# Effects of External Optical Feedback in Broad Area Lasers

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External optical feedback is applied to broad-area lasers to permit lateral mode selection and pattern stabilization of the output beam which usually suffers from undesirable filamentation.

Considerable effort has been recently focused on the development of coherent laser sources for applications which require high output powers such as free-space communications systems. Broad-area lasers have been proposed as possible candidates because they have wider injection regions than conventional lasers, so a large amount of stimulated photons can be generated. However, both the lack of guiding control of the optical mode and the spatial hole burning effect favor the simultaneous oscillation of several lateral modes when the laser is driven higher above threshold [1,2]. As a consequence, the output beam profile develops filamentation [3] which limits the operativity of these lasers devices. A reduction in the number of excited lateral modes is desirable in order to increase the spectral purity and spatial coherence of such lasers. Operation in the fundamental single-lobe lateral mode can provide spatially-coherent diffraction-limited high-power laser sources, but it requires a control mechanism of the excited lateral modes in these devices.

Optical feedback from an external cavity, where a laser diode is exposed to optical feedback by reflecting a part of the output beam back into the laser cavity, has been shown to yield single longitudinal mode operation, tuning of the lasing frequency, and substantial linewidth narrowing in Fabry-Perot multi-longitudinal mode lasers [4]. This highly coherent state is the result of the nonlinear interaction of the longitudinal modes of the laser cavity and the external cavity modes. In this work we study the possibility of lateral mode control and selection in broad area lasers through external optical feedback, in order to improve the optical characteristics of the laser beam of these lasers.

We model the spatio-temporal dynamics of the broad-area laser by the semiclassical Maxwell-Bloch equations for a two-level homogeneously broadened single mode laser [5]. The external optical feedback is incorporated to the field equation in the Lang–Kobayashi weak feedback approximation [6]. The equations of the model are solved numerically for a 30 $\mu$m wide, broad area laser for several injection currents. The reflectivity of both laser facets is $R = 32.0\%$. A low reflectivity external mirror of $R_{ext} = 0.34\%$ is used in all the simulations. The external cavity length, $L_{ext} = \frac{c\tau}{2}$, is chosen in such a way that the separation between external cavity modes, $\Delta\nu = \tau^{-1} = 70$ GHz, is larger than the width of the free-running laser spectrum. For such external cavity length ($L_{ext} \sim 1$ mm), the feedback coefficient [7] is C = 0.45 < 1, ensuring that only one external cavity mode is active."

Initially, the laser is switched on at t=0 ns from the transparency level (Fig. 1a) by applying an injection current of 1.1 $I_{th}$. The system presents relaxation oscillations towards

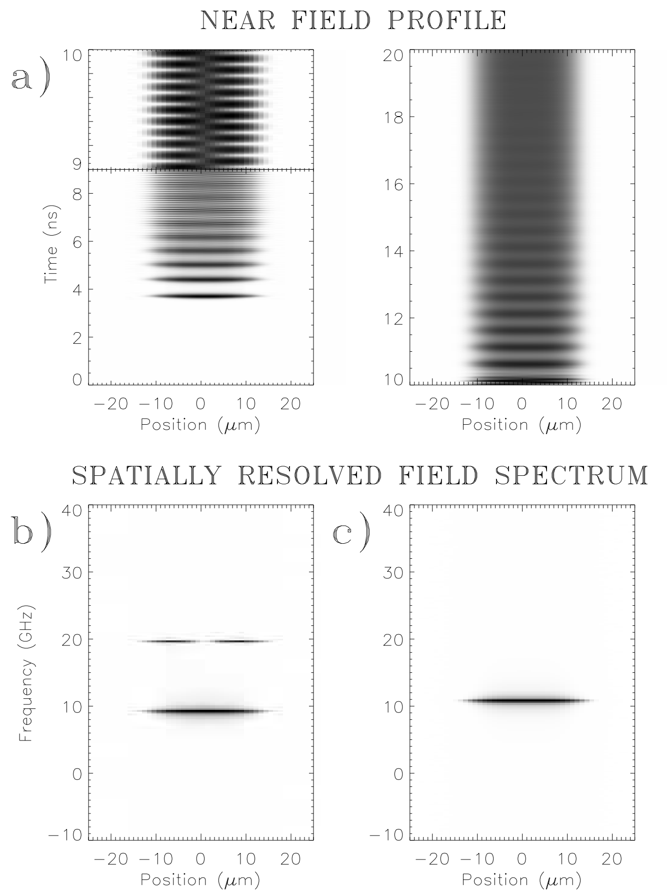


FIG. 1. *Effect of external optical feedback at I=1.1* $I_{th}$. *a) Time-resolved lateral near-field intensity pattern. External optical feedback is applied at t=10 ns. Associated field spectrum for b) no optical feedback; c) weak optical feedback with* $\phi_{fb} = 0$.

