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To cite this version:

D. Chyba. EFFECT OF CAVITY AND ATOMIC ”DETUNINGS” ON STABILITY IN A NEW FORMULATION OF THE STEADY STATES OF THE RING LASER WITH A SATURABLE ABSORBER. Journal de Physique Colloques, 1988, 49 (C2), pp.C2-367-C2-370. 10.1051/jphyscol:1988286 . jpa-00227703

HAL Id: jpa-00227703
https://hal.science/jpa-00227703

Submitted on 4 Feb 2008

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JOURNAL DE PHYSIQUE
Colloque C2, Supplément au n°6, Tome 49, juin 1988

EFFECT OF CAVITY AND ATOMIC "DETUNINGS" ON STABILITY IN A NEW FORMULATION OF THE STEADY STATES OF THE RING LASER WITH A SATURABLE ABSORBER

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Abstract

The method is outlined, graphical results are presented, and newly-discovered branches of zero-intensity solutions are also discussed.

1 Introduction

This report summarizes several new results for a semiclassical model of the detuned ring laser with an intracavity saturable absorber (DRLSA) in the uniform field approximation. These are: *(i)* formulation of a set of ordinary differential equations for the detuned case, by means of the uniform field approximation; *(ii)* an explicit solution for the steady states of these in the case of non-zero intensity via the roots of polynomials up to quartics; *(iii)* a separate formulation of the steady states for the case of zero intensity, leading to the discovery of new branches of zero-intensity solutions even in the tuned case; and *(iv)* selected numerical solutions for the stability of the steady state solutions, showing the effects of cavity detuning. A complete and detailed presentation of this work is being prepared for publication elsewhere.

2 Discussion

The model is based on the Maxwell-Bloch equations for a homogeneously broadened DRLSA in which the media consist of two-level atoms. The results for non-zero intensity illustrated here were obtained by transforming the Maxwell-Bloch equations into a purely real set of partial differential equations and applying the uniform-field approximation to obtain a set of ordinary differential equations which hold for the detuned case. It has been possible to solve for the steady states of these; in the fully tuned case, one has quadratic equations, and in the detuned case, a quartic in one of the state variables. Such a solution is, in principle, explicit, and allows very rapid and precise computation of the steady states. The differential equations also provide a convenient foundation for a linear stability analysis of the steady states, some of the results of which are illustrated here. The effect of even a small detuning on the solutions is evident.

A previous approach to this problem by the author and coworkers [1] utilized a dispersion curve—mode-line approach due to Casperson and Yariv to obtain numerical solutions for the steady states. That method can also be applied in the case of the zero-intensity steady state solutions, since the dispersion curve still exists in this case, and depends upon the excitation of the medium. Such a method yields the previously known solution at zero frequency and zero intensity for the tuned case, but also yields two additional branches, which bifurcate to form the known solutions at non-zero intensity. Previously, these had been thought to appear with increasing excitation disconnected from other branches of solutions [2]. The method also allows one to find the corresponding branches in the detuned case. Finally, a stability analysis based on the corresponding differential equations can be made, showing the changes of stability at the various bifurcation points lying along the branches.

Article published online by EDP Sciences and available at http://dx.doi.org/10.1051/jphyscol:1988286

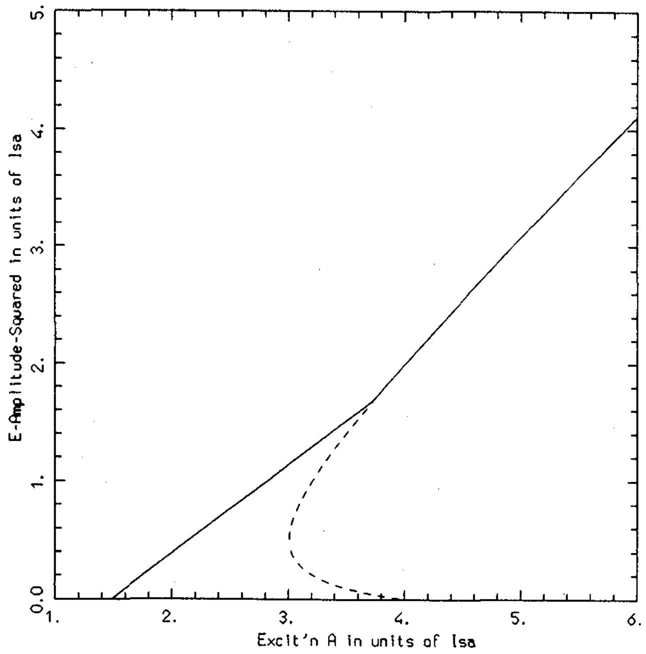

Fig. 1 Intensity vs. amplifier excitqtion in the fully tuned case. Solid lines: stable solutions; dashed, unstable. Both axes have units of the amplifier saturation intensity. Cavity linewidth: $0.40\,\gamma_{\perp a}$, the polarization decay rate of the amplifying medium. These results agree with those previously described in Refs. 2.

The straight stable segment at low intensity represents two branches degenerate in intensity but having different operating frequencies; compare Fig. 2. The degeneracy is broken by detuning, and the stability behavior is also changed; compare Fig. 3.

