7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Laser-guided lightning using kHz filamentation at 1030 nm

A. Houard[1], P. Walch[1], T. Produit[2], V. Moreno[2], B. Mahieu[1], A. Sunjerga[3], C. Herkommer[4], A. Mostajabi[3], U. Andral[2], Y.-B. André1, M. Lozano[1], L. Bizet[1], M. C. Schroeder[2], G. Schimmel[2], M. Moret[2], O. Maurice[5], B. Esmiller[5], K. Michel[4], W. Haas[6], T. Metzger[4], M. Rubinstein[7], F. Rachidi[3], V. Cooray[8], A. Mysyrowicz[1], J. Kasparian[2,9], J.-P. Wolf[2]

[1]Laboratoire d'Optique Appliquée – ENSTA Paris, Ecole Polytechnique, CNRS, IP Paris, France
[2]Groupe de Physique Appliquée, Université de Genève, Switzerland
[3]EMC Laboratory, Electrical Engineering Institute, EPFL, Switzerland
[4]TRUMPF Scientific Lasers GmbH + Co. KG, Germany
[5]ArianeGroup, France
[6]Swisscom Broadcast AG, Switzerland
[7]School of Management and Engineering Vaud, HES-SO, Switzerland
[8]Department of Electrical Engineering, Uppsala University, Sweden
[9]Institute for Environmental Sciences, Université de Genève, Switzerland
e-mail (speaker): aurelien.houard@polytechnique.edu

Controlling lightning is a long-time dream of mankind. Along with the rapid evolution of laser technologies, the idea to develop lightning protection based on filamentation of high-power ultrashort-pulse lasers emerged in the 1990s [1]. The goal of the Laser Lightning Rod (LLR) project that started in 2017 was to investigate a new type of lightning protection based on the use of upward lightning discharges initiated through a high-repetition-rate terawatt laser [2]. To that end, a high-power laser was developed by Trumpf scientific with pulse energy in the Joule-range, 1 ps pulse duration, and a repetition rate of 1 kHz [3]. This CPA laser system is based on Yb-YAG thin-disk technology allowing amplification at very high average power at a wavelength of 1030 nm.

The long-range propagation of this high energy kHz laser in the multiple filamentation regime and its ability to control high-voltage discharges were first studied in a 120-m long horizontal corridor. Then, a field campaign was carried out to assess the laser ability to trigger or guide upward lightning discharges from a tall structure. The lightning experimental station at the Säntis mountain in Northeastern Switzerland was chosen for this experiment. Located at an altitude of 2 500 meters, this unique site is fully instrumented for the study of lightning phenomena.

The guiding of an upward negative lightning leader over a distance of 50 m was recorded by two separate high-speed cameras. The guiding of negative lightning leaders by laser filaments was corroborated in three other instances by VHF interferometric measurements, and the number of X-ray bursts detected during guided lightning events was significantly increased [4]. While this research field has been very active for more than 20 years with many research groups around the world working to achieve this goal, this result demonstrates for the first time that lightning can be guided by lasers, which may lead to the development of a laser lightning rod.

Figure 1. Photography of the LLR experiment on Mount Säntis in July 2021. @TRUMPF/Martin Stollberg

References

[1] X.M. Zhao, J.C. Diels, C.Y. Wang, and J.M. Elizondo, "Femtosecond ultraviolet laser pulse induced lightning discharges in gases," IEEE J. Quantum Electron. **31**, 599 (1995)
[2] T. Produit *et al.,* "The laser lightning rod project, Eur". Phys. J. Appl. Phys. **92**, 30501 (2020)
[3] C. Herkommer et al., "Ultrafast thin-disk multipass amplifier with 720 mJ operating at kilohertz repetition rate for applications in atmospheric research", Opt. Express **28**, 30164–30173 (2020)
[4] A. Houard, *et al.* "Laser-guided lightning", Nat. Photon. **17**, 231 (2023)