JSTO in the News

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It's Not the Heat

Light Work

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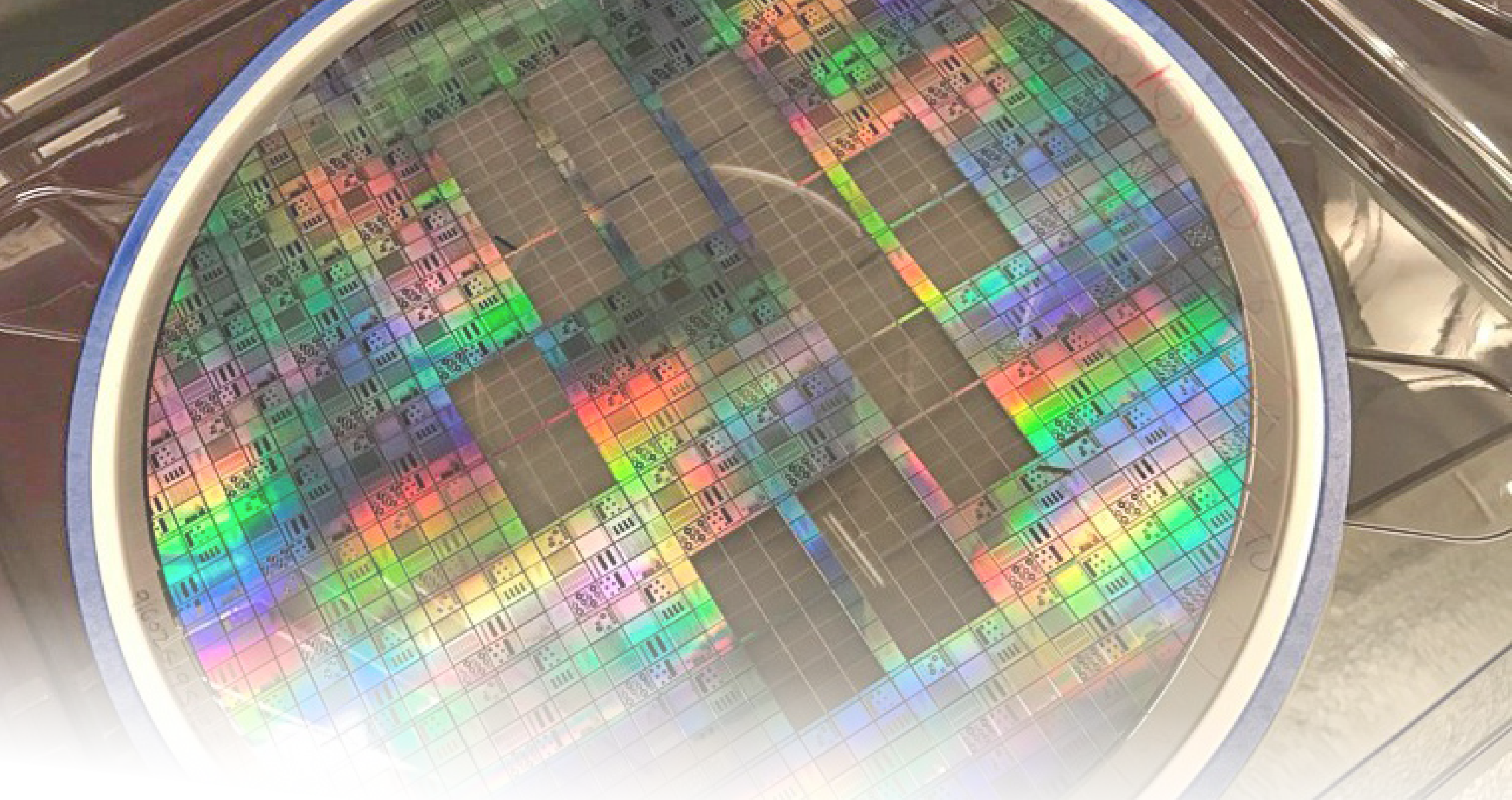

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Lead DoD science and technology to enable the Joint Force, nation, and our allies to anticipate, safeguard, and defend against chemical and biological threats.

