Spatial “rocking” in broad emission area semiconductor lasers

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Many nonlinear systems in nature and in techniques display self-sustained oscillations with particular amplitude and with free (invariant) phase. If such system is subjected to the periodic ***in time*** injection, i.e. to a periodic additive signal with zero average (such as $\propto \cos(\Omega t)$) then the phase invariance is broken and a pair of stable states with similar amplitudes and π -shifted phases can be obtained. Such **temporal** “rocking”, or the forcing mechanism which converts the phase-invariant oscillatory system into a phase-bistable system is a general effect in physics of dynamical systems [1].

More recently the ***spatial*** “rocking” was proposed, where the external injection is the periodic function ***in space*** on a small space scale [2]. The spatial rocking, similarly to the temporal rocking, results in phase-bistable dynamics in case of a small scale (original) system, and for phase-bistable patterns (phase-domains, rolls, phase solitons), in the large scale (averaged) system. The spatial rocking proposed in [2] has been studied for a general model of periodically driven complex Ginzburg-Landau equation (CGLE). In the present work we demonstrate theoretically for the first time that the spatial rocking can be realized in broad emission area semiconductor lasers.

Our study is based on the (2+1)-dimensional traveling wave model describing the spatio-temporal evolution of the slowly varying complex field amplitudes, counter-propagating along the longitudinal axis of the laser, the induced complex polarization functions, and the real carrier density function. This model takes into account lateral carrier diffusion, optical field diffraction, as well as non-homogeneities of the device geometry [3]. The spatial rocking is realized by the periodic in space injection function $\propto \sin(\alpha k x)$ entering the laser through its left facet. Experimentally it can be achieved by applying two, coherently interfering at some angle, beams, as shown in Fig.1(a). We demonstrate by numerical integration of the model the typical features of spatial rocking, such as the locking of the phase of emitted radiation to one of two values differing by π . We explore the range of efficient rocking and show that the effect could be experimentally observable. We also demonstrate typical spatial patterns induced by rocking, which are the phase domains and the phase solitons. The basic results are shortly summarized in Fig.1.

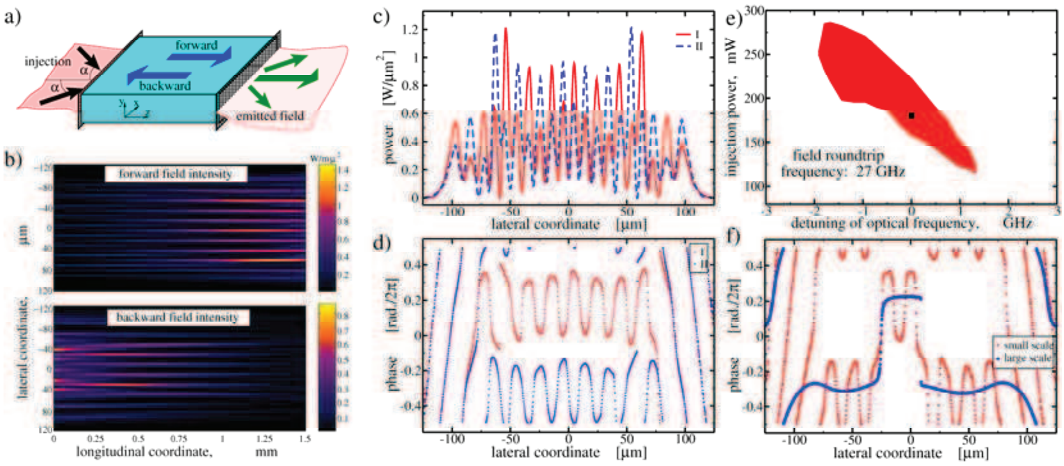

Fig. 1 Evidences of spatial rocking in broad emission area semiconductor lasers: (a): the scheme; (b): the characteristic spatial field intensity distributions, representing one of two phase-locked states; (c): intensities and (d): phases of two different stable space patterns (near fields) due to the spatial rocking; (e): parameter domain of coexisting stable phase locked states. Black square indicates parameters used in panels (b-d); (f): phase soliton.

References

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