Laser Lightning Rod

T. Produit[1], G. Schimmel[1], J. Kasparian[1], A. Houard[2], K. Michel[3], T. Metzger[3], B. Esmiller[4], A. Mysyrowicz[2,5], F. Rachidi[6], M. Rubinstein[7], J.-P. Wolf[1*]

[1]Université de Genève, Group of Applied Physics, Switzerland
[2]Laboratoire d'Optique Appliquée, ENSTA ParisTech, Ecole Polytechnique, CNRS, France
[3]TRUMPF Scientific Lasers, Germany
[4]ArianeGroup, France
[5]AMC SARL, Versailles, France
[6]EMC Laboratory, EPFL, Switzerland
[7]IICT, HES SO, Switzerland
*jean-pierre.wolf@unige.ch
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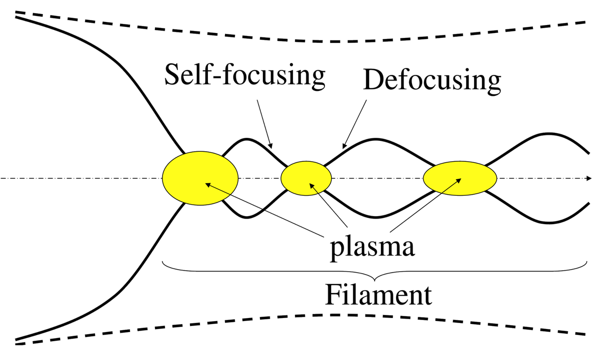
MOTIVATIONS

Ever since the invention of the lightning rod by Benjamin Franklin in the 18th century, mankind has become more and more invested in understanding and tame lightning as a natural phenomenon. Along with the rapid evolution of laser technologies, we propose to develop a new type of lightning protection based on high-power femtosecond lasers. The goal of the Laser Lightning Rod project is to investigate and develop the use of upward lightning discharges initiated by high repetition rate multi-terawatt laser as a lightning protection system.

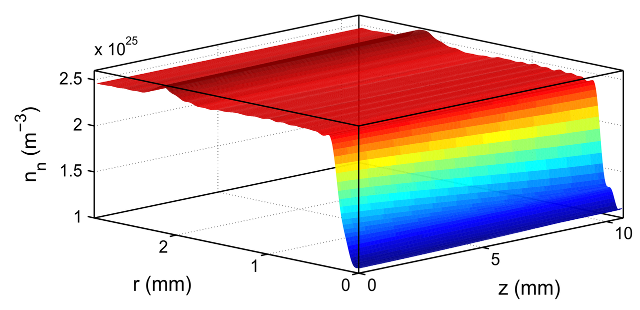
BACKGROUND

Laser Filaments

Ultra-short laser pulses in the subpicosecond range and with peak powers exceeding the 100 gigawatts show when propagating a spontaneous occurring narrow self-guided struture called filaments.
These filament allows one to reach unprecedented light intensities[1] going up to 10^{14} W/cm^2. At these intensities air ionizes and highly non-linear processes take place. These self-guided structure have been shown to sustain up to kilometric distances[2]. Finally the conductive path left behind have been used to guide electric arcs in the meter scale[3].



Schematic representation of the focusing–defocusing cycles undergone by an intense beam in the filamentation regime[1].

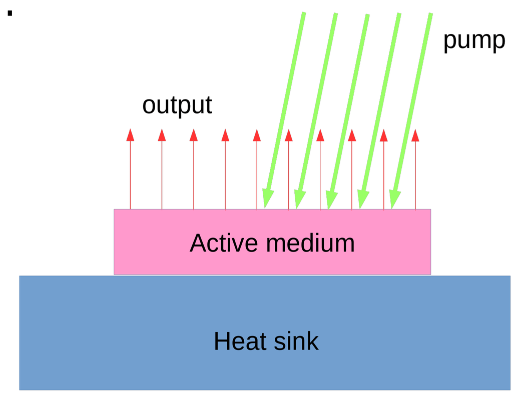


Shock wave and low density conductive path in air induced by a filament after 5 µs[4]. The z-axis is the propagation distance and r is the radial distance to the core.

Photography of the plasma luminescence induced by a filament.

