ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Non-linear frequency conversion I

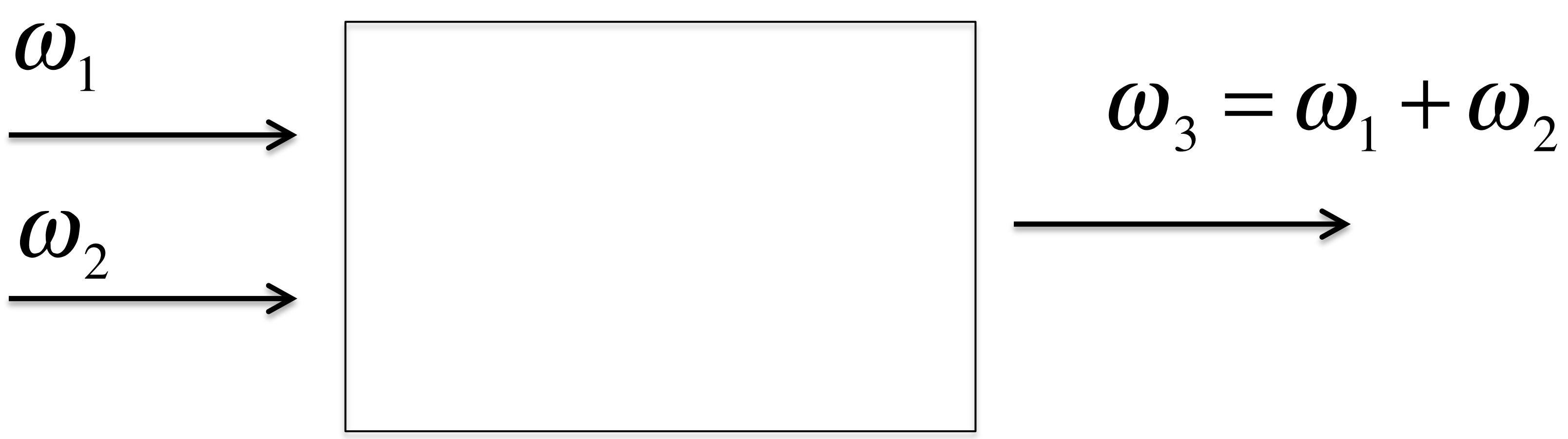
Lasers: theory and applications, lecture 12.3

