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Pyqt5-Based Alpha Energy Spectrum Analysis Software

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ABSTRACT

The alpha energy spectrum measurement is a very important nuclear radiation measurement method. In order to acquire and process and analyze the alpha energy spectrum on-line, it is necessary to cooperate with a well-functioning, easy-to-operate, and interactive and friendly energy spectrum analysis software. The software uses a PIPS (Passivated Implanted Planar Silicon) detector, which has the advantages of high energy resolution, low noise and excellent spatial resolution compared with the traditional semiconductor Si detector, and a set of α energy spectrum analysis software system is designed and developed based on the framework of PyQt5, which realizes the online acquisition and processing of the α spectrum data, and smooths the data. Based on PyQt5 framework, a software system for α energy spectrum analysis was designed and developed to realize the online acquisition of α energy spectrum data, and to realize the functions of smoothing, energy scale, peak searching, peak area calculation, etc. After experimental testing, the software realizes the important methods of α energy spectrum analysis and energy spectrum decomposition, and the human-computer interaction is friendly, with good practicability and maintainability, and it has a certain value of use.

KEYWORDS

Alpha energy spectrum, PIPS, PyQt5, Energy spectrum analysis

1. INTRODUCTION

α-ray measurement is an important means of analyzing α radionuclides. Unlike other ray particles, α particles have a weak penetrating ability and are often absorbed before they reach the detector when measured in air, which leads to a more difficult measurement of α particles, and a certain amount of vacuum is generally required for the measurement[1]. A large amount of spectral data needs to be processed for α spectrum measurements, and a software that can quickly and accurately analyze and decode α spectrum is needed to ensure the efficiency and accuracy of the data processing and spectral decomposition[2,3]. In order to ensure the efficiency and accuracy of data processing and spectral decomposition, a software that can quickly and accurately analyze and decompose the α energy spectrum is needed. At present, the research and development of energy spectrum analysis software is relatively small, basically focusing on the development of γ energy spectrum analysis software, and the α energy spectrum analysis software is realized through the design of languages such as C, C++, etc. C language has high execution efficiency and strong cross-platform, but its security is low, lack of object-oriented support and relatively poor readability of the code; C++ supports object-oriented programming, high execution efficiency and strong cross-platform, but it is relatively complex, prone to memory leakage, and has a relatively poor readability. C++ supports object-oriented programming, high execution efficiency, cross-platform, but is relatively complex, prone to memory leaks, and limited by the degree of optimization of the compiler. Python has a simple and clear syntax, and provides rich functions of data processing, mathematical calculation, statistical analysis, etc[5,6]. Therefore, Python can be used to build the software, collect the spectral data online, and draw the spectral lines, which will make the design of the α-energy spectral analysis software faster and simpler, with a shorter R&D cycle, and a more user-friendly human-computer interface.

2. INTRODUCTION TO THE ALPHA ENERGY SPECTRUM MEASUREMENT SYSTEM

The spectrometer used in this paper is the ORTEC-8-channel ALPHA-ENSEMBLE multichannel energy spectrum analyzer, which consists of a PIPS detector, a preamplifier circuit, a main amplifier circuit, a vacuum chamber, a vacuum pump, a leakage current detection circuit, and a digital multichannel energy spectrum analyzer. The spectrometer has eight independent channels, each of which is capable of completing experiments independently and supports simultaneous operation of multiple channels. The area of the detector and the area of the sample diameter can be selected according to the needs, and the distance between the detector and the sample ranges from 8mm to 44mm, with a total of 10 adjustable gears, each 4mm apart, to meet different experimental purposes. The vacuum chamber and vacuum pump create the vacuum conditions required for the experiment, and the vacuum level can be adjusted by the software. The leakage current detection circuit monitors the leakage current of the detection equipment and displays it digitally on the software interface to provide visualization of the experimental data. The alpha energy spectrum detection system is shown in Figure 1

Fig.1 Alpha Energy Detection System

3. OVERALL DESIGN OF SOFTWARE

In this paper, we aim to develop a set of localized α energy spectrum analysis software with friendly human-computer interaction interface, excellent spectrum processing and spectrum solving ability, to realize the real-time acquisition of α energy spectrum data, the visualization of the spectrum, and the analysis of the spectrum data (including the spectrum data smoothing, peak searching, calculating the peak area, and spectrum fitting, etc.), and the software will be used in the experimental analysis of detecting the α radioactivity.

This alpha energy spectrum analysis software is based on the PyQt5 platform. PyQt5, a GUI development toolkit for Python, has the advantages of a rich set of functional components, cross-platform, easy to learn and use, a powerful layout manager, rich documentation and examples, integration with the Qt ecosystem, a variety of event-handling and signal-slotting mechanisms, and good performance, which makes it suitable for the development of a variety of types of graphical interface applications.

