COST 240 Workshop

CHARACTERIZATION TECHNIQUES FOR ACTIVE AND PASSIVE PHOTONIC COMPONENTS

Budapest, Hungary

March 25, 1996.

Technical Programme Committee

Tibor Berceli
Carlo DeBernardi
Hartmut Hillmer
Faustino Martelli
Georg Sztefka

PROGRAMME

Oral sessions

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T. Farrel, D. McDonald, J. Dunne, R. F. O'Dowd: General characterisation algorithm for WDM lasers

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F. Steinhagen, H.L. Hartnagel and H. Burkhard: Up to 20 GHz high-frequency small-signal AM characterization of laser-diodes

M. Bertolotti, R. Li Voti, C. Sibilia, G.L. Liakhou, A.V. Syrbu, V.P. Yakovlev, and R.P. Wang: Analysis of the thermal stability for semiconductor laser diode using the photodeflection technique

P. Spano, A. Mecozzi, A. D'Ottavi, F. Martelli, S. Scotti, R. Dall'Ara, J. Eckner, G. Guekos : Characterization of wavelength converters based on four-wave mixing in semiconductor optical amplifiers

A. Hangleiter: Intrinsic dyamics of strained quantum well lasers (invited talk)

S. Pajarola and G. Guekos: External cavity laser: a configuration for the characterization of semiconductor optical amplifiers

G. Sztefka: Optical semiconductor amplifiers for system applications

P. Cinguino, G. Guiliani, A. Piccirillo: Multifunctional characterization of single and cascaded two-section amplifier-modulator-detector SOAs for add-drop applications

H. J. Troger, P. A. Nicati, A. Kueng and P. A. Robert: Group index measurement on InP waveguides using Fabry-Perot techniques: accurancy analysis and comparison with white light interferometry measurements

L.B. Soldano, F. Pozzi, C. De Bernardi: Near field distribution in integrated waveguides: some critical aspects in its measurement and interpretation

P. Verhoeve, G. Morthier, R. Baets, K. Sato, Y. Nakano: ASE-spectra based parameter estimation for DFB and DBR lasers

Poster session:

A. Destrez and Z. Toffano: Measurement of relevant characteristics of semiconductor lasers used in CATV applications

K. Czotscher, E.C. Larkinns, S. Weisser, W. Benz, J. Daleiden, I. Esquivias, J. Fleissner, M. Maier, J. D. Ralston, B. Romero, A. Schönfelder, and J. Rosenzweig: Ulra-high-speed InGaAs/GaAs MQW lasers with undoped and C-doped active regions

G. Mussi, N. Gisin, R. Passy, J.P. von der Weid: Very-high-sensitivity coherent reflectometer for characterization of pigtailed optical components with unambiguous determinations of reflection locations.

F. Girardin and G.-H. Duan: Characterization techniques of gain supression in semiconductor lasers and amplifiers

M. Bertolotti, P. Masciulli, C. Sibilia: Optical properties of multilayer filters realized with Cantor-like code

G. Renner, M. Serényi: Pulse shortening of actively mode-locked commercial diode laser by wavelength tuning

R. Paoletti, D. Bertone, A. Bricconi, R. Fang, L. Greborio, G. Magnetti, M. Meliga: Parasitic capacitance effect evaluation in three 1.55 μm InGaAsP buried laser structures using optical and electrical modulation bandwith measurement.

A. Ho-Quoc, S. Tedjini: Single mode integrated thermo-optic switch in glass by ion exchange

H.J. van Weerden, P. V. Lambeck, T. H. Hoekstra: Spectral attenuation measurement by moving prism method

T. Berceli, B. Cabon, A. Hilt, G. Járó, J. Ladvánszky: Dynamic characterization of optically controlled semiconductor devices.

