Magnetic fluids (Ferrofluids and Ferrofluid emulsions) are stimulus responsive soft materials whose physical properties can be strongly modified by an external magnetic field. Such magnetic fluids have several important technological applications. Magnetic fluids undergo interesting structural changes under an external magnetic field. Various techniques such as small angle neutron scattering (SANS), small angle X-ray scattering (SAXS), visible wavelength light transmission, Monte Carlo simulation, molecular dynamics, stochastic and Brownian dynamics simulation have been employed to get insight into the aggregation dynamics in magnetic fluids. Magnetic fluids exhibit field-induced optical anisotropy in the presence of an external magnetic field, which leads to many extraordinary magneto-optical properties such as static magnetic birefringence and dichroism, magnetically tunable refractive index, photonic hall-effect, vanishing of forward and backward scattered light and negative refractivity.

Optical studies show that magnetic fluids are ideal materials to study the scattering phenomena in different optical regimes, as the scatterer size can be tuned from Rayleigh regime (scatterer size $<< \lambda$) to geometrical regime (scatterer size $>> \lambda$) via Mie regime (scatterer size $~ \lambda$) by varying the external magnetic field. The scatterer size increases with increasing external magnetic field due to aggregation of suspended nano-sized magnetic particles. The field induced aggregation in these systems is mainly due to the dipolar interaction between the dispersed nano-sized magnetic particles, which depends on the applied magnetic field strength and particle size.
Irrespective of several studies in the past, a complete understanding of field induced aggregation dynamics and associated magneto-optical properties in magnetic fluids is still lacking, which is important for practical applications. The main objective of this thesis work was to obtain better insights into the complex aggregation, disorder-order transitions, and the intriguing magneto-optical phenomena in magnetic fluids using the forward light scattering, backscattering, and absorption and speckle dynamics studies. The role of aggregation parameters such as suspended nanoparticle size, volume fraction and temperature on structural transitions and associated magneto-optical properties in magnetic fluids are investigated. The thesis consists of nine chapters. Chapter 1 gives a brief description of soft matter, stimulus responsive materials, magnetic fluids and its extraordinary physical properties and literature survey on the study of field induced structural transitions, motivation and objectives of the present work. Chapter 2 describes the details of the samples, characterization techniques, experimental setup and the procedure adopted for (i) capturing the scattered speckle patterns, (ii) measuring the transmitted, (iii) backscattered light intensity, (iv) absorption and (iv) speckle intensities as a function of magnetic field and time. Chapter 3 presents the study of magnetic field dependent behavior of transmitted light intensity and scattered pattern in ferrofluid and nanoemulsion. The resonances in the total extinction efficiency and the forward anisotropy factor due to the changes in the dimension of scatterers due to dipolar interactions and the changes in the surface roughness of the field induced aggregates contribute to the observed variations in the transmitted light intensity and the scattered patterns. Chapter 4 presents the study of transmitted light speckle pattern through ferrofluid and nanoemulsion in presence of an
external magnetic field. The linear increase in speckle contrast of transmitted light spot from ferrofluids in the presence of external magnetic field indicates a transformation from ‘dynamic’ to ‘fully developed’ speckle pattern due to the formation of chain-like structures by nano sized particles. The surface roughness of field induced aggregates is found to hamper the speckle pattern from being ‘fully developed’. The transmitted speckle correlation coefficient showed power law decay with external magnetic field. In nanoemulsion, the angular speckle correlation coefficient decays exponentially with measurement angles in the observation plane and the angular speckle correlation is found to be symmetric on either side of the transmitted bright spot. **Chapter 5** presents the study of the effect of applied magnetic field on the backscattered light intensity from a ferrofluid consisting of poly-acrylic acid coated Fe$_3$O$_4$ nanoparticles dispersed in water. The effect of applied magnetic field on the backscattering of light showed a continuous evolution of backscattered speckle pattern as a function of magnetic field strength. The speckle contrast is found to increase linearly with external magnetic field because of the evolution from highly dynamic to static scatterers in the dispersion. The backscattered light intensity is found to diminish with external magnetic field due to a delay of light propagation of standing waves in the scattering medium. **Chapter 6** presents the study of magnetic field dependent near infrared photon absorption in nanoemulsion. The absorption of near infrared photons is found to be dependent on the volume fraction and applied magnetic field because of the variation in the Mie absorption efficiency during the field induced structural transitions of emulsion droplets. The absorption increases linearly with the incident near infrared photon energy up to a certain external magnetic field. The imaginary part of the refractive index of...
nanoemulsion is found to vary with external magnetic field and sample volume fractions. After a critical magnetic field, the field induced absorption of near infrared photons decreases because of the increase in the aspect ratio of the chain like aggregates and inter-chain spacing. **Chapter 7** presents the study of the effect of hydrodynamic particle size on the magnetic field induced light transmission and transmitted speckle pattern in water based ferrofluids containing functionalized Fe$_3$O$_4$ nanoparticles. The transmitted light intensity starts decreasing above a certain magnetic field and becomes a minimum at another field and these two critical fields signify the onset of linear aggregation process and zippering transitions, respectively. Both these critical fields shift towards lower magnetic fields with increasing hydrodynamic diameter, due to stronger magnetic dipolar interaction. The onsets of chaining and zippering transitions were clearly evident from the time dependent transmitted light intensity. Above the first critical field, the lobe part of the transmitted intensity and the lobe speckle contrast values increase with increasing external magnetic field due to the reduced Brownian motion of field induced aggregates. The speckle contrast was the highest for the nanoparticle with the largest hydrodynamic diameter, due to reduced Brownian motion of particles. **Chapter 8** describes the temperature dependent light transmission study which shows that the rate of extinction of normalized transmitted light intensity linearly decreases with increasing specimen temperature, indicating a slower rate of field induced aggregation kinetics at higher specimen temperature due to enhanced Brownian motion of suspended particles. **Chapter 9** summarizes the results obtained, conclusions and future scopes.