HORIZON 2020

Hybrid Optomechanical Technologies

Informe

Información del proyecto

HOT

Identificador del acuerdo de subvención: 732894

Sitio web del proyecto

DOI
10.3030/732894

Proyecto cerrado

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25 Octubre 2016

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EXCELLENT SCIENCE - Future and Emerging Technologies (FET)

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€ 10 000 000,00

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Periodic Reporting for period 3 - HOT (Hybrid Optomechanical Technologies)

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Resumen del contexto y de los objetivos generales del proyecto

A number of radically different technologies are currently on the horizon. Some, like quantum simulators, which are special-purpose computational devices that use one kind of quantum system to mimic the behaviour of a more complicated one, are likely to have a crucial impact in niche markets. Others, like improved inertial displacement sensors, which can be used to sense the movement of a device, could have significant mass-market appeal by augmenting the capabilities of the mobile devices we all take for granted. Bringing this promise to fruition requires developing new ways to translate between electromagnetic signals at widely different frequencies, e.g. between microwaves and optical signals. It requires the development of new on-chip components for signal processing that are compatible with the operating requirements of so-called superconducting quantum devices, which are crucial building blocks for producing quantum computers and other quantum technologies, and which operate close to absolute zero. It also requires the development of new techniques to sense displacements and tiny forces at the limit imposed by quantum mechanics.

To address these problems, HOT - Hybrid Optomechanical Technologies - laid the foundation for a new generation of devices that harness the interaction between electromagnetic radiation and the motion of microscopic devices. In doing so HOT created a convergence between two of the most important technologies in recent decades: micro-electro-mechanical systems (MEMS), which are ubiquitous and used in sensing and time-keeping devices, and photonic integrated circuits (PICs), which make possible direct interfaces between electrical computer chips and light-based communication systems. The operating principles of HOT devices are novel and will enable an entirely new family of uses for micro- and nano-mechanical systems that goes far beyond the state of the art.

HOT explored these hybrid opto- and electro-mechanical devices for the conversion, synthesis, processing, sensing, and measurement of electromagnetic fields. It used hybrid nano-scale opto-/electro-mechanical devices, which are able to convert energy from one form to another, to give rise to new ways for two-way conversion between electrical and optical signals with increased efficiency. It exploited the cooperative effects and new behaviours that arise when multiple electromagnetic fields and mechanical elements all interact together. Entangled quantum states, where the motion of two mechanical oscillators is linked so strongly that the two oscillators cannot be described as two independent objects, have been demonstrated by HOT and will make possible improved sensors. HOT explored new materials and architectures to establish optomechanical interactions at ultra-high frequencies and bandwidths in integrated on-chip platforms. Most importantly, HOT included a strong industrial component that explored how the devices developed can be manufactured using standard processing techniques and packaging solutions.

Trabajo realizado desde el comienzo del proyecto hasta el final del período abarcado por el informe y los principales resultados hasta la fecha

HOT has achieved a large number of breakthroughs during its lifetime. As highlights, we mention that HOT:
- Demonstrated the principles behind an optical isolator, which allows light to flow in one direction but not in reverse, and which can be reconfigured at will.
- Produced two on-chip proofs-of-concept of microwave radiation circulators.

- Demonstrated quantum entanglement between two mechanical elements.
- Developed theoretical tools to allow simplified read-out of important characteristics without requiring full knowledge of the system.
- Proposed ways to generate artificial magnetic fields that act on sound, and to use these and similar advances to create devices that can manipulate sound and light but are resilient to imperfections.
- Taken the first steps towards adapting the production of opto-/electro-mechanical devices using conventional chip fabrication and packaging facilities.
- Implemented a mechanical transducer between radio and optical frequencies on a silicon-on-insulator substrate.
- Progressed towards an integrated electro-opto-mechanical transducer for making optical measurements of radio-frequency voltages and magnetic fields with high sensitivity.
- Demonstrated an optical circulator based on a glass microtoroid on a silicon chip.
- Realised for the first time a proposal for increasing the single-photon optomechanical coupling strength by using multiple mechanical elements.
- Contributed to the theoretical understanding of the dynamics of non-linear optomechanical systems.
- Developed an optomechanical crystal based on InGaP, which is a piezoelectric semiconductor alloy that is lattice-matched to GaAs.
- Worked on the integration of electromechanical acoustic transducers.
- Described new mechanisms related to synchronisation of mechanical oscillators, including chimera states and the use of Floquet dynamics to control mechanical bistability.
- Demonstrated enhanced coupling in optomechanical systems by using multiple mechanical resonators.
- Delivered 3 prototype packaged devices.
- Participated in events coordinated by the highly visible Society of Photo-optical Instrumentation Engineers (SPIE), thus extending the reach of HOT to engineers, also contributing articles to two proceedings issues.
- Generated increased visibility for the project's results by giving talks at several international conferences.
- Increased the exposure of several publics to the concept of radiation pressure and the technological possibilities it enables.
- Put together four videos that describe the Action and its work to different target audiences
- Developed a mobile phone application that teaches schoolchildren the science of light and radiation pressure; this has been downloaded in over a dozen countries worldwide.
- Published a viewpoint article on nano-opto-electro-mechanical systems in the highly visible Nature Nanotechnology.
- Contributed to a review article in the Rivista del Nuovo Cimento.
- Written a technical but high-level overview of optomechanical technologies for IEEE Spectrum.
- Published well over 80 articles in major high-quality peer-reviewed journals and preprints currently under review. Scientific journals published in include Nature, Nature Communications, Physical Review Letters, and the Proceedings of the National Academy of Sciences of the USA.

Avances que van más allá del estado de la técnica e impacto potencial esperado (incluida la repercusión socioeconómica y las

implicaciones sociales más amplias del proyecto hasta la fecha)

HOT has produced advances well beyond the state of the art in developing technologies that operate using the pushing force that electromagnetic radiation exerts on microscopic objects. The work performed during the lifetime of this project promises to have a positive impact on several markets, ranging from communication and detection (e.g. high-speed data communication, and photonic frequency filters that are essential to telecommunications), science and technology (interfacing with superconducting quantum computing devices, and microwave photonics), sensing (for healthcare, and as Internet-of-things sensors), and fabrication as well as packaging processes.

More information about this project can be found at http://www.hot-fetpro.eu/ by following us on Twitter (@hot_h2020), and on our Facebook page (https://www.facebook.com/hot-fetpro).

Applications to be explored by HOT

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