M. Bertolotti, G. Liakhou, R. Li Voti, A. Matera, C. Sibilia, M. Valentino: Optical losses characterization of channelwaveguides through photodeflection method

M. Bertolotti, W. A. Ramadan, and E. Fazio: Measurement of the transverse refractive-index distribution of waveguides

L. Andersson, F. Lenner: Automatized Characterization of DBR-lasers

Opening address

The Cost Action 240 "Modelling and Measuring Advanced Photonic Telecommunications Components" started in 1991 is a European collaborative research effort in the field of semiconductor integrated-optical devices with potential for applications in fibre-optic communications. Both active and passive devices are investigated through theory, modelling and measurements. COST provides an open forum for exchanges of information, for collaboration on modelling tools for photonic structures and for the organisation of inter-laboratory comparative measurements. Over 40 laboratories have joined this COST Action and collaborate by providing modelling experience and tools, semiconductor photonic components not available commercially but of evident interest for future broadband fibre communications, and by participating in working groups on lasers and amplifiers, on passive structures, and on optical non-linear phenomena. The cooperation between the participating laboratories has proven very valuable, especially in the fields of modelling and experimental determination of key operational device parameters. In contrast to other large European projects, the work of the participating institutions that is the subject of the COST collaboration, is not centrally funded by COST. The launching of COST Actions follows the bottom-up approach and the participation is on a voluntary basis, where a strong positive correlation between motivation and quality of results can be developed.

This is the first COST 240 workshop in the field of characterisation techniques for active and passive photonic components. We feel this is a timely and interesting subject because, as the photonic structures developed for communications applications become increasingly complex, the techniques to master the experimental characterisation of the devices should be as clear and as handy as possible in order to allow an unequivocal interpretation of the results. Although this workshop was not especially advertised and is intended to be rather an internal COST event, the response by the scientific community engaged in the characterisation of photonic components was overwhelming. Many fine papers were proposed and several had to be accommodated in a poster session not originally planned. We feel that in a European environment of communication system development where the overall performance of a fibre optic system counts, the topic of measurements of the key components deserved higher attention. In this respect, the Budapest COST workshop responds to a need of the scientific community. In addition, the workshop is in line with the strong cooperative effort developed in COST 240 where lasers, optical semiconductor amplifiers and passive structures are continuously measured and the result between the laboratories compared and published in the scientific literature. Important issues, such as laser modulation and chirp, linewidth, wavelength conversion, thermal stability, optical amplification, accurate waveguide metrology, and several others will be covered by 27 invited, regular and poster papers in total. These papers are intended to not only report on results but also to stimulate discussions on questions that are of importance to all those associated with the metrology of photonic components.

The quality of the work to be presented and the steady organisational efforts by Prof. T. Berceli and his team set a solid basis for a successful workshop. We look forward to having a pleasant and fruitful event.

Georg Guekos

DYNAMIC CHARACTERIZATION OF OPTICALLY CONTROLLED SEMICONDUCTOR DEVICES

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ABSTRACT

Optical control of semiconductor devices is a new area, which can be used in several applications. The dynamic behavior of these devices is a crucial problem. Reliable method for its characterization is highly needed.

The paper presents characterization methods with their measurement procedures. The measurement setup consists of both optical and microwave instrumentation. The device under test is illuminated by a laser beam intensity modulated by a microwave signal. The modulation represents the perturbation. The device properties are measured without modulation and with varying modulation frequency.

INTRODUCTION

Any electrical parameter of an optically illuminated semiconductor device is a function of both electrical and optical parameters :

$$x = x(f_e, V, I, \ldots; P_{opt}, f_{mod.opt.}, \lambda, m_{opt}, \ldots),$$

where $f_{mod.opt}$ is the frequency modulating the laser light, m_{opt} is the optical modulation depth and P_{opt} is the average optical intensity. The dynamic electrical parameter of the illuminated device is defined as the function :

$$\frac{\delta x(y_1, y_2, \ldots, y_N)}{\delta y_i},$$

where y_i represents any of the electrical or optical variables given in the first equation.

A general measurement setup is shown in Fig. 1. for investigating the dynamic behavior of the device under test.

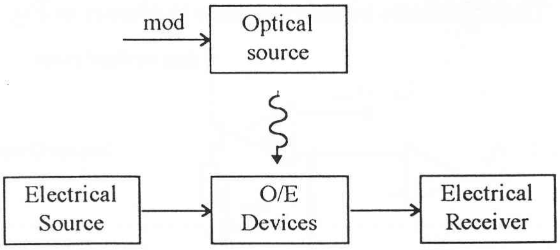

Figure 1. Dynamic characterization measurement setup

Usually the electrical source contains bias and high frequency signal source. The optical source may consist of laser sources modulated by microwave frequencies. Electrical network analyzer system can be constructed if the input port is the electrical generator and the output port is the electrical receiver synchronized to each other. So the S parameters of an optically controlled active or passive device can be measured [1]. However, an electrically controlled O/E transmission can be characterized using the optical source as the input port.

