Precise measurement of physics theory proves true even under extreme conditions

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A new measurement in quantum electrodynamics – an extension of quantum mechanics – is 10 times more precise than any recent measurements.

Quantum electrodynamics, or QED, is one of the most successful theories in physics and considered one of the fundamental theories of nature. QED describes the interaction of matter with photons, in which particles and antiparticles are constantly created and annihilated in electric and magnetic fields – known as a polarized vacuum – and where the electron is surrounded by a sea of photons, an effect that is dubbed the electron's self energy. QED is the foundation of modern physics and the standard model of particle physics.

Deviations from QED would have far-reaching consequences in our understanding of the universe because it would mean that QED is no longer a fundamental theory of nature.

Lawrence Livermore National Laboratory scientists have entered a new realm in the search for QED deviations by measuring light they generated in the extreme electric fields surrounding the nucleus of uranium. The group tested the theory using Livermore's SuperEBIT, an electron beam ion trap, to strip uranium of all but three electrons, forming a uranium plasma.

"Now we are in the regime where we see each manifestation of QED interacting with each other and even with itself," said Peter Beiersdorfer,

lead author of the paper from Livermore's Physics and Advanced Technologies Directorate. "There is a good analogy from basketball: before you could see one player at a time, say someone shooting a basket. With the precision we have now, we can see the team actually playing. We see how each player interacts."

The results appear in the December 2 edition of *Physical Review Letters*.

The researchers studied the radiation emitted by these extreme states of matter in a series of experiments over a two-month period conducted on SuperEBIT.

The Livermore group was able to improve the existing experimental precision by nearly an order of magnitude (10 times better). In doing so, the group beat their competitors at the Heavy Ion Research Institute in Darmstadt, Germany, who recently reported a measurement that has only one-hundredth the accuracy needed to be on par with the Livermore measurements.

"This is a new milestone in QED research," Beiersdorfer said. "We are still looking to see whether present-day QED is complete and whether we can find any deviations from it. Nevertheless, we put a new, much more stringent constraint on theory."

Employing high-resolution spectrometers in the experiments, the researchers were the first to take a direct look at the light emitted by the uranium plasma.

The high precision of the SuperEBIT measurements allowed Beiersdorfer's group to extract an experimental value for the new QED effects, in which the polarized vacuum as well as the self-energy interacted with each other and themselves. Previous measurements only tested the non-interacting manifestations of QED.

"These new results are a major step forward and will stimulate new calculations in QED theory," said Kwon-Tsang Cheng, from Livermore's A Division, who together with Mau Chen of Livermore's V Division and Jonathan Sapirstein from Notre Dame University, have been making calculations for comparison with the SuperEBIT results.

The Livermore team consists of Beiersdorfer, Hui Chen, Daniel Thorn and Elmar Träbert.

Source: Lawrence Livermore National Laboratory