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FINAL REPORT

TITLE: Exact Physical Models and Methods for Stabilization and Control of Reflection-Induced Instabilities in Semiconductor Lasers

EXECUTIVE SUMMARY : AFOSR Grant No: F496209310306

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The preliminary stage (6 months) of our contract work was focused on incorporating microscopic many-body effects into a full scale simulation code of a semiconductor laser (SCL). The latter includes counterpropagating optical waves in the Fabry-Perot structure, longitudinal carrier diffusion and, importantly, gain and refractive index dispersion derived from a look-up table. Boundary conditions are applied at each end of the cavity and an additional feedback mirror is simple to incorporate allowing us to study the transition from weak to strong optical feedback. This approach enables us to investigate multi-longitudinal mode oscillations and discriminate these from mode-hopping phenomena. Moreover, the response function derived from the many-body theory can be "engineered" to optimize the dynamic response of the SCL. In other words, we can systematically investigate the role of bulk, versus quantum well and strained layer materials on lasing action. When modulated internally (relaxation oscillations, feedback instabilities) or externally (injection current) the dispersion can vary significantly as the carrier density varies.

Fundamental challenges that we are currently facing include a reliable description of the gain/index dispersion as a function of carrier density and proper noise modelling at z locations along the laser axis. The former is critical to implementing a computationally efficient algorithm, especially when we extend our study to include transverse diffraction and diffusion at a later stage.

Professor Maxi San Miguel, on sabbatical leave from Spain, is an expert on noise modelling in lasers and is working directly with his student, Marga Homar, on the noise modelling. Professor John McInerney, a consultant on the project, is spending 3 weeks at Arizona in order to provide direct experimental input to our theoretical effort. In particular, we are testing the validity of the Lang-Kobayashi rate equation feedback model against our more elaborate theory. Dr. Ping Ru, the postdoctoral fellow on the project has completed the simulation code incorporating the look-up table and noise effects, and this is now being tested where possible against the known results of simpler rate equation models. Dr. Ru is also setting up a simulation to include the polarization dynamics by integrating the Maxwell-Semiconductor Bloch equations in the quasi-free particle approximation.

We have been in direct contact with scientists at the Phillips Laboratory (David Bossert, an experimentalist at Kirtland AFB) and Vassilios Kovanis (a theorist with a nonlinear optics group). David Bossert spent 6 days at Arizona earlier this month and Vassilios Kovanis visited for 3 days. Our group plans to visit the Phillips Laboratory in late October. We continue to maintain regular telephone, fax and e-mail contact with the Phillips group.

In addition to the listed publications, three papers have been submitted for publication:

Ru, P., et al, Microscopic modeling of bulk and quantum well GaAs-based semiconductor lasers, Optical and Quantum Electronics, 1993

Ru, P., et al, Mean-field approximation in semiconductor lasers, Physical Review A, 1993

Li, H., and McInerney, J.G., Detailed analysis of coherence collapse in semiconductor lasers, IEEE Journal of Quantum Electronics, September 1993.