

List of Figures

Fig 1. 1: A laser speckle pattern.....	5
Fig 1. 2: Geometries for the formation of objective and subjective speckle	5
Fig 1. 3: Several scattered fields $u_j(P)$, plotted in the complex plane with their respective random phases , contributing to the total field at point P , $U(P)$	7
Fig 1. 4: Normalized probability density function and probability that the intensity exceeds level for a polarized speckle pattern.....	8
Fig 1. 5: Schematic showing axial and lateral speckle size	10
 Fig 2. 1: Flow chart exhibiting the process of comparing the speckle pattern to obtain correlation coefficient values	23
 Fig 3. 1: Speckle-based sensor for low field Faraday rotation measurement	29
Fig 3. 2: Change in the speckle correlation coefficient as a function of time for reference speckle pattern (no applied field). Standard deviation determines the minimum measurable rotation, which in this case is 0.0025°	31
Fig 3. 3: Change in the speckle correlation coefficient (ΔC) versus the change in the strength of the applied magnetic field. Axis on top gives the corresponding rotation of the plane-polarized light. The straight line represents the linear fit to the measured values.	31
Fig 3. 4: Change in the speckle correlation coefficient (ΔC) for magnetic field variation from 0 to 26 G.....	32
Fig 3. 5: Rotation measurement with crossed polarizer-analyzer pair. The main figure shows the photodiode output as a function of the applied magnetic field. The inset shows the variation in the detector output in the shaded portion (low magnetic fields).....	33
Fig 3. 6: Change in the speckle correlation coefficient (ΔC) with time for different strengths of the applied magnetic field for a quartz rod with a 12-cm length. Note that the lines are equally spaced, which indicates a linear relationship between the variation in rotation and the strength of the magnetic field.....	34

Fig 3. 7: Measured Faraday rotation using change in the speckle correlation coefficient (for a rod of 12 cm length). Straight-line indicates values calculated theoretically. Triangles represent the error in measurement.....	35
Fig 3. 8: Measured Faraday rotations for small changes in the magnetic field (rod of 10-cm length). Note that the error in measurement has increased compared to Fig. 3.7	35
Fig 3. 9: Measured rotation using change in the speckle correlation coefficient for a quartz rod with a length of 15 cm using a cell phone camera as the speckle field detector.....	36
Fig 3. 10: Faraday Rotation Case1: Applied Magnetic field parallel to the direction of propagation of light. Case2: Applied Magnetic Field antiparallel to the direction of propagation of light. Optical Activity Case1: light entering the chamber containing optical active material from Side A and leaving from Side B. Case2: The light entering the chamber from Side B and leaving from Side A	40
Fig 3. 11: Experimental setup for the measurement of sugar concentrations. Solutions having different sugar concentrations were obtained by dissolving different masses of sugar in distilled water.....	43
Fig 3. 12: Recorded speckle patterns for different sugar concentrations. (a) 0g/ml (distilled water only), (b) 0.01g/ml, (c) 0.05g/ml and (d) 0.1g/ml. For each concentration 60 patterns at 30Hz were recorded for comparison with the reference pattern (pattern recorded with distilled water)	43
Fig 3. 13: Change in the correlation coefficient (ΔC) as a function of known sugar concentration. For each concentration, ten data sets were recorded. In the figure ♦ ♦ represent the mean of the DC obtained from all the data sets and - - - - represents the linear fit to the experimental data	44
Fig 3. 14: Results obtained using unknown concentrations and the calibration curve.....	45
Fig 3. 15: Change in the curvature of the wavefront striking the diffuser, with a change in the refractive index of the fluid inside the test chamber. $n_2 > n_1$, where n_2 and n_1 are the refractive indices of the test fluids inside the chamber.....	50