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Chemical and Biological Technologies Department
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Front cover: Air Force Master Sgt. Shellsea Quiroz, a respiratory therapist, checks her equipment on a C-130 aircraft after patients arrive from Audie L. Murphy VA Medical Center. (U.S. Air Force photo by Staff Sgt. Sarayuth Pinthong)

Inside cover: A 300 mm photonic integrated circuit (PIC) semiconductor wafer fabricated by AIM Photonics using a new low-optical-loss passive fabrication technique and components developed by the U.S. Naval Research Laboratory Optical Sciences Division in the Nanophotonics Characterization Laboratory. (U.S. Naval Research Laboratory Optical Sciences Division photo)

Back cover: U.S. Army soldiers conduct aircraft decontamination on a UH-60 Blackhawk helicopter. Soldiers practiced decontamination of the Blackhawks to reestablish readiness prior to their rotation to the National Training Center at Fort Irwin, Calif. (U.S. Army photo by Pfc. Caitlin Wilkins, 50th Public Affairs Detachment)

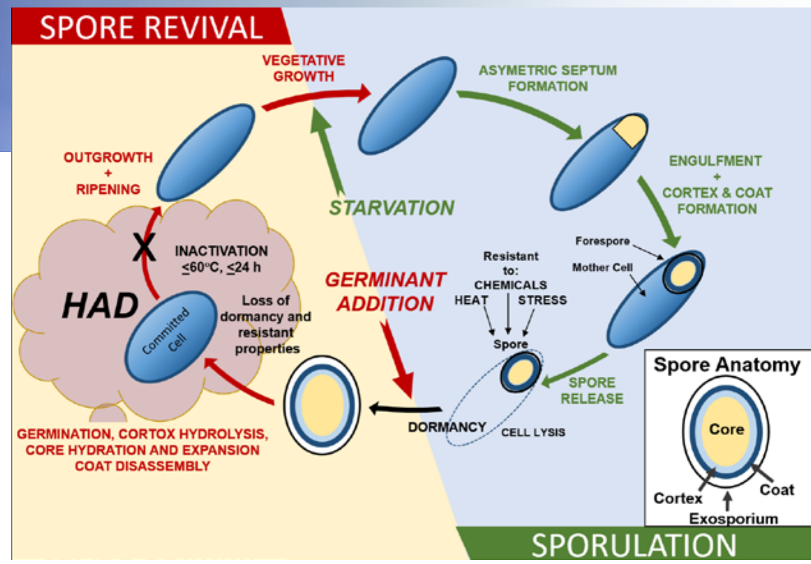
IT'S NOT THE HEAT

It's the spore germination solution.

New research in combating biological weapons agents (BWAs) seeks to decrease the amount of time it takes for hot air decontamination (HAD) to kill bacterial spores, such as *Bacillus anthracis* (anthrax), within and on aircraft. While HAD inactivates viruses in as few as 2 hours, it presently requires more than 72 hours to kill bacterial spores. A reduction in time and temperature to kill bacterial spores will reduce costs, improve compatibility of materials, and return the aircraft to mission faster.

The Defense Threat Reduction Agency's (DTRA) Chemical and Biological Technologies Department in its role as the Joint Science and Technology Office (JSTO) for the Chemical and Biological Defense Program invested in research at the Naval Surface Warfare Center Dahlgren Division (NSWC-DD) to reduce the HAD temperature and time requirements of the current Joint Biological Agent Decontamination System (JBADS).

JBADS returns a biologically contaminated aircraft to full service without risking exposure of the BWA to aircrew members and support personnel and without corrosive or reactive decontaminants. Hot, humid air is sustained inside the enclosure for up to several days until both the interior and exterior of the aircraft are decontaminated and can be returned to operation. Although the HAD process is within materials specifications for aircraft, extended hot air exposure may affect sensitive systems, so a reduction in the required time for HAD not only returns the aircraft to mission sooner but also improves its survivability.



Spore life cycle showing the stages of spore formation, germination, revival, and vegetative cell growth for a Bacillus species. The target within the cycle for HAD is the committed cell, after germinant addition and immediately after loss of dormancy but prior to outgrowth and vegetative growth. (Dr. Glenn Lawson image)

While spores are resistant to environmental extremes such as heat, most vegetative bacterial cells are susceptible to higher temperatures.

Presently, the goal is to reduce the JBADS parameters for bacterial spores from greater than 167°F and 70%–90% relative humidity for at least 72 hours to lower than 140°F (60°C) for fewer than 24 hours.

