Michael Interferometer

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Abstract. An experiment was designed and attempted to build a Michaelson Interferometer and quantify the interferences patterns observed. The experiment was conducted using a `HNLS008L` laser, beam splitter, and mirrors. The fringe contrast was calculated to be 0.5.

INTRODUCTION

Invented by Albert Abraham Michelson 1887 [2], the Michaelson Interferometer is a configuration of mirrors and beam splitters which can be used to quantify the interference patterns of light. It has been instrumental in the development of quantum mechanics and the theory of relativity. The Michaelson Interferometer is used in a variety of applications, including the measurement of the speed of light, the refutation of the existance of the ether, and the study of quantum mechanics.

Michaelson Interferometers work on the basic principle of interference. In the experimental setup, a beam of light is split into two paths by a 50:50 beam splitter. The two beams are then reflected by mirrors and recombined at the beam splitter. The recombined beams interfere with each other, creating a pattern of light and dark fringes. The fringe contrast is a measure of the visibility of the fringes and is calculated using (1).

$$F = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}} \tag{1}$$

Depending on the relative path difference, d, between the two reflected beams, there will be a time delay, τ defined by (2) [2].

$$\tau = \frac{d}{c} \tag{2}$$

With the resultant intensity quantified by (3) [2].

$$I = 2I_0\left[1 + \cos(\omega t)\right] \tag{3}$$

METHODOLOGY

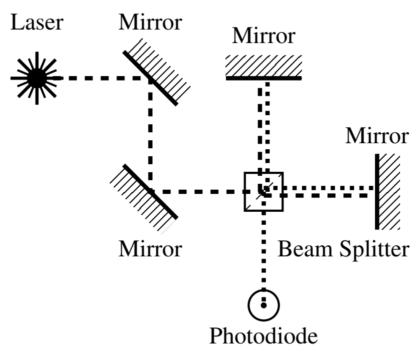

FIGURE 1: Figure

RESULTS & ANALYSIS

DISCUSSION

CONCLUSION

/home/adi/University/Physics/PHY385/Labs/Lab02/parta.csv

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Appendix

Raw Data

Analysis Code

Toolkit

```
# -*- coding: utf-8 -*-
"""
Created on Tue Jan 23 12:34:34 2024
Updated on Mon Oct 14 21:22:09 2024
Updated on Mon Feb 10 09:51:03 2025

Lab Toolkit

@author: Aditya K. Rao
@github: @adirao-projects
"""
import numpy as np
from scipy.optimize import curve_fit
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec
import os
import math
import textwrap

#from uncertainties import ufloat

font = {'family' : 'DejaVu Sans',
```

```
        'size'   : 30}

plt.rc('font', **font)

def curve_fit_data(xdata, ydata, fit_type, override=False,
                   override_params=(None,), uncertainty=None,
                   res=False, chi=False, uncertainty_x=None,
                   model_function_custom=None, guess=None):

    def chi_sq_red(measured_data:list[float], expected_data:list[float],
               uncertainty:list[float], v: int):
        if type(uncertainty)==float:
            uncertainty = [uncertainty]*len(measured_data)
        chi_sq = 0

        # Converting summation in equation into a for loop
        for i in range(0, len(measured_data)):
            chi_sq += (pow((measured_data[i] \
                - expected_data[i]),2)/(uncertainty[i]**2))

        chi_sq = (1/v)*chi_sq

        return chi_sq


    def residual_calculation(y_data: list, exp_y_data) -> list[float]:
        residuals = []
        for v, u in zip(y_data, exp_y_data):
            residuals.append(u-v)

        return residuals

    def model_function_linear_int(x, m, c):
        return m*x+c

    def model_function_exp(x, a, b, c):
        return a*np.exp**(b*x)

    def model_function_log(x, a, b):
        return b*np.log(x+a)

    def model_function_linear_int_mod(x, m, c):
        return m*(x+c)

    def model_function_linear(x, m):
        return m*x

    def model_function_xlnx(x, a, b, c):
