Introduction to lasers

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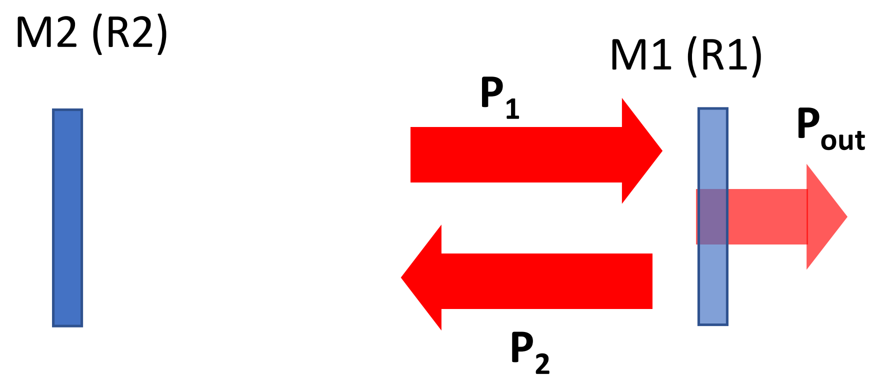
Chapter 4: Features of laser emission

I - Laser efficiency – output power

To complete

Only a small portion of the internal intensity (or power) determined by $\boldsymbol{P = Psat\left(\frac{\gamma_0}{\alpha_t} - 1\right)}$ leaves the resonator in the form of the useful light (P_{out}).

