Widefield diamond quantum sensing with neuromorphic vision sensors

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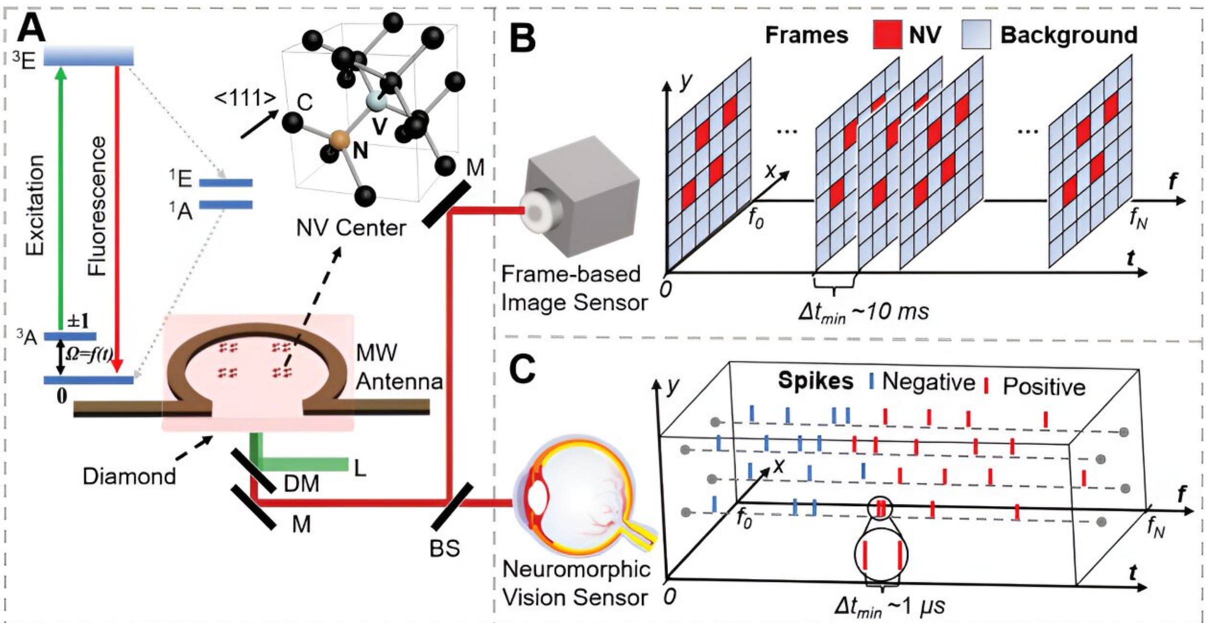


(A) Overview of NV-based widefield quantum sensing: energy level diagram and atomic structure of NV centers; and the experimental apparatus of widefield quantum diamond microscope. (B) A schematic showing the working principle of frame-based widefield quantum sensing, where a series of frames are output from a frame-based sensor recording both fluorescence intensity and background signals. (C) A schematic showing the working principle of proposed neuromorphic widefield quantum sensing, where the fluorescence changes are converted into sparse spikes through a neuromorphic vision sensor. Credit: *Advanced Science* (2023). DOI: 10.1002/advs.202304355

A collaborative project has made a breakthrough in enhancing the speed and resolution of widefield quantum sensing, leading to new opportunities in scientific research and practical applications.

By collaborating with scientists from Mainland China and Germany, the team has successfully developed a quantum sensing technology using a neuromorphic vision sensor, which is designed to mimic the human vision system. This sensor is capable of encoding changes in fluorescence intensity into spikes during optically detected magnetic resonance (ODMR) measurements.

The key advantage of this approach is that it results in highly compressed data volumes and reduced latency, making the system more efficient than traditional methods. This breakthrough in quantum sensing holds potential for various applications in fields such as monitoring dynamic processes in biological systems.

