Performance Optimization of Optical Devices Using Multicore

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Abstract— Integrated multicore structures are good candidates to improve the performance of active optical devices [1]. We are working on the characterization of these fabricated structures by femtosecond laser writing [2]. The two modal characterization techniques implemented by our group are presented.

Indexed Terms— multicore, power distribution, computer-generated holograms

I. INTRODUCTION

Control over modal composition is essential for the optimized design of multicore active embedded structures. In the literature there are two experimental techniques of modal characterization for this type of structures: [1][2][3] the recording with a camera of the transverse power distributions at the output of the structure and its treatment by computer using imaging techniques and [4][5][6] the use of Holographic Optical Elements (HOEs) to spatially separate in real time the components of each mode [7].

II. CHARACTERIZATION BY POWER DISTRIBUTION

The number of modes allowed and the transverse power distribution of each one are characteristic properties of each guide and the working wavelength. We have the necessary software to calculate all this, given the transversal distribution of the refractive index (RSoft CAD) [2][3][7][8]. On the other hand, the distribution of the total power coupled to the guide between its different modes depends on how it is excited.

Figure 1 shows the experimental set-up that allows the excitation of the guide to be varied and its transversal power distribution to be measured. Its location, within the substrate on which it has been recorded, is possible thanks to a microscope [9][10]. This also facilitates the optimization of the confrontation between the entrance of the guide and the optical fiber that provides the light. To optimize and ensure the stability of the assembly, the positions of the fiber and the guide are regulated with piezoelectric controllable micro-positioners [11]. Any lateral displacement between fiber and guide obviously modifies the total coupled power, but also the proportion of power carried by each mode. As a result, the transverse power distribution changes as the fiber-guide engagement is decentered [3][4][12][13].

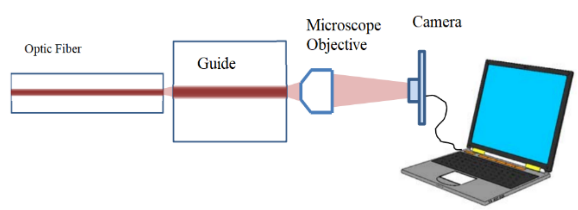

Fig. 1 Experimental setup to measure the transverse distribution of power at the output of a guide.

Next to the other end of this, a microscope objective is placed that forms the image of the exit face of the guide in a CCD camera (Bobcat 320 by Xenics). The magnification provided by the optical system, adjustable by moving the objective relative to the guide output, easily reaches a factor of 200x. Considering that the size of the pixels of the camera is 20μm, a resolution of up to 0.1μm to the transverse distribution of output power of the guide can be available[15]. The proportion of the total power carried by each mode is determined by adjusting the image obtained to a sum weighted cross-sectional distributions characteristics of each mode, previously calculated using the aforementioned software[16].

III. CHARACTERIZATION BY CGH

Another way of knowing the modal distribution at the exit of the guide is through the use of computer-generated holograms (CGH) [3][4][12][17]. These holograms can be digitally calculated and recorded in a spatial light modulator (SLM) device. When a hologram is recorded with the interference of a reference plane wave, R, and an object wave, O_n, formed by the complex amplitude distribution of one of the modes, n, at the output of the guide, the transmittance of the holographic element, t(x,y), is proportional to the intensity of said interference.

$$t(x,y) = [O_n(x,y) + R(x,y)][O_n^*(x,y) + R^*(x,y)] = O_n O_n^* + RR^* + O_n R^* + O_n{}^* R$$

The last two addends have information on both the amplitude and the phase of both waves. If we digitally record the fourth addend in a phase SLM, when the SLM is illuminated with the power distribution at the guide output, $\sum_n c_n O_n$, at the output of the SLM there will be a plane wave $c_n R$, in the direction of the reference wave R, whose intensity is proportional to the intensity of the modo n.

In the SLM, the interference of each of the modes can be recorded with a reference wave R tilted at a different angle for each mode. In this way, at the output of the SLM we will be able to identify the contribution of each mode through the diffracted waves, their intensity ratio being proportional to that of the different modes at the output of the guide. In order to achieve the same amplitude distribution on the modulator as at the output of the guide, a system $4f$ made up of two lenses (L1 and L2) has been included in the assembly. The beam diffracted by the holographic element recorded in the SLM propagates in a different direction and its intensity is collected in a detector with the help of a lens (L3) (Figure 2).

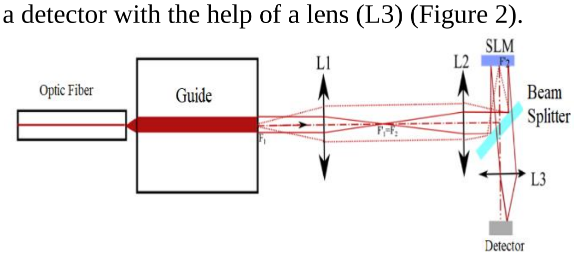

Fig. 2: Setup for mode recognition with a holographic optical element

CONCLUSION

The modal characterization of multicore integrated guides by means of two different experimental methods allows to test their validity and contributes to the optimized design of these structures.

