

Next-Generation Multiparameter Fiber Optic Photonic Nose for Energy Infrastructure Sensing

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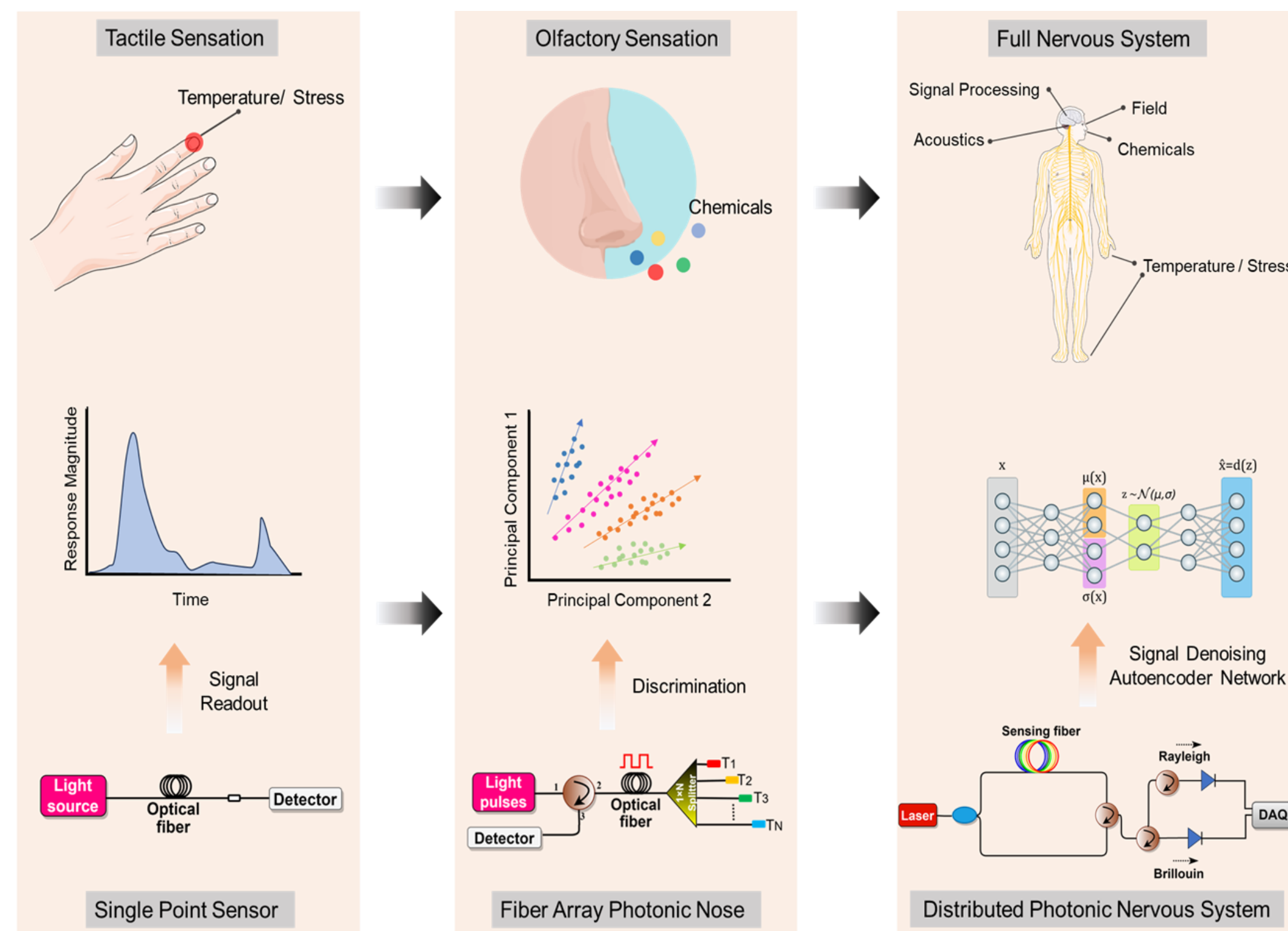
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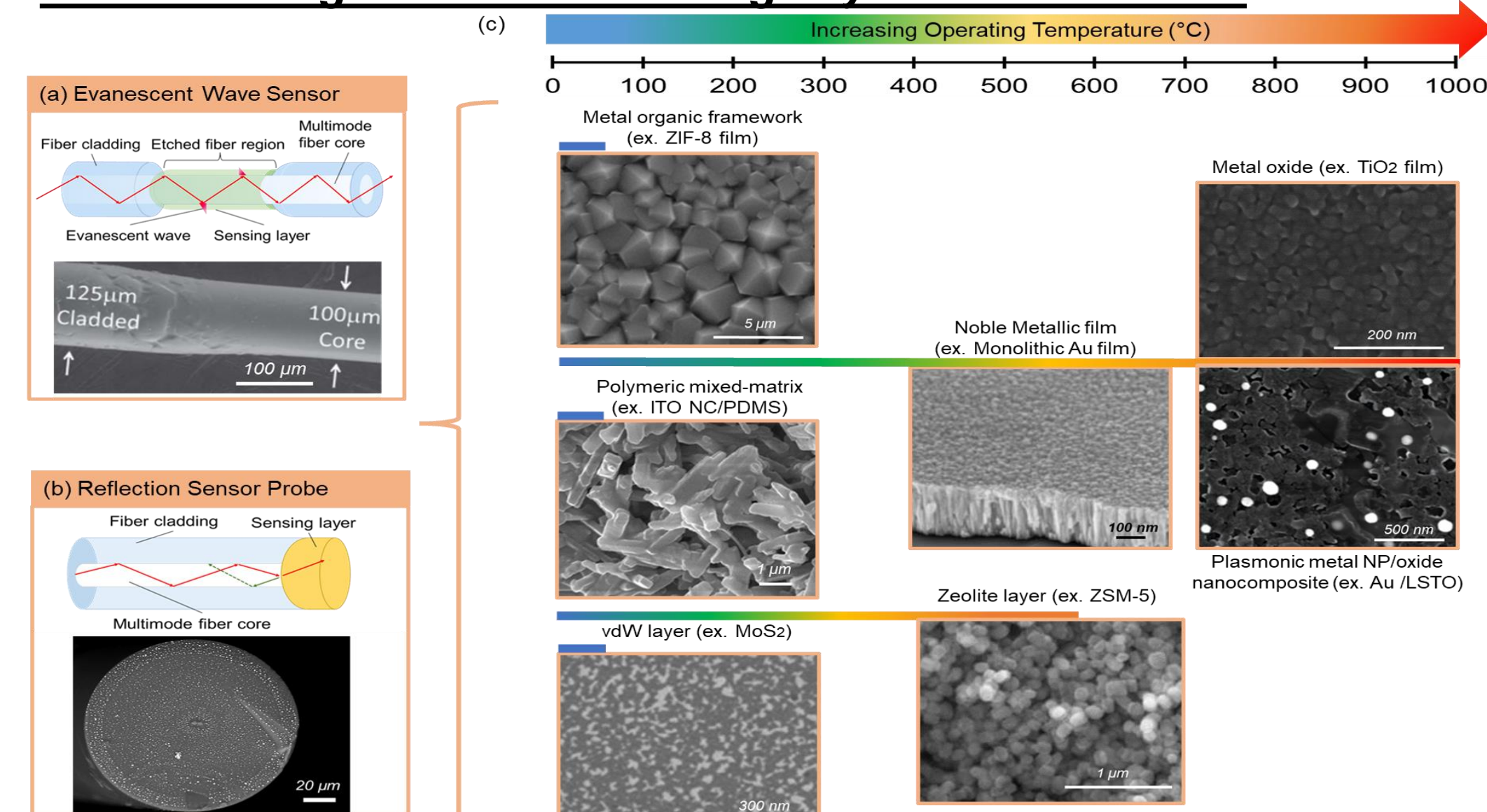
INTRODUCTION & CONCEPT DEVELOPMENT