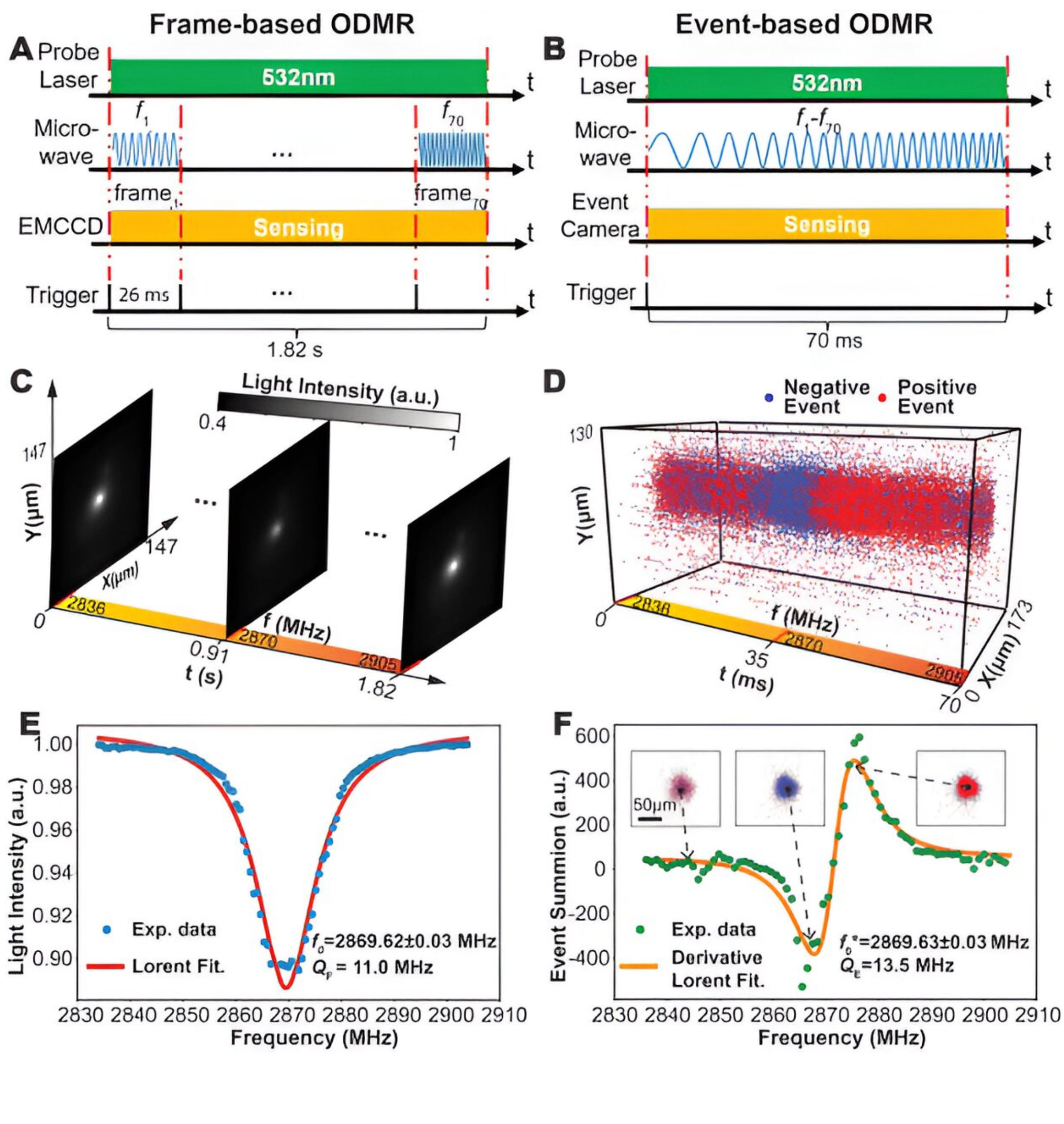
The research paper has been published in the journal *Advanced Science*, titled "Widefield diamond quantum sensing with neuromorphic vision sensors." The project was led by Professor Zhiqin Chu, Professor Can Li and Professor Ngai Wong, at the Department of Electrical and Electronic Engineering of the University of Hong Kong (HKU)

"Researchers worldwide have spent much effort looking into ways to improve the measurement accuracy and spatiotemporal resolution of camera sensors. But a fundamental challenge remains: handling the massive amount of data in the form of image frames that need to be transferred from the camera sensors for further processing.

"This data transfer can significantly limit the temporal resolution, which is typically no more than 100 fps due to the use of frame-based image sensors. What we did was trying to overcome the bottleneck," said Zhiyuan Du, the first author of the paper and Ph.D. candidate at the

Department of Electrical and Electronic Engineering

Du said his professor's focus on quantum sensing had inspired him and other team members to break new ground in the area. He is also driven by a passion for integrating sensing and computing.



Experimental demonstration. The measurement protocol, raw datasets and obtained ODMR spectrum (of the central point of ROI) using frame-based A, C, E and event-based sensor B, D, F respectively. The insert in F shows raw event frames (by accumulating events of 1ms range) at three different frequency points. The spectra in E and F are fitted with the Lorentzian and its derivative functions, respectively, from which the resonance frequency f0 is extracted (f0*is the averaged result from forward and backward sweeping; Error represents the standard deviation from 10 repeated measurements). Credit: *Advanced Science* (2023). DOI: 10.1002/advs.202304355

"The latest development provides new insights for high-precision and low-latency widefield quantum sensing, with possibilities for integration with emerging memory devices to realize more intelligent quantum sensors," he added.

The team's experiment with an off-the-shelf event camera demonstrated a 13× improvement in temporal resolution, with comparable precision in detecting ODMR resonance frequencies with the state-of-the-art highly specialized frame-based approach. The new technology was successfully deployed in monitoring dynamically modulated laser heating of gold nanoparticles coated on a diamond surface. "It would be difficult to perform the same task using existing approaches," Du said.

Unlike traditional sensors that record the light intensity levels, neuromorphic vision sensors process the light intensity change into "spikes" similar to biological vision systems, leading to improved temporal resolution (≈µs) and dynamic range (>120 dB). This approach is particularly effective in scenarios where image changes are infrequent, such as object tracking and autonomous vehicles, as it eliminates redundant static background signals.

"We anticipate that our successful demonstration of the proposed method will revolutionize widefield quantum sensing, significantly improving performance at an affordable cost," said Professor Zhiqin

Chu.

"This also brings closer the realization of near-sensor processing with emerging memory-based electronic synapse devices," said Professor Can Li.

"The technology's potential for industrial use should be explored further, such as studying dynamic changes in currents in materials and identifying defects in microchips," said Professor Ngai Wong.

More information: Zhiyuan Du et al, Widefield Diamond Quantum Sensing with Neuromorphic Vision Sensors, *Advanced Science* (2023). DOI: 10.1002/advs.202304355

Provided by The University of Hong Kong

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