Powerful Femtosecond Laser Induces 'Electrical Effects' during Thunderstorms

Experiments are a first step toward laser-induced lightning.

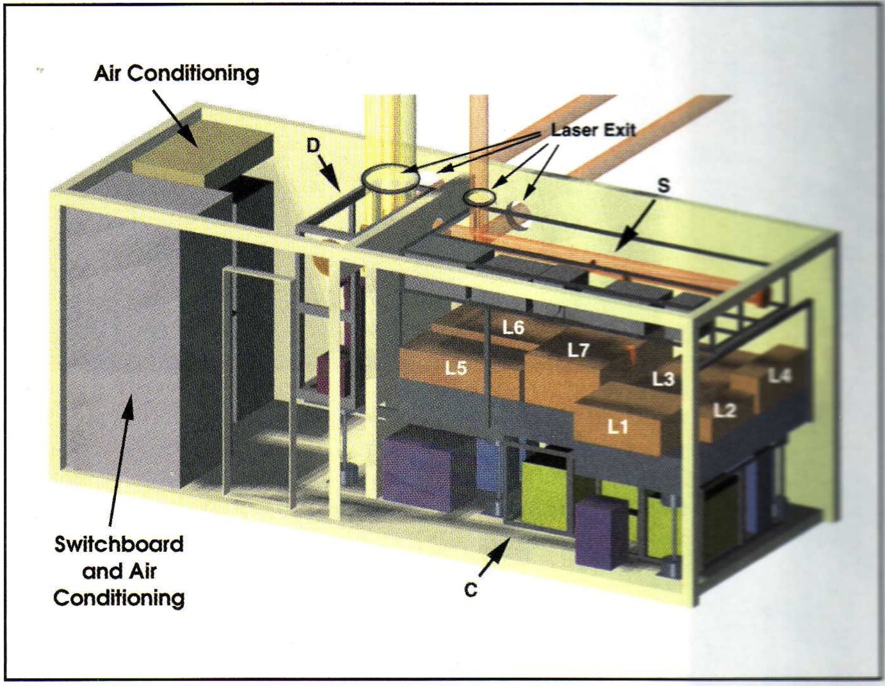

Figure 1. The Teramobile laser is a Ti:sapphire oscillator/chirped-pulse-amplifier system, packaged together with a detection system in a standard sea shipping container. C = heat exchanger, D = detection unit, S = beam expander, L1-L6 = CPA oscillator/amplifier. Reprinted, with permission, from the December 2002 issue of the *European Physical Journal — Applied Physics.*

Although considerably less destructive than earthquakes, lightning is nonetheless one of the great unpredictable forces Mother Nature inflicts on mankind. Just as some scientists try to understand and predict earthquakes, others study the dynamics of lightning. The difficulty is that lightning, like earthquakes, occurs randomly, making real-time observations problematic. Recently, scientists have aimed a high-power laser at the heavens from atop New Mexico's South Baldy Peak and have taken what they believe is one of the most positive steps yet toward producing laser-controlled lightning.

The scientists are affiliated with Centre National de la Recherche Scientifique in Palaiseau and Lyon, France, with Geneva University in Switzerland, and with Freie Universität Berlin and Forschungszentrum Dresden, both in Germany. They are careful to say that, so far, their experiments have triggered only "electrical events," not lightning. The events manifest themselves in the form of short bursts of 63-MHz radiofrequency activity, detected by an array of five lightning-mapping receivers on the ground.

Nonetheless, these experiments have been more successful than previous attempts at laser-induced lightning. Earlier experiments could not produce the long plasma channels

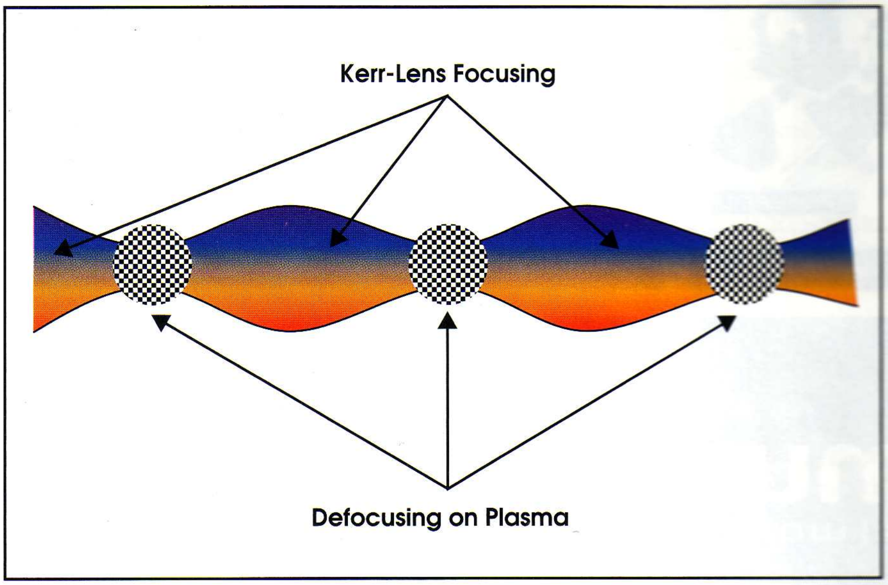

Figure 2. The filamentation effect as the beam propagates through air results from a balance between Kerr-lens focusing and defocusing caused by the ionized plasma. The resulting channel of periodic ionization can extend for 100 m or more. Reprinted, with permission, from the December 2002 issue of the *European Physical Journal — Applied Physics.*

necessary to guide lightning because the plasma generated by the leading edge of the pulse absorbed the rest of the pulse, preventing the formation of a long channel. Think of a cartoon truck collapsing into itself when it hits a brick wall. But subpicosecond pulses are too short to induce cascading ionization and can therefore generate long ionization tunnels in air.

