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Spotlight on "All-silicon monolithic Mach-Zehnder interferometer as a refractive index and biochemical sensor"

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Spotlight summary:

Imagine on the palm of your hand a small portable device for bio-chemical sensing. Now, someone tells you that the embedded detection apparatus exploits optical interferometry. Since you do not see any optical input/output, you guess that the whole optical system is well hidden somewhere inside, with light being internally generated by some optical source and sent to end-of-line photodetectors through suitable optical arrangements. If curiosity is so strong as to make you open the package, you would probably discover that in the optical system there are no components such as lenses, prisms and collimators. Quite reasonable indeed, because free-space bulk optics would hardly match the accuracy, reliability, size, and cost issues required by portable systems. What you would see instead is a small photonic chip, where every optical component is monolithically built on board.

How far is current reality from this picture? Actually, the suitability of integrated optics for high-sensitivity multi-analyte label-free sensing does not sound like anything new today. Yet, as long as cost effective solutions are not available, its potential will remain substantially untapped. So far, chip re-usability and the need for inexpensive packaging tools are among the main issues that have hindered the full exploitation of photonic technologies in commercial point-of-need portable analytical devices

In particular, a constant matter of concern in integrated optics is how to couple light to optical waveguides in a way that is effective, reliable, and cost effective. Direct integration of optical sources onto the photonic chip would probably be the best solution to the problem. Unfortunately, conventional interferometric sensing schemes, based for instance on microring or Mach-Zehnder interferometers (MZIs), require the use of monochromatic laser sources, whose monolithic integration is still an open issue. If only we could use a broadband source, everything would become much easier...

This is indeed what K. Misiakos and co-workers have demonstrated in their work, where they realized the first silicon device hosting complete on chip interferometry for multianalyte label-free biosensing. The key element they developed is a photonically engineered MZI interferometer that can accommodate the light from a broadband light emitting diode (LED), yet providing the same functionality as a conventional MZI device employing a monochromatic light source. This behaviour is achieved by suitably optimizing the waveguide design of both (sensing and reference) arms of the MZI, in such a way that the relative phase difference between the light propagating through the two arms is almost wavelength independent within the 200 nm bandwidth of the LED. The broadband functionality of the MZI dramatically relaxes the complexity of the optical source integration, because a LED can be directly realized in silicon, for instance by biasing an avalanche p/n diode beyond its breakdown voltage.

The full interferometric system includes ten LED sources, each coupled to a sensing cell (integrated MZIs), which share a single detector and provide a limit of detection of 10^{-5} refractive index units. Multianalyte detection is achieved by spotting the sensing arm of each

MZI with appropriate probe molecules and by time-multiplexing the optical sources (that is, biasing one LED at a time) so that all the ten interferometers can be sequentially interrogated. Having everything integrated on a silicon chip carries also additional benefits in terms of cost, foundry service availability and ability to integrate mainstream readout electronics. The photonic chip is then equipped with a fluidic chamber and a removable electrical probe head assuring small size, chip re-usability and inexpensive packaging.

After reading this work, we realize that bringing photonic technologies into portable analytical devices is today much more than a possibility an option. It is not unrealistic to imagine that, in the near future, we will keep in our pocket optical sensing systems, enabling point-of-care biochemical analyses, rapid and inexpensive diagnostics, and at-home self monitoring. Probably smaller and cheaper than our smartphone, or even inside it...

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