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

# Description of the funded research project

## 2nd Call for H.F.R.I. Research Projects to Support Post-Doctoral Researchers

Title of the research project: **Novel Multiresonant Photonic Metasurfaces for Broadband Control of Light (acronym: PHOTOSURF)**

Principal Investigator: **Odysseas Tsilipakos**

Reader-friendly title: **Proposing ultrathin and broadband optical components by exploiting multiple resonances**

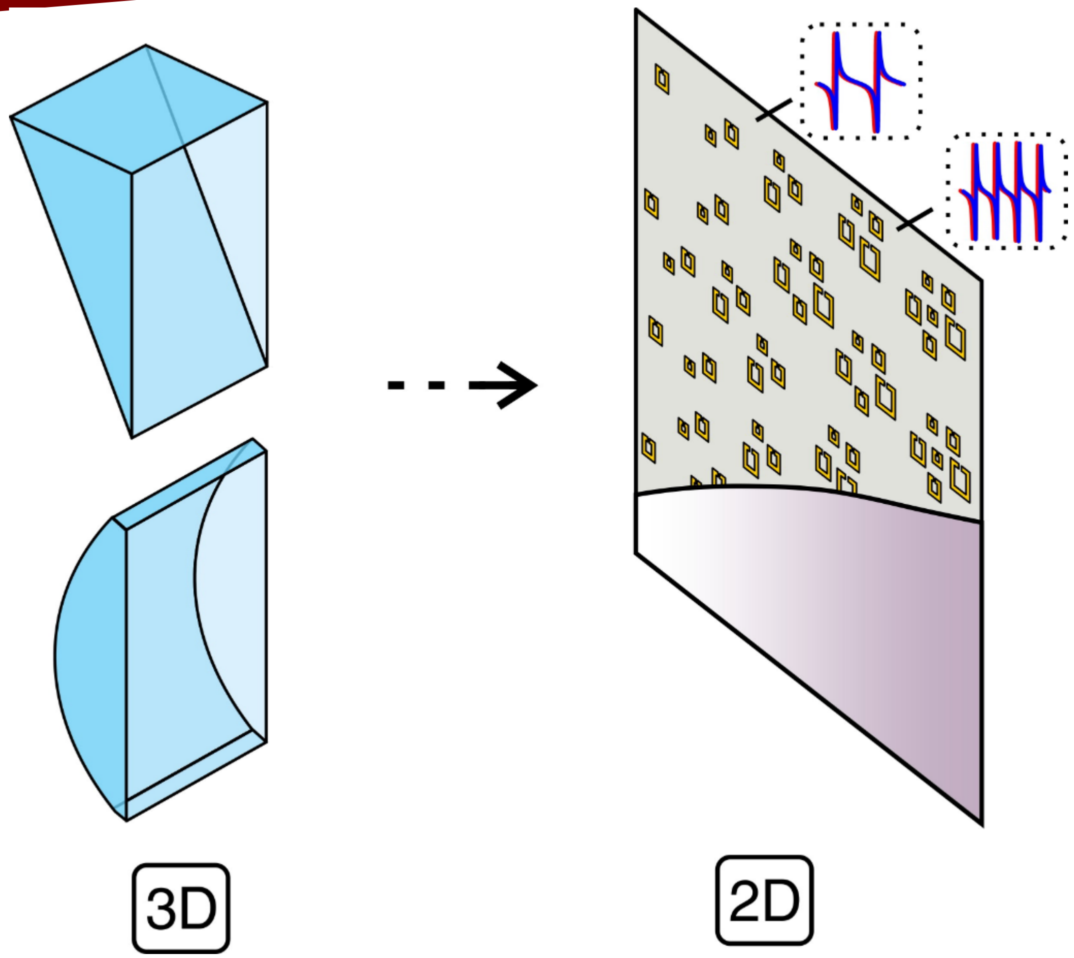
Scientific Area: **Physical Sciences (Optics)**

Institution and Country: **IESL-FORTH, Greece**

Host Institution: **Foundation for Research and Technology – Hellas (FORTH)**

Collaborating Institution(s): **Ames Laboratory (US)**

Project webpage: [https://photosurf.iesl.forth.gr](https://photosurf.iesl.forth.gr)




Budget: **159,586.00 €**

Duration: **36 months**

**The interaction of electromagnetic waves with matter is at the forefront of contemporary scientific research, since it underlies a vast range of physical phenomena and applications with significant technological and societal implications. Metasurfaces are ultra-thin man-made materials made of periodically arranged subwavelength building blocks. They hold the promise of revolutionizing the interaction of electromagnetic radiation with matter, by offering novel properties unattainable with natural materials (anomalous refraction, near-zero permittivity, artificial magnetism), enabled by the resonant nature of their building blocks. At the same time, they are extremely thin with respect to the wavelength and amenable to standard planar manufacturing techniques.**

