Diffraction of light by a narrow beam of high-frequency sound is called Brillouin scattering after the man who predicted it in 1922. If the sound beam is wide enough and the light incident upon it is at the appropriate angle, the diffraction which then takes place is most generally referred to as Bragg diffraction in analogy to the selective reflection of X rays by the lattice planes of crystals first described by W.H. Bragg in 1913. The ultrasonic phenomenon was verified experimentally in 1932 by P. Debye and F.W. Sears in the U.S.A. and by R. Lucas and P. Biquard in France.

Prior to the invention of the laser, this phenomenon generated interest mainly in the academic community. But it did have a few practical applications such as determining the velocity of sound, modulating the intensity and phase of light, imaging acoustic fields, correlating signals on optical beams, and analyzing spectra instantaneously. The advent of coherent light and the advances in high-frequency acoustics stimulated new interest in this field as its potential for new applications was recognized. Examples of these new applications include the visualizing of internal body structures for medical diagnosis; the nondestructive testing of materials; the modulating, detecting and frequency-shifting of light; the processing of signals; the probing of acoustic fields; and the convolving, pulse compressing, high-speed multi-port beam switching, time multiplexing and demultiplexing of optical pulse trains.

This chapter presents a tutorial review of the nature of bulk-wave acousto-optic Bragg diffraction and gives a number of applications. Since many of the physical concepts and the analytical approaches of bulk-wave acousto-optic Bragg diffraction are also applicable to guided-wave Bragg diffraction, this chapter also serves as an introduction to subsequent chapters. The first section describes a simple experiment which conveys a qualitative perspective of how Bragg diffraction works. The second section briefly reviews the history of the investigation of light-sound interaction which has led up to the development of Bragg diffraction and its many applications. The third section gives a heuristic picture of what
takes place in Bragg diffraction. Such a picture is helpful in understand­
ing the nature of the phenomenon and can be used effectively as a means
of arriving at correct notions and relationships.

Bragg diffraction of light from sound can be looked at from the
point of view of parametric excitation, and the fourth section does just
that. A closely related but independent point of view is that obtained
from quantum mechanics, and the fifth section describes Bragg diffrac­
tion in terms of photon-phonon interaction. The most rigorous analysis of
the phenomenon presented in this chapter comes in the sixth section on
wave theory. A sample calculation of Bragg diffraction effects is given in
Sect.2.7.

Up to that point, the considerations have involved only conventional
Bragg diffraction in which the incident light and the scattered light show
up on opposite sides of the region occupied by the sound. This is the
transmission case. However, an important case of interaction exists in
which the incident and the scattered light both appear on the same side of
the sound region. This, of course, is the reflection case and is described in
Sect.2.8.

In all of the preceding sections, the acousto-optic interaction has
been assumed to occur in such a way that the diffraction process does not
change the polarization of the light being diffracted. Birefringence there­
fore plays no part in any of the effects thus far considered. However,
Bragg diffraction may occur in an anisotropic medium. When this is the
case, birefringence is a factor and the phenomenon is more complicated.
Section 2.9 treats birefringent Bragg diffraction.

The question of what the proper combinations of material parameters
are for optimum device performance is considered next. What characteris­
tics should a good acousto-optic material possess? This subject is treated
in Sect.10.

From all of these considerations certain conclusions become apparent
and are presented in Sect.2.11.

2.1 A Simple Experiment

It is easy to perform an experiment that will tell a great deal about the
interaction between light and sound, and the acousto-optic phenomenon
known as Bragg diffraction. Take a box with transparent sides and fill it
with water. Locate an ultrasonic transducer at one end, as shown in Fig.
2.1. Place an anechoic wall at the other end. Feed electrical power to the
transducer and generate longitudinal compression waves in the water.
These are acoustic waves which will travel through the water to be ab­
sorbed at the opposite end of the box by the anechoic wall.

Drive the transducer at a frequency of several Megahertz. Since
acoustic waves propagate in water with a velocity of about 1500 meters
per second, their wavelength \( \lambda \) will be 1500/f meters, \( f \) being the ultra­
sonic frequency. The variations in compression in the water produce a