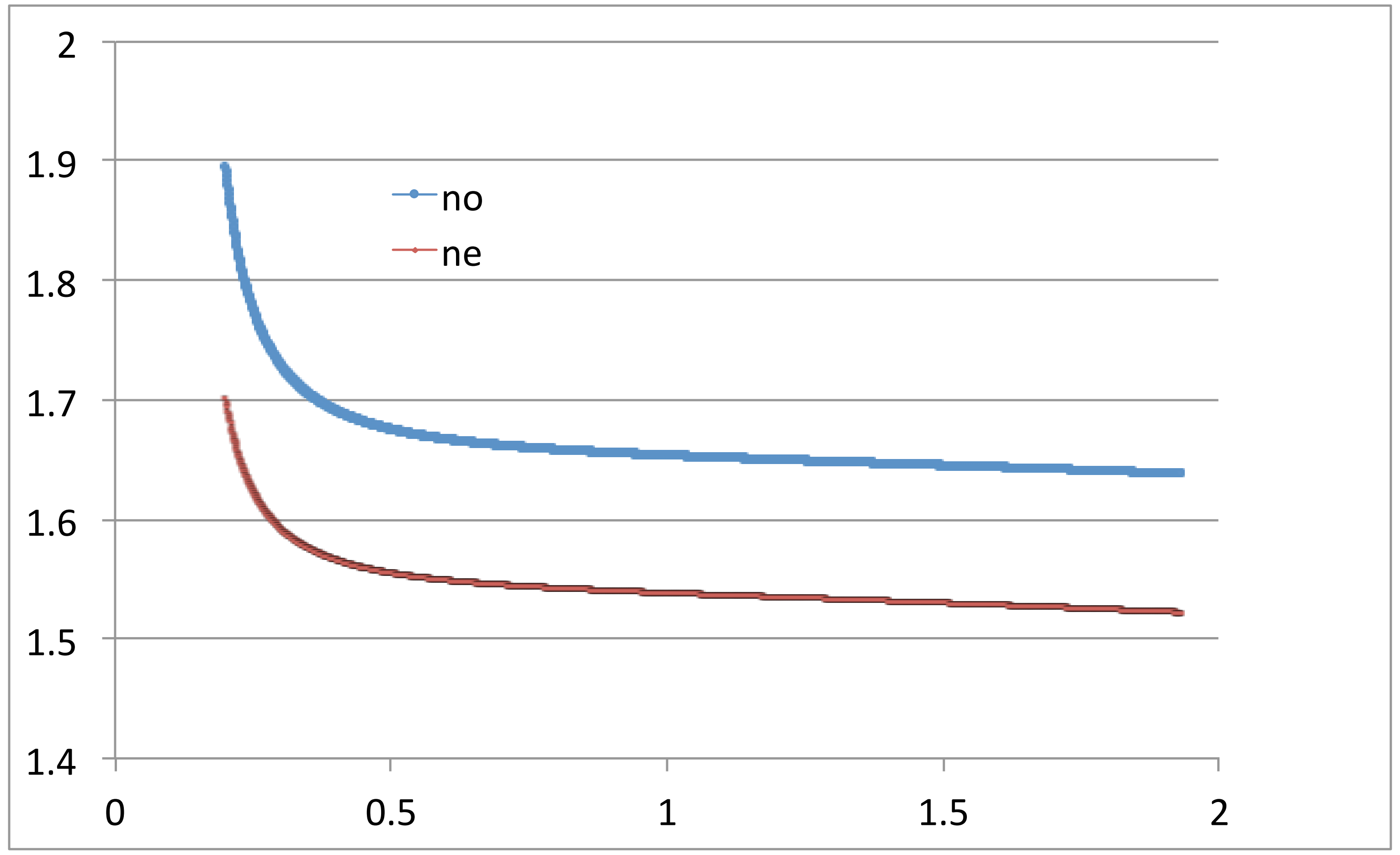
Christophe Moser

Non-linear frequency conversion I

- Phase matching with birefringent crystals
- Quasi phase matching

Phase matching





Phase matching condition $\Delta k = k_1 + k_2 - k_3$

$$\frac{\omega_1 n_1}{c} + \frac{\omega_2 n_2}{c} - \frac{\omega_3 n_3}{c} = 0 \qquad \omega_1 \le \omega_2 < \omega_3$$

$$\omega_1 n_1 + \omega_2 n_2 = \omega_3 n_3 \qquad \omega_1 + \omega_2 = \omega_3$$

