ISBN: 978-3-95450-254-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS1991-S05SRN11

A Control & Data Acquisition System for Photoelectron Spectroscopy Experiment Station at Hefei National Synchrotron Radiation Laboratory

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Abstract

The paper describes system configuration and software design. The system has the following features: flexible user interface, succinct control levels, strict protection and high intelligence. It can run EDC, CFS, CIS experiment modes very conveniently with SR light source. Its construction and design idea of the system can be applied to other data acquisition systems.

1. Introduction

Photoelectron Spectroscopy Experiment Station at HESYRL works from VUV to soft x-ray wavelength(10ev -- 1000ev), with resolution E/E 10^{-3} and flux 10^{10} phs/s[1]. The present photoelectron spectrometer is imported from VSW (Vacuum Scientific Instruments) Co., U.K. The software package also provided by VSW is mainly designed for regular light source and regular photoelectron spectroscopy analysis techniques, but not suitable for the special requirement of experiment modes with SR source. Up to now, having modified and developed the control system and software, the completely compatible system can not only carry out regular analysis techniques such as Auger Electron Spectroscopy (AES), UV-Photoelectron Spectroscopy (UPS), X-ray Photoelectron Spectroscopy (XPS), but also bring about Synchrotron Radiation Photoemission Spectroscopy (SRPES), Angle Resolved Photoemission Spectroscopy (ARPES), Near Edge X-ray Absorption Fine Structure (NEXAFS) and Photoelectron Diffraction (PED) with controllable SR source. We hope it will promote further research on surface science and material science.

2. Design principle

. Special requirement

The basic principle of photoelectron spectroscopy is to irradiate samples with monochromatic light source, causing photoemission from atoms or molecules, then analyze the electron energy and angular distribution and get the useful information. So a control system for photoelectron spectroscopy experiment is focused on two points: to change exciting source and acquiring methods of electron energy.

Exciting source

The system must control beam line availability, such as wavelength scanning for different users in different experiment techniques, zero order scan, photon intensity detecting and other analog signal measurement.

Four different spherical gratings and entrance/exit slits are installed in the beamline. It is demanded that the rotation of the grating and translation of stepping motor driven entrance and exit slits follow the Rowland circle.

Operating modes

Three operating modes with SR source must be inserted to the system: EDC mode, CFS mode and CIS mode.

.Design principle & implementation scheme

1) It is necessary not only to meet the special requirement above, but also to assume the most succinct man-machine interface. Beamline control is an example. Although there are so many parameters of intelligent motor controller, and the gratings and slits tracing movement is complex, there are just three necessary parameters in the user's interface to execute beamline scanning: grating number, initial and final energy of photon. The new added GPIB interface supports all beamline control.

2) The integrity of the original software manager level structure is to be preserved. All the extended periphery drivers are inserted into Software/Hardware interface layer. The Function layer is expanded and other layers are developed.

3) We assure a complete compatibility with original software both in general and details. In general, it includes the following fields: man-machine interface, experiment queue, file system, image display and protection measure, specific processing such as exciting source selection, experiment technique selection, parameters input and collection, the experiment condition recorded in data file, status display and so on are completely compatible.

3. General description

.General manager level structure

The system structure can be divided into the following layers: User interface layer, Analyzer, Scheduler, Function layer, Software/Hardware interface layer and Hardware layer, as shown in Fig. 1.

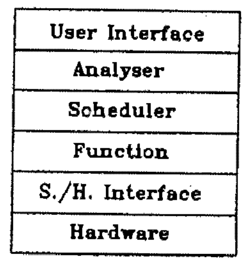

Fig.1 General manager level structure

User Interface layer

This level accepts and analyses preliminary user's input, it checks whether input is legal, displays peripheral equipment status and corresponding processing messages.

Analyzer

It makes a concrete analysis of user's input, then generates some legal results according to user's requirement and hardware environment. At last, the results are sent to the Scheduler.

Scheduler

It issues different function calls in the light of the results sent by Analyzer. If it must be supported by peripheral devices, it will transfer commands or parameters to peripheral devices and get status back through Software/Hardware interface. The calling skill is obtained by use of a special dictionary made of function pointers which just belongs to C language.

Function layer

It executes various concrete functions such as real time image display, reading and writing data files, queuing different experiments, running experiment and acquiring data. This layer and scheduler are the core of the system.

Software/Hardware interface layer

It is the lowest level of the software system. At this level, commands and data are transferred between system and peripheral devices. This layer includes all interface drivers and check of peripheral device status. If a certain device goes wrong or is not ready, a warning message will occur at the user interface.

