5. Experimental Examples

In this manual, six experiments are introduced at present. Users may perform more experiments by adding appropriate accessories.

1) Reflection experiment

An electromagnetic wave in propagation will be reflected when encountering an obstacle. Here, a metal plate is used as an obstacle to study the reflection law of an electromagnetic wave at a certain incident angle, i.e. a) the reflected ray is within the plane determined by the incident ray and the normal line at the incident point, 2) the reflected ray and the incident ray are located at the two sides of the normal line, and 3) the reflection angle is equal to the incident angle.

Figure 3 Setup of reflection experiment

As shown in Figure 3, the two horns initially should face each other with their axes located in a common line. The two pointers which indicate the angles of the two horns should indicate at 90° marks of the indexing disk, respectively. Place the support of the reflection plate onto the platform, and use the positioning pin and the carved line of the platform to align the support. Then use the four pressure knobs (with springs inside, pull to lift) on the platform to fix the support.

Place the metal reflection plate onto the support. Align the plane of the plate with the 90° line on the platform. Now, the 0° line of the platform is consistent with the normal line of the metal plate.

Rotate the platform and let the pointer of the fixed arm indicate at a certain angle, which is the incident angle of the electromagnetic wave. Then rotate the movable arm to find the angle where the micro-current meter reading maximizes. This angle is the reflection angle. If the reading is too large or too small, adjust the attenuator to make the meter reading close to a full scale. It is suggested to use an angle between 30° and 65° as the incident angle in order to avoid receiving direct microwave signal from the transmitter.

2) Single slit diffraction

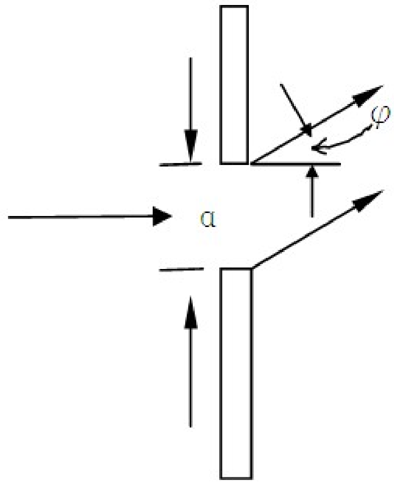

Figure 4 Schematic of single slit diffraction

As shown in Figure 4, when a plane microwave is incident to a slit of width comparable to the wavelength of the microwave, diffraction phenomenon occurs. The diffracted intensity distribution behind the slit is not uniform, i.e. the strongest and widest order is at the central region. The intensity reduces rapidly on either side of the central diffraction order, until the emergence of minimized diffraction intensity, which is the first minima order with the diffraction angle satisfying $\phi=\sin^{-1}(\lambda/a)$, where λ is the wavelength of the microwave, and *a* is the slit width. As the diffraction angle increases, diffraction intensity gradually increases until the first maxima order emerges with a diffraction angle of $\phi = \sin^{-1}\left(\frac{3}{2} \bullet \frac{\lambda}{\alpha}\right)$.

As shown in Figure 5, place the diffraction plate (single slit with slit width preset at a fixed value, e.g. 4 cm) onto the support and align its plane with the carved line on the support. Then place the support onto the platform with the carved line along with the 90° line of the platform. Rotate the platform to let the pointer of the fixed arm indicate at 180°. Now, the direction of the normal line of the diffraction plate is at 0°.

Adjust signal intensity to make the micro-current meter close to full scale. Then, rotate the movable arm at each side of the slit with a step of 1° starting from diffraction angle 0° while recording meter reading at each angle. Plot the relationship curve between diffraction intensity and diffraction angle.