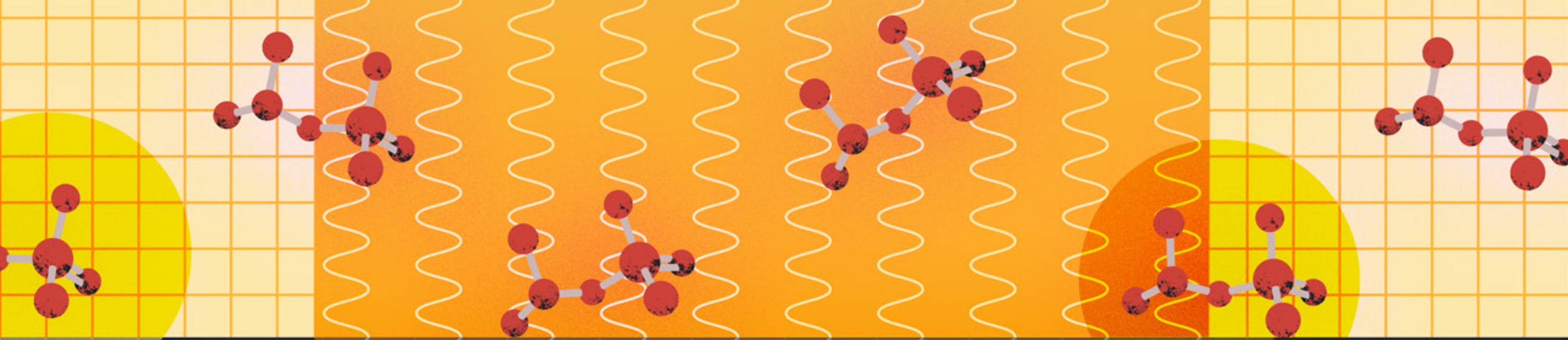
The research by NSWC-DD tested a new bacterial spore germination method to make bacterial spores more susceptible to HAD at lower temperatures. Germination occurs when a bacterial spore develops into a growing, vegetative bacterial cell. While spores are resistant to environmental extremes such as heat, most vegetative bacterial cells are susceptible to higher temperatures, so causing germination and raising ambient temperature is one way to kill bacterial spores.

The NSWC-DD team used a derelict C-130 aircraft and a human-safe bacterial surrogate for *Bacillus anthracis* to field test the bacterial spore germination process. Using a fog machine, the team evenly spread over 100 million surrogate bacterial spores per square meter on the interior surfaces of the C-130. After the spores dried, the team then applied a spore germination solution with no reactive chemicals that minimized risk to personnel and maintained aircraft materials compatibility. The team applied the germination solution with a battery-powered backpack electrostatic sprayer that was designed to evenly coat surfaces with a thin layer of the solution that included soaps to improve spreading. Because germination requires wet surfaces, the team continued to spray interior aircraft surfaces with germination solution at regular intervals of 2 hours to keep surfaces wet. After a 2-hour drying interval, the team repeated the process. The team then sampled surfaces at each interval to monitor the status of spore germination. After the final drying step, the team took samples to determine how many viable spores remained, and securely transported all samples to their laboratory for analysis.

Researchers found that the spore-germination process reduced biological spore and virus contamination by more than 99.9%. In a real situation, this would reduce risk to the Joint Forces as they pilot the contaminated aircraft to the JBADS location. In combination with JBADS, the entire process will inactivate biological contamination of aircraft to clearance levels and rapidly return the aircraft to mission. A spore-germination process will also reduce the time and temperature needed for JBADS aircraft decontamination, logistics needs, and impact to the aircraft components. ●

NSWC-DD researchers apply germinant solution to the interior of a C-130 aircraft during a field test at Holloman Air Force Base, NM. (Heather Welch/ Joint Research & Development, Inc. photo)

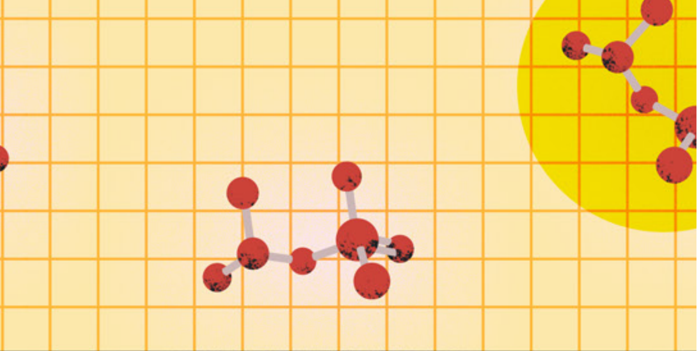
Fogging machines disseminated 100 million surrogate bacterial spores per square meter on the C-130 interior. (Heather Welch/Joint Research & Development, Inc. photo)

