Bursting dynamics in a two-mode semiconductor laser with optical injection: experimental results and theoretical analysis

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In this work we describe our recent experimental and theoretical studies of bursting dynamics in an optically injected two-mode semiconductor laser. The device we consider is a specially engineered Fabry-Perot laser diode with a large (terahertz) primary mode spacing. This device can be biased such that both primary modes oscillate simultaneously with the same average power level. Where one of the primary modes is optically injected, the presence of the second lasing mode leads to a very rich dynamical scenario. In particular, we have found two distinct examples of dynamics that are associated with large amplitude bursting of the intensity of the uninjected primary mode.

The first example is characterised by irregular bursting of the intensity of the uninjected mode in regions where the dynamics of the injected mode are chaotic. In contrast, the second example is characterised by regular bursts that are in antiphase and which have variable period. These regular dynamics are found close to regions where dramatic switching between single and two-mode dynamical regimes occurs.

We have found that both of these examples of dynamics are reproduced with remarkable accuracy by a deterministic four dimensional rate equation model. The structure of the model is such that the dynamics of the well-known model of the single mode injected system are contained in an invariant submanifold of the two-mode system. Irregular bursting dynamics are then described by on-off intermittency that is associated with the transverse instability of chaotic dynamics in the injected mode submanifold. Experimentally, we have found significant departures from ideal scaling in the distribution of interburst times in this case. We are currently studying the effect of correlations on these distributions, which are in good agreement with modelling results.

On the other hand we show that the bifurcation scenario for regular bursting dynamics is organised by codimension two points at which saddle node of limit cycle and transcritical bifurcation lines tangentially intersect. At the saddle node of limit cycle bifurcation line the time interval between bursts diverges, and therefore gives rise to a dynamical behaviour which is similar to the Blue Sky Catastrophe in generic systems. We discuss the associated phase space structure, and compare with other infinite period bifurcations described in the literature.