Ferrites have been studied and applied for more than 50 years and are considered as materials with mature technologies ranging from hard magnets to magnetic recording and to microwave devices. However, the advances in applications and fabrication technologies in the recent years have been impressive. Bulk ferrites remain a key group of magnetic materials, while nanostructured ferrites show a dramatic promise for applications in even significantly wider fields. The present investigations performed on five different spinel ferrites, $\text{NiFe}_2\text{O}_4$, $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$, $\text{ZnFe}_2\text{O}_4$, $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$ and $\text{CoFe}_2\text{O}_4$ brought out the conclusions, which could address the most fundamental questions that is existing in the area of spinel nano ferrites.

The sol-gel method using PVA as the chelating agent was found to be an effective method for the synthesis of these compounds, within a particle size range below 10 nm. The molar weight ratio of PVA to total metal ions and the sintering temperature was found to have a significant influence on the crystallite size. The method is found to be very cost effective and useful for producing spinel ferrite powders with very high shelf life and remarkable thermal, physical and chemical stability. A remarkable control over the size of the nanoparticle is the most versatile advantage of this method.

Investigations on the magnetic properties of these nanosystems brought more light into the micro-level magnetic phenomena. All the systems, except cobalt ferrite show superparamagnetic behaviour at room temperature. The coexistence of a superparamagnetic doublet
and magnetically split sextet in the Mossbauer spectra of NiFe$_2$O$_4$, Ni$_{0.5}$Zn$_{0.5}$Fe$_2$O$_4$ and Ni$_{0.5}$Co$_{0.5}$Fe$_2$O$_4$ samples indicates that the samples have a broad distribution of particle sizes, both above and below the critical size of superparamagnetism. The saturation magnetization value of NiFe$_2$O$_4$ is found to be lower than that of bulk. This reduction is inferred as the effect of broken exchange bonds, high anisotropy layer on the surface or a loss of long-range order in the surface layer, which are arising as a natural consequence of the reduction of particle size. The magnetization curve of zinc ferrite traces an ‘S’ shape, which shows the tendency for saturation and a perfectly zero hysteresis behaviour with no coercivity, which indicates superparamagnetism. This phenomenon is explained by the manifestation of the variation in the basic normal spinel structure of ZnFe$_2$O$_4$ nanoparticles. The absence of superparamagnetism in CoFe$_2$O$_4$ nanoparticles can be explained by the high value of anisotropy constant of that system. All the investigated systems were found to possess a noncollinear, canted magnetic spin structure. These spin contributions are found to influence the overall magnetic behaviour of the systems. It is found that the reduced size not only influences the macroscopic magnetic property, but also the spin canting angle. The presence of more surface atoms and the variations in cationic distribution can contribute to the spin canting in these spinel ferrites. The spin canting in zinc ferrite can also have contributions from the competition between the antiferromagnetic and ferrimagnetic spins.

From the Rietveld refinement of the neutron diffraction data, it is found that crystal parameters and bond lengths are varying as the temperature goes from room temperature to 20 K. This change in the bond parameters will affect the superexchange interactions and thus, the magnetic moment values. The observation of coercivity and
saturation magnetization of Ni$_{0.5}$Zn$_{0.5}$Fe$_2$O$_4$ nanosystems with three different particle sizes clearly indicates its size dependence. The blocking temperature in ZFC-FC measurements is found to be shifted to higher temperatures with particle size, indicating the dependence of the onset of superparamagnetism on particle size.

All the investigated samples showed good optical limiting property. The obtained nonlinearity fits to a two-photon like absorption process. Except for NiFe$_2$O$_4$, the observed nonlinearity has contributions from excited state absorption, which can be explained in terms of the bandgap values of these samples. The optical limiting response is also studied against particle size and the nonlinearity is found to increase with particle size within the range of our investigations. On comparing the optical limiting properties, ZnFe$_2$O$_4$ is found to be a better candidate for the optical limiting applications. This can be explained on the basis of polarization effects, which depends on the number of Fe$^{3+}$ ions in the octahedral sites.

The results obtained in these investigations are opening up a lot of new possibilities of technological applications with these spinel ferrites. The biological or electronic compatibility of these powders can be achieved by making silica composites of these powders. Layered samples of these ferrites with piezoelectric oxides can lead to a new generation of magnetic field sensors. These ferrites and piezoelectric ceramics can be combined to develop good quality magnetoelectric composites. The elastic coupling interaction between the magnetostrictive phase and piezoelectric phase leads to a giant magnetoelectric response in these magnetoelectric composites. Nanostructured composite thin films of these materials and ferroelectric oxides can also be developed for multiferroic applications. Such multiferroic nano-structures will be a promise to
the potential applications of magnetoelectric composites in microelectronic devices.

Besides the application in the conventional areas, such as inductors, high frequency, power and electromagnetic interface suppression, the special properties associated with these materials can also be utilized in various biotechnological applications. These magnetic nanoparticles can be used to guide radionuclide to specific tissues. These materials, which have superparamagnetic behaviour at room temperature can be used in magnetic resonance imaging applications since they can selectively associate with healthy regions of some tissues and their proton decay rate can produce contrast difference in the image. Spinel ferrite nanoparticles in combination with carbon nano tubes can efficiently absorb microwave radiation. Thermal energy from hysteresis loss of ferrites can be used in hyperthermia, that is, the heating of specific tissues or organs for treatment of cancer. The development of thin films of nanoparticle embedded polymers can be used for optical nonlinear applications. Spinel ferrite nanoparticles can also be used in a variety of advanced applications such as modification, detection, isolation and study of cells and isolation of biologically active compounds. Thus, future scope of these investigations is related with reorganising these materials compatible for advanced applications.