REFERENCES

[1] Abedin, K. S., T. F. Taunay, M. Fishteyn, D. J. DiGiovanni, V. R. Supradeepa, J. M. Fini, M. F. Yan, B. Zhu, E. M. Monberg, and F. V. Dimarcello. "Cladding-pumped erbium-doped multicore fiber amplifier." Optics express 20, no. 18 (2012): 20191-20200

[2] Abedin, K. S., T. F. Taunay, M. Fishteyn, M. F. Yan, B. Zhu, J. M. Fini, E. M. Monberg, F. V. Dimarcello, and P. W. Wisk. "Amplification and noise properties of an erbium-doped multicore fiber amplifier." Optics express 19, no. 17 (2011): 16715-16721.

[3] Han, Ke, Shanglin Long, Zhongliang Deng, Yannan Zhang, and Jiawei Li. "A novel germanium-around-source gate-all-around tunnelling field-effect transistor for low-power applications." Micromachines 11, no. 2 (2020): 164.

[4] Sakamoto, Taiji, Masaki Wada, Shinichi Aozasa, Ryota Imada, Takashi Yamamoto, and Kazuhide Nakajima. "Characteristics of randomly coupled 12-core erbium-doped fiber amplifier." Journal of Lightwave Technology 39, no. 4 (2020): 1186-1193.

[5] Yamada, Makoto, Kyozo Tsujikawa, Lin Ma, Kentaro Ichii, Shoichiro Matsuo, Nobutomo Hanzawa, and Hirotaka Ono. "Optical fiber amplifier employing a bundle of reduced cladding erbium-doped fibers." IEEE Photonics Technology Letters 24, no. 21 (2012): 1910-1913.

[6] Maeda, Koichi, Yukihiro Tsuchida, Ryuichi Sugizaki, and Hiroshi Matsuura. "Multicore erbium doped fiber amplifiers." In Optical Metro Networks and Short-Haul Systems VIII, vol. 9773, p. 977302. SPIE, 2016.

[7] Manakkadu, Sheheeda, and Sourav Dutta. "Bandwidth based performance optimization of

Multi-threaded applications." In 2014 Sixth International Symposium on Parallel Architectures, Algorithms and Programming, pp. 118-122. IEEE, 2014.

[8] Jain, Saurabh, Carlos Castro, Yongmin Jung, John Hayes, Reza Sandoghchi, Takayuki Mizuno, Yusuke Sasaki et al. "32-core erbium/ytterbium-doped multicore fiber amplifier for next generation space-division multiplexed transmission system." Optics Express 25, no. 26 (2017): 32887-32896.

[9] Lin, Wenliang, Zhongliang Deng, Qin Fang, Ning Li, and Ke Han. "A new satellite communication bandwidth allocation combined services model and network performance optimization." International Journal of Satellite Communications and Networking 35, no. 3 (2017): 263-277.

[10] Venkataramani, Vanchinathan, Mun Choon Chan, and Tulika Mitra. "Scratchpad-memory management for multi-threaded applications on many-core architectures." ACM Transactions on Embedded Computing Systems (TECS) 18, no. 1 (2019): 1-28.

[11] Dutta, Sourav, Sheheeda Manakkadu, and Dimitri Kagaris. "Classifying performance bottlenecks in multi-threaded applications." In 2014 IEEE 8th International Symposium on Embedded Multicore/Manycore SoCs, pp. 341-345. IEEE, 2014.

[12] Pricopi, Mihai, Thannirmalai Somu Muthukaruppan, Vanchinathan Venkataramani, Tulika Mitra, and Sanjay Vishin. "Power-performance modeling on asymmetric multi-cores." In 2013 International Conference on Compilers, Architecture and Synthesis for Embedded Systems (CASES), pp. 1-10. IEEE, 2013.

[13] Zhou, Lina, Yin Xiao, and Wen Chen. "Learning-based attacks for detecting the vulnerability of computer-generated hologram based optical encryption." Optics express 28, no. 2 (2020): 2499-2510.

[14] Flamm, Daniel, Philipp Gelszinnis, Christian Schulze, Siegmund Schröter, and Michael Duparré. "Characterizing the Mode Transmission During a Fiber-to-fiber Coupling Process." In Applications of Lasers for Sensing and Free Space Communications, pp. JTh2A-09. Optica Publishing Group, 2013.

[15] Liu, Mei, Lingzhao Fang, Shuli Liu, Michael G. Pan, Eyal Seroussi, John B. Cole, Li Ma, Hong Chen, and George E. Liu. "Array CGH-based detection of CNV regions and their potential association with reproduction and other economic traits in Holsteins." BMC genomics 20, no. 1 (2019): 1-10.

[16] Zhou, Lina, Yin Xiao, and Wen Chen. "Learning-based attacks for detecting the vulnerability of computer-generated hologram based optical encryption." Optics express 28, no. 2 (2020): 2499-2510.

[17] Pathania, Anuj, Vanchinathan Venkataramani, Muhammad Shafique, Tulika Mitra, and Jörg Henkel. "Distributed fair scheduling for many-cores." In 2016 Design, Automation & Test in Europe Conference & Exhibition (DATE), pp. 379-384. IEEE, 2016.