

Characterization of emission regimes in a 1.5 μm high brightness MOPA

M. Vilera, J. M.G. Tijero, S. Aguilera, P. Adamiec, A. Consoli, and I. Esquivias

Abstract- We present and analyze experimental results on the emission characteristics of a 1.5 μm distributed feedback tapered master-oscillator power-amplifier in a wide range of steady-state injection conditions, showing different emission regimes under cw operation: stable single frequency emission, multi-frequency Fabry-Perot-like emission, and self-pulsation operation.

I. INTRODUCTION

The integrated Master Oscillator Power Amplifier (MOPA) architecture with a tapered Power Amplifier (PA) section is a promising approach for those laser applications requiring simultaneously high brightness and good spectral properties. These devices consist of an index guided section acting as a master oscillator (MO), followed by the flared PA section. Ideally, the single lateral and longitudinal mode provided by the MO section undergoes free diffraction and amplification in the tapered PA section while keeping its initial beam quality. However, the residual reflectance of the amplifier facet can produce optical feedback or coupled cavity effects giving rise to the appearance of mode jumping and emission instabilities even when both sections are driven in CW conditions [1-4]. A good characterization and understanding of these effects is crucial for the application of these devices in static or dynamic operation.

In previous works [2, 3], we have presented initial results on the different emission regimes of a monolithic MOPA emitting at 1.5 μm under specific injection conditions. In this work we present a more extended and detailed experimental study of the emission regimes based on the analysis of the maps of the optical and RF spectra as a function of the injected currents.

II. EXPERIMENTAL TECHNIQUES

The device is a commercially available MOPA with emission wavelength at 1547 nm (QPC Lasers 4715-0000), consisting of a Distributed Feedback (DFB) laser and a tapered amplifier, with a total device length of around 2.5 mm. Both sections were separately injected in CW conditions. A fraction of the emitted power was collected by a lensed fiber and characterized in the optical and RF domains by an optical spectrum analyzer and by a photodiode with an electrical spectrum analyzer, respectively. Maximum care was taken in order to minimize the external feedback and to ensure that the recorded spectra were only dependent on the injection conditions.

III. RESULTS AND DISCUSSION

Three emission regimes were observed as a function of the injection conditions, with very different optical and RF spectra (see Fig. 1):

- Regime I: It is characterized by single frequency operation at a wavelength corresponding to the Bragg grating between 1546 and 1549 nm. The RF spectra are either flat or show the typical Relative Intensity Noise (RIN) feature. At low injection of the amplifier the emission peak shifts continuously as a function of the MO current, while quasi-periodic jumps are observed at medium and high injection conditions of the amplifier.
- Regime II: In this regime the optical spectra correspond to the typical multi-longitudinal mode operation of a Fabry-Perot (FP) laser emitting at a wavelength given by the amplifier gain maximum in the region 1520-1530 nm. In addition to the RIN peak, the RF spectra show clear peaks at 18 GHz with second harmonic at 36 GHz.
- Regime III: In this regime the optical and the RF spectra show a multi-peak structure. The main RF peak appears between 7 and 15 GHz with multiple harmonics. Under specific driving conditions, period doubling and broad RF spectra are also observed. Therefore, the dynamics in this regime is either self-pulsating or almost chaotic under some driving conditions.

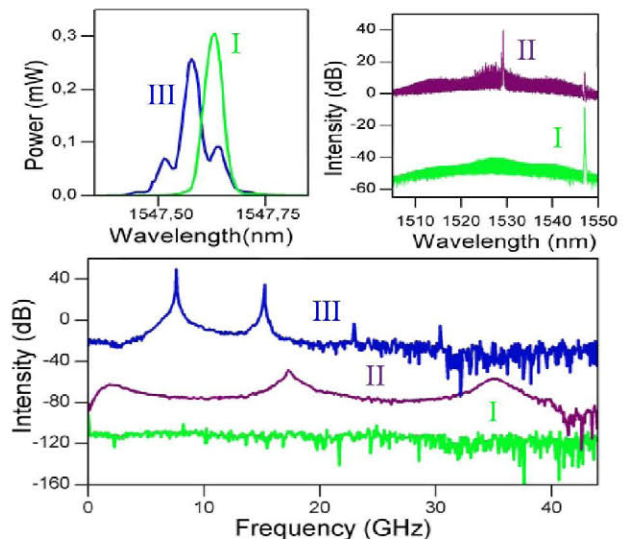


Fig. 1: Examples of optical (top) and RF (bottom) spectra corresponding to the three operation regimes: regime I (green), at $I_{MO} = 300$ mA and $I_{PA} = 3$ A; regime II (violet) at $I_{MO} = 30$ mA and $I_{PA} = 4.2$ A; and regime III (blue) at $I_{MO} = 300$ mA and $I_{PA} = 4$ A.

