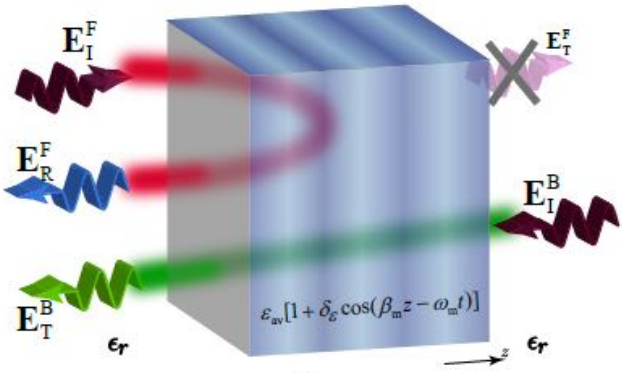
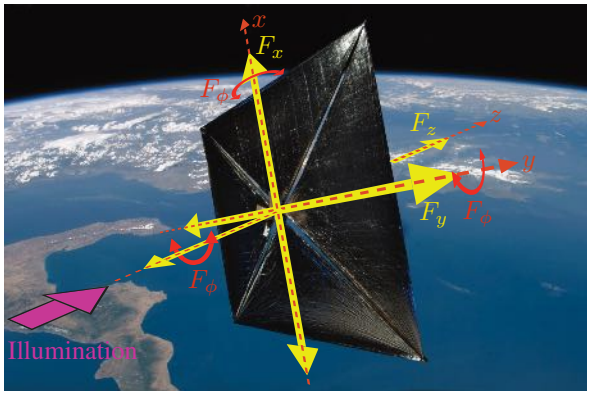
Ph D position

Space-time electromagnetic modulation by plasma.



from [1]



from [2] (crédit NASA).

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Context :
In recent years, Space-Time Modulations have revolutionized the control of electromagnetic waves. A multitude of potential applications can be found in reference [1]. This work, carried out in a few laboratories worldwide, is clearly disruptive: it leads to completely new component concepts or very original ideas [2].
Within the LAPLACE laboratory, the Electromagnetic Research Group has been developing for more than ten years a research axis on wave interactions with cold plasmas. Skills have also been capitalised in the fields of metamaterials and the Time Reversal of electromagnetic waves for the spatio-temporal control of plasmas.
The very innovative perspectives resulting from the Time-Modulation concepts in terms of pulsed energy storage and use with (or for) plasmas, motivate this Ph D proposal. The investigative skills and knowledge gathered within LAPLACE should enable the first experiment of plasma based microwave Time-Modulation.

Ph D work :
Based on the work of [3], simple concepts (circuit ones) will be used to understand how electromagnetic energy can behave unusually in a propagation medium or a dipole which electrical and magnetic properties change rapidly over time. We will study how energy accumulation can be used to create or maintain a plasma.
The example of a cavity will serve as a basis for understanding physical phenomena and electromagnetic energy flows.
The exploitation of a cold plasma in the cavity (or located at its access) will then be evaluated according to two purposes. Consideration will be given to the possibility of using it to obtain the required modulation scheme and to the possibility of optimizing the electromagnetic energy transferred to the plasma. The issue of pulsed nanosecond

discharges will be particularly targeted. This research presents an opportunity for a technological breakthrough in the way such discharges are created.

- 1st year:
  - goal: catch the basic physical concepts of Time Modulation for electromagnetism (if necessary, plasma training courses).
  - approach: circuit analysis, based on bibliography and simulations (if necessary, basic training with lab's plasmicians and in-house experiments).
- 2nd year:
  - goal: identify the pros and cons of using plasmas and cavities to perform Time Modulation experiments.
  - approach: understand the basic mechanisms in the specific context of a plasma partially filled cavity (which performs the modulation).
- 3rd year:
  - goal: design, build and characterize a Time Modulation experiment in a plasma cavity.
  - approach: based on the orientations previously identified: design, build and characterize (electromagnetically) the behaviour of such a cavity. In particular, assess the impact of the kind of modulation scheme on physical behaviour.

Desired candidate profile :
Grande Ecole of Engineering Master of Science with knowledge in electronics, *or* microwaves, *or* plasmas, *or* electrical *or* physical engineering.
Master's degree with honours in one of these specialties.
Group work and analytical development skills, curiosity, enthusiasm, appetite for multidisciplinary research activities.

[1] : S. Taravati & Al. : « Space-Time Modulation : Principles and Applications », to appear in the IEEE Microwave Magazine, https://arxiv.org/pdf/1903.01272.pdf.
[2] : K. Achouri & Al. : « Metasurface Solar Sail for flexible radiation pressure control », Physics.optics, https://arxiv.org/pdf/1710.02837.pdf
[3] : M. S. Mirmoosa & Al. : « Time-varying reactive element for extreme accumulation of electromagnetic energy », Phys. Rev. Applied, 2019.
[4] : D. Ramaccia & Al. : « Non-reciprocity in antenna radiation induced by space-time varying metamaterial cloaks », IEEE AWPL, 2018, DOI : 10.1109/LAWP.2018.2870688.
[5] : D. Sounas & Al. : « Non-reciprocal photonics based on time modulation », Nature Photonics, 2017.
[6] : A. Marini & Al. : « Metasurface-bounded open cavities supporting virtual absorption : free space energy accumulation in lossless systems », Metamaterials 2019, DOI : 10.1109/MetaMaterials2019.8900833.
[7] : D. K. Kalluri & Al. : « Frequency and polarization transformer (10 GHz to 1000 GHz) : interaction of a whistler wave with a collapsing plasma cavity », IEEE Trans. On Plasma Science, Vol. 40, 2012.