Nanooptics - Fitting a New Emperor into Old Clothes

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Recent years have witnessed the emergence of many new research topics which are related in one way or another to the application of optics at the nano scale. This includes topics ranging from dispersion management and slow light to left-handed materials and photonic crystals. Currently, many of these topics are evolving from being the subject of basic research to becoming enabling technologies for a large variety of applications.

Even a brief review reveals that many of the effects which are exploited in nanooptics have been known for a rather long time. In particular, microwave engineering and diffractive optics have accumulated a wealth of knowledge which can potentially be useful to model and design nanooptical devices.

It also means, however, that the innovation associated with nanooptics is rarely driven by the discovery and modelling of unknown electromagnetic effects, but rather their implementation on a nano scale. A bottom-up analysis of nanooptics, in fact, identifies new fabrication methods for structuring electromagnetic materials on a small scale as the most crucial component and driving force of ongoing research activities. A top-down analysis, in contrast, reveals the importance of investigating nanooptics as enabling technology for implementing a desired optical response. The latter, in particular, helps to identify application, which cannot be addressed by classical optics.

In this context, several projects will be discussed, which illustrate that nanooptics can be interpreted as applying mature concepts of modelling and design to a previously unexplored set of optical devices and systems. In particular, two methods for fabricating nanooptical devices will be highlighted. The first method focuses on the assembly of larger structures from custom designed nanoparticles. Simulation results for both the near field as well as the far field scattering will be presented to discuss the degrees of freedom available for the design of the particle response.

The second method is interference lithography to fabricate three-dimensional photonic crystals. Design methods are presented which allow one to control the degrees of freedom of the propagating wave field with conventional diffractive optical elements.

Enhanced spectroscopy is discussed as a potential application for nano devices which can be implemented in either way. In particular the trade-off between wavelength resolution, data acquisition time, and signal-to-noise ratio is considered. It is shown how the properties of the nanooptical device and the optical system have to be matched to achieve better resolution at a potentially better signal-to-noise ratio. Using spectroscopic methods for detecting chemical substances as a context preliminary results are presented on how to implement matched spectroscopy based on nanooptical structures.