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.Hardware configuration

The whole system configuration is shown in Fig. 2. All the experiment equipment is connected to host machine through two main interfaces: Asynchronous communication port RS232 and GPIB port.

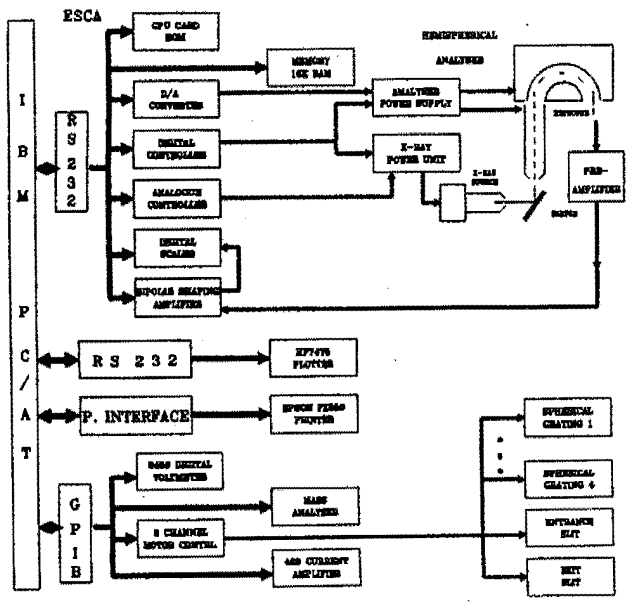

Fig. 2 Hardware configuration

RS232 serial interface

All devices of the photoelectron spectrometer and regular light source are connected to the special interface ESCA provided by VSW Co. and communicated with IBM-PC/AT via RS232. ESCA is an intelligent interface[2]. It contains CPU, ROM, RAM, converters, controllers, communication port and other I/O boards. The advantage of ESCA interface is to separate the software associated with hardware from data analysis at high level, so that users can cut out and extend software or hardware on the basis of different demands.

The photoelectron spectrometer has two kinds of electron energy analyzers: Angular Resolved HA50 which is equipped with HA5000 and HA300 controllers and Angular Integrated HA150 with HA5000 controller. The system provides Single Channel Detector (SCD) and Multi-Channel Detector (MCD) to acquire data. According to different conditions, MCD can be divided into three modes: Multi Slit Mode (MSL), pulse counting electronically variable slit mode (EVS) and Modulated Auger electronically variable slit mode (Auger)[3].

GPIB interface

All the devices concerned with beamline control, measurement and data acquisition are connected via GPIB interface. The essence of beamline scan is to control four different spherical gratings and entrance/exit slits by multi-channel stepping motor. The rotation of the grating and translation of the stepping motor driven entrance and exit slits follow the Rowland Circle to assure that the beamline has higher resolution over whole energy range. Besides, the mass analyzer also works via GPIB interface.

There are four CPUs in the whole system, 80286 in host computer, Motorola 6809 in ESCA interface, 8088 in stepping motor controller and CPU of multi voltmeter. These CPUs work in cooperation with each other and in charge of main control or sub control respectively.

.Software structure

Software system can be divided into the following function blocks as shown in Fig.3: Input module, File module, Image display module, Kernel processing module and Interface control module. The functions of each module are described in the following:

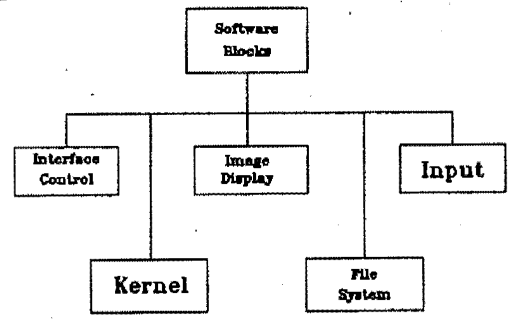

Fig.3 Software function blocks

Input module

It accepts user's input and belongs to User interface layer of manager level structure.

File module

It manages data files, generates or retrieves image files, builds or executes repeatedly command files. It belongs to Function layer.

Image module

It includes various technical processing such as to build man-machine interface windows, to display the acquired data, to form experiment spectrum, etc. This layer belongs to User interface and Function layers.

Kernel module

It executes user's command and implements concrete experiment task. It is permeated into all the layers in Fig.1 except for Software/Hardware interface layer.

Interface control module

It belongs to Software/Hardware interface layer. Besides transmitting common commands and data, it controls the two interfaces as follows:

ESCA Interface: Spectrometer control including to set up electrons' kinetic energy for energy analyzer, operation parameters, x-ray gun parameters, start energy, scan range and scan step, channels, dwell time of the detector for each channel and so on.

