The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

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2222-11

Preparatory School to the Winter College on Optics in Imaging Science

24 - 28 January 2011

Selected Topics of Fourier Optics Tutorial

William T. Rhodes

Florida Atlantic University
Boca Raton
USA

Strada Costiera 11, 34151 Trieste, Italy - Tel.+39 040 2240 111; Fax +39 040 224 163 - sci_info@ictp.it

Select Topics

A potpourri of topics from Fourier optics not found in most Fourier optics texts

William T. Rhodes, Ph.D.

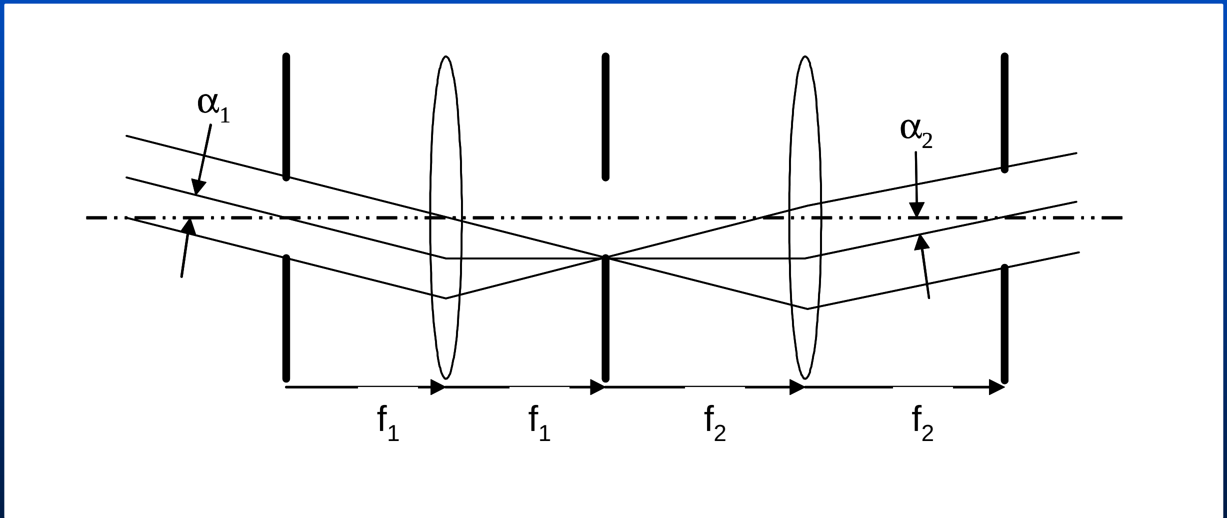
Florida Atlantic University
Imaging Technology Center
Boca Raton, Florida – USA
wrhodes@fau.edu

ICTP Winter College on Optics in Imaging

Preparatory School
27-28 January 2011
Trieste, Italy

Space invariance in 3-D: Afocal-telecentric imaging systems

- An afocal-telecentric imaging system is space invariant for both coherent and incoherent imaging. It is the *only* system that is so.



- An imaging system is said to be *telecentric* if the limiting aperture (aperture stop) of the system, as viewed from object and image planes, appears to be at infinity (Greek *tele*, meaning distant). A system can be telecentric from object space or image space. If it is both, it is referred to simply as telecentric.
- Mathematically its operation is described by the following equations:

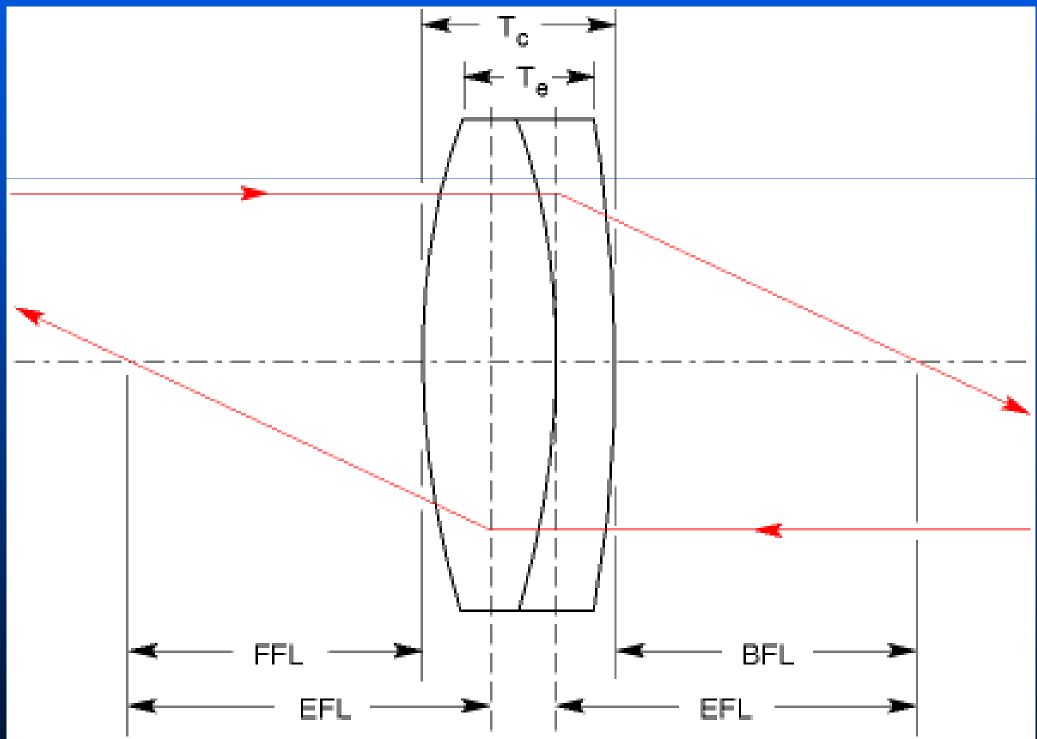
$$\mathbf{U}_{im}(x, y, z) = \mathbf{U}_g(x, y, z) *** \mathbf{h}_{3D}(x, y, z)$$

$$I_{im}(x, y, z) = I_g(x, y, z) *** s_{3D}(x, y, z)$$

Real lenses: minimizing aberrations.

- Real lenses are designed to be used in specific ways. A telescope lens is optimized to map plane waves from distant objects into points of light. A copy lens may be optimized for 1:1 imaging. Using a lens in the wrong way can increase significantly the effect of aberrations.

- The cemented doublet shown below is made to take plane waves from the left—i.e., from the more strongly-curved side—and map them into points in its back focal plane. Use it wrong and the point image will be poor.

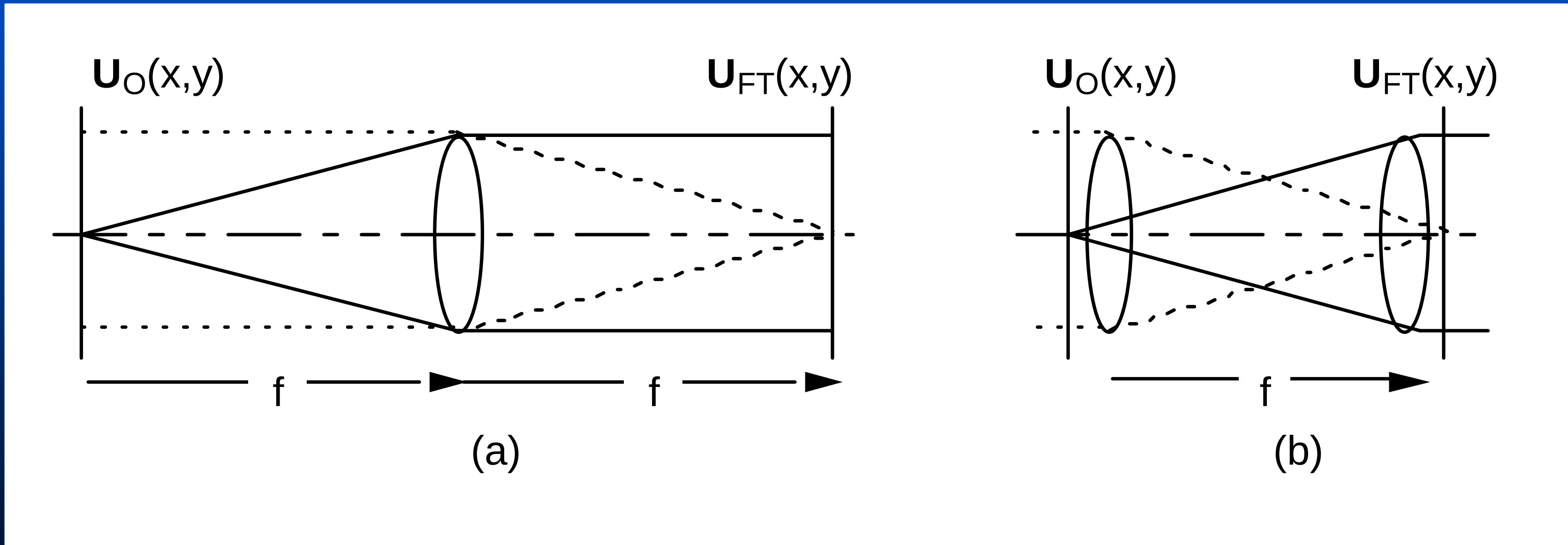


Where does the Fourier transform appear?