Testing O/E devices, which combine the electrical and the optical excitation the electrical receiver is a microwave spectrum analyzer, displaying the modulation sidebands, mixing and/or intermodulation products [2], [3].

The following electrical parameters can be varied : the bias (V, I), the source frequencies (f_e) and their power levels. In the optical domain we can change the optical wavelength (λ), the average optical power intensity (P_{opt}), modulation frequencies $(f_{mod.opt})$ and their modulation depths.

In this paper we show some specific measurement arrangements and typical results as examples of the general model presented above.

THE OPTICAL SOURCE

Two different laser sources had been utilized in the experiments, the HP 83420A Lightwave Test Set (LWTS) as a λ=1300 nm source, and a 785 nm HITACHI GaAlAs laser diode [4], respectively. The HP 83420A LWTS consists of a 1300 nm DFB laser diode connected to a fiber output external modulator up to 20 GHz [5]. The 785 nm source illuminates the optically controlled devices through a lens and free space. The focusing mechanism was developed by MFKI, Research Institute for Technical Physics, and allow a precise micropositioning and focusing. The diameter of the focused light spot is approximately 40 μm. The schematic circuit diagram is shown in Fig. 2.

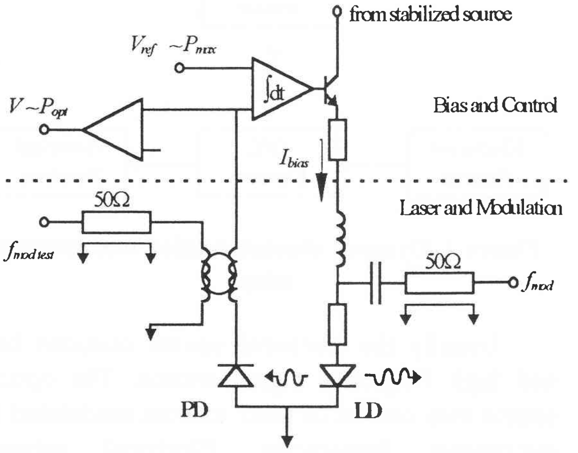

Figure 2. Circuit diagram of the 785 nm laser source

The modulation bandwidth was tested with a high speed (t_r=18 ps [6]) pin photodetector. (This photodetector was previously calibrated up to 20 GHz.) Fig. 3 shows the modulation bandwidth of the direct modulated 785 nm laser source.

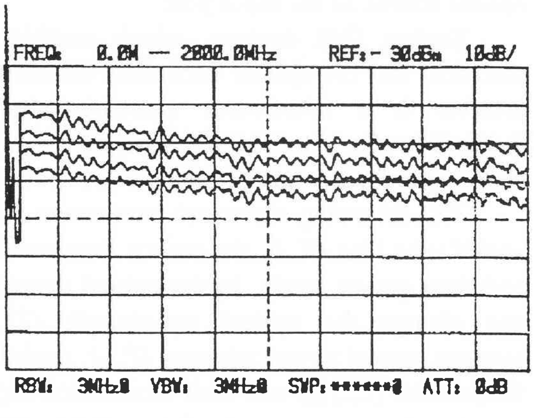

Figure 3. Modulation bandwidth of the 785 nm laser source

The parameter of the curves is the power level of the electrical modulation signal. Fig. 4. shows the emitted optical spectrum of the 785 nm multimode laser above threshold current.

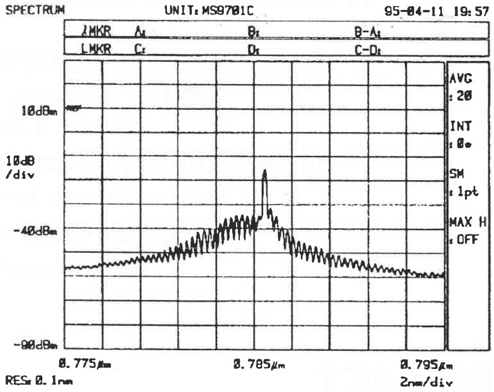

Figure 5. Optical spectrum of the 785 nm laser

TEST EXAMPLES

In the design of broadband optical front-ends it is necessary to characterize the responsivity of the photodetector. However, significant optical level modifies the microwave reflection of the detector devices, which influences the matching to the transimpedance amplifier. Fig. 5 shows the measurement setup for both responsivity and dynamic electrical reflection measurement.

