CHAPTER 1

INTRODUCTION

I.I AIM OF THE THESIS

There are two central objectives behind the present thesis. They are (A) a general exposition of the behaviour of Bloch electrons in a uniform electric field, and (B) a study of several issues relevant to what is called 'Wannier Stark Ladders' — the phenomenon characterising one special feature of Bloch electrons in presence of a uniform electric field. The investigation in regard to the objective (A) is carried out by taking recourse to an exhaustive and critical review of the literatures concerned with the behaviour of Bloch electrons in an electric field. This review covers the area since 1928, the year in which the first study regarding the effect of an electric field on the Bloch electrons was published [reference 4] by F. Bloch himself ; we will discuss later (chapter 2) how the just-mentioned work of Bloch gave rise to what is known in literatures as the " Bloch's acceleration Theorem" . Among other things, the review displays coherently the successes and limitations of the various approaches developed for the purpose of studying how the Bloch electrons would behave in presence of a uniform electric field, and surveys lucidly the phenomena connected with the effects of uniform electric fields on Bloch electrons.

The part of the thesis dealing with the objective (B) is based on our own investigations of several aspects

of Wannier Stark Ladders — the phenomenon which was predicted in a mathematically straightforward way by Wannier in 1960 [the reference 5]. A substantial portion of our investigations in regard to the Stark Ladders is dependent on the use of certain forms of EVOLUTION OPERATORS , which we have ourselves derived for the purposes; we have shown, in particular, how the approach of 'evolution operator' provides a unified basis for studying diverse facets of the Bloch electrons in presence of uniform electric fields. Some of our works on Stark Ladders (SL) are based on NUMERICAL METHODS and the TIGHT BINDING APPROXIMATION (TBA) . Our studies of various issues related to the Stark Ladders, have led to several interesting and fruitful results. Some of our results have proved to be useful in resolving many (rather) long-standing controversies in respect of the Stark Ladders, while some others have exposed new features of the phenomenon of Stark Ladders. The detailed discussion of the multifarious findings of ours, is given at appropriate places in the thesis.

It is worthwhile to put in the 'INTRODUCTORY CHAPTER' a brief description of how we have presented the materials of our thesis and this we do in the next section.

I.II PRESENTATION OF THE INVESTIGATIONS OF THE THESIS

The thesis contains seven chapters (including the present one), six appendices and, of course, the Bibliography.

The chapter 2 is a critical review of the works relevant to the Bloch electrons in an electric field during the period 1928 - 1959 ; this period begins with the year of appearance of the " Bloch's acceleration theorem" , and spreads upto the year just prior to the publication of Wannier's prediction of Stark Ladders.

The chapter 3 reports our development of the form of the evolution operator $\mathcal{L}$ denoted as $U_E(t,o)$ in the text $\mathcal{J}$ for Bloch electrons in presence of ONLY an electric field ; this chapter further deals with an application of the evolution operator $U_E(t,o)$ to (i) an elucidation of Houston's wave function, (ii) an exposition of the perspectives of Bloch's acceleration theorem, (iii) a study of the energy spectrum of Bloch electrons in infinite crystals in a uniform electric field and, hence, an exploration of Stark Ladders in INFINITE crystals, and (iv) an analysis of Zener tunnelling.

The chapters4 and 5 , report our investigations of the energy spectrum of Bloch electrons in FINITE CRYSTALS in presence of a uniform electric field. The chapter 4 is based on the use of the TBA, while the chapter 5 is dependent on a numerical approach.

The chapter 6 is concerned with our study of the optical absorption by Bloch electrons in presence of a uniform electric field. Finally, the chapter 7 deals with our

investigation of the electrical conduction in semiconductors, specially under the conditions which favour the occurrence of Stark Ladders. The approaches used in both the chapters 6 and 7 , are dependent on certain forms of EVOLUTION OPERATORS which are obtained by augmenting appropriately the evolution operator $U_E(t,o)$. The studies of both the chapters 6 and 7 elucidate, among many other things, how we should be able to demonstrate experimentally the occurrence of Stark Ladders.

Besides what we have stated in the preceeding four paragraphs about the involvements of the chapters 2-7 , they include the reviews of relevant literatures, the exposure of the motivations behind the choices of the aspects of our investigation, and a critical discussion of the findings yielded by our studies.

The appendices are connected with the detailed proofs of certain results used in the chapters 3-7 . The appendix 1 is concerned with the chapter 3, appendix 2 with the chapter 4, appendix 3 with the chapters 4 and 5, appendix 4 with the chapter 6, and appendices 5 and 6 are related to the chapter 7 .

I.III PUBLICATIONS

On the basis of a very large fraction of our works reported in the thesis, we have published quite a few papers in professional journals of well-established standing.