Special Session 12: Photonic Artificial Intelligence: Fundamental Research on Two-Dimensional Black Phosphorus and Its Optical Computing Applications

Chairs: Han Zhang, Shenzhen University, China.

Brief Description of the Session

This study addresses the bottlenecks of "power consumption wall" and "memory wall" in electronic computing by proposing a laser-driven photonic neural network architecture based on the anisotropic optoelectronic properties of black phosphorus, achieving significant breakthroughs in energy efficiency and intelligent processing. The main contents include:

- **Dynamic In-Memory Computing:** Leveraging the layer-tunable bandgap of black phosphorus (0.3–2.0 eV), a laser-induced photoluminescence modulation mechanism was developed to construct an all-optical inference architecture, achieving an accuracy of 96.34% in fingerprint recognition tasks.
- **Associative Learning Neural Network:** By simulating the STDP learning rule via two-photon polymerization effect and incorporating temporally controlled laser modulation, brain-like conditioned reflex was realized, with a pattern recognition rate exceeding 97%.
- **Cross-Modal Low-Power Sensing and Computing:** Utilizing the stress-induced luminescence property of the material, a laser-mechanical cross-modal perception and decision-making system was established, enabling gesture recognition with near-zero energy consumption (<1 nW).
- **Ultra-Fast Optical Logic Gate Array:** Based on the nonlinear Kerr effect of black phosphorus, seven types of laser-driven optical logic gates were implemented, with a single operation latency below 100 ps and energy consumption under 10 fJ.

This research establishes a full-chain innovation system from material property modulation to optical chip integration and has been awarded the First Prize of Natural Science by Guangdong Province. Future work will focus on overcoming key challenges such as high-density photonic integration, dynamic weight reconstruction algorithms, and multi-modal sensing fusion, thereby providing core support for China's efforts to achieve independent and controllable optical computing chips.

Topics

- Optoelectronic Physics and Devices of Black Phosphorus and Novel 2D Materials
- Novel Compute-in-Memory Architectures and Devices based on Photonics
- Brain-Inspired Learning Algorithms and Hardware Implementation in Optical Neural Networks
- Cross-Modal Sensing and Ultra-Low Power Systems for Edge Computing
- Ultrafast Optical Logic Gates and Signal Processing based on Nonlinear Optics
- High-Density Integration and Design of Intelligent Optical Computing Chips
- Dynamic Reconfiguration Algorithms and Models for Photonic Neural Network

Brief Introducation of Chair

- Han Zhang, Shenzhen University, China.

Han Zhang, Distinguished Professor, Ph.D. Supervisor at Shenzhen University, Fellow of the Optical Society of America (OSA Fellow). He has long been committed to research in novel optoelectronic devices and has led more than 10 national-level projects, including the Key R&D Program of the Ministry of Science and Technology, Key Programs of the NSFC, and key national defense projects. He has published over 100 papers in top journals such as Nature Photonics, PNAS, and National Science Review, with total citations exceeding 100,000 and an H-index of 180.

He was a recipient of the first NSFC "Excellent Young Scientists Fund" (2012, the youngest recipient) and the "Thousand Young Talents Program." He has received awards such as the First Prize of the Guangdong Provincial Natural Science Award, the Second Prize of the Ministry of Education Natural Science Award, the Guangdong Ding Ying Technology Award, the Guangdong Youth Science and Technology Award, the Guangdong May Fourth Youth Medal, and the Wu Wenjun Artificial Intelligence Award (a total of 7 provincial and ministerial science and technology awards).