Anti-Compton High Purity Germanium Gamma Spectrometer

Model：TK-102

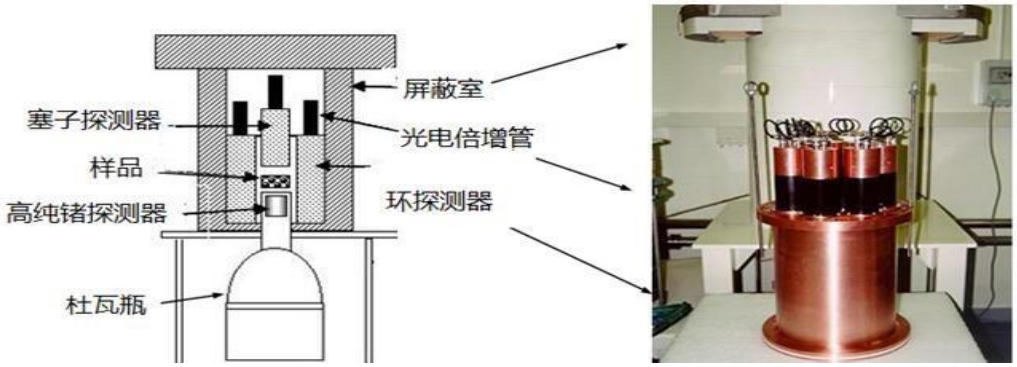

Fig. 1　TK-102 type anti-Compton high purity germanium γ system

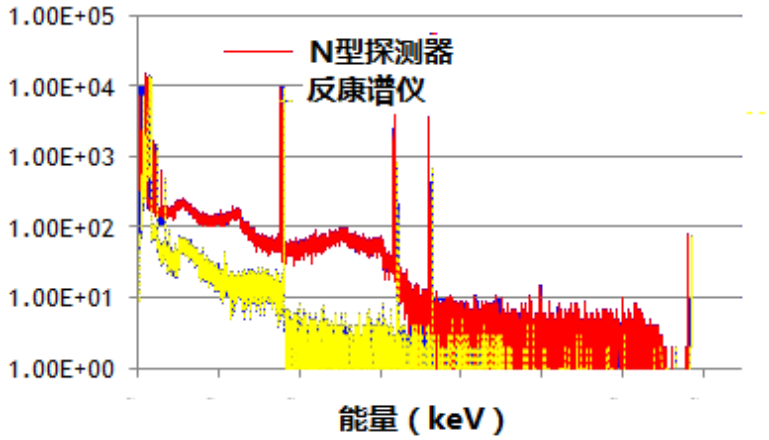

Fig. 2　Diagram of comparison of energy spectrum before and after anti-Compton for TK-102

Ⅰ. Product Introduction

When measuring radioactivity using a gamma-ray spectrometer, the useful information is the all-energy peak of the characteristic gamma ray; for the gamma ray emitted from the source, if a part of energy is deposited in the detector after Compton scattering, this signal can not enter the full-energy peak; this signal is the background for the radioactivity measurement, and its existence will raise the detection limit of the measurement, not conducive to the measurement of low-level gamma radioactivity. The use of anti-coincidence technology can effectively reduce the impact of Compton scattering, and is conducive to reducing the detection limit and to the measurement of low-level radioactivity. TK-102-type anti-Compton high-purity germanium gamma spectrometer uses a high-purity germanium detector as the main detector, and uses a NaI ring detector as the anti-coincidence detector; when the particles produce signals in the ring detector and the main detector simultaneously, it means that the main detector records gamma particles without full energy deposited, thus the signal is rejected using the anti-coincidence technique in order to achieve suppression of the Compton scattering and to reduce the detectable limit. The TK-102 consists of N-type (or P-type wide energy)

high purity germanium detector, sodium iodide ring detector, sodium iodide plug detector, anti-coincidence electronic modules, multi-channel analyzer, lead chamber and sourceless efficiency calibration software, spectrum analysis software and other components. With the joint use of common multi-channel analyzer and anti-multi-channel analyzer, TK-102 can obtain the anti-Compton and non-anti-Compton energy spectrums simultaneously, allowing that the system has advantages of both ordinary laboratory high-purity germanium spectrometer and anti-Compton high-purity germanium spectrometer.

