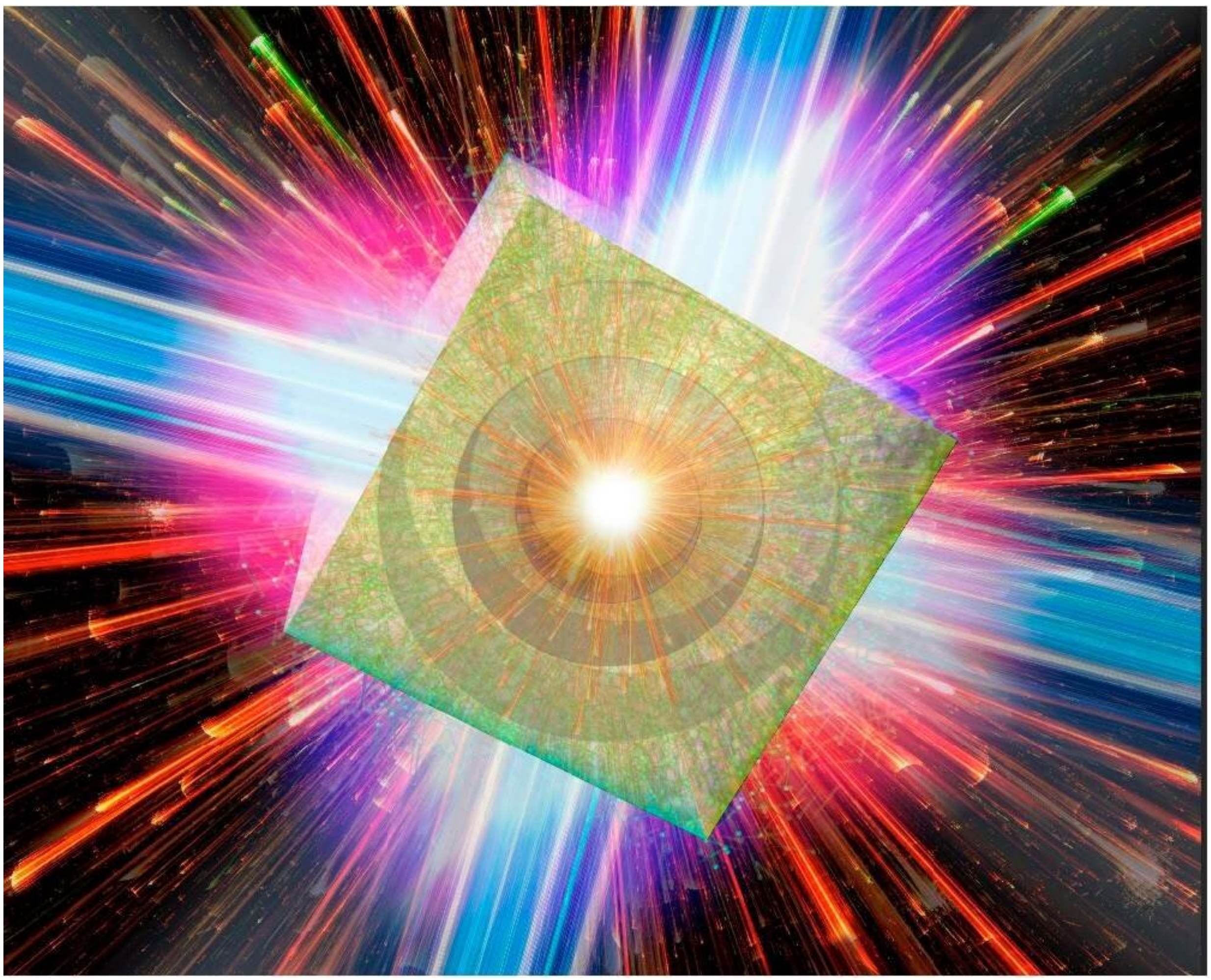
Could vacuum physics be revealed by laser-driven microbubbles?

July 9 2019



All of the main events of microbubble implosion, i.e., laser illumination, hot electron spread, implosion, and proton flash at the end. Credit: M. Murakami

A vacuum is generally thought to be nothing but empty space. But in fact, a vacuum is filled with virtual particle-antiparticle pairs of electrons and positrons that are continuously created and annihilated in unimaginably short time-scales.

The quest for a better understanding of vacuum physics will lead to the elucidation of fundamental questions in modern physics, which is integral in unraveling the mysteries of space, such as the Big Bang. However, the laser intensity required to forcibly separate the virtual pairs and cause them to appear not as virtual particles but real particles would be 10 million times higher than current laser technology is capable of. This field intensity is the so-called Schwinger limit, named a half-century ago after the American Nobel laureate Julian Schwinger.

In 2018, scientists at Osaka University discovered a novel mechanism that they called a microbubble implosion (MBI). In MBIs, super-high-energy hydrogen ions (relativistic protons) are emitted at the moment when bubbles shrink to atomic size through the irradiation of hydrides with micron-sized spherical bubbles by ultraintense, ultrashort laser pulses.

