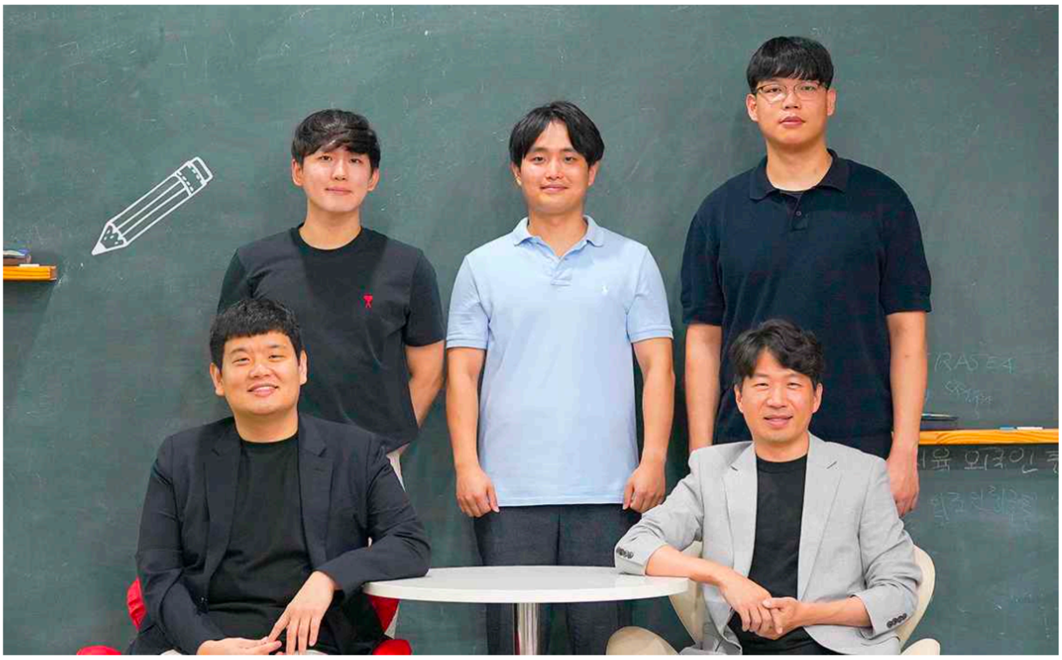
Precise design in just 1 second... Development of optical Fano resonator using AI technology

- Overcoming irregularities and structural complexity in the existing Fano resonator design process
- Expected to be applied to biosensors, such as color modulation of optical filters and confirmation of COVID-19 infection



▲ (Clockwise from the right in the front row) Professor Young Min Song, Professor Hae-Gon Jeon, doctoral student Joo Hwan Ko, combined master's and doctoral candidate Jin-Hwi Park, and master's student Jiwon Kang

A Korean research team succeeded in quickly and accurately designing a film-shaped Fano resonance in about 1 second by combining artificial intelligence (AI) technology in the field of optics.

The Gwangju Institute of Science and Technology (GIST, President Kichul Lim) School of Electrical Engineering and Computer Science Professor Young Min Song's joint research team with Artificial Intelligence Graduate School Professor Hae-Gon Jeon designed and developed an optical Fano resonance* with an error rate of less than 7% in 1.14 seconds using artificial intelligence (AI).

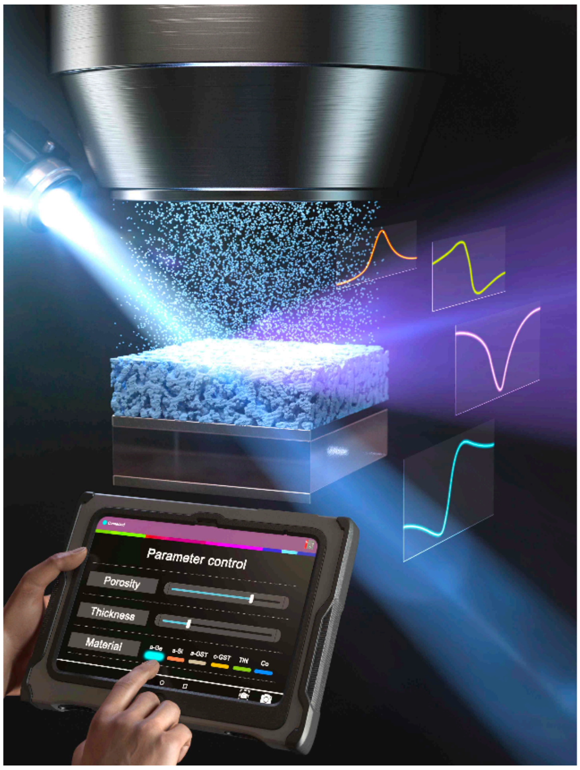
* Optical Fano Resonance: An optical structure that can control the spectral shape by inducing concentration or reflection/transmission of light at a specific wavelength based on the interaction of light and material that occurs between two optical structures.

Existing Fano resonances have complex nanostructures, making them difficult to manufacture, and predicting the spectral shape requires a lot of variables, so the design process takes a lot of time.

The research team designed a full range of spectral shapes by inserting a porous layer into a simple film-type laminated structure. Using artificial intelligence (AI) technology based on multi-layer perceptron (MLP)*, the spectrum shape was derived quickly and accurately.

* Multi-layer perceptron (MLP): An artificial neural network composed of multiple layers of neurons. It is used for data processing and pattern learning starting from the input layer through the hidden layer to the output layer, and it is used to model complex nonlinear relationships.

This can be expanded to various combination-based optical structure designs through efficient design methods applying machine learning-based AI technology and diversified deep learning artificial intelligence. The thin-film structured Fano resonator can transmit light and can also be used as an interactive display.