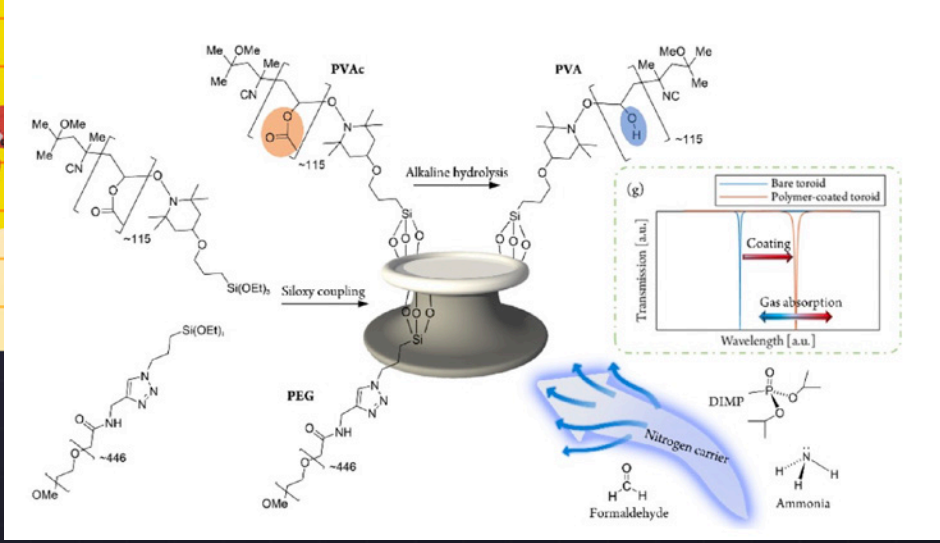


Light Work

Advancements in photonics research may lead to smaller and lighter chemical sensors

New developments in photonics-based technologies are being used to develop highly sensitive chemical sensors the size of computer chips that will reduce the physical burden on the Joint Force while increasing the detectability of trace levels of toxic chemical threats in a complex mixture. Photonics is the science of the generation, detection, and manipulation of both light particles—or photons—and light waves. Current optical detection systems have bulky setups with moving mirrors that make them heavy, expensive, and fragile.