        return b*x*(np.log(x)) + c

    def model_function_ln(x, a, b, c):
        return b*(np.log(x)) + c

    def model_function_sqrt(x, a):
```

```
        return a*np.sqrt(x)

    model_functions = {
        'linear' : model_function_linear,
        'linear-int' : model_function_linear_int,
        'xlnx' : model_function_xlnx,
        'log' : model_function_log,
        'exp' : model_function_exp,
        'custom' : model_function_custom
        }

    try:
        model_func = model_functions[fit_type]

    except:
        raise ValueError(f'Unsupported fit-type: {fit_type}')


    if not override:
        new_xdata = np.linspace(min(xdata), max(xdata), num=100)


        if type(uncertainty) == int:
            abs_sig =True
        else:
            abs_sig = False

        if guess is not None:
            popt, pcov = curve_fit(model_func, xdata, ydata, sigma=uncertainty,
                                   maxfev=20000, absolute_sigma=abs_sig, p0=guess)
        else:
            popt, pcov = curve_fit(model_func, xdata, ydata, sigma=uncertainty,
                                   maxfev=20000, absolute_sigma=abs_sig)
        param_num = len(popt)

        exp_ydata = model_func(xdata,*popt)

        deg_free = len(xdata) - param_num

        new_ydata = model_func(new_xdata, *popt)

        residuals = None
        chi_sq = None

        if res:
            residuals = residual_calculation(exp_ydata, ydata)

        if chi:
            chi_sq = chi_sq_red(ydata, exp_ydata, uncertainty, deg_free)

        data_output = {
            'popt' : popt,
            'pcov' : pcov,
            'plotx': new_xdata,
```

```
            'ploty': new_ydata,
            'chisq' : chi_sq,
            'residuals' : residuals,
            'pstd' : np.sqrt(np.diag(pcov))
            }

        return data_output

    else:
        return model_func(xdata, *override_params)


def quick_plot_residuals(xdata, ydata, plot_x, plot_y,
                         residuals, meta=None, uncertainty=[], save=False,
                         uncertainty_x=[]):
    """
    Relies on the python uncertainties package to function as normal, however,
    this can be overridden by providing a list for the uncertainties.
    """
    fig = plt.figure(figsize=(14,14))
    gs = gridspec.GridSpec(ncols=11, nrows=11, figure=fig)
    main_fig = fig.add_subplot(gs[:6,:])
    res_fig = fig.add_subplot(gs[8:,:])

    main_fig.grid('on')
    res_fig.grid('on')
    if type(uncertainty) is int:
        uncertainty = [uncertainty]*len(xdata)

    elif len(uncertainty) == 0:
        for y in ydata:
            uncertainty.append(y.std_dev)

    if meta is None:
        meta = {'title' : 'INSERT-TITLE',
                'xlabel' : 'INSERT-XLABEL',
                'ylabel' : 'INSERT-YLABEL',
                'chisq' : 0,
                'fit-label': "Best Fit",
                'data-label': "Data",
                'save-name' : 'IMAGE',
                'loc' : 'lower right'}

    main_fig.set_title(meta['title'], fontsize = 46)
    if len(uncertainty_x)==0:
        main_fig.errorbar(xdata, ydata, yerr=uncertainty, #xerr=uncertainty_x,
                          markersize='4', fmt='o', color='red',
                          label=meta['data-label'], ecolor='black')
    else:
        main_fig.errorbar(xdata, ydata, yerr=uncertainty, xerr=uncertainty_x,
                          markersize='4', fmt='o', color='red',
                          label=meta['data-label'], ecolor='black')

    main_fig.plot(plot_x, plot_y, linestyle='dashed',
```

```
                  label=meta['fit-label'])

    main_fig.set_xlabel(meta['xlabel'])
    main_fig.set_ylabel(meta['ylabel'])