The internal power (or intensity) is the sum of P1 and P2



Optimization of the output coupler coefficient → see exercise

To complete

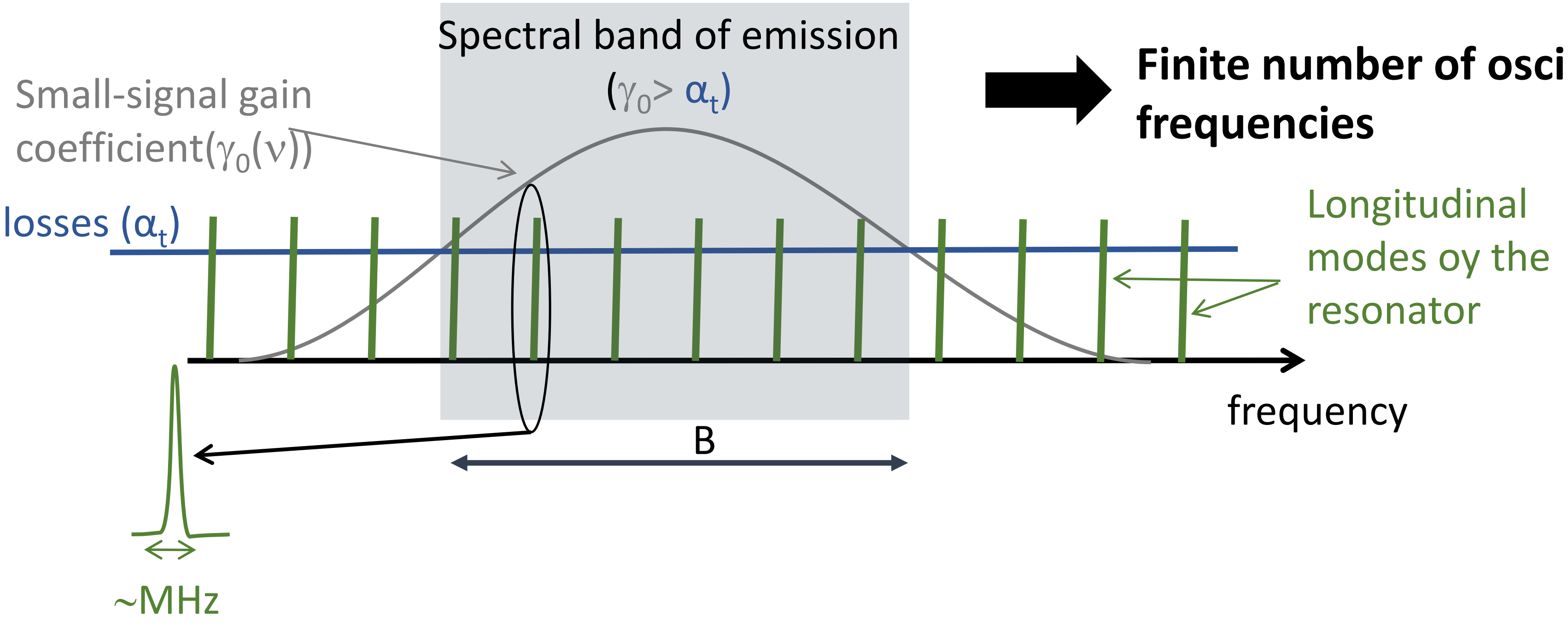
To complete

Optimization of the output coupler coefficient → see Tutorial 1

Comment: Laser efficiency → $P_{out} = f(P_{pump})$ → see Tutorial 1

II - Spectral characteristics

- Threshold condition: $\gamma_0 > \alpha_t$
- Phase condition giving the longitudinal modes: $\nu_q = q.\frac{c}{2,[L]}$

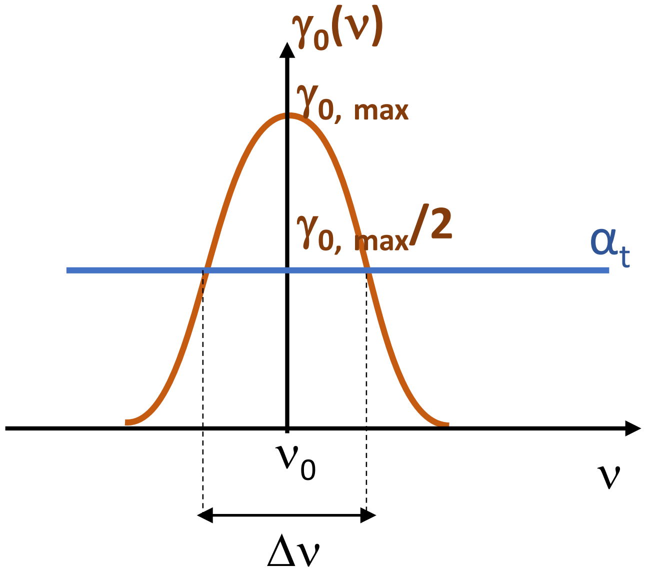


Finite number of oscillation frequencies

*

Typical spectral characteristics of well-known lasers

	$\Delta\nu$ Gain bandwidth	L (cavity)	c/2L	Number of modes*
He-Ne (λ = 632 nm)	1 GHz/ 1.3 pm	0,3 m	2 GHz	2;3 modes
Nd:YAG (λ = 1064 nm)	150 GHz/ 0.5 nm	1 m	150 MHz	1 000 modes
Ytterbium doped fiber (λ = 1050 nm)	2.7 THz/ ~10 nm	10 m	15 MHz	180.10^3 modes



To complete

III - Spatial characteristics

1. Definition of a transverse mode

Transverse mode: electromagnetic field distributions which reproduces itself after a full cavity round trip