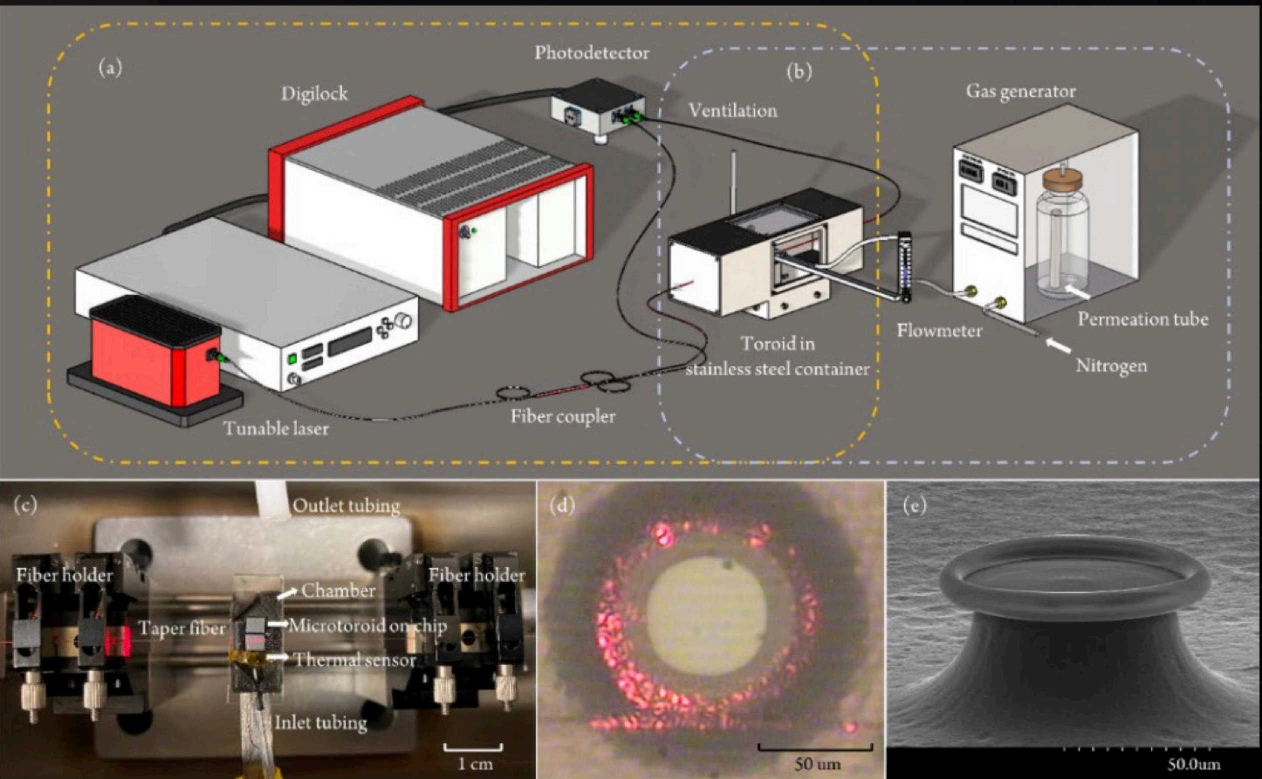


Example of microtoroid with different polymer coatings for the selective capture of toxic chemicals. Inset: Shift in the resonance frequency of the microtoroid due to the polymer coating and gas adsorption. (University of Arizona image by Judith Su)

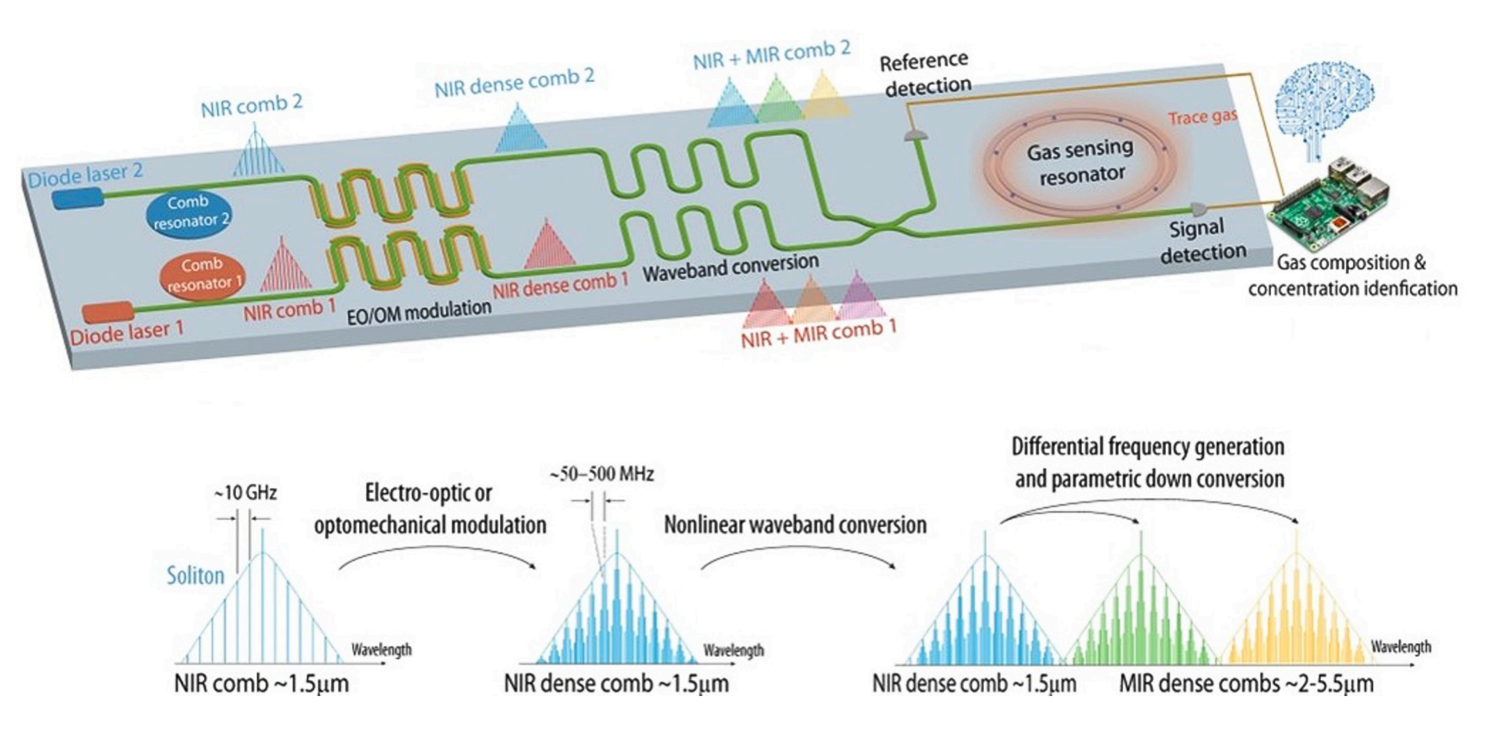
The Defense Threat Reduction Agency's (DTRA) Chemical and Biological Technologies Department in its role as the Joint Science and Technology Office (JSTO) for the Chemical and Biological Defense Program has invested with researchers at the University of Arizona and the California Institute of Technology (Caltech) to use technical advancements in integrated photonics research to create small, lightweight, and low-power chemical sensors.