    main_fig.legend(loc=meta['loc'])


    res_fig.errorbar(xdata, residuals, markersize='3', color='red', fmt='o',
                     yerr=uncertainty, ecolor='black', alpha=0.7)
    res_fig.axhline(y=0, linestyle='dashed', color='blue')
    res_fig.set_title('Residuals')
    save_name = meta["save-name"]
    plt.savefig(f'figures/{save_name}.png')

def quick_plot_test(xdata, ydata, plot_x = [], plot_y = [],
                    uncertainty=[]):
    plt.figure(figsize=((14,10)))

    plt.title("Test Plot for data")
    plt.xlabel("X Data")
    plt.ylabel("Y Data")

    if len(uncertainty) != 0:
        plt.errorbar(xdata, ydata, yerr=uncertainty, fmt='o')
    else:
        plt.scatter(xdata, ydata)

    plt.grid("on")
    plt.show()
    plt.savefig('Test.png')
    plt.close()

def block_print(data: list[str], title: str, delimiter='=') -> None:
    """
    Prints a formated block of text with a title and delimiter

    Parameters
    ----------
    data : list[str]
        Text to be printed (should be input as one block of text).
    title : str
        Title of the data being output.
    delimiter : str, optional
        Delimiter to be used. The default is '='.

    Returns
    -------
    None.

    Examples
    --------
    >>> r_log = 100114.24998718781
    >>> r_dec = 0.007422298127465114
    >>> data = [f'r^2 value (log): {r_log}',
```

```
                f'r^2 value (real): {r_dec}']
    >>> block_print(data, 'Regression Coefficient', '=')
    ========================== Regression Coefficient ===========================
    r^2 value (log): 100114.24998718781
    r^2 value (real): 0.007422298127465114
    ================================================================================
    """
    term_size = os.get_terminal_size().columns

    breaks = 1
    str_len = len(title)+2
    while  str_len >= term_size:
        breaks += 1
        str_len = math.ceil(str_len/2)


    str_chunk_len = math.ceil(len(title)/breaks)
    str_chunks = textwrap.wrap(title, str_chunk_len)
    output = ''
    for chunk in str_chunks:
        border = delimiter*(math.floor((term_size - str_chunk_len)/2)-1)
        output = f'{border} {chunk} {border}\n'

    output=output[:-1]

    output+= '\n'+ '\n'.join(data) + '\n'
    output+=delimiter*term_size

    print(output)

def numerical_methods(method_type, args=None, custom_method=None):
    def gaussxw(N):

        # Initial approximation to roots of the Legendre polynomial
        a = np.linspace(3,4*N-1,N)/(4*N+2)
        x = np.cos(np.pi*a+1/(8*N*N*np.tan(a)))

        # Find roots using Newton's method
        epsilon = 1e-15
        delta = 1.0
        while delta>epsilon:
            p0 = np.ones(N,float)
            p1 = np.copy(x)
            for k in range(1,N):
                p0,p1 = p1,((2*k+1)*x*p1-k*p0)/(k+1)
            dp = (N+1)*(p0-x*p1)/(1-x*x)
            dx = p1/dp
            x -= dx
            delta = max(abs(dx))

        # Calculate the weights
        w = 2*(N+1)*(N+1)/(N*N*(1-x*x)*dp*dp)

        return x, w
```

```

    def gaussxwab(N,a,b):
        x,w = gaussxw(N)
        return 0.5*(b-a)*x+0.5*(b+a),0.5*(b-a)*w

    methods = {
    'gausswx' : gaussxw,
    'gaussxwab' : gaussxwab,
    'custom' : custom_method
    }

    try:
        method = methods[method_type]

    except:
        raise ValueError(f'Unsupported method-type: {method_type}')

    return method(*args)


def interpolation_methods(method_type, args=None, custom_method=None):

    methods = {
    'custom' : custom_method
    }

    try:
        method = methods[method_type]

    except:
        raise ValueError(f'Unsupported method-type: {method_type}')

    return method(*args)
```