▲ Graphic image showing the optical pano resonance design and implementation process

Cameras for sensors in self-driving cars will be developed in the future through more sophisticated optical coupling resonance design, and it is expected that it can be widely applied in the field of ultra-precision optical sensors such as inspection equipment.

‘Fano resonance’ is realized through the combination of a ‘porous ultra-thin film’ resonator in the continuous state* and a ‘Fabry-Perot’ resonator in the discrete state*.

‘Fano resonance’ has a unique asymmetry and sudden change in the shape of the spectral line, and it is applied to color modulation of optical filters and biosensors that detect very small nano-sized viral infections.

* continuum state: In optical physics and mathematics, a continuous state generally refers to a situation in which parameters such as time, space, or energy can have continuous values within a certain range.

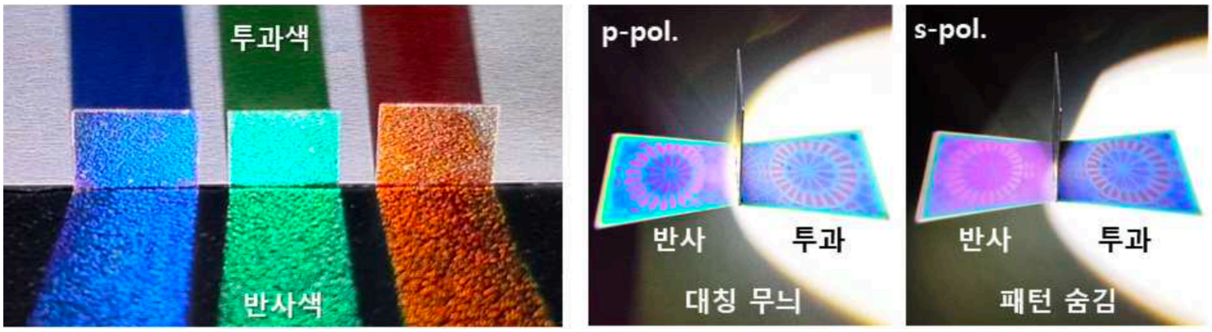
* discrete state: The opposite of a continuous state, and it refers to a situation in which parameters can only have separate values.

Recently, a simple thin-film Fano resonance structure has been developed to solve the complexity of the design and fabrication of Fano resonance. In most cases, it was difficult to implement the desired spectrum due to limited material selection and non-standardized design methods.

The spectral form is a change in light intensity depending on the wavelength, and it is an important factor in determining performance in the sensor/display field, so an accurate and fast design method is needed.

Spectrum control appears as a color change in the visible light range, and the research team created a porous ultra-thin film resonator to be anisotropic*, thereby creating an interactive display that can freely change color depending on the direction of polarization.

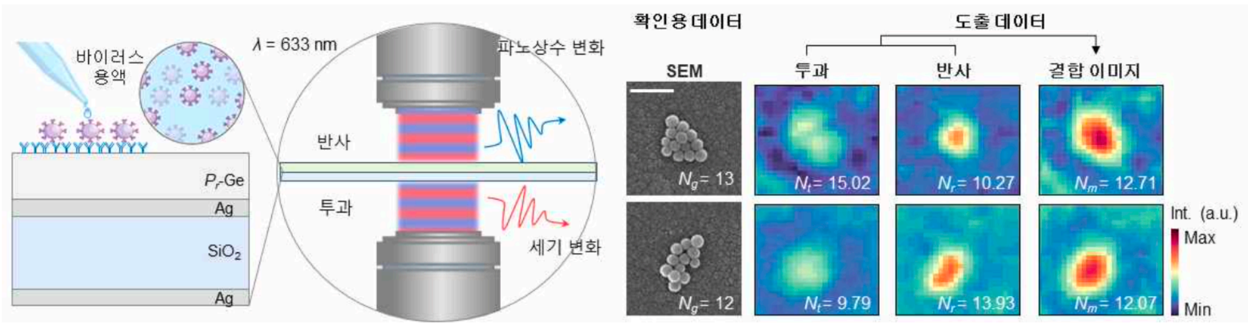
* anisotropic: This refers to the physical properties of an object being different depending on the direction. For example, surfaces such as brushed aluminum, fibers, cloth, and muscle have optical anisotropy with different reflectance depending on the direction of incoming light.



▲ Interactive display and reflection color change depending on polarization: Interactive display designed through pano resonance design (left). Depending on the direction of polarization, the pattern can be hidden or revealed by adjusting the reflection color (right).

The research team applied this to the pendulum motion model to design the coupling relationship between the two resonators, and, based on this, combined the learning data to derive the thickness and material information of the porous Fano resonance structure.

The research team designed the porous, ultrathin resonator to maximize the amount of spectral variation, allowing them to observe color changes as the resonant properties change sensitively to viruses with low refractive index. Experiments have shown that the resonator can detect very small virus particles such as COVID-19.



▲ Comparison of the number of virus particles measured by quantitative analysis and the actual number of virus particles: Schematic diagram of a platform for virus detection through AI design (left). The reflection and transmission intensity varies depending on the attached virus, and the attachment of particles is detected (right).

Professor Young Min Song said, "By overcoming the irregularities and structural complexity of the existing Fano resonator design process, we developed a system that allows precise spectral shape design through enhanced interaction between light and matter."

Professor Hae-Gon Jeon said, "This technology is an example of an efficient design method applied by artificial intelligence technology and can be expanded to various coupling-based optical structure designs, so this is expected to be widely applied to more sophisticated optical coupling real-world systems in the future."

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