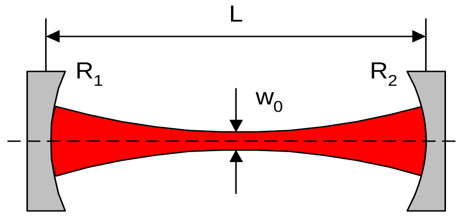
LASERS

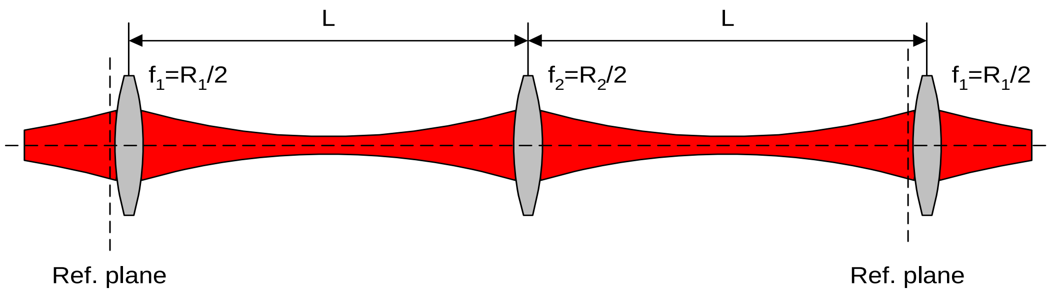
Stable laser resonator with gain.

$\mathrm{mrad} \equiv 10^{-3} \cdot \mathrm{rad} \qquad \mu\mathrm{m} \equiv 10^{-6} \cdot \mathrm{m}$

Introduction

When two (curved) mirrors are placed at a certain distance from each other and are properly aligned a Fabry-Perot resonator has been formed. If the curvature of these mirrors have been chosen according to some rules, and have large enough dimensions to neglect edge-diffraction effects, radiation can be trapped between the mirrors. The field distribution is, of course, a solution of the (paraxial) wave equation with boundary conditions, and a set of solutions are the Gauss-Hermite and Gauss-Laguerre resonant eigen modes of the stable resonator. After each round-trip through the resonator part of the field will be coupled out due to the partial reflectivity of one (or both) of the mirrors. Thes and other losses must be compensated for by placing a gain medium between the mirrors. The stable resonator can be simulated starting with an arbitrary field that circulates between the mirrors towards a steady state solution. In this example we simulate a stable resonator. In stead of mirrors, we use a lens-guide of alternating positive and positive lenses, separated a distance, L, the resonator length.





The laser simulation

Below is the program which consists of a iteration loop for $n = 100$ round trips. The calculation starts with random intensity- and a random phase distribution. An aperture is placed in the resonator in order to limit the number of transverse modes.

$$
F := \left|\begin{array}{l}
K \leftarrow LPBegin\left(\frac{size}{m}, \frac{\lambda}{m}, N\right) \\
K \leftarrow LPRandomIntensity(8, K) \\
K \leftarrow LPRandomPhase(13, 1, K) \\
\text{for } i \in 0..n \\
\quad \left|\begin{array}{l}
K \leftarrow LPCircAperture\left(\frac{D}{2m}, 0, 0, K\right) \\
K \leftarrow LPGain\left(I_{sat}, \alpha_0, \frac{L_{gain}}{m}, K\right) \\
K \leftarrow LPLensForvard\left(\frac{f_1}{m}, \frac{L}{m}, K\right) \\
K \leftarrow LPTilt\left(t_x, t_y, K\right) \\
K \leftarrow LPLensForvard\left(\frac{f_2}{m}, \frac{L}{m}, K\right) \\
Power_i \leftarrow LPNormal(K)_{N,6} \\
K \leftarrow LPInterpol\left(\frac{size}{m}, N, 0, 0, 0, 1, K\right) \\
K \leftarrow LPConvert(K) \\
K \leftarrow LPIntAttenuator(R, K) \\
F_i \leftarrow K
\end{array}\right. \\
\begin{pmatrix} F \\ Power \end{pmatrix}
\end{array}\right.
$$

Also a saturable gain-sheet has been added. Use has been made of spherical coordinates. Therefore conversion to normal coordinates and interpolation to the initial grid is needed after each round trip. A tilt can be introduced to simulate the effect of misalignment of the mirrors.

