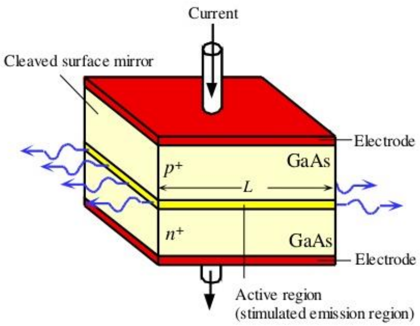
Measurement of the Linewidth broadening factor

Linewidth broadening factor (LBF)



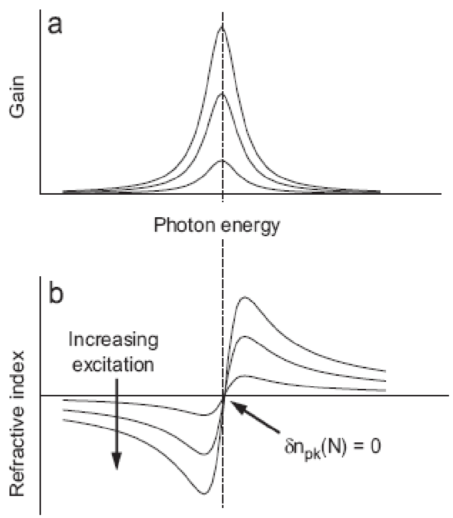
❑ Linewidth broadening factor, or α-factor, describes the coupling between the carrier-induced variation of real and imaginary parts of the optical susceptibility.

C. H. Henry, JQE QE-18, 259, 1982

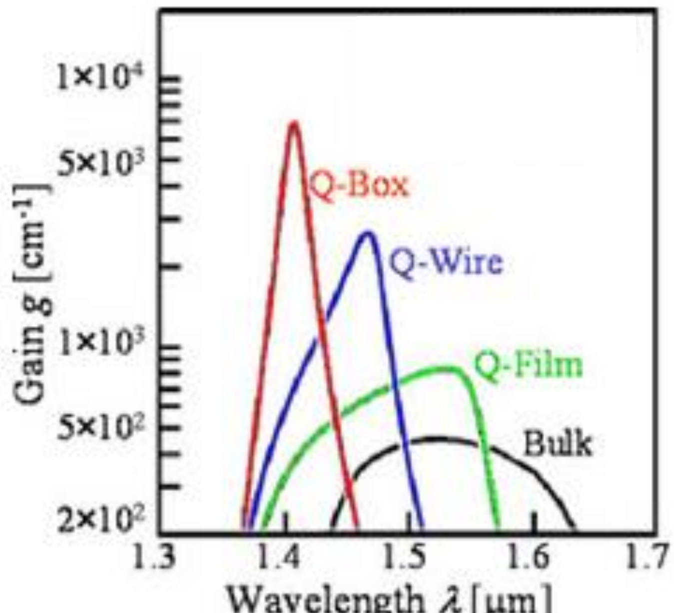
$$\alpha_H = \frac{\partial \boxed{Re\{\chi\}} / \partial N}{\partial \boxed{\text{Im}\{\chi\}} / \partial N}$$

Refractive index

Optical gain



Kramer-Kronig relation



Zero α-factor value was expected in Qdot lasers!