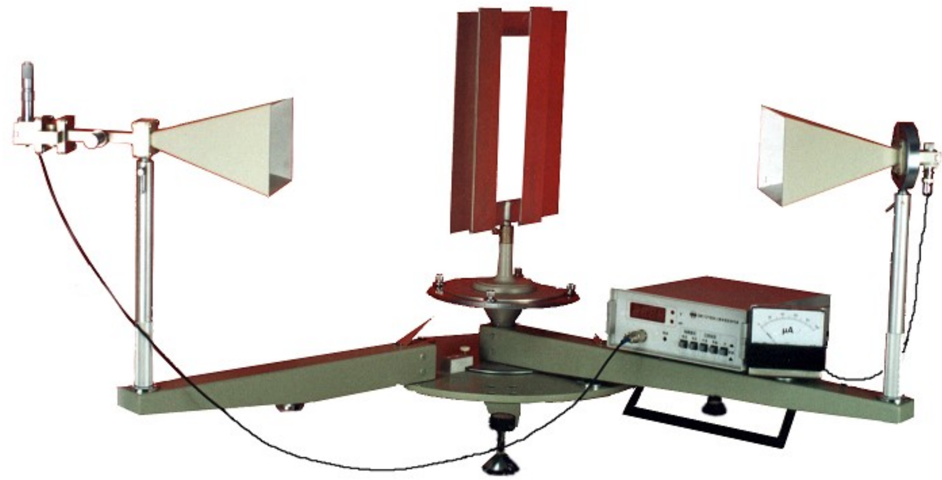

Figure 5 Setup of single slit diffraction

Calculate the diffraction angles of the first minima and the first maxima orders from the microwave wavelength and slit width. Compare the calculated values with the experimental values. Note, the central region of the experimental curve flattens or even slightly sags, this may be due to the diffraction plate not big enough.

3) Double-slit diffraction

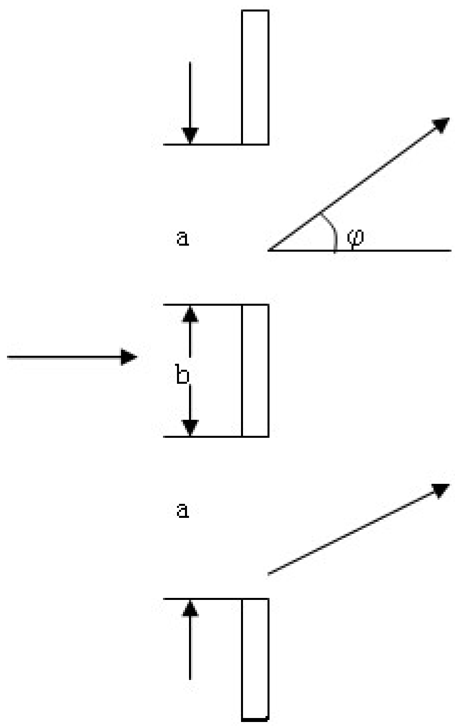

Figure 6 Schematic of double-slit diffraction

As shown in Figure 6, when a plane microwave is vertically incident on a metal plate with two narrow slits, with each slit being a secondary wave source. The two secondary sources will generate interference in space behind the double-slit plate. Also, there is a diffraction phenomenon from each individual slit. Therefore, the experimental result is a combination of diffraction and interference. To solely study the interference phenomenon generated by the central diffraction orders of the two slits, slit width a must be close to wavelength λ, e.g. λ=32 mm, a=40 mm. Under such case, the 1st minima of the single slit diffraction is located at 53°. When choosing a large b, the influence of single slit diffraction to double-slit interference is relatively small.

The angles for a series of interference constructive orders are $\varphi = \sin^{-1}\left(K \bullet \frac{\lambda}{a+b}\right)$, and for a series of interference destructive orders are $\varphi = \sin^{-1}\left(\frac{2K+1}{2} \bullet \frac{\lambda}{a+b}\right)$, when K=1, 2, …..

The experimental setup is same as shown in Figure 5 except the single slit plate is replaced with a double-slit plate. The adjustment process is also similar. Since the horizontal size of the diffraction plate is small, the rotation angle of the movable arm should be small in order to avoid receiving waves coming from the side of the plate or direct waves from the source.