Extracting the calculated fields

Here we extract the calculated fields and the power of the field from the solution structure, F:

$i := 0..n \quad Field_i := (F_0)_i \qquad Power := F_1$

The outcoupled field

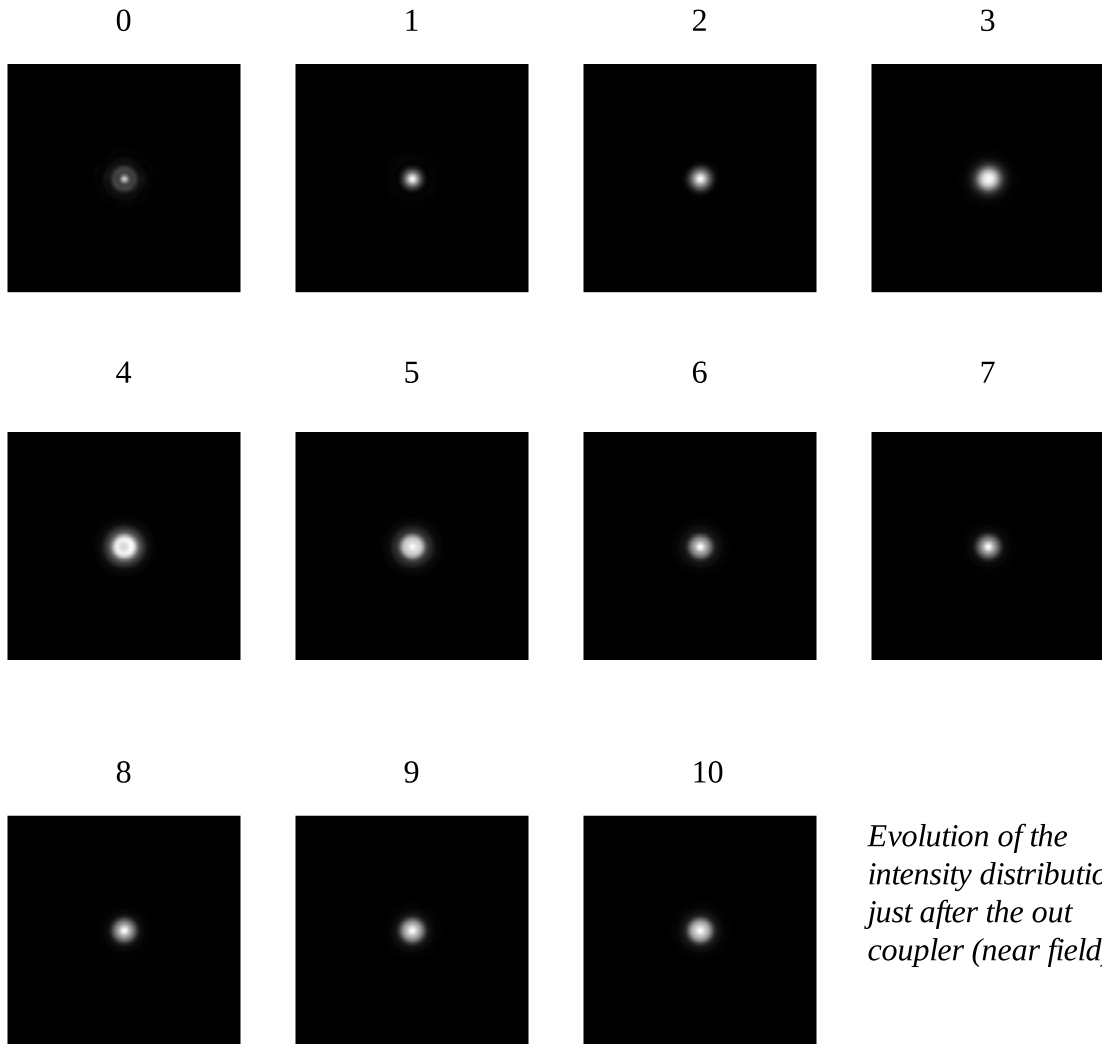
After the field inside the resonator has been calculated we attenuate the field with the transmission of the out coupling mirror to obtain the out coupled (near) field:

$Field_i := LPIntAttenuator(1 - R, Field_i)$

The field- and phase distributions at the outcoupling mirror

Calculation of the near-field intensity and phase for each round trip:

$I_i := LPIntensity(2, Field_i) \qquad phase_i := LPPhase(Field_i)$



Evolution of the intensity distribution just after the out coupler (near field)

