or ferrimagnetic material, in which a static magnetization $\boldsymbol{M}_0$ exists, the properties of the medium at an optical frequency are dependent on $\boldsymbol{M}_0$. Then, instead of (7.4) and (7.5), we have

$$\mathbf{P}(\omega, \boldsymbol{M}_0) = \epsilon_0 \boldsymbol{\chi}(\omega, \boldsymbol{M}_0) \cdot \mathbf{E}(\omega) = \epsilon_0 \boldsymbol{\chi}(\omega) \cdot \mathbf{E}(\omega) + \epsilon_0 \Delta \boldsymbol{\chi}(\omega, \boldsymbol{M}_0) \cdot \mathbf{E}(\omega) \tag{7.6}$$

and

$$\mathbf{D}(\omega, \boldsymbol{M}_0) = \boldsymbol{\epsilon}(\omega, \boldsymbol{M}_0) \cdot \mathbf{E}(\omega) = \boldsymbol{\epsilon}(\omega) \cdot \mathbf{E}(\omega) + \Delta \boldsymbol{\epsilon}(\omega, \boldsymbol{M}_0) \cdot \mathbf{E}(\omega). \tag{7.7}$$

While $\boldsymbol{\chi}$ and $\boldsymbol{\epsilon}$ are changed in the presence of $\boldsymbol{H}_0$ or $\boldsymbol{M}_0$, the magnetic permeability of the material at an optical frequency remains the constant μ_0, and the relation between $\mathbf{B}(\omega)$ and $\mathbf{H}(\omega)$ remains independent of $\boldsymbol{H}_0$ or $\boldsymbol{M}_0$:

$$\mathbf{B}(\omega) = \mu_0 \mathbf{H}(\omega). \tag{7.8}$$

Therefore, magneto-optic effects are completely characterized by $\boldsymbol{\epsilon}(\omega, \boldsymbol{H}_0)$, if no internal magnetization is present, or by $\boldsymbol{\epsilon}(\omega, \boldsymbol{M}_0)$, if an internal magnetization is present. In general, these effects are weak perturbations to the optical properties of the material. The *first-order, or linear, magneto-optic effect* is characterized by a linear dependence of $\boldsymbol{\epsilon}$ on $\boldsymbol{H}_0$ or $\boldsymbol{M}_0$, and the *second-order, or quadratic, magneto-optic effect* results from a quadratic dependence of $\boldsymbol{\epsilon}$ on $\boldsymbol{H}_0$ or $\boldsymbol{M}_0$. Note that like electro-optic effects, both first- and second-order magneto-optic effects are nonlinear optical effects.

The general description of magneto-optic effects in terms of $\boldsymbol{\epsilon}(\omega, \boldsymbol{H}_0)$ or $\boldsymbol{\epsilon}(\omega, \boldsymbol{M}_0)$ is analogous to the general description of electro-optic effects in terms of $\boldsymbol{\epsilon}(\omega, \boldsymbol{E}_0)$. The classification of first- and second-order magneto-optic effects is also analogous to that of first- and second-order electro-optic effects. However, there are many important fundamental differences between magneto-optic and electro-optic effects. These differences originate from basic distinctions in the electric and the magnetic characteristics of materials and are mostly tied to the fact that electric and magnetic fields follow different rules of transformation under space inversion and time reversal, as described in Section 1.1. The major differences and their implications are summarized below.

1. **Space-inversion symmetry.** Materials with the space-inversion symmetry are centrosymmetric. In such materials, no spontaneous electric polarization can exist, and the first-order electro-optic effect also vanishes. However, *neither a spontaneous magnetization nor the first-order magneto-optic effect is not forbidden in a centrosymmetric material*. This difference is due to the fact that under space inversion, the polar vectors **P** and **E** change sign, but the axial vectors **M** and **H** do not. Therefore, amorphous solids can be ferromagnetic or ferrimagnetic but cannot be ferroelectric. The first-order magneto-optic effect appears in gases and liquids, as well as in amorphous solids and nonpolar cubic crystals, where the Pockels effect does not exist.