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【Department Spotlight】Physics Faculty Hung-Chung Hsueh and Hsi-An Pan Publish Research in Leading International Journal

Campus focus

Faculty members from Tamkang University's Department of Physics have recently published 2 major research papers in leading international journals.

Professor Hung-Chung Hsueh, together with Chih-En Hsu, a second-year Ph.D. student in Applied Science, and Yung-Ning Hsu, a second-year master's student in Physics, published their paper "Efficient light upconversion via resonant exciton-exciton annihilation of dark excitons in few-layer transition metal dichalcogenides" in Nature Communications (Impact Factor: 14.7) in March. This journal is considered one of the most important for reporting significant scientific discoveries. Meanwhile, Assistant Professor Hsi-An Pan served as first author for the paper "SDSS-IV MaNGA: Spatial Evolution of Gas-phase Metallicity Changes Induced by Galaxy Interactions," published on April 2 in The Astrophysical Journal.

Department Chair Cheng-Hao Chuang noted that The Astrophysical Journal has been published for over 30 years as a leading Q1 journal in astronomy with an Impact Factor of 4.8 in 2023 and emphasized that these achievements highlight the department’s growing strengths in both theoretical and observational research.

Hung-Chung Hsueh explained that their study explored the electronic excitation properties of transition metal dichalcogenides (TMDs). The research team focused on the electronic and optical properties of nano-materials like TMDs, which hold great potential for next-generation optoelectronic and quantum devices. The team successfully predicted changes in electronic interactions and energy band structures under excited states, offering theoretical support for future material design and semiconductor development. Hsueh emphasized that the results demonstrate Tamkang University’s strong competitiveness in computational physics and quantum materials, and that the department will continue providing opportunities

for students to engage in cutting-edge research.
Hsueh expressed deep gratitude for the collaboration with two outstanding domestic teams: experimental scientist Dr. Shao-Yu Chen from the Center for Condensed Matter Sciences at National Taiwan University, and theoretical scientist Professor Shun-Jen Cheng, Chair of the Department of Electrophysics at National Yang Ming Chiao Tung University. This close collaboration between theoretical predictions and advanced experimental measurements enabled more profound insights into the excited-state physical behavior of materials under extreme conditions. Yung-Ning Hsu, the third author and a second-year master's student in physics, was responsible for the theoretical calculations of excited-state band structures and analysis of electronic composition. It was her first experience collaborating with experimentalists on a research project. "It was truly an honor to be part of this collaboration and to publish in an international journal," she said. "I sincerely thank Professor Hsueh and all the team members who contributed to completing this work. I also hope this experience will inspire younger students to pursue research opportunities."
Meanwhile, Hsi-An Pan's paper analyzed the phenomenon of galaxy collisions, investigating how gas and metallic elements flow and evolve when galaxies approach or merge. The research used data from the large astronomical survey project MaNGA (Mapping Nearby Galaxies at Apache Point Observatory), which conducted detailed observations of hundreds of nearby galaxies. Results showed that gas inflows of lower metallicity into galactic centers caused a temporary dilution of metal content, followed by a metallicity rebound as newly formed stars released fresh metals. "This research further illustrates the diversity and complexity of galaxy evolution, offering important insights into the formation and development of the universe," Pan concluded.

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Efficient light upconversion via resonant exciton-exciton annihilation of dark excitons in few-layer transition metal dichalcogenides

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Yi-Hsun Chen[1,2,14] ✉, Ping-Yuan Lo[3,14], Kyle W. Boschen[2,4], Chih-En Hsu[5], Yung-Ning Hsu[5], Luke N. Holtzman[6], Guan-Hao Peng[3], Chun-Jui Huang[3], Madisen Holbrook[7], Wei-Hua Wang[8], Katayun Barmak[6], James Hone[9], Pawel Hawrylak[10], Hung-Chung Hsueh[5], Jeffrey A. Davis[2,4], Shun-Jen Cheng[3] ✉, Michael S. Fuhrer[1,2,11] & Shao-Yu Chen[2,12,13] ✉

Materials capable of light upconversion—transforming low-energy photons into higher-energy ones—are pivotal in advancing optoelectronics, energy solutions, and photocatalysis. However, the discovery in various materials pays little attention on few-layer transition metal dichalcogenides, primarily due to their indirect bandgaps and weaker light-matter interactions. Here, we report a pronounced light upconversion in few-layer transition metal dichalcogenides through upconversion photoluminescence spectroscopy. Our joint theory-experiment study attributes the upconversion photoluminescence to a resonant exciton-exciton annihilation involving a pair of dark excitons with opposite momenta, followed by the spontaneous emission of upconverted bright excitons, which can have a high upconversion efficiency. Additionally, the upconversion photoluminescence is generic in MoS_2, $MoSe_2$, WS_2, and WSe_2, showing a high tuneability from green to ultraviolet light (2.34–3.1 eV). The findings pave the way for further exploration of light upconversion regarding fundamental properties and device applications in two-dimensional semiconductors.

Upconversion photoluminescence (UPL) is an anti-Stokes phenomenon of light-matter interactions in which a material radiatively emits photons at an energy higher than the excitation energy. Since the process is able to generate high-energy photons, UPL is of interest in a wide range of applications across various fields such as biology[1–3], medicine[4,5], and energy[6–8]. Starting from the very first rare-earth doped nanomaterials[9], the demonstration of UPL has been reported in inorganic[10,11], organic[12,13], and organic-inorganic hybrid[14,15] semiconductors. Recent advancements, particularly in molecular systems employing triplet–triplet annihilation, have achieved high-quantum efficiency and/or low excitation density in the upconversion process[16,17]. However, there is still a growing demand for solid-state

[1]School of Physics and Astronomy, Monash University, Clayton, VIC, Australia. [2]Australian Research Council Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET), Monash University, Clayton, VIC, Australia. [3]Department of Electrophysics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan. [4]Optical Sciences Centre, Swinburne University of Technology, Hawthorn, VIC, Australia. [5]Department of Physics, Tamkang University, New Taipei City, Taiwan. [6]Department of Applied Physics and Applied Mathematics, Columbia University, New York, NY, USA. [7]Department of Physics, Columbia University, New York, NY, USA. [8]Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei, Taiwan. [9]Department of Mechanical Engineering, Columbia University, New York, NY, USA. [10]Department of Physics, University of Ottawa, Ottawa, Ontario, Canada. [11]Monash Centre for Atomically Thin Materials, Monash University, Clayton, VIC, Australia. [12]Center for Condensed Matter Sciences, National Taiwan University, Taipei, Taiwan. [13]Center of Atomic Initiative for New Material, National Taiwan University, Taipei, Taiwan. [14]These authors contributed equally: Yi-Hsun Chen, Ping-Yuan Lo.
✉e-mail: yihsun.chen@uq.edu.au; sjcheng@nycu.edu.tw; shaoyuchen@ntu.edu.tw

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