**However, there are specific physical limitations that restrict the potential of metasurfaces: (i) their response is typically narrowband and (ii) the phase delay that can be imparted on the incident wave is limited (less than 2π). PHOTOSURF aims to break free from these longstanding limitations by proposing broadband multiresonant metasurfaces that combine the advantages of strong resonant response (phase delay, energy storage, field enhancement) with an arbitrarily-broad spectral bandwidth controlled by the number of resonances. This is achieved by implementing a very specific combination of multiple electric and magnetic resonances which arise from meta-atoms properly arranged in the unit cell.**

**Having the broadband response as a common baseline, PHOTOSURF will address in a unified approach different physical problems, targeting the control of different aspects of the electromagnetic wave (temporal and spatial wavepacket profile, polarization, frequency). The broader scope of PHOTOSURF is to replace conventional dispersive, diffractive, polarization-converting, and nonlinear bulk components with ultra-thin counterparts, offering significant technological advantages (size, weight, fabrication, integration). The envisioned breakthroughs will open metasurfaces to real-world photonic applications, where signals are rarely narrowband (monochromatic).**

The objective of PHOTOSURF is to propose novel functional metasurfaces with broadband operation, while at the same time exploiting the numerous advantages of strongly resonant response. As metasurfaces are typically narrowband, this breakthrough will be enabled by the original concept of implementing multiple resonances within a metasurface unit cell. Opening metasurfaces to broadband applications while retaining a resonantly-enhanced response constitutes the main novelty of PHOTOSURF. This extension is of utmost importance since in real-word photonic applications signals are rarely narrowband (monochromatic).

Within PHOTOSURF the concept of broadband response through specifically-designed multiple resonances will be transferred and applied to different physical phenomena (e.g., dispersion, wavefront, and polarization control), leading to a novel, unified design approach for ultrathin and broadband optical components. In each case, we will follow a three-step strategy for the analysis, design and verification, starting from (i) rigorously deriving the required resonant electric and magnetic surface conductivities, (ii) then proceeding to design physical implementations that can satisfy the derived specifications by investigating different material/geometry configurations, and (iii) finally demonstrating the performance of proof-of-concept designs through fabrication and characterization. The simulation tools that will be exploited and developed within the project include a broad range of (i) analytical frameworks for the interaction of electromagnetic waves with ultrathin electric- and magnetic-polarizable sheets, (ii) rigorous full-wave Maxwell simulators, and (iii) simplified models for obtaining deeper physical insight.

# Expected results & Research Project Impact

**PHOTOSURF targets the exploration and deep theoretical understanding of the complex interaction between multiresonant metasurfaces and light, culminating in proposing and demonstrating ultrathin and broadband photonic components for different applications in the optical, near-infrared, THz, and microwave regimes. The expected results include metasurfaces for delaying and compressing broadband pulses, for performing achromatic wavefront shaping operations, and for switching from reflection to transmission operation at will.**

**The proposed research and the anticipated outcomes will have a strong impact on science, in both the fundamental and applied aspects. Extending ultra-thin metasurfaces to broadband control of light while manipulating at the same time different characteristics of electromagnetic radiation (amplitude, temporal and spatial wavepacket profile, polarization, and frequency) is of significant scientific and practical importance. Dispersive, diffractive, polarization-conversion, and nonlinear photonic components are ubiquitous in contemporary photonics and daily telecommunications; replacing such components with ultra-thin analogues, which are easier and cheaper to manufacture, will offer significant technological (size, weight, integration), economic and social benefits.**

# The importance of this funding

**The 3-year funding from H.F.R.I. will allow me to extend my research activities from a position of greater independence and responsibility. It will allow me to continue working in the Institute of Electronic Structure and Laser of the Foundation for Research and Technology – Hellas, where I am able to interact with excellent colleagues. Given the very limited new faculty positions and resources for research, it constitutes a strong motivation to continue performing research in Greece.**

**The direct funding of post-doctoral researchers is very important since it provides an opportunity to take a both useful and necessary next step in terms of building a small research team and also facing dissemination and managerial duties. The support of fundamental research setting high scientific quality as the top selection criterion is central to the advance of science and society. In these respects, H.F.R.I. offers a unique opportunity at national level.**

**COMMUNICATION**

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