Relativistic plasma could boost intensity of petawatt laser

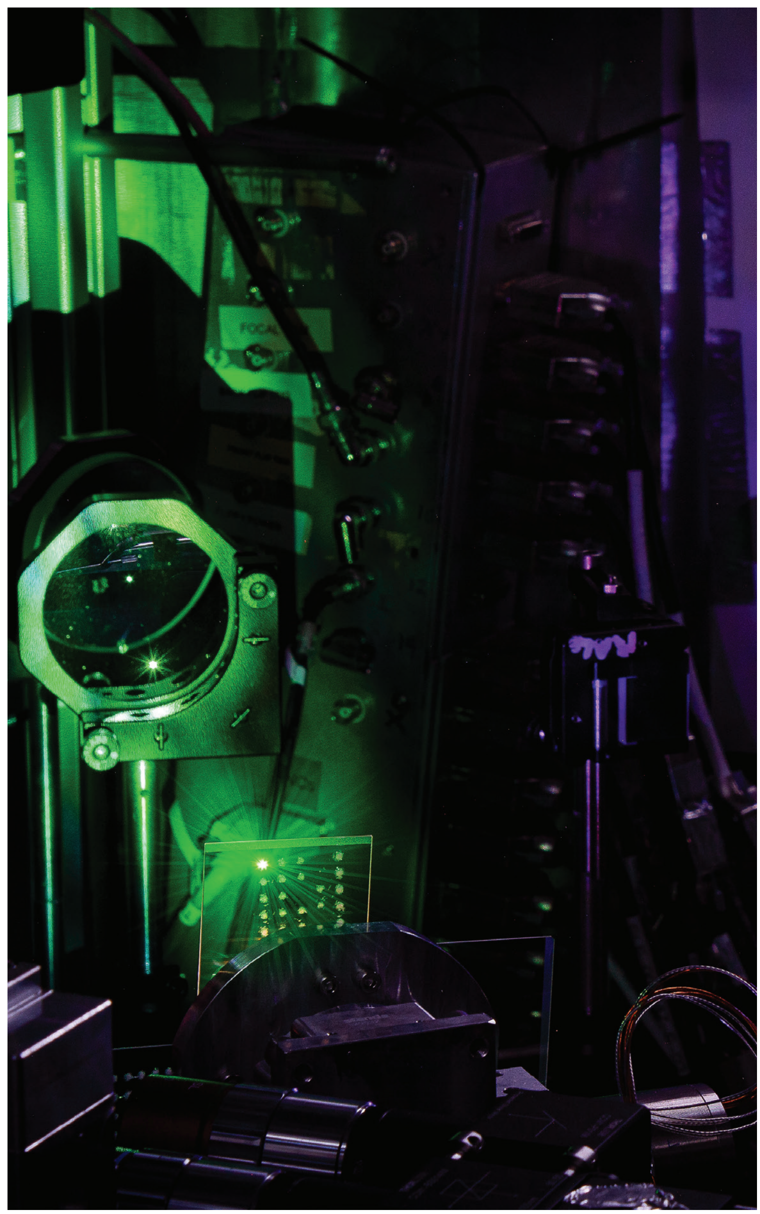
With a new approach to generating powerful laser pulses, researchers may have the means to observe phenomena in quantum electrodynamics.

By Alex Lopatka

A vacuum isn't empty space. According to quantum electrodynamics, virtual particles and antiparticles flit in and out of existence across exceedingly small spaces and in short periods of time.

One way to study quantum vacuum fluctuations is to use an extremely strong electromagnetic field. For intensities greater than 10^{29} W/cm^2, known as the Schwinger limit, the field is able to spontaneously create virtual electron–positron pairs from the quantum vacuum. No source, however, has yet generated an electromagnetic field of that intensity. Robin Timmis and Peter Norreys (University of Oxford), Brendan Dromey (Queen's University Belfast), and their colleagues have now used the Gemini laser system at the Rutherford Appleton Laboratory in the UK to generate bright, coherent extreme-UV light with an intensity of 10^{21} W/cm^2.[1] Although still eight orders of magnitude away, the team argues that the same approach, if implemented at other, high-power laser facilities, could scale up and reach the sought-after Schwinger limit.

A key component for generating a high-intensity field is a plasma that is relativistic—free electrons oscillate near the speed of light—and well shaped. The researchers created such a plasma by shining 5 J, 50 fs pulses from Gemini's petawatt laser onto a glass target. The plasma interacts with the same laser pulse that generated it, and that interaction leads to the emission of coherent high-frequency harmonics of the laser. Under the right conditions, the harmonics become tightly focused. The result is a train of spatially compressed atto-



A high-power laser pulse is focused on a glass target and generates a plasma, appearing here as a glowing green spot. The laser–plasma interaction produces high-frequency harmonics of the original laser. When the harmonics are focused together into a coherent beam, the laser intensity is boosted to levels that approach those relevant for studying quantum vacuum fluctuations. (Image courtesy of Jonathan Kennedy, Queen's University Belfast.)

second pulses whose intensity is many orders of magnitude greater than that of the incident laser.