Ⅱ. Main Features

- Combination of Common multi-channel analyzer and anti-Compton multi-channel analyzer enables to obtain the anti-Compton and non-anti-Compton energy spectrums simultaneously.
- With optimized design and low background materials, the system integration background is less than 0.6cps, and the system peak-to-Compton ratio is better than 1000: 1.
- The multi-channel, high-voltage module and other electronic systems use military-grade devices, with a special temperature stabilization design used, so the system has excellent long-term stability; the energy resolution at 1460.8KVV can be maintained less than 1.9KeV during the one-month continuous measurements.
- Energy spectrum analysis is mainly automatic, with auxiliary interactive analysis; the software has a powerful multiplet analysis ability.
- The radial information is provided for more than 3000 kinds of isotopes, with the nuclide library tightly combined with energy spectrum analysis software, for easy operation by user.
- Peak fitting results can be seen by users; users can understand the effect of energy spectrum analysis. Which is not be available by other commercial software.

Ⅲ. Technical Specifications

1. Overall technical indicators

- System peak-to-Compton ratio: ≥ 1000: 1;
- Simultaneous obtain and display the spectrograms before and after anti-Compton;
- Integral background: ≤ 0.6cps (can be lower with customized low-background lead).

2. High purity germanium detector

The N type or P type wide-energy detectors with various types and efficiencies can be optional, with the typical indicators as follows:

- Energy range: 3keV ~ 10MeV;
- Relative efficiency: ≥ 60%;

- Resolution: ≤ 1.1keV@122keV; ≤ 2.2keV@1332keV;
- Peak shape parameters: FW0.1M / FWHM ≤ 2.0, FW0.2M / FWHM ≤ 3.0;
- Liquid nitrogen refrigeration or liquid nitrogen condensation-return refrigeration is used.

3. Ring detector

- 9 "x 9" NaI (Tl) shield ring with a resolution of 9.5% @ 662 keV;
- Six PMT with 2" diameter.

4. Plug detector:

- 3 "x 3" NaI (Tl) crystal, with resolution of 7.5% @ 662 keV;
- One PMT with 3" diameter

5. Digital multi-channel

Special multi-channel for high-purity germanium spectrometer is used, with the main performance characteristics as follows.

- Maximum data throughput: greater than 100kcps;
- Coarse adjustment gain: 1, 2, 4, 8, 16 or 32 optional;
- Fine adjustment gain: 0.45 ~ 1 adjustable;
- Maximum address: 16384;
- Shaping time constant: rise time from 0.8μs to 23μs adjustable, with 0.2μs per step; flat-top time from 0.3 to 2.4μs, with 0.1μs per step, selected by the computer (automatically adjusted under automatic optimization);
- Linearity: integral nonlinearity ≤ ± 0.025%; differential nonlinearity ≤ ± 1%;
- Temperature coefficient: gain <35ppm / ° C; zero point <3ppm / ° C;
- Overload recovery: at maximum gain, 1000 times overload recovers to within 2% of rated output at 2.5 times non-overload pulse width;
- Pulse anti-accumulation: automatically set the field value, the pulse pair resolution: 500ns;
- Signal processing: with digital spectrum stabilization, automatic pole-zero adjustment, digital gated baseline recovery and other functions;
- Data memory: 16384-channel non-volatile memory, with each capacity of 2^{31}-1 counts;
- Memory segmentation (system conversion gain): 16384, 8192, 4096, 2048, 1024 or

512 channels selected by the computer;

- Digital spectrum stabilization: controlled by the computer; to stabilize the gain and zero;
- Automatic digital pole-zero adjustment: controlled by the computer, with manual or automatic setting;
- Count rate display: real-time display on the computer screen;
- Dead time correction: accuracy (changes with peak area) <3% (0 ~ 50000cps);
- Communication interface: USB2.0;
- Single-channel or twin-channel: a single-channel MCA and twin-channel MCA optional;
- Dimensions: 252mm × 150mm × 50mm;
- Weight: 1kg;
- Operating temperature: -10 ~ 50 ℃;

6. Anti-compliance electronic module

TK-102-A anti-Compton electronic module produced by Beijing Tai Kun Industrial Equipment Co.,Ltd. is used, including seven-circuit fast amplifiers, frontier discrimination tripper, delayer and stretcher, as shown in Fig. 3, with specific indicators as follows:

