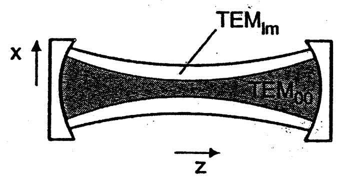
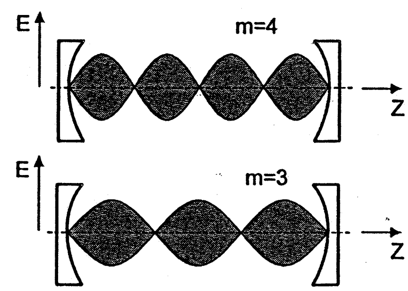
2) Non-uniform mode intensity (spatial hole burning)



transverse modes

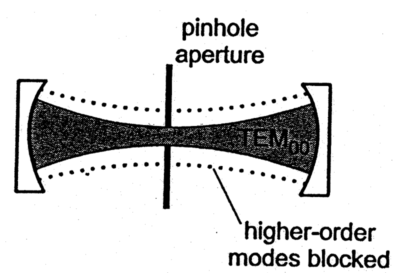


longitudinal modes

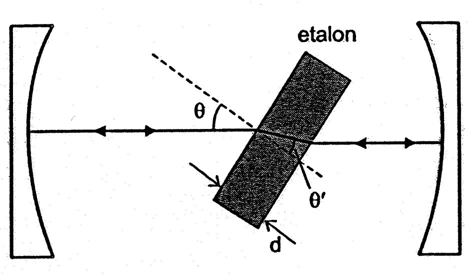
These cause inefficient use of pump energy

Acheiving single-mode operation:

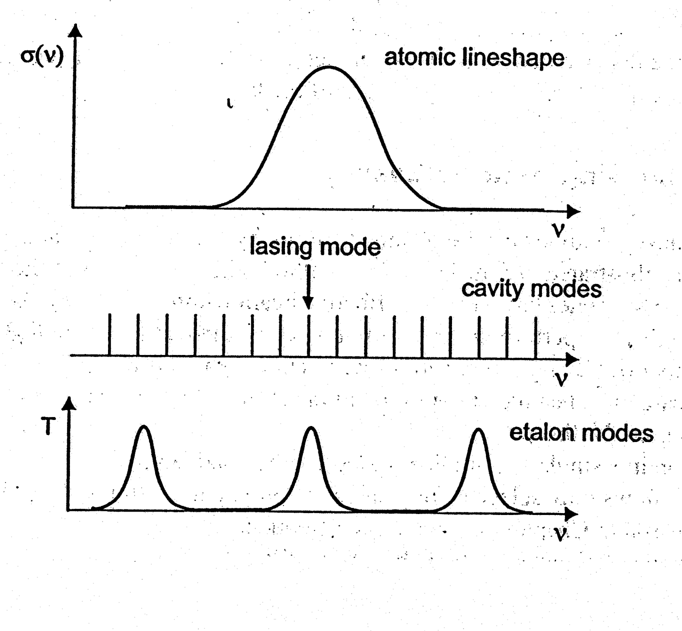
1) Single transverse mode:



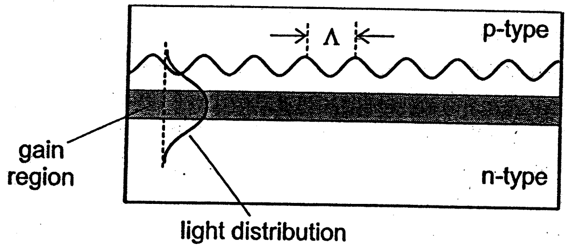
2) Single longitudinal mode:



