BRAGG REFLECTION CUBE SET
## No. 36860

Operating Instructions

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Introduction

The Bragg Reflection Cube Set uses microwaves to simulate x-ray diffraction from the faces of a crystal. Knowing the wavelength of the microwaves, the distance between the Bragg planes, and the angle between the incident and diffracted beams, you can verify the Bragg equation. The set is intended for use with the CENCO 3cm Microwave Apparatus (36811).

The main components of the Bragg Reflection Cube are the 5 layers of 1.9cm (3/4-inch) polyethylene foam, which are virtually transparent to microwaves. The layers have holes to accommodate 125 steel chrome balls that act as scattering centers. Also included are a foam hub assembly with angle indicator for cube positioning, an alignment disk assembly with angular graduations, a rail indicator for angular measurements, and an extension connector block to lengthen the transmitter arm.
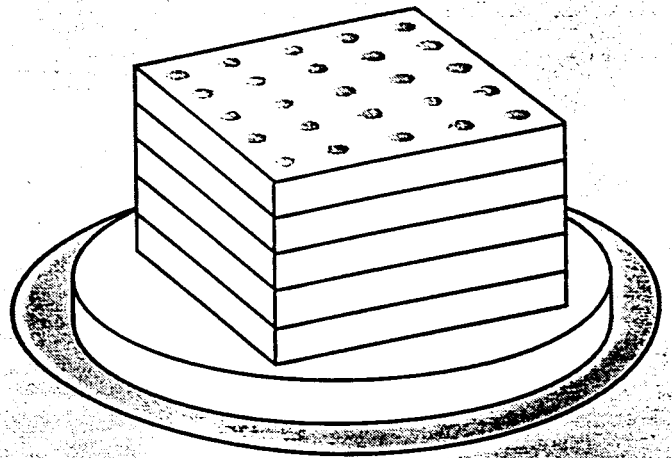
Bragg Reflection Cube Set

Theory

In 1912 Max Von Laue discovered that ordinary crystals could diffract X-rays. A simple interpretation of the diffraction process was given by Sir William H. Bragg a short time later. Bragg showed that the diffraction pattern could be explained in terms of the reflection of the incident beam from planes of atoms within the crystal. For example, in a two-dimensional representation of the atoms in a crystal (Fig.1) the lines along AA, BB, and CC represent planes of atoms from which diffraction could be observed.

In order to derive the Bragg equation for diffraction, consider the diffraction of waves from two adjacent and parallel Bragg planes a distance d apart, as shown in Fig. 2. A wave of wavelength λ is incident upon the Bragg planes at an angle of θ with respect to the planes. The incident wave is partially diffracted at an angle θ, while the transmitted wave is diffracted from the second Bragg plane also in the direction of θ. It is for this reason that the diffraction process appears as reflection.
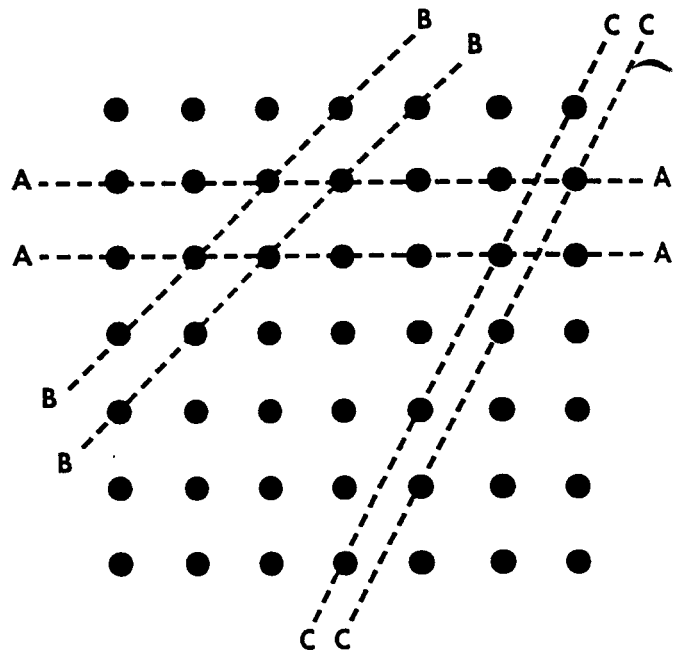

Fig 1: Rows of atoms in different directions

Consider the wavefront BOD perpendicular to the two reflected rays. Constructive interference from atoms in successive planes only occurs if the reflected rays have the same phase at the points B and D. Notice that the paths BOD and BOA are equal in length. With d the distance between the Bragg planes, the path difference ACD becomes:

$$AC=OC\sin\theta=d\sin\theta$$
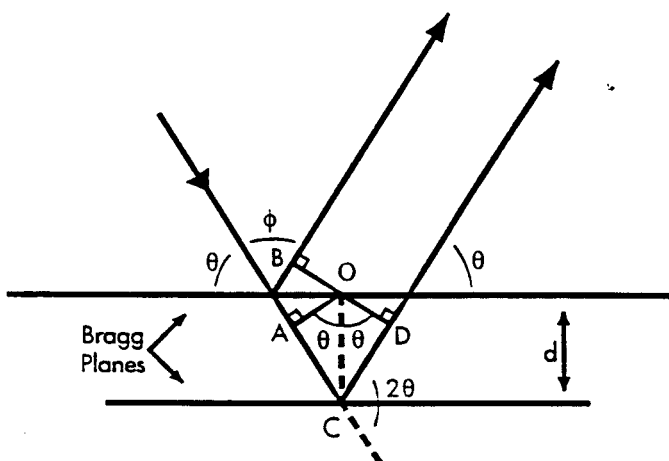$$CD=OC\sin\theta=d\sin\theta$$
$$ACD=AC+CD=2d\sin\theta$$

Fig 2: Bragg equation for diffraction

The points B and D have the same phase when the path difference is equal to an integral number of wavelengths. The direction of constructive interference will be given by the angle θ. Hence the condition for constructive interference or diffraction maxima is:

$$n\lambda=2d\sin\theta$$

where $n=1,2,3,...$This relationship is known as the Bragg Reflection equation. Take notice that the equation puts an important restriction on the wavelength and atomic spacing.

