FROM SENSING TO MAKING SENSE

Ultra-sensitive And Selective Chemical Threat Sensing Microtoroid Resonators

Judith Su University of Arizona **Cheng Li** University of Arizona **Trevor Lohrey** Caltech **Gwangho Choi** University of Arizona **Brian Stoltz** Caltech **Euan McLeod** University of Arizona

Background information: Ultra-sensitive and selective chemical threat sensors are needed for personal, industrial, and defense applications.

Purpose: Our purpose is to create an ultra-sensitive and as well as selective chemical threat sensor for warfighter use.

Objective: The objective of this project is to create an ultra-sensitive as well as selective sensor based on whispering gallery mode microtoroid resonator technology.

Rationale of the research: Microtoroidal whispering gallery mode resonators have inherently high sensitivity due to their long photon confinement time and as such have great potential as sensitive chemical sensors. Although they are sensitive, the next step is to engineer them to be highly specific and selective using both surface chemistry and an array-based format. We have developed a label-free biological and chemical sensing system known as a frequency locked optical whispering evanescent resonator (FLOWER) that integrates microtoroid optical resonators with frequency locking feedback control, auto-balanced detection, and data processing techniques to aid the suppression of noise. Having previously demonstrated FLOWER capable of highly sensitive, single macromolecule, biological detection, we have recently adapted it for highly sensitive and selective chemical threat sensing using absorptive polymer coatings. In addition, we present preliminary results on microresonator frequency comb generation in air and water which may lead to ultra-sensitive sensing in combination with absorption spectroscopy.

Relationship to other areas of study: This work has implications in biological threat detection as well as underwater chemical detection and emerging, changing threats.

Methods: Chemical sensing experiments of warfare agent surrogates and toxic industrial chemicals were conducted using FLOWER. Microtoroids were coated with custom synthesized, covalently bonded polymer coatings, including polyethylene glycol, polyvinyl acetate, and polyvinyl alcohol. The chemical agents sensed included the chemical warfare agent surrogate diisopropyl methylphosphonate (DIMP) as well as the toxic industrial chemicals formaldehyde and ammonia. The concentration of the chemical agent of interest was controlled using a KinTek mass flow controller. Frequency comb generation in microtoroid resonators was accomplished via an avoided mode crossing approach.

Preliminary Results: We demonstrate the selective detection of DIMP, formaldehyde, and ammonia with limits of detection of 304, 434, and 117 ppt, respectively. We find near-orthogonal responses of the three polymers to these three different gases, making specific chemical identification a possibility. In addition, we demonstrate microresonator frequency comb generation in air and water at visible to near IR wavelengths.

Preliminary Conclusions: FLOWER can selectively detect warfare agents at part-per-trillion concentrations in ambient conditions. In addition, we show that toroids coated with a polymer mixture can detect multiple agents, and we provide the first demonstration of microresonator frequency comb generation in water.

Impact to the DTRA mission and warfighter: We expect to construct prototypes of these sensing systems that could be readily deployed on the battlefield, in clinics, and in other laboratories to sense chemical warfare agents and toxic industrial chemicals.

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