energy conservation

<u>Degenerate case:</u> $\omega_1 = \omega_2$ $\qquad \omega_3 = 2\omega_1$

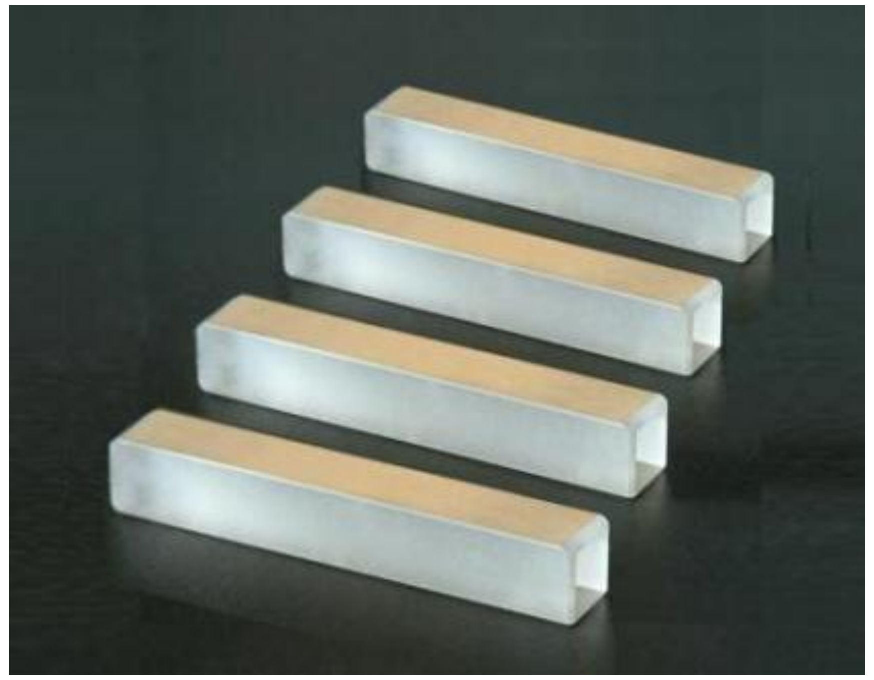
second harmonic generation

$$2 \cdot \omega_1 \cdot n_1(\omega_1) = \omega_3 \cdot n_3(\omega_3) = 2 \cdot \omega_1 \cdot n_3(\omega_3)$$

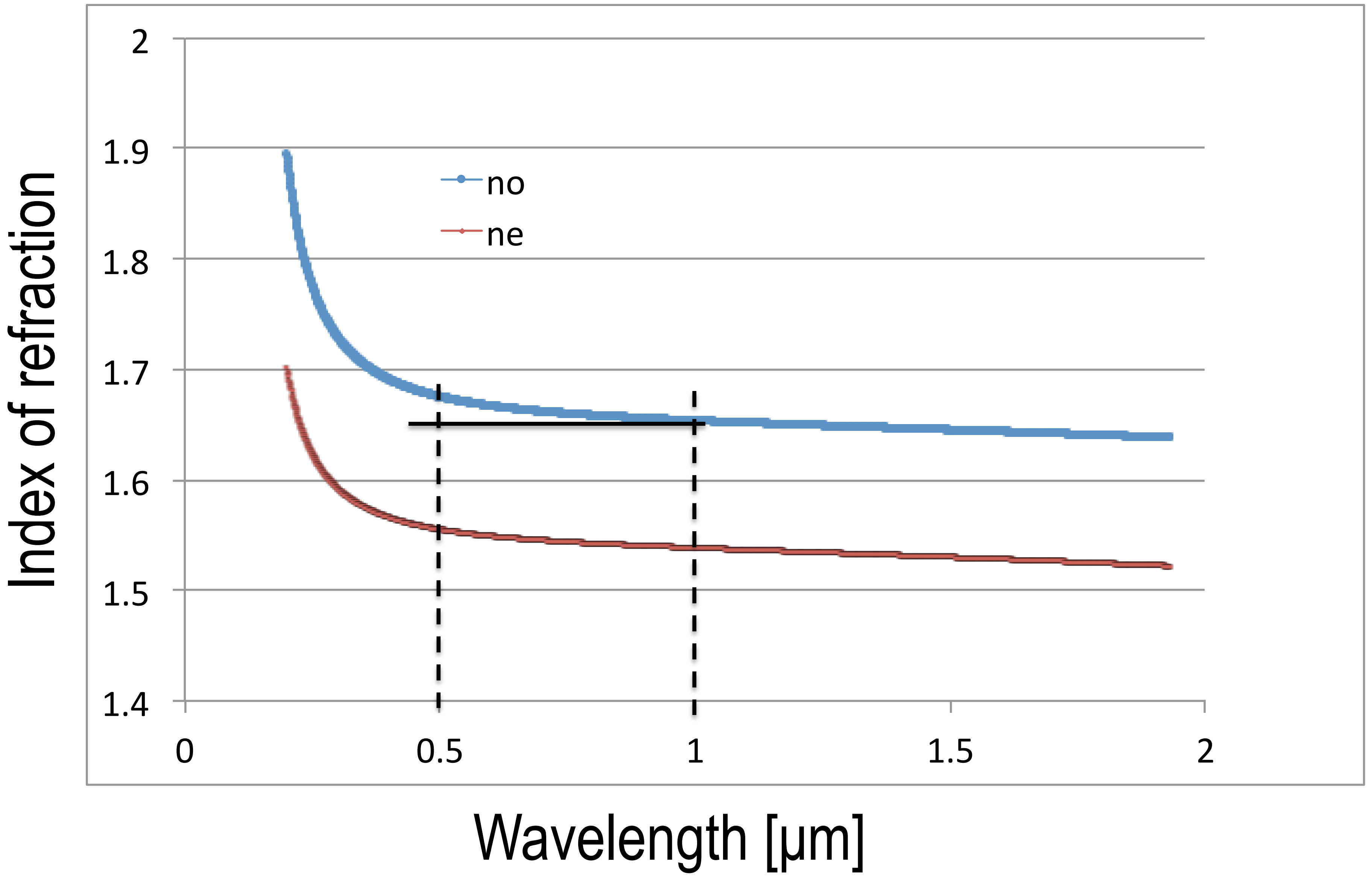
$$n_1(\omega_1) = n_3(\omega_3 = 2\omega_1)$$

