

PHOTOACOUSTIC SENSING – SCIENCE & TECHNOLOGY

NEWS: Researchers at the **Indian Institute of Science (IISc)** have developed a groundbreaking technique that offers a **painless alternative to traditional blood glucose testing**.

- This new technique, called **photoacoustic sensing**, **eliminates the need for frequent needle pricks**, offering a more comfortable and safer alternative for **diabetic patients**.

WHAT'S IN THE NEWS?

How Photoacoustic Sensing Works?

- **Principle:** Photoacoustic sensing is based on the interaction between **light (typically a laser beam) and biological tissue**, leading to the generation of **ultrasonic sound waves**.
- **Light Absorption & Heating:** When a **laser beam is directed at biological tissue**, the tissue **absorbs the light energy**, causing a **slight temperature rise (less than 1°C)**.
- **Thermal Expansion & Contraction:** The **localized heating** leads to **rapid expansion and contraction** of the tissue, creating pressure variations.
- **Generation of Sound Waves:** These pressure variations result in the formation of **ultrasonic sound waves**, which propagate through the tissue.
- **Molecular Fingerprints:** Since **different molecules absorb light at different wavelengths**, the generated **sound waves carry unique acoustic signatures (or fingerprints)** of the substances in the tissue.
- **Detection & Analysis:** The emitted ultrasonic signals are **captured by acoustic sensors or transducers**, then analyzed to **determine tissue composition, molecular concentration, or structural properties**.

About the Photoacoustic Effect

1. Discovery and History

- The **Photoacoustic Effect** was **discovered in 1880** by **Alexander Graham Bell** while conducting experiments with **modulated sunlight** and its interaction with different materials.
- Bell observed that **materials emitted sound waves when exposed to modulated light**, leading to the foundation of **photoacoustic spectroscopy**.

- Initially, the effect was used for **gas analysis**, but with technological advancements, it has found broader applications in **imaging, sensing, and diagnostics**.

2. How the Photoacoustic Effect Works?

1. Light Absorption:

- A **pulsed or modulated light source**, typically a **laser**, is directed onto a material.
- The **wavelength of light is selected based on the material's absorption properties**.

2. Thermal Expansion:

- The **absorbed light energy converts into heat**, causing **localized temperature rise** in the material.
- This heating results in **rapid thermal expansion** of the material.

3. Ultrasound Generation:

- The **thermal expansion creates pressure waves** (acoustic waves) that propagate through the material.
- These waves fall within the **ultrasonic frequency range** and can be **measured using acoustic sensors**.

4. Detection of Acoustic Signals:

- **Microphones** are used to detect **photoacoustic signals in gases**, while **ultrasound transducers** are used for **solids and biological tissues**.
- The strength, frequency, and pattern of these signals provide information about the **material's composition**.

5. Analysis & Interpretation:

- The detected signals undergo **signal processing and spectral analysis** to determine:
 - **Chemical composition of gases** (in environmental monitoring).
 - **Structural characteristics of biological tissues** (in medical imaging).
 - **Material properties in nanotechnology and semiconductor studies**.