$$\delta\nu_{etalon} = \frac{c}{2nd\cos\theta'}$$



Distributed feedback (DFB) laser



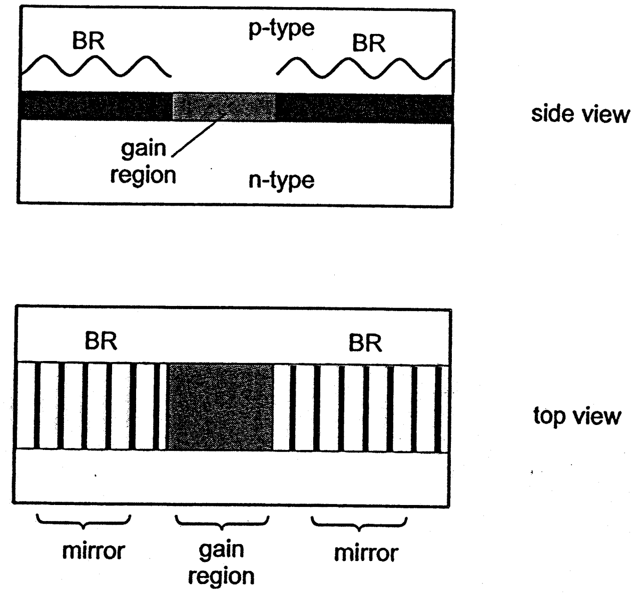
* high reflection for

$$\Lambda = \frac{\lambda}{2n} \cdot m$$

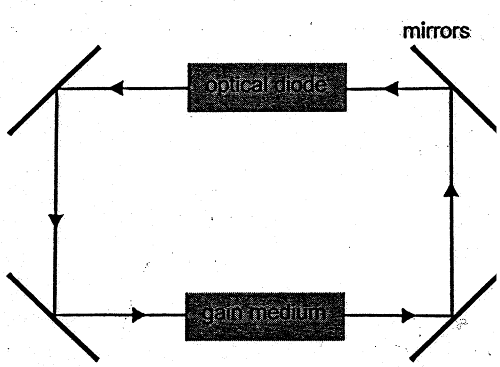
usually $m = 1$

* can temperature tune with $n(T)$

Distributed Bragg grating (DBG) laser



Ring laser



* no standing waves
* efficient utilization of pump energy

Frequency stabilization

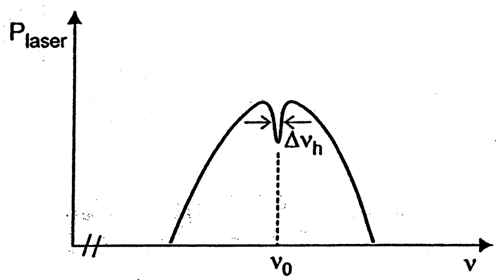
$$\nu_m = m \frac{c}{2nL}$$

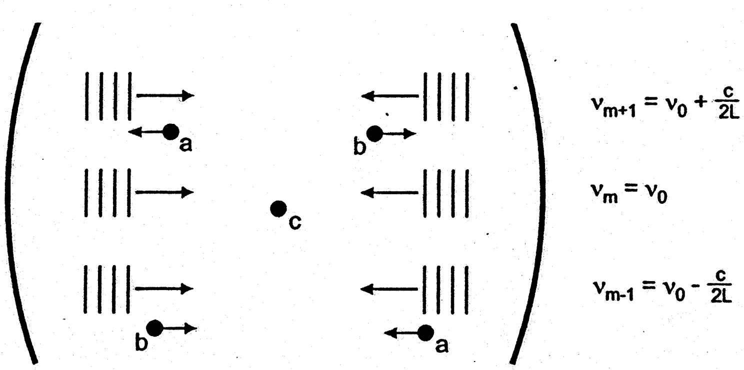
* L varies with temp
* n varies with temp
* "mode sweeping"

Solutions:

1) Temperature controller
2) Active stabalization with atomic resonance

Lamb dip

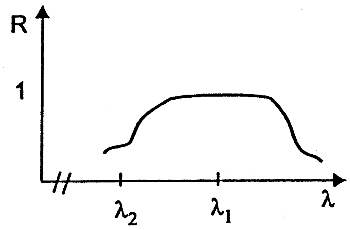


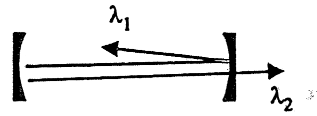


Atoms with zero velocity along axis interact with both counter propagating travelling waves.

Tuning the laser wavelength

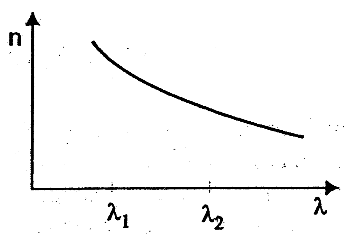
1. Spectrally selective mirrors

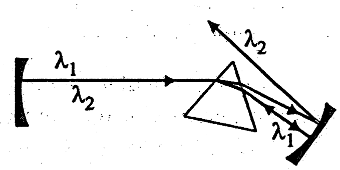




* good when λ_1 and λ_2 widely separated (He-Ne, Nd:YAG)

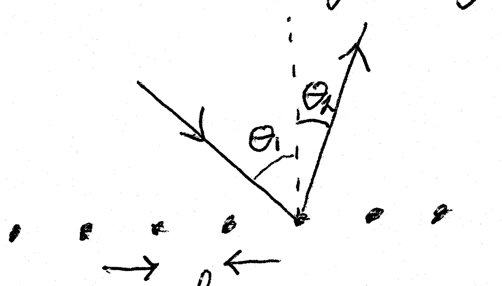
2. Intracavity prism

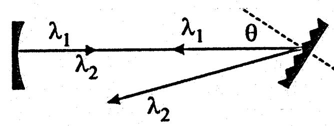




* good for low gain closely spaced λ_1 and λ_2 (e.g. Argon ion laser)

3. Diffraction grating





$$d(\sin\theta_1 - \sin\theta_2) = m\lambda$$

$m = 0, \pm 1, \pm 2, \ldots$ (order)

Retro-reflection: $\theta_2 = -\theta_1$

$2d\sin\theta_1 = m\lambda$ Bragg reflection

* Tune λ by changing θ
* Good for high gain lasers (inherent losses) (e.g. CO_2, dye laser)