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Title: Metaoptics-enhanced supersensitive lab-on-chip modules

Photonics-enabled biological and chemical sensing by means of miniaturized read-out systems, called lab-on-chips (LOCs), has attracted a lot of attention over the last years. The sensing devices are based on, amongst others, fluorescence and Raman scattering, and can serve a wide variety of applications ranging from microplastics identification in water to the detection of Alzheimer biomarkers in blood. An important challenge is to miniaturize the light collection optics in the LOC modules, while keeping the collection efficiency and the resulting sensitivity high, and minimizing optical aberrations. Over the last years in the domain of optics, the field of metaoptics has attracted a tremendous academic and industrial attention due to performance, compactness and multifunctionality with respect to standard bulky refractive/reflective optical components. Metaoptics is based on metasurfaces (2D (flat) version of 3D metamaterials) that are electromagnetic (EM) structures, typically sub-wavelength in thickness, electrically large in transverse size and composed of sub-wavelength elements (often called meta-atoms in their simplest form). Metaoptics based on supercells and multilayer structures has also been proposed in the literature.

In this project, we focus on developing disruptive metaoptics-based solutions to miniaturize the light collection optics in the LOC modules, while keeping the collection efficiency and the resulting sensitivity high and the optical aberrations low. The effect of fabrication tolerances (e.g., layout, material property and alignment tolerances) on the design performances will be considered by advanced Uncertainty Quantification techniques. Constraints in volume occupied and weight need to be considered. Multilayer metasurfaces and a suitable combination of metaoptics with refractive optics or freeform optics can be envisaged to handle design specifications with a gradually increasing complexity.

The physics of fluorescence and Raman scattering, computational electromagnetics, ray tracing-based solvers, and advanced machine learning techniques for design (design exploration, optimization and variability analysis) of complex systems and data analysis (e.g., image processing) will be the backbone of this groundbreaking multi-inter-disciplinary project. The fabrication of prototypes to validate the full modeling and design flow is possible and supported**.** This project is embedded into a multi-inter-disciplinary research environment at Brussels Photonics (B-PHOT) of the Vrije Universiteit Brussel (VUB). The disruptive results of this project will pave the way towards a multitude of real-life applications such as medical diagnostics and real-time environmental monitoring.

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