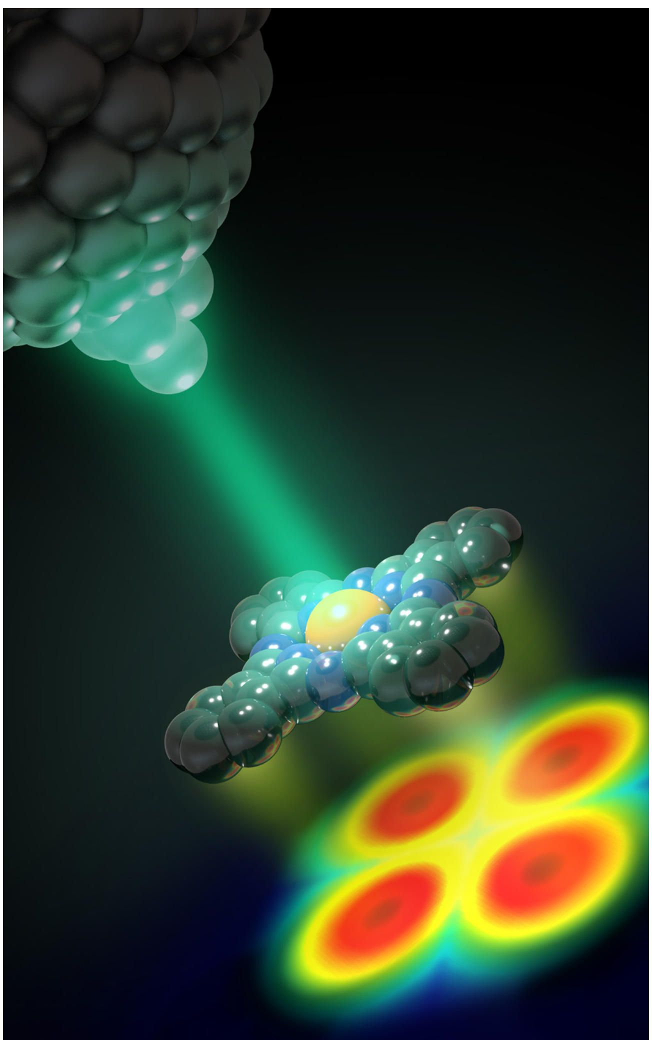
Shining a light on sub-molecular structures

Light-based microscopy is realizing resolutions previously achieved by ELECTRON MICROSCOPES.



New imaging illuminates light and matter interactions at the sub-molecular scale.

Scientists are now able to image a range of materials down to a sub-molecular level, thanks to light-based techniques based on Raman scattering developed by a team led by Jian-Guo Hou.

"The hope is that with AI-based data-handling, this technique could one day provide a consistent means for determining local structural and chemical heterogeneity down to the single-bond level for molecules and the defects on their surfaces," explains Hou.

The group reported its first big breakthrough in *Nature* in 2013 with the first Raman super-resolution technique to achieve sub-nanometre imaging.

Their advance involves causing molecules to vibrate using laser light and then measuring the light scattered from the sample, whose energy has been depleted by an amount equal to the energy imparted to the vibrating molecules. This breakthrough surpassed the previous limits of fluorescen ce microscopy, which has a spatial resolution of only about 6 nanometres.

Raman imaging is able to achieve ultrahigh spatial resolution because Raman signals are associated with a polarization change induced by the vibration of chemical bonds that can be highly localized in space, even within a single chemical bond, explains Hou. This aids accurate measurements based on light scattering data.

In 2019, through further technical developments at low temperatures, the team demonstrated the imaging of single bonds within a molecule, achieving a spatial resolution of about 0.15 nanometres. This unprecedented resolution resulted in a new methodology – scanning Raman picoscopy – that can structurally reconstruct a single molecule.

Recently, in combination with electrical and force measurements, the team also used this method to definitively determine different, but structurally similar, surface chemical species at the single-bond limit. "This strategy could provide a comprehensive view of surface chemistry at the sub-molecular level," says Bing Wang, a team member specialized in scanning probe microscopy.

The researchers have also made breakthroughs in fluorescence imaging. In 2016, by exploiting sub-nanometre resolved electroluminescence imaging, they demonstrated coherent intermolecular dipole–dipole coupling and superradiance in real space; and in 2020, they realized a sub-nanometer resolution of 0.8 nanometres in photoluminescence imaging, using high precision tip-engineering and positioning, and 'quenching' management.

"This is the first time that single-molecule photoluminescence imaging with sub-molecular resolution has been achieved," says Zhen-Chao Dong, a team member specialized in spectral imaging.

The team believe that the ultimate spatial resolution of their new Raman imaging technique is about 0.1 nanometre, and that they are probably close to the limits of resolution for Raman and fluorescence methods. But they plan to extend their techniques by using ultrafast optics to allow them to obtain snapshots of the dynamic behaviour of electrons and nuclei at very fast time-scales. They also want to investigate biomolecules such as DNA, RNA and proteins. ■