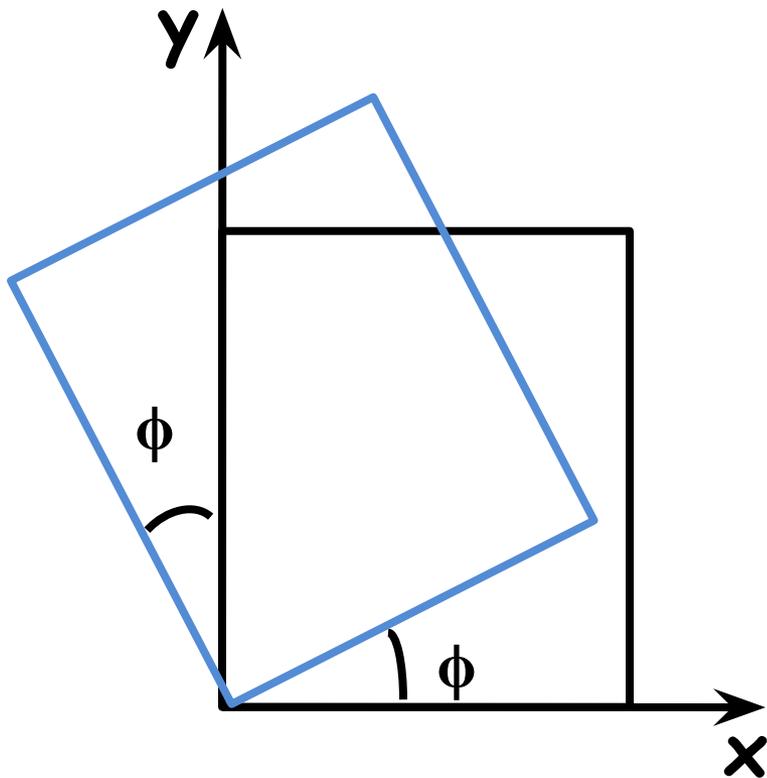
Упругие свойства *Континуальное*



**Тензор
напряжений**

$$\hat{\sigma} = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} \end{pmatrix}$$





Тензор
деформаций

$$\hat{e} = \begin{pmatrix} e_{11} & e_{12} & e_{13} \\ e_{12} & e_{22} & e_{23} \\ e_{13} & e_{23} & e_{33} \end{pmatrix}$$

$$\sigma_{11} = C_{1111} e_{11} + C_{1112} e_{12} + C_{1113} e_{13} + C_{1122} e_{22} + C_{1123} e_{23} + C_{1133}$$

$$\sigma_{12} = C_{1211} e_{11} + C_{1212} e_{12} + C_{1213} e_{13} + C_{1222} e_{22} + C_{1223} e_{23} + C_{1233}$$

$$\sigma_{13} = C_{1311} e_{11} + C_{1312} e_{12} + C_{1313} e_{13} + C_{1322} e_{22} + C_{1323} e_{23} + C_{1333}$$

$$\sigma_{22} = C_{2211} e_{11} + C_{2212} e_{12} + C_{2213} e_{13} + C_{2222} e_{22} + C_{2223} e_{23} + C_{2233}$$

$$\sigma_{23} = C_{2311} e_{11} + C_{2312} e_{12} + C_{2313} e_{13} + C_{2322} e_{22} + C_{2323} e_{23} + C_{2333}$$

$$\sigma_{33} = C_{3311} e_{11} + C_{3312} e_{12} + C_{3313} e_{13} + C_{3322} e_{22} + C_{3323} e_{23} + C_{3333}$$

