**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


**External cavity - model**

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

\[
T(\zeta, L) = \sqrt{1 + \zeta^2 + 2\zeta \cos(2\pi \frac{d}{L})}
\]

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

Relative feedback
External cavity - model

- From stationarity condition, but without assuming \( \zeta \ll 1 \) we relate the change in gain to the change of power

\[
\Delta g = -\frac{\ln(T(\zeta, L))}{T} = \frac{\Delta I_{\text{th}}}{b}
\]

\[
P = P_0 \left( 1 + \frac{k_t b \ln(T(\zeta, L))}{I_p - I_{\text{th}}} \right)
\]

With a plane mirror – simple cavity without optical elements – a relative feedback of 0.5 is achieved with \( L \sim 10\mu m \)

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.

\[
E(x, y, z, \theta_1, \theta_2) = \frac{2P_0}{W_1 W_2 \pi} \times e^{i k/2} e^{i 2kR_{1y} + k x^2/R_{1y} + y^2/R_{1x}} \times e^{-(x^2/w_1^2 + y^2/w_2^2)}
\]
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
  - $\zeta \sim 0.2$
- Bottom: cavity length ~10µm
  - $\zeta \sim 0.5$
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