Chapter 7

Conclusions

CP violation studies are important from the point of view of cosmology as well as for a complete understanding of particle interactions. The scope of observational effects of the violation of CP symmetry is limited within SM. The only system in which CP violation has been observed is the K-meson system. The B-meson system offers another place to study this effect in the coming years. At the same time SM, though highly successful, is not considered to be the ultimate theory. Due to various reasons, many models have been considered which lie outside the regime of SM. In the thesis we have constructed ways to observe CP violation in particle colliders taking into account effects beyond SM.

Our studies mainly concentrate on CP violation effects arising due to the top quark weak and electric dipole form factors. In the previous chapters we studied some of the CP-violating asymmetries, obtained using an effective Lagrangian with complex dipole coupling, which could be tested in the next generation linear colliders. These asymmetries were constructed out of the final state momenta. Apart from the process, $e^+e^- \rightarrow t\bar{t}$ we have looked at the top-antitop quark pair production in photon-photon collisions. Apart from the effective Lagrangian method, we have
considered a scenario were scalar leptoquarks, whose coupling with lepton and quark could be in general complex, couple with \( \tau \) and \( t \) with the effect of giving a large dipole moment to these fermions at one loop order.

The main results of our studies and the conclusions drawn from them are the following. The four parameters studied are the real and the imaginary parts of the electric and the weak dipole form factors of the top quark. Different asymmetries which could be observed in the \( \ell \ell \) pair production in \( e^+e^- \) collisions are described in Chapter 2. At a c.m. energy of 500 GeV, and at an integrated luminosity of \( 10 \, fb^{-1} \), our calculations show that the asymmetries will be observable if the dipole form factors are of the order of \( 10^{-18} \) e cm. This may be compared with the model predictions which are mostly two orders of magnitude lower than this value. We have considered electron beam polarization effects and found that longitudinal polarization improves the sensitivity of the experiment. Our calculations are done at 50% \( e^- \)-beam polarization with unpolarized \( e^+ \)-beam. The improvement in sensitivity with this polarization over the unpolarized case is sometimes an order of magnitude. Considering the fact that a large longitudinal polarization is likely to be available in linear colliders, we expect to obtain better sensitivity. Again, the expectation is that higher luminosity will be possible in the future colliders. This factor will improve the sensitivity further.

In Chapter 3 we have considered asymmetries which do not depend on the top quark momentum. Experimentally this is preferable as compared to the asymmetries described in Chapter 2 because the reconstruction of the top quark momentum is not required in this case and higher efficiency can be expected. Limits on dipole form factors are similar to those obtained in Chapter 2.

Possible background to the above asymmetries arising from the helicity-flip collinear
photon emission from the initial state are considered in Chapter 4. Our calculations show that in case of charge asymmetry and the forward-backward asymmetry combined with the charge asymmetry, described in Chapter 3, the background from initial state radiation is almost two orders of magnitude smaller than the statistical fluctuation at $\sqrt{s} = 500$ GeV and $f \mathcal{L} = 10 \ fb^{-1}$. The result is similar for different beam polarizations. T-odd asymmetries like the up-down asymmetry described in Chapter 2 do not have a background from this process as it requires absorptive part for non-zero background whereas the interaction is a tree-level process.

Photon Linear Colliders provide another place to look for $t \bar{t}$ production and hence $C\bar{P}$ violation effects due to top quark dipole moment. Chapter 5 of the thesis describes the charge asymmetry and the combined asymmetry in the process $\gamma \gamma \rightarrow t \bar{t}$. At an electron beam energy of 250 GeV and laser beam energy of 1.24 eV EDFF of top quark obtained is of the order of $10^{-16}$ e cm. Charge asymmetry measured with a cut-off angle of around 60° gives better limits than other cut-off angles. On the other hand, the combined asymmetry seems to give better limits at smaller cut-offs. Beam energy around 500 GeV gives better sensitivity for the combined asymmetry while for charge asymmetry the sensitivity peaks at a higher beam energy. The above results are with opposite helicity combination of electron beam helicities and laser beam helicities with the product of corresponding electron-beam and laser-beam helicities kept to be -1/2. Looking at the variation with $x$ values, it is seen that larger $x$ gives better limit. Our calculations are done at a geometrical luminosity of the electron-electron collider of $20 \ fb^{-1}$. Increase in the luminosity will improve the limits.

Apart from these asymmetries obtained from an effective lagrangian study of the
processes $e^+ e^- \rightarrow t\bar{t}$ and $\gamma\gamma \rightarrow t\bar{t}$, we have considered in this thesis (Chapter 6) the one loop effects on the $t\bar{t}\gamma(Z)$ vertex. For leptoquark masses of a few hundred GeV and unit coupling constant the electric dipole form factor of tau lepton (both real and imaginary parts) is found to be of the order of $10^{-18}$ $e\, cm$ whereas the weak dipole form factors are an order smaller than this. In the case of top quark these are of the order of $10^{-20}$ $e\, cm$ and $10^{-21}$ $e\, cm$ respectively. To accommodate the constraints on masses and couplings of leptoquarks obtained from LEP results by Eboli [60] the EDFF of tau lepton should be of the order $10^{-19}$ $e\, cm$ up to a mass range of up to .5 TeV and above this the EDFF should be an order or magnitude less. Mass-coupling countours are obtained for different values of the real and the imaginary parts of both EDFF and WDFF of the top quark and the tau lepton. Best limits on mass and coupling obtained is from the experimental bound on the real part of the weak dipole moment of the tau lepton.