1) Fast amplifier

- Rise time is less than 8 nanoseconds;
- With gated baseline recovery;
- With pole - zero phase cancellation;
- 50-Ω delay line;
- Voltage gain adjustment factor: 0.9 ~ 500;
- Output drive voltage ± 5V (with 50Ω load);

2) Frontier discrimination trigger

- Constant-ratio timing discrimination;
- Excellent time resolution;
- Rejection patterns with differential, integral, constant ratio and slow rise time;
- Upper and lower threshold adjustable, with adjustment range of 30mV ~ 5V;
- Time travel ≦ 75ps (dynamic range: 100: 1);
- Adjustable output pulse width;

3) Delayer

- Four independent input parts;
- 50-Ω calibration delay line for linear or logic signals;
- 0 ~ 63.5ns delay, 0.5ns step;
- Delay accuracy: <+ - 0.1ns or + -1.0% (for each switch);

4) Stretcher

- Delay time: 0.5 ~ 5us adjustable;
- Broadening: 0.5 ~ 5us adjustable.

Fig. 3 Anti-Compton Electronics

7. Lead chamber

- Integral casted, press-type open door design with top translation ;
- Outer layer material: 1cm low-carbon steel;
- Middle layer material: 10cm low background radiation lead 4π direction shield;
- Inner layer material: 1mm thick tin and 3 mm oxygen-free copper, absorb X-ray;
- Area: 65cm x 65cm;
- Cavity size: Φ307mm x 604mm.

8. Energy spectrum analysis software

TK-102 is configured with a gamma-ray energy spectrum analysis software Gamma-4 that has developed its own distinctive features as well as integrating the advantages of main energy spectrum analysis software products internationally; that is, based on the automatic analysis as navigation, analysis results are exported through the selective precise interactive analysis. Gamma-4 is the only commercial energy spectrum analysis software that is capable of accurate analysis of multiplet. Gamma-4 integrates hardware control, energy spectrum acquisition, data analysis, report generation

and quality control in one, able to obtain 10 energy spectrum data simultaneously, having good compatibility with Windows7, Windows8 and Windows XP, with the following main functions:

- Spectrometer control: achievable parameter settings include: gain fine adjustment, start digital spectrum stabilization, adjusting high voltage, real time / live time display, setting the upper and lower discrimination threshold;
- Energy calibration: precise positioning of the peak position by unimodal fitting; the user determines the energy corresponding to the peak position according to the knowledge; the software provides nuclide peak information real-time query function;
- Peak searching: The first-order derivative and the second-order derivative method are used to search the isolated peak. On the basis of the fitting of the peak shape, the Mariscotti method is used to search the peak for the secondary peak searching, to determine the position of multiplet;
- Efficiency calibration: the software provides two functions, with one to call the efficiency calibration curve obtained by the experimental measurement and with the other to use calculation results got through the Gamma-4 sourceless efficiency calibration software seamless connecting wit this software; as the sourceless efficiency calibration is used, a variety of complex correction functions are no longer required in the spectral analysis, such as solid angle correction and attenuation correction;
- Peak fitting: through background deduction by the peak fitting to distinguish multiplet, the net counting rate is obtained. Gamma-4 provides excellent multiplet analysis function, using quasi-Newton method and Monte Carlo method and other numerical methods, to accurately analyze 20 multiplet. The non-linear background deduction is used to automatically adapt to the trend of changes in energy spectrum. The peak shape is fitted with a Gaussian function or a Gaussian function plus an front-to-rear exponential function trailing, having excellent fitting ability for distorted peak shape;
- Radioactivity calculation: For the different γ peak of the same nuclide, the radioactivity is calculated through the weighted average taking the branching ratio, and efficiency calibration factor into account. The nuclide attenuation and dead time correction during the measurement are also taken into account in the calculation of the radioactivity;