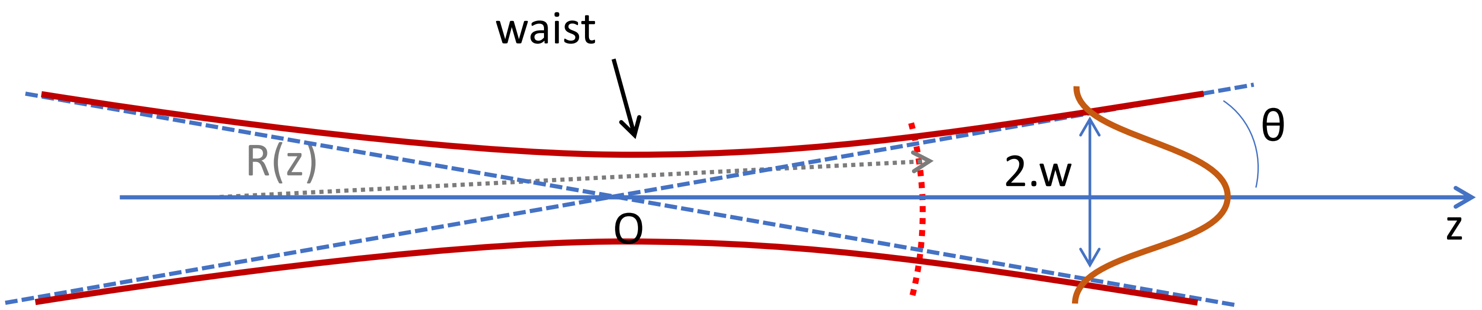
To complete

2. Autocollimation condition for free-space cavities

Case of the Gaussian beam

3. Gaussian beam: TEM00 mode

- Lowest divergence beam

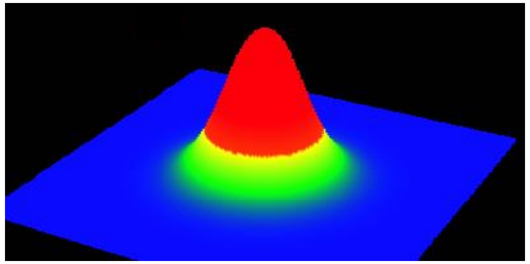


$\alpha = \pi w_0^2/\lambda$ = Rayleigh length

$w^2(z) = w_0^2[1+z^2/\alpha^2]$ = beam radius

$R(z) = z[1+ \alpha^2/z^2]$ = curvature radius

$\theta = \lambda/\pi w_0$ = half divergence

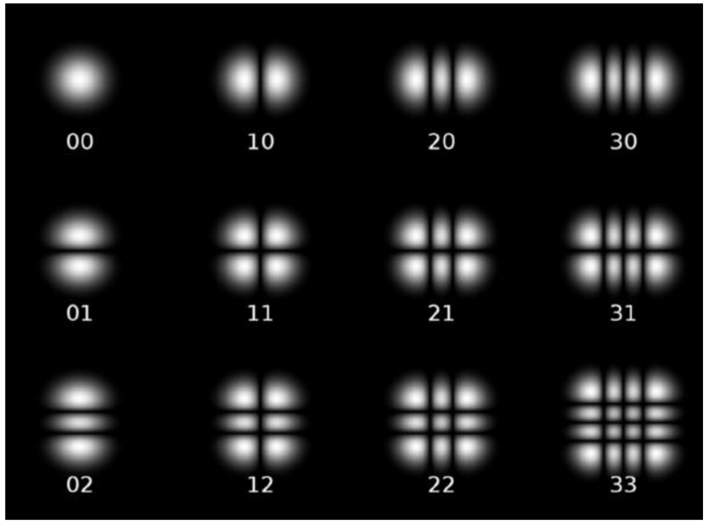


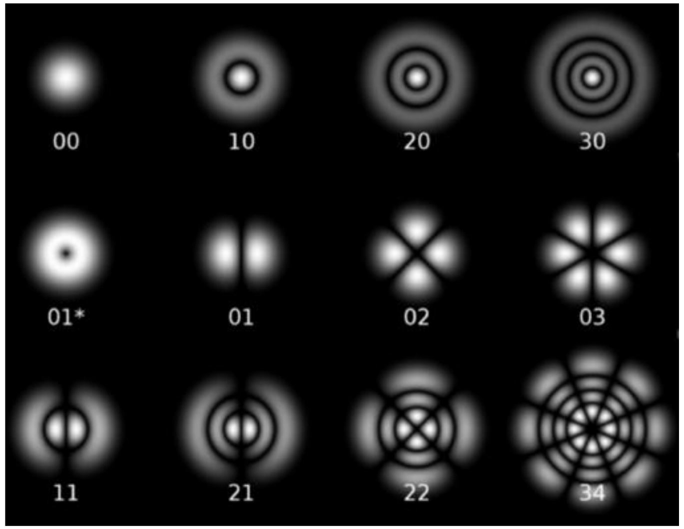
4. Other modes

Modes of free-space cavities:

Laguerre-Gauss modes : rotational symmetry
Hermite-Gauss modes: cartesian symmetry

Free-space propagation invariant





Selection by diffracting obstacles
+ cavity geometry (phase matching on mirrors)

