lattices having a semi-elliptic DOS for $Z \to \infty$ (cf. Sec. 2.2) and present formalism and results for several possible choices. We will demonstrate why some approaches fail to describe coherent transport and that the extended-hopping general-dispersion approach proposed in Sec. 2.3 produces the physically most desirable results.

As indicated above, the numerical results of this chapter correspond to a consistent theory which is exact in $d = \infty$. We will also point out how one may alternatively use the formalism as a local approximation in finite dimensions, e.g., in connection with LDA calculations (cf. subsection 5.4.3). We will not, however, discuss vertex corrections which may change the picture completely in $d = 3$ or even lower dimensions.

The remainder of this chapter is structured as follows: In Sec. 4.1, we introduce $\sigma(\omega)$ and other dielectric quantities on a phenomenological level, collect relevant sum rules, point out the relation to experimental results, and discuss the impact of model abstractions. The Kubo formalism is reviewed in Sec. 4.2 both for continuum and lattice models. The simplifications arising in $d \to \infty$ are discussed in Sec. 4.3 where we will also point out that the formalism widely used in the literature so far is very specific to the hypercubic lattice and must be modified in the general case. Variants of the general formalism applicable to tight-binding models with a semi-elliptic density of states are studied in Sec. 4.4. Generalizations to models with varying degree of coherence and to finite dimensions as well as the theory of transport properties for frustrated lattices with $t - t'$ hopping are discussed in Sec. 4.5. Finally, we present numerical results for the Hubbard model with semi-elliptic DOS in Sec. 4.6.

4.1 Definition and General Properties of the Optical Conductivity

If a system is subjected to an external electric field then, in general, a redistribution of charges occurs and currents are induced. For small enough fields, the induced polarization and the induced currents are proportional to the inducing field. If the Hamiltonian of the unperturbed system is not explicitly time-dependent, we have specifically for the total current density in linear response,

$$J_\alpha(\boldsymbol{r}, t) = \sum_\beta \int \mathrm{d}\boldsymbol{r}' \int_{-\infty}^{t} \mathrm{d}t' \, \sigma_{\alpha\beta}(\boldsymbol{r}, \boldsymbol{r}', t - t') E_\beta(\boldsymbol{r}', t'), \tag{4.2}$$

where α, β label space directions and $\boldsymbol{E}$ is the (total) electric field. If the system is homogeneous above some length scale a (e.g., for a lattice spacing a), then the response to perturbations which are slowly varying on this length scale is also homogeneous,

$$J_\alpha(\boldsymbol{r}, t) = \sum_\beta \int \mathrm{d}\boldsymbol{r}' \int_{-\infty}^{t} \mathrm{d}t' \, \sigma_{\alpha\beta}(\boldsymbol{r} - \boldsymbol{r}', t - t') E_\beta(\boldsymbol{r}', t'), \tag{4.3}$$