Fig. 2 shows a color map of the optical spectra recorded as a function of the MO current, I_{MO} , for a constant current in the PA, $I_{PA} = 1$ A. The emission regime is type I, corresponding to

the ideal MOPA operation, where the emission of the DFB is amplified in the tapered section. The DFB threshold current is around 30 mA. The non-linearity of the power-current characteristic (see inset in Fig. 2) is due to the amplifier saturation. The approximately quadratic shift of the emission peak as a function of I_{MO} is due to heating effects. Under these conditions, the amplifier is relatively weakly pumped and thus active internal feedback or coupled cavity effects are virtually absent.

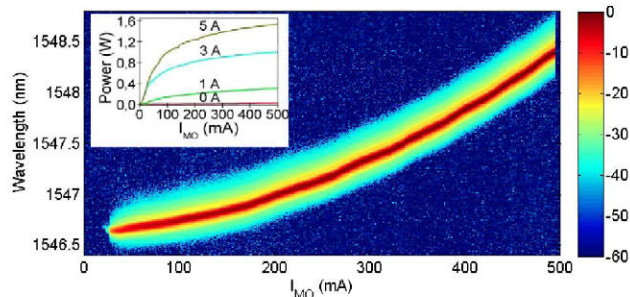


Fig. 2: Color map of the optical spectra of the MOPA as a function of I_{MO} for $I_{PA} = 1$ A. The intensity has been normalized to the maximum intensity in the whole map and plotted in a logarithmic color grading. The inset shows the optical power as a function of I_{MO} for different values of I_{PA} , measured with a large area thermal detector.

The MOPA operation is completely different when the amplifier is strongly pumped, as can be seen in the color maps of Fig. 3, corresponding to the optical and RF spectra as a function of I_{MO} for $I_{PA} = 5$ A. By increasing the MO current abrupt changes of operation regime are apparent: at very low I_{MO} currents, below the DFB threshold current, regime I is observed (label A); then a small region of regime II (label B) takes place, followed by a new region of regime I (label C). By further increasing I_{MO} , a periodic alternation of regions of regimes I and III is observed (labels D-E-F). The higher the MO current, the smaller is the regime III region and the lower the intensity of its RF peaks. There is not a clear correlation between the conditions at which the wavelength jumps of regime I take place and the conditions for the appearance of a regime III (see labels D-E-F and G-H-I in Fig. 3).

The complex emission dynamics of the MOPA is due to the coupling of the complete and DFB laser cavities, which can be alternatively interpreted as an active feedback from the amplifier into the DFB section [5]. When changing the injection conditions, the self and cross-heating modify the refractive indices of both sections yielding quasi-periodic transitions between different regimes [2]. The transition between regimes I and II, at low MO injection, was analyzed in detail in [3], where it was attributed to a competition between the FP modes of the complete cavity and the DFB emission mode. At high amplifier injection, as in Fig. 3, the situation is far more complex. It can be interpreted as an alternation of single mode emission, with longitudinal mode jumps, characteristic of Distributed Bragg Reflector lasers, with self-pulsation regime originated by the so-called dispersive Q-switching [5].

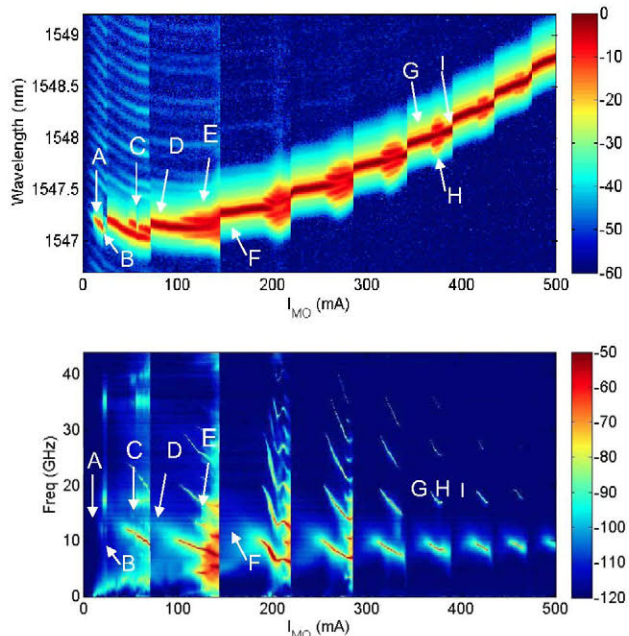


Fig. 3: Color map of the optical (top) and RF (bottom) spectra as a function of I_{MO} for $I_{PA} = 5$ A. The intensities have been normalized to the maximum intensity in the whole map and plotted in a logarithmic color grading.

IV. CONCLUSIONS

We have identified three quite different operation regimes in a 1.5 μm high brightness tapered MOPA, and attributed them to the coupling between the complete and master oscillator cavities. At high power levels, the stable single frequency regime alternates with an unstable self-pulsation regime. It is thus possible to select operation points appropriate for good spectral quality and high brightness applications, or suited for applications making use of a high optical power with intensity oscillations in the GHz range.

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