

# Optics: Interference Patterns and Analysis

Computational Science Templates

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## 1 Introduction

Interference phenomena demonstrate the wave nature of light through the superposition of coherent waves. This analysis explores Young's double-slit experiment, multiple-beam interference, Michelson interferometry, and Fabry-Pérot cavities, examining both intensity patterns and their applications in metrology and spectroscopy.

## 2 Mathematical Framework

### 2.1 Two-Beam Interference

For two coherent beams with amplitudes  $E_1$  and  $E_2$  and phase difference  $\delta$ :

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \delta \quad (1)$$

### 2.2 Double-Slit with Diffraction

The intensity pattern for double-slit interference with single-slit diffraction:

$$I(\theta) = I_0 \left( \frac{\sin \beta}{\beta} \right)^2 \cos^2 \alpha \quad (2)$$

where  $\alpha = \frac{\pi d \sin \theta}{\lambda}$  (interference) and  $\beta = \frac{\pi a \sin \theta}{\lambda}$  (diffraction).

### 2.3 Multiple-Beam Interference

For  $N$  slits (grating), the intensity is:

$$I = I_0 \left( \frac{\sin \beta}{\beta} \right)^2 \left( \frac{\sin N\alpha}{\sin \alpha} \right)^2 \quad (3)$$

## 2.4 Fabry-Pérot Interferometer

Transmission of a Fabry-Pérot cavity:

$$T = \frac{1}{1 + F \sin^2(\delta/2)} \quad (4)$$

where  $F = \frac{4R}{(1-R)^2}$  is the finesse coefficient and  $\delta = \frac{4\pi nd \cos \theta}{\lambda}$ .

## 3 Environment Setup

## 4 Young's Double-Slit Experiment

## 5 Multiple-Slit Interference (Diffraction Grating)

## 6 Michelson Interferometer

## 7 Fabry-Pérot Interferometer

## 8 Newton's Rings and Thin Film Interference

## 9 Coherence and Visibility

## 10 Results Summary

## 11 Statistical Summary

- Wavelength:  $\lambda = ??$  nm
- Slit separation:  $d = ??$  mm
- Slit width:  $a = ??$   $\mu$ m
- Screen distance:  $L = ??$  m
- Fringe spacing:  $??$  mm
- Fringes in central maximum:  $\approx ??$
- Fabry-Pérot FSR:  $??$  pm
- Fabry-Pérot finesse ( $R = 0.98$ ):  $??$
- Resolving power:  $?? \times 10^6$

## 12 Conclusion

Interference patterns provide crucial evidence for the wave nature of light and enable high-precision measurements. The double-slit pattern shows interference fringes modulated by a single-slit diffraction envelope. Multiple-slit gratings provide enhanced resolution proportional to the number of slits. Michelson interferometry enables nanometer-scale displacement measurements with applications in gravitational wave detection. Fabry-Pérot cavities achieve ultra-high spectral resolution with finesse values exceeding 1000, critical for laser spectroscopy and optical communications. Understanding coherence is essential for predicting fringe visibility and designing interferometric systems.