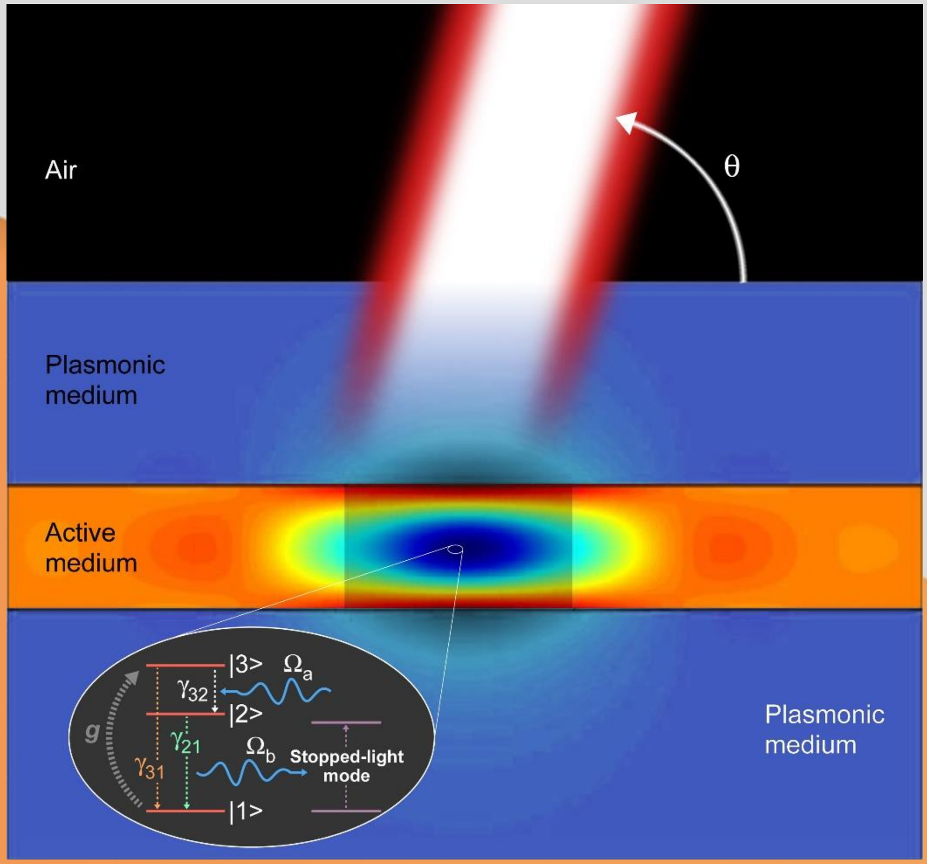
H.F.R.I.
Hellenic Foundation for
Research & Innovation

Research Project Title:

Quantum self-organized criticality and nonequilibrium light localization



Principal Investigator:

Kosmas L. Tsakmakidis

Popular Title:

The emergence of order and organization in Nature from quantum “nothingness”, and its study from nano-photonics

Scientific Field:

Nanophotonics, metamaterials, quantum criticality, self-organization

Host Institution:

National and Kapodistrian University of Athens, dep. of Physics

H.F.R.I.
Hellenic Foundation for Research & Innovation

The ability of many types of complex, nonequilibrium systems to spontaneously, without any external agent, arrange their components in non-random manners and develop structures and patterns is a ubiquitous phenomenon in natural and life sciences, from biological systems and neural networks to soft-matter physics and nanoscience. The self-organization of such systems often reaches a 'critical' point, with scale-invariant characteristics, from where onwards a phase-transition occurs without any fine-tuning of external parameters, giving rise to 'self-organized criticality' (SOC) – a theory which, since its inception 30 years ago, has had a major impact across a broad range of seemingly dissimilar fields of science, from neuro- and geo-science to physics and biology. However, until now, it has primarily been identified in classical systems, and it remains a fundamental open question whether the theory also finds a place in complex systems driven by quantum fluctuations.

A seemingly unrelated open question in the field of optics and photonics is whether robust non-trivial light localization might be possible. Localizing light in the absence of trivial cavity effects is of fundamental importance in photonics, both from a theoretical and applied perspective. During the course of this proposal, we shall introduce and study fully a class of nanostructures where, similarly to the Anderson scheme but far from thermodynamic and optical equilibria, a phase-transition to localized light behavior can be obtained in a minimalistic way (absence of cavities), yet – unlike the Anderson scheme – the localization will be resilient to dissipative losses, nonlinear interactions and time-varying potentials. Dissipative systems with such dynamic and adaptive characteristics are well-known to fall within the realm of nonequilibrium physics. The type of robust, nonequilibrium light localization that we shall here introduce will be driven by quantum fluctuations, and will lend itself to the study – for the first time – of quantum self-organized critical phenomena.

The astonishingly high speed of light is a real asset for modern optical-fiber networks, enabling real-time communications from one side of the Earth to the other. However, nowadays there are many important applications for which we would also like to 'trap' and 'localize' light to increase its interaction with matter. The objective of this project is to introduce and analyze a fundamentally new way of spatially localizing light, not aided by standard cavity effects, but instead exhibiting a, so called, 'nonequilibrium phase transition' to localization.

Potential applications include ultrafast lasers requiring strong nonlinear light-matter interactions, or photovoltaics and light harvesting devices where light should not pass through the material quickly so that it can be efficiently absorbed and converted into electricity. Another application is for optical bio-sensing and diagnostic devises, in which light is used to identify and trace various chemical elements and should thus interact strongly with these elements.

To me, H.F.R.I. funding would mean...

“

The three-year funding I received, will allow me to set up my own independent research group in the Department of Physics of the National and Kapodistrian University of Athens, by recruiting talented young scholars to work with me, both, as doctorate and postdoctoral researchers. In light of the rather strained financial situation in the country at the moment, and the limited resources – on a national level – available for research funding, this opportunity is quite unique and highly praiseworthy, as it allows young researchers who would have otherwise remained abroad to return back in Greece and pursue high-quality research, competitive internationally. In my personal case, we aim at nothing short of designing the first practical ‘invisibility cloak’, capable of concealing a macroscopic object across the entire visible band, as well as elucidating the ‘secrets’ of how order and structure emerge in complex -seemingly chaotic- systems in condensed matter physics and life/geo-sciences.

The Principal Investigator,
Kosmas L. Tsakmakidis

Funding

Amount: **200,000 €**

Duration: **36 months**

Foundation: **H.F.R.I.**

H.F.R.I.
Hellenic Foundation for Research & Innovation

CONTACT

185, Syggrou Ave. & Sardeon St. 2
17 121 Nea Smyrni, Greece
info@elidek.gr
www.elidek.gr

HELLENIC REPUBLIC
MINISTRY OF DEVELOPMENT AND INVESTMENTS

GSRT
GENERAL SECRETARIAT FOR RESEARCH AND TECHNOLOGY