9:15am-9:30am
ThB3

Measurements of laser rate equation parameters for simulating the performance of directly modulated 2.5Gb/s Metro area transmission systems and networks

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The characteristics of the cost-sensitive metropolitan-area networks, in terms of transmission distance and bit rate, are not so demanding compared to Long-haul networks and therefore the requirements on the performance of the optical devices are somewhat relaxed. Therefore, cost-effective directly modulated lasers (DML) have attracted much attention recently for Metro area applications. However, DMLs have some drawbacks. The major of these drawbacks is their frequency chirp [1-4]. The interaction of the chirp with the dispersion of conventional single-mode fibers deteriorates the signal and limits the maximum transmission distance [1-4]. In metro-area networks utilizing DMLs, this chirp-induced distortion is the major impairment. The use of negative dispersion fibers to enhance the transmission distances of DML has been discussed recently [4]. The choice of transmission fiber characteristics for optimum performance in metro area networks should first be determined through simulations that will identify the transmission performance of DMLs.

The system designer should select the model and simulation parameters that provide results representative of commercially available DMLs. It has been acknowledged [1-4], that using the rate equations-based model the laser dynamics can be evaluated sufficiently accurate for system simulation purposes. Many works have been published in recent years discussing the extraction of the rate equation parameters [1-3]. To our knowledge, it is not possible to determine experimentally with a single measurement each one of the actual rate equation parameters from a packaged device. In the previous studies [1-3] the chirp waveforms that mainly determine the transmission performance of the DMLs were either not measured or were not used for extraction of chirp-related parameters. In addition, the validity of the extraction procedures was verified mainly by comparing measured and simulated power waveforms.

In this work, we will present a detailed study on the extraction procedures for rate equation parameters. Some published procedures [1-3] have been updated (more accurate theoretical expressions were used), while others are presented here for the first time. In this work parameters related to the chirp characteristics are extracted directly from chirp measurements. Moreover, the procedures have been applied for the characterization of DMLs with different characteristics. The laser dynamics were accurately simulated as shown by comparing the measured and simulated results for both chirp and power waveforms. The extracted parameters were then used in transmission simulations to identify the best fiber choice for Metro area networks utilizing DMLs. This work can be a useful tool whenever the influence of DML characteristics on the overall performance of a system must be accurately evaluated.

The extraction procedures are based on fitting the measurements of (a) the P-I curve [1-2], (b) the IM frequency response [1-2] and (c) the power and chirp waveforms. The details of all the procedures will be presented in the conference. We focus here on how to extract parameters related to the frequency chirp.

The theoretical expression that relates the chirp $\Delta\nu(t)$ with the laser output optical power P(t) [2] is:

$$\Delta\nu(t) = \frac{\alpha}{4\pi}\left(\frac{d}{dt}[\ln(P(t))] + \kappa P(t)\right) \qquad (1)$$

The procedure to extract values for the α-parameter and the adiabatic chirp coefficient κ follows: First, the power waveform and the corresponding chirp waveform are measured using a technique similar to that described in [5]. Then, the measured chirp waveform are fitted using the measured power waveform and equation (1) for appropriate values of the parameters α and κ. In Fig. 1 the measured chirp waveform is shown together with the fitted curve for two DMLs having different chirp characteristics. The fitting is very good, yielding values of α=2.2 and κ=28.7·1012 HzW-1 for DML-1 and α=5.6 and κ=1.5·1012 HzW-1 for DML-2. DML-1 is an adiabatic chirp-dominated laser while DML-2 is transient chirp dominated.

In Fig. 2 the measured and simulated power and chirp waveforms are compared. For this figure the simulation conditions were adjusted to the experimental ones. The simulation results for both the power and chirp waveforms and for all DMLs are in excellent agreement with the experimental results and indicate the robustness of the extraction procedure and the validity of the rate equation model.

Having a sufficiently accurate representation of the dynamics of DMLs (Fig. 2), we performed simulations to compare the transmission performance of DMLs having different chirp characteristics over a distance of 300Km. These simulations utilized two different fiber types that are likely to be used in metro-area networks. Fiber-type-1 is a fiber with the dispersion characteristics of conventional single-mode fiber with positive dispersion of 17ps/nm/Km at 1550 nm (i.e. SMF-28™ fiber). Fiber-type-2 (Corning MetroCor™ fiber) is a novel non-zero dispersion shifted

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fiber with negative dispersion of about half the absolute dispersion of SMF-28 fiber at 1550nm [4]. For the simulations, the extinction ratio and the average output optical power at the transmitter was 8.2dB and 0dBm respectively. The simulation results (Fig.3) indicate that the use of negative dispersion fiber resulted in better transmission performance for both adiabatic (Fig. 3(a)) and transient (Fig. 3(b)) chirp dominated DMLs. Such a fiber choice will allow for transparent uncompensated metropolitan-area networks over large distances. Conventional fibers will support transparency, but over shorter distances.

