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A multiparameter data acquisition system based on universal serial bus interface for electron momentum spectrometer

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A versatile multiparameter data acquisition system based on universal serial bus (USB) interface was designed and has been used on the electron momentum spectromenter. Digitized data were first buffered in a FIFO memory in an event-by-event mode with a check bit, and then transferred to computer through the USB interface. USB interface combined with a microcontroller unit provides much flexibility for data acquisition and experimental controls. The operation performance of the system is demonstrated in the measurement of electron momentum spectra of CH_2F_2 molecules. © *2004 American Institute of Physics.* [DOI: 10.1063/1.1781384]

Electron momentum spectroscopy (EMS), or (e, 2e) spectroscopy, is a powerful tool for investigating the electronic structure of matter. It measures the energy-momentum density of electrons in atoms, molecules, and solids by means of a kinematically complete ionization reaction initiated by an electron beam.[1] A low energy electron impacts on a target molecule, and is ionized so there are two emitting electrons in a (e, 2e) event. The energies and angles of the two emitted electrons have to be measured simultaneously in EMS. To ensure that the two outgoing electrons come from the same ionizing event, it is necessary to detect them in coincidence. Details of electron momentum spectrometer constructed in Tsinghua University have been reported in Ref. 2, and only a brief description was given. The (e, 2e) reaction was carried out under non-coplanar symmetric geometry, and the energy of the incident electron was scanned over 1200 eV. Two 180° half spherical electrostatic analyzers were used to disperse the electrons with different energies, and two resistive anode (RA) position sensitive detectors (PSD) were used to detected the two outgoing electrons. Two chevron-mounted stack of microchannel plates can amplify 10^6–10^7 times of signals generated by electrons, and PSDs encode the position of the detected electrons by a charge division method.[3] To obtain high signal noise ratio and low accidental coincident rate, the fast–slow coincidence techniques was used. To correct a misaligned bug of our previous system, an event-by-event acquisition mode with a check bit was taken.

The previous multiparameter system used in our laboratory is based on an ISA bus,[4] however, as the update of computer and its operation system, the multiparameter system based on the ISA bus has not been a good choice. Many personal computers do not have such ISA slots. Presently, USB has become more and more popular for computer peripheral devices, which is plug and play, and is supported by almost all computers and all operation systems, and can be extended to 3 m distance with a 12 Mbit/s band rate of USB1.0 protocol, or 480 Mbit/s of USB2.0.

In our spectrometer, two resistive anode PSDs were used to detect the electrons. The fast timing pulses are picked up from the back conductive layer of the resistive anodes, and are amplified by Ortec820, then passed through constant fraction discriminators (CFD) Ortec584 to minimize the timing jitter. The fast NIM logic pulse from one CFD is used as the start signal for time-to-amplitude conversion (TAC) Ortec567, and from the other, after a suitable delay, as the stop signal. The amplitude of the output from TAC is proportional to the time difference between the start and the stop pulses. The charge on the resistive layer of RA is collected, respectively, from the two electrodes by charge sensitive preamplifiers (house-in made), then amplified and shaped by amplifiers Ortec572. These pulses are rather slow, but give a good signal noise ratio. In our spectrometer, the typical position resolution is about 150 μm, and the typical width of true coincidence peak of time spectrum is about 10 ns (FWHM). To uniform the binding energy efficiency response, the energy of the incident electrons are usually scanned over a few tens eV range with a step of 5 eV.[5] A fixed count scan mode is taken instead of a fixed time scan mode because it is difficult to keep stable the intensities of the electron beam and target gas during the whole experimental period, typically one month for one sample. The counts of TTL logic pulse from one CFD are divided by 1024, then counted by a 12 bit counter, so the counting accuracy is about ±512, which is accurate enough for EMS.

