



Mode Coupling Measurement in Dual-Frequency Quantum Well-based VECSEL

Gaëlle Brévalle, Salvatore Pes, Cyril Paranthoen, Mathieu Perrin, Christophe Levallois, Cyril Hamel, Alexandru Mereuta, Andrei Caliman, Eli Kapon, Laurent Chusseau, et al.

► To cite this version:

Gaëlle Brévalle, Salvatore Pes, Cyril Paranthoen, Mathieu Perrin, Christophe Levallois, et al.. Mode Coupling Measurement in Dual-Frequency Quantum Well-based VECSEL. Compound Semiconductor Week 2019 (CSW 2019), May 2019, Nara, Japan. pp.1-2. hal-02290594

HAL Id: hal-02290594

<https://hal.science/hal-02290594>

Submitted on 5 Nov 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Mode Coupling Measurement in Dual-Frequency Quantum Well-based VECSEL

Gaëlle Brévalle¹, Salvaore Pes¹, Cyril Paranthoën¹, Mathieu Perrin¹, Christophe Levallois¹, Cyril Hamel¹, Alexandru Mereuta², Andrei Caliman², Eli Kapon², Laurent Chusseau³, Hervé Folliot¹ and Mehdi Alouini¹

¹Univ Rennes, INSA Rennes, CNRS, Institut FOTON – UMR 6082, F-35000 Rennes, France

²Laboratory of Physics of Nanostructures, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

³IES, Université de Montpellier, CNRS, Montpellier, France
gaelle.brevalle@insa-rennes.fr

Abstract—We experimentally investigate the Lamb coupling constant C in InGaAlAs Quantum Wells active medium. An Optically-Pumped Vertical-External-Cavity Surface-Emitting Laser emitting at 1.54 μm is designed to sustain the oscillation of two orthogonally polarized modes sharing the same active region while separated by 1 mm in the rest of the cavity. It enables to tune independently the two wavelengths and to apply differential losses in order to directly measure the coupling constant. We found C to be almost constant and equal to 0.839 ± 0.023 for a wavelength difference between the two eigenmodes ranging from 0.36 nm up to 10.8 nm.

Keywords—Lamb Coupling; VECSEL; dual-frequency laser

I. INTRODUCTION

The Lamb coupling constant C governs the dynamics of two coupled modes in a laser, and consequently the dynamics of dual-frequency lasers. For $C < 1$, simultaneous oscillation of two modes is possible. In practical cases, this regime becomes increasingly perturbed as C approaches the unity, until moving towards bistability when C exceeds 1 [1]. In dual-frequency solid-state lasers, this coupling constant can be quite weak, $C \sim 0.16$ [2], or high: $C \sim 0.8$ [3] depending on the active medium. However, even though dual-wavelength oscillation has been demonstrated in semiconductor Quantum Well (QW) based Vertical External Cavity Surface Emitting Lasers (VECSELs) [4], a direct measurement of the Lamb coupling constant in QWs active media has never been reported. Indeed, because of the homogeneously broadened gain offered by QW-based active medium, the two eigenmodes of a QW-VECSEL suffer from strong coupling making it necessary to lift the degeneracy by introducing a spatial separation inside the active medium, thus reducing the coupling for the purpose of a steady dual-frequency oscillation. To the best of our knowledge, the value of such a coupling constant has only been measured by indirect methods based on the measurement of C for different spatial separations leading to an extrapolated value of $C=0.8$ [5]. The purpose of our work is to measure directly this coupling constant for different wavelength separations between the two modes and to show possible dual-frequency operation without the necessity to reduce the coupling by introducing a spatial walk-off in the active medium.

II. LAMB COUPLING CONSTANT MEASUREMENTS

To that end, an Optically-Pumped Vertical-External-Cavity Surface-Emitting Laser (OP VECSEL) emitting at 1.54 μm was designed to sustain the oscillation of the two orthogonally polarized modes sharing the same active region while separated in the rest of the cavity. The laser cavity is depicted in Figure 1a). Inside the cavity, we inserted two etalons to independently tune the two eigenmodes I_1 and I_2 separated by 1 mm thanks to a birefringent crystal. The etalons ensure in addition single frequency oscillation of each eigenmode, confirmed with a Fabry-Perot interferometer and an Optical Spectrum Analyzer (OSA). Some acquired spectra are shown in figure 1b). To measure C, we introduce for one mode weak extra optical losses with a razor blade mounted on a piezoelectric actuator. We then measure the intensity variations of I_1 and I_2 to obtain the cross- to self-saturation ratios K_{12} . This operation is repeated on the other mode in order to obtain K_{21} and finally $C = K_{12} K_{21}$. As shown in Fig.3, C has been measured for several wavelength differences $\Delta\lambda$ between the two modes, by fixing I_1 at 1535.4 ± 0.2 nm while changing I_2 's wavelength by rotating the etalon. We found that C is almost constant for $\Delta\lambda$ ranging from 0.36 nm up to 10.8 nm, with a mean value of 0.839. The overall standard deviation is 0.023, leading to $C = 0.839 \pm 0.023$.

This work is supported by the IDYLIC ANR project (ANR-15-CE24-0034-01).

