Projet FET Open LLR
« Laser Lightning Rod »

Aurélien HOUARD

Coordinateur du projet LLR

Laboratoire d'Optique Appliquée

ENSTA ParisTech, Ecole Polytechnique, CNRS

Email: houard@ensta.fr

HORIZON 2020

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

Présentation du projet

Laser Lightning Rod (LLR)

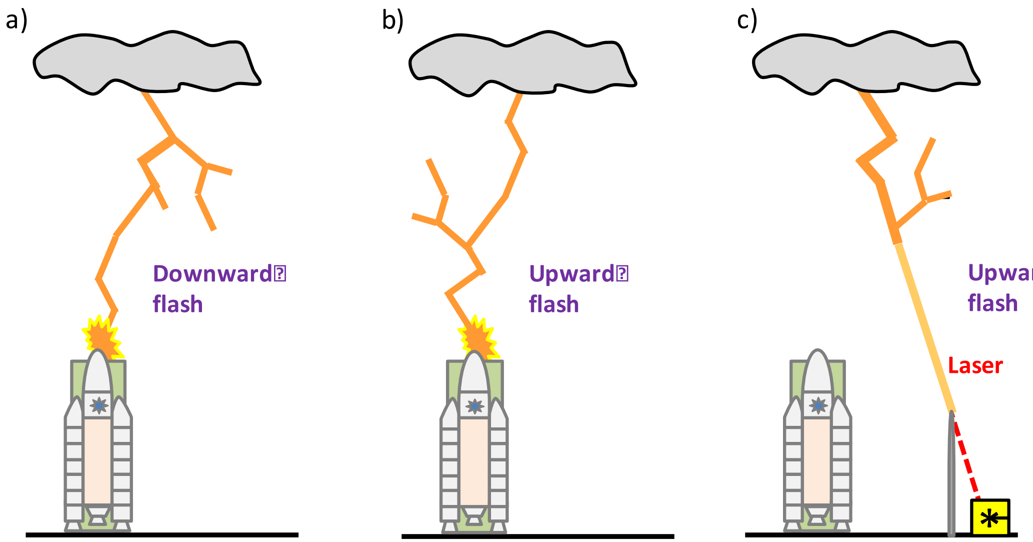
Goal: Investigate and develop a new type of lightning rod based on filaments produced by a high repetition rate terawatt laser

- **Partners:**
  - Trumpf Scientific Lasers (Germany), University of Geneva, EPFL, HESSO (Switzerland), CNRS, Airbus Group, AMC (France)
- **Total budget:** 3.9 M€
- **Coordinator:** A. Houard (LOA-CNRS)
- **Duration:** 4 years, starting on January 2017
- Website: llr-fet.eu

Objectif du projet

- A portable device for active control of lightning

  The **laser-based system could be easily deployable for the protection of vulnerable installations** such as electrical plants, launching pad, airports...

