ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Non-linear frequency conversion I

Lasers: theory and applications, lecture 12.4

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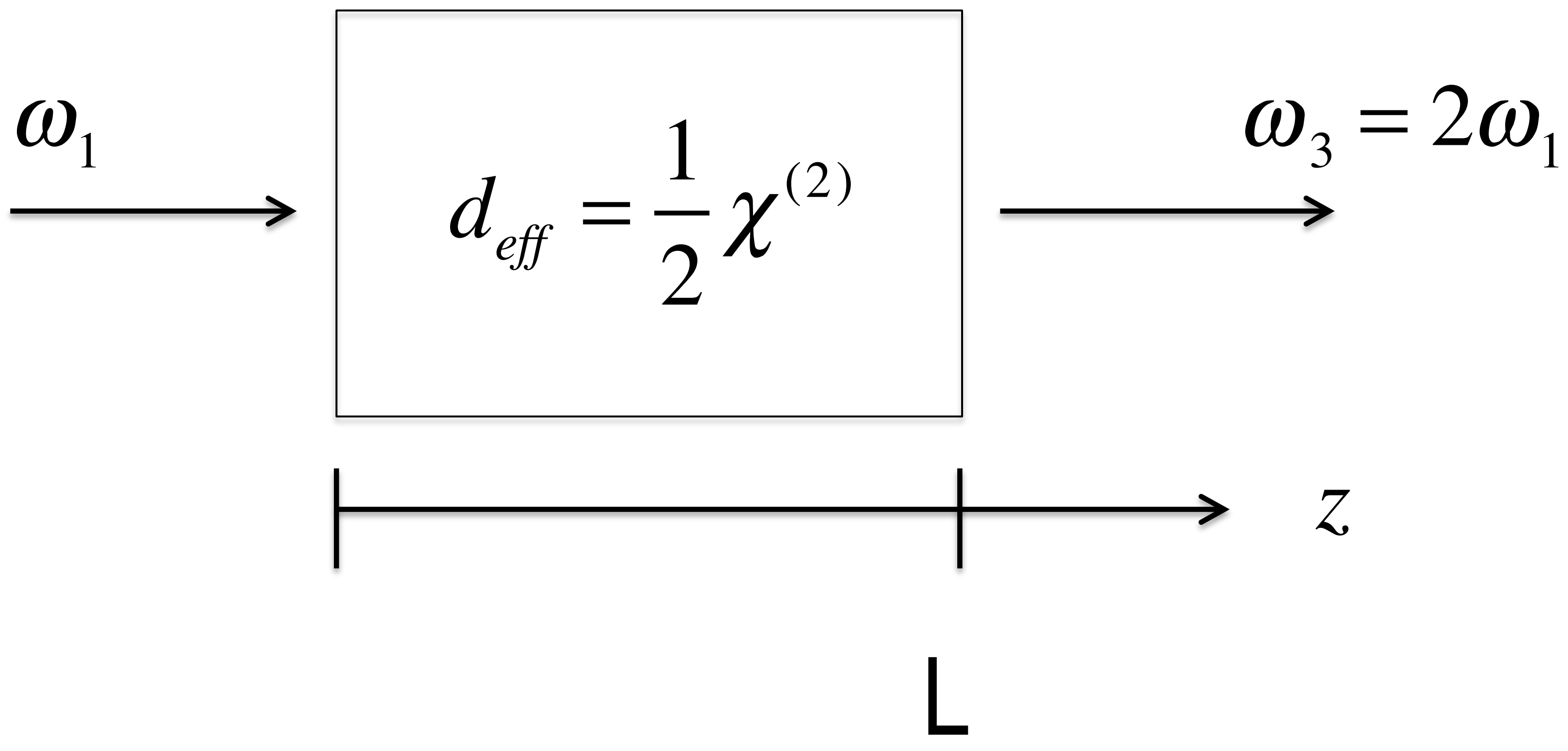
Non-linear frequency conversion I

- Frequency doubling examples

Second harmonic generation



Wave equation $\frac{\partial^2}{\partial z^2} E_j(z,t) - \frac{n^2}{c^2}\frac{\partial^2 E_j(z,t)}{\partial t^2} = -\frac{1}{\varepsilon_o c^2} \cdot \frac{\partial^2 P_j^{NL}(z,t)}{\partial t^2}$ j=1,3