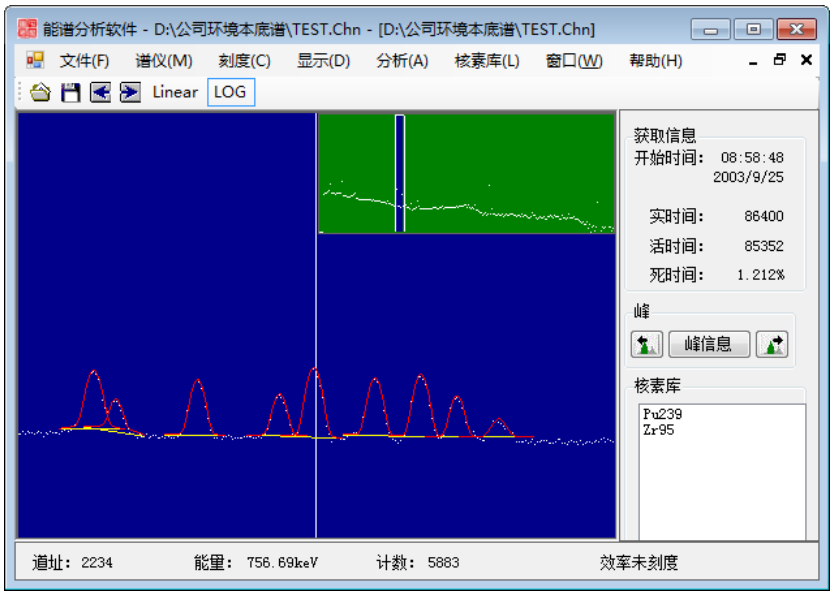

Fig. 4 Gamma-4 energy spectrum analysis software typical interface

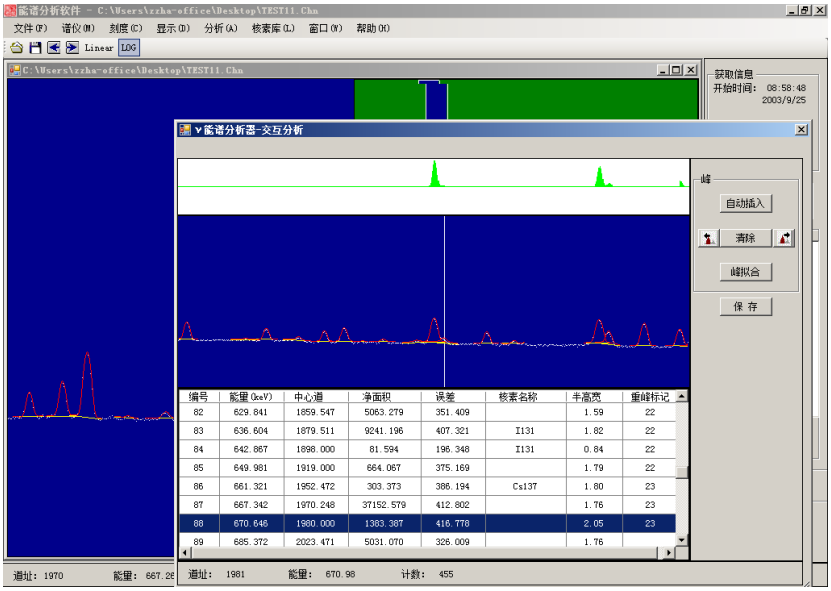

Fig. 5 Gamma-4 energy spectrum analysis software interactive analysis interface

- Minimum detectable limit calculation: built-in Currie MDA, KTA MDA, PISO MDA, Critical level and other analytical methods for selection;
- Uncertainty analysis: the comprehensive calculation of the uncertainty of the detection efficiency and the uncertainty of the counting rate is used to get the uncertainty of energy spectrum measurement results;
- Nuclide library for analysis: from ENSF (Evaluated nuclear structure data file), there are spectral line systems of more than 3000 kinds of radioisotopes; user can query line information in real time in the use process.

- Software assessment: 100 energy spectrums from 16 international laboratories are compared for software assessment, with the analysis results accuracy meeting the following requirements:
- User interface: complete Chinese interface or complete English interface;
- Analysis process: first full automatic analysis is made; the user selects concerned nuclide and energy peak based on the results of automatic analysis, and then does high-precision interactive analysis, and then outputs the report. In general, fully automated analysis function is able to meet users' needs. With the interactive analysis function, users are allowed to add comments to the sample, to delete false peak in the spectrum, and to add peak that is not detected in the automatic processing, and to change the shape of fitting peaks;
- Report output: Output reports in TXT, PDF, HTML and XML formats.

