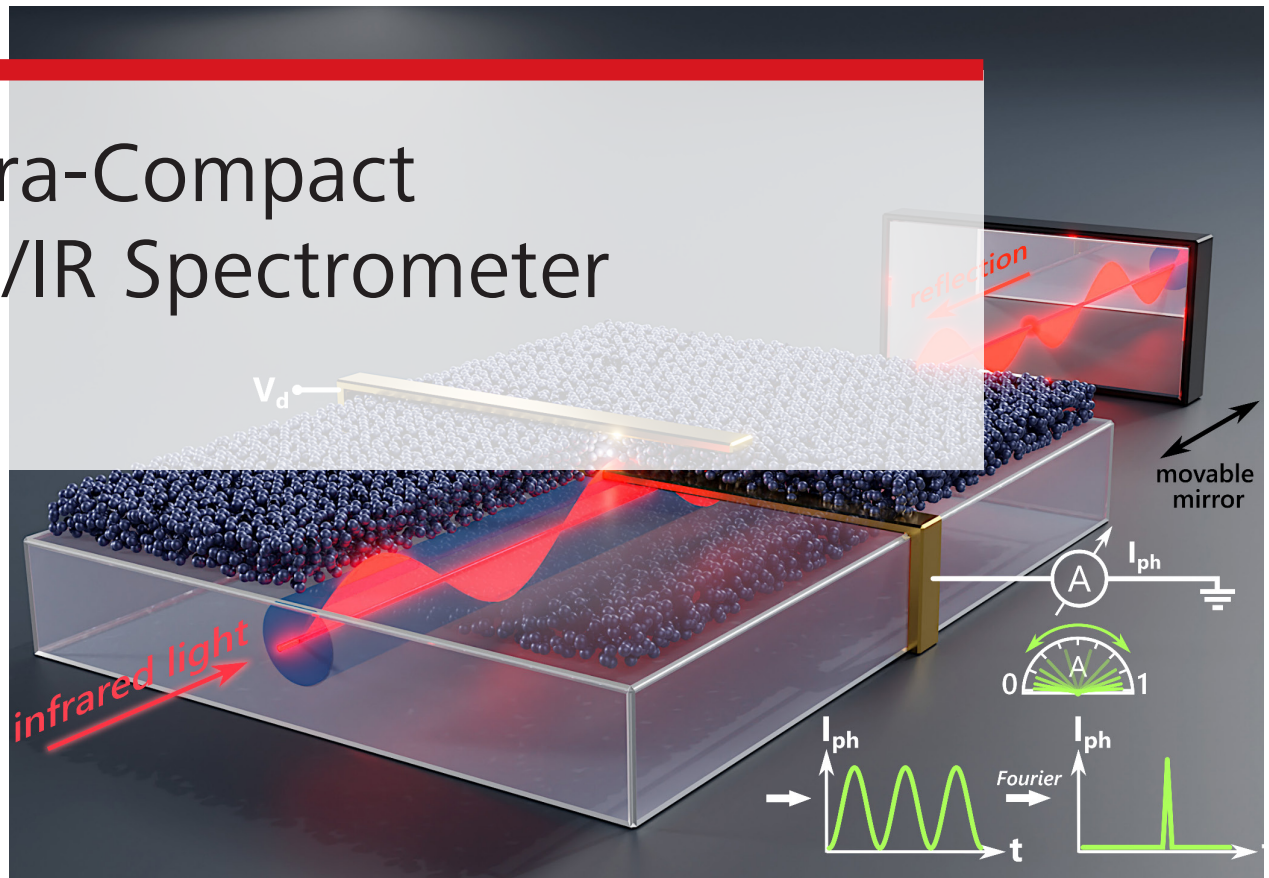


Ultra-Compact VIS/IR Spectrometer



Highlights

- identify organic and inorganic substances by spectroscopic fingerprint in visible and near infrared wavelength range
- small sensor size (100 μm edge length) – high spectral resolution (50 cm^{-1})
- high-speed, high-accuracy, high-sensitivity quality control and counterfeit detection
- for applications in industrial and pharmaceutical production, agriculture, control of food or drug quality, or environmental surveillance

Background

VIS/IR spectrometers are widely used for identifying substances, such as counterfeit medication, air and water quality control, or detection of contaminations in food. For this, high spectral resolution and large bandwidth are needed in the infrared (IR) light region. Among the miniaturized spectrometer concepts currently available, waveguide Fourier-transform spectrometers are best-suited to address the trade-off between spectral resolution and bandwidth, and overcoming the typical limitation to the visible range.

Current commercial Fourier-transform spectrometers rely on external imaging systems, are of desktop computer size and cost tens of thousands of Swiss Francs. Overcoming the cost and size barrier would make this analytical tool available to a broad public and would enable individuals to perform checks currently reserved to expensive laboratory testing. Miniaturized, cost-effective, yet high-quality, infrared spectrometers could close this gap, e.g., by integration in consumer electronics.

Applications

This technology provides a smaller, cost-effective alternative for current applications in agriculture, industrial and pharmaceutical production, control of food or drug quality, or environmental surveillance.

In addition, it creates access to a vast range of potential new applications:

- plastics recycling: in-situ analysis of plastics and determination of contaminations,
- forensics and safety: analysis of powders of drugs and explosives; handheld spectrometers would allow on-site detection of drugs and explosives by government officials,
- agriculture: analysis of animal feed and soil,
- space: search for life-indicating molecules (O_2 , O_3 , CO_2 , CH_4 , H_2O); use in nano- and femtosatellites ($< 100g$),
- consumer electronics: built-in microspectrometers will allow the general public to determine the origin and quality of, e.g., medicine, pesticides on food items, and toxic chemicals on children's toys,
- medical applications, e.g., in early diagnosis of skin cancer

Functionality has been successfully demonstrated with a laboratory proof-of-principle (TRL 3).

Advantages

This technology provides a tiny and cost-effective high-performing sensor, featuring:

- extreme miniaturization compared to existing photodetectors, allowing a complete spectrometer within an edge length of just 100 μm ,
- high performance both in wavelength range (400 nm – 2 μm) and in resolution (50 cm^{-1}),
- low-cost fabrication in large quantities, using spin-coating thin-film technology,
- option to arrange multiple units into 2D arrays of spectrometers with approx. 250 dpi resolution.

Invention

The invention introduces an ultra-compact, quantum dot-based photodetector of sub-wavelength dimension (down to 30 nm). The photodetector, optically coupled with the waveguide, consists of stacked layers with a conductive electrode on the bottom, at least one semiconductor film in the middle, and one conductive electrode on top.

Key elements of the invention are

- the use of the bottom electrode as both scattering element and conducting electrode,
- the use of a quantum-dot material for ultra-low thickness photodetectors (down to 1 μm),
- the combination of the miniaturized photodetector with the waveguide spectrometer technology.

In an advanced version of the invention, arrays of photodetectors along the waveguide axis will further improve the miniaturization efforts while still keeping a high spectral resolution and bandwidth.

Ownership

Empa, Swiss Federal Laboratories for Materials Science and Technology, Überlandstrasse 129, CH-8600 Dübendorf; patent pending, WO 2023 198 358

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Keywords

Miniaturized optical spectrometer, waveguide spectrometer, infrared analyzer, IR, VIS, subwavelength, high resolution, quantum dot, monolithically integrated photodetector, point-of-care, solution processed, quality control, smart consumer devices, mobile monitoring

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