GPIB Interface: Beamline control including to set up parameters for each stepping motor, photon initial scan energy, scan range and scan step size, zero-scan, status display, photon intensity monitor and other analog signal measurement.

The layout of interface control is shown in Fig.4. Both INTERPRET and TERMINAL drop menu are man-machine interfaces associated with interface control. INTERPRET function dictionary belongs to kernel module.

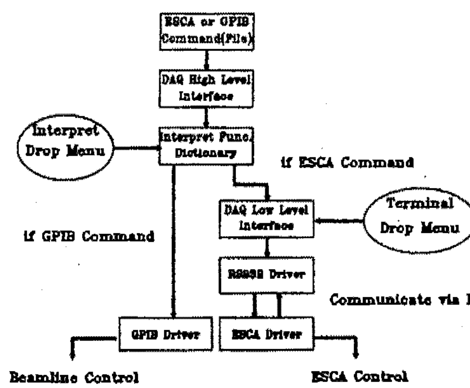

Fig.4 Structure of two interface control levels

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.Experiment course
The system supports the following modes & techniques:

Operating Mode	
Electron Density Curve with fixed photon energy	EDC
Constant Final State with scanning photon energy	CFS
Constant Initial State with scanning photon energy	CIS

Experiment Technique	
Synchrotron Radiation Photoemission Spectroscopy	SRPES
Angle Resolved Photoemission Spectroscopy	ARPES
Near Edge X-ray Absorption Fine Structure	NEXAFS
Photoelectron Diffraction	PED
Auger Electron Spectroscopy	AES
X-Ray Photoelectron Spectroscopy	XPS
UV-Photoelectron Spectroscopy	UPS

Experiment Queue
To normalize experiment course, the system provides standard experiment queue table (Table 1) and experiment scan regions table (Table 2).
Table 1 shows Experiment Queue and its legal options.

Active	File	Regions	Technique	Analyser Controller	Detector	Source
y/n	•	#	EDC	HAC5000 or HAC300	MCD(MSL,EVS) or Scaler	SR
y/n	•	#	CFS	HAC5000 or HAC300	MCD(EVS) or Scaler	SR
y/n	•	#	CIS	HAC5000 or HAC300	MCD(EVS) or Scaler	SR
y/n	•	#	XPS	HAC5000	MCD(MSL,EVS) or Scaler	XRAY
y/n	•	#	UPS	HAC5000 or HAC300	MCD(MSL,EVS) or Scaler	UV
y/n	•	#	AES	HAC5000	MCD(MSL,EVS, Auger) or Scaler	E.G.

Table 1. Experiment Queue

Table 2 shows Scan Regions (take CFS mode as an example).

Active	Lable	Sweeps

CFS Mode					
Start	Span	Step	Points	KEFixed	Dwell

HAC 5000						
Mode	Pass	+/-	Lens	Mag	Res	Contact

MCD Detector			
Mod	Slits	Mode	Threshold

SR Source	
GratingNo	PhotonEnergy

Table 2. Scan Regions

Scan Regions table is composed of five parameter blocks. It will display a different parameter block according to the selected operating mode or experiment technique and experiment condition (in Table 1).

Experiment procedure
Users can set up parameters in the two tables above for different experiments and input command to start the system, then the whole experiment procedure will be run automatically. The acquired data are real time displayed on the screen, then are saved into memory. The data in memory are written to data file automatically after finishing scan for further processing later. If users have set up several experiments, it will run to next experiment as soon as finishing the last one. In addition, the system provides multi regions and multi scan functions to satisfy different user's needs. Users can deal with data in a special region repeatedly, so that the ratio of signal to noise and experiment result precision are improved.
It is convenient to build some non-standard experiment techniques at INTERPRET and TERMINAL man-machine interfaces.

.Data processing
Users can process experiment data off line by a separate data process software. The methods provided are the following: Data analysis (Smoothing, Background subtraction, Peak area measurement, Addition/Subtraction & Data re-scaling), Curve fitting and spectroscopy resolution, Deconvolution (Deconvolution by FFT or Iteration, Spin orbit partner removal by Deconvolution, X-ray satellite removal by deconvolution , Curve fitting by deconvolution)

All source files about 200 in number, are written in Microsoft C 5.1 and C 6.0.

4.Software features
The system adopts the following software techniques:
.Windows
All man-machine interfaces adopt advanced window techniques. The whole user layer can be located by keyboard and mouse. Users can input parameters, display status or execute action by main menu, drop menu, submenu, parameters input menu, command line and command file as shown in Fig.5. Generating, overlaying, saving and retrieving windows are implemented by reading/writing video memory directly.

