

# From sensors to smart systems: the rise of AI-driven photonic noses

GA, UNITED STATES, February 4, 2026 /EINPresswire.com/ -- Detecting complex chemical odors and gas mixtures is essential for environmental safety, healthcare, and food quality control, yet traditional gas sensors often struggle with limited selectivity, sensor drift, and slow response. A new generation of photonic noses—optical sensing systems inspired by the human sense of smell—offers a transformative solution. By combining advanced optical sensing technologies with artificial intelligence, photonic noses can capture detailed chemical fingerprints and interpret them with high accuracy. These systems leverage light-matter interactions and machine learning algorithms to achieve fast, label-free, and highly sensitive detection of volatile compounds, paving the way for smarter, more reliable sensing platforms capable of operating in complex, real-world environments.



Roadmap of AI-driven photonic noses. Early gas sensors (including colorimeters, refractive sensors, absorptive sensors, and spectroscopic sensors) paved the way for subsequent innovations. With advancements toward high-throughput sensors, distributed node

Conventional electronic noses rely on arrays of chemical sensors whose electrical responses are often affected by humidity, temperature fluctuations, and long-term drift. While these systems have found practical applications, their performance limitations become critical when detecting trace gases or complex mixtures. Optical sensing technologies, in contrast, offer inherent advantages such as higher sensitivity, better stability, and richer information content through spectral signals. However, interpreting these high-dimensional optical signals remains challenging, especially in dynamic or noisy environments. Based on these challenges, there is a pressing need to develop integrated sensing systems that combine optical detection with advanced data processing capabilities to enable accurate, real-time, and robust chemical analysis.

In a comprehensive review published in *Microsystems & Nanoengineering* in 2025, researchers from Northwestern Polytechnical University systematically examine the evolution of photonic nose technologies and their integration with artificial intelligence. The article analyzes how optical sensing methods—ranging from colorimetric and refractive-index sensors to spectroscopy—are being enhanced by machine learning and cloud-to-edge computing architectures. By bridging photonic hardware with intelligent algorithms, the study outlines how photonic noses are transitioning from laboratory prototypes into compact, intelligent microsystems capable of real-time chemical sensing across diverse application domains.

The review highlights four core optical sensing mechanisms underpinning photonic nose systems: colorimetric sensing, refractive index modulation, optical absorption, and spectroscopy. These techniques enable photonic noses to generate rich, multidimensional optical signatures in response to chemical analytes. Artificial intelligence plays a central role in translating these signatures into meaningful information. Machine learning algorithms can automatically extract subtle spectral features, correct sensor drift, suppress noise, and disentangle overlapping chemical signals that are difficult to resolve using traditional methods.

The authors further describe three intelligence paradigms shaping modern photonic noses. In post-sensing intelligence, data are analyzed after acquisition using advanced learning models to improve accuracy and selectivity. Cloud intelligence enables large-scale data aggregation, distributed sensing networks, and continuous model updating across multiple locations. Edge intelligence pushes computation directly onto photonic chips or nearby processors, allowing real-time decision-making with minimal latency and power consumption. Together, these architectures transform photonic noses from passive detectors into autonomous, intelligent systems capable of learning, adapting, and operating reliably in complex environments.

According to the authors, the convergence of photonics and artificial intelligence marks a critical turning point in chemical sensing. They emphasize that AI-driven photonic noses no longer merely detect gases but actively interpret complex chemical landscapes, much like a biological olfactory system. By integrating sensing, computation, and communication into unified microsystems, these technologies can deliver faster responses, higher robustness, and scalable deployment. The researchers note that such systems are particularly valuable in scenarios where traditional sensors fail, offering new possibilities for autonomous monitoring and intelligent decision-making in real-world settings.

AI-driven photonic noses are poised to impact a wide range of fields. In environmental monitoring, networks of compact photonic noses could provide continuous, high-resolution mapping of air pollutants and hazardous gases. In healthcare, noninvasive breath analysis may enable early detection of diseases by identifying volatile biomarkers. In agriculture and food safety, photonic noses can monitor ripening, spoilage, and contamination with high sensitivity, even under humid or complex conditions. Looking ahead, continued advances in photonic integration, low-power AI hardware, and data-driven algorithms are expected to accelerate the

deployment of intelligent photonic noses as ubiquitous sensing tools in smart cities, precision medicine, and sustainable food systems.

## References

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