

The diagram illustrates a line source (slit) of length L located at $z = 0$. The slit is represented by a black horizontal bar. A coordinate system is shown with the x -axis pointing right and the z -axis pointing up. A wave vector \mathbf{k} is shown pointing along the $-x$ direction. To the right, a graph plots Intensity against x . The intensity is zero for $|x| > L/2$ and follows a rectangular pulse profile for $|x| \leq L/2$, reaching a maximum value E_0 . A box indicates: '(For illustration only!)'. The assumption is summarized as:

$$\text{Assumption: } E(x,0) = \begin{cases} E_0 & |x| \leq L/2 \\ 0 & |x| > L/2 \end{cases}$$

$$\begin{aligned}\hat{E}(k_x; z=0) &= \frac{1}{4\pi^2} \int_{-\infty}^{\infty} E(x,0) \exp(-ik_x x) dx = \frac{E_0}{4\pi^2} \int_{-L/2}^{L/2} \exp(-ik_x x) dx \\ &= \frac{E_0 L}{4\pi^2} \frac{\sin(k_x L/2)}{k_x L/2}\end{aligned}$$

$$E(x,z) = \int_{-\infty}^{\infty} \hat{E}(k_x; z=0) \exp(i[k_x x + k_z z]) dk_x \quad k_z = \sqrt{k^2 - k_x^2} = \sqrt{(\omega/c)^2 - k_x^2}$$

$$\text{Propagating waves: } |k_z| \leq \frac{\omega}{c}; \quad \text{Evanescence waves: } |k_z| > \frac{\omega}{c}$$

Nanooptics 11/1

Vigoureux et al., AO (1992)

KIT
Karlsruhe Institute of Technology

Imaging of a Line Source – Fourier Optics



Karlsruhe Institute of Technology

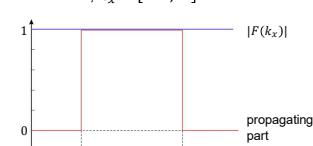
Imaging of a Line Source – Fourier Optics

Point-like light source: $f_s(x) = \delta(x - x_0)$

Spatial frequency spectrum of Delta-function has no limits, $k_x \in [-\infty, \infty]$:

$$F(k_x) = \int_{-\infty}^{\infty} f_s(x) e^{ik_x x} dx = e^{ik_x x_0}$$

$$|F(k_x)| = 1$$

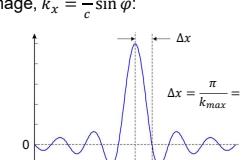


Evanescent waves do not contribute to the image, $k_x = \frac{\omega}{c} \sin \varphi$:

$$k_{max} = \frac{\omega}{c} = \frac{2\pi}{\lambda}$$

$$f_i(x) = \int_{-k_{max}}^{+k_{max}} F(k_x) e^{-ik_x x} dk$$

$$= 2k_{max} \frac{\sin[k_{max}(x - x_0)]}{k_{max}(x - x_0)}$$



Nanooptics 11/3

Vigoureux et al., AO (1992)

A Perfect Lens based on an Optical Metamaterial

Special solution of Maxwell's equations:

$$n = \pm\sqrt{\epsilon\mu} \quad \epsilon, \mu < 0 \Rightarrow n < 0$$

Interface Air-Metamaterial, $n = -1$:

$$\frac{\sin \alpha}{\sin \beta} = n = -1$$

A slab of MM with negative n acts as a lens (see figure).

$$k = |\vec{k}| = n \frac{\omega}{c_0} = - \frac{\omega}{c_0} \quad \text{Evanescent waves: } k_z = - \sqrt{\frac{\omega^2}{c_0^2} - (k_x^2 + k_y^2)}$$

According to the negative k , the waves emerge from the right side of the medium and are *enhanced* in amplitude by the transmission process!

$$T = e^{ik_z d} = e^{+|k_z|d}$$

Since $d = a + b$, the damping of the evanescent waves in air is compensated so that they can fully contribute to the image formation without loss of information.

Nanooptics 11/4

Pendry, Phys. Rev. Lett. (2000)