e_{33}

ФOXT

11 → 1 23,32 →

4

22 → 2 12,21 →

$$\sigma_5 = C_{51} e_1 + C_{55} e_5 + C_{56} e_6 + C_{52} e_2 +$$

$e_3 +$

$$+ C_{54} e_4 + C_{53} e_3$$

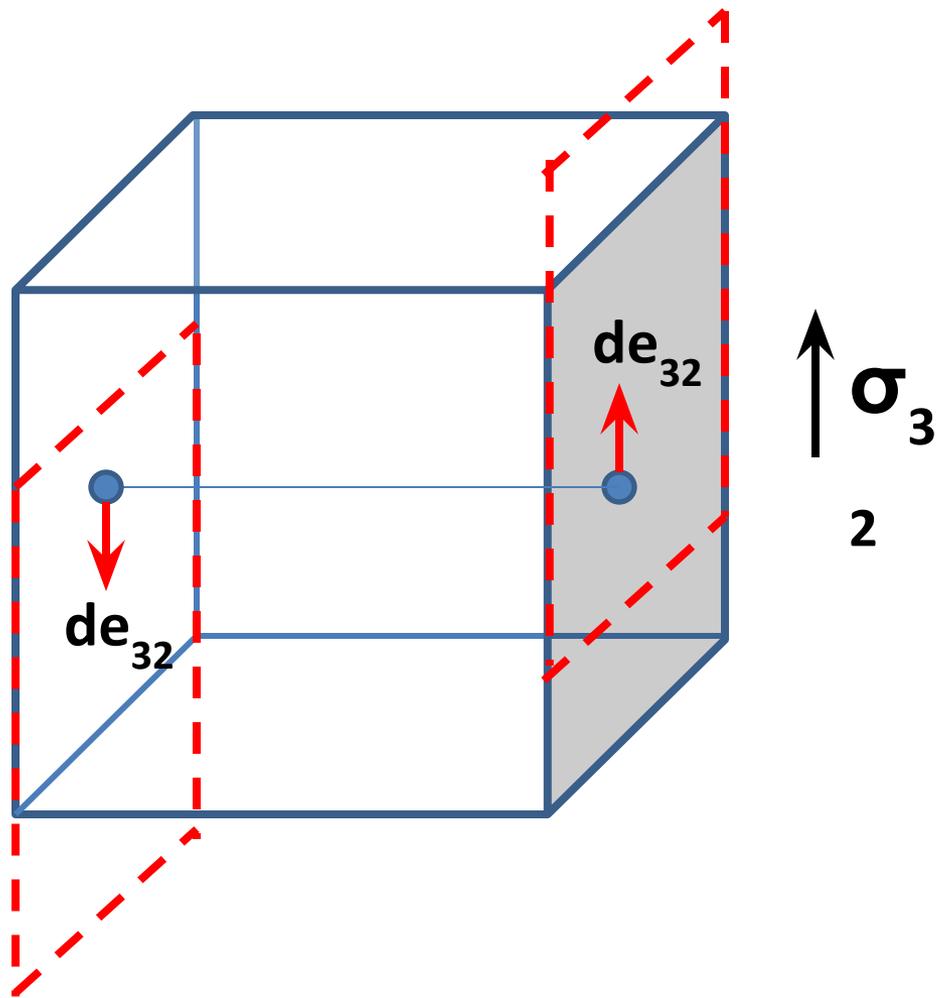
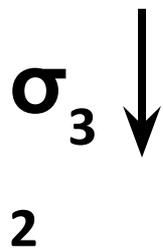
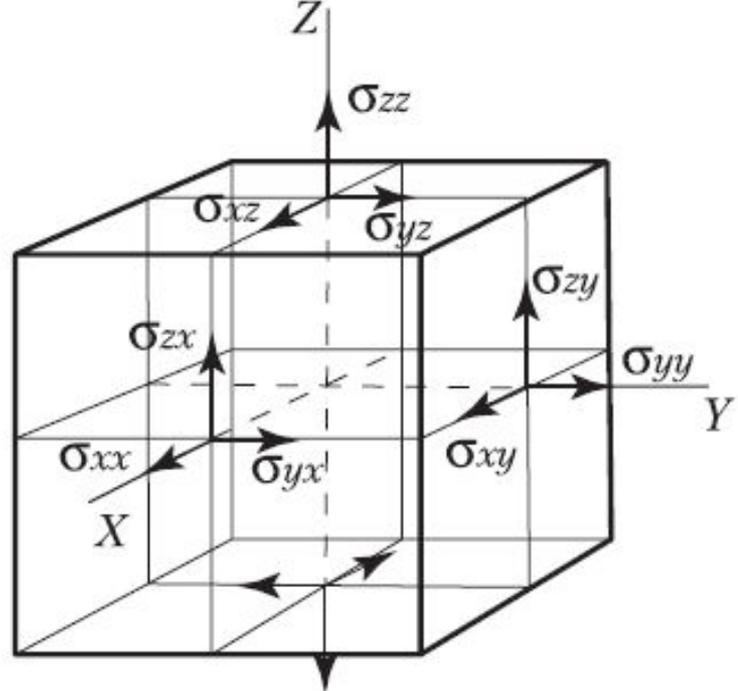
C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
C_{12}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}
C_{13}	C_{23}	C_{33}	C_{34}	C_{35}	C_{36}
C_{14}	C_{24}	C_{34}	C_{44}	C_{45}	C_{46}
C_{15}	C_{25}	C_{35}	C_{45}	C_{55}	C_{56}
C_{16}	C_{26}	C_{36}	C_{46}	C_{56}	C_{66}