The challenge encountered in past attempts to generate coherent harmonic focusing was that the harmonic spectrum decayed too fast. Timmis, Dromey, and their colleagues overcame that problem by implementing a specialized plasma mirror. It functions essentially as an optical switch that increases or decreases the reflectivity of the plasma created at the glass target's surface. For years, plasma mirrors have been used for boosting laser intensity. Using material coatings to carefully tune the plasma mirror's reflectivity, the researchers enabled the laser pulse to generate a coherent harmonic beam more efficiently.

Simulations of the Gemini laser's interaction with the relativistic plasma by Timmis, Dromey, and colleagues suggest that the intensity of the incident laser pulse can be boosted even further, to 10^{23} W/cm^2. The coherent harmonic focus should scale with laser intensity, so reaching the Schwinger limit could, in principle, be done with a higher-powered laser. The lasers at the ELI-NP (Extreme Light Infrastructure Nuclear Physics) facility in Romania are 10 PW, an order of magnitude more powerful than Gemini's. Laser systems that are even more powerful, including the 25 PW NSF OPAL (Optical Parametric Amplifier Line) lasers at the University of Rochester and the 100 PW system at the Station of Extreme Light in Shanghai, China, are currently in development. **PT**

Reference

1. R. J. L. Timmis et al., "Efficiency-optimized relativistic plasma harmonics for extreme fields," *Nature* **652**, 1153 (2026).

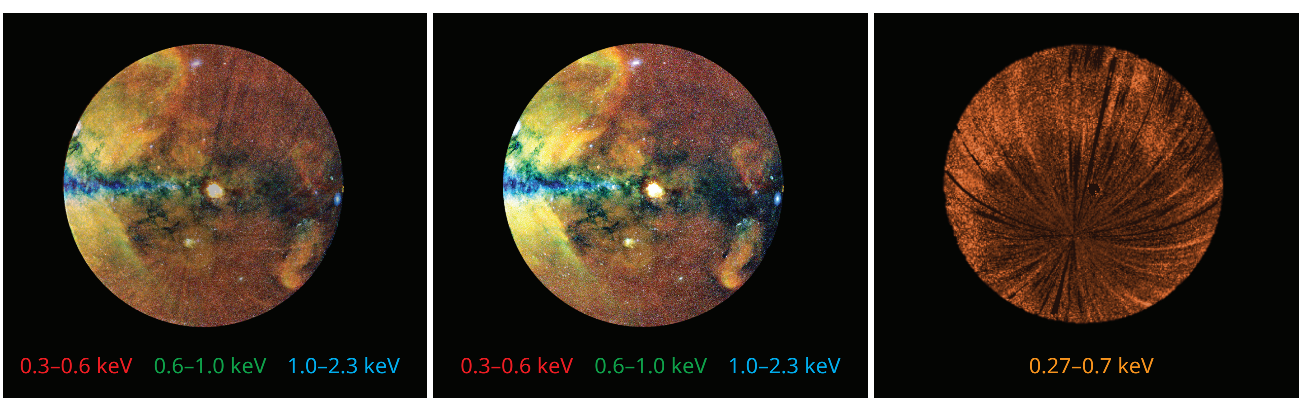
Separating signals in the soft x-ray sky

An analysis of two years of measurements from far beyond Earth's atmosphere has yielded a comprehensive map of x rays that are generated by solar wind.

By Laura Fattaruso

X rays are a valuable source of information about distant, hot celestial bodies, such as supernova remnants and active galactic nuclei. But measurements of soft x rays—which have photon energies of no more than a few kiloelectron volts—have been clouded by local contamination. Gas throughout the solar system emits soft x rays, and so does Earth's outermost atmosphere, which reaches as far as the Moon. And that contamination varies in both space and time.

Far beyond the Moon's orbit, the eROSITA telescope measured x rays outside the influence of Earth's atmosphere. And now, using data from its four full-sky surveys of the western galactic hemisphere, Konrad Dennerl of the Max Planck Institute for Extraterrestrial Physics and colleagues have separated the signals of x rays generated in the heliosphere from those generated beyond it.[1] The resulting map provides a clearer



Measurements from the eROSITA telescope were used to separate soft x rays generated in the solar system **(right)** from x-ray emissions generated beyond the heliosphere **(middle)**. A superposition of the two **(left)** represents the combined x-ray emissions. Because of restrictions on the release of the dark-sky x-ray map, the middle image shows x-ray emissions from the first eROSITA survey, which closely resemble dark-sky x-ray emissions. The right image shows heliosphere x-ray emissions from the third eROSITA survey. (Images courtesy of Konrad Dennerl/Max Planck Institute for Extraterrestrial Physics.)