Noise spectra and correlations in semiconductor ring laser in the bidirectional regime

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We consider the effects of the spontaneous emission noise in the Langevin formulation for a two mode rate equations model for a SRL operating in the bidirectional regime. The model is a two-mode Maxwell-Bloch rate equation model[1]. The analysis has been carried out by linearizing the model close to a stable stationary solution, and considering effect of noise as stochastic perturbations expressed by Langevin forces. We analytically investigate the influence of complex backscattering coefficients when the two modes are reinterpreted in terms of mode-intensity sum and difference. As a result we have calculated two noise spectra versus ω, the dimensionless frequency rescaled to photon lifetime: the Total Intensity Noise spectrum (I-Spectrum, $< |I(\omega)|^2 >$, behaving similarly to the standard RIN for single-mode semiconductor lasers, see fig. 1) and Intensity Difference Noise spectrum (D-spectrum, $< |D(\omega)|^2 >$), see fig. 2, which unveiled new features.

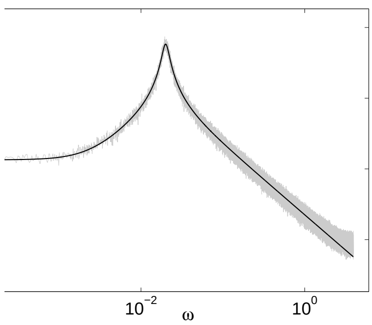

Figura 1. Total Intensity Noise spectrum. The black line is the analytical result and the grey is the numerical simulation.

Indeed, the I-spectrum is shaped by total field carrier inversion energy exchange processes (relaxation oscillations) whereas the D-spectrum is shaped by the intermodal energy redistribution processes which are strongly influenced by backscattering and induce alternate oscillations. The effect of the noise as a generic perturbation emphasize the system resonances associated to the physical processes of field/medium energy exchange and the energy exchange between modes. Moreover we analize the cross and auto correlations which are related to the spectra by Wiener-Khinchin theorem, like D autocorrelation C_{DD}, see fig. 3. Our analytic results are in excellent agreement with numerical simulations.

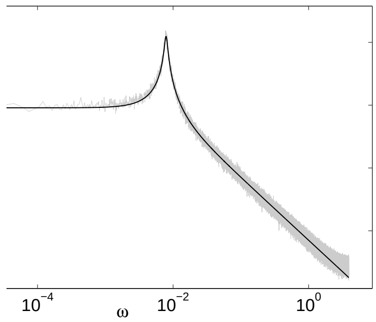

Figura 2. Intensity Difference Noise Spectrum. The black line is the analytical result and the grey is the numerical simulation.

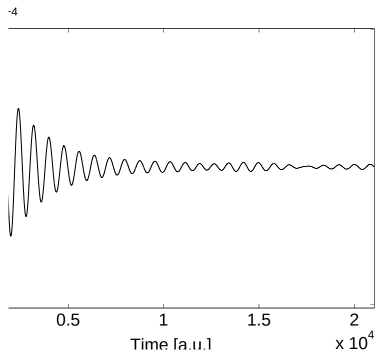

Figura 3. Intensity Difference numerical auto-correlation .

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