M. Asada et al. JQE QE-22, 1915, 1986

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Importance of LBF

- Spectral linewidth broadening

C. H. Henry, JQE QE-18, 259, (1982)

$$\boxed{\Delta\upsilon \propto \left(1+\alpha_H^2\right)}$$

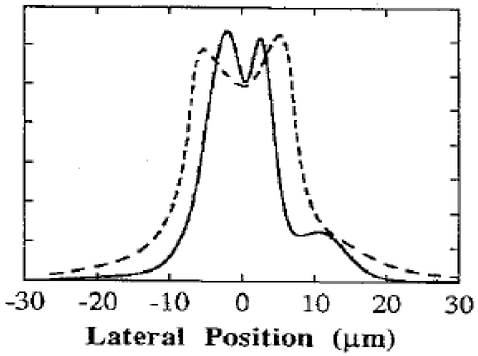
- Chirp under direct modulation

L. A. Coldren, Diode Lasers and…, Wiley, 1995

$$\boxed{\Delta f \propto \alpha_H}$$

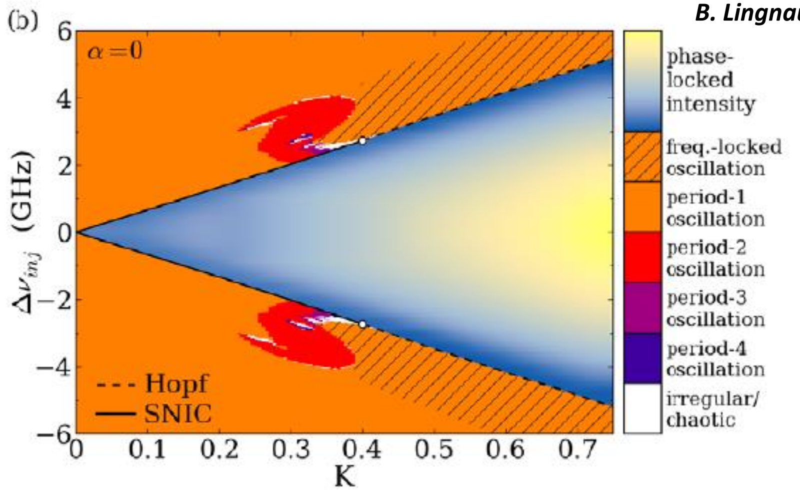
- Laser beam filamentation

J. R. Marciante, G. P. Agrawal. JQE32, 590 (1996)



- Optical injection/feedback dynamics

B. Lingnau, et al. NJP15, 093031 (2013)



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Hakki-Paoli method

- The definition of the LBF is equivalent to

$$\alpha_H = -\frac{4\pi}{\lambda}\frac{dn/dN}{dg/dN}$$

- Assume the gain g and the refractive index n have a linear dependence with the carrier density N (i. e. no gain compression)

$$\alpha_H = -\frac{4\pi}{\lambda}\frac{\Delta n}{\Delta g}$$

- The equivalent forms are

$$\frac{c}{n} = \lambda v \Rightarrow$$
$$\frac{\Delta n}{n} = \frac{\Delta\lambda}{\lambda}$$
$$\frac{\Delta n}{n} = -\frac{\Delta v}{v} \Rightarrow$$
$$\alpha_H = -\frac{4\pi}{\lambda^2}\frac{n\Delta\lambda}{\Delta g}$$

- The mode spacing

$$D_v = \frac{c}{2nL} \Rightarrow$$
$$\frac{D_v}{v} = \frac{D_\lambda}{\lambda} \Rightarrow$$
$$D_\lambda = \frac{\lambda}{v}D_v = \frac{\lambda}{v}\frac{c}{2nL} = \frac{\lambda^2}{2nL}$$

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Hakki-Paoli method

- The LBF

$$\alpha_H = -\frac{2\pi}{LD_\lambda}\frac{\Delta\lambda}{\Delta g}$$

- Here the wavelength and the gain are varied by changing the bias current

$$\alpha_H = -\frac{2\pi}{LD_\lambda}\frac{\Delta\lambda / \Delta I}{\Delta g_{net} / \Delta I}$$
$$with$$
$$g_{net} = g - \alpha_i$$

$$g_{net}^{th} = \alpha_m = \frac{1}{2L}\ln\frac{1}{R_1 R_2}$$

- The net modal gain is extracted from the peak-to-valley ratio of the amplified spontaneous spectrum

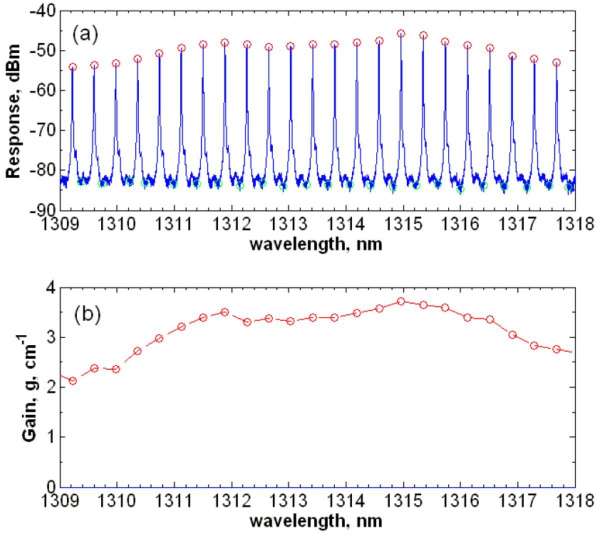
$$g_{net} = \frac{1}{L}\ln\left(\frac{1}{R}\frac{\sqrt{r}-1}{\sqrt{r}+1}\right)$$
$$with$$
$$r = P_{\max} / P_{\min}$$

