Miniature Multifunction Fluorescence Sensors on *Si* Substrates

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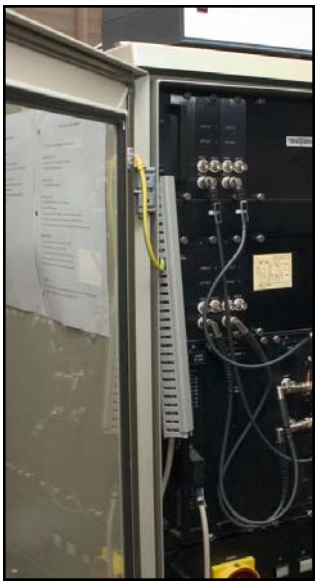

TOP—Dr. David Starikov, research associate professor, earned both his M.S. and Ph.D. degrees in physics at the State University of Chernovtsy in the Ukraine. (*bottom*) Clement Joseph, a UH Ph.D. student in electrical engineering, earned his M.S. in electrical engineering at the University of Houston, and his B.S. in electrical and electronics engineering from Anna University in Chennai, India.

Abstract—The study of fluorescence sensors was a continuation of the research initiated in the ISSO mini-grant titled "Miniature Multifunction Fluorescence Sensors on *Si* Substrates" and has progressed, to date, to (1) modeling of the advanced sensor control and acquisition circuit and (2) realization of an Artificial Neural Network (ANN)-based analysis system.

RECENT WORK ON THE INTEGRATION OF CHIP-BASED miniature multifunction fluorescence sensors indicated that such miniaturization results in a loss of sensor sensitivity. Additional work was needed to improve the dynamic range and sensitivity of the multifunctional sensors. The most limiting factor toward that goal is the decrease in detectors of the signal-to-noise (S/N) ratio. Loss of sensitivity may be attributed to many factors, including inherently low signal levels and various noise sources. To that end we have implemented well proven communication coding schemes in an effort to increase the S/N ratio through excitation source coding.

This approach among other issues seems to significantly reduce the direct cross-talk between the LED and the receiving photodetectors. In particular, we have compared the noise immunity of a multi-band sensor prototype device using Frequency Division Multiple Access (FDMA) and Code Division Multiple Access (CDMA) coding for the excitation source. The results indicate that the two coding schemes offer comparable performance at low signal-over-noise levels, but the CDMA approach offers a much better noise immunity in noisy/dilute environments above –30dB. Currently, we are using the CDMA approach to code the excitation source in a design that uses two chips, a Field Programmable Gate Array (FPGA) and an analog-to-digital converter (ADC). A CPU core is also embedded into the FPGA for additional signal process-

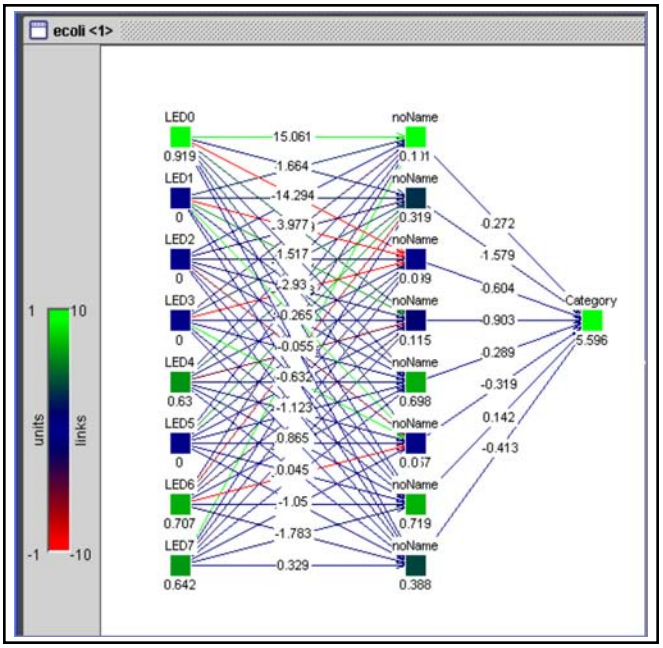

Figure 1. The architecture of the Stuttgart Neural Network Simulator employed for measurement analysis.

