Solution de la série de TD N°2

Exercice 1 : corrigé en présentiel

Exercice 2

1.

Constante de propagation: $\beta = \sqrt{k^2n^2 - (m+1)^2 \frac{\pi^2}{h^2}}$

Angle de propagation $\cos\theta_m = \frac{(m+1)\pi}{knh}$

Nombre des modes: $M = \frac{2h}{\lambda}\sqrt{n^2 - n'^2}$

2.

$$M = \frac{2h}{\lambda}\sqrt{n^2 - n'^2} = \frac{2 \times 30}{0.85}\sqrt{(1.52)^2 - (1.42)^2} \simeq 38$$

$$\beta_0 = \sqrt{k^2n^2 - \frac{\pi^2}{h^2}} = \sqrt{\left(\frac{2\pi \times 1.52}{0.85}\right)^2 - \frac{\pi^2}{(30)^2}} = 11.235\,\mu\text{m}^{-1}$$

$$\beta_1 = \sqrt{k^2n^2 - \frac{4\pi^2}{h^2}} = \sqrt{\left(\frac{2\pi \times 1.52}{0.85}\right)^2 - \frac{4\pi^2}{(30)^2}} = 11.234\,\mu\text{m}^{-1}$$

$$\cos\theta_0 = \frac{\pi}{knh} = \frac{\lambda}{2nh} = \frac{0.85}{2 \times 1.52 \times 30} = 9.3202 \times 10^{-3}$$

$$\Longrightarrow \theta_0 = \arccos(9.3202 \times 10^{-3}) = 1.5615\,\text{rad} = 89.467\,°$$

$$\cos\theta_1 = \frac{2\pi}{knh} = \frac{\lambda}{nh} = \frac{0.85}{1.52 \times 30} = 0.01864$$

$$\Longrightarrow \theta_1 = \arccos(0.01864) = 1.5522\,\text{rad} = 88.935\,°$$

3.

$$M = \frac{2h}{\lambda}\sqrt{n^2 - n'^2} = \frac{2h}{\lambda'}\sqrt{n^2 - n''^2}$$

$$\Longrightarrow \lambda' = \lambda\frac{\sqrt{n^2 - n''^2}}{\sqrt{n^2 - n'^2}} = 0.85\frac{\sqrt{(1.52)^2 - (1.48)^2}}{\sqrt{(1.52)^2 - (1.42)^2}} = 0.54305\,\mu\text{m}$$

4.

$$x_m = \frac{1}{\sqrt{\beta_m^2 - k^2n_1^2}}$$

$$x'_0 = \frac{1}{\sqrt{\beta_0^2 - k^2n'^2}} = \frac{1}{\sqrt{\beta_0^2 - \left(\frac{2\pi n'}{\lambda}\right)^2}} = \frac{1}{\sqrt{(11.235)^2 - \left(\frac{2\pi \times 1.42}{0.85}\right)^2}} = 0.24964\,\mu\text{m}$$

$$h'^* = h + 2x'_0 = 30 + 2 \times 0.24964 = 30.499\ \ \mu\text{m}$$

$$\beta''_0 = \frac{2\pi}{\lambda'}\sin\theta_0 = \frac{2\pi}{0.54305}\sin(1.5615) = 3.6827\pi = 11.570$$

$$x'_0 = \frac{1}{\sqrt{\beta_0'^2 - k^2n'^2}} = \frac{1}{\sqrt{\beta_0'^2 - \left(\frac{2\pi n''}{\lambda'}\right)^2}}$$

$$= \frac{1}{\sqrt{(11.570)^2 - \left(\frac{2\pi \times 1.48}{0.54305}\right)^2}} = \frac{1}{\sqrt{133.86 - 29.71\pi^2}} = -7.9214 \times 10^{-2}j$$

ou si on conserve l'ancienne β_0 :

$$x'_0 = \frac{1}{\sqrt{\beta_0^2 - k^2n'^2}} = \frac{1}{\sqrt{\beta_0^2 - \left(\frac{2\pi n''}{\lambda'}\right)^2}} = \frac{1}{\sqrt{(11.235)^2 - \left(\frac{2\pi \times 1.48}{0.54305}\right)^2}}$$

$$= \frac{1}{12.923j} = -7.7382 \times 10^{-2}j$$

Exercice 3 : corrigé en présentiel

Exercice 4

1.