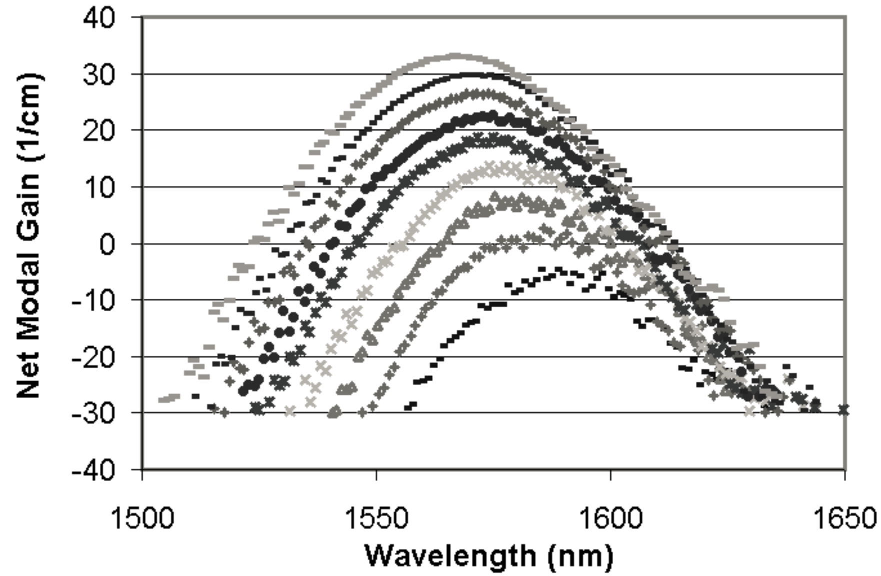
- The optical power

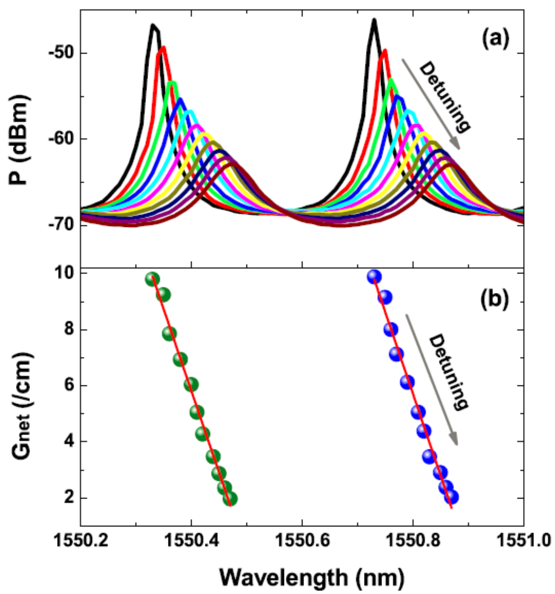
$$(dBm) = 10\log_{10}(mW)$$

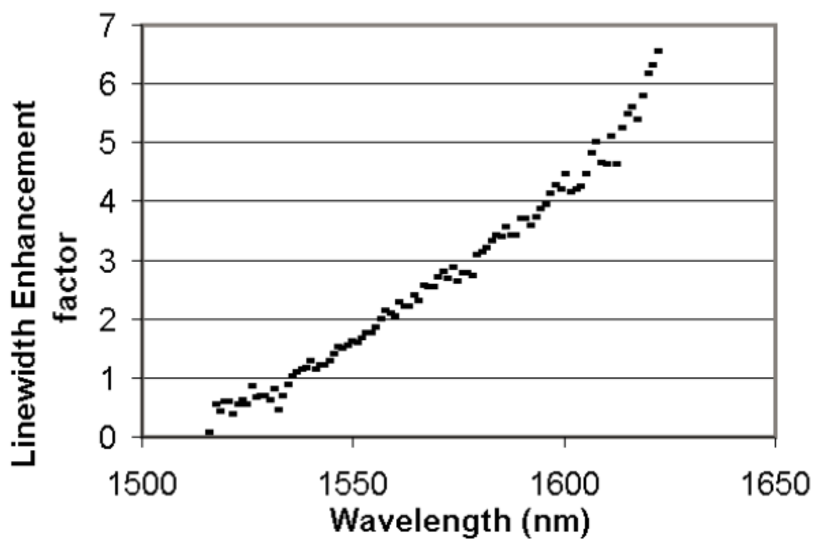
- The wavelength change is directly obtained from the optical spectrum

