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A uniformly accurate scheme for a Bloch model

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To describe light-matter interactions in quantum optics, a Maxwell-Bloch model can be used. It leads to the time evolution of the density matrix associated to a quantum system with a discrete set of energy levels coupled to that of the classical electromagnetic field.

Here, we consider a given electromagnetic field which varies on a fast scale and we are interested in the long time evolution of the Bloch solution. In the present regime, it has been proved, introducing successive approximations and using averaging techniques, that the diagonal part of the density matrix is asymptotically solution to a Master equation with averaged transition rates.

In this work, we use the information given by these successive approximations to build a numerical scheme for the diagonal part of the density matrix that is uniformly accurate, i.e. whose accuracy does not depend on the asymptotic parameter. The idea is to decompose the problem into a micro-macro system that allows to use standard explicit schemes without order reduction. We will explain how a recent approach proposed for highly-oscillatory evolution equations can be used with quasi-periodic oscillations and exponentially decreasing terms and we will illustrate it with numerical experiments performed on the Bloch problem.

It is a work in collaboration with B. Bidégaray-Fesquet and L. Trémant.

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