New data on ultrafast electron photoemission from metallic nanostructures obtained

May 22 2019

The results of a Russian-Japanese experiment explain the mechanism of electron photoemission by metallic nanostructures under ultrafast laser excitation. Metallic nanoparticle ensembles are capable of emitting short bunches of electrons when irradiated by powerful laser pulses of femtosecond (1 fs = 10^{-15} s) duration. Scientists at Lobachevsky University have long studied the plasmon effect—the excitation by light of collective electron oscillations in nanoparticles and the amplification of the light field associated with these oscillations in the vicinity of the nanoparticle, which plays the main role in this process. It is the plasmon amplification of the field that provides effective photoemission of electrons from a metal.

The prospects for practical application of plasmon nanostructures are associated with their use as ultrafast photocathodes to create pulsed sources of high-brightness coherent X-ray radiation and to produce microscopes with high temporal resolution.

The photoemission of electrons from metallic nanoparticles is accompanied by the emission of terahertz radiation (its range in the scale of electromagnetic waves is between light and microwaves), which makes it possible to use this radiation as a tool for studying photoemission.

"The intensity of terahertz radiation depends non-linearly on the intensity of the laser pulse and demonstrates a high nonlinearity order (from 3 to 6 in various experiments). Although the mechanism of terahertz radiation generation by photoelectrons is not fully understood, it is believed that the high order of nonlinearity is explained by the multi-photon nature of electron emission, that is, by the need to transfer energy from several laser photons to the electron for performing the work to release the electron from the metal," explains Michael Bakunov, Head of the General Physics Department at Lobachevsky University.

To test the hypothesis of a multi-photon photoemission mechanism, scientists from Lobachevsky University together with their Japanese colleagues from Shinshu University, Osaka University and Tokyo Institute of Technology conducted an experiment in which the same metallic nanostructure, an array of gold nanorods ("golden nanoforest") was irradiated with powerful ultrashort light pulses of various wavelengths—from 600 nm to 1500 nm.

The result was surprising. Despite the fact that the energy of quanta differed more than twofold, the order of nonlinearity was approximately the same (4.5-4.8) for wavelengths from 720 to 1500 nm and even greater (6.6) for a wavelength of 600 nm (with the highest quantum energy).

"These results disprove the hypothesis of multi-photon emission of electrons. At the same time, the experimental dependences are in good agreement with the tunnel emission mechanism, whereby electrons are made to escape from the metal by a plasmon enhanced light field," concludes Michael Bakunov.

The results of Russian and Japanese scientists' research were published in one of the leading scientific journals, *Scientific Reports*

More information: Keisuke Takano et al, Terahertz emission from gold nanorods irradiated by ultrashort laser pulses of different wavelengths, *Scientific Reports* (2019). DOI:

10.1038/s41598-019-39604-5

Provided by Lobachevsky University