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Recent advances in microwave metasurfaces

David A. Powell*, Ashif A. Fathnan, Andreas E. Olk
School of Engineering and Information Technology,
University of New South Wales, Canberra ACT 2610, Australia

Extended Abstract

This talk will give an overview of developments in the field of metasurfaces, followed by a presentation of our recent contributions to the field. Metasurfaces have recently emerged as one of the most promising forms of metamaterials for applications at frequencies ranging from RF to visible. Building on the established concepts of reflect-arrays and frequency-selective surfaces, they promise to become a key technology for the manipulation of microwave radiation. As shown in Figure 1, the anomalous refraction effect underlies many metasurface devices such as lenses and generators of vortex beams. Other applications include low-profile antennas, absorbers, diffusers, polarizers, retro-reflectors, polarimeters and hologram generators.

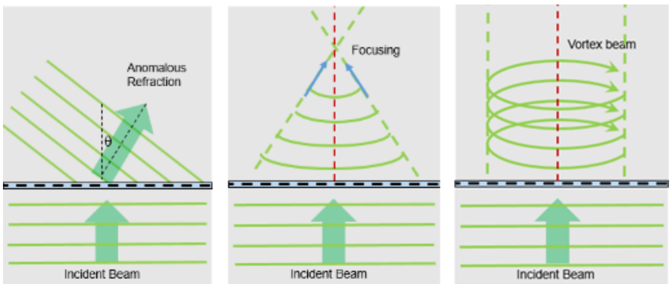

Figure 1. Examples of metasurface functions: anomalous refraction, focussing, and generation of vortex beams.

For high efficiency in transmission mode, Huygens' metasurfaces [1] are widely used, as they achieve impedance matching through balanced electric and magnetic dipole responses of each element. This also enables them to achieve arbitrary phase shift over the full 2π range, while being highly sub-wavelength in thickness. For implementation at optical frequencies, dielectric resonators have achieved the most promising results, due to their low loss. However, at microwave frequencies, multi-layered metallic structures are much more prevalent [2], due to their compatibility with printed-circuit board technology.

To achieve strong wave manipulation in a sub-wavelength thickness, resonant elements are required. Many applications require a significant operating bandwidth, over which the metasurface should refract waves at a constant angle, (i.e. without chromatic aberrations). We have recently showed the physical limits on achromatic operation in printed-circuit metasurfaces. We developed a limit based on the aperture size, operating bandwidth and refraction angle (or focal length) of a lens, based on the requirement that the structure must tbe passive and causal.

We have also undertaken work to improve the analytical methods for metasurface synthesis with three-layered metallic structures. Existing methods presented in the literature ignore the near-field coupling between resonators, which is often quite strong in practice. This means that designs made according to analytical formulas will have poor efficiency, which is typically remedied by intensive optimization with a numerical solver. We have demonstrated how this near-field coupling can be precisely quantified, enabling it to be compensated for in a rational design process which precisely identifies the elements requiring modification.

References

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[2] A. Epstein and G. V. Eleftheriades, "Huygens' metasurfaces via the equivalence principle: Design and applications," *Journal of the Optical Society of America B*, vol. 33, no. 2, p. A31, Feb. 2016.