Popular science summary

Before discussing this research, it helps to look at a familiar phenomenon in daily life: why does your laptop's fan suddenly roar like a jet engine when you open several programs at once? It is not struggling with the tasks, but it has to shuttle data back and forth between the processor and the memory, and this movement is inherently inefficient.

Nature, however, works differently. Even a small creature like a bee can quickly judge whether a flower is worth approaching or if a place is dangerous. Its secret is that processing and memory usually occur in the same physical location. Synapses change their connection strength according to recent events, and the experience is recorded in subtle structural changes. There is no need to move information around; it naturally flows through the system.

This contrast has prompted scientists to ask: could materials also learn from biological synapses, changing their internal state after a stimulus and retaining it for some time? Light is a fascinating candidate for such systems. It is fast, does not interfere much with other signals, and can even "speak different languages" through different wavelengths and polarization.

Photoreversible molecules such as DASA undergo reversible structural changes under light and slowly return to their original state once the light is removed. This "bleach-and-recovery" behavior resembles a short-term memory. Earlier studies on light-responsive synapses often began with single-molecule systems. This research expands on that basis: if two molecules sensitive to different spectral regions are mixed in the same thin film, will two independent optical memory traces appear? Can the material "understand" multiple light inputs at the same time?

To explore this, we chose two types of molecules with different "personalities", each preferring a different spectral region. After mixing them, we deposited the film on a semiconductor nanowire array. This "forest of nanowire light catchers" enhances the local optical field, amplifies small molecular changes, and converts them into electrical signals so we can read the traces left by light.

When the film is illuminated with different spectral components, different molecular groups are activated, leaving their own optical memories. Although the two responses show some mutual influence, they remain distinguishable within the same material. In other words, a single device now has two different input channels. It is also observed that the polarization of the light affects the response. Light has not only "color" but also "direction", and if the material can sense this difference, future devices may encode information through both wavelength and polarization.

Although this is still an early prototype, it shows the potential of light-driven synapses in future brain-like computing. As data volumes grow and energy becomes a bottleneck, if materials can perform both "computation + memory" internally, it will help reduce energy consumption and pave the way for new computing architectures.