OAK RIDGE NATIONAL LABORATORY FACT SHEET
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Computer Science and Mathematics Division

Integrated Multichannel Sensors

Optical Fiber Array for High-Speed and High-Sensitivity Chemical/Biological Sensing

Technology Impact

A novel multichannel chemical/biological sensor based on an optical fiber array is proposed, which will be able to effectively detect concentration of different analytes simultaneously and independently from each other. Advantages of the proposed technology include:

- Multichannel, simultaneous, and independent measurement of tens of different analytes at different concentrations;
- High sensitivity, high selectivity, high speed;
- Simple signal processing based on intensity detection;
- Ability of recording history of molecular binding for accurate sensing;
- Easy implementation using the well-developed fiber components;
- Low manufacturing cost;
- Compact size;
- Wide range applications to various chemical and biological substances.

Technical Concept

Each sensing channel consists of three parts: (1) A pair of fibers - a reference fiber and a sensing fiber, being considered is a multiple fiber with the core diameter about 50 μm and the cladding diameter about 125 μm; (2) the input port which includes a coherent light source and a fiber beam splitter equally dividing beams into two fibers; (3) the output port which including a fiber beam coupler and a photodiode detecting the intensity of the interference signal resulting from the coupling of the beams from the two fibers. At the sensing window, a part of the sensing fiber claddings is removed and the glass core is immobilized with a chemo-optical transducer receptor layer, which can selectively bind to a certain type of analyte molecules present in the medium. When a binding process is taking place on the sensing window of the measuring channel, a phase change between reference and measuring branches will occur. Such a phase change is proportional to the change of the refractive index Δn at the core-cladding interface. By measuring the intensity change of the interference signal, the refractive index change Δn taking place on the measuring window will be calculated and, accordingly, the concentration of a specific analyte in the sample will be measured.

Multichannel sensing can be readily implemented by using the above fiber sensor units. In particular, the fiber array provides a number of advantages in the technical realization of the multichannel system over the conventional optical sensing methods. First, the fiber (cladding) diameter is very small (125 μm) and multiple fibers can be easily integrated in the 3-dimensional space. Second, the beam splitting and beam coupling can be easily realized by using the commercial available fiber components and technologies. Multichannel interference signal can be either simultaneously detected by using multiple detectors or measured in a sequential way from one set of detectors while using an optical switch. Using multichannel measurement, one can simultaneously detect different analyte molecules in the sample by immobilizing different receptor molecules at different channels. Our preliminary investigation shows that the refractive index change as small as $\Delta n \approx 10^{-8}$ can be measured using the proposed method. Higher sensitivity and resolution will be achieved by combining the multichannel sensor geometry, appropriate optical phase control, and signal analysis.

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Development Approach

Implementation of the proposed tasks will be performed at the Center for Engineering Science Advanced Research (CESAR), ORNL. The CESAR staff has considerable experience in optical interferometry, fiber optics, material science, and signal processing. In recent years, CESAR has developed technologies of laser array synchronization, ultra-weak optical signal sensing, and multiple-beam interference.

Further investigations on the multichannel chemical/biological sensor include

- Theoretical modeling and investigation of index change due to binding at the fiber core-cladding interface;
- System manufacturing including signal analyzing and processing and proof-of-principle demonstration of multichannel sensing

ORNL Facilities

CESAR's Optical Systems laboratory has state-of-the-art equipment and facilities, including high-stability optical tables for various types of optical experiments, different types of lasers with wavelengths ranging from UV to infrared bands, various fiber optical components, photo detectors at various detection bandwidths, and a variety of measurement setups. These proposed system will be implemented with the above equipments.

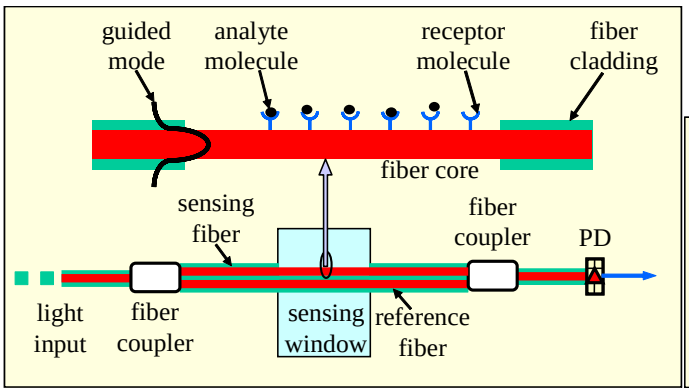

Fig. 1 Scheme of chemical/biological sensor.

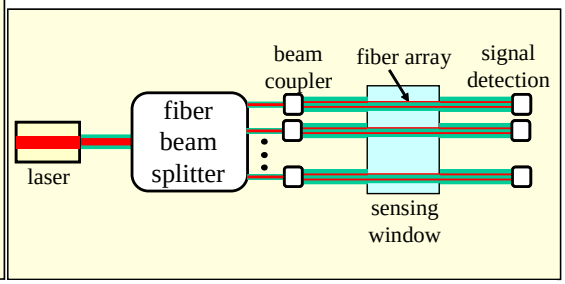

Fig.2 Scheme of multichannel sensor based on fiber array.

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