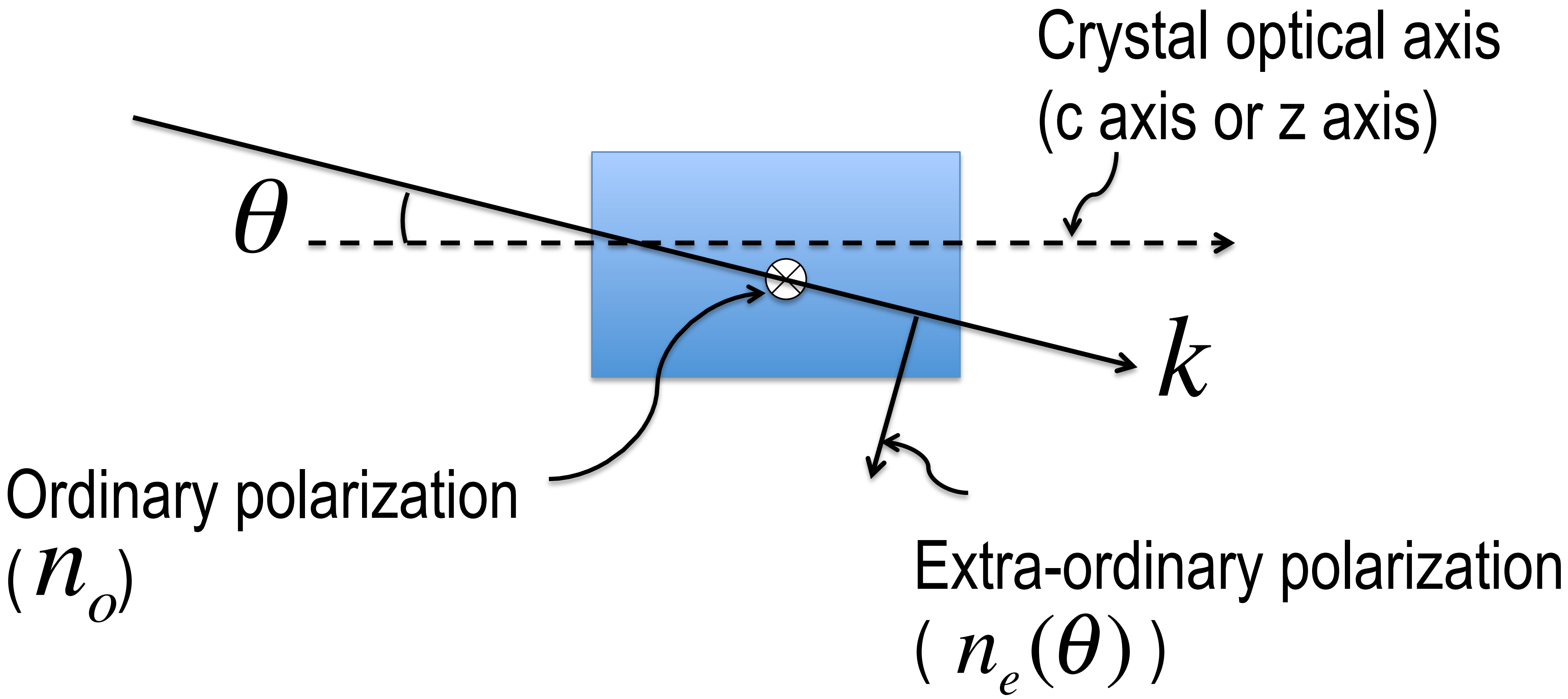
✗ Not possible with Normal dispersion

Phase matching with birefringent crystals



BBO crystal



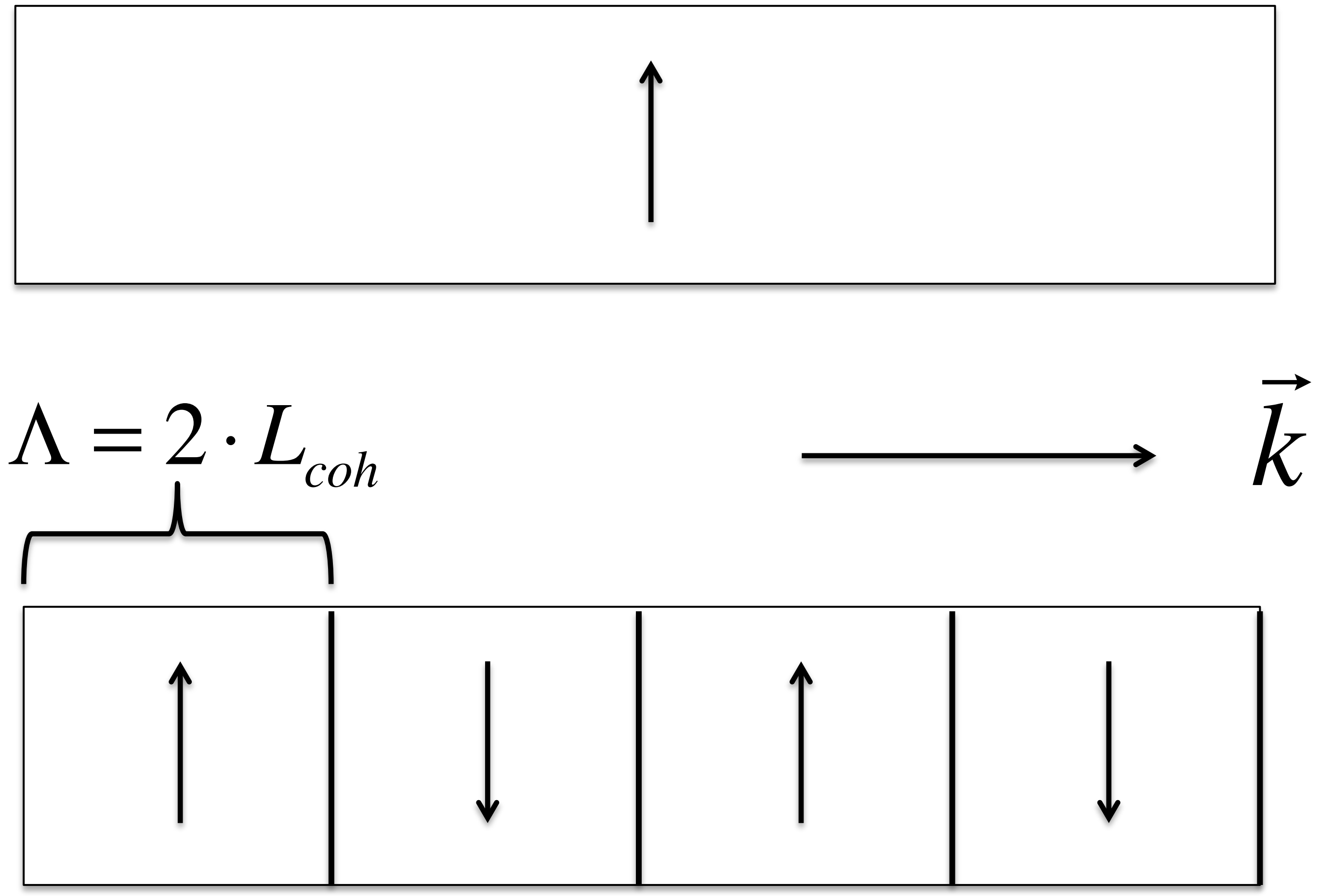


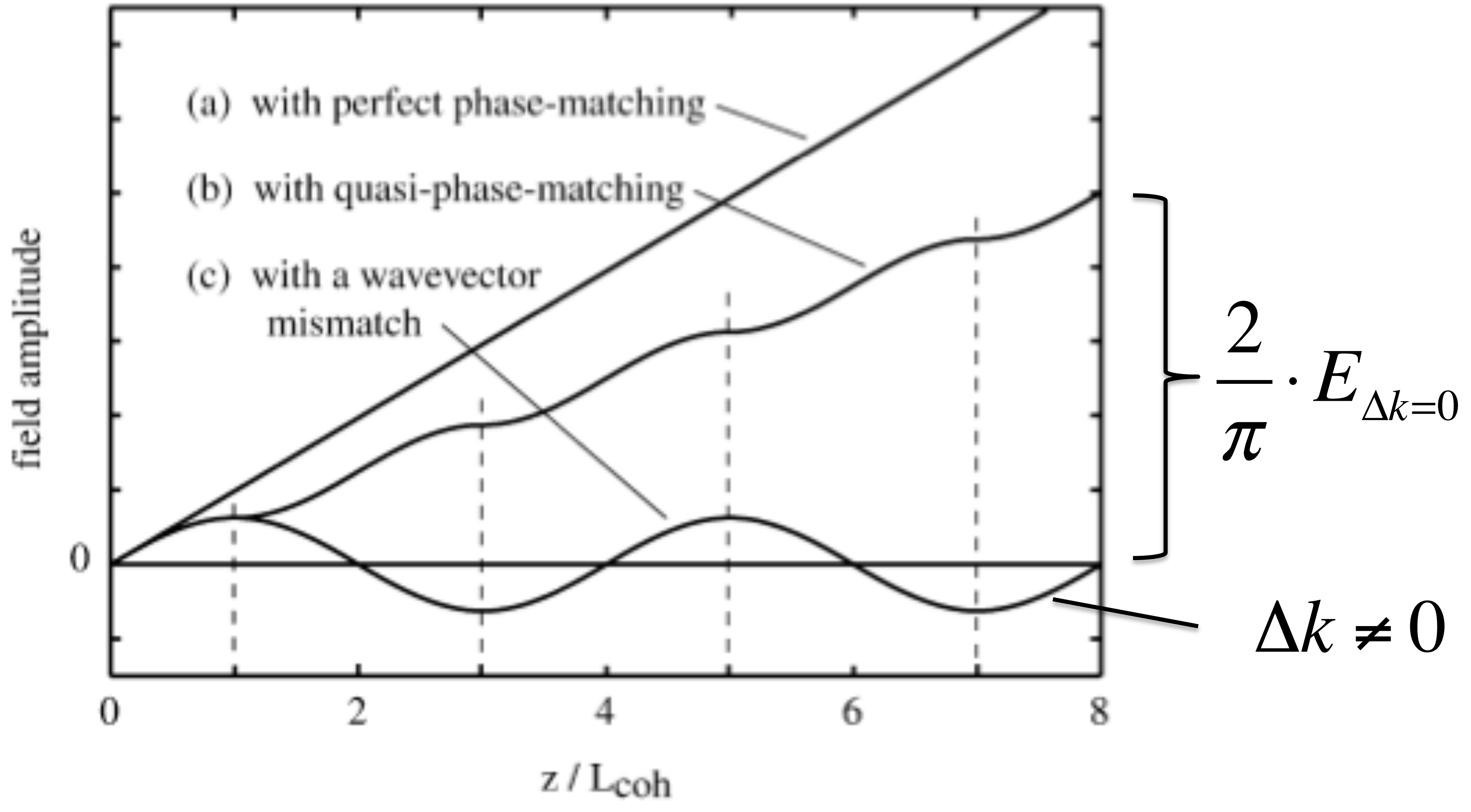
$$\frac{1}{n_e^2(\theta)} = \frac{\cos^2\theta}{n_o^2} + \frac{\sin^2\theta}{n_e^2}$$

$$n_3^e(\omega_3 = 2\omega_1, \theta) = n_1^o(\omega_1)$$

“Type I” phase matching in negaitve uni-axial crystals (means o polarization for fundamental and e polarization for harmonic)

Quasi phase matching





$$E \propto d_{eff} \cdot z \cdot \sin c\left(\frac{\Delta k z}{2}\right) = \frac{2 d_{eff}}{\Delta k} \sin\left(\frac{\Delta k z}{2}\right)$$

$$L_{coh} = \frac{\pi}{\Delta k}$$

$$E \propto \frac{2 d_{eff}}{\Delta k} \cdot \sin\left(\frac{\pi z}{2 L_{coh}}\right)$$

$$\Delta k = k_1 + k_2 - k_3 + \frac{2\pi}{\Lambda}$$

$$d_{periodic-poling} = \frac{2}{\pi} d_{eff}$$