Double Slit interference And Doppler Effect

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The double-slit interference shows that the product of the wavelength and the distance from the slit plate to the projection screen is conserved in all inertial reference frames. This conservation ensures that the observed wavelength in any inertial reference frame is identical to the original wavelength in the rest frame of the light source. According to the Doppler effect, the observed frequency depends on the choice of inertial reference frame. With the same wavelength but different frequency, the speed of light is different in a different inertial reference frame.

I. INTRODUCTION

The double-slit interference can be formulated with the principle of superpostion[1]. There are two significant properties imposed on the wavelength. The wavelength is proportional to the displacement of the fringe on the interference pattern. The wavelength is inversely proportional to the distance between the slit plate and the projection screen.

Both properties are conserved in all inertial reference frames. Such conservation can be used to calculate the wavelength of a coherent light in any inertial reference frame.

With the wavelength determined, the speed of light can be determined if the frequency can be obtained from the Doppler effect[2] which shows that the frequency of the same light is different in different inertial reference frame.

II. PROOF

A. Wavelength

A light emitter emits coherent light along the x-direction through a plate with two parallel slits to reach a projection screen. Both the plate and the screen are aligned with the y-z plane. The emitter, the plate, and the screen are all stationary relative to a reference frame F_1.

A series of alternating light and dark bands appear on the projection screen along the y-direction. Let the distance between the plate and the screen be D_1. The location of the light band is y_1. The seperation between the parallel slits is d_1.

If $d_1 << y_1 << D_1$, the constructive interference can be described by the equation of phase shift[1] for the constructive phase difference as

$$y_1 = m * \lambda_1 * \frac{D_1}{d_1} \tag{1}$$

λ_1 is the wavelength in F_1. m is a positive integer.

$$\lambda_1 = \sqrt{\lambda_{1x}^2 + \lambda_{1y}^2} \tag{2}$$

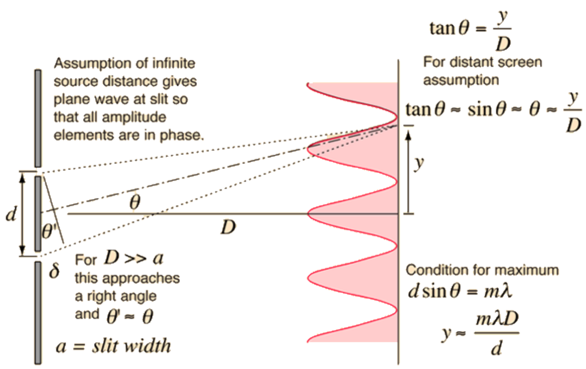

FIG. 1. Double Slit Interference

Let another reference frame F_2 move along the x-direction at a constant velocity relative to F_1. The interference pattern is conserved in all inertial reference frames. Neither redshift nor blueshift appears on the intereference pattern because the emitter is stationary relative to F_1. The conservation of phase shift requires

$$y_2 = m * \lambda_2 * \frac{D_2}{d_2} \tag{3}$$

$$\lambda_2 = \sqrt{\lambda_{2x}^2 + \lambda_{2y}^2} \tag{4}$$

The choice of inertial reference frame along the x-direction has no effect on the measurement along the y-direction.

$$y_2 = y_1 \tag{5}$$

$$d_2 = d_1 \tag{6}$$

$$\lambda_{2y} = \lambda_{1y} \tag{7}$$

From equations (1,3,5,6),

$$\lambda_2 * D_2 = \lambda_1 * D_1 \tag{8}$$

The choice of inertial reference frame along the x-direction may alter the measurement along the x-direction. Let γ be the proportional factor between the original measurement in F_1 and the new measurement in F_2.

$$D_2 = \gamma * D_1 \tag{9}$$

$$\lambda_{2x} = \gamma * \lambda_{1x} \tag{10}$$

From equations (2,4,7,10),

$$\lambda_2 = \sqrt{\gamma^2 * \lambda_{1x}^2 + \lambda_{1y}^2} \tag{11}$$

From equation (8,9,11),

$$\sqrt{\gamma^2 * \lambda_{1x}^2 + \lambda_{1y}^2} * \gamma = \sqrt{\lambda_{1x}^2 + \lambda_{1y}^2} \tag{12}$$

$$(\gamma^2 \lambda_{1x}^2 + \lambda_{1y}^2)\gamma^2 = \lambda_{1x}^2 + \lambda_{1y}^2 \tag{13}$$

$$\lambda_{1x}^2(\gamma^4 - 1) + \lambda_{1y}^2(\gamma^2 - 1) = 0 \tag{14}$$

$$(\gamma^2 - 1)(\lambda_{1x}^2(\gamma^2 + 1) + \lambda_{1y}^2) = 0 \tag{15}$$

$$\gamma^2 = 1 \tag{16}$$

From equations (7,10,16),

$$\lambda_2 = \lambda_1 \tag{17}$$

The wavelength is conserved in all inertial reference frames.

B. Doppler Effect

Let an observer P_1 be stationary relative to F_1. The emitter is stationary relative to P_1. The frequency of the coherent light is f_1 for P_1

Let another observer P_2 be stationary relative to F_2. The emitter moves toward P_2. The frequency of the coherent light is f_2 for P_2.

According to the Doppler Effect[2],

$$f_2 > f_1 \tag{18}$$

The speed of the coherent light for P_1 is

$$c_1 = f_1 * \lambda_1 \tag{19}$$

The speed of the coherent light for P_2 is

$$c_2 = f_2 * \lambda_2 \tag{20}$$

From equations (17,18,19,20),

$$c_2 > c_1 \tag{21}$$

The speed of coherent light increases if the light emitter is moving toward the observer.

III. CONCLUSION

The speed of light is related to the relative motion between the light emitter and the light detector.

In the double-slit interference, the product of the wavelength and the distance from the slit plate to the projection screen is conserved in all inertial reference frames.

The conservation of intereference pattern proves that the wavelength is conserved in all inertial reference frames. However, the frequency is different in different reference frame according to the Doppler effect. Consequently, the speed of the same coherent light is different in different reference frame.

The speed of light depends on the motion of the light source in the rest frame of the light detector.

[1] "Double Slit Interference", http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/slits.html

[2] Possel, Markus (2017). "Waves, motion and frequency: the Doppler effect". Einstein Online, Vol. 5. Max Planck Institute for Gravitational Physics, Potsdam, Germany. Retrieved September 4, 2017.

[3] Eric Su: List of Publications, http://vixra.org/author/eric_su