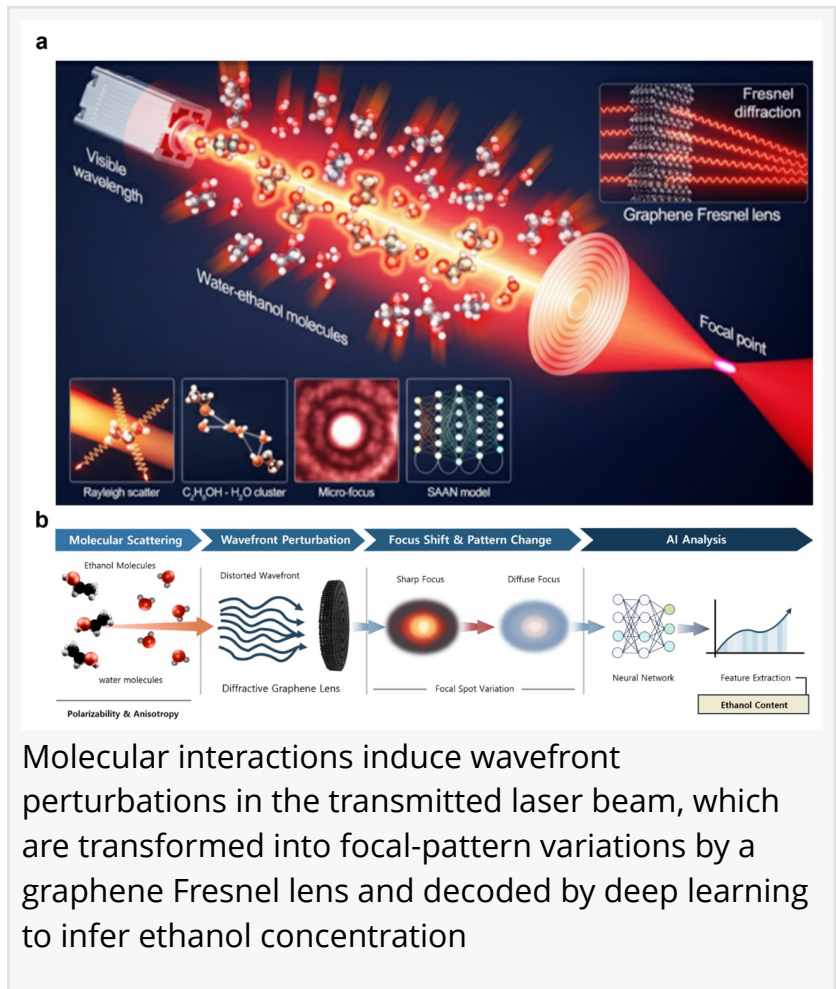


Rayleigh-driven ethanol cluster inference based on non-contact optical sensing and deep learning

A non-contact optical sensing strategy that infers molecular information from light-field distortions using graphene optics and deep learning

CHINA, June 22, 2026

/EINPresswire.com/ -- Detecting gas molecules through light scattering is fundamentally limited by weak signals and environmental noise. To address this, researchers developed a non-contact optical sensing strategy based on inverse inference that avoids direct measurement of scattered light. Instead, it analyzes subtle distortions in a transmitted laser beam after interaction with gas molecules and decodes them to infer molecular information. By combining a graphene-based diffractive lens with deep learning, the system enables stable and precise ethanol sensing.



Detecting gas molecules in air is far more challenging than it may seem. Many molecules are invisible to the naked eye and interact only weakly with light, making them difficult to identify or quantify. One of the most fundamental optical phenomena used to probe such molecules is Rayleigh scattering, in which light is scattered when it encounters particles much smaller than its wavelength. While this effect is responsible for familiar natural phenomena such as the blue color of the sky, it is extremely weak at the molecular scale. As a result, directly measuring Rayleigh scattering signals for practical sensing applications has remained a longstanding challenge.

To overcome this limitation, the research team developed a fundamentally different approach.

Rather than attempting to directly measure the faint scattered light, they focused on how the main laser beam itself is subtly altered after interacting with gas molecules. When light passes through a region containing ethanol molecules, its wavefront becomes slightly distorted due to scattering-induced interactions. Although these distortions are too small to be directly observed, they can influence how the light behaves when it is subsequently focused.

To capture these minute changes, the researchers used a specially designed graphene-based Fresnel lens. Unlike conventional lenses, which rely on refraction, this ultrathin diffractive lens focuses light through interference, making it highly sensitive to even small variations in the incoming wavefront. As a result, tiny molecular interactions are transformed into measurable changes in the size and shape of the focal spot formed by the lens. Their findings were made available online on May 06, 2026 and published in the journal *Opto-Electronic Advances* on June 07, 2026.

These optical patterns serve as a kind of “fingerprint” of the molecular environment. However, because the relationship between molecular properties and optical patterns is highly complex and nonlinear, the team employed a deep-learning model to interpret the data. By training the model on experimental measurements, they enabled it to recognize subtle variations in focal patterns and infer the concentration of ethanol in air.

