Researchers use 'flying focus' to better control lasers over long distances

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When you were a kid, you might have used a magnifying glass to focus the sun's light onto a spot on the sidewalk. The lens of the magnifying glass allowed you to concentrate the sun's energy by converging the light rays on a point.

Say instead of focusing the sun's light on the ground, you wanted to focus the light on a piece of paper. Then imagine that piece of paper was moving. If you wanted to keep the focus on the paper, you could move the lens (the magnifying glass) or you could make the focus (the concentration of light) move. Allowing the focus to move creates a concept known as the flying focus.

For the first time, researchers at the University of Rochester's Laboratory for Laser Energetics (LLE) have found a way to use the flying focus to better control the intensity of lasers over longer distances. Their technique includes capturing some of the fastest movies ever recorded and has the potential to help researchers design the next generation of high-power lasers or produce light sources with novel wavelengths. The next generation of high-power lasers could be powerful enough to generate particles from a vacuum, while the light sources could produce new terahertz beams for studying complex materials and molecules.

The researchers published their findings in a paper in *Nature Photonics*.

"People may have unintentionally produced flying focus in the past, but this is the first time the flying focus has been recognized as a useful way to manipulate the focal velocity," says Dustin Froula, a senior scientist at the LLE and an assistant professor of physics at Rochester.

The top frame shows what happens when you, for instance, use a magnifying glass to direct all the colors of the sun's light—arranged from blue (shorter wavelengths) to red (longer wavelength)—to a single focal point (the vertical green line). All of the colors would focus there and come to a stop. The bottom frame shows what happens when researchers use a flying focus lens to direct all the colors from a laser beam, from blue to red, allowing each color to come to a different focal point. Blue would focus first and then this focus would move backwards to the red. The focus does not come to a stop, but instead moves.

"This turns out to be super powerful," Froula says. "The flying focus allows us to have that high intensity over hundreds of times the distance than we could before. Right now we're trying to make the next generation of high-powered lasers and flying focus could be that enabling technology."

The technique LLE researchers developed allows them to conduct measurements by capturing movies of the moving focal spot at a rate of one-trillionth of a frame per second—one of the fastest movies ever recorded.

Froula and his colleagues accomplished this using a short pulse laser and a diffractive lens, made by Terry Kessler, an optical and imaging sciences group leader at the LLE.

"There are only a few of these lenses in the world and three of them were built at the LLE by Terry and his team more than 10 years ago as part of the OMEGA EP project," Froula says. "Our plasma physics group set out to design an experiment that would measure the propagation of a focal spot at any velocity, including 50 times the speed of light. This required a diagnostic that could make a movie with frames at a trillionth of a second."

Froula says the cooperative support of the LLE's Laser Science Team helped to achieve this feat: "The collaborative cross-disciplinary groups at LLE enabled this novel concept to become reality and are leading breakthroughs in many laser-plasma applications."

More information: Spatiotemporal control of laser intensity, *Nature Photonics* (2018). nature.com/articles/doi:10.1038/s41566-018-0121-8

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