The schematic diagram of the multiparameter system used on EMS is shown in Fig. 1. Five house-in made 12 bit ADCs were used to digitize the amplitude of pulses from amplifiers and TAC. Compared with the previous used system, a peak detecting (PD) circuit was used to give the triggering signals instead of the leading edge trigger (LET), because the LET signals have a significant time jitter due to the variation of pulse amplitudes. For pulses with a 1 μs shaping time constant and with heights which ranged from 0.1 to 10 V, the jitter time is about 2 μs, which will make the pulse

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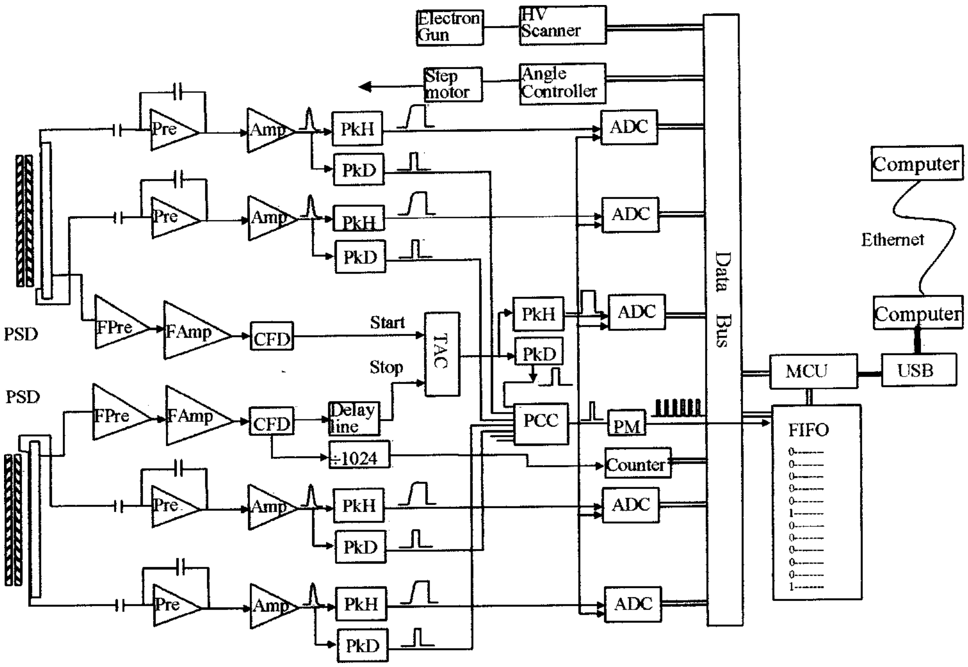

FIG. 1. Schematic diagram of multiparameter acquisition system for the electron momentum spectrometer.

coincident controller (PCC) lose some true (e, 2e) events. The conversion time of ADC is 5 μs, so a peak-hold circuit is used to hold the pulse height during the conversion time. PCC judges if the coincidence for the five pulses occurs with a coincident time adjustable from 0.1 to 50 μs. The output of PCC starts the conversion of all ADCs and triggers the pulse multiplier (PM). PM can generate a number of pulses in series when triggered, and the number of output pulses is programmable. In this case, PM generates six pulses in series for writing all ADCs results and the counter number into the FIFO memory when triggered.

The typical coincident rate of (e, 2e) is a few events per second, so a 4 k Word-size FIFO is used in the multiparameter system, although a 256 k Word FIFO is available commercially. The data are listed in the FIFO in event-by-event mode, as shown in Fig. 2. Since the data are 12 bit long, the highest bit is used as the check bit. The check bits of all data from the five ADCs are set to “0,” and the check bit of counter data is set to “1.” So, each valid event data should have five “0”s and one “1” in series at the highest bit, otherwise the data will be discarded. This is a significant improvement to our previous system, which occasionally had a misaligned mistake, and unfortunately, could not be discriminated by a computer. Figure 2 compares the previous mode with the new event-by-event mode. To realize the USB 1.0

