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Internship offer 2025/2026

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Nonlinear metasurface on silicon photodiode for infrared detection

Scientific project: In the last decade metasurfaces, that is 2D arrays of optical nanoantennas with sub-λ size and separation, revolutionised the field of optics. They also showed their potential in the nonlinear regime,[1] especially in connection with the huge non-resonant $\chi^{(2)}$ of III-V semiconductors in the short-wavelength infrared (SWIR) spectral range. In this domain, MPQ recently demonstrated second harmonic generation (SHG) with phasefront control in a nonlinear metasurface (NLMS), with 10^{-5} conversion efficiency.[2,3] To improve this figure, relevant efforts are currently being devoted by the NLMS community, mainly by exploiting the narrow resonances of quasi-bound states in the continuum (q-BIC) associated to nonlocal modes and strong near-field coupling between meta-atoms.

In this rapidly evolving context, this internship project aims at an **efficient up-conversion of infrared radiation into the silicon (Si) absorption band, with a device allowing for ultrafast detection of SWIR radiation**. Building upon our above breakthroughs plus the recent demonstration of NLMS for SWIR-to-visible up-conversion via sum frequency generation (SFG),[4] the targeted device depicted in Figure 1 brings together a NLMS with a Si avalanche photodiode (APD). We will address signals with wavelength beyond the fast-detection limit of InGaAs, by combining a Si APD with an AlGaAs-on-insulator NLMS. The latter will mix a signal at $\lambda_S \approx 1.8$ µm with a pump at $\lambda_P \approx 1.3$ µm to perform SFG at $\lambda_{SFG} \approx 0.75$ µm, i.e. at about the maximum spectral responsivity of Si. Our device will enable ultrafast SWIR detection by integrating four components: a high-Q, non-local uniform NLMS based on q-BIC resonances; two optical filters; and a TiO_2 metalenslens for focusing the SFG field onto the active region of the APD (Figure 2).

This internship will take place at MPQ, in collaboration with CEA (technology, photodetection) and INRIA (advanced nonlocal design; inverse-design optimization of single meta-atoms or meta-molecules).

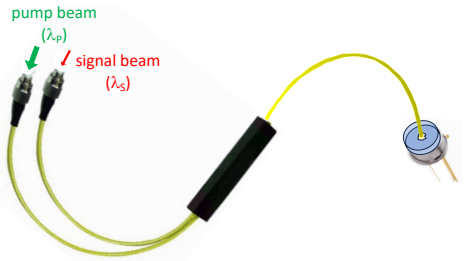

Figure 1. Targeted device : a tiny button placed on a Si APD, enables it to detect a SWIR signal (λ_S) once the latter has been converted to λ_{SFG} via frequency mixing with a pump at λ_P. Both signal and pump are brought to the SPAD with an optical fiber glued on the device.

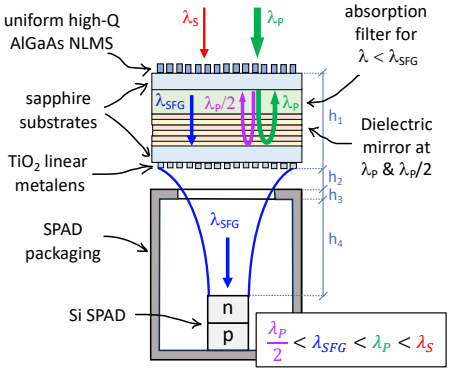

Figure 2. Scheme and operation of the device (CNRS patent application N°2412550).

Methods and techniques: nanofabrication and experimental nonlinear photonics.

Possibility to go on with a PhD ? YES
Envisaged fellowship ? YES

[1] C. De Angelis, G. Leo, D. Neshev, "Nonlinear Meta-Optics", CRC Press - Taylor & Francis (2020).
[2] C. Gigli et al., "Tensorial phase control in nonlinear meta-optics", Optica 8, 269 (2021).
[3] L. Coudrat et al., "Unravelling the nonlinear generation of designer vortices with dielectric metasurfaces", LSA 14, 51 (2025).
[4] R. Camacho-Morales, et al., "Infrared up-conversion imaging in nonlinear metasurfaces", Adv. Phot. 036002, 1 (2021).