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Laser dynamics: Weak versus strong harmonic-expansion modelling

Laser dynamics still bears some challenging and open questions in the physics underlying the field of light-matter interactions inside an oscillating cavity. We aim at giving a comprehensive review of the weak and strong harmonic-expansion methods that handle both the Laser-Lorenz and the integro-differential Maxell-Bloch equations, respectively known to describe the homogenous and inhomogeneously broadened gas-laser systems, when these are operated under bad cavity conditions and high excitation mechanisms. While the weak-side band approach is shown to handle most of the properties of the transient solutions, it fails to describe the permanent pulsing signals. After outlining the physical origin of such a failure, we apply a strong harmonic-expansion procedure to light-up some analytically unexplored aspects of laser dynamics. In particular, we demonstrate that, in their unstable regime of operation, the laser equations are characterized by an additional natural pulsing frequency stemming from the non-linear nature of light-matter interactions inside the amplifying medium. The derived closed-form expression of this fundamental frequency is exclusively related to the three relaxations rates of the interacting variables, namely for the electric field, for the polarization and for the population inversion. The system enters its natural period-one pulsing regime with this fundamental driving frequency at a particular pumping level, distinct from the well-known second-laser threshold that delimits the boundary transition from stable to unstable operation. From these new physical insights, most of the dynamic aspects pertaining to the unstable regime of operation are pulled out. In particular, the strong harmonic expansion method is shown to naturally allow for a precise construction of the corresponding self-pulsing solutions. These are not limited to the regular period-one regime, but extend to a large domain of the control-parameter space that governs the dynamic behaviour. A hierarchy of analytical solutions including the period-doubling cascade, as well as a few asymmetrical time traces, is constructed with a straightforward application of the strong-harmonic expansion procedure.

Biography

Belkacem Meziane received the MS degree in Electrical Engineering (1978) from the Florida Institute of Technology, Melbourne, USA, PhD degree (1992) and the "Habilitation à Diriger des Recherches"(1996) from ENSSAT, Université de Rennes I, Lannion, France. From 1979 to 1990, he was a Lecturer at the Algiers-University Physics Department (USTHB), Algeria. From 1990 to 1998, he was a member of the Optronics Division at ENSSAT, where he participated in the development of various experiments and theories connected to the light-matter interactions issue. Since1999, he's been tenured Professor at the Faculty of Sciences, Universitéd'Artois, Lens, France. He is the author of over 30 published papers, including 2 book chapters on laser dynamics.

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