ABSTRACT

Title of dissertation: NONLINEAR DYNAMICS OF SEMICONDUCTOR LASERS WITH OPTICAL FEEDBACK

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The spontaneous emission noise effect on the dropout phenomenon of semiconductor lasers with optical feedback is demonstrated by experiments with modulation of the pumping current or the feedback strength of the system and a necessity in the rate equations to produce results that match the experimental observations. In the phase space of the population inversion and the external cavity round-trip phase shift, the noise reduces the amplitude of the fluctuation of the trajectory around the external cavity modes and the dropout rate. With an optimal noise level, the different dropout dynamics under different kinds of modulations are well explained by the dynamics of the system in the phase space.

The Hilbert phase analysis is used to extract phase information from an experimental real intensity time series. Through this analysis, the hopping and interaction

between different external cavity modes are observed. The probability distribution of residence time of the external cavity modes is a direct application of the method.

The Hilbert-Huang transformation is used to decomposes the original time series into a small number of intrinsic mode functions from which the Hilbert phase can be uniquely defined. The fluctuation of the Hilbert phase indicates that the system has the fractional Brownian dynamics, which is clarified by computation of the Hurst exponent of the observed fluctuations.

The prehistory probability density analysis is also used to study the dropout phenomenon. The histogram shows that there are periodic build-up spiking behavior before the dropout with period of one round-trip time. This is an indication of a series of attempt of the attractors to collide with the antimodes in the phase space. The population inversion dynamics is represented by the AC voltage fluctuation across the anode and cathode of the laser diode. By using the intensity and the diode voltage as the coordinates of the phase space, a complete and direct correspondence between the experimental and simulated results is achieved.