A vacuum-ultraviolet laser with submicrometer spot for spatially resolved photoemission spectroscopy

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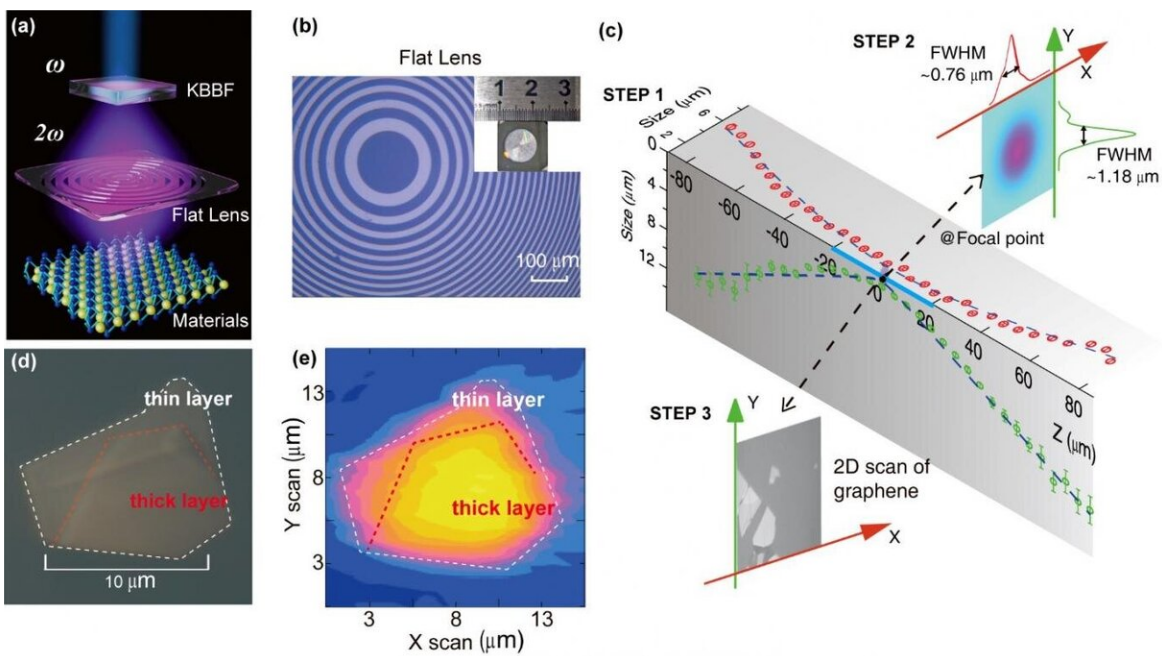

(a) Illustration of the laser beam going through the KBBF crystal (top) and the flat lens (middle); (b) microscopic image of the flat lens etched on a CaF2 substrate (insert: photo of the optical device); (c) Measurement of the focal spot. The experimental profiles of focal spots near the focal plane are measured by knife-edge scanning. Based on the profiles at the different z-cut planes, the lateral (x- and y-direction) intensity profiles of the real spot are retrieved by our homemade algorithm and then yield the spot size (FWHM) labelled by red (x-direction) and green (y-direction) circles (d) Microscopic image and (e) scanning transmission image of a graphene sample on a CaF2 substrate. Credit: Yuanhao Mao, Dong Zhao, Shen Yan, Hongjia Zhang, Juan Li, Kai Han, Xiaojun Xu,

Chuan Guo, Lexian Yang, Chaofan Zhang, Kun Huang, Yulin Chen

If vacuum ultraviolet lasers can be focused into a small beam spot, it will allow investigation of mesoscopic materials and structures and enable the manufacture of nano-objects with excellent precision. Towards this goal, Scientist in China invented a 177 nm VUV laser system that can achieve a sub-micron focal spot at a long focal length. This system can be re-equipped for usage in low-cost angle-resolved photoemission spectroscopy (ARPES) and might benefit condensed matter physics.

The rapid development of two-dimensional quantum materials, such as twisted bilayer graphene, monolayer copper superconductors, and quantum spin Hall materials, has demonstrated both important scientific implications and promising application potential. To characterize the electronic structure of these materials/devices, ARPES is commonly used to measure the energy and momentum of electrons photoemitted from samples illuminated by X-ray or vacuum ultraviolet (VUV) light sources. Although the X-ray-based spatially resolved ARPES has the highest spatial resolution (~100 nm) benefitting from the relatively short wavelength, its energy resolution is typically mediocre (>10 meV), which makes it difficult to visualize the fine details of the electronic structure in many novel quantum materials. Complementary to X-ray light sources, VUV laser-based light sources can offer much better energy resolution (~0.2 meV), deeper depth of detection and lower cost (compared to synchrotron light sources). However, the longer wavelength of the VUV light source also deteriorates its spatial resolution (typically several micrometres to date), making it insufficient for characterizing small-size flake samples or spatially inhomogeneous (e.g., magnetic, electronic or composite domain) materials.

In a new paper published in *Light Science & Applications*, Mao and his coworkers have developed a 177 nm VUV laser system for scanning photoemission microscopy with a focal spot of

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