The Frequency-Locked Optical Whispering Evanescent Resonator (FLOWER) developed at the University of Arizona uses light from a laser that internally reflects around microtoroid resonators, which are glass, mushroom-shaped devices. When chemicals or small biomolecules interact with the surfaces of the microtoroid resonators, the refractive index—the amount the path of light is bent—causes a frequency shift in the light spectrum. FLOWER uses peak-locking feedback control, noise reduction, and data analysis to be able to detect down to a single macromolecule (large molecule containing many atoms) without having to label the molecule of interest.

FLOWER was adapted for selective trace gas detection using synthesized polymer coatings developed at Caltech. As gas molecules diffuse through the polymer layer, they cause an index of refraction change and swelling of the polymer that result in a change in resonance frequency. A nerve agent simulant, ammonia, and formaldehyde were detected at part-per-trillion concentrations, extremely more sensitive than existing technologies tested in an ambient environment and offering chemical selectivity. Lowering the detection limit for chemical threats helps keep warfighters safe by providing them more time to don the proper protective equipment and avoid a contaminated area before experiencing an adverse effect of the chemical exposure.



Top: (a) Schematic of the current FLOWER prototype and (b) vapor testing setup. Bottom: (c) Close up of vapor testing setup with microtoroid, (d) example of light reflection along microtoroid surface, and (e) electron microscope image of microtoroid. (University of Arizona image by Judith Su)



Schematic of the interleaved difference generation (iDFG) dual-comb spectroscopy (DCS) setup. (Caltech image by Kerry Vahala)

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While the initial FLOWER prototype is a bench-scale instrument, researchers plan to design a small, low-cost sensor prototype. Microtoroids can be fabricated on a chip, significantly reducing size, and facilitating future experiments. To realize these possibilities, researchers at the University of Arizona are developing free-space coupling methods, which would enable the parallel read out of multiple microtoroids coated with different capture agents, which will aid DTRA JSTO's goal to have the Joint Force ready to fight and win in a CB-contested environment.

Another research effort at Caltech, the University of Rochester, and the University of Victoria developed a new detection method based on an interleaved difference frequency generation (iDFG) dual-comb spectroscopy (DCS) approach. This work successfully integrated the electro-optic modulators directly with the comb resonator on a single microchip, which should result in small sensors that can be cost-effectively produced.

A high spectral resolution allows the technique to be sensitive to the molecular rotations and vibrations of both gas and vapor molecules. This helps differentiate between toxic compounds of interest versus ambient contaminants, which is critical for detecting threats in a complex chemical environment and reducing false alarm rates. Current efforts on this project have included designing a microcontroller with an efficient machine-learning code to provide real-time spectral analysis to identify the presence of different gas molecules and quantify their concentration with the goal of making it easier for end users to interpret results.

Together, FLOWER and the iDFG DCS technologies, while still early in development, offer the promise of photonics-based chemical sensors to detect threats in a complex mixture, all in a smaller and lighter format that reduces the physical burden on the Joint Force.

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Within the Defense Threat Reduction Agency's Research and Development Directorate resides the Chemical and Biological Technologies Department performing the role of Joint Science and Technology Office for the Chemical and Biological Defense Program. This publication highlights the department's advancements in protecting the Joint Force and citizens from chemical and biological threats through the innovative application of science and technology.

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