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

Description of the funded research project

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment

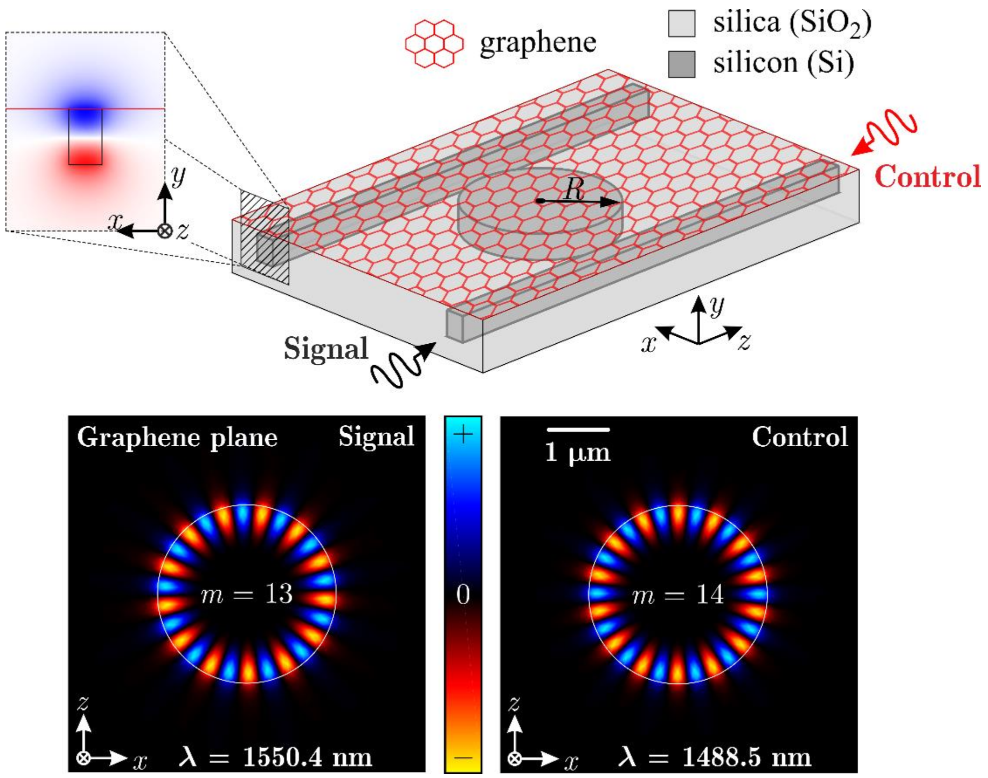
Title of the research project: Graphene-enhanced on-chip nanophotonics for switching and lasing applications

Principal Investigator: Prof. Emmanouil Kriezis

Reader-friendly title: GRAINS

Scientific Area: Engineering Sciences & Technology

Institution and Country: AUTH, Greece



Host Institution: Aristotle University of Thessaloniki

Collaborating Institution(s): Institute for Microelectronics and Microsystems (IMM), CNR, Rome

Project webpage: http://photonics.ee.auth.gr/GRAINS/

Budget: 187,927.43 €

Duration: 36 months

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DESCRIPTION

Nanophotonics is a constant driving force for the photonics integrated circuit (PIC) industry, with Silicon Photonics at its forefront, exhibiting technological maturity and providing an ideal platform for passive components in the near infrared. The implementation of diverse active functionalities in Si-photonics with existing approaches, intended for applications in optical switching or lasing, still presents challenges, associated with the ever-growing requirements in bandwidth and response speed together with the requirements for lower energy consumption and lower losses. This highlights the need for novel ways of controlling the optical response, based on dynamically (re)configurable revolutionary materials that are compatible with the PIC platforms and can fully meet the requirements listed above. Towards this direction, two-dimensional (2D) materials emerge as the missing element, thanks to their disruptive physical properties and inherent compatibility with integrated/planar photonic structures. Graphene, the most prominent 2D material, provides a multitude of high-potential paths to control light in waveguide- and resonator-based nanophotonic devices, mainly through electro-optical or nonlinear effects. Thus, a new research area is being shaped, collectively referred to as *graphene nanophotonics*. GRAINS aims at exploring the interplay between linear and nonlinear effects in graphene-enhanced Silicon Photonics, with special emphasis on the nonlinear effect of saturable absorption. GRAINS is focused on the demonstration of breakthrough proof-of-concept components for on-chip optical switching and lasing applications. The full deployment of 2D materials in PICs as key functional elements for optically self-controlled or optically addressed devices with complementary electrical tunability is set as the long-term vision of the project.

ORIGINALITY

GRAINS originality and novelty lies on the combination of the underlying material used, the nonlinear effects exploited, and the theoretical & computational techniques developed within the project. Saturable absorption in graphene can provide a highly promising physical mechanism for implementing a range of switching and other all-optical functions in graphene-enhanced silicon photonics, thanks to its very low saturation intensity that allows manifestation at reduced power levels compared to other nonlinear effects (such as the Kerr effect or other third-order nonlinear effects). GRAINS will exploit device concepts that have been demonstrated in all-fiber configurations, re-shaping and adapting them for integrated photonics. Using a large array of advanced computational techniques and theoretical models, supported by new findings from the continuously expanding graphene and silicon photonics literature, GRAINS aims to develop a unified framework for linear and nonlinear effects in graphene-comprising silicon waveguides and resonators. We are targeting a thorough bottom-up approach, incorporating as many physical effects as possible in our methodology, while, at the same time, avoiding simplistic/heuristic correction factors. The developed set of methodologies will be capable of rigorously investigating structures not only restricted to graphene, but also involving other 2D materials, which will be assessed as future candidates to further improve the performance of the envisioned nanophotonic components.

EXPECTED RESULTS

GRAINS aims to investigate both linear and nonlinear effects in graphene and exploit them in nano-scale photonic components for on-chip switching and lasing applications. In the core of the project lies the study of functional, tightly confining, silicon waveguides enhanced by graphene and compatible with state-of-the-art photonics and 2D-material deposition technologies; the second pillar is the study of compact traveling/standing-wave resonators with tailored intrinsic quality factors and characteristic power levels in the order of milliwatts, enabled by graphene's saturable absorption. The long-term vision includes the deployment of 2D materials in photonic integrated circuits as key functional elements, either self-controlled or optically addressed, but also electrically tunable for optimum performance and control. The project sets ambitious and highly challenging goals, with the proof-of-concept demonstration of on-chip optically self-controlled or optically addressed switching elements and pulsed laser sources being at its apex. Finally, GRAINS targets the exploration and deep theoretical understanding of the interplay between graphene's saturable absorption and other nonlinear effects, originating both from graphene and silicon, such as the Kerr effect, Two Photon Absorption, and Free Carrier Effects.

FUNDING IMPORTANCE

It is very important that H.F.R.I. through its Calls supports fundamental research, setting as top selection criteria high scientific quality and academic excellence. In this respect, H.F.R.I. offers the unique opportunity at national level for funding of pure research, without any thematic or regional restrictions whatsoever. Funding meeting the above conditions is of outmost importance for restraining the brain-drain and managing to keep some of our talented graduates here in Greece, to conduct research at our universities.

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