- Some texts suggest that the Fourier transform of an object appears in the back focal plane of the lens. This is true only if the object is illuminated by a plane wave. If the object is illuminated by a converging spherical wave, the Fourier transform appears in the plane to which the spherical wave converges.

Plane waves into points and points into spherical waves

- The two Fourier transform modules below map plane waves into points and points into plane waves—two defining characteristics of Fourier transform optical systems.



- A critical feature of a Fourier transform lens system is that it map plane waves into points. If it maps points of light into spherical waves, this aspect may not be important because the corresponding quadratic phase factor disappears in the calculation of the optical intensity distribution.

Interchanging the geometrical scaling and convolution boxes

- Traditionally the blurring operation associated with the convolution operation is associated with the image, and it is preceeded by the geometrical scaling operation. However, it can as easily be associated with the image, in which case the order of the convolution and the geometrical scaling operations are interchanged.

Virtual Fourier transform distributions

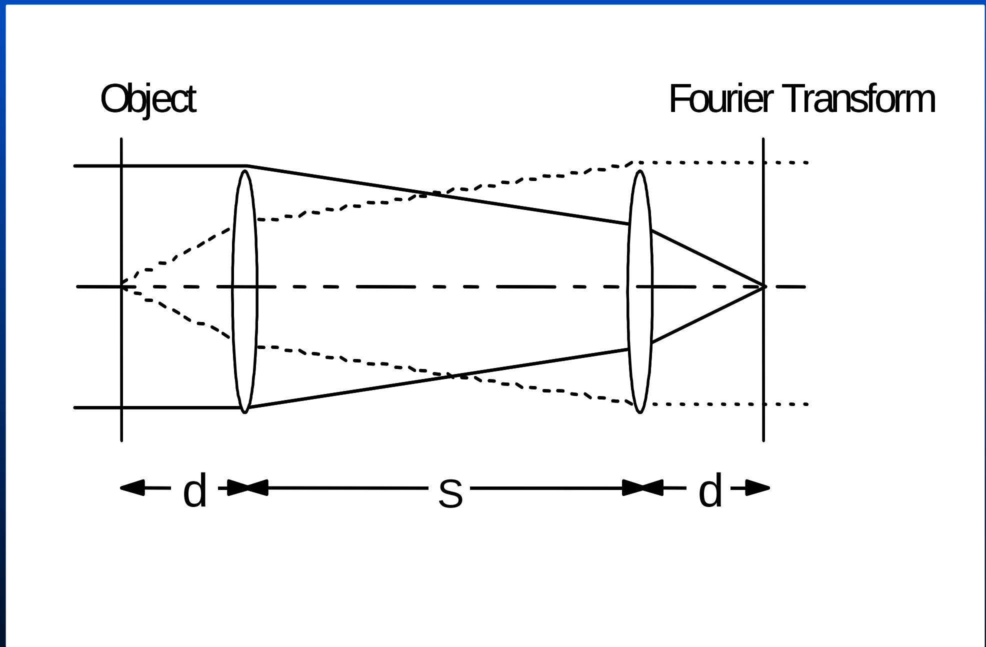
- Shine a laser pointer beam at a distant wall and view it through a diffraction grating structure of some sort. Centered on the point of light on the wall appears a diffraction pattern. This pattern is a virtual Fourier transform distribution. The “real” Fourier transform is actually incident on the retina of the eye.

Cardinal points & principal planes

- Gerd Häusler in his talk referred to “cardinal” planes. In fact, he was talking about *principal* planes and confused the translation from German into English. See http://en.wikipedia.org/wiki/Cardinal_point_%28optics%29

Practical 2-lens ideal Fourier transform module

- The system below maps plane waves into points and points into plane waves, but it leaves room for the object and for a detector array.



Pinhole spatial filter

- The objective of a pinhole spatial filter (example shown below—assuming light enters it from the right!)—is to “clean up” a laser beam. See, e.g., http://www.edmundoptics.com/technical-support/lasers/understanding-spatial-filters/

Canonical Fourier transform configurations

- The object transparency can be positioned either in the converging beam or in the diverging beam. In either case, the Fourier transform distribution appears in the Fourier transform plane centered at the point conjugate to the point source.