A planar optical system for generalised phase contrast imaging

Vincent Daria*, Jesper Glückstad*, Paul Mogensen*, René Eriksen*, Stefan Sinzinger

The generalised phase contrast (GPC) imaging technique is an enhanced approach primarily because it is not limited to small phase disturbances, as is the Zernike technique due to its first order approximation [1]. The essence of the GPC method is the analytic derivation of the exact working parameters where a phase disturbance at the input yields optimum amplitude contrast in the output [2]. The diameter of the circular input aperture has to match the spatial dimensions of the phase contrast filter (PCF) in the Fourier plane. Moreover, if the phase distribution at the input can be controlled, then optimisation can be achieved by dynamically encoding the phase distribution using a spatial light modulator. This approach, however, is useful when the filter parameters (spatial dimension and phase shifting property) are fixed or have restricted dynamic range. When applied to the sensing of unknown wavefront disturbances at the input, the filter parameters can be adjusted to get optimum visualisation of the phase disturbance at the input. The derivation of equations for choosing these parameters can be found in ref. [2] and the references therein. We have fabricated a planar optical system for GPC imaging. The systems corresponds to a 4f system with integrated phase filter (PCF). The reflective optical components are integrated on the top surface of a fused silica substrate (thickness 12 mm) while the bottom surface is reflection coated.

L1 and L2 were fabricated as 4 phase level diffractive lenses \( (D_l = 5 \text{ mm, } f/\# \approx 5) \). An incident laser beam \( (\lambda = 0.633 \mu m) \), is coupled into the substrate at an angle of 11.7° by a coupling grating. L1 focuses the beam to the PCF located in the Fourier plane. The PCF \( (\text{diameter } D_f = 5 \mu m) \) introduces a π-phase shift. The image plane is located on the coupling grating which couples the light out of the substrate.

![Fig. 1: Implementation of the GPC method in planar-integrated microoptics platform.](image)

We used a US Airforce resolution target phase mask as the input phase pattern. Fig. 2.a shows a low-contrast image achieved by detuning the alignment such that the PCF in the Fourier plane is ineffective. Phase contrast imaging, however, yields a high contrast image (Fig. 2.b).

![Fig. 2: Output image showing (a) low contrast image taken without the PCF and (b) high contrast image with PCF.](image)

The diameter of the input images is \( D_{ap} = 2.5 \text{ mm} \), which is not the optimum aperture diameter \( (D_{ap} \approx \frac{\lambda}{D_f} = 3.1 \text{ mm}) \) for maximum contrast or dark background. This is necessary to reduce corruption of the images due to interference from higher order diffracted beams generated by the binary coupling grating. This interference is manifested by the fringes at the boundary of the images in Figure 2.

*Optics and Fluid Dynamics Department, Risø National Laboratory, PO Box 49, DK-4000 Roskilde, Denmark.