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# A Simple X-ray Spectrometer and PC-based Data Acquisition System for Newly Developed X-ray Source Based on Laser Compton Scattering*

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**Abstract**: A simple X-ray spectrometer and a PC-Based Data Acquisition System(DAS) have been developed newly in Shanghai Institute of Applied Physics(SINAP), Chinese Academy of Sciences (CAS) for the measurement of the X-ray source generated using laser Compton scattering. The system consists of liquid nitrogen cooled high resolution Si(Li) detector, electronics and a DAQ. The Si(Li) detector was designed and made by Center of Advanced Instruments in SINAP, CAS, it allows us to measure X-rays with the energy up to 60 keV and the energy resolution(FWHM) of 184 eV at 5.9 keV. We measured the system uncertainty was 0.2 eV and time drifting of detector was 0.05% both at 5.9 keV. The DAQ was based on Object-Oriented software LabVIEW 7.1, it has data on-line analysis and original data saved functions.

**Key words**: laser Compton scattering; Si(Li) detector; energy resolustion

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## 1 Introduction

A newly developed X-ray source based on $\lambda$= 1.064 $\mu$m Nd:YAG laser beam Compton scattered by 108 MeV electron beam described in Ref. [1]. This will be installed as the prototype of the Shanghai Laser Electron Gamma Source (SLEGS)[2—4]. It is expected to generate X-rays of 24.8 keV when laser interacted with electron by angle of 40°, the possible obtained luminosity of X-rays is at the range of 0.2—0.3 W$^{-1}$ · nC$^{-1}$. The merit and characteristic of this kind of X-ray beam is adjustable. It is high intensity, high quality and polarization (linear or circular polarization). In addition, time structure of nanosecond pulse belongs to this kind of X-ray source.

X-ray source consisted mainly of Nd:YAG laser and its optical system, 100 MeV LINAC in SINAP, Compton chamber, synchronization system (time synchronization and space synchronization), Si(Li) detector and data detection system, etc (see Fig. 1). The Nd:YAG laser beam is generated, transmitted by its optical system, then focused and injected in vacuum target chamber, and finally scattered by 108 MeV relativistic electrons under the control of synchronization system, X-ray with a narrow divergence will be generated and detected

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by SLH-06160 detector at the end of the 100 MeV LINAC facility.

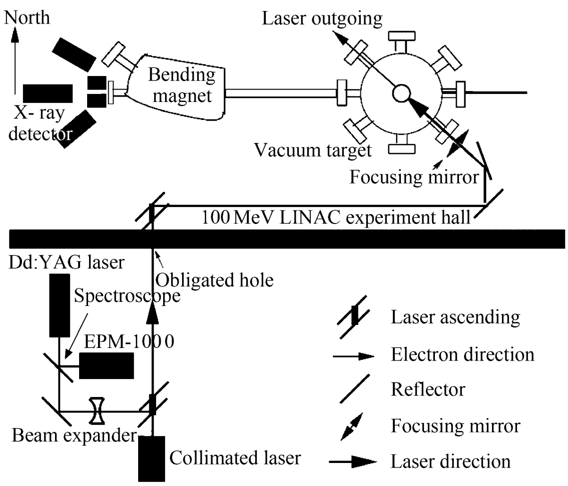


Fig. 1 The partially schematic diagram of facility of X-ray source.

The aim of this work is to develop a simple X-ray spectrometer and PC-Based Data Acquisition system based on SLEGS prototype. The data acquisition system was developed based on Object-Oriented software LabVIEW 7.1. The X-ray spectrometer is checked-up with its characteristic and performance. At the same time, making use of this system we did experiment with the detection of radioelement $^{125}$I in environment sample for Environmental Tech. Center in SINAP.

# 2 Setup of X-ray Spectrometer and PC-based Data Acquisition System

## 2.1 Si(Li) detector

Si(Li) detector as X-ray spectrometer was designed and made by Center of Advanced Instruments in SINAP, CAS (see Fig. 2). It's proposed to measure 20—30 keV X-ray produced by Laser Compton scattering here, and the full energy detector efficiency is near 100% at this energy range. The energy resolution of this kind of detector is 184 eV at 5.9 keV by radionuclide $^{55}$Fe. The related parameters of SLH-06160 are listed in Table 1. The detector has energy output port, time output port, high voltage input port and signal detect port. Here the detector was power supplied by ORTEC products HV659[4].