Applications of the Photoacoustic Effect

1. Biomedical Imaging

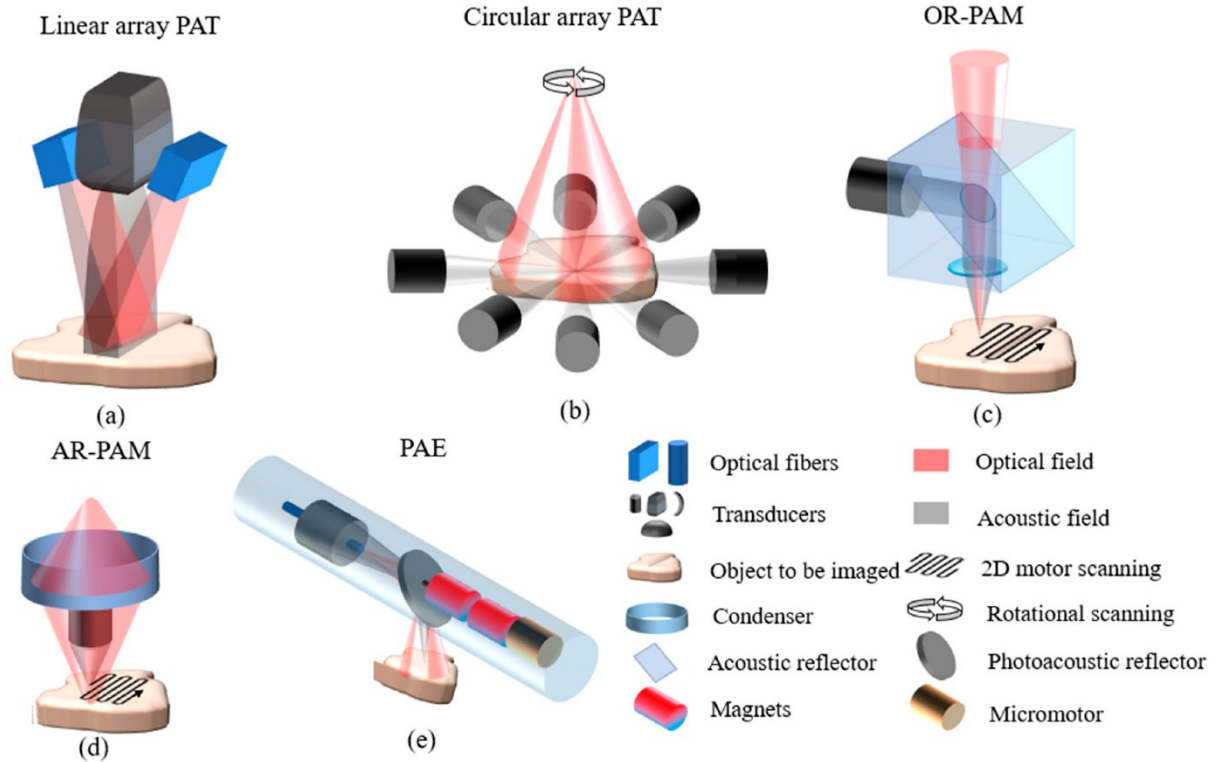
- **Photoacoustic Tomography (PAT)** and **Photoacoustic Microscopy (PAM)** use laser-induced ultrasound to generate high-resolution images of biological tissues.
- Enables **non-invasive imaging** of **blood vessels, tumors, and internal tissue structures**.
- Can detect **early-stage cancers** by identifying abnormal blood vessel growth.
- Used in **functional brain imaging** to study oxygen saturation levels in the brain.

2. Gas Sensing & Environmental Monitoring

- Used in **industrial and environmental applications** to detect **trace gases** such as:
 - **Carbon Dioxide (CO₂)** – for climate monitoring and air quality assessment.
 - **Methane (CH₄)** – for leak detection in oil and gas industries.
 - **Ammonia (NH₃)** – for pollution control and agricultural applications.
- Photoacoustic gas sensors provide **high sensitivity** and can detect gas concentrations at the **parts-per-billion (ppb) level**.

3. Material Characterization

- Used in **nanotechnology and semiconductor research** to study material properties such as:
 - **Thermal conductivity** of nanomaterials.
 - **Surface coatings and adhesion strength** of thin films.
 - **Mechanical properties of advanced materials** used in aerospace and biomedical devices.



Future Implications of Photoacoustic Sensing

1. Revolutionizing Non-Invasive Medical Diagnostics

- Photoacoustic sensing has the potential to **transform medical diagnostics**, especially for **glucose monitoring in diabetic patients**.
- Unlike traditional blood tests, this technique could allow **painless, real-time glucose measurement** without pricking the skin.
- Studies show a **strong correlation between glucose levels and changes in acoustic signal intensity**, opening new possibilities for **continuous glucose monitoring (CGM) devices**.

2. Advances in Wearable Health Sensors

- Photoacoustic technology could be integrated into **wearable health sensors** for **continuous monitoring of blood oxygen levels, cholesterol, and hydration**.
- Smartwatches and fitness trackers could **incorporate miniaturized photoacoustic sensors** to provide real-time health data.

3. Enhanced Early Disease Detection

- By analyzing **molecular-level changes in tissues**, photoacoustic imaging can **detect diseases like cancer, atherosclerosis, and neurodegenerative disorders** at an earlier stage than conventional imaging.
- This could significantly improve **treatment outcomes and survival rates**.

4. Development of Portable & Low-Cost Sensors

- The miniaturization of **photoacoustic gas sensors** could lead to the development of **portable air quality monitors**, improving real-time pollution tracking in urban areas.
- Affordable photoacoustic devices could enable **low-cost disease screening in remote healthcare settings**.

5. Expanding Applications in Security & Industrial Monitoring

- Could be used for **explosive and chemical detection** in security and defense applications.
- May enhance **industrial safety** by detecting **toxic gas leaks and material defects in real time**.

Conclusion

- **Photoacoustic sensing** is a revolutionary technology that combines **light absorption and ultrasound detection** to analyze **biological tissues, gases, and materials**.
- The **non-invasive and highly sensitive nature** of this technique makes it ideal for **medical imaging, environmental monitoring, and industrial applications**.
- As research continues, **photoacoustic sensors** could become an integral part of **future healthcare, security, and smart technology advancements**, offering **painless diagnostics and high-precision material analysis**.

Source: <https://www.thehindu.com/sci-tech/health/new-iisc-research-offers-to-detect-glucose-through-painless-photoacoustics/article69352988.ece>