Timing is everything in new nanotechnology for medicine, security and research

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Researchers working to advance imaging useful to medicine and security are capitalizing on the same phenomenon behind the lingering "ghost" image that appeared on old television screens.

A team of researchers from Purdue University and Macquarie University in Sydney has created a way to control the length of time light from a luminescent nanocrystal lingers, adding a new dimension of time to color and brightness in optical detection technology.

Detection based on the lifetime of the light as well as its specific color, or wavelength, exponentially boosts the number of different combinations that can be created and used as unique signatures, or tags, for biomedical screens. Screens based on this new technology could identify thousands of different target molecules simultaneously, far surpassing the current limits of such screens to roughly 20 different molecules.

"These nanocrystals can form combination codes, like barcodes, to form a vast library of distinguishable molecular probes, which can be used for complex diagnostics," said Dayong Jin, the professor of photonics at Macquarie who led the research. "They could be used for screening tests that can more quickly and accurately identify the cause of infection, residue cancers at an early stage and locate the specific molecular targets for targeted drug therapies."

In addition, light emitted by the new nanocrystals far outlasts that which occurs naturally in biological systems, called autofluorescence. That difference in timing distinctly separates the signal from background noise, said J. Paul Robinson, the professor of cytomics in Purdue's College of Veterinary Medicine and professor in Purdue's Weldon School of Biomedical Engineering who helped lead the study over the last four years.

"The photons emitted by these nanocrystals last 1,000 times longer than the photons emitted by biological systems that cause background noise," said Robinson, who also is director of the Purdue Cytometry Laboratories. "The nanocrystal photons remain, just like the photons that created the 'ghost' images on old television screens that would linger after you turned off the set. A similar phenomenon is happening in these nanocrystals. We can capture this signal after the others have gone dark and obtain incredible resolution."

The team's work is detailed in a paper that will be published in the next issue of *Nature Photonics* and is currently available online. Jin led the design and manufacture of the nanoparticles, which the researchers named t-Dots. Robinson led the concept development and biological testing of the detection technology.

Robinson's research focuses on flow cytometry, the analysis of cells that are contained in a liquid flowing past a laser beam. The research team built a time-resolved scanning cytometry system that was able to evaluate the lifetime of the light emitted as well as color and capture the τ-Dot signals.

"Particles containing these τ-Dots can be easily tailored to bind different antibodies," Robinson said. "A small and portable system could be created to probe for multiple pathogens at once in beverages or food."

The research team successfully layered the nanocrystals with a specific sequence of lifetimes within individual τ-Dots to create unique signatures and successfully bound a protein to the τ-Dots allowing them to seek out and bind to Giardia lamblia, he said. Robinson next plans to refine designs of flow cytometry instruments that can read the τ-Dot signatures and to explore the biomedical applications of new detection tools.

"Flow cytometry is a diagnostic tool that is used in a variety of applications from health care to homeland security," Robinson said. "It can analyze blood and urine to diagnose disease, or can analyze a sample taken from a surface or the air mixed with water to detect food-borne pathogens or chemical agents. With the τ-Dot 'nano-tags,' we have the ability to screen for many targets at once, and only one small volume of sample will be needed to glean a vast amount of information in a very short amount of time."

The nanocrystals are tiny clusters of sodium, yttrium and fluoride ions with added trace amounts of ions of ytterbium and the blue-emitting rare earth element thulium. The ytterbium ion serves as a trigger to the reaction that controls the thulium fluorescence, and the researchers controlled the length of time this light is emitted by varying the distance between the two.

When a laser strikes a nanocrystal it triggers a reaction that leads to the emission of a photon at a visible wavelength, or a burst of visible light.

The τ-Dots also could be used to create invisible and nearly impossible to forge marks on documents, items or currency as an anti-counterfeit measure, said Yiqing Lu, a senior Macquarie University Research Fellow in Photonics.

"By applying τ-Dots to any surface, we can leave a secret message or mark on any product, which will only be revealed by a specially designed scanner," Lu said. "This has huge potential in confirming the authenticity of any product, from pharmaceutical drugs to medical courier supplies."

The research team at Macquarie is investigating this application as well as the ability to layer the τ-Dots to create higher density data storage, he said.

Provided by Purdue University

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