# In Young's Double Slit Experiment, 402 Nm Light Gives A Fourth-order Bright Fringe At A Certain Location

**In Young's Double Slit Experiment, 402 Nm Light Gives A Fourth-order Bright Fringe At A Certain Location** is a fascinating phenomenon that illustrates the principles of wave interference and the nature of light. This particular observation provides insight into the behavior of light waves when they pass through a double slit apparatus, producing distinct bright and dark fringes on a screen. Understanding how a specific wavelength, such as 402 nanometers (nm), results in a fourth-order bright fringe at a particular position reveals the underlying physics of interference patterns and the mathematical relationships governing them.

## Understanding Young's Double Slit Experiment

### Historical Background and Significance

- Developed by Thomas Young in the early 19th century, the double slit experiment was pivotal in demonstrating the wave nature of light.
- It challenged the particle theory of light and supported the wave theory, laying the groundwork for modern wave optics.
- The experiment involves passing monochromatic light through two narrow slits and observing the resulting interference pattern on a screen placed some distance away.

### Basic Setup and Components

- A coherent light source, such as a laser or monochromatic lamp.
- Two closely spaced slits, typically very narrow.
- A screen or photographic plate to observe the interference fringes.
- The key parameters include slit separation (d), wavelength of light (λ), and the distance from the slits to the screen (L).

## Wave Interference and Fringe Formation

### Constructive and Destructive Interference

- When waves passing through the two slits meet, they interfere with each other.
- Constructive interference occurs when the path difference between waves is an integer multiple of the wavelength, leading to bright fringes.
- Destructive interference occurs when the path difference is a half-integer multiple of the wavelength, resulting in dark fringes.

### Mathematical Relationship for Fringe Positions

- The position of bright fringes on the screen is given by the formula:

$y_m = (m\lambda L) / d$

where:
- $y_m$ = position of the mth bright fringe from the central maximum

- m = order of the fringe (0, 1, 2, 3, ...)
- λ = wavelength of the light
- L = distance from slits to the screen
- d = separation between the two slits

- The same formula applies for dark fringes, with a slight modification involving half-integer orders.

# Analyzing the 402 nm Light and Fourth-Order Bright Fringe

## Wavelength and Fringe Order

- Light with a wavelength of 402 nm (nanometers) corresponds to the violet-blue end of the visible spectrum.
- The "fourth-order" bright fringe refers to the fringe where m=4 in the interference pattern.

## Calculating the Fringe Position

- To determine the exact location of the fourth-order bright fringe, we can use the fringe position formula:

*y4 = (4λL) / d*

- Suppose the experimental setup has known parameters:

- Wavelength, λ = 402 nm = $402 \times 10^{-9}$ meters
- Distance from slits to screen, L = 2 meters (example value)
- Slit separation, d = 0.1 mm = $1 \times 10^{-4}$ meters (example value)

- Plugging in the values:

$$
\begin{aligned}
y_4 &= (4 \times 402 \times 10^{-9}\ \text{m} \times 2\ \text{m}) / (1 \times 10^{-4}\ \text{m}) \\
&= (4 \times 402 \times 2 \times 10^{-9}) / (1 \times 10^{-4}) \\
&= (4 \times 402 \times 2) \times 10^{-9} / 10^{-4} \\
&= (4 \times 402 \times 2) \times 10^{-5} \\
&= (4 \times 804) \times 10^{-5} \\
&= 3216 \times 10^{-5}\ \text{meters} \\
&= 0.03216\ \text{meters or approximately } 3.216\ \text{centimeters}
\end{aligned}
$$

- This calculation indicates that, for these parameters, the fourth-order bright fringe appears approximately 3.216 centimeters from the central maximum.

# Factors Influencing Fringe Positions

## Slit Separation (d)

- Increasing d decreases the fringe spacing ym, bringing fringes closer together.
- Decreasing d increases the fringe spacing, moving fringes further apart.

## Wavelength (λ)

- Longer wavelengths produce wider fringe spacing and vice versa.
- For 402 nm light, the fringe spacing is defined by the specific setup parameters.

## Distance to Screen (L)

- Increasing L increases the distance ym for all fringes, making fringes more spread out on the screen.

# Significance of the Fourth-Order Bright Fringe in Experiments

## Practical Applications

- Precise measurement of wavelength: By observing fringe positions and knowing L and d, experimentalists can calculate λ with high accuracy.
- Optical calibration: Used in calibrating spectrometers and interferometers.
- Demonstrating wave phenomena: Reinforces the wave nature of light and the principle of superposition.

## Challenges and Limitations

- Higher-order fringes tend to be less intense and may be harder to observe, especially in less coherent sources.
- Precise alignment of the apparatus and stable environmental conditions are necessary for accurate measurements.