The software can be divided into four modules, including file operation module, data acquisition module, energy spectrum analysis module and energy spectrum plotting module, and the basic block diagram of the overall design is shown in Figure 2.

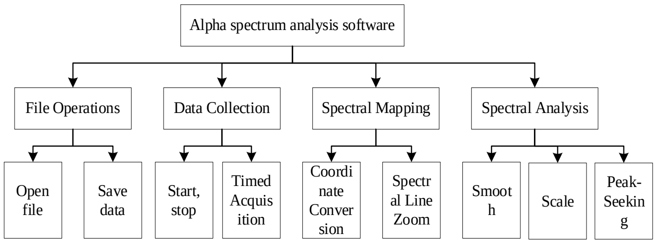

Fig.2 Alpha energy spectrum analysis software structure diagram

The main functional requirements of each module are as follows:

(1) File operation: It is required that the upper computer program can save the collected data, and the format of the saved data is ".Csv" file; the saved historical data can be opened for offline analysis.

(2) Data acquisition: communicate with the α energy spectrum analyzer, and set the acquisition time.

(3) Spectrum plotting: the currently collected data or offline historical data can be visualized on the main interface, and support the operation of spectral line scaling, the main interface should have a cursor to display the current user-selected channel address.

(4) Spectral analysis: It can process the spectral data and analyze the measurement results, including spectral smoothing, energy scale, peak searching and calculation of effective peak area.

The basic operation flow of the software is shown in Fig 3. The basic operation flow of the software is as follows: firstly, determine the data source for the energy spectrum analysis; if the data are acquired in real time, the spectrometer and detector need to be set up according to the purpose of this experiment, and then the data acquisition is carried out as the data used in the subsequent analysis; if it is analyzed offline, it is necessary to open the saved energy spectrum data and then carry out the analysis. Whether it is online or offline analysis, the process of spectral analysis is the same, first of all, the spectral data will be plotted in the main interface of the plotting workspace, and then set up the analysis parameters, which is mainly for the energy scale and other parameters are set up, and then after the completion of the setup, start to analyze the spectra and solve the spectra, and ultimately get the required results.

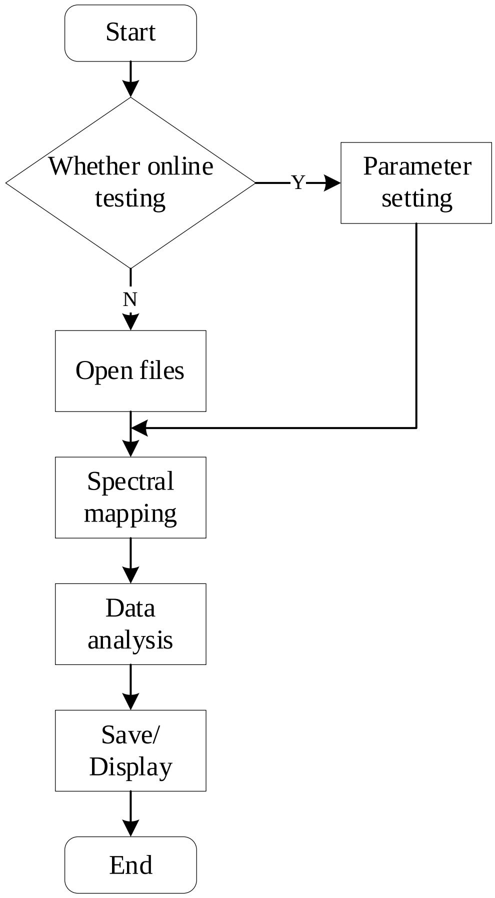

Fig.3 Software running flow chart

4. ALPHA SPECTRUM SOFTWARE TESTING

According to the needs of the software and the overall structure, the human-computer interaction interface of the software is designed following the principles of beautiful, practical and easy-to-operate interface. The main interface of the software is shown in Fig. 4, which mainly includes the menu bar, toolbar, spectrum plotting area and key information display area. The spectrum plotting area is mainly used to visualize the original spectrum or processed spectrum, and the cursor displays the currently selected peak position or the channel site selected by the current user. The menu bar and the toolbar of the software contain all the functions of parameter setting, acquisition control, spectrum analysis, spectrum fitting and so on. The right side of the main interface of the software is the information column, which displays the following information: the currently connected spectrometer, the simple acquisition information of the current spectrum, the energy of the currently selected site after the energy scale, the preset information of the acquisition control, as well as the related operations of spectral line scaling, and so on.

