The fundamental principles of charged particle beam dynamics as discussed in previous chapters can be applied to almost every beam transport need. Focusing and bending devices for charged particles are based on magnetic or electric fields which are specified and designed in such a way as to allow the application of fundamental principles of beam optics leading to predictable results.

Beam transport systems can be categorized into two classes: The first group is that of beam transport lines which are designed to guide charged particle beams from point A to point B. In the second class we find beam transport systems or magnet lattices used in circular accelerators. The physics of beam optics is the same in both cases but in the design of actual solutions different boundary conditions may become necessary. Basic linear building blocks in a beam transport line are the beam deflecting bending magnets, quadrupoles to focus the particle beam, and field free drift spaces between magnets. The transformation matrices for all three types of elements have been derived in Chap. 5 and we will apply these results to compose more complicated beam transport systems. The arrangement of magnets along the desired beam path is called the magnet lattice or short the lattice.

Beam transport lines can be made up of an irregular array of magnets or a repetitive sequence of a special magnet arrangement. Such a repetitive magnet sequence is called a periodic magnet lattice and if the magnet arrangement within one period is symmetric this lattice is called a symmetric magnet lattice. By definition a circular accelerator lattice is a periodic lattice with the circumference being the period length. To simplify the design and theoretical understanding of beam dynamics it is customary, however, to segment the full circumference of a circular accelerator into sectors which are repeated a number of times to form the complete ring. Such sectors are called superperiods and include usually all salient features of the accelerator in contrast to much smaller periodic segments called cells which include only a few magnets.

In this chapter we will concentrate on the study of periodic focusing structures. For long beam transport lines and specifically for circular accelerators it is prudent to consider focusing structures that repeat periodically. In this case one can apply beam dynamics properties of one periodic lattice structure as many times as necessary with known characteristics. In circular
particle accelerators such periodic focusing structures not only simplify the
determination of beam optics properties in a single turn but we will also
be able to predict the stability criteria for particles orbiting an indefinite
number of revolutions around the ring.

To achieve focusing in both planes we will have to use both focusing
and defocusing quadrupoles in a periodic sequence such that we can repeat
a lattice period any number of times to form an arbitrary long beam line
which provides the desired focusing in both planes.

6.1 FODO Lattice

The most simple periodic lattice would be a sequence of equidistant fo­
cusing quadrupoles of equal strength. This arrangement is unrealistic with
magnetic quadrupole fields which do not focus in both the horizontal and
vertical plane in the same magnet. The most simple and realistic compro­
mise is therefore a periodic lattice like the symmetric quadrupole triplet
which was discussed in Sect. 5.2. This focusing structure is composed of
alternating focusing and defocusing quadrupoles as shown in Fig. 6.1.

![Fig. 6.1. FODO - lattice (QF: focusing quadrupole; QD: defocusing quadrupole)](image)

Each half of such a lattice period is composed of a focusing (F) and a
defocusing (D) quadrupole with a drift space (O) in between. Combining
such a sequence with its mirror image as shown in Fig. 6.1 results in a
periodic lattice which is called a *FODO lattice* or a *FODO channel*. By
starting the period in the middle of a quadrupole and continuing to the
middle of the next quadrupole of the same sign not only a periodic lattice
but also a symmetric lattice is defined. Such an elementary unit of focusing
is called a *lattice unit* or in this case a *FODO cell*. The FODO lattice is
the most widely used lattice in accelerator systems because of its simplicity,
flexibility, and its beam dynamical stability.