Fig 3. 16: Schematic of the technique used for the determination of change in refractive index	51
Fig 3. 17: (a) The 3D printed refractometer (b) the power supply assembly that provides the necessary voltage and current to the laser diode. (c) Top view of the device showing all major significant components.	51
Fig 3. 18: A speckle pattern recorded by the smartphone, when attached to the webcam of the refractometer with the help of a USB OTG	52
Fig 3. 19: (a) Simulated speckle pattern corresponding to water ($n = 1.333$). (b) Change in correlation coefficient with a change in refractive index in the case of simulated speckle patterns.	53
Fig 3. 20: Recorded speckle patterns for sugar solutions of different refractive indices. (a) $\Delta n = 0$ (distilled and de-ionized water) (b) $\Delta n = 0.0014$, (c) $\Delta n = 0.0029$, (d) $\Delta n = 0.0044$, (e) $\Delta n = 0.0058$ and (f) $\Delta n = 0.0073$	55
Fig 3. 21: (a) Time variation of the correlation coefficient after averaging over 7 measurements for each refractive index value. (b) Calibration curve: change in the speckle correlation coefficient (ΔC) with a change in refractive index.....	56
Fig 4. 1: Experimental configuration. The heating element was mounted on a translation stage	63
Fig 4. 2: Change in speckle correlation coefficient with time for heating element kept 1 mm away from the sensor head. Four regions are visible.....	64
Fig 4. 3: Change in speckle correlation with time for heating element while the steady temperature was kept at different distances from the sensor head. The inset in the figure shows the expanded version of the region inside the rectangle	66
Fig 4. 4: Slope of the ΔC versus ΔT during heating (saturation region is not considered).....	67
Fig 4. 5: Variation in the slope of C as a function of time. This can be used to determine the time it takes the sensor head to reach saturation.....	68
Fig 4. 6: Change in the time it takes the sensor head to yield saturation in the speckle correlation values as a function of the change in the temperature.....	68

Fig 4. 7: Experimental setup for measuring magnetic field without using the speckle correlation technique.....	72
Fig 4. 8: Movement of focused image on the photodiode when magnetic field varies	73
Fig 4. 9: Calibration curve giving the relation between the magnetic field and the output of the photodiode	74
Fig 4. 10: Cantilever action for one fixed and one open end.....	74
Fig 4. 11: Measured magnetic field along with percentage error	75
Fig 4. 12: The Schematic of the experimental setup for measuring the magnetic field	76
Fig 4. 13: Change in the speckle correlation coefficient (ΔC) for magnetic field variation from 15.6 mG to 312 mG in the step of 15.6 mG.....	78
Fig 4. 14: Correlation coefficient (a) Response time (b) Recovery time.....	79
Fig 4. 15: Variation in sensitivity with the applied magnetic field.....	79
Fig 4. 16: Change in correlation coefficient with number of frames for different values of magnetic fields oscillating at 0.5 Hz	81
Fig 4. 17: Change in correlation coefficient (ΔC) with number of frames for different values of magnetic fields oscillating a 1 Hz.....	83
4. 18: Change in correlation coefficient (ΔC) with number of frames for frequency of 2 Hz and 3 Hz	84
Fig 5. 1: Coordinate system for the numerical reconstruction process.....	89
Fig 5. 2: Single beam lens-less Fourier transform holography setup for investigation of phase objects	94
Fig 5. 3: (a) Hologram recorded using the setup in Fig. 1. (b) Area inside region of interest showing the holographic fringes.....	94
Fig 5. 4: Refractive index distribution inside axi-symmetric phase object. In axi-symmetric case, the refractive index depends only on the distance (r) from the axis of symmetry (in this case y-axis).....	96
Fig 5. 5: Phase contrast images of the refractive index distribution (a) wrapped phase distribution and (b) three-dimensional representation of the phase	

distribution obtained after unwrapping. Chord integrated phase profiles along the lines in (a), were Abel inverted to obtain the local refractive index values (which varies radially)	97
Fig 5. 6: Chord integrated phase profiles obtained from the reconstructed holograms at different positions in the flame. Left and right side of the distribution are color coded in red and blue respectively. They are individually used in Abel integral to obtain the refractive index distributions.....	98
Fig 5. 7: Radial distribution of refractive index inside the flame obtained after Abel inversion of the chord integrated data shown in Fig. 5.6a–f	99
Fig 5. 8: Histogram of path length fluctuation across the field of view. Inset shows the pathlength variation as a function of time.....	100
Fig 5. 9: (a)–(f) Spatiotemporal evolution of phase difference for a fused silica glass slab exposed to a heating rod. Each frame is separated in time by 10 s	100
Fig 5. 10: (a) Chord integrated phase values along the line shown in Fig. 8f. (b) Local values of refractive index change obtained after Abel inversion.....	101
Fig 5. 11: Thermal stressing of the sample using a heating rod	102
Fig 5. 12: Spatiotemporal evolution of probe beam phase under thermal stressing. This phase distribution is then used for imaging of defects in translucent materials	103
Fig 5. 13: Defect characterization by thermal stressing. (a) Unwrapped phase difference obtained by Goldstein branch cut method for the wrapped phase map at $t=150$ s (Fig. 11). (b) Numerical phase obtained by row wise least square fitting of unwrapped phase shown in (a) (c) Phase distribution due to defect obtained after subtracting the numerical phase obtained by least square fitting from the unwrapped phase. (d) Three-dimensional refractive index distribution of the defect obtained by Abel inversion of object phase shown inside the rectangle in (c).	104
Fig 5. 14: (a) Experimental setup of single beam Lens less Fourier transform DH Microscope, (b) fabrication of wavefront division element. It consists of a ground glass diffuser co-located with a pinhole.....	107