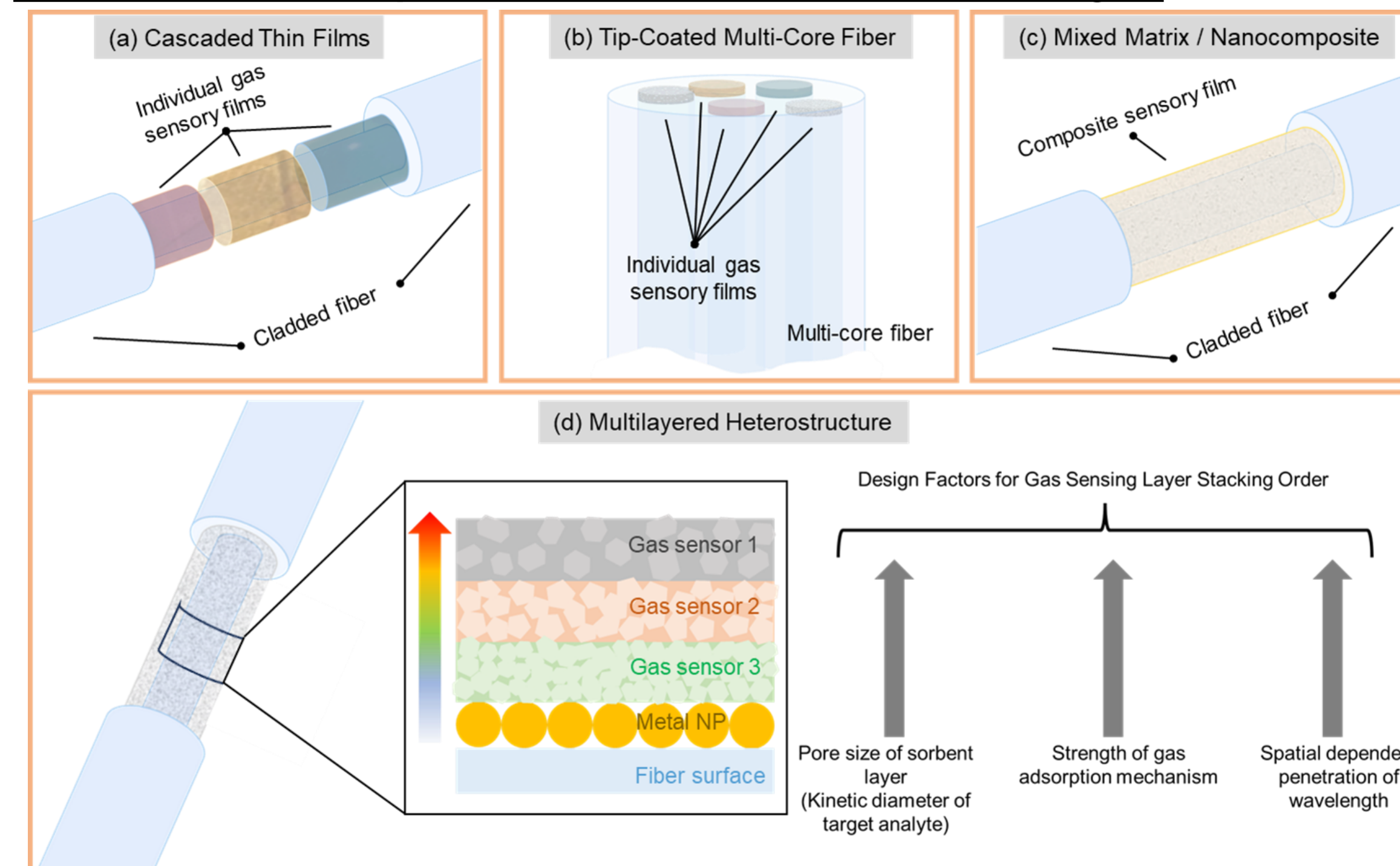
The concept of an optical fiber based "photonic nose" via multiple interrogation wavelengths and/or sensor nodes offers a compelling platform technology to realize multiparameter speciation of chemical analytes within complex gas mixtures. We further generalize the notion of multiparameter sensing through the novel "photonic nervous system" concept based upon low-cost, functionalized optical fiber sensor probes monitoring a variety of distinct analyte classes (physical, chemical, electromagnetic, etc.) simultaneously to provide broad situational awareness via integrated sensors. (Y-D Su et al., APL Photonics, Under Review)