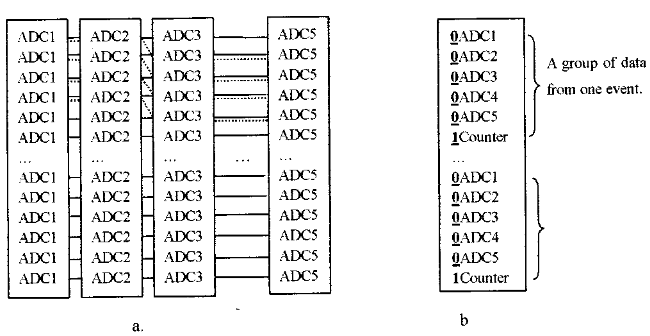

FIG. 2. The buffering mode of the multiparameter systems: (a) the previous system, each ADC has a FIFO memory, and the data from the one event were aligned according to the arriving order (thick line) but if some errors happen, partial data from one event were lost, and partial data were stored, so the next event data will be stored in order shown as the dash line. Unfortunately, all the next data will inherit this error and computer cannot discriminate this misaligned error; (b) the event-by-event mode with a check bit, all ADCs share one FIFO, and the highest bit of data were set as a check bit, the highest bit of data from ADCs were set to “0” and “1” from counter, so there are five 0’s, and one 1 in series for one event data, if not, this group of data will be discarded.

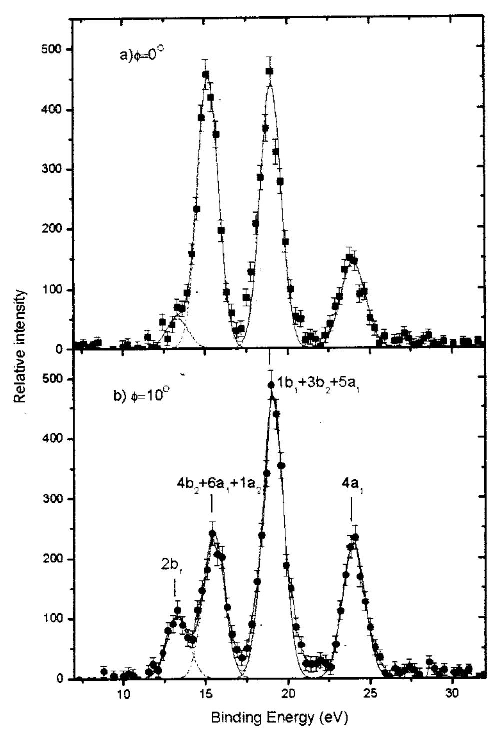

FIG. 3. Binding energy spectra of CH_2F_2 at ϕ=0° and ϕ=10°. The solid line is the theoretical calculation convolved with the instrument resolution and the natural width. The signs on the top of each peak are the orbital point group representation of CH_2F_2.

protocol, a microcontroller unit (MCU, Winbond778E5) and a USB interface chip (Philips PDIUSBD12) were used. MCU was also used to control the system bus, to realize the energy and angle scan, and other controls. Since MCU is programmable and directly orients the hardware, it is very flexible to realize these versatile controls with MCU.

When used on the EMS, the multiparameter system can be operated in three distinct modes by setting the ping–pong switches of PCC. (I) pulse height analyzing mode; in this mode, each individual ADC is used as a multichannel analyzer (MCA). This mode is mainly used to check that all pulses fall within defined lower and upper thresholds, and to calibrate the time spectra and gains of amplifiers; (II) elastic energy analyzing mode. This mode is mainly used to adjust the energy analyzer and to calibrate the energy spectra with known energy of the incident electrons. To obtain a good energy resolution, a good linearity, and a uniform electrons collecting efficiency, all parameters of the spectrometer must be very carefully adjusted in this mode, (III) coincident mode. The (e, 2e) events are measured in this mode. The binding energy spectra and time spectra are collected and displayed in real time on the computer, and all raw data are recorded on the hard disk.

In our recent work, this new data acquisition system described above was used to first measure the electron momentum spectra of CH_2F_2.CH_2F_2 has C_{2V} point group symmetry, Ref. 6 had more details about its valence shell electronic configuration. The incident electron energy was scanned over 1200–1230 eV, and the azimuthal angle was scanned over 0–30°. The binding energy spectra of CH_2F_2 at 0° and at 10° are compared in Fig. 3. There are distinct differences between the two graphs, and that is the highlight of EMS. The more details about the electronic states of CH_2F_2 obtained by this muliparameter system will be reported in other paper.

Although all above discussions are limited to six parameters, it can be easily expanded up to 14 parameters.

The USB interface makes the multiparameter acquisition system more adaptable to the developments of computer technologies, and MCU makes it more versatile, and the event-by-event mode with a check bit makes it more reliable. The performance of the system has been demonstrated in the measurement of electron momentum spectra of CH_2F_2.

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