Karlsruhe Institute of Technology

Division V – Physics und Mathematics

Institute of Nanotechnology (INT)

Optical Metasurfaces

Nanostructures enable compact multifunctional components

Metaoptics are thin nanostructured layers that can replace conventional optical components or systems. Tiny nanostructures, so-called meta-atoms, can manipulate light in a targeted manner. The properties of meta-atoms can be designed to create compact multifunctional optical components. These are suitable, for example, for focusing light, generating structured light, for polarization optics, for generating holograms or even for replacing several optical elements with a single metasurface. The production of such meta-optics is compatible with standard semiconductor manufacturing processes, making this technology suitable for mass production. Metaoptics can be used in sensors, cameras and displays, among other things.

Metagrating for light control

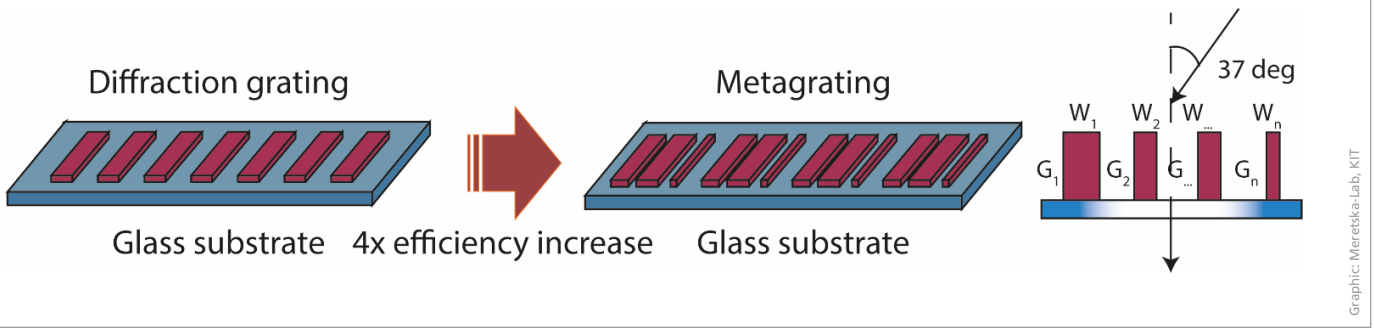
One example of the potential of optical metasurfaces is a newly developed meta-grating for light control, which effectively guides light waves even at steep angles of incidence. Usually, the efficiency of diffraction gratings decreases as the angle of incidence increases. However, the new metagrating shows a fourfold higher efficiency than conventional diffraction gratings. The applications of the meta-grating developed at KIT extend to various branches of industry and include, for example, material sorting, quality control, projection systems, solar cells and barcode scanners.

Metaoptics - new optical components

Conventional lenses for imaging, microscopy, sensor technology, detection and photonics in general are based on the refraction of light by curved glass or polymer materials. Archaeological finds indicate that the Egyptians and Mesopotamians already used polished pieces of glass as optical components. Since then, the basic principle of production has not changed. Although there are advanced polishing tools, their function is limited by the shape of the components that can be produced. Lenses produce aberrations, they are bulky and limited in their functionality, resulting in bulky optical systems with limited functionality.

Recent advances in the semiconductor industry have enabled the development of fundamentally new optical components known as meta-optics. In contrast to conventional optical components, metalenses are based on nanostructured arrays, i.e. meta-atoms, to manipulate the phase, amplitude and polarization of light on a sub-wavelength scale.

Metalenses offer several advantages over conventional lenses: their ultra-thin, planar design significantly reduces size and weight, making them particularly attractive for use in mobile devices, compact cameras, sensors and portable optics. In addition, the design flexibility of metasurfaces enables multifunctionality, allowing them to replace multiple optical components.

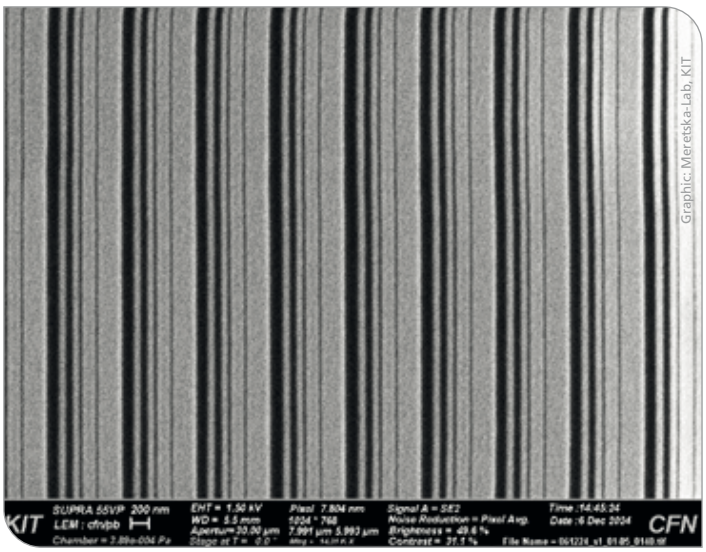


Conventional diffraction grating (left), meta-grating with four times higher efficiency (center), meta-grating seen from the side (right).

