face-to-face stacking and a strong $\pi\cdots\pi$ interaction (over a distance scale of 3.348 Å). Both experimental results and theoretical calculations prove that the green UOP originates from an aggregated triplet state that has a lower energy level than that of the corresponding monomer.

The two emissive centres for the blue and green UOP emission were found to be from the single-molecule state and H-aggregation phase, respectively. Shorter wavelength (250–347 nm) ultraviolet light excitation made the single-molecule blue phosphorescence stronger than the H-aggregation phosphorescence. Meanwhile, longer wavelength (347–390 nm) ultraviolet light excitation enabled the H-aggregation phosphorescence to become dominant. Thus, colour-tunable UOP was achieved by tuning the emission intensity ratio of the two emissive centres[2].

To prove the scope of this strategy, two emissive centres were also applied to two additional compounds, 2-chloro-4,6-dimethoxy-1,3,5-triazine (DMOT) and 1,3,5-triazinane-2,4,6-trione (CYAD). Dual UOP consisting of violet emission (originating from a single molecule) and sky-blue emission (originating from H-aggregation) was observed in these two crystals by varying the excitation wavelength from 250 to 400 nm. Therefore, multicolour UOP spanning all the way from 380 to 505 nm could be obtained by changing the excitation wavelength applied to the crystals of TMOT, DMOT and CYAD (Fig. 1c)[2].

Excitation-dependent UOP opens the door to several potential applications, such as the realization of multicolour displays or the visual detection of a specific wavelength in the ultraviolet region. Huang and co-workers investigated this by using silk-screen printing to fabricate patterns. Multicolour UOP emission maps were obtained on changing the excitation wavelength in the ultraviolet region. Such emission colour changes could be employed to precisely monitor the excitation wavelength in the ultraviolet region.

In summary, the findings of Huang and co-workers provide an exciting example of the design of colour-tunable UOP materials through the use of multi-emissive centres. These interesting UOP materials could be promising for bioimaging, multicolour displays and ultraviolet detection, to name just a few potential applications. ❐

Hongwei Wu and Yanli Zhao*
Division of Chemistry and Biological Chemistry, School of Physical and Mathematic Sciences, Nanyang Technological University, Singapore, Singapore.
**e-mail: zhaoyanli@ntu.edu.sg*

Published online: 23 May 2019
https://doi.org/10.1038/s41566-019-0447-x

References

1. Xu, S., Chen, Y., Zheng, C. & Huang, W. *Adv. Mater.* **28**, 9920–9940 (2016).
2. Gu, L. et al. *Nat. Photon.* https://doi.org/10.1038/s41566-019-0408-4 (2019).
3. Ogoshi, T. et al. *Adv. Funct. Mater.* **28**, 1707369 (2018).
4. Gu, L. et al. *Angew. Chem. Int. Ed.* **57**, 8425–8431 (2018).
5. Bolton, O., Lee, K., Kim, H.-J., Lin, K. Y. & Kim, J. *Nat. Chem.* **3**, 205–210 (2011).
6. Sun, Y.-P. et al. *J. Am. Chem. Soc.* **128**, 7756–7757 (2006).
7. Zhu, L. et al. *J. Am. Chem. Soc.* **135**, 5175–5182 (2013).
8. Zhang, Q. et al. *Nat. Photon.* **8**, 326–332 (2014).
9. Yang, Z. et al. *Angew. Chem. Int. Ed.* **55**, 2181–2185 (2016).
10. An, Z. et al. *Nat. Mater.* **14**, 685–690 (2015).

SYNCHROTRONS

Inspired by chaos

Chaos control theory could provide synchrotrons with opportunities for new regimes of operation with improved stability and intensity. That's the finding of a French team of scientists from the University of Lille and the SOLEIL synchrotron facility (see image) near Paris. Clement Evain and co-workers report that the chaos control theory developed by Edward Ott, Celso Grebogi and James Yorke at the University of Maryland in the 1990s can be used to stabilize inherently unstable terahertz synchrotron radiation (*Nat. Phys.* https://doi.org/10.1038/s41567-019-0488-6; 2019).

Credit: Synchrotron SOLEIL - CAVOK Production - Laurent PERSIN

Synchrotrons are large-scale light sources that harness the radiation emitted by relativistic electron bunches circulating around a storage ring. Their high brightness, short pulse duration and tunable nature (photon emission energy can span from terahertz frequencies to hard X-rays) make them a very useful source of electromagnetic radiation for studies in biology, materials science and physics.

It has been known for many years that unstable microstructure patterns of electron charge density can spontaneously form within the storage ring and result in transient bursts of terahertz emission that are many orders of magnitude more powerful than usual. However, the irregularity and unstable nature of these microstructure-induced emissions have prevented their practical use.

The innovation of the French team is that they have shown that a feedback scheme inspired by chaos control can be used to stabilize these microstructures and their terahertz emission, allowing the system to operate in an otherwise unstable solution. The team used a fast bolometer (1 μs response time) to measure fluctuations in the power of the coherent terahertz radiation emitted in SOLEIL. A suitable control signal to modulate the amplitude of the radio-frequency wave injected into one of SOLEIL's acceleration cavities is then calculated and used to modify the electron bunch length, and mitigate the bursting behaviour. The result is that within just a few milliseconds the terahertz power is stabilized. A modification in the strength of the radio-frequency signal of less than 0.3% is found to be sufficient to reduce fluctuations in the terahertz output by more than 40 dB. ❐

Oliver Graydon

Published online: 23 May 2019
https://doi.org/10.1038/s41566-019-0455-x