CEA – Saclay, 91191 Gif-sur-Yvette Cedex
Service de Physique de l'Etat Condensé - UMR 3680
Mardi 11 Février 2025 à 11h15

SÉMINAIRE SPEC
Orme des Merisiers, en amphi Bloch Bât.774

Jennifer A. Dionne

Stanford University

Exploring light and life: Nanophotonics and AI for scalable molecular sensing, sequencing, and synthesis

The earth's biosphere is incredibly information-rich, with estimated information transmission rates exceeding those of the technosphere by 9 orders of magnitude (Lingam et al, Life 13, 1850, 2023). Yet, current methods to extract this information are slow and laborious, hindering our ability to understand the genesis and evolution of biochemical systems, and to optimize their performance. Here, we present nanophotonic methods that may enable unprecedented data about biochemical systems, at rates previously unattainable. First, we describe our lab's Si-photonic "Very-large-scale Integrated high-Q Nanophotonic Pixels" (VINPix). These photonic resonators achieve high-Q factors, subwavelength mode volumes, and controlled dipole-like radiation, simultaneously, with Q-factors from the thousands to millions, and resonator densities exceeding 100M/cm^2. By combining VINPix arrays with acoustic bioprinting for local chemical functionalization, we develop Si chips and the associated AI framework that detect multi-omic signatures on the same platform. We discuss integration of these sensors with workflows in Stanford's Clinical Laboratories for label-free interrogation of the tumor-immune microenvironment, as well as with autonomous underwater robots from Monterey Bay Aquarium Research Institute (MBARI) for ocean biodiversity monitoring. Then, we describe how these chips can be used for peptide sequencing. By tailoring each resonator for strong Raman enhancement, we demonstrate high-resolution identification and de-novo sequencing of wildtype and mutated human leukocyte antigens. We also show how VINPix can be converted into reaction sites for DNA molecular synthesis by integrating optically absorbing heating elements. Reactions at each of the nanoantennas can be activated by a unique combination of optical wavelength and polarization, eliminating errors seen in other solid-state synthesis platforms. Further, the high-Q of each VINPix prevents spectral and spatial crosstalk between the nanoantennas, enabling maximum molecular sequence diversity with minimal error. Finally, we present our work uniting nanophotonics and mechanobiology to develop a new class of *in vivo* force probes, "microgauges". Our design is based on inorganic nanoparticles that, when excited in the near-infrared, emit light of a different color in response to compressive strain. We feed these nanoparticles to freely crawling worms, who readily ingest and excrete these sensors without measurable toxicity. We dynamically measure force changes during digestion, and show that the temporal pattern of force generation is consistent with the timing of action potentials. Collectively, we anticipate that these nanophotonic platforms can shed completely new data on the biosphere – from improved understanding of molecular communication systems, to optimization of novel biochemical sensing and synthesis platforms for sustainability.

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Bio: Jennifer (Jen) Dionne is a Professor of Materials Science and of Radiology at Stanford. She is also a Chan Zuckerberg Biohub Investigator, deputy director of Q-NEXT (a DOE-funded National Quantum Initiative), and co-founder of Pumpkinseed, a company developing improved T-cell therapies. From 2020-2023, Jen served as Stanford's Inaugural Vice Provost of Shared Facilities. Jen received her B.S. degrees from WashU in St. Louis, her Ph. D. at Caltech, and her postdoctoral training at Berkeley. As a pioneer of nanophotonics, she is passionate about developing methods to detect and direct biochemical transformations, emphasizing critical challenges in global health and sustainability. Her research has developed culture-free methods to detect pathogens and their antibiotic susceptibility; amplification-free methods to detect and sequence nucleic acids and peptides; and new methods to image light-driven chemical reactions with atomic-scale resolution. She is the recipient of the NSF Waterman Award, NIH New Innovator Award, and the Presidential Early Career Award for Scientists and Engineers, and was featured on Oprah's list of "50 Things that will make you say 'Wow'!". Dionne alum hold faculty positions spanning top academia (eg, professors at MIT, Stanford, Berkeley, Northwestern), industry, startups, policy, and communications, including a Pulitzer prize winner.

Coffee and pastries will be served