Hakki-Paoli method

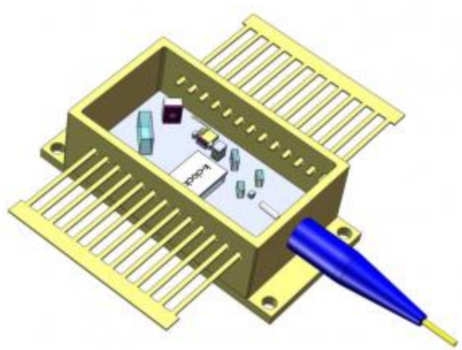


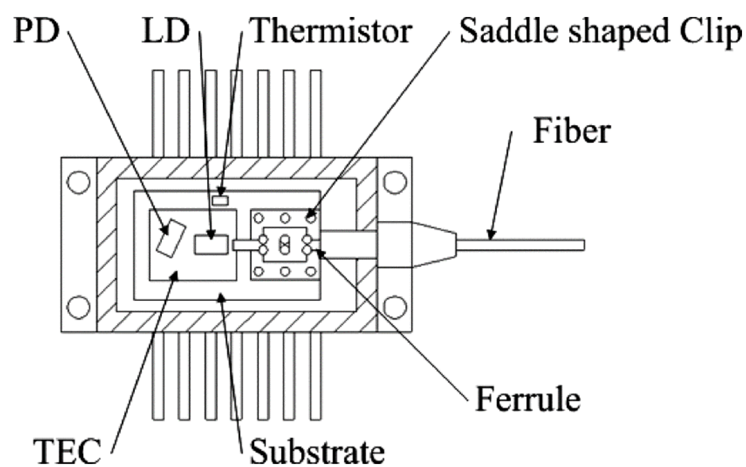






Laser device under test





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Measurement

❑ The device under study is a quantum well Fabry-Perot laser, lasing around 1550 nm. The refractive index is 3.5, and the facet reflectivity is 0.32.

1. L-I curve measurement

a) Measure the L-I curves from 0 mA to 80 mA (step 2 mA) at 15^0 , 20^0, and 30^0, and plot it

b) From the L-I plot, extract the lasing threshold I_{th}.

2. Optical spectrum measurement

Condition: Set the temperature at 20^0, the bias current at the threshold, adjust the spectrum peak to the middle of the screen, set the span at 20 nm, set the resolution at 0.02 nm.

a) Measure the optical spectrum at the lasing threshold, and plot it

b) From the spectrum, extract the mode spacing both in wavelength D_x and in freauency D_v, and then calculate the cavity length.

Measurement

3. Net gain measurement

1) Following the conditions in 2., measure the optical spectra from (I_{th}-10) mA to (I_{th}+10) mA, with a step of 0.5 mA.
2) Extract the net gain from the optical spectra for each bias current, and plot it (gain clamping)
3) Below threshold, plot dg_{net}/dI as a function of the wavelength in the 20-nm span
4) Below threshold, plot $(d\lambda/dI)_{below}$, which is due to both carrier change (blue shift) and thermal effect (red shift) .
5) Above threshold, plot $(d\lambda/dI)_{above}$, which is due to only the thermal effect
6) Below threshold, the carrier induced wavelength shift is obtained by

$$d\lambda/dI = (d\lambda/dI)_{below} - (d\lambda/dI)_{above}$$

7) Plot the linewidth broadening factor as a function of the wavelength

$$\boxed{\alpha_H = -\frac{2\pi}{LD_\lambda}\frac{d\lambda/dI}{dg_{net}/dI}}$$