Vol. A53 (1978) ACTA PHYSICA POLONICA No 6

SEARCH FOR THE EXACT SPATIAL FREQUENCY PLANE OF A FOURIER-TRANSFORMING LENS

By R. S. Kasana, K. Dayal

Department of Physics, University of Indore*

and G. P. Bhatnagar

School of Studies in Physics, Vikram University, Ujjain**

(Received February 10, 1977; final version received October 4, 1977)

This article concerns the experimental method to find-out the exact spatial frequency plane (e.g. back focal plane of the Fourier-transform lens). A new simple technique has been used to search-out this exact spatial filtering plane in a coherent optical processor. The exact location of this plane is very essential for optical data processing operations.

1. *Introduction*

The spatial frequency plane or Fourier-transform plane is the back focal plane of the lens used in optical data processing configuration. The coherent plane wave illumination has been used as an information carrier. This fundamental constant of any optical system is of great importance in removing the Sidel-aberrations and the defect of defocusing of images as well as in determining the magnification of the optical system.

Many workers [1–4] have reported various techniques for determining the focal length of an optical processor. Mechanical gauges and autocollimators are used to evaluate the focal length of the lenses. However, such techniques are seldom useful during the operational modes of the experiment. The plane reflector method is generally used for quick but rough estimation of focal length.

To obtain the optimum accuracy in the spatial frequency filtering operations, the filter is to be positioned exactly at the spatial frequency plane. In other words, the Fourier-transform should overlap with the filter function. For if the spatial filter is displaced even slightly, there is every possibility that some useful information may be missed. Due to

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* Address: Department of Physics, University of Indore, Indore 452 001, India.

** Address: School of Studies in Physics, Vikram University, Ujjain 456 010, India.

defocusing, the size of the Fourier-transform spectrum may be larger than the size of the filter function. Hence only limited information will be filtered-out. Therefore, for the best processing, exact location of the Fourier-transform plane must be searched out.

2. Optical system

The optical configuration used during the experiment is shown in Fig. 1. Monochromatic light from a point source S_0, collimated by a lens L_c, is incident on a Fourier-transform lens. The incident plane wave front is than converged to a point by this Fourier-transform lens in its back focal plane P_0 on the optical axis. This plane P_0 is the plane in which a spatial filter is to be placed exactly coincident, to have better results.

A spatial filter such as a diffraction grating of high spatial frequency or a diffusing glass plate can be placed along various planes from P_1 to P_{-1} in the neighbourhood and on either side of the desired plane P_0. The diffraction pattern produced by the spatial filter is received on a screen placed at a convenient plane. However, the position of the screen is to be kept fixed during experimental observations or investigations.

3. Experiment

All the components of the optical system described above are mounted on an optical bench and the experiment is performed in a dark room. The stand, holding the spatial filter can slide on the optical bench by a micrometer screw arrangement. To locate the exact position of the back focal plane of the Fourier-transform lens, the filter is shifted from the plane P_1 to P_{-1}. The separation of maxima or minima of the diffraction pattern produced on the screen is observed for each position of the spatial filter. P_1 and P_{-1} are the arbitrary positions of the spatial filter on the optical bench. During the operations the filter is moved and the broadening of the diffraction pattern on the screen is observed. The maximum broadening confirms the exact spatial frequency plane. The position of the screen is fixed for a particular set of observations. The screen is always placed away from the spatial frequency plane in the positive direction. The position of the screen is arbitrary but it must remain fixed for a particular set of observations.

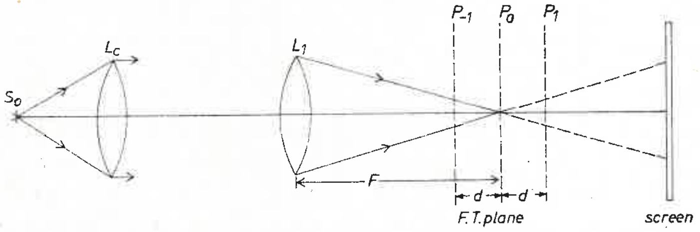


Fig. 1. Optical configuration used to search out the exact spatial frequency plane of the Fourier-transform lens

It is observed that the broadening of the diffraction pattern decreases as the spatial filter is moved either to P_1 or to P_{-1} from the plane P_0. The broadening is maximum only when the spatial filter exists in plane P_0 which is the required spatial frequency plane.

PLATE I

$d = +0\cdot2$ cm

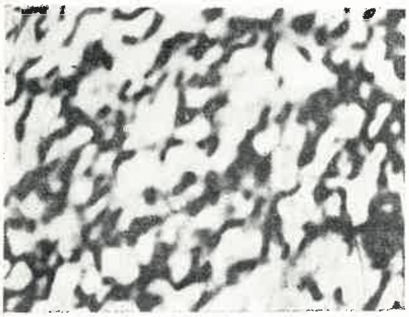
$d = +0\cdot1$ cm

$d = 0\cdot0$ cm

$d = -0\cdot1$ cm

$d = -0\cdot2$ cm

PLATE II

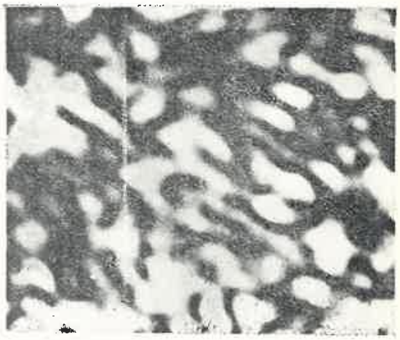


d = +0·2 cm

d = +0·1 cm

d = 0·0 cm

d = −0·1 cm



d = −0·2 cm

4. *Results*

A high spatial frequency grating and diffusing glass plate have been employed to search out the exact filtering plane.

The results of high spatial frequency grating are reproduced in plate No. I, and those of diffuser glass-plate in plate No. II. In each plate, the photographs of five diffraction patterns of the same magnification, formed at a certain fixed position of the screen (photographic-film), are reproduced.

The central photograph corresponds to the position of the spatial filter when maximum broadening occurs, the position of the spatial filter in this case is, therefore, taken as $d = 0.0$ cm (desired plane P_0). The two photographs above this correspond to $d = +0.2$ cm and $d = +0.1$ cm which means that the spatial filter is displaced on the right hand side of the exact back focal plane of the lens. The last two photographs below the central one correspond to $d = -0.1$ cm and $d = -0.2$ cm which indicate the displacement of the spatial filter on the opposite side.

An inspection of these photographs in each plate clearly shows that the separation of the fringes is the measure of spatial frequency plane.

The best advantage of this technique is that here the plane of the spatial filter itself locates the exact spatial frequency plane. Hence any error of longitudinal displacement of the spatial filter in the filtering plane is completely eliminated.

The intensity, if desired at these planes, can be easily calculated by using the Fresnel–Kirchhoff formula [5] or it can be measured by physical sensors.

The same technique may be applied to search out the exact back focal planes of gas lenses and holographic lenses.

We thank Prof. S. K. Chatterjee and Shri S. D. Mehta of Indian Institute of Science, Bangalore and Dr. V. P. Bhatnagar of Delhi College of Engineering (University of Delhi) for interesting discussions and suggestions. The first two authors are thankful for constant encouragement from Prof. P. G. Deo and Prof. Siddheshwar Lal of the University of Indore, during the progress of the work.

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