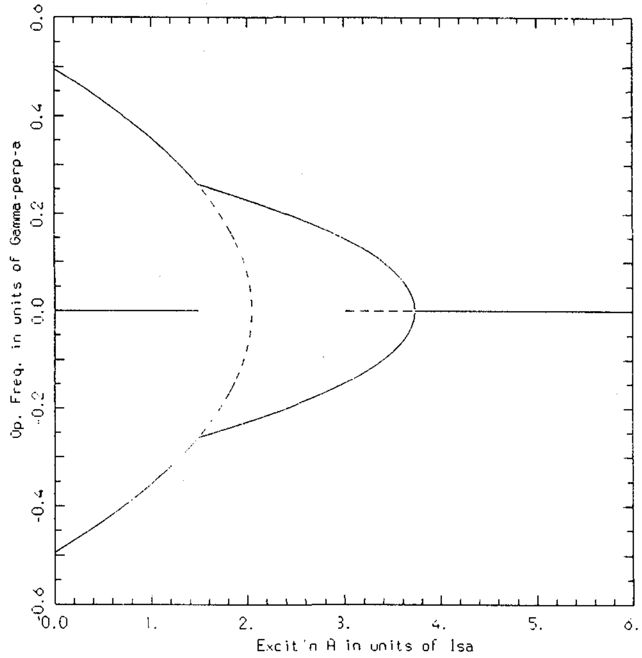

Fig. 2. Operating frequency vs. amplifying medium excitation for the case of Fig. 1. The frequency is shown as displacement from the amplifier line center and is given in units of $\gamma_{\perp a}$. Solid lines are stable; dashed, unstable.

Zero-intensity solutions are the broad parabolic arc at left and the line at zero frequency at left. The latter continues to all higher A values but is unstable. Note the isolated stable arcs surrounded by unstable arcs.

Finite-intensity solutions are the narrower parabola and the right-hand line at zero intensity; compare Fig. 1. The finite-intensity parabola bifurcates from the zero-intensity parabola where the latter changes stability.

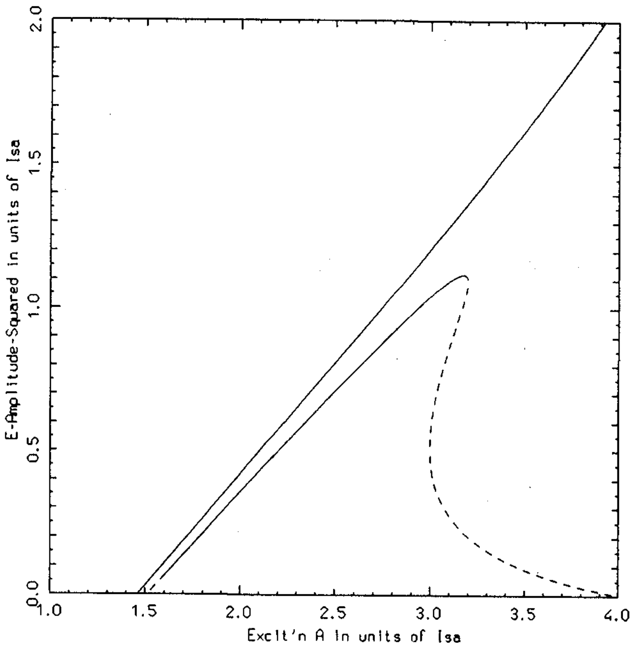

Fig. 3. Similar to Fig.1, but with a cavity detuning = $0.03\,\gamma_{\perp a}$. Note the splitting of the degeneracy of the stable branches at low intensity in Fig. 1, and the alternations in stability of the lower-intensity branch here (it is unstable at sufficiently low excitation).

Similar results appear for the cavity tuned to the amplifier line center, but slightly off-resonant absorber atoms.

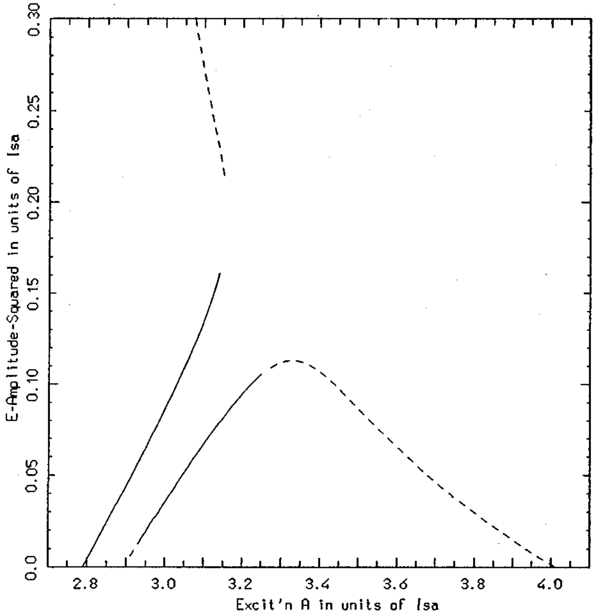

Fig. 4. Similar to Fig. 3 but for cavity linewidth $0.065\,\gamma_{\perp a}$ and cavity detuning $0.0025\,\gamma_{\perp a}$. The high-intensity branch eventually curves again to the right, at which point it becomes stable, giving a region of tristability. As in Fig. 3, the low-intensity branch is unstable at sufficiently low excitation values.

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