Minimum losses

Multimode beam

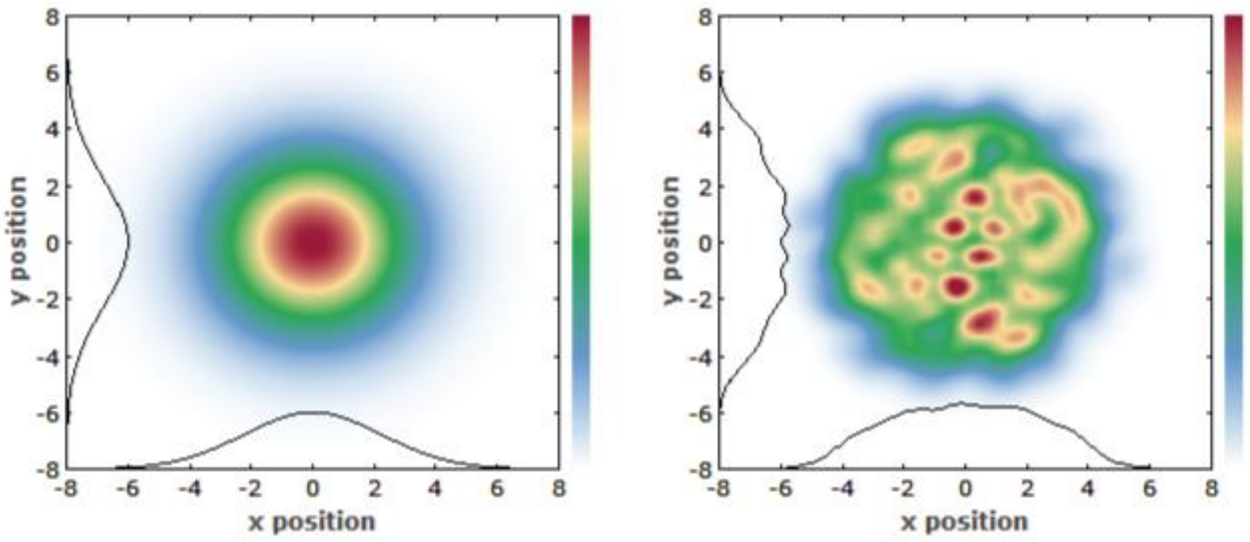
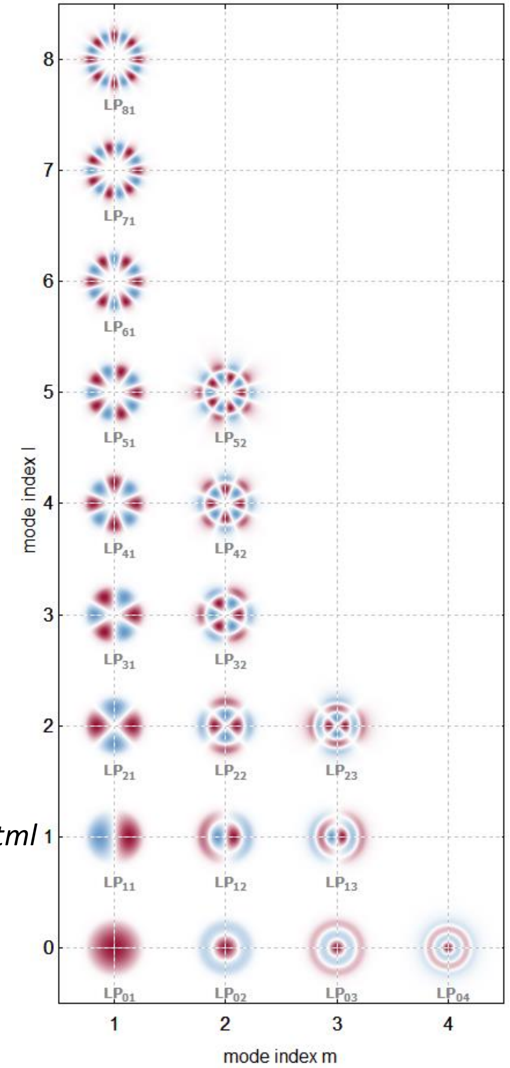


Figure 1: Intensity profiles of a Gaussian beam (left) and a multimode laser beam (right). The latter exhibits more complicated variations of the intensity. Such multimode beams can be generated in lasers where the fundamental resonator modes are substantially smaller than the pumped region in the gain medium.

https://www.rp-photonics.com/beam_profilers.html

Modes of fiber lasers: **LPmn modes**

Invariant propagation though the fiber



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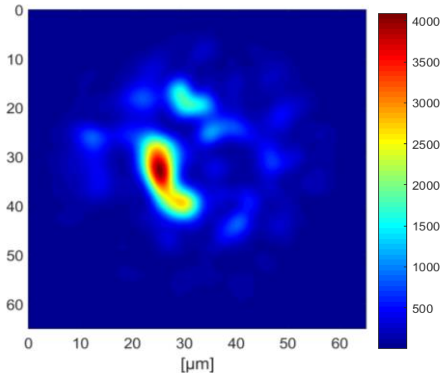

Multimode beam