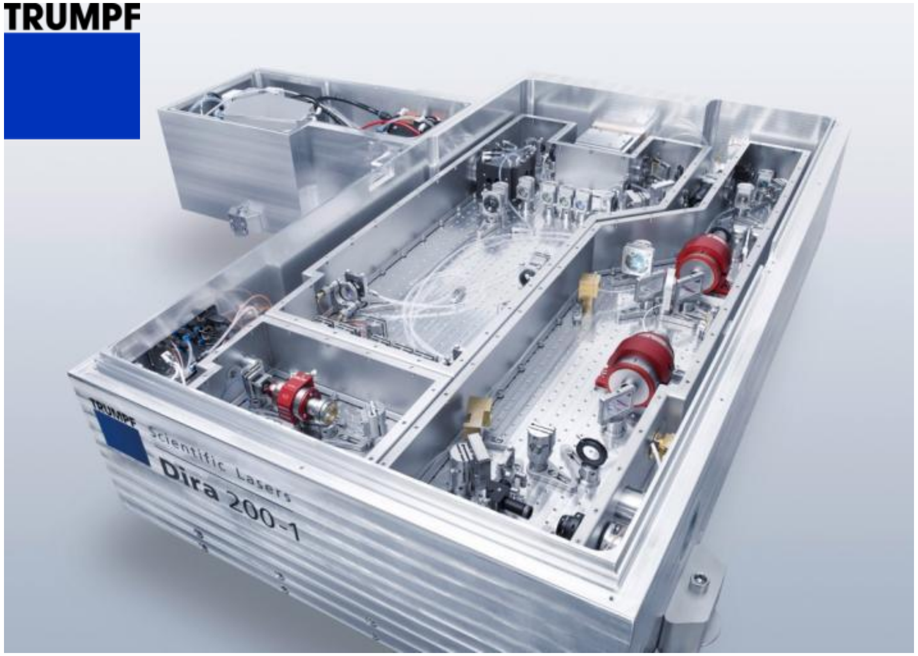


a) Downward lightning to victim; b) upward lightning; c) upward lightning facilitated by laser filamentation discharges the cloud and protects the potential victim.

Technical program

To upscale the previous laboratory experiments to real lightning conditions a **unique compact laser source** with an unprecedented combination of energy and repetition rate will be developed

- Compact **high rep rate TW laser** fully pumped by diodes (Trumpf Scientific)
  - Energy of > **1 J/pulse**
  - Repetition rate **1 kHz**
  - Pulse duration 600 fs



Technical program

The aim of this project is to use this guiding effect in real lightning conditions: The laser will stimulate the number of upward lightning flashes, transferring cloud charges to the ground and thus influencing the incidence of downward natural lightning.

Location : **meteorological station of Saentis** (Switzerland)

- Altitude 2 500 m
- Fully instrumented for the detection of lightning (by EPFL and HES)
- 100 lightning strikes every year
- Many events of upward lighting leader

- Comment avez-vous abordé les « Gatekeepers » dans votre proposition ?
  - Long-term vision
  - Breakthrough scientific and technological target
  - Novelty
  - Foundational
  - High-risk
  - Interdisciplinary

PRÉPARATION DU PROJET

- 5 Nov 2015 : première réunion avec 5 partenaires
- Jan 2016 : choix du coordinateur et début de la rédaction du projet
- Fev 2016 : demande d’un **soutien IPE CNRS**
- Avril 2016 : 2 partenaires additionnels (spécialistes foudre)
- 11 mai 2016 : soumission du projet

- 4 octobre 2016 : notification d’acceptation
- 22 décembre 2016 : signature du Grant Agreement
- 1er janvier 2017 : début du projet (date de début imposée par la commission)

Quelques recommandations

- Choisir rapidement le coordinateur
- S'inspirer de proposals acceptées
- Demander l'aide d'un ingénieur projet européen
    - Rédaction du projet (hors contenu scientifique)
    - Budget (éligibilité des dépenses, amortissement..)
    - Soumission du projet en ligne
    - Questions juridiques (accord de consortium)
- Faire du lobbying à Bruxelles
- Préparer l'accord de consortium en amont et mentionner les grandes lignes dans le proposal

QUELQUES REMARQUES SUR LE PROPOSAL

- 1. Excellence scientifique (7-8 pages)
  - Pas trop de détails scientifiques
  - Un objectif et des applications à long terme clairement identifiés
  - Mettre l'accent sur tous les aspects innovants du projet
  - Complémentarité des partenaires, interdisciplinarité
  - Implication d'un industriel pour concrétiser la vision à long terme (end user)
- 2. Impact (2-3 pages)
  - Importance de la formation de doctorants et postdoctorants
  - Importance des PME (ou assimilées), des femmes, jeunes PI ou responsables de WP
  - Dissémination, open access et Data Management Plan
- 3.Implémentation (7 pages)
  - Pas plus de 5-6 work packages

Sur l'évaluation

- 4 reviewers
- Une note /5 pour chaque critère en commentant chaque sous-partie
- Expliciter clairement l'adéquation à tous les gatekeepers pour faciliter le travail des reviewers
- Un reviewer négatif n'est pas forcément pris en compte dans la note finale

SUR L'ÉVALUATION

Associated with document Ref. Ares(2016)5558033 - 26/09/2016

Proposal Evaluation Form

EUROPEAN COMMISSION

Horizon 2020 - Research and Innovation Framework Programme

Evaluation Summary Report - Research and Innovation actions

Call: H2020-FETOPEN-1-2016-2017
Funding scheme: RIA
Proposal number: 737033
Proposal acronym: LLR
Duration (months): 48
Proposal title: Laser Lightning Rod
Activity: FETOPEN-RIA-2016

