Two-wave Ring Nonlinear Fibre Microcavity Spatio-Temporal Dynamics Modelling

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It is obvious that the ability to predict the electromagnetic field behavior in the microcavities has a heavy practical value. Since such cavities operate in highly nonlinear regimes, it is possible to investigate their dynamics only by employing the numerical modeling methods, with the models used being adequate enough to describe the ongoing process, but at the same not being time costly. Modal approach is the main one [1], when the field inside of the microcavity is expanded along the longitudinal modes, and equations for the time dependant complex amplitudes of those modes are written. The result would be a set of tens or even hundreds of common boundary nonlinear equations, and solving them on a computer is a non-trivial task. For example, the nonlinearity causes sums of all the possible modes products to appear in the equations, and the calculation will take significant temporal and machine resources to be carried out. Moreover, to calculate the temporal profile of the field it is necessary to add all the fields of every mode, what also takes a lot of time, if there are large numbers of such modes. These are all examples of a spectral expand method. An alternative way to approach the problem of the field dynamics inside of a microcavity would be a differences scheme, built upon the transport equations [2], successfully used to simulate Raman and SBS lasers. This work is devoted to the further improvement of this numerical model [2], and analysis of the results, achieved when using this method.

The equations describing the pulse propagation inside of a microcavity are given as follows:

$$2i\left(\frac{\partial F}{\partial t}+v\frac{\partial F}{\partial z}\right)+D\frac{\partial^2 F}{\partial z^2}+2\chi(|F|^2+2|B|^2)F=0,$$

$$2i\left(\frac{\partial B}{\partial t}-v\frac{\partial B}{\partial z}\right)+D\frac{\partial^2 B}{\partial z^2}+2\chi(2|F|^2+|B|^2)B=0.$$

Boundary conditions are: $F(0)=\sqrt{1-R}\sqrt{1-r}F(L)+\sqrt{R}\sqrt{A}\sqrt{1-r}+\sqrt{r}B(0)$; $B(L)=\sqrt{1-R}\sqrt{1-r}B(0)-\sqrt{r}(1-r)F(L)+\sqrt{Rr}\sqrt{1-R}\sqrt{A}$.

Here F and B – are fields of the waves, propagating clock and counterclockwise respectively, $D<0$ – GVD coefficient, v – group velocity, χ – phase cross and self-modulation coefficient, R – coupler reflection coefficient, r – intra-cavity mirror reflection coefficient, A – continuous pump intensity, L – cavity length.

In our model we consider the dispersion and nonlinearity of the microcavity, coupler and a mirror, situated in a random spot inside of the fiber. Beside the aforementioned effects there could also be modulation instability. To solve the problem we use an effective second order difference scheme “Cabaret” [3]. The figure shows an example of the model being used to calculate the effects of the nonreciprocal phase shift caused, for example, by the fibre rotation, and Rayleigh scattering on the random impurities in the cavity medium [4].

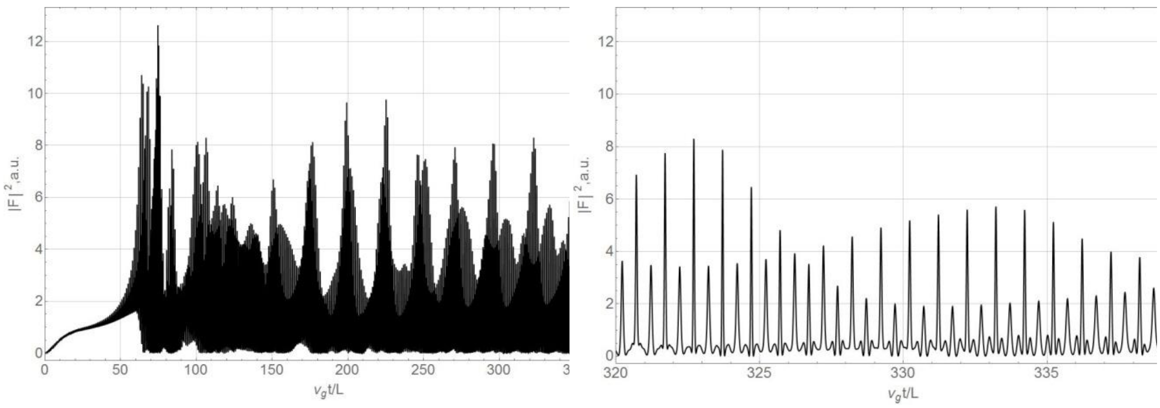

Fig. 1. Optical frequency comb formation. Strong background phase noise is visible. Modulation coefficient χ = *0,25*. Wave linear interface coefficient *r* = *0.001*. Losses ratio *0.0001*.

Summarizing we can conclude that using the implicit-explicit "Cabaret" scheme we can with ease consider for the necessary nonlinear effects in the system under investigation. It is nearly impossible when using the modal method since the number of the equations is several times greater with every new effect introduced, with the respective growth in the necessary time to compute the results.

References

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