$$\sigma_\alpha = C_{\alpha\beta} e_\beta$$

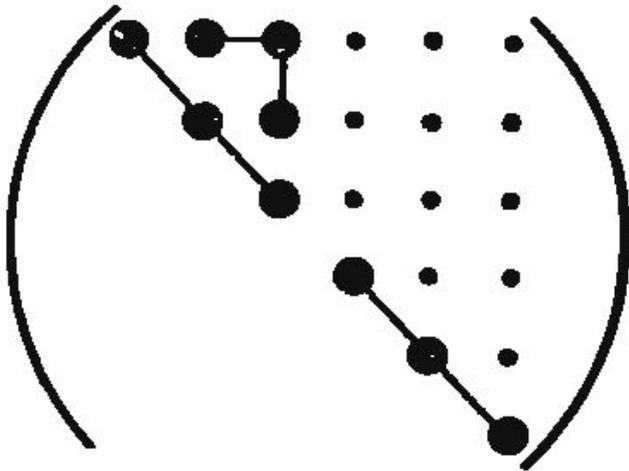
S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}
S_{12}	S_{22}	S_{23}	S_{24}	S_{25}	S_{26}
S_{13}	S_{23}	S_{33}	S_{34}	S_{35}	S_{36}
S_{14}	S_{24}	S_{34}	S_{44}	S_{45}	S_{46}
S_{15}	S_{25}	S_{35}	S_{45}	S_{55}	S_{56}
S_{16}	S_{26}	S_{36}	S_{46}	S_{56}	S_{66}

$$e_\alpha = S_{\alpha\beta} \sigma_\beta$$

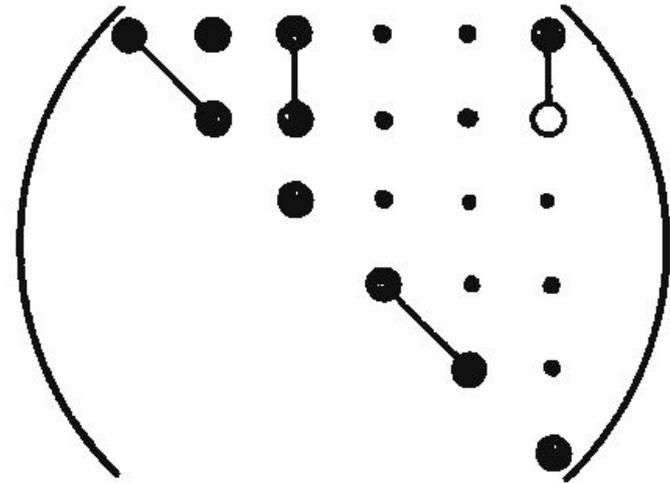
$$\widehat{C}\widehat{S} = \mathbf{1} \quad \widehat{S} = \widehat{C}^{-1}$$



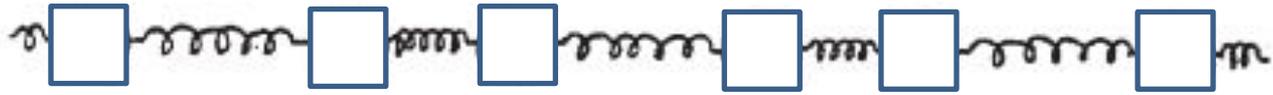
Кубическая система



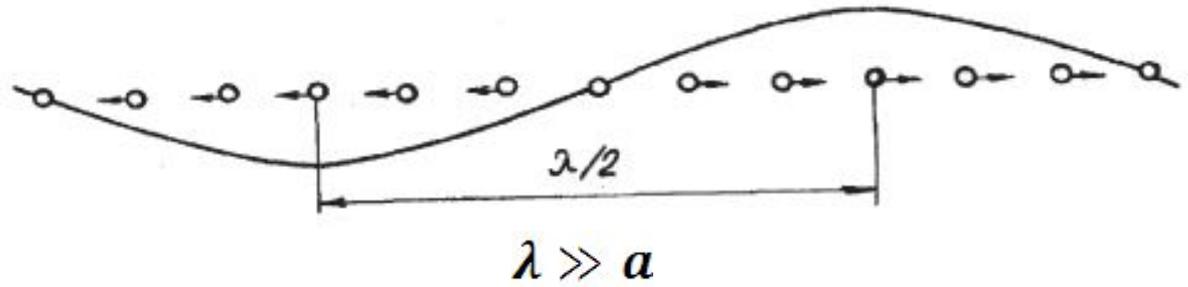
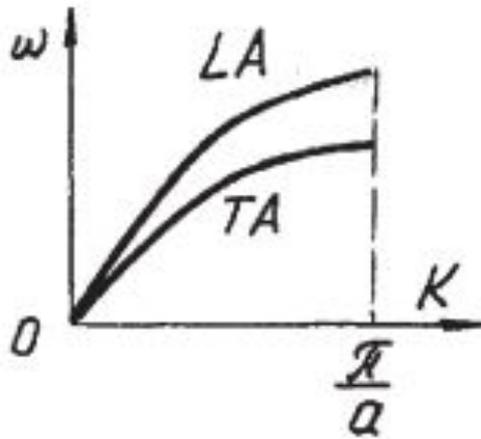
Тетрагональная система