In this experiment, the foam cube is the simulated crystal. The steel balls act as diffraction centers for the microwaves in much the same way that atoms diffract x-rays. The signal can be diffracted from either the primary or diagonal planes, AA and BB, respectively, in Fig.1. The diffracted signal is picked up by the receiver and measured with an oscilloscope and/or a multimeter as the cube and receiver arm are stepped through 180°. Quantitative analysis of the data then leads to the verification of the Bragg Reflection equation.

Procedure

1. Secure one of the side arms to the end of the main arm using the extension connector block for stability. The holding screws in the extension block may have to be adjusted to facilitate a proper fit.

2. Attach the movable arm to the center post below the turntable disk, and slide the alignment disk assembly over the center post on the turntable. Ensure that the rail support on the underside of the disk assembly is straddling the main arm. Place the foam hub assembly on the alignment disk with the arrow pointing to 0°.

3. To minimize errant signals from the transmitter side lobes, place the transmitter on the stationary arm 50-60cm from the turntable assembly. Place the receiver on the rotatable arm at about 35cm.

4. Complete the setup as shown in figure 3. Adjust the function generator to produce a 4kHz square wave with minimal gain. The oscilloscope should be switched to AC with the time per division at about 50μs. The voltage per division should be set at 50mV and adjusted as necessary. If also using a digital multimeter, set it to 2VAC. Verify that the multimeter is capable of measuring an AC signal at 4kHz.
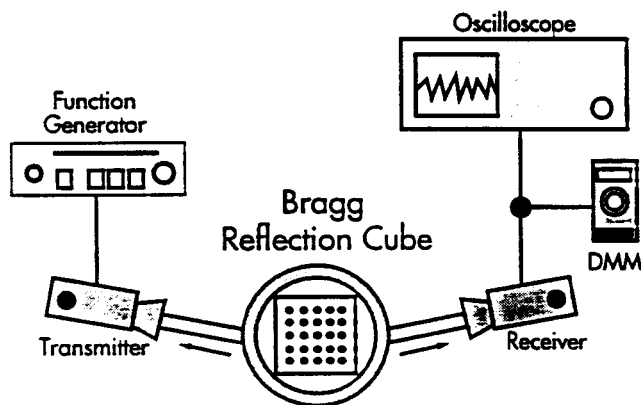

Fig 3: Transmission of waves from Bragg Reflection Cube

5. Set the Bragg Cube in the foam positioner so the side of the cube is perpendicular to the incoming microwaves. Move the receiver arm to 180° and turn the gain on the receiver to its maximum setting. Turn on the transmitter. At this point you should see a waveform on the oscilloscope. If not, adjust the oscilloscope settings so that an entire period is visible. Vary the frequency of the function generator to maximize the waveform. Next, adjust the gain on the function generator until the signal begins to

saturate. This effect can be noticed on the oscilloscope by a flattening of the waveform and on the multimeter by a severe "leveling-off" of the voltage reading. If the waveform is already saturated, turn down the gain on the receiver to just below the saturation point.

6. Turn the receiver arm to the smallest possible angle (about 30°) and the foam hub to half that value. Record the voltage from the oscilloscope and/or the multimeter and the angle between the arms. Increase the angle of the receiver 6° and that of the cube 3°. Again, measure the voltage and the angle. This stepping procedure insures that the angle of incidence and reflection remain èqual. Continue stepping through 180°. Return to the angles where large voltages appeared and make further measurements using a smaller stepping procedure — move the receiver 2° and the cube 1°.

7. Repeat steps 5-6 for the diagonal planes.

Computation and Analysis

1. Calculate the distance between the Bragg planes for both cube orientations.

2. Find an expression relating the angle measured ϕ and the Bragg Reflection angle.

3. What limit is imposed on the wavelength by the Bragg Reflection equation? How could you increase the number of orders observed?

4. Make a plot of voltage versus Bragg Reflection angle θ for both cases. Calculate the theoretical values of the angles for which Bragg Reflection will occur. Compare the peak values to the theoretical values you calculated. Can you explain any disagreements?

Maintenance

No special maintenance is needed for the Bragg Reflection Cube Set. Should any difficulty occur that can not be corrected, contact Central Scientific Company. So that we may best serve you, please do not return the apparatus or any of its parts before receiving authorization from Central Scientific Company.

Replacement Parts

Description	Cat. No.
Alignment Disk Assembly	06860-20
Extension Connector Assembly	06860-x
Foam Hub Assembly	06860-17
Foam Square	06860-00
Rail Indicator Assembly	06860-03
Steel Balls	06860-18

Recommended Accessories

Description	Cat. No.
3cm Microwave Optics Set	36811
Digital Multimeter	32098
Oscilloscope	32046
Sweepable Function Generator	31574

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