Ouverture Numérique: $ON = \sqrt{n_1^2 - n_2^2}$

pour $\lambda = 1.13\,\mu$m on a $n_1 = A + B\lambda^{-2} = 1.583 + \dfrac{2.174 \times 10^{-2}}{(1.13)^2} = 1.6$

$ON = \sqrt{(1.6)^2 - (1.5)^2} = 0.556\,78$

$\alpha = \arcsin ON = \arcsin(0.556\,78) = 0.590\,5\,\text{rad} = 33.833\,°$

2.

Nombre de modes $M = \dfrac{V^2}{2}\dfrac{\alpha}{\alpha+2} = \dfrac{k^2a^2ON^2}{2} = 2\left(\dfrac{\pi \times 20 \times 0.556\,78}{1.13}\right)^2 \simeq 1917$

3.

$$\alpha_{dB/km} = \frac{10}{L}\log_{10}\left(\frac{P_s}{P_e}\right) = \frac{10}{20}\log\left(\frac{P_e/e}{P_e}\right) = \frac{1}{2}\log_{10}\frac{1}{e} = -0.217\,15 \text{ dB/ km}$$

4.

Dispersion intermodale $\Delta\tau_n = \dfrac{L}{2cn_1}(ON)^2$

5.

$$\Delta\tau_n = \frac{L}{2cn_1}(ON)^2 = \frac{20 \times 10^3 \times (0.556\,78)^2}{2 \times 3 \times 10^8 \times 1.6} = 6.458\,4 \times 10^{-6}\,\text{sec}$$

$$M_d = -\frac{\lambda}{c}\frac{d^2n}{d\lambda^2} = -\frac{\lambda}{c}\left(\frac{6B}{\lambda^4}\right) = -\frac{6 \times 2.174 \times 10^{-2}}{3 \times 10^5 \times (1.13)^3} = -3.013\,4 \times 10^{-7}\,\text{sec km}^{-1}\,\mu\text{m}^{-1}$$

$$\Delta\tau_m = M_d L \Delta\lambda = -3.013\,4 \times 10^{-7} \times 20 \times 0.01 = -6.026\,8 \times 10^{-8}\,\text{sec}$$

$$D_g = \frac{8.37\,\lambda}{a^2 n_1} = \frac{8.73 \times 1.13}{(20)^2 \times 1.6} = 1.541\,4 \times 10^{-2}\ \text{ps km}^{-1}\,\text{nm}^{-1}$$

$\Delta\tau_g = D_g L \Delta\lambda = 1.541\,4 \times 10^{-2} \times 20 \times (0.01 \times 10^{-3}) = 3.082\,8 \times 10^{-6}\,\text{ps} = 3.082\,8 \times 10^{-18}\,\text{sec}$

$$\Delta t = \sqrt{(6.458\,4 \times 10^{-6})^2 + (-6.026\,8 \times 10^{-8})^2 + (3.082\,8 \times 10^{-18})^2} = 6.458\,7 \times 10^{-6}\,\text{sec}$$

Exercice 5

1. Diode laser monomode
   - Largeur de raie d'environ 100 fm, ce qui donne en fréquence : $\Delta f = \frac{c\Delta\lambda}{\lambda^2}$
   - Application numérique : $\Delta f = 18\,MHz$.
2. La stabilité en température doit être meilleure que 1/100°C
3. Avec le courant de polarisation, il y a une élévation de 0.5°C, ce qui cause un écart de 5 pm équivalent à 900 MHz.