N.	Proposer name	Country	Total Cost	%	Grant Requested	%
1	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	FR	470,000	11.88%	470,000	11.88%
2	UNIVERSITE DE GENEVE	CH	835,000	21.10%	835,000	21.10%
3	TRUMPF Scientific Lasers GmbH + Co. KG	DE	1,790,000	45.24%	1,790,000	45.24%
4	AIRBUS GROUP SAS	FR	168,000	4.25%	168,000	4.25%
5	AMCS	FR	167,500	4.23%	167,500	4.23%
6	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	CH	235,000	5.94%	235,000	5.94%
7	HAUTE ECOLE SPECIALISEE DE SUISSE OCCIDENTALE	CH	291,000	7.35%	291,000	7.35%
	Total:		3,956,500		3,956,500	

Abstract:
Controlling lightning is a long time dream of mankind. The goal of the present project is to investigate and develop a new type of lightning protection based on the use of upward lightning discharges initiated through a high repetition rate multi terawatt laser. The feasibility of the novel technique and the project's prospect of success are based on recent research providing new insights into the mechanism responsible for the guiding of electrical discharges by laser filaments, on cutting-edge high power laser technology and on the availability of the uniquely suitable Säntis lightning measurement station in Northeastern Switzerland. The LLR consortium is ideally positioned to succeed and to raise the competitiveness of Europe in lightning control as it relies on the integration of trans-disciplinary fields in laser development, nonlinear optics, plasma physics, remote sensing, and lightning: The project team is made up of leaders in the domains of high power nonlinear propagation of laser pulses in the atmosphere, laser control of electric discharges, lightning physics, high power laser development, and high-repetition-rate lasers. In addition, the largest European company in aeronautics brings its expertise in lightning direct effects and protection means on aircraft and infrastructures.

Evaluation Summary Report

Evaluation Result

Total score: 4.90 (Threshold: 0)

Form Information

SCORING

Scores must be in the range 0-5.

Interpretation of the score:

*0 **The proposal fails to address the criterion** or cannot be assessed due to missing or incomplete information.*

***1 Poor.** The criterion is inadequately addressed, or there are serious inherent weaknesses.*

***2 Fair.** The proposal broadly addresses the criterion, but there are significant weaknesses.*

***3 Good.** The proposal addresses the criterion well, but a number of shortcomings are present.*

***4 Very good.** The proposal addresses the criterion very well, but a small number of shortcomings are present.*

***5 Excellent.** The proposal successfully addresses all relevant aspects of the criterion.Any shortcomings are minor.*

*** The asterisk means mandatory field**

Criterion 1 - Excellence

Score: 5.00 (Threshold: 4/5.00 , Weight: 60.00%)

Note: The following aspects will be taken into account, to the extent that the proposed work corresponds to the topic description in the work programme. If a proposal is partly out of scope, this must be reflected in the scoring, and explained in the comments. Compliance with the FET-gatekeepers as described in the call:

Clarity and novelty of long-term vision, and ambition and concreteness of the targeted breakthrough towards that vision.

1---------
The long term vision, namely a laser based 'lightning rod' designed to proactively trigger and guide lightning strikes in order to protect major infrastructures and individuals exposed to this threat is very novel and very clearly articulated in this excellent proposal. The ambition is large but based on a body of work done to date by the proposers, sometimes in prior collaborations. The technological breakthrough needed to

Associated with document Ref. Ares(2016)5558033 - 26/09/2016

realise the vision, namely a kW, kHz rep-rate, Joule level picosecond laser to be developed by Trumpf looks very concrete with a clear explanation on how its thin disk technology can be improved and scaled to increase from the current 0.2J per pulse to the 1 J level. Work indicating that another breakthrough, i.e., extension of the low density channel to a km scale by increasing the rep-rate to 1 kHz is also convincing. Overall this sub-criterion is highly convincing on all fronts: vision, concreteness of key technological and scientific breakthroughs and ambition.

2---------
The project is presented very clearly, with supporting literature citations and straightforward explanations. The long-term aim is concrete and practical. On the other side, the impact that one can expect form this research on the future society is quite low, as it is limited to a very specific field. As a consequence, its visionary character is weak and its targeted innovation will hardly become a technological breakthrough.