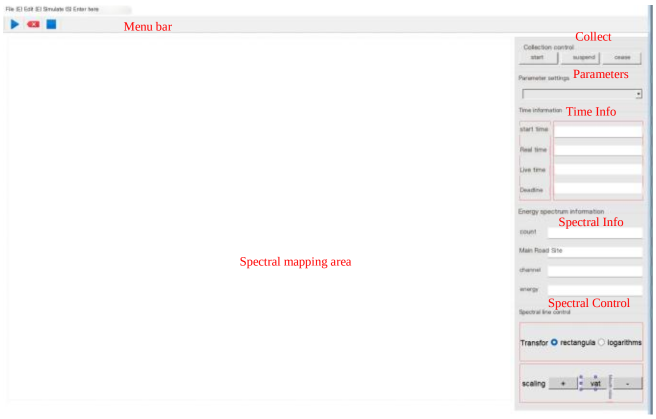

Fig.4 Main interface of the software

In order to reduce the influence of statistical rise and fall on the measurement and analysis of α-energy spectra, to ensure that the effective peaks have distinctive features in the energy spectrum, and to obtain relatively true and reliable analysis results, spectral smoothing must be performed. In the following, the five-point smoothing method in the center of gravity method will be introduced, centered on the data with subscript i[7]. The 5-point method obtains the subscripts of the points as i-2, i-1, i, i+1, i+2, and the center of gravity of the ith channel is:

$$Y_i = (y_{i-2} + 4y_{i-1} + 6y_i + 4y_{i+1} + y_{i+2})/16 \quad (1)$$

Where Y represents the smoothed data and y represents the original data. Figure 5 represents a comparison plot of the effect of 241Am raw energy spectrum in using the five-point smoothing method.

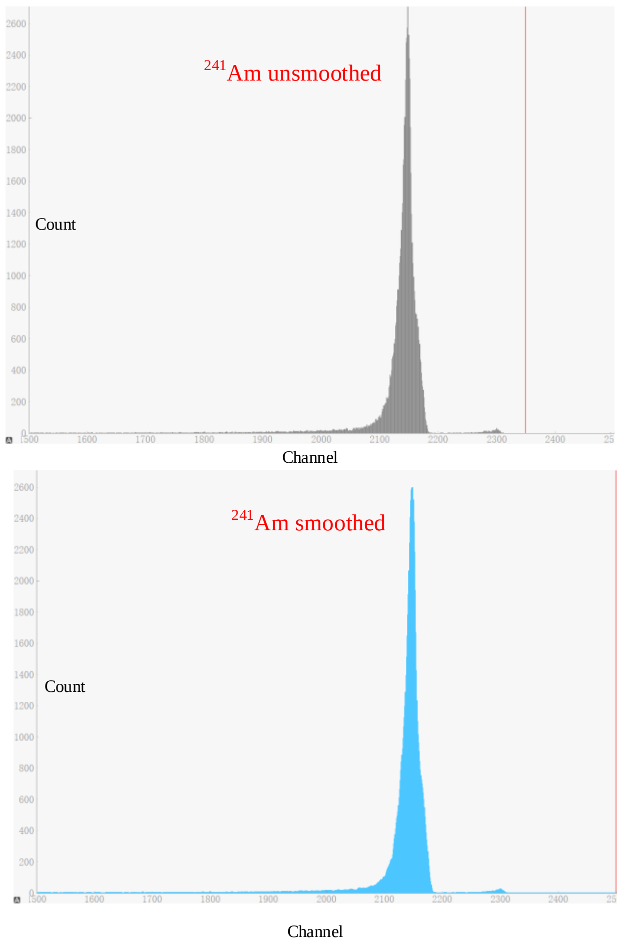

Fig.5 Comparison of Am five-point smoothing method

Energy scaling in the software is done using two main methods: least squares linear regression and least squares polynomial regression[8,9]. For linear regression analysis, at least two data points are required and a model similar to Eq. (2) is fitted.

$$E = a * x + b \tag{2}$$

When polynomial fitting is used, the input is at least three points and the form of the fit is shown in Eq. (3):

$$E = a * x^2 + b * x + c \tag{3}$$

The effect of 241Am using a linear energy scale is shown in Figure 6.