Fig 5. 15: Results obtained for a phase grating. (a) Reconstructed intensity profile at the diffuser plane and (b) Phase contrast image of the grating	108
Fig 5. 16: Computed optical thickness distribution of the grating obtained from the phase information. (a) 3D thickness profile and (b) cross-sectional thickness profile.....	109
Fig 5. 17: (a) Reconstructed intensity profile of a blood smear at diffuser plane, and (b) the phase contrast image of the rectangle shown in (a). (c) 3D thickness profile computed from the phase-contrast image.....	109
Fig 5. 18: Histogram of the path length fluctuation. The computed mean fluctuation was 1.24 nm.....	110
Fig 5. 19: Experimental results obtained for red blood cells using 100 microscopic objective (a) Intensity profile, (b) phase contrast image (c) 3D thickness profile and (d) cross-sectional thickness profile along the line shown in (b). (e) Temporal evolution of cell thickness at points shown in (b), mean and standard deviations of the thickness fluctuations are also given.....	111
Fig 6. 1: The Schematic of the experimental setup (a) Transmission mode for transparent object (b) Reflection mode for opaque/reflecting objects.....	120
Fig 6. 2: Experimental Setup shape measurement (a) Transmission mode for a positive achromatic lens (b) Reflection mode for a concave mirror.....	121
Fig 6. 3: Configuration used for simulation of speckle pattern corresponding to the test object at various axial positions	122
Fig 6. 4: Simulated speckle pattern for the object shown in Fig.6.3 at various distances from the diffuser (a) 30mm (b) 40mm (c) 50mm.....	122
Fig 6. 5: Variation in intensity of the simulated speckle pattern (a) In the lateral direction (b) In the axial direction	123
Fig 6. 6: Variation of SSE as a function of (a) Number of intensity samples (b) Number of iterations	123
Fig 6. 7: Simulation of two-wavelength contouring. (a) Object phase distribution at $\lambda_1=611\text{nm}$. (b) Object phase distribution at $\lambda_2=632\text{nm}$. (c) Phase difference (contour phase). (d) Inputted contour phase. (e) Shape quantified using synthetic	

wavelength. (f) Line profile of object shape (red dotted line is obtained from propagation)	125
Fig 6. 8: Recorded speckle pattern at different axial positions for $\lambda_1=611\text{nm}$. The positions of the axial planes from the diffuser are (a) 30mm, (b) 39mm, (c) 45mm	126
Fig 6. 9: Recorded speckle pattern at different axial positions for $\lambda_2=632\text{nm}$. The positions of the axial planes from the diffuser are (a) 30mm, (b) 39mm, (c) 45mm	126
Fig 6. 10: Reconstructed intensity patterns at different axial planes. The distance of the axial planes from the first sampling planes was (a) 5mm, (b) 30mm (best focus) (c) 45mm	127
Fig 6. 11: Phase maps obtained for numerical focusing distance over a single wavelength. Each axial plane is separated from the next plane by a distance of $\lambda/4$ ($\lambda=611\text{nm}$). The first plane is situated 30mm from the first sampling plane	127
Fig 6. 12: Phase maps at the best focus plane for (a) $\lambda_1=611\text{nm}$ and (b) $\lambda_2=632\text{nm}$	128
Fig 6. 13: (a) Phase difference ($\phi_1 - \phi_2$) (b) Phase difference inside the area of interest (c) Continuous phase distribution showing the aberrations in the wavefront.	128
Fig 6. 14: Iterative phase retrieval process for reflection mode (a) Phase maps at the best focus plane for $\lambda_1=611\text{nm}$, (b) Phase maps at the best focus plane for $\lambda_2=632\text{nm}$ (c) Phase difference ($\phi_1 - \phi_2$), (d) continuous phase distribution	129