This approach effectively shifts the problem from direct measurement to indirect inference. Instead of trying to detect weak signals directly, the system decodes the hidden information embedded in light-field distortions. This enables non-contact, rapid, and stable sensing without relying on chemical reactions or direct interaction with the target molecules.

The technology introduced in this study represents a conceptual shift in how optical sensing systems can be designed. Traditional gas detection methods typically rely on either direct chemical interactions, such as those used in electrochemical or semiconductor sensors, or high-precision analytical techniques like gas chromatography. While effective, these approaches often suffer from limitations including material degradation, slow response times, and lack of portability.

In contrast, the proposed method is entirely non-contact and relies solely on optical interactions. This eliminates the need for consumable sensing materials and significantly improves long-term stability. Moreover, because the system does not require direct sampling or chemical reactions, it has the potential to operate in environments where conventional sensors may fail or degrade.

One of the most important aspects of this work is the integration of physical optics with artificial intelligence. Rather than treating machine learning as a purely data-driven tool, the system is designed to extract physically meaningful features from light. The optical setup encodes molecular information into spatial intensity patterns, and the deep-learning model decodes this information into quantitative predictions. This combination allows the system to handle complex, nonlinear relationships that are difficult to model analytically.

The practical implications of this approach are significant. Potential applications include non-invasive breath analysis for medical diagnostics, real-time monitoring of environmental pollutants, and detection of hazardous gases in industrial settings. Because the system is compact and based on visible-light optics, it could be integrated into portable or even wearable devices in the future.

Importantly, the study also highlights a key design trade-off between sensitivity and stability. While shorter wavelengths produce stronger scattering signals, they also introduce greater variability and noise. The researchers addressed this by selecting a longer wavelength that provides more stable optical features for reliable deep-learning inference. This demonstrates a shift in design philosophy—from maximizing raw sensitivity to optimizing overall system robustness.

Looking forward, this research opens new possibilities for extending optical sensing beyond traditional limits. By further improving sensitivity and expanding the range of detectable molecules, similar approaches could be applied to a wide variety of gases and biological markers. More broadly, the concept of decoding physical phenomena through learned models may influence future developments in optical diagnostics and intelligent sensing systems.

Reference

Title of original paper: Rayleigh-driven ethanol cluster tracking based on non-contact deep optical molecular diagnosis

Journal: Opto-Electronic Advances

DOI: <https://doi.org/10.29026/oea.2026.250278>

About Yonsei University

Yonsei University has consistently followed a righteous path through the twists and turns of Korea's modern history. As a distinguished global academic institution, Yonsei has made significant contributions to Korean society and humanity. Yonsei University serves as the "alma mater" of all arts and sciences to nurture leaders who will contribute to the Korean and international society, in the ecumenical spirit of Christian teaching epitomized in its motto of "truth and freedom." Yonsei University is dedicated to educate future leaders of our society in the spirit of Christianity, fostering a strong and lasting commitment to the principles of truth and freedom.

About Prof. Seong Chan Jun from Yonsei University

Prof. Seong Chan Jun is affiliated with the School of Mechanical Engineering, Yonsei University. His group focuses on the integration of optics, nanomaterials, and artificial intelligence to develop next-generation sensing and diagnostic technologies.

Their research spans several key areas, including graphene-based optical devices, diffractive optics, and machine-learning-driven signal analysis. By combining advanced material fabrication

techniques with data-driven modeling, the group aims to overcome the limitations of conventional sensing systems and enable new forms of non-contact measurement.

A distinctive feature of the group's work is its emphasis on bridging physical principles with computational intelligence. Rather than relying solely on empirical data, their systems are designed to encode meaningful physical information into measurable signals, which are then interpreted using machine learning. This approach allows for improved robustness, interpretability, and scalability across different applications.

In addition to gas sensing, the group is actively exploring applications in biomedical diagnostics, optical security systems, and intelligent photonic devices. Their long-term goal is to develop integrated optical platforms capable of real-time, high-precision analysis in complex environments.

Funding information: This work was supported by the National Research Foundation of Korea grant funded by the Korean government (RS-2024-00339770) and Korea Environment Industry & Technology Institute through the Technology Development Project for Biological Hazards Management in Indoor Air Program (or Project), funded by the Korea Ministry of Environment (ARQ202101038001).

Conor Lovett
Compuscript Ltd
+353 61 475 205
[email us here](#)

This press release can be viewed online at: <https://www.einpresswire.com/article/921362476>

EIN Presswire's priority is source transparency. We do not allow opaque clients, and our editors try to be careful about weeding out false and misleading content. As a user, if you see something we have missed, please do bring it to our attention. Your help is welcome. EIN Presswire, Everyone's Internet News Presswire™, tries to define some of the boundaries that are reasonable in today's world. Please see our Editorial Guidelines for more information.

© 1995-2026 Newsmatics Inc. All Right Reserved.