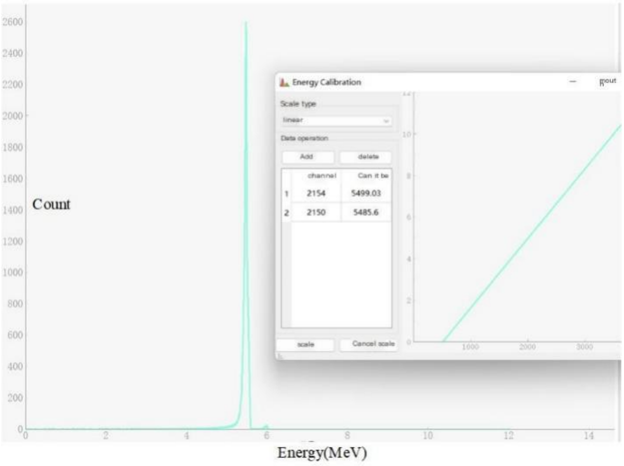

Fig.6 Am energy scale effect

The peak finding algorithm adopted in this paper is the derivative peak finding method, which integrates the functions of peak finding, calculating half-height width, background deduction and calculating peak area, etc[10]. In the process of peak detection, the user can synchronize the tasks of peak finding, half-height width and area calculation. Users in the process of peak detection, the software can be synchronized to complete the task of peak half-height width and area calculation, the calculated data in the form of a table intuitively displayed on the main interface. The result of peak searching by the software is shown in Fig. 7.

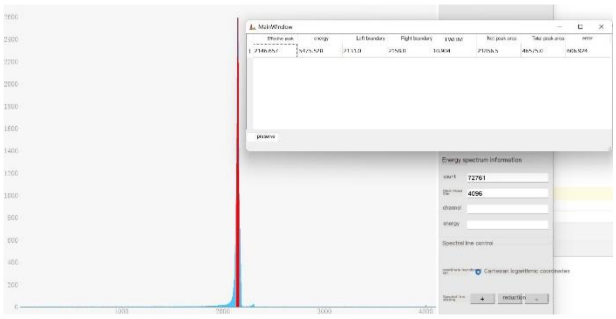

Fig.7 Am derivative peak finding effect

5. CONCLUSION

Based on PyQt5, the overall framework of the software is built, and then the required functions are gradually realized to complete the development of the α energy spectrum analysis software, and the functionality test of the software is carried out, which shows that the software realizes the on-line and off-line analysis of the α energy spectrum, and the deconvolution of the α spectrum, and the human-computer interactive interface of the software is friendly and easy to operate to meet the demands, and the spectral line smoothing function and energy scale function of the software provide a variety of methods to improve the analysis accuracy. The spectral line smoothing function and energy scaling function of the software provide a variety of methods for analysts to use flexibly according to the actual situation and improve the analysis accuracy. The software not only improves the efficiency of experimental data processing, but also provides an important tool for researchers.

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REFERENCES

[1] Xu Yangyang, Tou Xianguo, Shi Rui, et al. Monte Carlo simulation of detection efficiency of PIPS-α spectrometer and its influencing factors[J]. High Power Laser and Particle Beams, 2017, 29(10): 155-160.

[2] Shi R, Tuo X G, Li H L, et al. 239Pu alpha spectrum analysis based on PIPS detector response function and variations with vacuum and distance[J]. Nuclear Science and Techniques, 2017, 28(1): 4.

[3] Yao Xiaoyu, Tou Xianguo, Shi Rui, Li Qiang. Qt and Matlab hybrid programming method for designing alpha energy spectrum analysis software[J]. Nuclear Electronics and Detection Technology, 2018, 38(01): 70-75.

[4] Yang Yue, Luo Xujia, Li Chu. Design and development of nuclear energy spectrum data processing software based on Matlab[J]. Jiangxi Chemical Industry, 2019.

[5] Zhu Hao. Research on nuclear energy spectrum data acquisition and processing based on Matlab [D]. South China University, 2017.

[6] Zhang YT, Jia YM. Analysis and implementation of algebraic polynomial curve fitting in least squares[J]. Computer and Digital Engineering, 2017, 45(04): 637-639+654.

[7] Pöllänen R. Performance of an in-situ alpha spectrometer[J]. Applied Radiation and Isotopes, 2016, 109: 193-197.

[8] Shi R, Tuo X, Cheng Y, et al. Applications of non-negative iterative deconvolution method in the analysis of alpha-particle spectra[J]. The European Physical Journal Plus, 2020, 135(2): 225.

[9] Zhao Zhiyuan, Song Zhao, Wang Xiaoshan, et al. Design of calculation software for ground motion parameters based on PyQt5[J]. North China Earthquake Science, 2022, 40(4): 7-11

[10] Hao J, Ho T K. Machine learning made easy: a review of scikit-learn package in python programming language[J]. Journal of Educational and Behavioral Statistics, 2019, 44(3): 348-361.