In conclusion, we presented a study on the extraction of laser rate equation parameters. Very good agreement has been obtained between the simulated and measured results of the characteristics of DMLs. Using the model we performed simulations to determine the optimum fiber choice for Metro area networks utilizing DMLs. We also obtained good agreement between the measured and simulated received waveforms after transmission over different fiber types and results will be shown in the conference.

References

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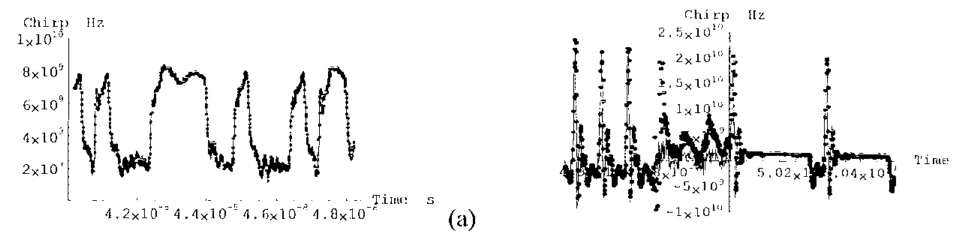

Fig. 1 - Measured (dots) and fitted (lines) chirp waveforms for (a) adiabatic and (b) transient chirp-dominated DMLs.

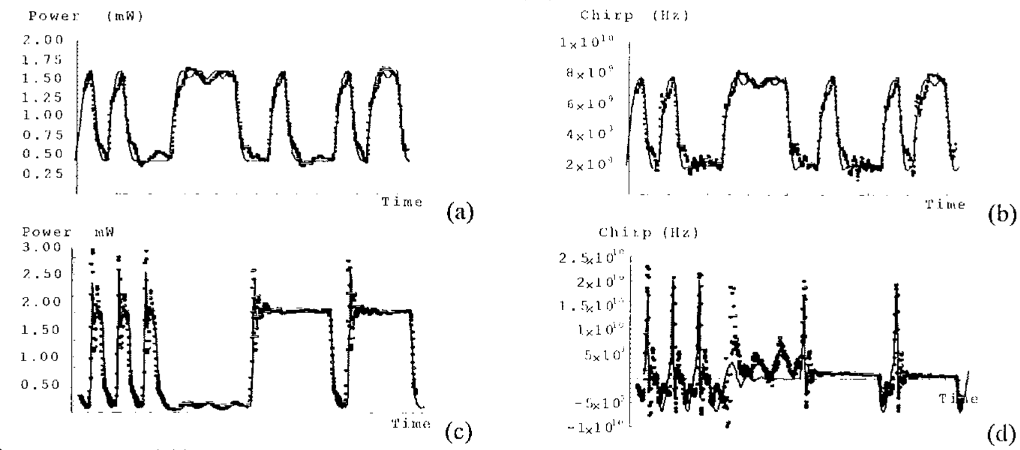

Fig. 2 - Measured (dots) and simulated (lines) power (a) and chirp (b) waveforms for two different DMLs. Upper row: adiabatic chirp-dominated DML, Bottom row: transient chirp-dominated DML.

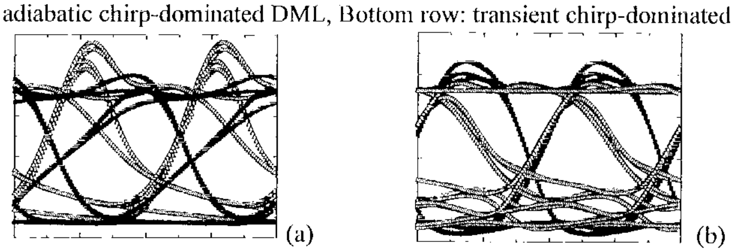

Fig. 3 – Received eye-patters after transmission over 300Km of the output field of the adiabatic chirp-dominated DML-1 (a) and the transient chirp-dominated DML-2 (b) over fiber-type-1 (triangles) and fiber-type-2 (squares).