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How nanophotonics can speed up detection

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This presentation will present the opportunities offered by nanophotonics to improve the performance of detectors including results obtained from the ATTRACT-Photoquant project [1] that aimed at demonstrating that recent nanophotonics innovations such as metalenses and more generally metamaterials could allow a breakthrough in single-photon time resolution. Silicon photomultipliers are bidimensional arrays of single photo-avalanche diodes (SPADs). Many applications would benefit from a single photon time resolution much lower than what is the current state of the art, ideally 10 ps, or even less. Moreover, a photo-detection efficiency as close as possible to 100% is also required. Simulations and measured results show that, using both a light concentrator and including light trapping features to the device stack, the photo-electron generation can be confined in a region as small as 820×780×500 nm3, which could greatly improve the single-photon time resolution and the sensitivity of the device. A concentrator based on a metatamerial gradient index (MM GRIN) lens was created as a 2D square lattice of holes with different diameters [2]. The focusing effect is generated by the refractive index gradient, with bigger holes in the outer region of the concentrator. A concentration factor of about 8 shows the ability of the MM GRIN lens to concentrate light. Moreover, we have shown thanks to numerical simulations that modified SPAD with a thickness reduction of the Si layer down to 500 nm (usually several µm Silicon thickness) and a grating at the bottom or above of the stack resulted in a photon absorption efficiency of nearly 100% in the Si layer. The societal value of such an achievement will be tremendously high in a plethora of fields, from automotive, medical devices and cancer diagnoses to high energy physics.

1 - https://phase1.attract-eu.com/showroom/project/nano-photonics-applied-to-ultrafast-single-photon-quantum-sensors-photoquant/
2 - Mikheeva, E., et al. (2020). CMOS-compatible all-dielectric metalens for improving pixel photodetector arrays. APL Photonics, 5(11), 116105.

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