Non linear pol: $P^{NL} = \varepsilon_0 \chi^{(2)} [E_1 e^{-i\omega_1 t} + E_2 e^{-i\omega_2 t} + c.c]^2$

$\omega_1 = \omega_2$

$$P^{NL} = \underbrace{\varepsilon_0 \chi^{(2)} E_1^2}_{\text{Term arising from SHG}} + \underbrace{2\varepsilon_0 \chi^{(2)} E_1 E_3}_{\text{Term arising from sum freq.}}$$

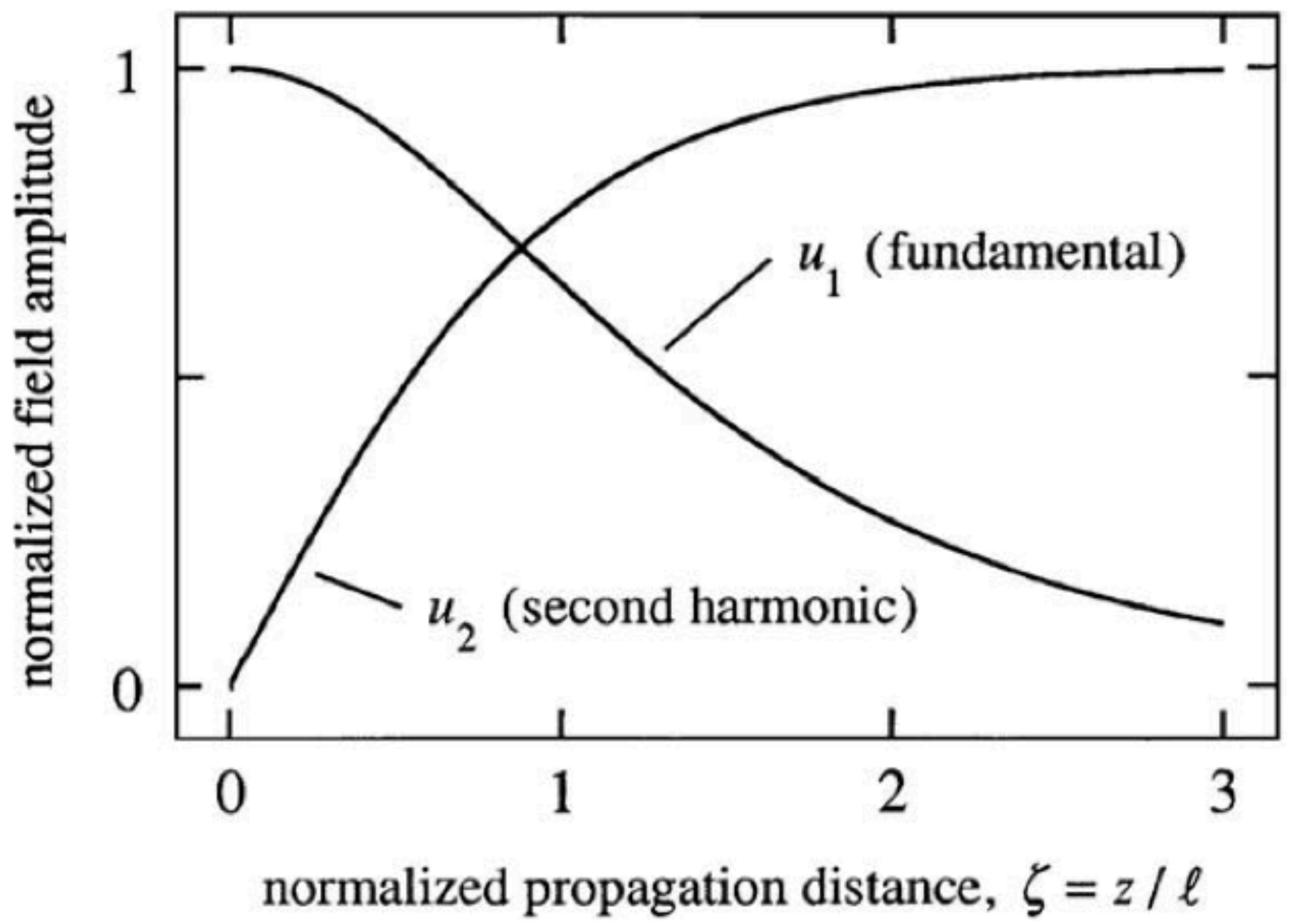
Coupled wave for E1 and E2. $\Delta k = 2k_1 - k_3$