$$\begin{pmatrix}
 C_{11} & C_{12} & C_{12} & 0 & 0 & 0 \\
 C_{12} & C_{11} & C_{12} & 0 & 0 & 0 \\
 C_{12} & C_{12} & C_{11} & 0 & 0 & 0 \\
 0 & 0 & 0 & C_{44} & 0 & 0 \\
 0 & 0 & 0 & 0 & C_{44} & 0 \\
 0 & 0 & 0 & 0 & 0 & C_{44}
 \end{pmatrix}$$

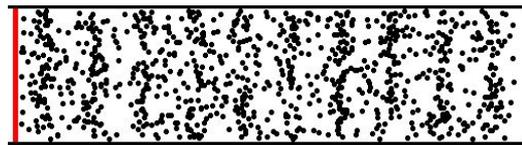
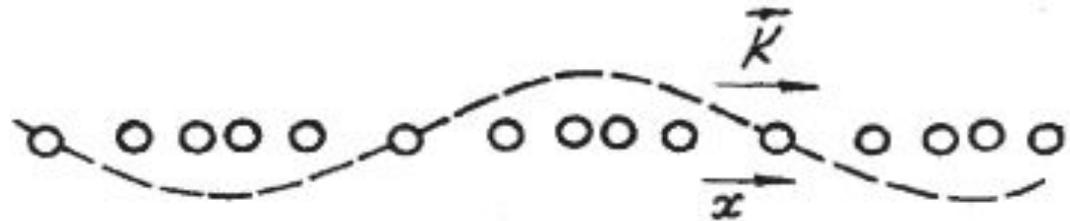


	структура	Расст. между ближ. соседями (Å°)	плотность (кг/м ³)	Упругие модули (10 ¹⁰ Н/м ²)	вычис. скорость звука (м/с)	Измер. скорость звука (м/с)
натрий	B.C.C	3.71	970	0.52	2320	2250
медь	F.C.C	2.55	8966	13.4	3880	3830
аллюминий	F.C.C	2.86	2700	7.35	5200	5110
свинец	F.C.C	3.49	11340	4.34	1960	1320
кремний	Diamond	2.35	2330	10.1	6600	9150
германий	Diamond	2.44	5360	7.9	3830	5400
NaCl	Rocksalt	2.82	2170	2.5	3400	4730



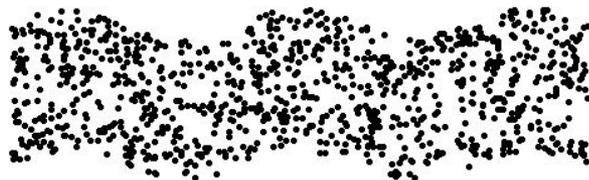
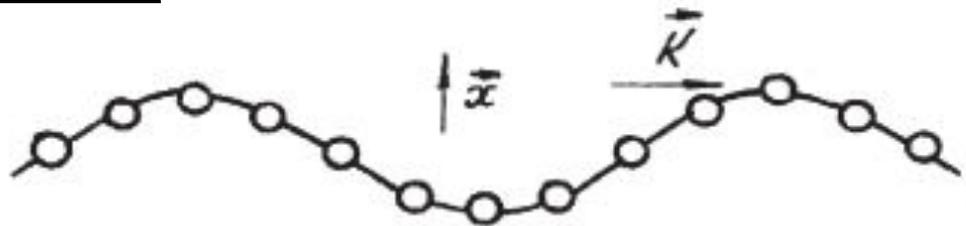
Продольная волна

LA



Поперечная волна

TA



Уравнения Кристоффеля

$$u_1(L_{11} - \rho\omega^2) + u_2L_{12} + u_3L_{13} = 0$$

$$u_1L_{12} + u_2(L_{22} - \rho\omega^2) + u_3L_{23} = 0$$

$$u_1L_{13} + u_2L_{23} + u_3(L_{33} - \rho\omega^2) = 0$$