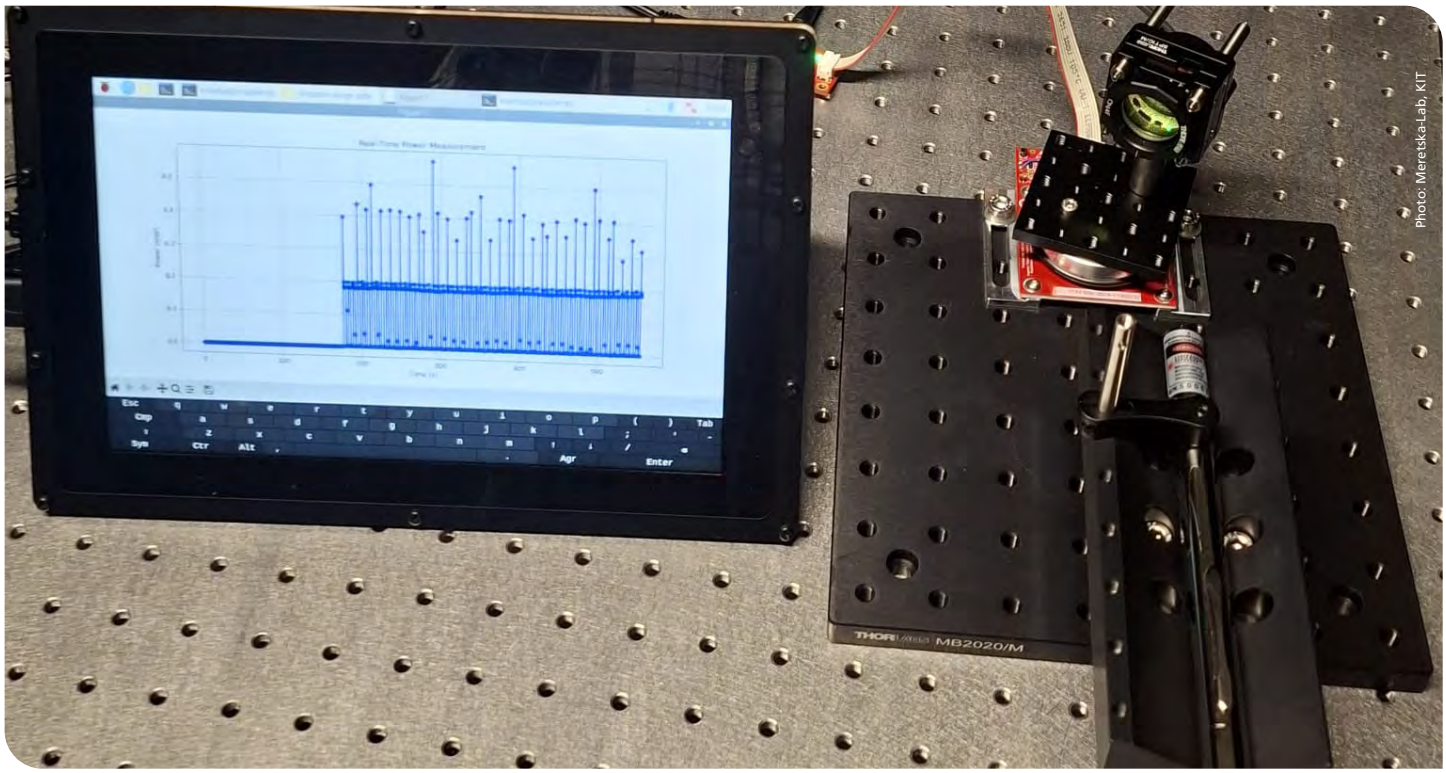
Improved performance and efficiency

Small form factor, low weight and multifunctionality of the components allow the development of optical systems with improved performance and at the same time lower weight, lower transportation costs and less maintenance. The improved performance can extend to several parameters of the system. It may be possible to add additional functions without nominally increasing the price of the optical systems.

The development of meta-optical solutions begins with a detailed analysis of the optical system in question. Meta-optical components are designed based on electromagnetic simulations. The meta-optical demonstrator component is nanofabricated in the KIT clean room. Since meta-optics can be manufactured in semiconductor factories, the scalability of production is comparable to the semiconductor industry, where millions of chips are manufactured every day.



Scanning electron micrograph of a metagrid.



The sample mounted in the lab.

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