9. Sourceless efficiency calibration software

TK-102 is equipped with a Sourceless Efficiency Calibration Software Gamma-4, which is a patented product used for sourceless efficiency calibration of semiconductor gamma-ray detector. The software features with powerful geometry and material modeling ability, high calculation precision, fast speed, simple interface, easy operation. The correctness of the core algorithm is verified by experimental measurement results of more than 200 pieces of sources of different shape and energy. The main functions are as follows:

- The use of powerful CAD software modeling is to achieve three-dimensional rapid visual modeling for source of an arbitrary shape;
- The distance from the radioactive source to the detector can be 0 to infinity;
- Calibration energy range: from 45keV to 7MeV;
- Integral control accuracy can be adjusted artificially, with the software default value of 3%. The relative error of the test results of 200 body sources is generally not more than 10% from 45keV to 80 keV, and is not more than 5% from 80keV to 7MeV;
- Efficiency calibration curve calculation time: for symmetrical body source (such as environmental sample source), the calculation time is less than 20 seconds. For the shape of the asymmetric body source, the calculation time is generally less than 10 minutes;
- Chinese and English interfaces.

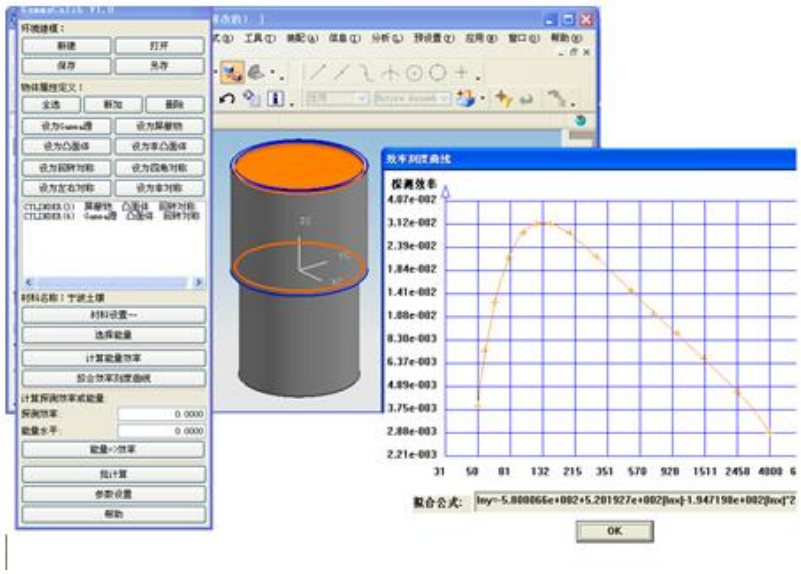

Fig. 6 Sourceless efficiency calibration software Gamma-4 typical interface

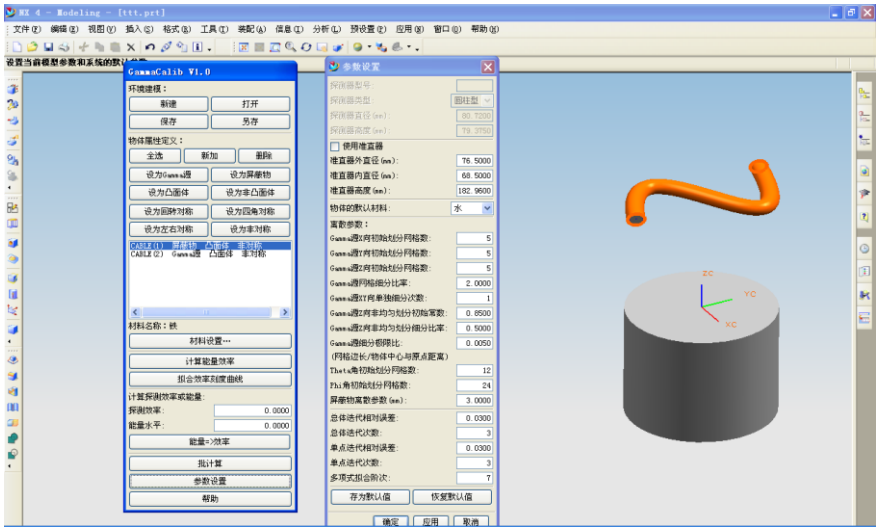

Fig. 7 Sourceless efficiency calibration software Gamma-4 typical parameter interface

Ⅳ. Applications

- Applicable for professional laboratories for measurement of soil radioactivity, food radioactivity, water radioactivivity, metal radioactivity, building materials radioactivity, and biological samples radioactivity, with a particular advantage for measurement of sample containing trace radioactive nuclei.

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