LASPULSE: Multi-section tapered lasers for all-optical signal processing and short pulse generation

Summary

The generation of short optical pulses with low jitter is very important to extend the capacity of fiber optical communication systems. High power short pulses are also of strong interest in telemetry, and Free-Space-Optics (FSO) communications. On the other hand all-optical signal processing will play a major role in the future photonic networks in order to fully utilize ultra-wide bandwidth of the optical carrier.

Within the FP7-People Marie Curie Program (Intra- European Fellowship), at the Universidad Politécnica de Madrid, Pawel Adamiec has investigated, both from a theoretical and an experimental point of view, high power multi-section semiconductor lasers focusing on its applications in short pulse generation, high speed modulation, and all-optical signal processing for optical communication systems. The main goal was to achieve a better understanding of the dynamics of these devices in order to assess their possible use in previous applications. The investigated devices lasers were two-section tapered lasers (TL) and monolithic Master Oscillator Power Amplifiers (MOPA).

A rate equation dynamic model for two-section TL was developed and implemented. The main idea was to convert the tapered section into a rectangle with the same area, assuming uniformity of carriers and photons in each section. The input parameters for the model were taken from the simulation results obtained with a 3D steady-state model, which was also used as a validation test of the simplified rate equation model in steady-state. The model was applied to simulate the pulse generation of 1060 nm Distributed Bragg Reflector (DBR) TLs, which were also experimentally characterized. To improve the agreement between the modeling results and experiments one-dimensional intensity travelling wave was implemented into the model. The model was able to predict qualitatively the behavior of the two-section DBR TLs, i.e, the pulse power, pulse width, and rise time as a function of driving parameters. As an example Fig. 1 shows the experimental and simulated pulses in gain-switching conditions.

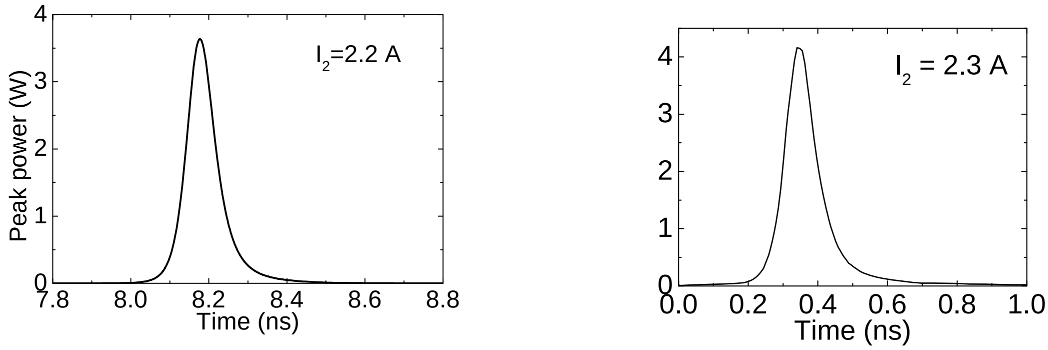

Fig. 1. Pulse shapes in gain-switching, simulation (left) and experiment (right); f=900 MHz, RW current I_1 = 50 mA, tapered current I_2 = 2.2 A and 2.3 A in the theory and experiment, respectively.

The experimental setup to measure two-section TL or MOPAs in continuous wave (CW) and dynamic operation was designed and implemented. It included equipment and software tools to measure the output power and spectra as a function of both, tapered current and ridge waveguide (or MO). The dynamic measurements included different approaches: (i) gain switching, (ii) direct modulation, (iii) RF measurements.

Two-section TL emitting at 1060 nm and MOPA emitting at 1550 nm were extensively characterized to understand the static and dynamic behavior and to study the performance limits. In this respect some outstanding results have been obtained. In gain switching regime short 100 ps pulses with 2.7 peak power were obtained from the monolithic MOPA. These devices suffer from instabilities due to mode competition and self-pulsation processes. The instabilities are apparent in Fig. 2 where the Power-PA current characteristics and the spectra corresponding to specific PA currents are correlated. The instabilities were consistently explained in terms of mode hopping between the distributed feedback mode of the MO (1550 nm) and the Fabry-Perot mode of the entire cavity (1520 nm) allowed by the residual reflectance of the PA front facet. This mode hoping results in the ripples observed in the power-current characteristics. Nevertheless, regions of high stability were found, in which high power and stable pulses were obtained.

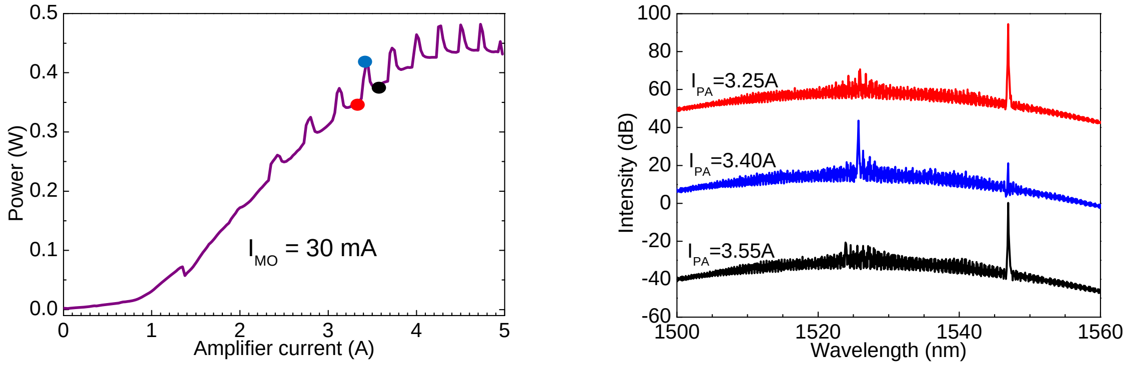

Fig. 2. Power-PA current characteristic of a MOPA for a fixed MO current and spectra corresponding to the three marked points (each point in same color than spectrum) showing the mode-hopping.

Another state-of-the-art achievement is the direct modulation of the two section tapered laser emitting at 1060 nm at high frequency, controlling the high output power with a relatively small current in the RW section. The measured eye diagram with a Q factor of 6.5 at 2.5 Gbit/s is shown in Fig. 3. This result points to a potential application of these devices in FSO communications.

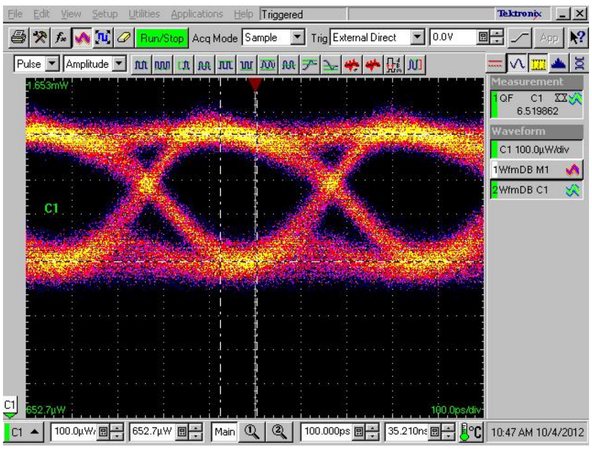

Fig. 3. Eye diagram at 2.5 Gbit/s for 1060 nm tapered laser.

In addition, RF measurements were performed in order to determine relative intensity noise in TLs and MOPAs and further to obtain internal parameters of the device like differential gain, which was used in the modeling. Finally, the developed model was used to study the influence of different geometries on the dynamics of two-section tapered lasers and on the bistable behaviour to be used in all-optical signal processing.

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References

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