Raman Laser on a Silicon waveguide

Researchers from INTEL company recently demonstrated the realization of a laser on a silicon chip using the stimulated Raman scattering effect. A ridge waveguide of length $L = 4{,}8\,\text{cm}$ is used (waveguide with a "S" shape in Fig. 1). The effective mode area of the waveguide is $A_{eff} = 0{,}17\,\mu\text{m}^2$. A cw laser beam at the wavelength $\lambda_P = 1536\,\text{nm}$ is injected in the waveguide. The cavity is formed by two mirrors with the reflectivities for the output signal of $R_1 = 0.925$, for the front mirror, and $R_2 = 1$, for the back mirror (see Fig. 1). Their reflectivity at λ_P is zero.

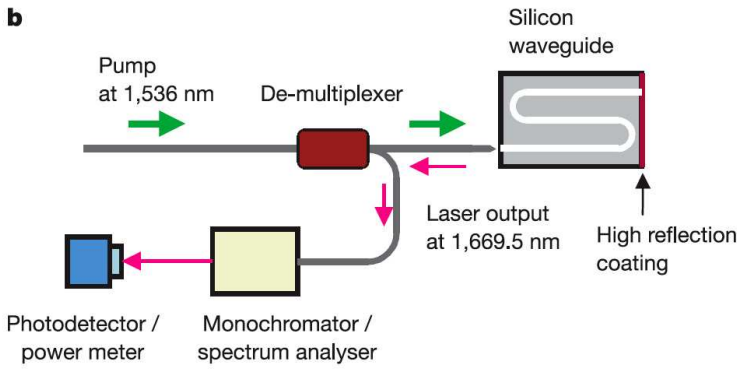

FIG. 1 – *Experimental set-up for the realization of a Raman laser on a Silicium chip - Source : Rong et al. Nature, Vol. 433 (2005).*

The Raman shift in silicon is 15,6 THz. The value of the Raman gain is G_R =8 cm/GW. We remind the coupled equations which describe the evolution of the power of the signal P_s and of the pump P_p waves (validity: resonant interaction and copropagative geometry):

$$\frac{dP_s}{dz} = -\alpha P_s + \frac{G_R}{A_{eff}} P_p P_s, \tag{1}$$

$$\frac{dP_p}{dz} = -\alpha P_p - \frac{\omega_p}{\omega_s}\frac{G_R}{A_{eff}} P_p P_s, \tag{2}$$

with α the coefficient of attenuation of the waveguide, which is assumed to be equals for both the signal and the pump.
Subsequently, the undepleted pump approximation is assumed.

1. Give the wavelength of the outgoing beam.
2. Neglecting the attenuation losses in the waveguide, give the expression of the amplification gain for the signal : $G_s = Ps(L)/P_s(0)$.
3. Derive the oscillation condition (or the lasing condition) of the cavity.
4. Calculate the threshold pump power required to achieve the oscillation condition.
   Now, we take into account the effect of the attenuation of the waveguide.
5. Give a new expression for G_s in terms of the effective length of the waveguide L_{eff}, which is expressed in terms of L and α.
6. Assuming a coefficient of attenuation equal to $0{,}5\,\text{cm}^{-1}$, calculate the threshold of the cavity. Compare the value to the one calculated at question 4. Is it a reasonable value in practise?

Solutions

1. 1669,5 nm
2. Expression de G_s donnée en cours.
3. $R_1 R_2 G_s^2 = 1$
4. 3,6 mW
5. Nouvelle expression de G_s + expression de L_{eff} : cf cours.
6. 300 mW