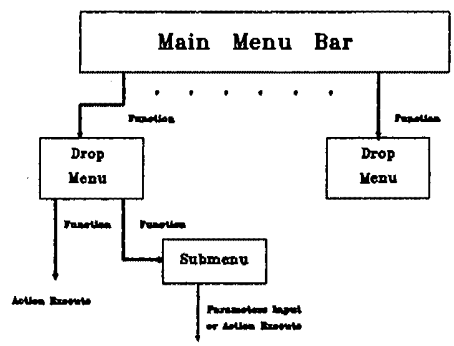

Fig.5 Menu levels

.File processing
File system has the functions of "save" and "retrieve". There are three kinds of files in the system.
The first one records experiment technique, experiment condition and experiment data. It can be further processed by a separate professional data processing software.
The second kind is an image file which displays real time during an experiment course. It ignores experiment conditions but preserves image attributes (screen color, image style, point coordinate...). It can be turned into image at any time but couldn't be processed by other data processing software.
The last one is a command file. The system can record command lines input by users and form a command file, then reserve it in order to run the experiment repeatedly at any time.
All the three kinds of files have one thing in common: the course of building, retrieving or executing files is implemented automatically. Users can input file name when message occurs.
.Real time display and image processing
The acquired data are displayed on the screen in separate (point) or continuous (line) style. The results are that a data file is formed and saved to disk automatically. The picture on the screen is a spectrum produced in the experiment course. In order to deal with wave peak or for other purposes, users can display the whole image, enlarge any part of the spectrum to full screen or move any part of the image to any location of screen. Of course, users can abort experiment and display course at any time.

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.Protection measures

To avoid abnormal phenomena caused by mis-setting parameters and commands or unreasonable steps during an experiment course, some protection measures are adopted. The protection measures are as follows:

Protecting against mis-setting parameters

If users set incorrect parameters because of being new to the instrument, the system will match hardware set and correct it, so that the hardware can be well protected.

Long jump from error sites

Error sites, such as device error or device not ready, mismatch of experiment technique and experiment condition will make machine dead and abort experiments. In that case, apart from displaying various warning messages in time, the system can save sites and stack environment at any position where errors may occur. When an error is detected, the system restores stack environment and jumps back to the original site.

.Data structure

Among source files, all variables and data structures such as pointer, dimension, structure, union, enumeration, table, chain, tree are used alternately and flexibly. Thus, source files not only have good readability, but also support the modular design for the whole software system. For example, INTERPRET drop menu, one of the man-machine interfaces, accepts FORTH style command and parameters and matches professional dictionary to control devices connected to ESCA and GPIB interfaces. The data structure relative to this part is a table. Each table item is a structure, whose structure members are composed of command names and corresponding function pointers.

.Modularization design

In spite of the software system composed of about 200 source files, the structure is succinct and well readable. The method is to concentrate the functions which implement a certain kind of function, construct one or a few source files and form independent function modules. The external interfaces of such modules are minimized and the implementation details for other modules are transparent. For example, the window module includes all the necessary functions. When you would like to make a window, you just call the interface function of window module and pass attributes such as length, width, coordinate, color, title label, without considering implementation details such as video mode, window overlay, the location of video memory etc. The same principle is adopted in real time display, file system, exciting source control, analog signal measure and SR experiment modules.

.Portability

Although the control & data acquisition system has professional experiment techniques and was designed specially as a synchrotron radiation photoelectron spectroscopy experiment station, it can be referred to in other control & data acquisition systems. Especially, the structure parts of the software such as experiment course, image real-time display, data file generation, interface control levels and strict protection are important elements in a large data acquisition system. The system can be applied to other conditions if modified somehow according to hardware configuration and experiment demands.

Modularization structure and flexible data structure in software improve portability of programs. Users can cut out or extend the original software in the light of different demands. Most function modules can be separated to insert other software systems. Thus, programming work is reduced and efficiency increased.

Portability is shown in the Software/Hardware interface layer too. This is because the analysis schedule functions are at high level in software and don't involve low level at which functions relative to hardware are located. So, if you want to build a new control system with different hardware, just modify the function layer, insert Software/Hardware function layer, which matches new devices into the system. A new control and data acquisition system with different functions but of the same style will be created. We have designed and developed a new system for a photochemistry station at HESYRL with the same structure and have made a great success in this field.

Acknowledgment

The authors gratefully acknowledge Mr. W. J. Ellword of VSW Co. U.K. who wrote the original commercial software for his helpful advice on general design and software technique. The thanks will be also extended to Ms. Jin Liu of IHEP for her part in work on motor control, Mr. P. Xu and J. Li of HESYRL for their information about concrete experiment demand.

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