INNOVATING CROSS-DOMAIN SOLUTIONS TO DETECT EMERGING BIOLOGICAL THREATS

An Integrated Nanophotonic Biosensor For Biological And Chemical Threat Detection

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Deployed personnel face emerging threats from chemical exposure (e.g., organophosphates, nerve agents, industrial pollutants, and synthetic narcotics). Rapid and accurate detection is critical to provide life-saving warnings; the current state-of-the-art relies on chemical detection paper, which lacks both versatility and sensitivity crucial for real-time field use. Chemical detection paper is single use, detects only one threat analyte at a time, and offers a limited spectrum, leading to repeated testing in response to changing environments. In addition, the limited spectrum of detection may cause misdiagnoses leading to inappropriate treatment and further injury to personnel.

Recent developments allow us to address these challenges using photonic-integrated-circuit (PIC) based biosensors. These low size, weight, and power devices use optical waveguide modes with attached biological detection molecules to detect the presence of an analyte, enabling small-form-factor, high-sensitivity, and high-throughput detection that can be multiplexed to detect various analytes at once. The biological detection molecule, such as an antibody or aptamer, grants our sensor exquisite selectivity against the target analyte because these molecules have evolved to function in an extremely complex biological background. PIC based biosensors have been shown to detect targets such as viral and bacterial pathogens, chemical agents, and host biomarkers in a label free manner down to nanomolar concentrations. Detection molecules for existing targets are commercial off the shelf, and new molecules can be rapidly developed using well established inexpensive protocols. Existing sensors can be multiplexed to detect over 16 independent analytes at once. Detection occurs within seconds, requires no user effort or interaction, and can be indicated using visual means or communicated through either wired or wireless means.

Existing PIC-based biosensors lack rapid field-reconfigurability, as they are manufactured to only detect one fixed set of biochemical agents. Reconfiguration requires wet etching to remove old receptors and attach new receptors; this is a lengthy process which requires specialized facilities, creates supply chain dependence, and degrades the PIC itself. A simple, fast way to reconfigure a biosensor to detect new threats would enable dynamic responses to real-world field environments. We have developed a unique solution to these limitations to allow PIC-based biosensors to be deployed in dynamic field environments. We leverage the benefits of existing PIC biosensor technology with the novel enhancement of using light-activated optogenetic proteins to reconfigure the biosensor by optically releasing and attaching various receptors. Our solution is a “factory-forward” method for detecting multiple analytes and reconfiguring in the field to meet different mission requirements, bringing the power of reconfigurable biosensing directly to the deployed warfighter, and significantly reducing the logistical burden required for threat agent identification. BBN has proven success in design-for-packaging of integrated electronic/photonic chips using optical waveguides for field-deployment applications. The targeted capabilities enable sensitive, multiplexed, and reconfigurable detection, which is crucial for rapidly changing threat environments.