Physicist builds useful light source from harmonic generation

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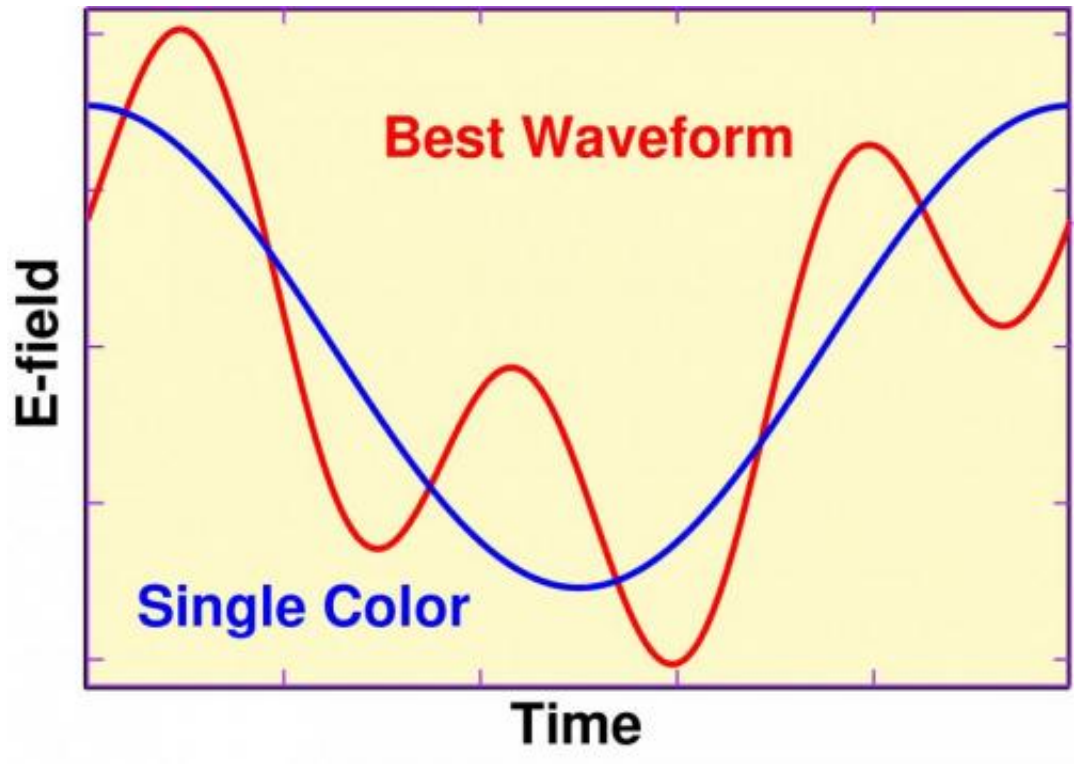

Kansas State University physicists are researching new ways of creating tabletop light sources in the laboratory. Credit: Kansas State University

A Kansas State University physicist's proposal may lead to a new way of creating tabletop light sources in the laboratory.

Cheng Jin, research associate in physics; Chii-Dong Lin, university distinguished professor of physics; and collaborators are developing a

way to greatly enhance the generation of high-order harmonics to create powerful small tabletop light sources that are important to science and technology.

The researchers are building theoretical framework and providing experimental guidance in the area of strong-field physics. The work is associated with the physics department's James R. Macdonald Laboratory.

"The ultimate goal of this research is to design any waveforms to control physical processes for different applications," Jin said.

The research appears in a recent *Nature Communications* article, "Waveforms for optimal sub-keV high-order harmonics with synthesized two- or three-colour laser fields." In the field of atomic, molecular and optical physics, it is rare for such a theoretical paper to be published in a multidisciplinary research journal such as *Nature Communications*, Jin said.

Other Kansas State University researchers involved include Anh-Thu Le, research associate professor of physics; Hui Wei, doctoral student in physics; and Guoli Wang, visiting scholar in physics and associate professor at Northwest Normal University in China.

High-order harmonic generation is an extreme nonlinear process when intense infrared lasers are focused in a gas medium. When used with the right filters, high-order harmonic generation pulses, which range from extreme ultraviolet to X-ray, can be used for numerous applications in science and technology.

For example, the emitted harmonics can produce isolated attosecond pulses or attosecond pulse trains. An attosecond is one-billionth of a billionth of a second. These attosecond pulses are used to study the

dynamics of atoms, molecules and condensed media, and to investigate their evolution at the femtosecond and attosecond timescales. A femtosecond is one-millionth of a billionth of a second.

"High-order harmonic generation has been considered a very promising way to provide the tabletop coherent light sources in the extreme ultraviolet to X-ray regions, but so far is limited by its low intensity," Jin said.

While Jin has extensively studied high-order harmonic generation, the latest publication proposes a method of synthesizing two- or three-color lasers to optimize the intensity of high-order harmonic generation.

"Our method can greatly enhance the harmonic intensity by one to two orders of magnitude without the increase of total laser power," Jin said. "With the emerging intense high-repetition megahertz lasers, this paves a way to make high-order harmonic generation as a useful light in the coming years."

While laser technology of synthesizing two- or three-color lasers already exists, without the guidance of their work it is difficult to locate the laser parameters, such as laser intensities and relative phases between each two colors to form a waveform that optimizes the harmonic intensity in the laboratory by taking trial-and-error methods, Jin said. When these waveform-optimized laser pulses are combined with the emerging high-repetition megahertz lasers, they can generate high harmonics that are much higher than what is available today.

Lin's research group plans future research in the area of strong-field physics.

The group is exploring how to eliminate atto-chirp with a designed waveform, how to achieve the optimized waveform in the gas-filled

hollow-core waveguide and how to optimize the waveforms over multiple optical cycles to enhance the intensity of the single harmonic.

"We expect waveform control of intense laser pulses will lead the next wave of research in strong-field physics and the theoretical study carried out in this work is essential for this research to move forward," Jin said.

More information: Jin's previous research on high-order harmonic generation has been summarized in his book, "Theory of Nonlinear Propagation of High Harmonics Generated in a Gaseous Medium." The book was published by Springer in 2013 and supervised by Lin.

Provided by Kansas State University