The simulation has been done using the following parameters:

number of grid points: $N \equiv 300$

grid size: $size \equiv 32 \cdot mm$

wavelength (CO2 laser) $\lambda \equiv 10.6 \cdot \mu m$

focal length first lens (concave mirror): $f_1 \equiv 5 \cdot m$

reflection of the first mirror: $R \equiv 0.9$

focal length second lens (concave mirror): $f_2 \equiv 500000 \cdot m$

resonator length: $L \equiv 30 \cdot cm$

number of round trips calculated: $n \equiv 100$

mirror misalignment: $t_x \equiv 0.0 \cdot mrad$, $t_y \equiv 0.0 \cdot mrad$

diameter of the aperture: $D \equiv 6 \cdot mm$

saturation intensity of the gain medium: $I_{sat} \equiv 100$

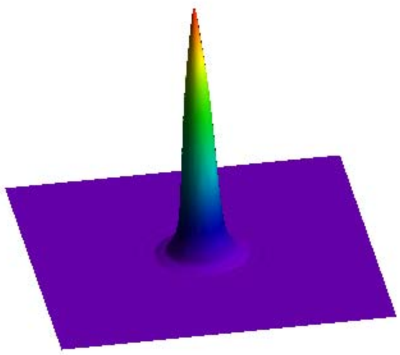
small signal gain: $\alpha_0 \equiv 4.0$

gain length: $L_{gain} \equiv 30 \cdot cm$

Here we interpolate to a smaller grid dimension to get a nice surface plot:

$N_{new} := \frac{N}{2}$ $\quad$ $Field_1 := LPInterpol\left(\frac{size}{m}, N_{new}, 0, 0, 0, 1, Field_n\right)$

$I_1 := LPIntensity\left(0, Field_1\right)$



Intensity distribution just after the outcoupler.

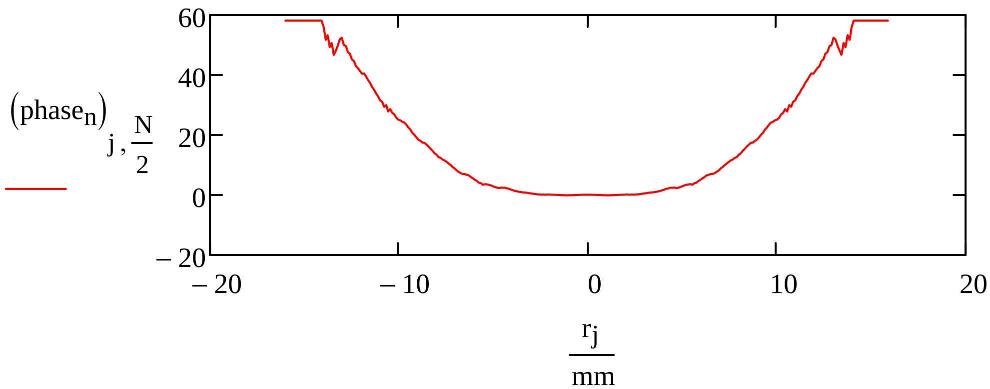
I_1

The phase distribution

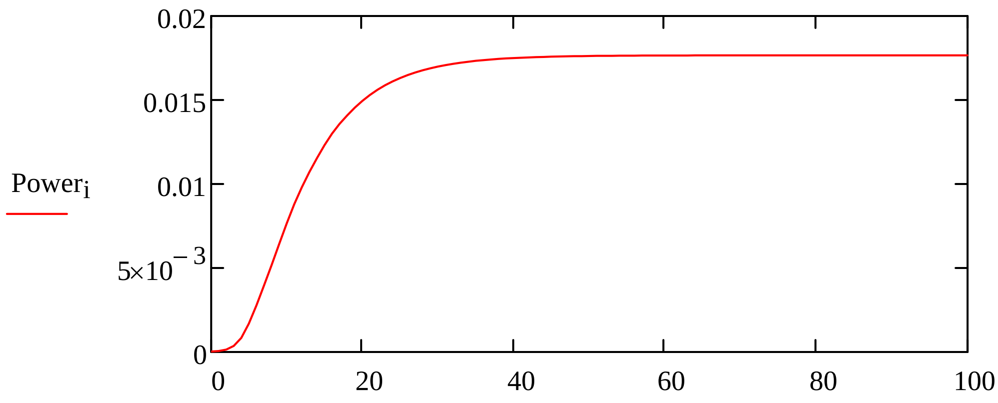
$phase_i := LPPhaseUnwrap\left(1, phase_i\right)$

$j := 0 .. N - 1$ $\quad$ $r_j := \frac{-size}{2} + j \cdot \frac{size}{N}$

Cross section of the phase distribution of the beam.



Beam power



Total beam power as a function of the number of round trips.