Lighting can be artificially induced also by shooting a small rocket trailing a thin wire into a thundercloud. However, rockets cannot be fired repeatedly and rapidly into a thundercloud, and there is an unavoidable delay between a rocket's launch and its entry into the thundercloud.

The laser used in these experiments was itself something of an engineering feat. Dubbed by its designers the "Teramobile," it was basically a Ti:sapphire oscillator-amplifier that was compactly packaged into a standard sea shipping container (Figure 1). Capable of 350-mJ, 70-fs pulses at a 10-Hz repetition rate, it started with a compact Femtosource Ti:sapphire oscillator followed by a Coherent Nd:YAG-pumped, chirped-pulse amplification chain. The chain included a regenerative amplifier and two four-pass amplifiers. Developed by the scientists in cooperation with Thales Laser of Orsay, France, the laser was constructed by TSU GmbH of Bremerhaven, Germany.

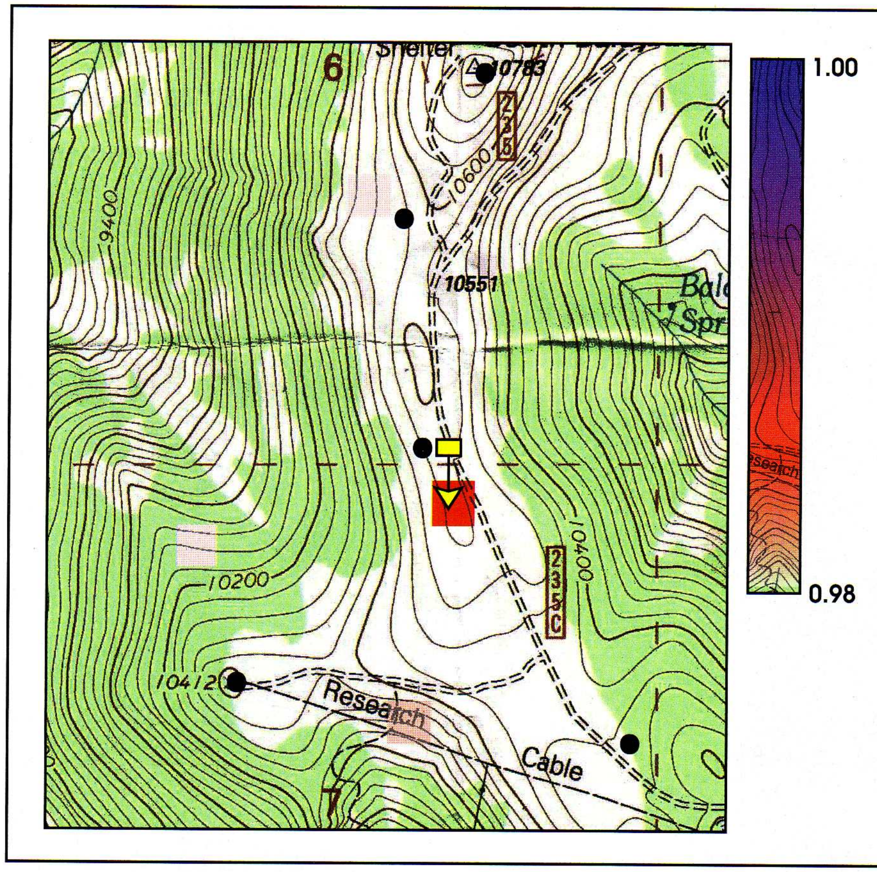

Figure 3. After analyzing their raw data, the scientists saw many more electrical events synchronized with the laser pulses in the 100-m² grid encasing the filamentation pictured in Figure 2. The color represents the statistical significance of the correlation between laser pulses and electrical events. The yellow arrowhead is the laser beam, and the tail of the arrow shows the location of the laser. Reprinted with permission of *Optics Express*.

The Teramobile's femtosecond pulses, propagating through the rainy night in New Mexico, produce an unusual filamentation effect that can extend over a range as long as hundreds of meters — a distance much longer than the Rayleigh length, which limits how long a beam normally can stay focused (Figure 2). It's this trail of ionized spots of air that apparently precipitates the electrical events observed in the experiments.

The scientists monitored the electrical noise at 63 MHz emanating from the thunderhead with an array of five receivers located within a kilometer of the laser. By timing the arrival of a noise pulse at each receiver, they could pinpoint the electrical event that was its source to within 100 m in the ~4-km² test area. What they looked for then was a preponderance of 63-MHz pulses in sync with the 10-Hz laser pulses and located in the 100 × 100-m² grid traversed by the laser-induced filamentation.

What they saw, after statistically analyzing their raw data, was precisely what they were looking for (Figure 3). There was a definite increase in the number of observed electrical events in the region around the laser beam, and they were synchronized with the beam's pulses.

The scientists considered how they might extend their experiments to the point where the laser actually induces a bolt of lightning, as does the wire trailed behind a rocket. The limitation is the short lifetime of the filamentation pictured in Figure 2 — typically no more than a microsecond or so. Lightning propagates at speeds of several million meters per second, resulting in a discharge length of only approximately a meter. Rockets have been observed to induce lightning over only a few tens of meters of wire, so presumably a factor of 10 increase in the filamentation length would likewise produce a real bolt of lightning.

They plan to investigate various timing sequences of the pulses, various repetition rates and beam profiles, and higher-power lasers as means of extending the filamentation to lengths that might result, for the first time, in laser-induced lightning. □

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