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PHYC20090 Electronics and Devices

Experiment No.9 Holography

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Abstract

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Consider the reflected waves as seen in Figure 1. The detailed nature of this "object beam" is dependent on the object's shape and surface characteristics. Taking a general approach, describe the object beam as a superposition (combination) of plane waves,

$$\psi_0(r,t) = A_0 \iint F_0(k_x,k_y)e^{i(\omega t - k_x x - k_y y - k_z z)}dk_x dk_y$$

where $(k_x^2 + k_y^2 + k_z^2)^{1/2} = k = \lambda/2$. Suppose we have permitted this wave ψ_0 to interfere with a reference beam given by

$$\psi_1(r,t) = A_1 e^{i(\omega t - kz)}$$

and have recorded the resulting intensity pattern on a photographic plate positioned in the plane $z = 0$. The intensity recorded on the plate is then

$$I(x,y) = |A_1 + A_0 \iint F_0(k_x,k_y)e^{-i(k_x x + k_y y)}dk_x dk_y|^2$$

Expanding the right-hand side of this equation, we will have terms proportional to $|\psi_0|^2$, $|\psi_1|^2$, and $|\psi_0\psi_1^*|$.

Assuming that the reference beam is much more intense than the object beam (ie. $|\psi_1| \gg |\psi_0|$), then the term in $|\psi_0|^2$ can be ignored, and the intensity can be approximated as

$$I(x,y) \approx |A_1|^2 + A_0 A_1^* \iint F_0(k_x,k_y)e^{-i(k_x x + k_y y)}dk_x dk_y + A_1 A_0^* \iint F_0(k_x,k_y)e^{+i(k_x x + k_y y)}dk_x dk_y$$

The transmission function for a developed plate can be expressed as $T(x,y) = 1 - \gamma I(x,y)$ where γ is a function of the exposure and developing processes. Therefore, the hologram's transmission function is

$$T(x,y) = C_0 - \gamma A_0 A_1^* \iint F_0(k_x,k_y) e^{-i(k_x x + k_y y)} dk_x dk_y - \gamma A_1 A_0^* \iint F_0(k_x,k_y) e^{+i(k_x x + k_y y)} dk_x dk_y$$

where C_0 is a constant. Essentially, the hologram contains both scaled versions of the two-dimensional Fourier tranform of the object beam and its inverse, superimposed on each other. When this hologram is illuminated with a plane wave life the originall reference beam, another Fourier transformation occurs, which leads to

$$\psi(r,t) = \iint F(k'_x, k'_y) e^{i(\omega t - k'_x x - k'_y y - k'_z z)} dk'_x dk'_y$$

where, according to Fourier optics,

$$F(k'_x, k'_y) = \left(\frac{1}{2\pi}\right)^2 \iint T(x,y) e^{i(k'_x x + k'_y y)} dx dy$$

The three terms that make up $T(x, y)$ obligingly integrate as delta functions (unlike the ignored $|\psi_0|^2$ term, which would not behave as such), and we find

$$F(k'_x, k'_y) = -\gamma A_1^* A_0 F_0(k'_x, k'_y) - \gamma A_1 A_0^* F_0^*(-k'_x, -k'_y) + C_0 \delta(k'_x)\delta(k'_y)$$

As a result, when the hologram is illuminated correctly (as in Figure), the emerging wave consists of three parts: (left) a term that is proportional to the original object beam, effectively reconstructing the object in all details of amplitude and phase; (centre) a so-called "twin reconstruction" or "twin image", which can be shown to be the original object beam, reflected across the photographic plate and travelling backwards in time; and (right) an undeflected segment of the reference beam travelling along the z-axis.

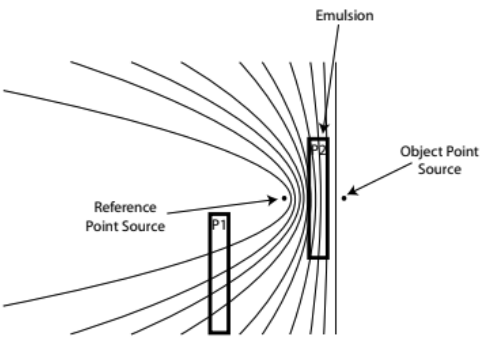

Figure 1: sample caption [1]

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References

[1] J. H. Taylor, A. Erickcek, and Z. Kermish, "Holography," in *Physics 312*. Princeton University, 1990-2002, [Accessed 9 March 2025].

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