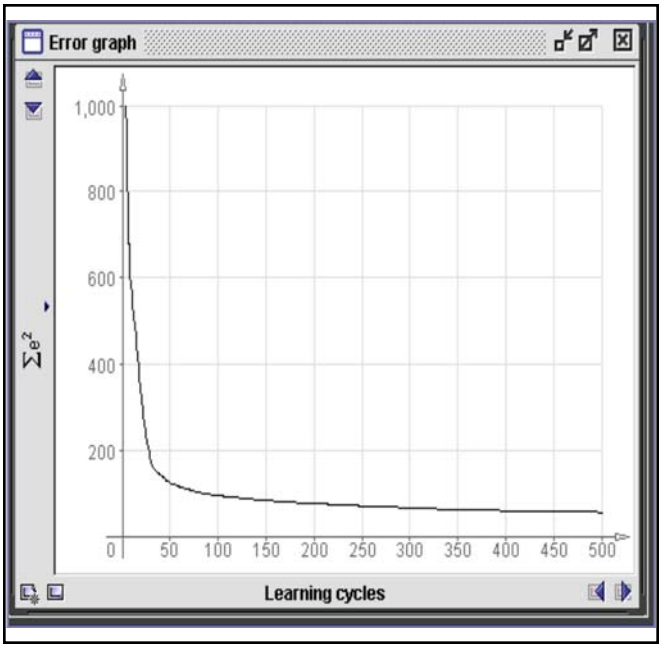

Figure 2. Dramatic decrease of the sensor errors at the number of learning cycles approaching 50.

ing operations such as Artificial Neural Network (ANN).

The architecture of the artificial neural network (ANN) that has been implemented for analysis of data generated by the multifunctional fluorescence sensors is shown in Fig. 1. The Stuttgart Neural Network Simulator of a resilient back propagation type had one hidden layer and one input layer with 8 neurons for 8 LED/PDs. It allowed for adaptive, error-controlled analysis and resulted in faster learning and better overall performance (Fig. 2). The categorization accuracy of the sensor was about 70% without any knowledge of the analyte type (such as: organic, inorganic, bacteria, etc.), and 98-100% with such knowledge.

With this two-chip solution, we expect to build a battery-operated, miniature device that can be used for operation of a sensor prototype similar for real time measurements in field, and on-board applications.

Presentations

Boukadoum, M., A. Bensaoula, and D. Starikov. "A Portable Multi-Band Optoelectronic System for Identifying and Measuring the Concentration of Fluorophore Substances ," *Proc.*, IEEE North East Workshop on Circuits and Systems (NEWCAS 2004), Montreal (Canada), June 2004.

Boukadoum, M., K. Tabari, A. Bensaoula, and D. Starikov. "Comparison of the Noise Immunity of a LED-Based Multi- Band Optoelectronic Sensor when Using FDMA and CDMA to Code the Excitation Source," IEEE Asia-Pacific Conference on Circuits and Systems (APCCAS 2004), Tainan, Dec., 2004.

Starikov, D., C. Joseph, M. Boukadoum, and A. Bensaoula. "Chip-Based Integrated Filterless Multi-Wavelength Optoelectronic Bio-Chemical Sensors," *Proc.*, Sensors for Industry Conference Sicon/05, Houston, TX, Feb. 8–10, 2005.

Funding and Proposals

"Solid-State High Temperature Jet Engine Fire Detector," DOD (Air Force) SBIR proposal, Aug. 3, 2004–May 3, 2005, $100,000 (*awarded*).

"Multifunctional Optoelectronic Chemical Sensors for Super-Ambient Environments," NASA, TCSAM (UH) (*mini-proposal*).

"High Performance Broadband Optical Calibration Sources for In-Flight Stellar Simulation," NASA, NRA (ASTID-04) (*submitted)*.

[P. 104] EXPERIENCE—Rajeev Pillai gains valuable research experience in TCSAM laboratories on LED-based multi-band optoelectronic sensors working under the supervision of Dr. Bensaoula and Dr. Starikov. A doctoral student in electrical engineering, Mr. Pillai earned his M.S. in electrical engineering at the University of Houston. He graduated with a B.S. in electrical and communications engineering from the Bharathiar University, situated in the city of Coimbatore, a major industrial center in India.