VCSELs as Highly Sensitive Stand-Alone Distance Sensors

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The development of novel optical components as alternatives to their electronic counterparts has become a very active field of research during the last decades [1]. Especially for sensing purposes a wide variety of different applications has been investigated to measure surface topographies, temperature changes or mechanical strain, among others [2]. Next to the investigation of optical waveguiding structures also the field of light sources as key components for optical communication or miniaturized optical measurement devices, respectively, showed significant advance. Especially vertical-cavity surface-emitting lasers (VCSEL) have become important components for data transmission in data centers [3,4].
In our work we extend the field of application for the VCSEL by using them as light sources and sensing elements simultaneously. This allows highly sensitive detection of surface topographies of integrated optical structures opening the path towards their use as inline and online monitoring tool in integrated optics production [5].
We investigate a novel sensor concept based on a coupled resonator configuration and the use of VCSELs as central elements. The back reflection of a sample surface next to the emission window of the VCSEL affects the internal resonator conditions of the laser resulting in a change of the emitted wavelength and operating current. The cross section in figure 1 a) depicts the fundamental parts of a VCSEL. The two distributed Bragg reflection (DBR) grating stacks with the active layer located in between them form the internal resonator. Next to the emission window on the upper part a partially reflecting sample is placed. The light which is reflected back into the VCSEL interferes with the internal resonator modes. This leads to a slight shift of the emission wavelength, figure 1 b), and of the operating current, respectively, when the operation voltage is kept constant. The formed coupled resonator is very sensitive to movements of the sample along the optical axis of the emitted laser beam.

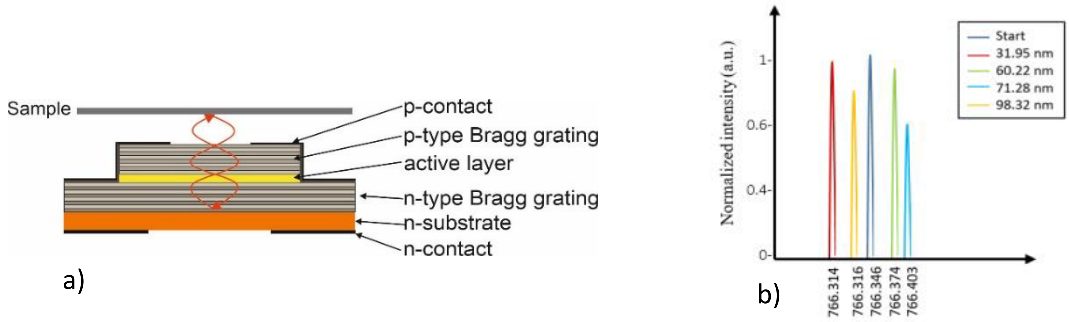

Fig. 1: Cross section of a standard VCSEL showing the active layer and the distributed Bragg reflection (DBR) grating which are essential parts of the developed system. The sample next to the emission window reflects the light partially back into the resonator where it interacts with the internal modes forming a coupled resonator configuration.

The setting enables us to detect changes of the distance between sample and emission window of a few nm only with high precision. In future, we will integrate the new sensor systems into an inline production process chain for additive manufacturing of optics to verify the topography of the created structures and establish a closed feedback loop in for correction of manufacturing inaccuracies.

References

[1] N.K. Guimard, N. Gomez and C.E. Schmidt, "Conducting polymers in biomedical engineering", Prog. Polymer Sci. **32**, 876-921 (2007)
[2] H. Tazawa, T. Kanie and M. Katayama, „Fiber-optic coupler based refractive index sensor and ist application to biosensing", Appl Phys. Lett. **92**, 113901 (2007)
[3] J. Tatum, D. Gazula, L. Graham, J. Guenter, R. Johnson, J. King, C. Kocot, G. Landry, I. Lyubomirsky, A. MacInnes, E. Shaw, K. Balemarthy, R. Shubochkin, D. Vaidya, M. Yan and F. Tang, "VCSEL-based interconnects for current and furture data centers", J. Lightwave Technol. **33**, 727-732 (2015)
[4] G. Kanakis, N. Iliadis, W. Soenen, B. Moeneclaey, N. Aryris, D. Kalavrouziotis, S. Spiga, P. Bakopoulos and H. Avramopoulos, "High-speed vcsel-based transceiver for 200 Gb short-reach intra-datacenter optical interconnects", Appl. Sci **9**, 2488 (2019)
[5] C. Gorecki, S. Khalfallah, H. Kawakatsu and Y. Arakawa, "New SNOM sensor using optical feedback in a VCSEL-based compound-cavity", Sens. Actuator A Phys. **87**, 113-123 (2001)