times larger than for PCP complexes deposited on bare cover slips, which agrees with previously reported fluorescence measurements. For some complexes, the researchers observed as much as an 18-fold increase in the fluorescence intensity. In addition, the distribution of the fluorescence intensity was substantially broadened. The researchers said that this is proof of the efficient coupling between silver nanoparticles and PCP, and also a consequence of geometrical inhomogeneities, for example the size distribution of the silver islands and the distances between the silver islands and the PCP complexes. Ensemble fluorescence measurements at 532 nm agree with the single-complex results, but the enhancement is 8.5-fold at 632 nm, where the fluorescence is due only to plasmonic interaction with chlorophylls. The researchers said that the dramatic increase in light absorption, which explains the increased fluorescence, also explains the increased photobleaching they observed for PCPs on SIFs. Model calculations show that electric-field enhancement of both absorption and emission outweighs quenching due to energy transfer to the silver nanoparticles.

The researchers said, "We envision a breakthrough in developing strategies for efficient light-harvesting systems through controlled fabrication of hybrid structures composed of the natural light-harvesting antennae and inorganic systems, including metal nanoparticles."

STEVEN TROHALAKI

Extreme UV Photoionization of Xe at Ultrahigh Intensities Demonstrates the Dual Nature of Light

The photoelectric effect at short wavelengths and ultrahigh intensities has been largely unexplored. A.A. Sorokin and M. Richter from the Physikalisch-Technische Bundesanstalt, Berlin; T. Feigl from the Fraunhofer IOF Jena; K. Tiedtke and H. Wabnitz from the Deutsches Elektronen-Synchrotron, Hamburg, and S.V. Bobashev from the Ioffe Physico-Technical Institute, St. Petersburg have observed high degrees of photoionization on xenon atoms by ion mass-to-charge spectroscopy after using high irradiance levels in the extreme ultraviolet (EUV) in a free-electron laser (FEL) beam.

As reported in the November 2007 issue of *Physical Review Letters* (213002; DOI: 10.1103//PhysRevLett.99.213002), the researchers used an EUV wavelength of 13.3 nm (a photon energy of 93 eV), generated by the FEL beam at the new Free-electron LASer in Hamburg FLASH, with a full width at half maximum (FWHM) focus diameter of 2.6 ± 0.5 μm at 60 m from the source point, combined with a pulse duration of 10 ± 2 fs, to yield a pulse irradiance of 10^{12}–10^{16} W cm^{-2}. The experimental vacuum chamber was filled with xenon gas at low pressures (0.6–2.0 × 10^{-4} Pa) to avoid interactions between neighboring atoms.

The main process of one-photon excitation of Xe at 93 eV is the resonant photoelectron emission from the inner 4d electron shell that leads, through Auger decay, to Xe^{2+} or Xe^{3+}. With increasing irradiance, the researchers explain the formation of additional higher charges by higher order multiphoton effects. The formation of Xe^{6+}, where the outer $5p^6$ shell is completely removed, may be explained by a sequence of one-photon transitions in which an ion created in a preceding step represents a new target for a subsequent step. Further transitions require more than one photon to be involved, culminating in the generation of Xe^{21+} from Xe^{20+}, for which seven EUV photons are required.

According to the researchers, using the framework of perturbation theory and the particle picture of light, one has to consider about 19 steps to generate Xe^{21+} from atomic Xe, involving a total energy of more than 5 keV, which represents more than 57 EUV photons of 93 eV photon energy. However, the different slopes of the ion signal intensities measured for Xe ionic species with high charges demonstrate a behavior like that in the optical strong-field regime, where ion generation is described by nonperturbative theories within the wave picture of light, the researchers said. "Neither a pure particle nor a pure wave picture of light seems to give a satisfying explanation for these experimental results which nicely demonstrates the dual nature of light," the researchers said. Such results may have strong impact on future applications of large x-ray laser facilities.

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https://doi.org/10.1557/mrs2008.58 Published online by Cambridge University Press