Nonlinear phase accumulation of the resultant optical field for a linear phase delay between interfering fields

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Abstract

This thesis investigates the new realms of phase of superposed in interferometry. In optical metrology, the phase difference between interfering fields is analyzed through the recorded intensity, interferogram. We go further one step ahead, to comprehend the phase of superposed field and its variation with respect to the phase difference between interfering fields. In many amplified sensing schemes such as weak measurements and spectral switches, out-of-phase interference or the orthogonal projection of the field is shown to induce large shifts in the centroid of the measured intensity distributions. The associated singularity results in a nonlinear phase accumulation in the resultant field for a finite phase change between interfering fields. This hints that the detection of phase of superposed field can have potential application in sensing phase differences. Followed by a brief theoretical formulation associated with phase of superposed field, we demonstrate the concept using a modified Michelson interferometer. The phase shift introduced by one of the beams in a tilted three-beam interference is shown to induce amplification in the phase of two-beam interference when measured with respect to the third beam acting as reference. To overcome the stringent stability requirement for the reference beam, our focus of investigation shifts to common path interferometry employing devices like spatial light modulators, which are capable of producing three-beam interference through computer-generated holograms. The three-beam interference of sample field with two tilted and phase conjugated reference fields is shown to not only introduce nonlinearity in the phase of superposed, but also double the phase change for the sample with respect to reference fields. The phase of superposed field exhibiting nonlinearity is extended to the low coherence interferometry. Nonlinearity in the accumulation of spectral phase of two-beam spectral interference as a function of path delay is experimentally demonstrated. The effect of dispersion is also analyzed for characterization of experimental conditions. A topological representation of phase of spectral interference as a function of path delay sheds light on the dynamics of associated line singularities. We explore the possibility of modifying the topology in order to transform line singularities to point singularities viz. spectral vortices. In short, in this thesis, we explore harnessing the nonlinear behaviour of phase associated with interference for enhancing the phase sensing capabilities in optical metrology.