Integration of ultrafast signal processing functionalities via Si-compatible lithium niobate nanophotonic platforms

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The phenomenal growth of data traffic over the Internet and the current digital revolution is setting ever-increasing capacity demands on optical communications and computing systems. Integrated optical approaches can potentially provide viable solutions to still cope with these requirements by scaling up system capacity and still keeping consumption per bit and component count low.

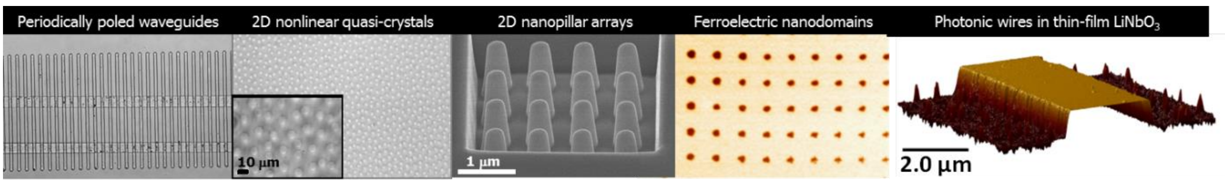
Photonics had long suffered from the lack of a platform affording seamless and cost-effective integration of multiple functionalities on the same chip, essentially until the recent emergence of integrated silicon photonics as a unifying platform for photonics and electronics. Silicon photonics has successfully put to use the power of CMOS manufacturing to efficient harness the huge transmission capacity of optical systems in combination with the computing power of electronics, paving the way to truly scalable and global connectivity across systems, from chip to network levels.

Silicon nanotechnology has been the driver of massive technological developments in photonics, bringing about dramatic reductions in the footprints of optical devices and improvements in their speed and power-consumption, rapidly setting the standards for all other photonic platforms. Nevertheless, there are several critical functionalities at photonic level which cannot naturally be afforded on monolithic silicon platforms: they concern the integration of optical sources, ultrafast modulators and detectors, for which other materials can still grant much better performances.

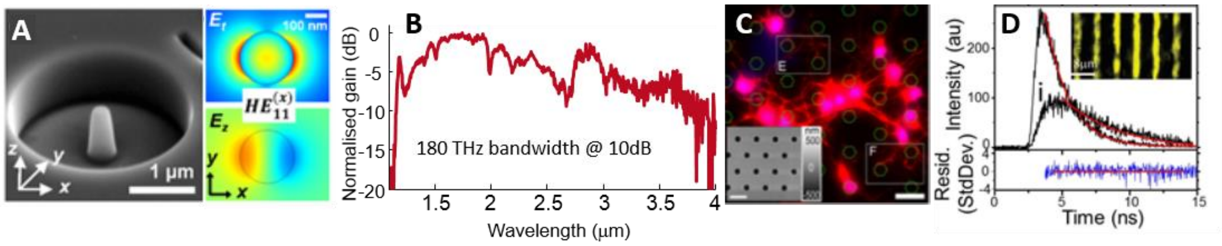
Hybrid integration of such materials with silicon appears as the most promising approach to overcome such limitations. While the previous talk addressed developments and applications associated with the integration with silicon of III-V materials, this talk shall address developments, challenges and applications associated with the integration of nonlinear and electro-optic materials to boost the performance of Si photonic devices and achieve coherent low-noise ultrafast optical modulation, switching and wavelength conversion functionalities.

We shall specifically discuss the case of lithium niobate ($LiNbO_3$), a ferroelectric material which intrinsically affords superb electro-optic, acousto-optic and nonlinear optical properties, still setting the standards for telecommunications and quantum optics in critical applications such as high-speed modulation, frequency conversion and antenna remoting devices in RF photonics.

The successful exploitation of the unique features of $LiNbO_3$ in those applications has been made possible by (micrometric) integrated optics technology in combination with optical fibers. In a similar way, the deployment of nanotechnology tools on $LiNbO_3$ in combination with silicon photonics can be expected to provide the latter with missing functionalities for ultrafast signal processing, based on quadratic optical nonlinearities and electro-optic effects.



The talk shall review historical milestones in the development of integrated optical devices in $LiNbO_3$, including waveguide and ferroelectric domain structuring technologies. It shall then address the most exciting technology developments which have recently taken place, concerning emerging thin-film-on-insulator and integrated nano-photonic platforms in $LiNbO_3$, which might afford electro-optic and nonlinear optical devices of unprecedented efficiency and speeds, compatible with silicon photonics standards. Finally, it shall also touch upon possible implications for other fields, such as quantum information, interfacing of $LiNbO_3$ ferroelectric-photonic chips with biological systems and optical sensing.



A) Images of a lithium niobate nanopillar and of its sub-wavelength field distributions at 850 nm; **B**) ultrabroadband infrared generation by parametric frequency downconversion; **C**) Neurons cultured on lithium niobate with hexagonal pits, stained for F-actin (red) and nuclei (blue). Inset: AFM image of the substrate; **D**) Lifetime decay traces of the fluorescence emission from Rhodamine B on a patterned ferrolectric template with (ii) and without (i) plasmonic Au nanostructures.

Short biography

Katia Gallo holds a M.Sc. and a Ph.D. degree in Electronic Engineering from the Universities of Roma "La Sapienza"(1997) and Palermo (2000) in Italy and a Ph.D. in Condensed Matter Physics from the University of Nice - Sophia-Antipolis in France (2001). She was responsible for the research line on $LiNbO_3$ integrated nonlinear optical devices for fibre telecommunication systems at the Optoelectronics Research Centre in Southampton (UK), from 2001 to 2007. She subsequently joined the Department of Applied Physics at KTH, Royal Institute of Technology (Sweden), where she currently holds a Professor position, appointed as Special Research Fellow in the discipline "Semiconductor physics, electronics, electrical engineering and photonics" by the Swedish Research Council (2011). At KTH she is heading the Ferroelectric Photonics group, whose research activity spans theory, technology and experiments of nonlinear optical interactions in periodically poled ferroelectrics, photonic crystals and integrated all-optical devices, with a focus on telecom and quantum optics applications. Her research interests include nanotechnology, nonlinear integrated optics, ferroelectric material science, fibre and quantum optics. She is the author of more than 130 journal and conference contributions, 3 book chapters, 2 invited reviews, 31 invited talks at international conferences and symposia in the fields of nonlinear optics, polar dielectric materials, laser physics and optical telecommunications. She was the recipient of the Centre and South Italy IEEE Student Award in Electronic Engineering in 1996 and fellowships from the EU (Marie Curie TMR in France and Marie Curie IEF in Sweden), the UK (Leverhulme Trust and London Technology Network) and Sweden (Swedish Research Council).