the steady state, which, due to spatial hole burning, consists of a single intensity lobe moving periodically across the stripe. The spatially resolved field spectrum associated to this dynamics (Fig. 1b) shows the coexistence of the fundamental and the second order lateral modes of the laser cavity. Weak optical feedback is applied at t=10 ns (Fig. 1a). The two-mode dynamics previously described in absence of feedback is washed out before t=10.5 ns. After some relaxation oscillations, the system reaches fundamental mode operation (see Fig. 1c) at t= 16 ns. Pattern stabilization is achieve due to the strong interaction of the fundamental mode of the free-running laser and an external cavity mode located at $\nu_i$= 0 GHz. This well-behaved state is stable in a wide range of feedback phase values (variations of $L_{ext}$ within half a wavelength that can be experimentally produced by a PZT, produce a change in the feedback phase $\phi_{fb} = \omega_o \tau_{ext}$ from 0 to $2\pi$).

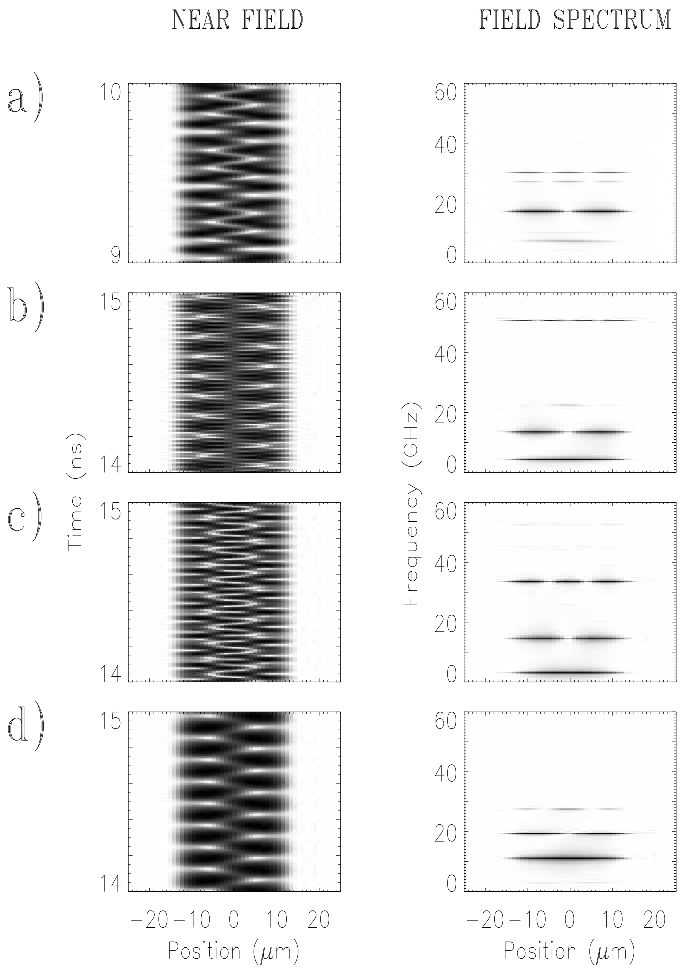


FIG. 2. *Time-resolved lateral near-field intensity pattern and spatially-resolved field spectra for I=1.3 $I_{th}$. a) Absence of feedback. Weak optical feedback with b) $\phi_{fb} = \frac{\pi}{2}$, c) $\phi_{fb} = \frac{3\pi}{4}$, and d) $\phi_{fb} = \frac{7\pi}{4}$. The other feedback parameters are those of Fig. 1b*

When the injected current is increased to I=1.3 $I_{th}$ in absence of feedback, the third order lateral mode is simultaneously excited with the fundamental and second order mode

(Fig. 2a). After applying optical feedback at t=10 ns we leave the system to relax to its steady state. Different situations are observed depending on the value of $\phi_{fb}$. For $\phi_{fb} = \pi$ (Fig. 2b), an external cavity mode is located at the frequency $\nu_{i+1}$=61.25 GHz, which excites the fourth order lateral mode at expense of the third order mode. A small change of the cavity length to give $\phi_{fb} = \frac{3\pi}{4}$ shifts the external cavity mode to 43.75 GHz, close to the frequency of the third order lateral mode which becomes strongly excited it (Fig. 2c). Finally, suppression of the third order mode is achieved for any value of the feedback phase between $\frac{3\pi}{2}$ and $\frac{\pi}{4}$. However, the highest linewidth narrowing of the lateral modes is obtained for $\phi_{fb} = \frac{7\pi}{4}$, which is shown in Fig. 2d.

For higher injection levels, the same type of behavior as shown in Fig. 2 has been observed, but with a higher number of lateral modes simultaneously excited.

In summary, we have shown that a certain degree of lateral mode control and pattern stabilization can be achieved in broad area lasers by applying external optical feedback.

**Aknowledgments:** This work has been partially supported by CICYT Projects No. TIC93/0744, and PB94-1167 (Spain), and European Union HCM Grant CHRX-CT-93-0114

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