Conservation of energy : $I_1(z) + I_3(z) = I$

Normalized field u1(z) and u2(z) $u_1(z) + u_3(z) = 1$

Caracteristic distance $l = \left(\frac{2n_1^2 n_3}{\varepsilon_0 c I}\right)^{1/2} \frac{c}{2\omega_1 d_{eff}}$

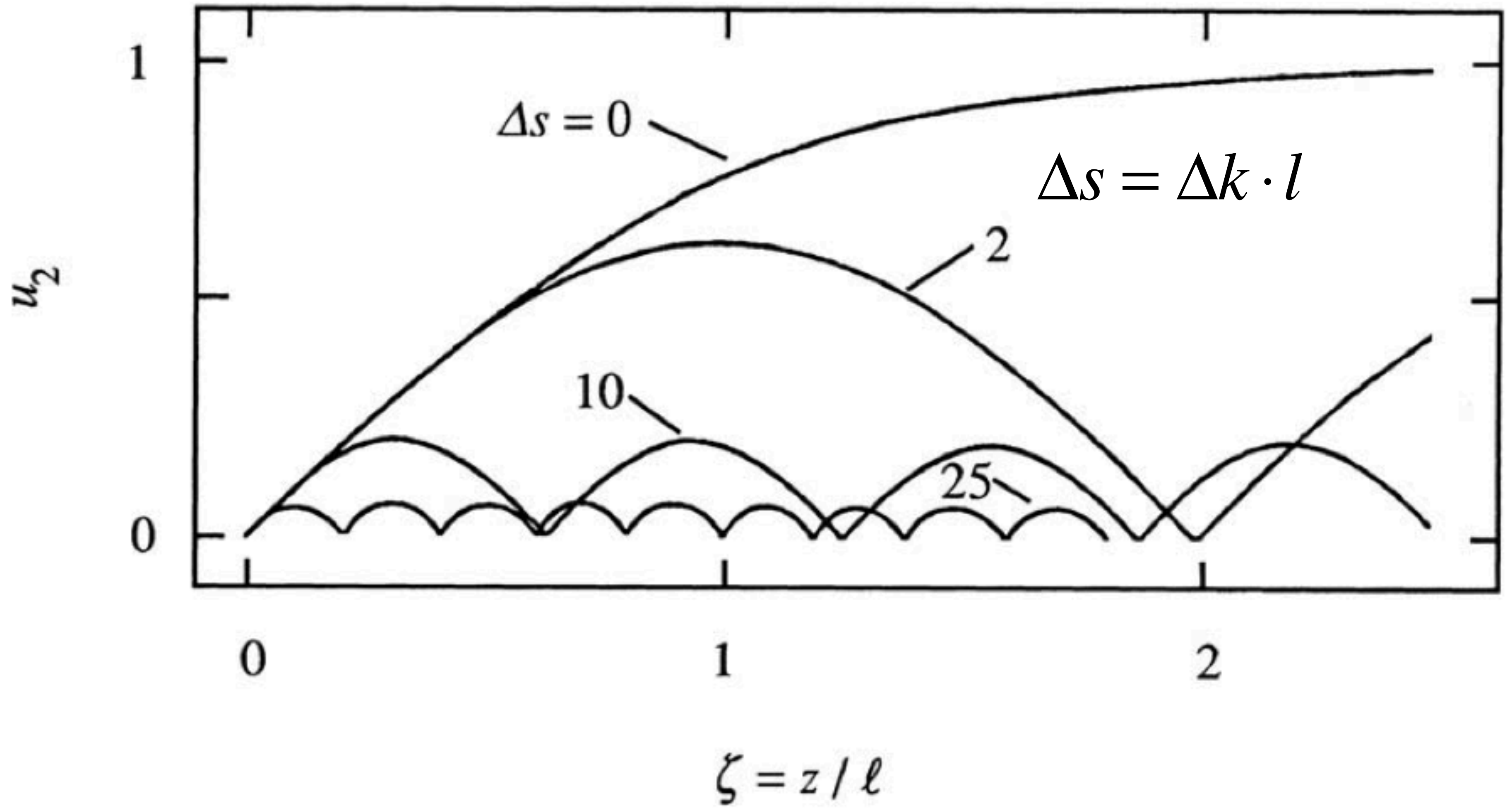
Second harmonic generation



Perfect phase matching, SHG field zero at entrance

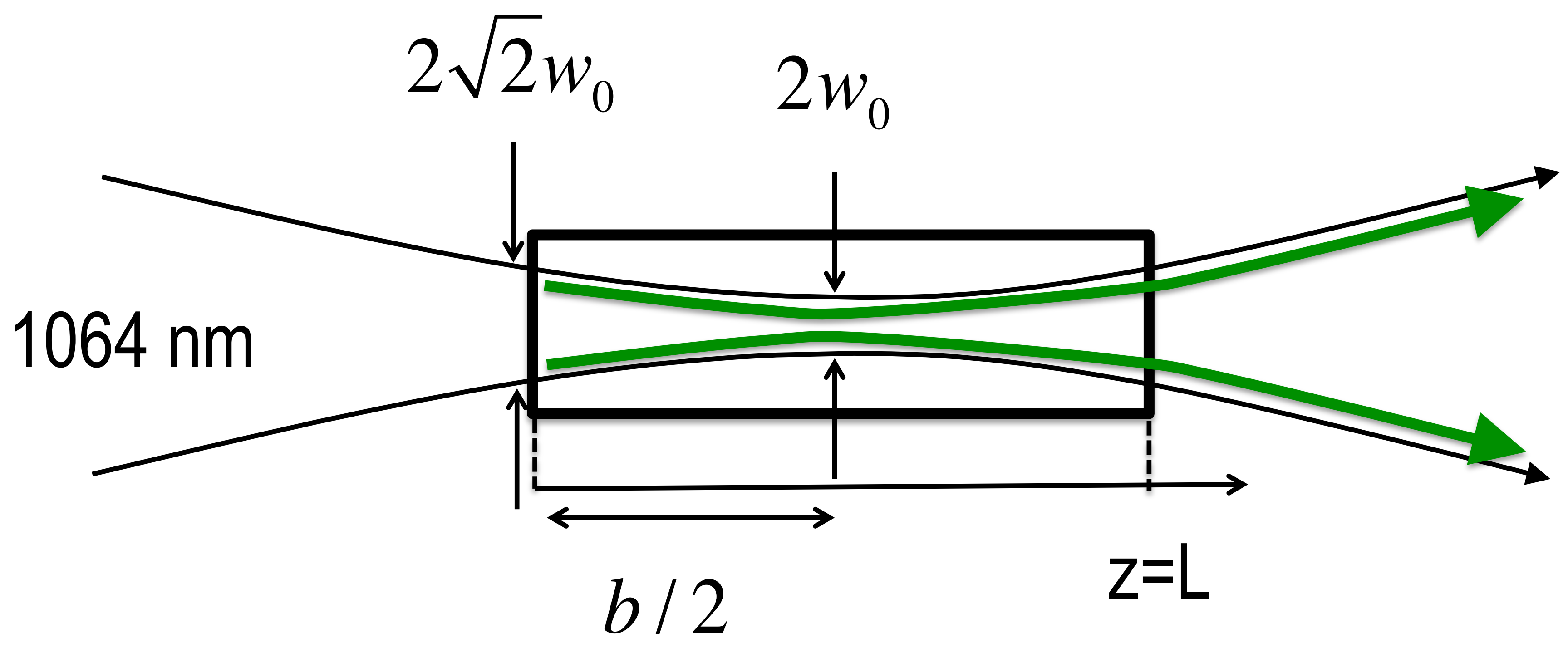
$$u_3(\zeta) = \tanh(\zeta)$$

$$u_1(\zeta) = \mathrm{sech}(\zeta)$$



Effect of phase mismatch

Conversion efficiency



Intensity at minimum spot $$I_w = \frac{P}{\pi w_o^2}$$

Gaussian beam focusing: depth of field $$b = \frac{2\pi w_0^2}{\lambda_1 / n_1} = L$$

$$l = \left(\frac{2n_1^2 n_3}{\varepsilon_0 c I_w}\right)^{1/2} \frac{c}{2\omega_1 d_{eff}} \qquad \zeta = L/l = \left(\frac{16\pi^2 d_{eff}^2 LP}{\varepsilon_0 c n_1 n_3 \lambda_1^3}\right)^{1/2}$$

L=1cm, P=1W, n=2, lambda=532 nm, deff=4 pm/V

$$\zeta = 0.14$$

$$\eta = \frac{u_2^2(L/l)}{u_1^2(0)} = \frac{\tanh^2(L/l)}{1} = \frac{0.02}{1} = 2\%$$