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Electromagnetics:
Microwave Engineering

Luneburg Lens

Outline

- What is a Luneburg lens?
- Numerical studies

Rudolf Karl Lüneburg
20 March 1903 – 19 August 1949

What is Luneburg Lens?

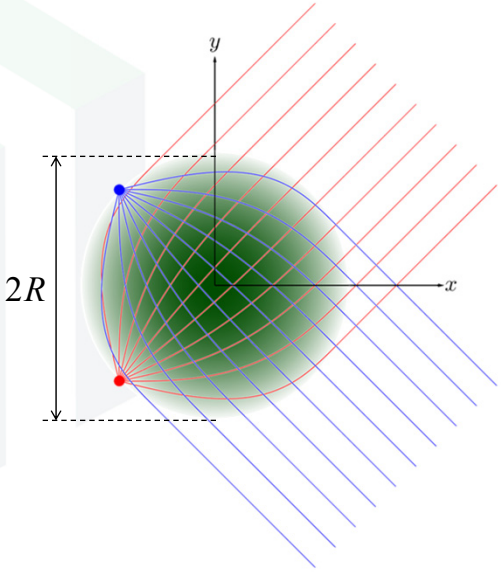
Definition of a Luneburg Lens

A *Luneburg lens* is a spherically symmetry gradient-index lens that focuses a plane wave at a single point on the opposite side of the lens. Used in the opposite direction, it will collimate a point source placed at the edge of the lens.

$$\varepsilon_r(r) = 2 - \left(\frac{r}{R}\right)^2$$

$r \equiv$ radial position

$R \equiv$ radius of lens



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Simulation of a Luneburg Lens

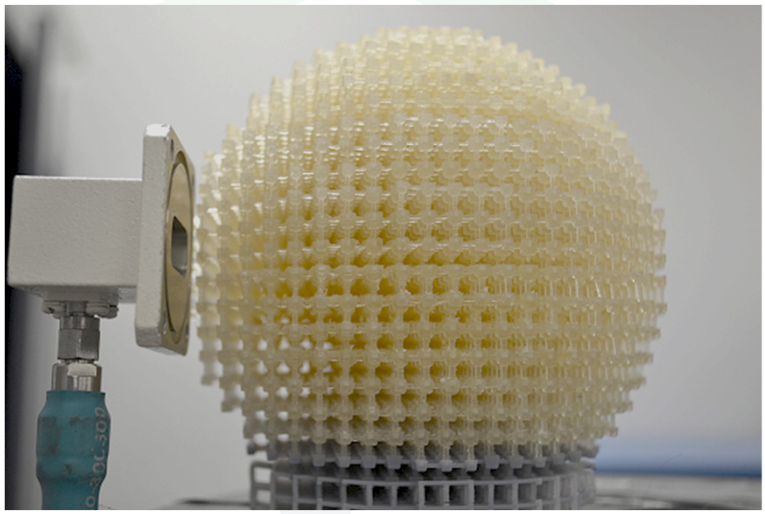
Ideal Luneburg Lens

Effective Medium Luneburg Lens

Commercial Luneburg Lenses

https://commons.wikimedia.org/wiki/File:Parts_of_a_Luneburg_lens.jpg

3D Printed Luneburg Lenses



https://3dprintingindustry.com/news/lunewave-3d-printed-lenses-eyes-autonomous-cars-120316/

Luneburg Lens at Optical Frequencies

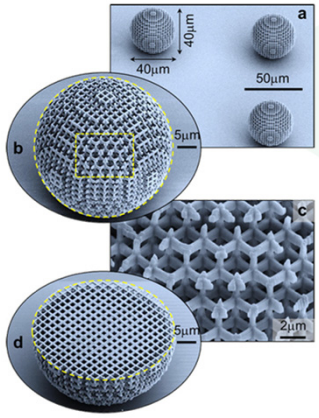


Figure 3 Scanning electron microscope images of a 3D Luneburg lens. (a) Global view showing the fabricated 3D Luneburg lens array in the glass substrate. (b) Oblique view of a single complete 3D Luneburg lens. (c) Zoom-in view of the highlighted area in b. (d) Internal sectional view of the fabricated 3D Luneburg lens with subwavelength lattice simple cubic structure. The radius of a 3D Luneburg lens is 20 μm. The period of the lattice is 2 μm.

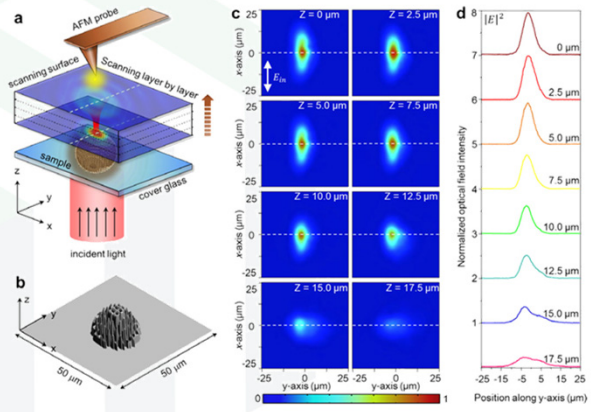
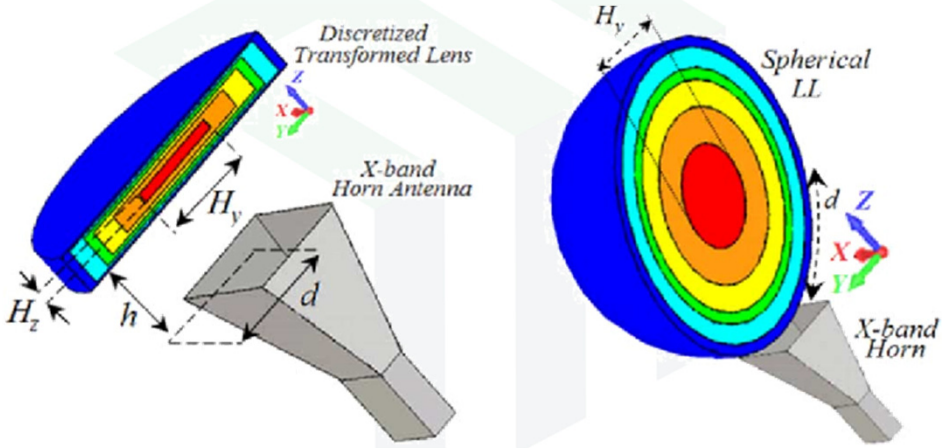