In this study, the group led by Masakatsu Murakami confirmed that during MBI, an ultrahigh electrostatic field close to the Schwinger field could be achieved because micron-sized bubbles embedded in a solid hydride target implode to have nanometer-sized diameters upon ionization.

From the 3-D simulations carried out at the Osaka University Institute of Laser Engineering, they also found that the density during the maximum compression of the bubble reaches several hundred thousand to 1 million times solid density. At this density, something no larger than a lump of sugar would weigh a few hundred kilograms. The energy density at the bubble center was found to be about 1 million times higher than that at the sun. These astonishing numbers have been thought to be impossible to achieve on Earth. Their research results were published in *Physics of Plasmas*.

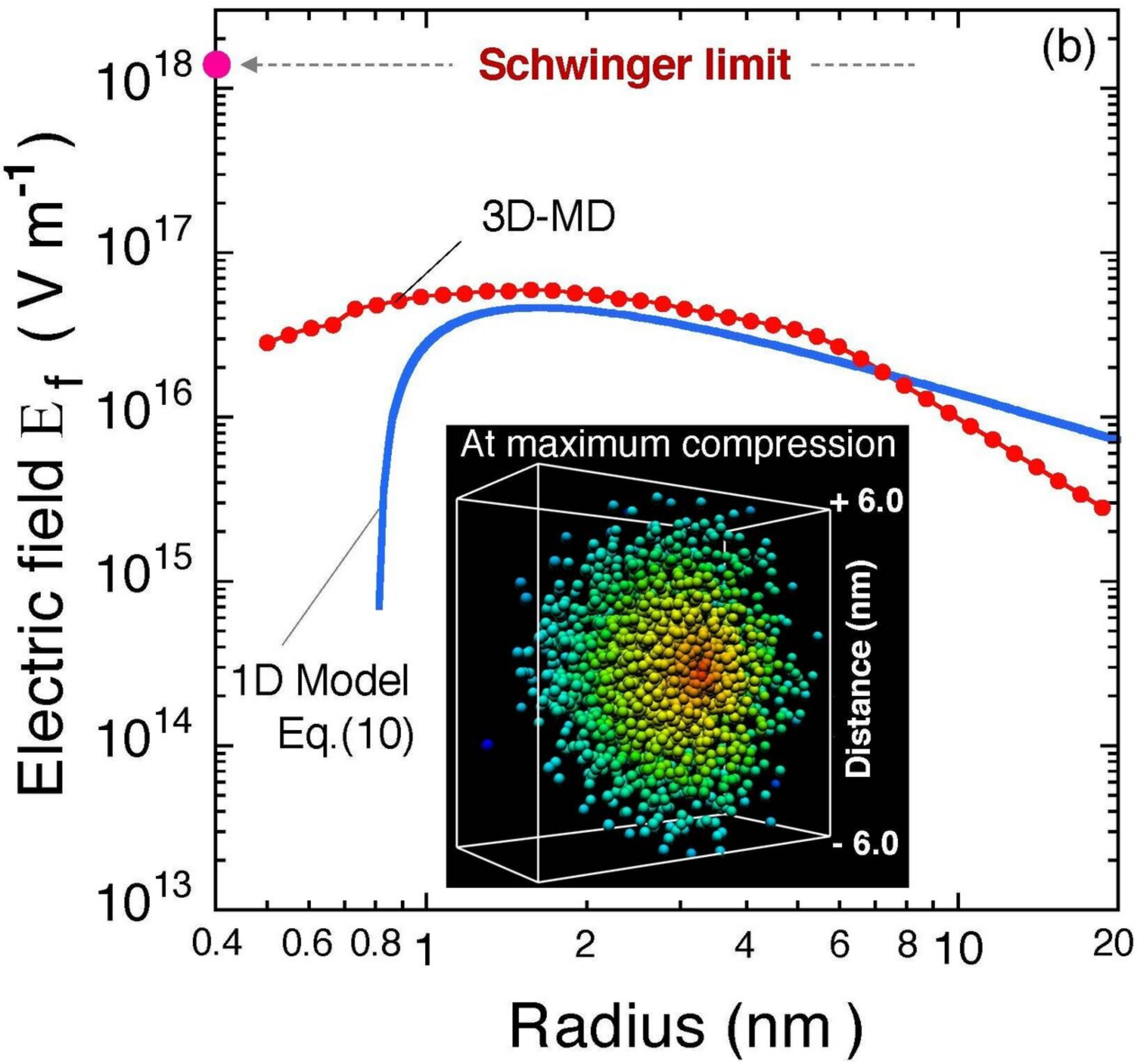


Fig.2 Comparison of the electrostatic fields between the 3D simulation and the model. The inset shows the proton distribution around the center (color-coded in accordance with the distance from the center). Credit: M. Murakami

More information: M. Murakami et al. Relativistic proton emission from ultrahigh-energy-density nanosphere generated by microbubble implosion, *Physics of Plasmas* (2019). DOI: 10.1063/1.5093043

Provided by Osaka University