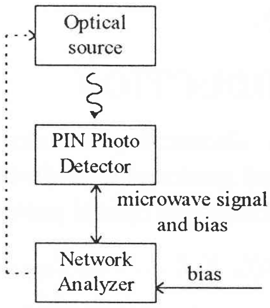

Figure 5. Setup for responsivity and electrical reflection measurement of a photodetector

Responsivity *(R)* is a static and dynamic parameter. In the static case, it is the ratio of the average electrical current to the average optical power. In the dynamic situation, responsivity refers to the change in the electrical current due to the change of the incident optical power :

$$R = \frac{\delta I_{pd}}{\delta P_{opt}}$$

Responsivity of a photodetector expressed in decibels, is related to the level of 1 *A/W* responsivity :

$$R\ [dB(A/W)] = 20\ \log_{10} \frac{R\ [A/W]}{1\ [A/W]}$$

Fig 6. shows *R[dB(A/W)]* of the pin chip photodiode as a function of the reverse bias voltage, measured by the LWTS (the chip was terminated with a 50 Ω impedance).

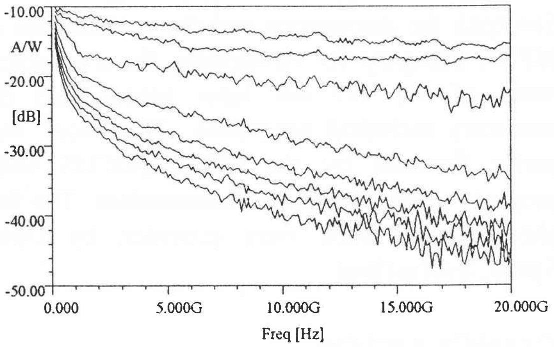

Figure 6. Responsivity of the pin photodiode

Fig. 7 shows the significant change of the reflection (S_{11}) in the f = 130 MHz...20 GHz frequency band due to the change of incident optical power in case of a high speed pin photodetector chip [6].

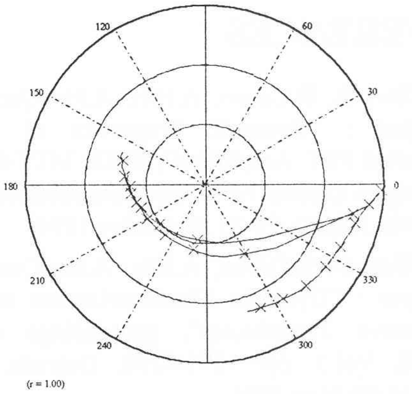

Figure 7. Polar plot of S_{11} versus optical intensity $P_{opt} = 0\ \mu W,\ 105\ \mu W$ and $323\ \mu W$

Close to the forward bias condition the photodiode can not be treated as a linear element. To characterize the nonlinearity some well-known methods exist. Fig. 8 shows a two-tone measurement (by means of an optical and an electrical signal) to test the nonlinearity. The circulator is needed to match the photodetector to the microwave source and to the spectrum analyzer, respectively. (In practice the impedance of the photodiode is far from the matched case, see Fig. 8.)

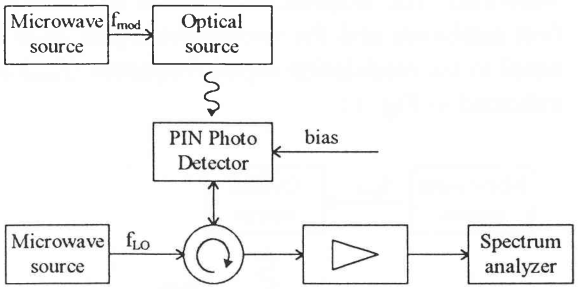

Figure 8. Nonlinearity measurement setup

Fig. 9 shows the spectrum of the detected optical modulation (f_{mod}) upconverted by the microwave source signal (f_{LO}) due to the electrical nonlinearity of the photodiode.