3---------
The long term vision represents a very focused proposal to reach a clear objective. This long-term vision can represent a scientific breakthrough in that until today, the theory of lightning formation and propagation is not completely understood. The use of lasers can provide guided paths for the electrical discharges, allowing for an increase in the understanding of their mechanisms. It is a very interesting technical development in the field of electrical discharge protection. World lightning costs are at the scale of billions of euros annually. However, much of that amount corresponds to forest fires in places grading from difficult to impossible to reach in time. The proposed system is a mobile laser operating in the range of terawatts, frequencies of 1 kHz, and energies of around 1 J. The long-term vision of using a Tw/kHz mobile laser is clear and novel, ambitious and concrete and can provide a technical breakthrough.

4---------
The proposal is consistent, coherent and sound aiming the development of innovative lightning protection systems.
Future implications in other areas such as magnetic fusion and nuclear contaminated fields diagnostics are considered.
Although a challenging project with many vulnerabilities, various risk mitigation steps are very well argued. Indeed the project is based on successful laboratory experiments suggesting its feasibility.
Development stages needed to achieve the final goal are timely and wisely described.
At long term the novel device has he potential to be use in decreasing lightning strike at airports and later as a cheap, reliable and movable system for protection of vulnerable areas, such as events gathering, rockets launching, storage or transport of hazardous materials.

Novelty, non-incrementality and plausibility of the proposed research for achieving the targeted breakthrough and its foundational character

1---------
The project is designed to get to km scale lightning triggers in a controlled fashion with laser focus scanning and is a long-standing objective of lightning researchers. In that sense the project idea is not outstandingly novel but it requires a number of very non-incremental key innovations in laser technology (Fig. 5), filamentation physics (Fig 2) and long distance laser focusing and scanning optics (inspired by astronomical/atmospheric adaptive optics). These could lead to the first demonstration of a real world laser based lighting rod. On plausibility it is clear that, if all the elements are in place on the time-scale of the project, there is a very high probability that key breakthroughs will be made and the vision realised. There is likely to be significant foundational knowledge created in plasma physics, optics, atmospheric physics, etc. The laser technology could be widely applied in particle acceleration, laser plasma EUV/X-ray sources, materials deposition/processing, etc.

2---------
The proposal basically takes advantage of new laser technologies recently developed or that will be developed in the project. Its novelty consists in the mixing of these technologies for their application to lighting guiding and in the design of a complete system for the diagnostic, control and protection from lightnings.
A deep continuity may be noticed with respect to the previous research in the field of filamentation and electric discharges guiding; as a consequence, this research doesn't show a strong novelty, nor a foundational character suitable for future disruptive developments and researches in the same field.

3---------
The proposal of using a Tw/kHz mobile laser is a novelty in science and technology. The idea of micro-controlling the laser direction to provide for a ionized path in the air for the electricity motion is novel and plausible. The proposed research is not incremental as regards any other previous research in the field. The development of Tw high frequency lasers will, doubtless, stimulate the use of such sources of power for many other applications, and facilitate the understanding of lightning generation and propagation in the atmosphere.

4---------
The intended lightning device aiming safety issues, achievable by an innovative scientific approach, will also broaden the scientific understanding of this phenomenon. This synergy makes the proposal highly attractive.
Collaborative research conducted by four of the applicants demonstrated encouraging results on the progress on the the breakdown voltage for guided electric discharges (impact of high average power and high repetition rate of an ultra-short laser).
Major innovative efforts are foreseen (i) construction of a mobile up-scaled version of the Trumpf Scientific laser, which require innovation on laser technology development, (ii) conceptual implementation of laser beam focus sweeping and (iii) on-site diagnostics development based on time resolved interferometry.

Appropriateness of the research methodology and its suitability to address high scientific and technological risks.

1---------
This is clearly laid out and described in the proposal. It comprises four elements, namely laser development - optics development - tests on filamentation (horizontal) over long space scales (100s m) - final deployment on the Santis test tower to enable real controlled triggering and guiding of lightning events. Using adaptive optics for both laser spot focusing/scanning and wavefront correction for atmospheric induced aberrations improves the potential efficacy of the laser lightning rod and concomitantly reduces risk of failure to realise the long term vision. The industry partner (Airbus) will take care of safety and regulatory arrangements for the final phase of the work. On diagnostics, high speed/repetition rate imaging is planned and appropriate as is the interferometric diagnostic (an extension of an existing device) for plasma channel density measurements.