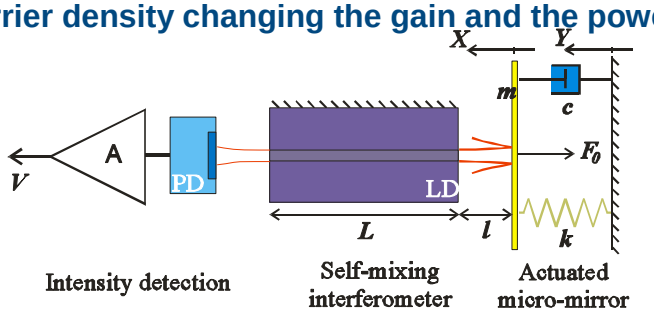
External cavity laser sensor

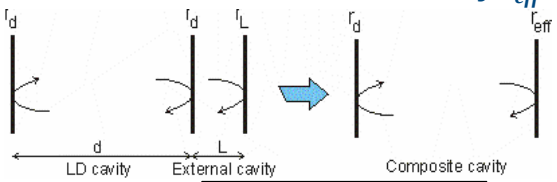
- Modulation in the external cavity length results in a variation of the feedback in the LD that modulate the carrier density changing the gain and the power



Chollet F., Hegde G. M., Zhang XM., Liu AQ., Asundi A., "Vibration measurement with a micromachined mirror in a very-short external cavity laser", Sensors and Actuators A, vol. 116, no. 2 : 232 -240 (2004)

External cavity - model

- Improved model for any feedback level (no weak feedback assumption) but neglecting multiple reflections
- Based on effective reflectivity r_{eff}



$$r_{eff} = R_{eff}\, e^{(-i\,\phi_L)}$$

$$R_{eff} = r_d T(\zeta, L)$$

$$\phi_L = \arcsin\left(\frac{\zeta \sin(2\pi\nu 2d/c)}{T(\zeta, L)}\right)$$

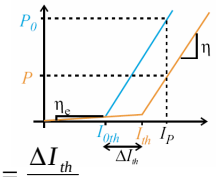
$$T(\zeta, L) = \sqrt{1 + \zeta^2 + 2\zeta \cos(2\pi\nu \tfrac{2L}{c})}$$

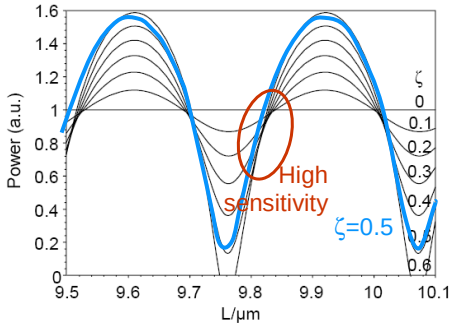
$$\zeta = \frac{f_L}{f_d} = \frac{\gamma(1 - r_d^2) r_L}{r_d}$$

Relative feedback

External cavity - model

- From stationarity condition, but without assuming ζ <<1 we relate the change in gain to the change of power





$$\Delta g = -\frac{\ln(T(\zeta, L))}{d} = \frac{\Delta I_{th}}{b}$$

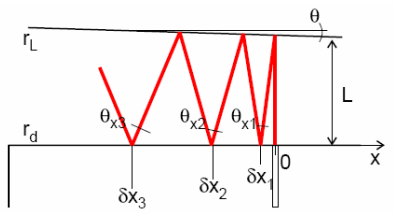
$$P = P_0\left(1 + \frac{k_1 b \ln(T(\zeta, L))}{I_P - I_{0th}}\right)$$

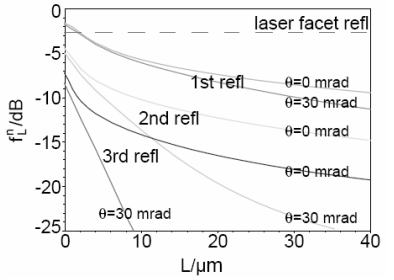
With a plane mirror – simple cavity without optical elements – a relative feedback of 0.5 is achieved with L~10μm

External cavity - model

- In the model we neglect the multiple reflection yet we assume that the feedback is strong – how is this possible?
- Diffraction and mirror tilt are the key: only the first reflection couples back with a high efficiency.

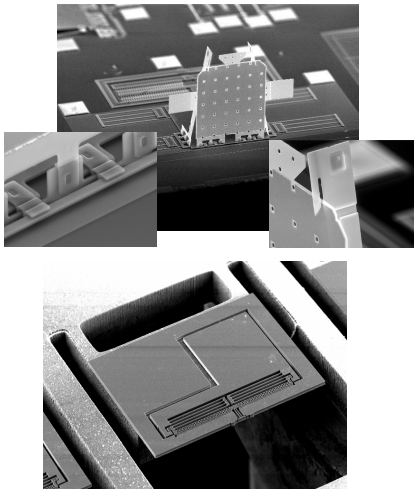
$$E(x, y, s, \theta_x, \theta_y) = \sqrt{\frac{2P_0}{w_x w_y \pi}} \times e^{i(k/2)(2\theta_x x + 2\theta_y y + x^2/R_x + y^2/R_y)} \times e^{-(x^2/w_x^2 + y^2/w_y^2)}$$





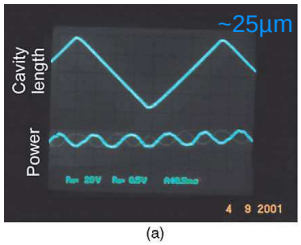
External cavity - mirrors

- **Actuator + short cavity**
- **Surface micro-machined mirror with**
  - ➔ Edge position
  - ➔ Top-locking feature
  - ➔ Compact hinges
- **SOI micro-machined mirror**
  - ➔ Requires no assembly

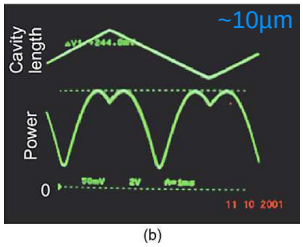


External cavity - feedback

- **The length of the cavity controls the relative feedback and the fringe visibility**
- **Top: cavity length ~25µm**
  - ➔ ζ ~ 0.2
- **Bottom: cavity length ~10µm**
  - ➔ ζ ~ 0.5



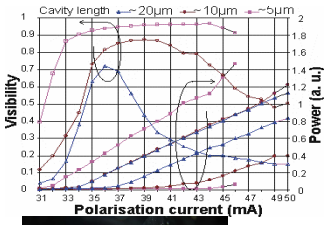
(a)

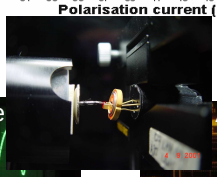


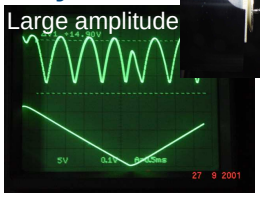
(b)

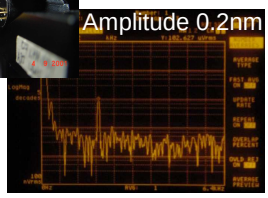
External cavity - resolution

- With cavity < 10µm the sensitivity is highest
- Resolution is measured at least as 5pm/Hz$^{1/2}$ @ 2kHz
- Dynamic >10^5
- Noise at low frequency









External cavity - packaging

- Packaging the hybrid system is a challenge and still need a complete solution
- Bumper on the mirror side are added to control the cavity length by contact