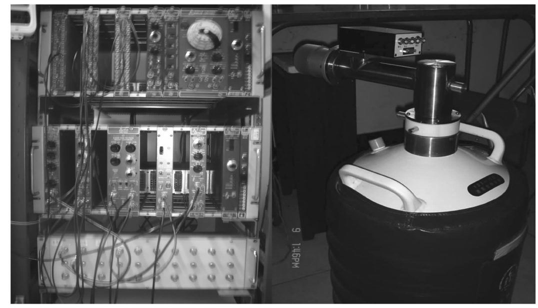

Fig. 2 The aspect of electronic system (left) and Si(Li) detector designed by Center of Advanced Instruments in SINAP, CAS (right).

**Table 1 Basic parameters of Si(Li) detector made by Center of Advanced Instruments in SINAP, CAS**

| Paramenter | Value |
|---|---|
| Crystal area /mm$^2$ | 30($\phi$6) |
| Crystal thickness /mm | 3.8 |
| Energy resolution at 5.9 keV/eV | 184 |
| Thickness of Be windows /$\mu$m | 7.5 |
| Negative bias voltage /V | 300—500 |

## 2.2 Electronics

For this study the electronics (see Fig. 2) referred mainly to the processing of the data from Si(Li) detector to ADC chip. The signals were pre-amplified by pre-amplifier and then energy signal and time signal were given out respectively. The energy signal was magnified by Amplifier 571 as Channel 1 of ADC. The delay time between time signal magnified by Timing Filter Amplifier (TFA) 474 and 100 MeV LINAC signal will be transformed by Time-to-Amplitude Converters (TAC) 567 as Channel 2 of ADC, the signal from TFA and from LINAC coincidence with each other by 4-Input Logic CO4020 as the trigger of ADC. The width of the trigger pulse can be adjusted up to 40 $\mu$s. The schematic diagram and aspects of electronics are shown in Fig. 3 and Fig. 2 (left), respectively.

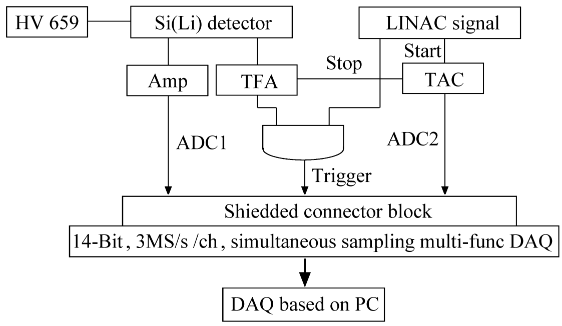


Fig. 3 Schematic diagram of electronics and data acquisition system, electronic instruments are manufactured by ORTEC Company. Information about the products can be found at Ref. [5].

## 2.3 DAQ System

The DAQ system consisted of DAQ interfaces NI BNC-2110, DAQ chip NI PCI-6132 (see Fig. 4)[6,7] and the corresponding LabVIEW procedure based on PC running with the Inter Core 2 CPU6400 processor using Windows XP as the Operation System which provides communication between the VME-bus and the PCI-bus.

The LabVIEW procedure of DAQ system mainly contains three modules as follows: read in data, on-line data analysis and original data saved.

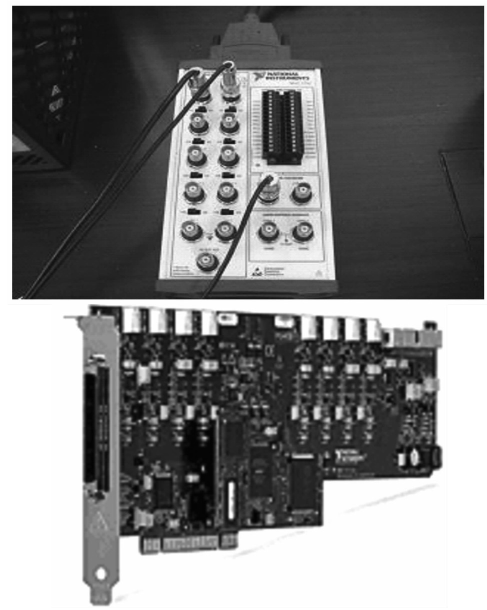

Fig. 4 DAQ interfaces NI BNC-2110(top) and DAQ chip NI PCI-6132(bottom).

