FRED® Application Note

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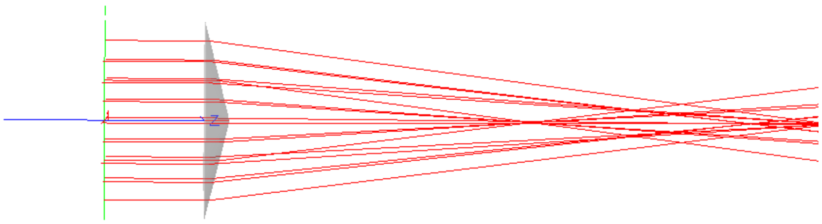
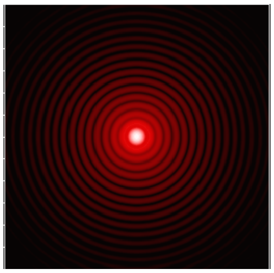
Illuminating Ideas

Bessel Beam Generation Using an Axicon





Introduction

Bessel beams are a special type of light propagation that does not diffract. The light distribution of a Bessel beam maintains a tight focus with high irradiance over great distances. Bessel beams are also self-healing, which means that the light pattern will regenerate after being partially obstructed. Such properties make this phenomenon useful for optical trapping and tweezing, high-precision drilling, and communication applications.

Description of a Bessel beam

Bessel beams are propagating light fields with a distribution described by a Bessel function of the first kind. The cross section of a Bessel beam consists of concentric rings. Each ring (including the central lobe) contains the exact same infinitesimal amount of energy.

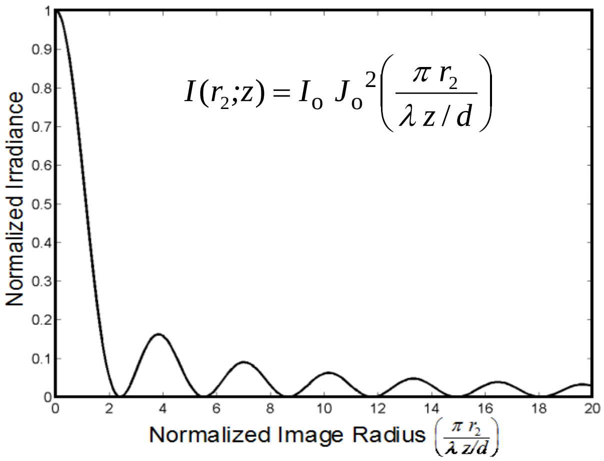


Figure 1. Irradiance pattern along the cross-section of a Bessel beam. The Bessel function is shown in the upper right.

Higher-order Bessel beams are modified along the azimuthal direction according to the equation $J_l(k_r r)\exp(il\phi)$, where k_r *determines ring spacing and* l *determines azimuthal phase variation. In the far-field, the Bessel beam takes the form of an annular ring.*

Axicon generation of a Bessel beam

Practically speaking, the mathematically ideal Bessel beam is impossible to create: it contains an infinite amount of rings over an infinite extent. Pseudo-Bessel beams, on the other hand, are confined to an aperture. The most straightforward way to create a Bessel beam is with an axicon (a cone-shaped refractive material or reflective surface that transforms an incident plane wave into a self-interfering cone of light). Self-interference forms concentric fringes.

It is simple to create an axicon in FRED. Create a “circular cone” element primitive with *Simple Glass* material, *Transmit* coating, and *Allow All* raytrace control. Choose a base semi-aperture of 1 mm and height of 0.1 mm. Next, create a Simplified Optical Source of the type *Collimated Source (plane wave)* and check the *Coherent* box to ensure self-interference. Assign a wavelength of 500 nm to the source. Finally, place an absorbing surface with attached analysis surface 12 mm from the axicon.

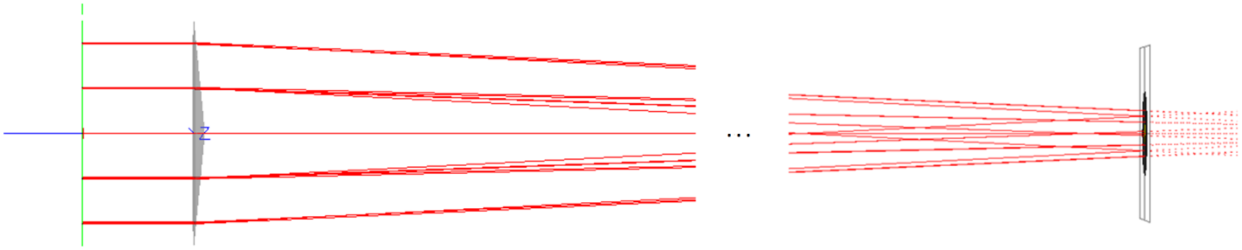


Figure 2. Left: a collimated plane wave illumination passes through a glass axicon. Right: further along the axis, a detector is placed in a region of self-interference where a pseudo-Bessel beam is generated.

To observe the Bessel beam, click *Analysis→Coherent Scalar Wave Field*. A graph of irradiance is shown. To see the light field, simply right-click the graph and select *Show Field Amplitude*. Over a 0.2 mm diameter observation region, distinct Bessel rings are visible (Figure 3).

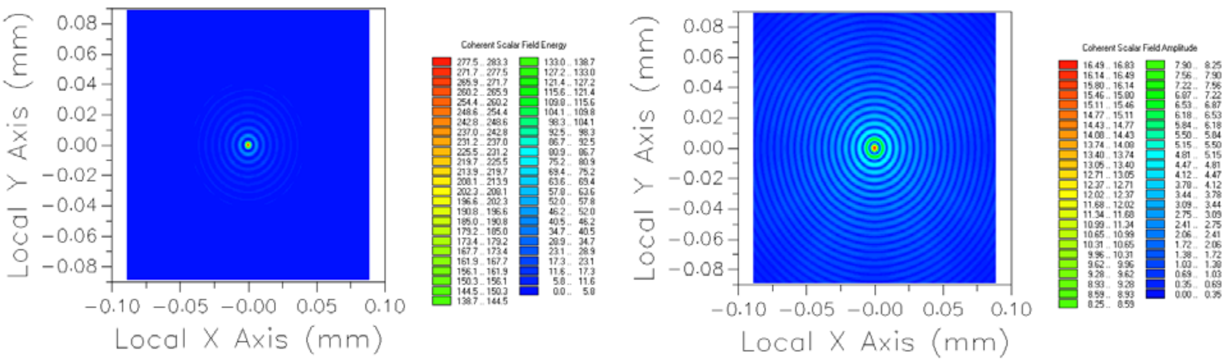


Figure 3. Distribution of irradiance (left) and light field (right) in self-interfering region beyond an axicon illuminated by a plane wave with wavelength of 500 nm.

Conclusions

FRED is capable of modeling Bessel beam behavior in a practical way: by simulating the creation of pseudo-Bessel beams using coherent illumination and standard optical elements such as axicons, lenses, and annular slits.

References:

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