4) Michelson interferometer

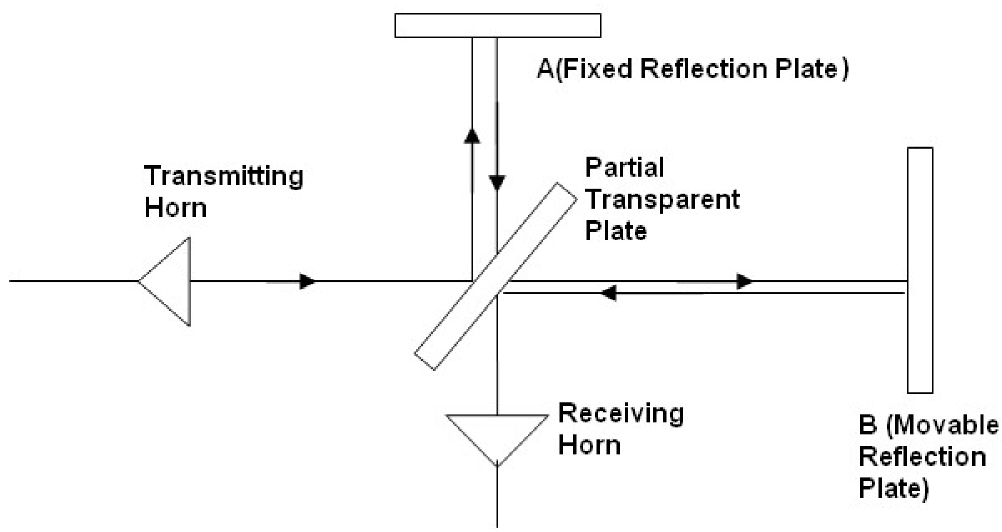

Figure 7 Schematic of Michelson interferometer

As shown in Figure 7, by placing a partially transmissive plate in the path of a plane microwave incident at 45°, the incident wave is split into two beams, with one to reflection plate A and the other to reflection plate B. Both beams are reflected back by the two reflection plates and recombine at the partially transmissive plate towards the receiving horn. Hence, the receiving horn receives two waves of same frequency and same vibration direction. If the phase difference of the two waves is an integer times of 2π, constructive interference occurs; if the phase difference is an odd integer times of π, destructive interference occurs. This is the basic principle for Michelson interference. As a result, as the movable plate B moves, the reading of the micro-current meter changes alternatively between minimum and maximum. In two adjacent minimas, the moving distance of plate B is $\lambda/2$. From this, the wavelength of the plane wave can be determined.

Figure 8 Setup of Michelson Interferometer

As shown in Figure 8, the two horns are perpendicular to each other. The angle between the partially transmissive plate and the axis of either horn is 45°. Mount the translation stage onto the base using the two screws attached (at the opposite side of the fixed arm), and then insert the reflection plate. Align the normal line of the fixed reflection plate to the axis of the receiving horn and the normal line of the movable reflection plate to the axis of the transmitting horn.

Place the movable plate to one end of the translation stage. By gradually moving the movable plate from end to end, the reading of the micro-current meter changes between maximum and minimum. Starting from the first minima, continuously count N number of minima (excluding the first minima) while recording the corresponding moving distance L of the movable plate. The wavelength of the incident wave is calculated as $\lambda = \frac{2L}{N}$.

5) Polarization experiment

A plane electromagnetic wave is a transverse wave, with its electric field strength vector E perpendicular to its propagation direction. If E stays in one fixed plane when the wave propagates, this transverse wave is called a linearly polarized wave. The energy of the electromagnetic field in a certain direction ϕ is related to $\sin^2(\phi)$, i.e. $I=I_0\cos^2(\phi)$, where I is the intensity of the microwave in direction ϕ when ϕ is the angle deviated from the linear polarization direction. This is the Malus's law in optics.

Figure 9 Setup of polarization experiment

As shown in Figure 9, align the two horns parallel to each other with their central axis aligned horizontally. Ensure the opening of each horn is in the same orientation as that of the other horn. By rotating the receiving horn while recording the reading from the micro-current meter and the angle reading from the bearing of a short waveguide connected to the receiving horn, microwave power with corresponding deviation angle can be thus acquired. Compare these data with Malus's law.

6) **Bragg diffraction experiment:**

Ions, atoms or molecules in a crystal are orientated regularly in geometric space according to a certain rule, i.e. a lattice structure. The distance between two adjacent nodes is called the lattice constant of the crystal, which is normally around 10^{-8} cm comparable to the wavelength of x-ray. Therefore, lattice constant and lattice array structure of crystal can be studied by x-ray diffraction techniques.

This experiment simulates the basic principle of x-ray crystal diffraction. A simulated crystal of cubic lattice is used with microwave to replace x-ray for the study of the lattice constant of the simulated crystal by observing the microwave diffraction from the lattice array under the Bragg scheme. Under such condition, if a plane microwave of wavelength λ is incident onto the surface of a crystal of lattice constant a at angle θ with regard to the normal line of the surface, diffraction occurs when condition $n\lambda = 2a\cos\theta$ is met (n is an integer). The diffracted ray is in the direction of the surface reflection.

Figure 10 Setup of Bragg diffraction experiment

As shown in Figure 10, the experimental configuration is similar to that of the reflection experiment. Make sure the small balls of the simulated crystal are arranged in a cubic point array and mount the simulated crystal assembly onto the center of the platform by aligning the normal line of the crystal surface at 0° scale line of the indexing disk. Again, to avoid receiving the direct wave, it is suggested the incident angle should be between 30° and 70°.