METHODOLOGIES

Sensor Configuration and Sensing Layer Considerations

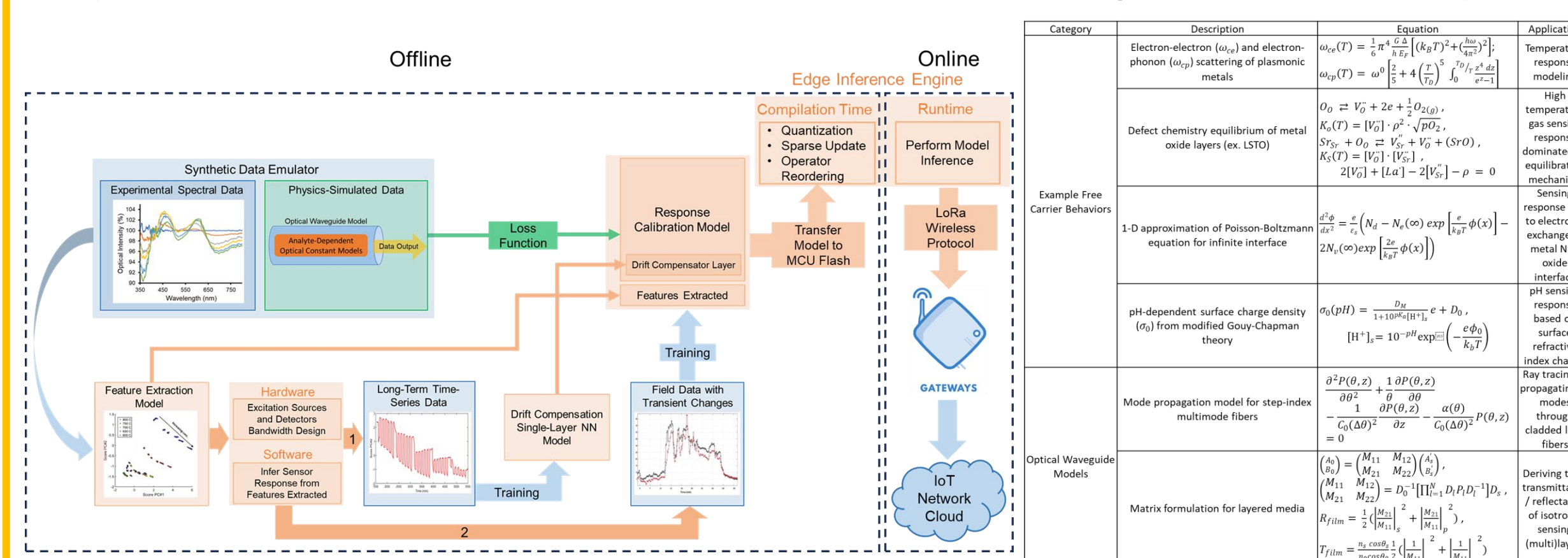


Device-Level Fiber Optic Photonic Nose Fabrication Strategies



Combined with multivariate analytics, various multiparameter approaches can be demonstrated at the sensing layer device level. One unique way to introduce spectral dependences and selective responses of each contributing layer is to leverage the multilayered structure itself, imposing a leaky engineered waveguide. By leveraging the nature of optical penetration depth difference between light at different wavelengths within each layer, a particular bandwidth for each sensing layer can be sensitized and detected, thus presenting a potential wavelength multiplexing scheme using multi-sensing layer structure. (Y-D Su et al., APL Photonics, Under Review)