# Conclusion

Understanding how 402 nm light produces a fourth-order bright fringe at a specific location in Young's double slit experiment exemplifies the fundamental principles of wave interference. By applying the mathematical relationships between wavelength, slit separation, and screen distance, scientists can predict and analyze the fringe pattern with remarkable precision. The observation of such high-order fringes not only confirms the wave nature of light but also serves as a vital tool in optical research, measurement, and the development of advanced technologies in spectroscopy and photonics. Whether in educational demonstrations or cutting-edge laboratories, the phenomena exemplified by the fourth-order bright fringe continue to illuminate the wave behavior of light and deepen our understanding of the universe.

# Frequently Asked Questions

## What is the significance of the 402 nm wavelength in Young's Double Slit Experiment?

The 402 nm wavelength is a specific light wavelength used to observe interference fringes, helping analyze fringe positions and verify wave nature of light in the experiment.

## How is the position of the fourth-order bright fringe calculated in Young's Double Slit Experiment?

The position is given by the formula $y = (n\lambda L)/d$, where n is the fringe order (4 for the fourth order), $\lambda$ is the wavelength (402 nm), L is the distance to the screen, and d is the slit separation.

## What does the appearance of a fourth-order bright fringe indicate about the interference pattern?

It indicates that the path difference between the two waves is integer multiples of the wavelength, specifically four times the wavelength for the fourth-order fringe, demonstrating constructive interference.

## Why is the wavelength of light important in determining fringe positions in Young's experiment?

Because the fringe spacing and position depend directly on the wavelength; different wavelengths produce different fringe patterns, allowing analysis of light's wave properties.

## How can the fringe order be used to determine unknown parameters in the experiment?

By knowing the fringe order and other parameters like wavelength, one can calculate slit separation or distance to the screen, or verify the wavelength of the light used.

## What are the typical assumptions made in calculating fringe positions in Young's experiment?

Assumptions include monochromatic light, coherent sources, small angle approximation, and uniform slit widths and separation.

## How does increasing the wavelength to 402 nm affect the fringe spacing compared to shorter wavelengths?

Increasing the wavelength results in larger fringe spacing, making fringes more widely spaced and easier to observe.

## What is the role of coherence in observing bright fringes at higher orders such as the fourth order?

Coherence ensures stable and well-defined interference fringes; lack of coherence would blur higher-order fringes like the fourth order.

## Can the position of the fourth-order bright fringe help verify the wavelength of the light source?

Yes, by measuring the fringe position and knowing other parameters, the wavelength can be calculated and verified against the known value of 402 nm.

# Additional Resources

**In Young's Double Slit Experiment, 402 nm light gives a fourth-order bright fringe at a certain location** — a statement that encapsulates the fascinating interplay of wave interference, optical physics, and precise measurement techniques. This phenomenon exemplifies the core principles that underlie the wave nature of light and demonstrates how carefully orchestrated experiments can reveal intricate details about the behavior of electromagnetic waves. Understanding this specific case requires delving into the fundamentals of Young's double slit experiment, the nature of interference fringes, and the mathematical relationships that govern their formation.

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# Introduction to Young's Double Slit Experiment

Historical Context and Significance

The double slit experiment, first performed by Thomas Young in the early 19th century, marked a pivotal moment in physics by providing compelling evidence for the wave nature of light. Prior to this, Newton's corpuscular theory of light dominated scientific discourse, positing that light consisted of particles. Young's experiment demonstrated that light waves could interfere, producing characteristic bright and dark fringes on a screen placed behind two closely spaced slits.

Basic Concept

At its core, Young's experiment involves shining a coherent light source through two narrow, closely spaced slits. As the light waves pass through, they diffract and spread out, overlapping and interfering with each other. The resulting pattern of bright and dark fringes on a screen is a direct manifestation of constructive and destructive interference.

Key Components

- Coherent Light Source: Typically laser light or monochromatic sources to ensure phase consistency.
- Double Slits: Precisely manufactured narrow slits separated by a known distance.
- Screen: Positioned at a known distance from the slits to observe the interference pattern.

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# Understanding Interference Patterns and Fringe Formation

Constructive and Destructive Interference

Interference fringes arise when waves from the two slits meet. The phase difference determines whether the waves reinforce each other (constructive interference, bright fringes) or cancel out (destructive interference, dark fringes).

- Constructive interference occurs when the path difference between the two waves is an integral multiple of the wavelength (\(n\lambda\)), leading to bright fringes.
- Destructive interference occurs when the path difference is a half-integer multiple of the wavelength \((n + 0.5)\lambda\), leading to dark fringes.

