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Title: Disruptive cross-fertilization of metaoptics and freeform optics for next-generation optical design

The 21st century is sometimes termed the Century of the Photon. The general trend in optics and photonics is about better performances, compactness and multifunctionality in the same volume. Over the last years in the domain of optics, the fields of metaoptics and freeform optics have 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). Freeform optics instead is based on components that deviate from rotational symmetry and, in extreme cases, do not have any kind of symmetry. Metaoptics and freeform optics share one fundamental aspect: exploring design degrees of freedom by sub-wavelength elements and by breaking geometrical symmetries in refractive/reflective components, respectively. These two disruptive scientific domains have not fully met yet.

Metaoptical and freeform optical components can be used into complex applications such as imaging systems for augmented and virtual reality (AR,VR) (e.g., glasses), energy harvesting, holographic displays, space optics, and spectroscopy applications.

Cross-fertilizing the two technologies leads to multiple fundamental challenges:

- Developing innovative multiscale optical simulation tools able to efficiently link the nano-scale world (electromagnetic simulations and metasurfaces) and the macro-scale world (ray-tracing and freeform optics).

- Developing an innovative systematic methodology that can guide designers about how to choose the best combination of these two technologies to have a full control of multiple optical aberrations for high-end optical design.

- Developing an innovative full-chain design flow oriented towards optimization and tolerance analysis that can take into account realistic tolerances that micro-nano-fabrication inherently brings.

In this project, we focus on addressing these challenges (and other related aspects), which will lead to disruptive results in optical design. Computational electromagnetics, ray tracing-based solvers, and advanced machine learning techniques for design (design exploration, optimization and variability analysis) of complex systems 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).

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