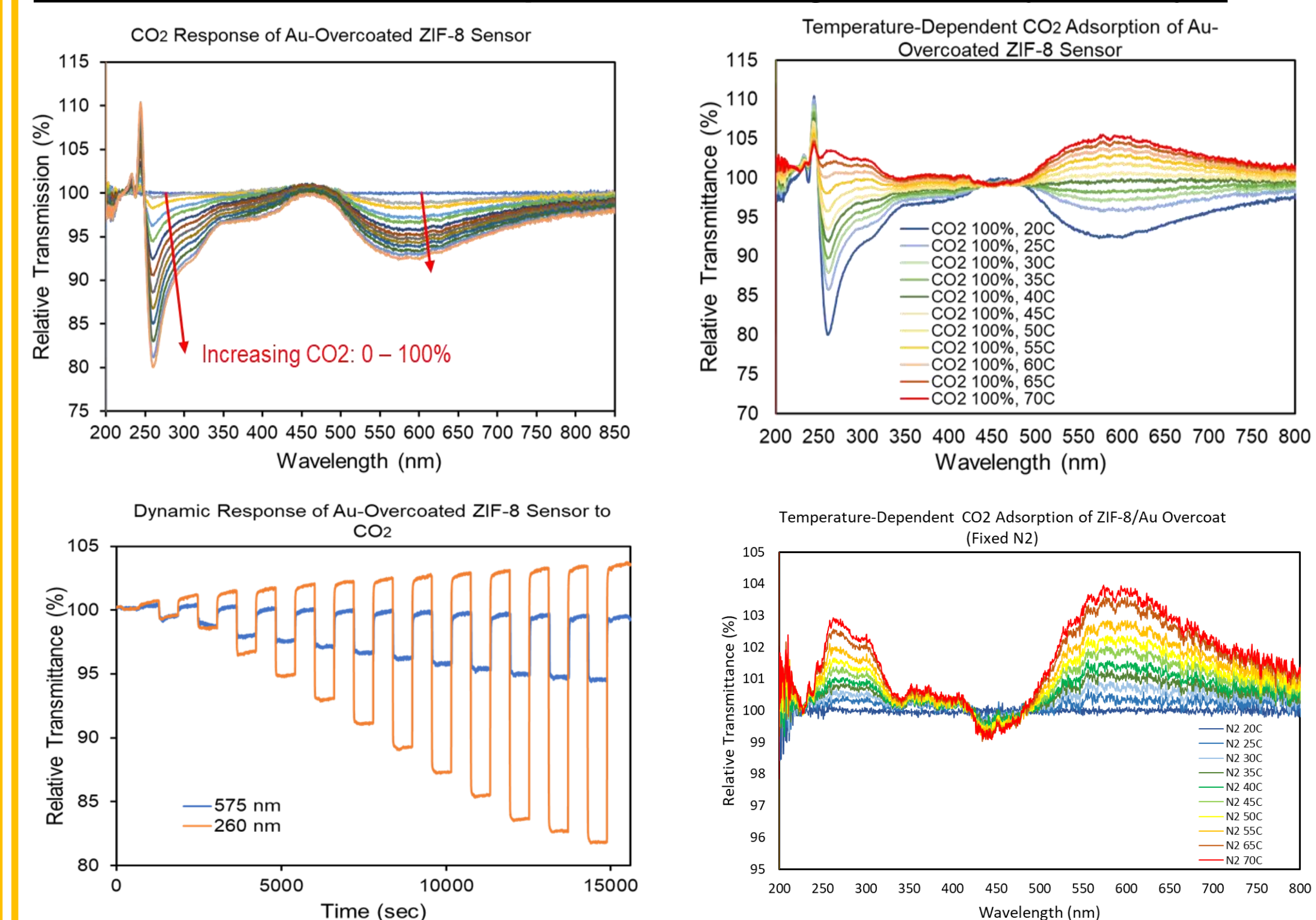
Physics-Informed Sensor Response Calibration and Edge-Inference Analytics



To address the challenges in (1) acquiring calibration data in "beyond lab" conditions and (2) avoiding overfitting model to the bias of a subset of calibration data, we incorporate the concepts in recent trends of synthetic training dataset that combines simulated data with empirical data, and physics-informed learning method. The importance, of integrating data analytic algorithms with edge-compatible hardware/firmware for grid-tied energy applications, necessitates the approaches of compile-time and runtime separation and model quantization that make edge inference or even training possible. (Y-D Su et al., APL Photonics, Under Review)

PRELIMINARY RESULTS & PERSPECTIVES

Simultaneous CO2 and Temperature Sensing Possible by Multilayer



Potential Applications

Near-Ambient Conditions: Oil-Immersed Power Transformer

Multi-functionalized EW Fiber Sensor Probe

Oil Flow

Radiator

Fiber Optic Photonic Nose Interrogator

Oil-Immersed Three-Phase Core and Insulated Winding

Insulation Oil

Flux Gas Exhaust

Gas Turbine

Compressor

Secondary Burner

HRSG

SCR Catalyst

CO Catalyst

CO2

SCR Catalyst

CO2

SCR Catalyst

CO2

SCR Catalyst

CO2

SCR Catalyst

CO2

SCR Catalyst

CO2

SCR Catalyst

CO2

SCR Catalyst

Extreme Conditions: Catalysis and Combustion Process in a Power Plant

Critical gas species exist in both oil-type power transformers and harsh environment such as combined-cycle power plants, indicating informative health status and process control parameters. Selective sensing layers in an integrated photonic nose suite using MOF / zeolite sorbents or perovskite thin films are promising solutions. (Y-D Su et al., APL Photonics, Under Review)

ACKNOWLEDGEMENT

This work is supported by DOE Nuclear Energy University Program, and Solar Energy Technologies Office under Office of Energy Efficiency & Renewable Energy.