Fringe Location and Spacing

The position of fringes on the screen is determined by the geometry of the setup and the wavelength of the light. The key parameters include:

- Slit separation ($d$): Distance between the two slits.
- Wavelength ($\lambda$): Wavelength of the incident light.
- Distance to screen ($L$): Separation between the slits and the observation screen.
- Fringe order ($n$): An integer representing the sequence of bright fringes from the central maximum.

The position of the $n^{th}$ bright fringe ($y_n$) relative to the central maximum is given by:

$$
y_n = \frac{n \lambda L}{d}
$$

This linear relationship allows precise calculation of fringe positions for given experimental parameters.

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## Specifics of the 402 nm Light and Fourth-Order Bright Fringe

Wavelength and Its Implications

The wavelength in question, 402 nm (nanometers), lies in the violet-blue region of the visible spectrum. This short wavelength leads to closely spaced interference fringes, demanding high precision in experimental setup and measurement.

Interpreting the Fourth-Order Bright Fringe

The "fourth-order bright fringe" refers to the fringe where $n=4$. Using the fringe position formula:

$$
y_4 = \frac{4 \lambda L}{d}
$$

This indicates that the bright fringe occurs at a specific position on the screen corresponding to the fourth multiple of the wavelength's interference pattern.

Significance of the Fringe Order

Higher-order fringes, like the fourth order, are typically farther from the central maximum. Their visibility and clarity depend on factors such as:

- Coherence length of the light source
- Slit width and separation
- Distance to the screen

The existence of a bright fringe at this order confirms the wave nature of light and the accuracy of the experimental setup.

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## Calculating the Fringe Position for 402 nm Light

Mathematical Framework

Assuming known parameters:

- $d$: slit separation
- $L$: distance from slits to screen
- $\lambda = 402\,\text{nm} = 402 \times 10^{-9}\,\text{m}$

The position of the fourth-order bright fringe:

$$
y_4 = \frac{4 \times 402 \times 10^{-9}\,\text{m} \times L}{d}
$$

Practical Example

Suppose the experimental setup has:

- $d = 0.1\,\text{mm} = 1 \times 10^{-4}\,\text{m}$
- $L = 2\,\text{m}$

Then,

$$
y_4 = \frac{4 \times 402 \times 10^{-9} \times 2}{1 \times 10^{-4}} = \frac{4 \times 402 \times 10^{-9} \times 2}{1 \times 10^{-4}}
$$

Calculating:

$$
y_4 = \frac{4 \times 402 \times 2 \times 10^{-9}}{10^{-4}} = \frac{4 \times 402 \times 2 \times 10^{-9}}{10^{-4}}
$$

$$
= \frac{4 \times 402 \times 2}{10^{-4} / 10^{-9}} = \frac{4 \times 402 \times 2}{10^{5}}
$$

$$
= \frac{4 \times 402 \times 2}{100,000} = \frac{4 \times 804}{100,000} = \frac{3216}{100,000} = 0.03216\,\text{m}
$$

Thus, the fourth-order bright fringe appears approximately 3.2 centimeters from the central maximum.

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# Factors Affecting Fringe Visibility and Measurement Accuracy

Coherence and Monochromaticity

- Coherence length: The maximum path difference over which the light remains in phase. For high-visibility fringes, the coherence length must exceed the path difference.
- Monochromatic source: Narrow spectral bandwidth minimizes fringe blurring, making high-order fringes more discernible.

Slit Dimensions and Separation

- Narrow slits produce well-defined diffraction patterns.
- Slit separation ($d$) influences fringe spacing; larger $d$ results in closer fringes.

Experimental Stability

- Vibrations and air currents can distort fringe patterns.
- Precise alignment and environmental control are crucial.

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## Implications and Broader Significance

Confirming Wave Nature of Light

Observation of higher-order fringes, such as the fourth order at 402 nm wavelength, reinforces the wave hypothesis. The precise matching of measured fringe positions with theoretical predictions validates the wave interference model.

Applications in Modern Optics

- Spectroscopy: Fringe analysis for wavelength measurements.
- Metrology: High-precision distance and measurement techniques.
- Quantum Physics: Understanding coherence and superposition principles.

Challenges and Limitations

- As the fringe order increases, fringes become faint and challenging to resolve.
- Instrumental limitations, such as resolution and stability, constrain the highest observable fringe order.

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## Conclusion

The specific case of 402 nm light producing a fourth-order bright fringe in Young's double slit experiment encapsulates the intricate harmony of wave physics, experimental precision, and mathematical rigor. By analyzing the fringe position, scientists can not only verify fundamental principles but also develop sophisticated applications that hinge on wave interference. This phenomenon underscores the deep connection between wavelength, geometry, and interference, reminding us of the profound insights that can be gleaned from carefully orchestrated optical experiments. As technology advances, the ability to observe and utilize higher-order fringes continues to expand, opening new frontiers in optical science and engineering.

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