Thin-disk laser technology

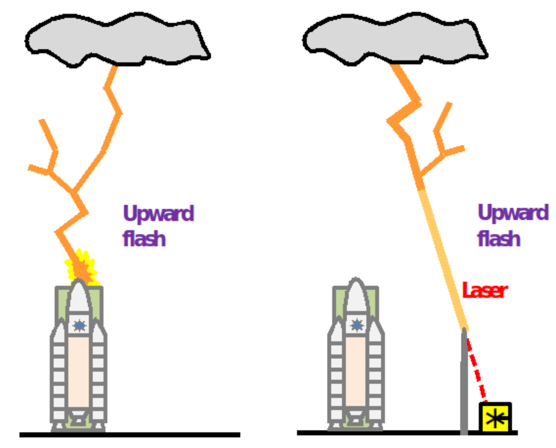
Latest research on ultrafast lasers based on Yb:YAG and thin-disk technology has resulted in the recent demonstration of powerful regenerative amplifiers with pulse durations below 2 ps, pulse energies of more than 200 mJ and average powers of more than 300 W at kHz repetition rates[5].
Due to the efficient one-dimensional heat removal of the thin disk geometry of the gain medium, high pump densities of nearly >12 kW/cm^2 can be achieved by simultaneously avoiding thermal lensing and depolarization losses hence keeping good beam quality. Though a low amplification per round trip is obtained, this technology has already been shown to be suitable for high average power high energy pulsed lasers[5,6].



Thin disk technology principle. Excess heat is well evacuated by the reduced thickness (100 µm to 1 mm) of the active medium.

Lightning protection

Passive control by lightning rods is widely used for the external protection of fixed intallations. However, there are many situation where the protected object cannot support a bulky metallic rod and an easily deployable active protection then becomes necessary[7,8].
Furthermore conventional lightning rods do not protect sensitive sites from the various indirect effect of the strong EM fields that are induced by lightning strikes, such as induced overvoltages.
Diverting lightning strikes to another location is hence a preferable solution for the protection of sensitive sites such as airports, refineries or even aircrafts[9].

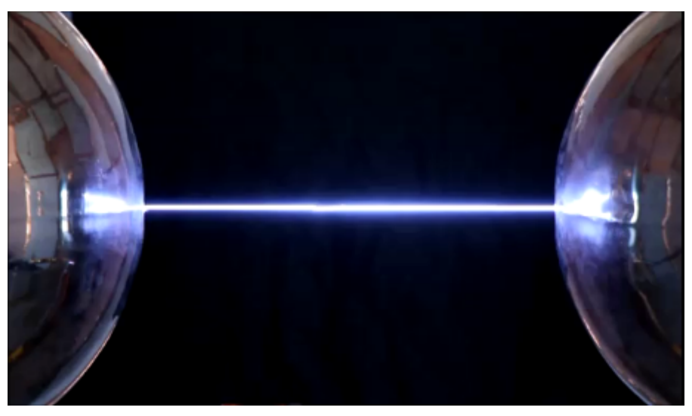


Laser lightning rod principle. The upward flash is diverted to another safer location.

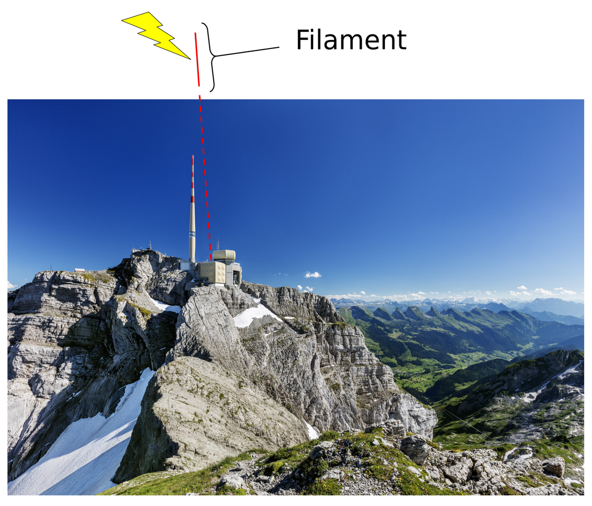
GOALS OF THE PROJECT

Guiding and triggering natural lightning strikes

A long lasting, low-density air channel generated by laser filaments at high repetition rate will stimulate natural upward lightning discharge initiation from an existing grounded tall object[7]. Electric discharges triggering at smaller scales has already been shown using multi-terawatt ultra-short pulsed lasers[3,8]. A demonstration of laser-induced upward lightning though would constitute a major breakthrough in lightning research with potentially profound impact on future lightning protection systems.
This demonstration will be done by using a high power, high energy laser at the Säntis lightning research site in Switzerland. The tower at the Säntis site is struck over 100 times a year[10] and hence represents an ideal location to demonstrate convincingly a laser-assisted upward lightning.