# 3 Energy Calibration

Radionuclide $^{55}Fe$, $^{241}Am$, $^{238}Pu$ and $^{125}I$ were used to calibrate the data detection system. The X-ray spectrums of $^{55}Fe$, $^{241}Am$ and $^{238}Pu$ are shown in Fig. 5. Considering the spectrum shapes were

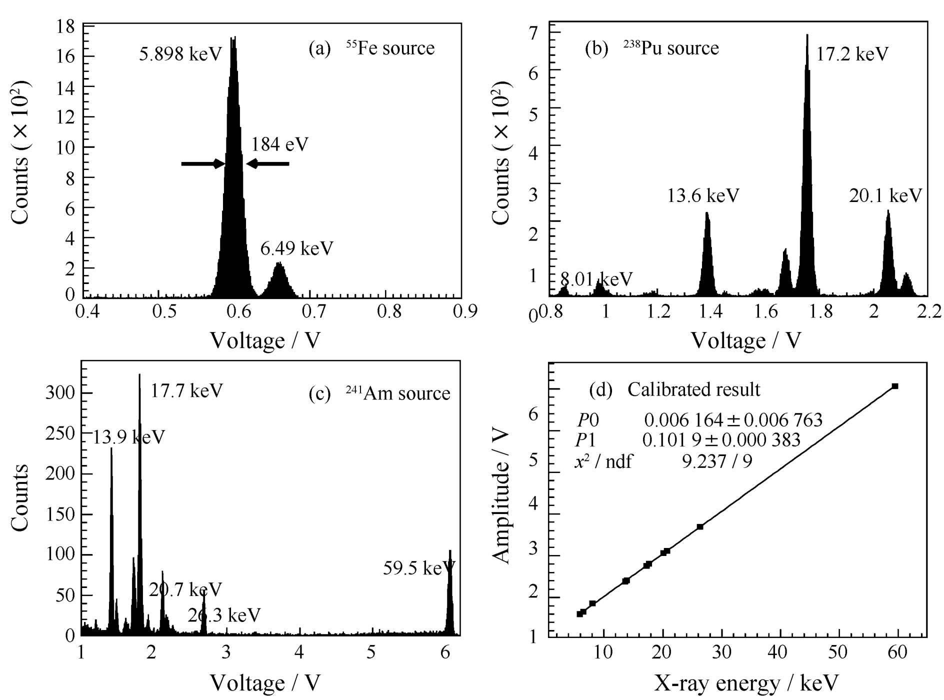


Fig. 5 X-ray spectrum of calibrated source $^{55}Fe$ (a), calibrated source $^{238}Pu$ (b), calibrated source $^{241}Am$ (c) and energy calibration result of data acquisition system (d); the fitted first-order line was passed-by origin point.

purely Gaussian, we can get the three parameters of X-ray Gaussian spectrum. Here the energy resolution of system was calculated to be 184 eV at 5.9 keV.

Because of the X-ray energy is proportional to its peak amplitude. So the first-order linearity correlation between X-ray energy and its peak amplitude was obtained (see Fig. 6). The corresponding formula is as follows:

$$A = P0 + P1 \times B;$$
$$P0 = -0.0014 \pm 0.0023,$$
$$P1 = 0.1021 \pm 0.0002.$$

Here $A$ represents the peak amplitude (in unit of V) of X-rays; $B$ is the X-rays energy peak (in unit of keV).

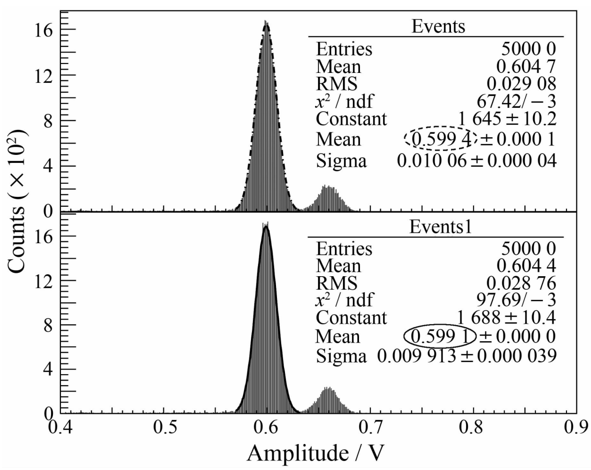


Fig. 6 X-ray spectrum of $^{55}$Fe source. Each spectrum corresponds to 10 000 Counts. The measured time gap is 72 h.

# 4 System Error and System Stability

$^{55}$Fe source was used to detect the whole system stability. Based on the same parameters of electronics and DAQ, we measured two group data with the measured time gap was 72 h. Considered the spectrum shapes were purely Gaussian, the 5.9 keV X-ray peak value are 0.5994 V and 0.5991 V, respectively. Compared both, the time drifting was 0.05%. Also the measured system uncertainty was 0.2 eV at 5.9 keV.

# 5 Conclusion

The results presented in this work have shown that a simple X-ray spectrometer and DAQ was designed successfully, it will be used to detect almost 25 keV X-ray generated by Laser Compton Scattering in SINAP, CAS. The good performance of system was detected by its energy resolution of 184 eV at 5.9 keV and system uncertainty of 2 eV at 5.9 keV. The DAQ software will be worked under the low counting mode which can meet the laser Compton scattering experiment of SINAP.

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