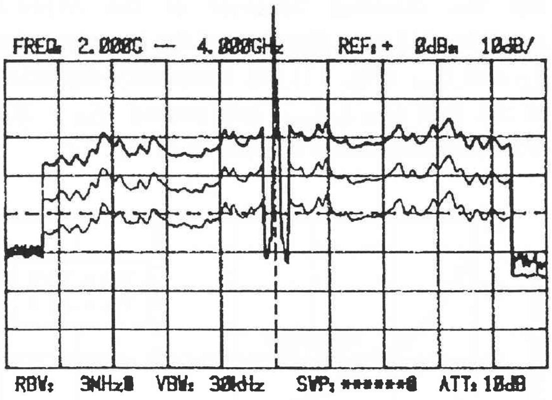

Figure 9. Upconverted optical modulation spectrum

The gain of MESFET amplifiers can be controlled by laser light illuminating the active device (Fig. 10).

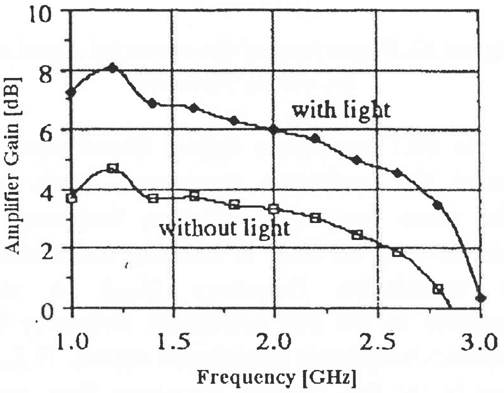

Figure 10. MESFET amplifier gain controlled optically

The laser can be modulated in this case also. Similarly to the photodiode shown in Fig. 9-10 the nonlinearity of the MESFET creates sidebands. The frequency difference between the first sidebands and the microwave signal (f_{LO}) is equal to the modulation signal frequency (f_{mod}) as indicated in Fig. 11.

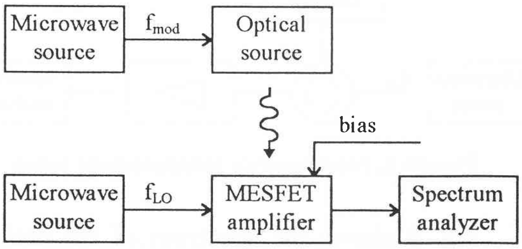

Figure 11. Optically controlled MESFET amplifier

Measuring the level of the sidebands we can test the dynamic behavior of the MESFET amplifier [1] as a function of the transistor bias, f_{LO} and f_{mod} (Fig. 11) [2]. Frequency dependence of the first ($f_{LO} \pm f_{mod}$) and second ($f_{LO} \pm 2f_{mod}$) sideband amplitudes are shown in Fig. 12.

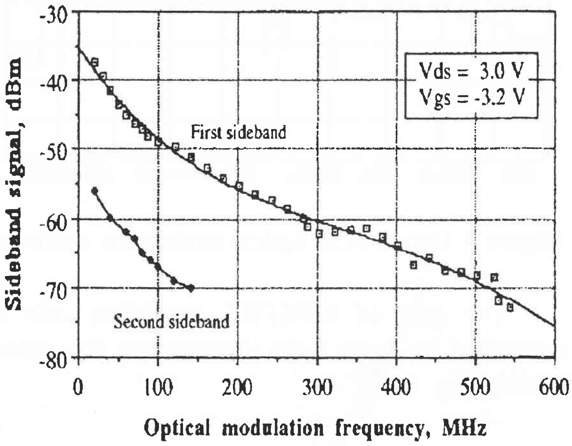

Figure 12. Power level of the converted signal and the second harmonic

In FET oscillators optical illumination can control the oscillation frequency. Static laser light tunes the self oscillation frequency. In dynamic case the laser is intensity modulated. If the modulation frequency (f_{mod}) is small compared to the self oscillation frequency then frequency/amplitude modulation occurs. If f_{mod} is close to the free running frequency then optical injection locking is observed on the spectrum analyzer as it is illustrated in Fig. 13.

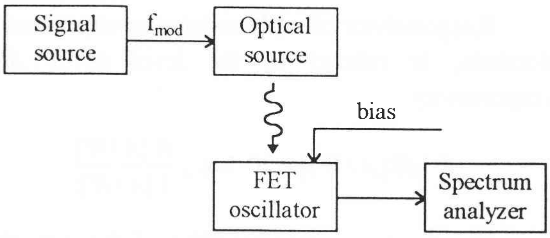

Figure 13. Optically controlled FET oscillator

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CONCLUSION

In the paper dynamic properties of optically controlled devices were studied. Different measurement setups were presented and some representative measured results were shown utilizing pin photodiode and MESFET devices as examples.

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