SCIENCES & BIOENGINEERING SCIENCES

The Research Group

# Applied Physics

has the honor to invite you to the public defense of the PhD thesis of

## Sophie VIAENE

to obtain the degree of Doctor of Sciences and

to obtain the degree of Doctor of Philosophy

**Joint Phd with Chalmers University**

Title of the PhD thesis:

Exploring metamaterial horizons:
New concepts and geometrical tools for the description of advanced electromagnetic phenomena

**Promotors:**

Prof. Jan Danckaert
Prof. Philippe Tassin (Chalmers University)

The defence will take place on

**Tuesday June 19 2018 at 16h00**

in Auditorium D.2.01 at the Campus Humanities, Sciences and Engineering of the Vrije Universiteit Brussel, Pleinlaan 2 - 1050 Elsene, and will be followed by a reception.

**Members of the jury:**
Prof. Freya Blekman (chairman)
Prof. Sophie de Buyl (secretary)
Prof. Vincent Ginis (co-promotor)
Prof. Tünde Fülöp (Chalmers University)
Prof. Jari Kinaret (Chalmers University)
Prof. John Pendry (Imperial College London)
Prof. Humeyra Caglayan (Tampere University)
Prof. Oscar Quevedo-Teruel
(KTH Royal Institute of Technology)

### Curriculum vitae

Sophie Viaene obtained her master's degree with greatest distinction at the Vrije Universiteit Brussel in 2014 and subsequently started a joint PhD at the Vrije Universiteit Brussel and Chalmers University of Technology. She has actively promoted her field to a wide audience, e.g., by participating in the Bright Club, and has co-supervised bachelor and master students at both universities. Her work has resulted in advanced metamaterial designs that are based on intuitive geometrical concepts and has been awarded with several distinctions, such as a publication in the special issue of Optics and Photonics News.

### Abstract of the PhD research

Einstein's theory of general relativity has dramatically changed our world view, by describing gravity as an intrinsic deformation of space and time. About fifteen years ago, John Pendry and Ulf Leonhardt had the intriguing idea to emulate the behaviour of light in a deformed space by making use of carefully designed artificial metamaterials. Metamaterials consist of elements that are very small with respect to the characteristic length of light waves. By optimizing the shape, the density, and the size of these elements, metamaterials can control light rays in a very precise way.
A priori, it is very difficult, if not impossible, to determine what metamaterial properties impose a desired bend, split, or concentration of light rays. Transformation optics is a geometrical technique that allows determining what metamaterial properties reproduce the light path inside a deformed space. This has resulted in impressive and, at the same time, intuitive, material designs such as invisibility devices that hide an object by guiding light rays around it.
Thanks to rapidly advancing fabrication methods, metamaterial designs may result in a variety of novel properties, such as reconfigurable, two-dimensional, or quantum properties. In the first part of her thesis, Sophie Viaene introduces new concepts to describe reconfigurable metamaterials with properties that are controlled by an external signal. For example, she has developed a consistent description of materials that implement vector potentials for photons to enhance optical forces, and she has discovered that reconfigurable metamaterials are subject to a fundamental speed limit. These findings are important because they point out that active photonic switches can only be improved up to a certain point by making use of metamaterial structures. In the second part of her thesis, Sophie extends the geometrical tools of transformation optics to improve on the understanding of two-dimensional metamaterials and quantum metamaterials. This has allowed designing metamaterial layers that guide light along their surface and has provided new insights into the behaviour of light sources inside metamaterial black holes, which impose a gravitational wave vector shift.
By describing advanced electromagnetic phenomena inside reconfigurable, two-dimensional, and quantum metamaterials in an intuitive way, this thesis has contributed to advanced material designs that may be useful in future light-based applications.