

3. Song, K., Kim, B., Yoon, H., Yang, J., Kim, K., Xiao, H., Cho, M., (2015), Aspherical lens design and injection mold analysis using extracted shape information, Transactions of Materials Processing, 24(6), 437-442.
4. Kim D.-I., Kim, G.-H., (2014), Reconstruction and method for unknown aspheric surface equations from measurement of aspheric surfaces, KR101425780B1.
5. Github, lmfit/lmfit.py. <https://github.com/lmfit/lmfit-py>
6. Non-Linear Least-Squares Minimization and Curve-Fitting for Python, Performing fits and analyzing outputs. <https://lmfit.github.io/lmfit-py/fitting.html#goodness-of-fit-statistics>

APPENDIX

본 연구에서 개발한 파이썬 전체 코드를 첨부한다. Mac OS 환경 기준으로 작성하였음을 밝힌다.

```
import sys
from PyQt5.QtWidgets import *
import os
from openpyxl import load_workbook
import numpy as np
from lmfit import Model, Parameters

class MyApp(QWidget):
    def __init__(self):
        super().__init__()
        self.initUI()

    def initUI(self):
        # 라벨 및 텍스트 입력창 생성
        self.createLabel('Data Radius(mm) =', 20, 20)
        self.createLabel('If Checked, the value is fixed', 300, 60)

        self.qleR = QLineEdit(self)
        self.qleR.move(150, 20)

        self.createButton('??', 300, 15, self.onChanged)

        # 체크박스 생성
        self.checkboxes = {}
        self.createCheckboxes()

        self.setWindowTitle('Aspheric Compensation')
        self.setGeometry(300, 300, 500, 180)
        self.show()

    def createLabel(self, text, x, y):
        label = QLabel(text, self)
        label.move(x, y)

    def createButton(self, text, x, y, func):
        button = QPushButton(text, self)
        button.move(x, y)
        button.resize(button.sizeHint())
```

```
button.clicked.connect(func)
return button

def createCheckboxes(self):
    positions = [(20, 60), (20, 90), (70, 90), (120, 90), (170, 90),
                 (220, 90), (270, 90), (320, 90), (20, 120), (70, 120), (120, 120), (170,
                 120), (220, 120), (270, 120), (320, 120), (20, 150), (70, 150), (120,
                 150), (170, 150), (220, 150), (270, 150)]
    names = ['k', 'a1', 'a2', 'a3', 'a4', 'a5', 'a6', 'a7', 'a8', 'a9', 'a10', 'a11',
             'a12', 'a13', 'a14', 'a15', 'a16', 'a17', 'a18', 'a19', 'a20']
    unchecked_names = {'a2', 'a4', 'a6', 'a8', 'a10'}

    for pos, name in zip(positions, names):
        checkbox = QCheckBox(name, self)
        checkbox.move(*pos)

        if name not in unchecked_names:
            checkbox.toggle()

    self.checkboxes[name] = checkbox

def onChanged(self):
    Lens_Dia = self.qleR.text()
    Lens_Diameter = float(Lens_Dia)

    # 체크박스 값 설정
    parameters_var = {name: not cb.isChecked() for name, cb in
                       self.checkboxes.items()}

    # 파일 경로 설정
    path = ((os.path.sep.join(sys.argv[0].split(os.path.sep)[-1:])) + "/"
            excel/file/")
    list = [file for file in os.listdir(path) if file.endswith('.xlsx') and '~'
            not in file]
    print(list)

    Pitch = int(Lens_Diameter * 100 + 1)

    for file_name_raw in list:
        # 위에서 정의한 경로와 같은지 확인필요
        file_name = path + file_name_raw

        wb = load_workbook(filename=file_name, data_only=True)
        wf = load_workbook(filename=file_name, data_only=False)
        # 불러올 엑셀의 시트를 정함.
        ws = wb['Sheet1']
        # 시트에서 피팅할 로우데이터와 데이터 초기값 불러오기
        data = [ws[f'L{i}'].value for i in range(28, Pitch + 28)]
        initial_values = [float(ws[f'P{i}'].value) for i in range(3, 26)]

    # 비구면 함수 정의
    def asphere_complete(x, r0, k, a1, a2, a3, a4, a5, a6, a7, a8, a9,
                         a10, a11, a12, a13, a14, a15, a16, a17, a18, a19, a20):
        Aspherical_Term =
        a1*x+a2*(x**2)+a3*(x**3)+a4*(x**4)+a5*(x**5)+a6*(x**6)+a7*(
        x**7)+a8*(x**8)+a9*(x**9)+a10*(x**10)+a11*(x**11)+a12*(x**1
        2)+a13*(x**13)+a14*(x**14)+a15*(x**15)+a16*(x**16)+a17*(x**
        17)+a18*(x**18)+a19*(x**19)+a20*(x**20)
        Root_Term = 1 - (1 + k) * ((x / r0) ** 2)
        Spherical_Term = (x ** 2) / (r0 * (1 + np.sqrt(Root_Term)))
```

```

    return Spherical_Term + Aspherical_Term    # 위젯에서 지
정한 범위의 데이터 좌표(위에서 정의한 값으로 데이터 범위 설정)
    x = np.linspace(0, Lens_Diameter, Pitch)
    z = np.array(data)

    # 데이터값에 맞춰 정의된 함수의 변수를 피팅
    # 피팅하기 전에 초기값을 세팅해주어야 한다.
    fmodel = Model(asphere_complete)
    parameters = Parameters()
    r_max = np.max(x)
    parameters.add('r0', value=initial_values[0], vary=True)
    parameters.add('r_max', r_max, vary=False)
    parameters.add('k', value=initial_values[2],
vary=parameters_vary['k'])
    for i in range(1, 21):
        parameters.add(f'a{i}', value=initial_values[i+2],
vary=parameters_vary[f'a{i}'])

    # 피팅된 파라미터 값
    result = fmodel.fit(z, parameters, x=x)
    print(result.fit_report())

    ws2 = wf['Sheet1']
    ws2['O3'] = result.params['r0'].value
    ws2['O5'] = result.params['k'].value
    for i in range(1, 21):
        ws2[f'O{i + 5}'] = result.params[f'a{i}'].value

    wf.save(filename=file_name)

    self.close()

if __name__ == '__main__':
    app = QApplication(sys.argv)
    ex = MyApp()

```

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