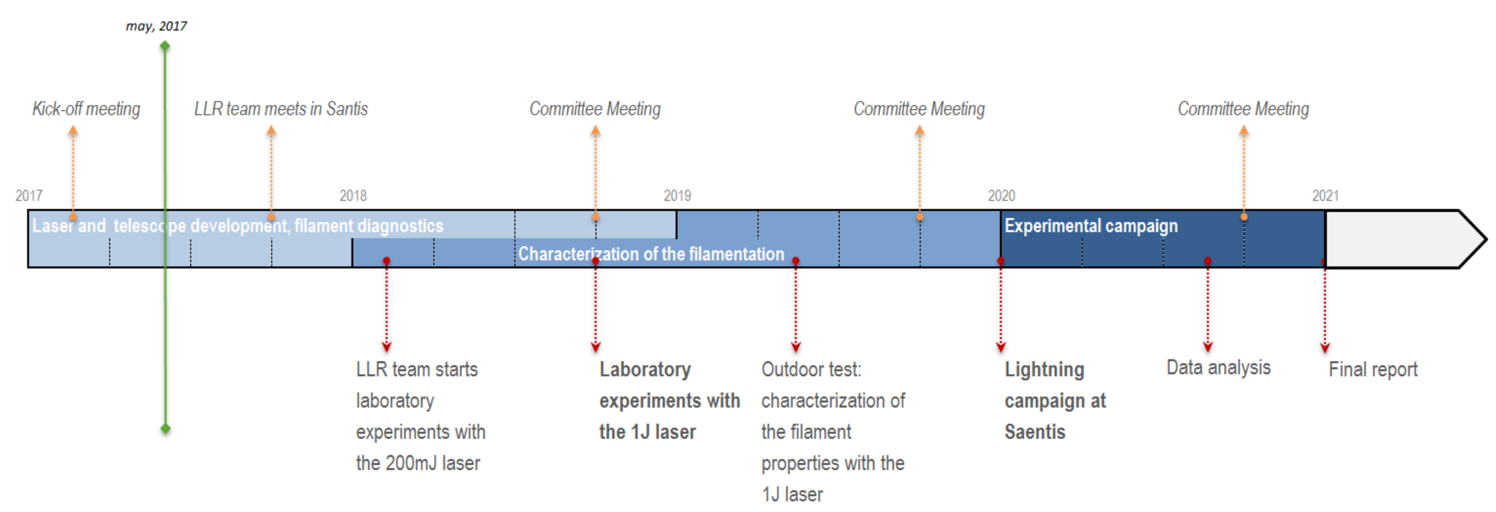
Laser filament-assisted guided discharge between two sperical electrodes.



Säntis tower site in Northeastern Switzerland with sketch of planned lightning triggering laser shootings.

High energy, high power filamentation and laser technology

Taking advantage on latest research in laser thin disk technology, the development of a pulsed laser source with pulse durations of 1 ps, pulse energies of 1 J at kHz repetition rates will be the first milestone of this project.
In the continuity of previous outside experiments showing laser filamentation at long distances, the filamentation regime at these conditions of high average power of 1 kW and high pulse energy will be investigated in detail. Finally the new laser wil be installed at the Säntis site in order to demonstrate the feasability of a laser lightning rod.



CONCLUSION

Cutting-edge laser technology associated with the latest research in laser filamentation and lightning protection are united in an European funded (FET-OPEN) consortium, to tame the natural lightning phenomenon. The construction and operation of a high repetition rate multi-terawatt at the Säntis lightning research site in Northeastern Switzerland to produce long-lived extended filaments at an exceptionally lightning active location is planned. Ultimately this technology could represent an alternative to conventional passive lightning rods to protect sensitive sites by diverting lightning strikes to safer locations.

Acknowledgments

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