Figure 4 Characterization of optical-field distributions for 3D Luneburg lens. (a) 3D schematic diagram of the experimental setup (a transmission-mode s-SNOM). The sample is illuminated from below with an infrared laser beam at the wavelength of 6.25 μm. (b) The measured region is a 50 × 50 μm^2 square area on the *x*–o–*y* plane. An AFM probe was used to detect the normalized optical-field distribution on a cross-sectional plane in perpendicular to the optical axis direction. (c) Measurement results of the normalized optical-field intensity $|E|^2$ map on the *x*–o–*y* plane at varied height (z = 0, 2.5, 5, 7.5, 10, 12.5, 15 and 17.5 μm) along the *z*-axis outside the 3D Luneburg lens. (d) Plot of the optical-field intensity $|E|^2$ along the *y*-axis. Positions of the *y*-axis are marked by the white dotted line in (c).

Zhao, Yuan-Yuan, et al. "Three-dimensional Luneburg lens at optical frequencies." *Laser & Photonics Reviews* 10.4 (2016): 665-672.

Flat Luneburg Lens



Mateo-Segura, Carolina, et al. "Flat Luneburg lens via transformation optics for directive antenna applications." *IEEE Transactions on Antennas and Propagation* 62.4 (2014): 1945-1953.

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Numerical Studies

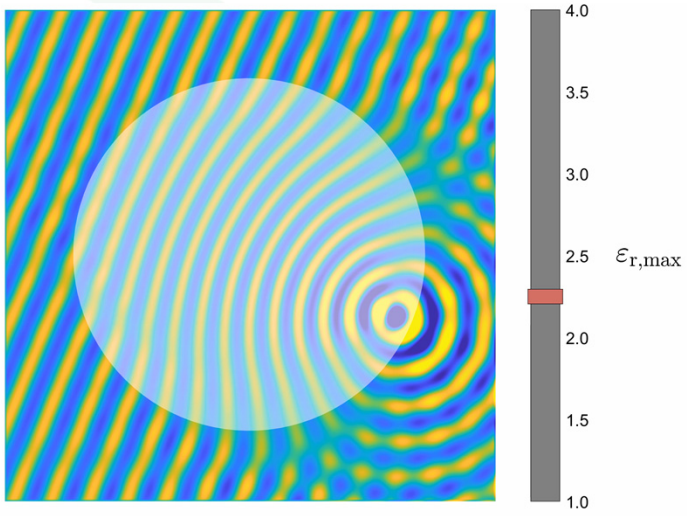
Maximum Permittivity Tolerable

Due to manufacturing, it may not be possible to achieve permittivity exactly at 2.0 and 1.0.

It is useful to study what is tolerable.

$$\varepsilon_r(r) = \varepsilon_{r,min} - (\varepsilon_{r,max} - \varepsilon_{r,min})\left(\frac{r}{R}\right)^2$$

$$\varepsilon_{r,max} \approx 2.25$$



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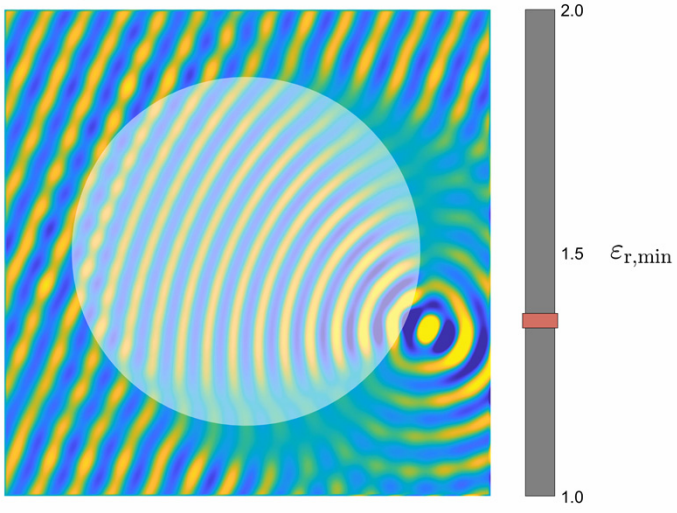
Minimum Permittivity Tolerable

Due to manufacturing, it may not be possible to achieve permittivity exactly at 2.0 and 1.0.

It is useful to study what is tolerable.

$$\varepsilon_r(r) = \varepsilon_{r,min} - (\varepsilon_{r,max} - \varepsilon_{r,min})\left(\frac{r}{R}\right)^2$$

$$\varepsilon_{r,min} \approx 1.30$$



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https://empossible.net/academics/emp4301_5302/