- [1] M. Sargent *et al.*, *Laser physics*. London : Addison-Wesley, 1974.
- [2] M. Brunel, *et al.*, “Differential measurement of the coupling constant between laser eigenstates,” *Appl. Phys. Lett.*, vol. 70, no. 16, pp. 2070–2072, Apr. 1997.
- [3] A. McKay *et al.*, “Polarisation-mode coupling in (100)-cut Nd: YAG,” *Opt. Express*, vol. 15, no. 25, pp. 16342–16347, 2007.
- [4] G. Baili *et al.*, “Experimental demonstration of a tunable dual-frequency semiconductor laser free of relaxation oscillations,” *Opt. Lett.*, vol. 34, no. 21, pp. 3421–3423, Nov. 2009.
- [5] V. Pal *et al.*, “Measurement of the coupling constant in a two-frequency VECSEL,” *Opt. Express*, vol. 18, no. 5, p. 5008, Mar. 2010.

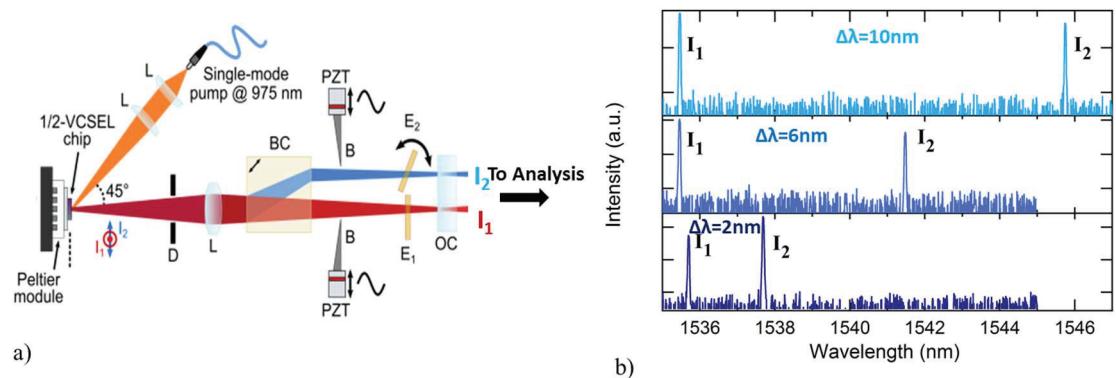


Fig. 1. a) Coupling constant measurements cavity setup. L: lens, D: diaphragm, BC: YVO₄ birefringent crystal, PZT: piezo actuator, B: razor blade, E: etalon, OC: planar output coupler. Index 1 and 2 are referred to the two orthogonally polarized eigenmodes I₁ (ordinary) and I₂ (extraordinary). b) Emission spectra acquired by the OSA for several wavelength differences.

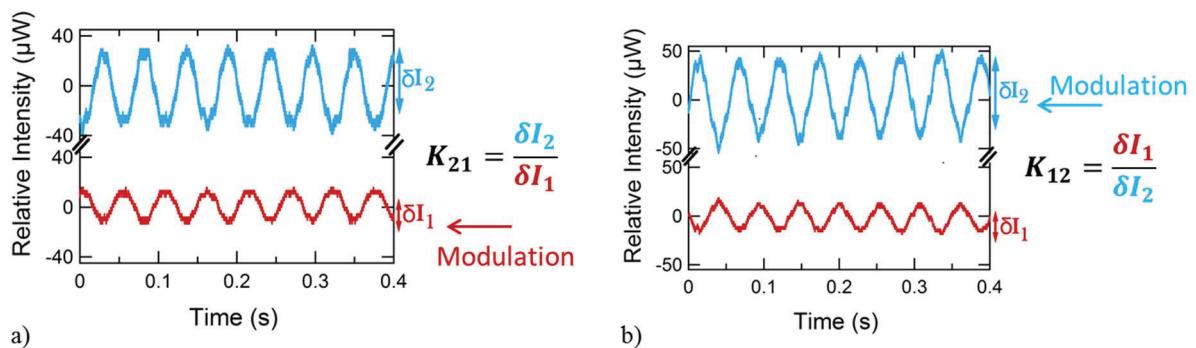


Fig. 2. Evolution of the traces observed at the oscilloscope when the modulation losses are applied to a) mode I₁ or b) mode I₂.

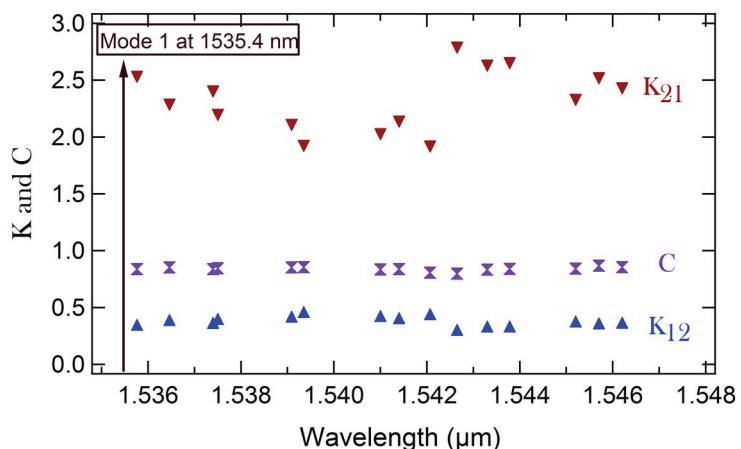


Fig. 3. Cross- to self- saturation ratios K₁₂ and K₂₁, and Lamb coupling constant C versus the wavelength of mode I₂ with I₁ kept at 1535.4 nm.