Researchers create low-cost, AI-powered device to measure optical spectra

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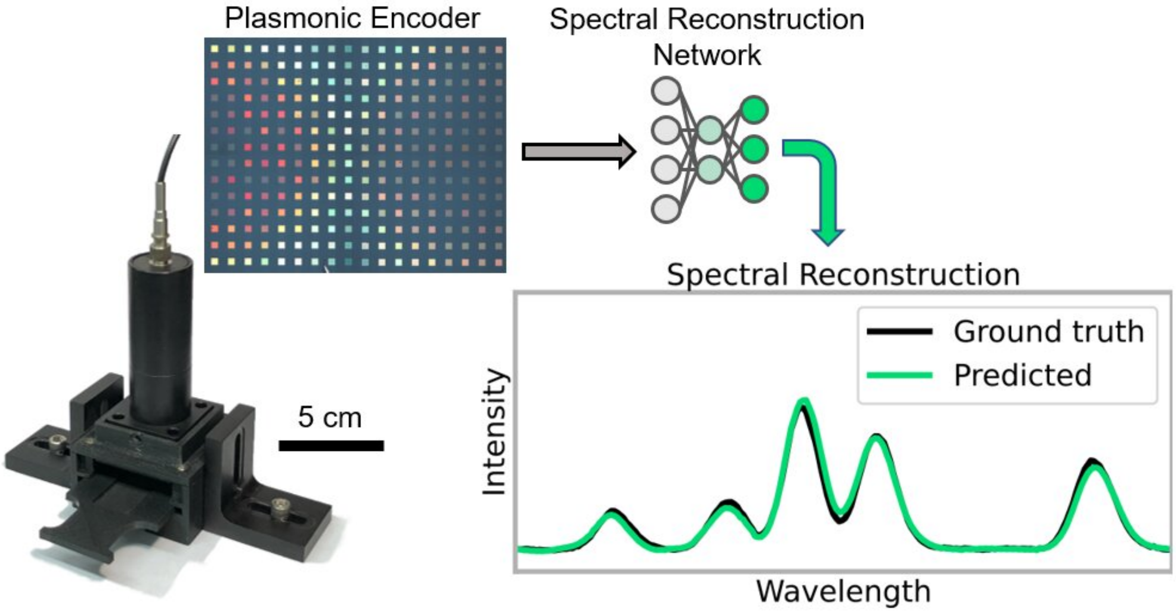

Neural network-based on-chip spectroscopy using a scalable plasmonic encoder. Credit: UCLA Engineering Institute for Technology Advancement

A team of researchers at the UCLA Samueli School of Engineering has demonstrated a new approach to an old problem: measuring spectra of light, also known as spectroscopy. By leveraging scalable, cost-effective nano-fabrication techniques, as well as AI-driven algorithms, they built and tested a system that is more compact than conventional spectrometers, while also offering additional design advantages.

Spectroscopy is a central tool for many applications in the life sciences, medicine, astrophysics and other fields. Conventional spectrometers split light into its constituent colors so that the intensity of each one can be measured. This leads to several constraints and design tradeoffs: finer spectral resolution (with tighter spacing between detectable colors or wavelengths) may require using more expensive hardware, increasing the physical footprint of the device and potentially sacrificing signal strength. This can be problematic for applications requiring high sensitivity, high spectral resolution, and compact system design. It also presents further challenges for hyperspectral imaging, which involves capturing a spectrum for each pixel in an image, a technique commonly used for remote sensing tasks such as environmental monitoring for assessing crop health or the prevalence of greenhouse gases among other uses.

The UCLA researchers' approach, powered by AI, re-envisions the spectroscopy problem from the ground up. Instead of relying on splitting the light into a rainbow of constituent wavelengths, a nanostructured chip spectrally deconstructs the light using hundreds of unique spectral filters in parallel. This chip uses plasmonic structures as a spectral encoder, which is composed of 252 tiles, each featuring a unique nanoscale pattern that transmits a distinct spectrum of light. In other words, the unknown spectrum of light to be measured is "encoded" in the transmission of each of these plasmonic tiles. This nanostructured encoder is fabricated through an imprint lithography process that could drastically reduce the cost of production and enable scaling to large production volumes.

The light transmitted by the spectral encoder chip is captured using a standard, inexpensive image sensor that is routinely used in our mobile phone cameras, producing an image that is then fed into a neural network tasked with reconstructing the unknown spectrum of light from the encoded image information. This spectral reconstruction neural network was shown to produce accurate results much faster than other computational spectroscopy approaches, yielding a result in less than one thirtieth of a millisecond. This new AI-powered spectrometer framework demonstrates a path around the typical tradeoffs between device cost, size, resolution and signal strength.

"We are not only demonstrating a proof on concept device here," said Aydogan Ozcan, Chancellor's Professor of Electrical and Computer Engineering and Associate Director of the California NanoSystems Institute (CNSI), whose group conducted the research. "We are presenting an entirely new framework for chip-scale spectrometer design. The neural network, the training spectra, the nano-encoder geometries and materials; each of these components could be optimized for different applications or specific tasks, enabling compact, cost-effective spectrometers that produce high quality measurements for a given sample type or spectral regime."

This AI-enabled on-chip spectrometer framework could find various applications ranging from environmental monitoring of gases and toxins, to medical diagnostics where spectral information is needed to distinguish the presence of different biomarkers. The researchers also note that the plasmonic tiles could be scaled down and tessellated (like a camera pixel grid) to perform hyperspectral imaging, which can be important in, for example, autonomous remote sensing where compact, lightweight form factor is essential.

The other authors of the work were Electrical & Computer Engineering researchers Calvin Brown, Artem Goncharov, Zachary S. Ballard and Yunzhe Qiu, undergraduate students Mason Fordham and Ashley Clemens, and Adjunct Professor of Electrical and Computer Engineering Yair Rivenson.

The study was published in the journal *ACS Nano*.

More information: Calvin Brown et al. Neural Network-Based On-Chip Spectroscopy Using a Scalable Plasmonic Encoder, *ACS Nano* (2021). DOI: 10.1021/acsnano.1c00079

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