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Development of pulse counting system for TOF-MS with high-speed digitizer

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Secondary ion mass spectrometry (SIMS) is useful to determine elemental and isotopically abundances of various materials in a microscopic region. Multi-isotopes can be simultaneously detected by using time-of-flight mass spectrometry (TOF-MS), which is one of the features for TOF-MS. A mass resolving power is proportional to its flight distance. We are developing a spattered neutral mass spectrometer (Laser Ionization MAss nanoscope: LIMAS) [1]. LIMAS is consisted of focused Ga ion beam in order to examine a nano-scale region, femto-second laser which ionized spattered neutral particles, and multi-turn TOF-MS (MULTUM-II, [2]). The detection system of TOF-MS is as follows. Ions of each isotope (or compound) pass through the MULTUM-II. The ions are separated from each other during the flight, which depend on their m/z then they are detected by ion detection system with multi-channel plate (MCP). The ions are introduced as a packet of which time scale is several nano-seconds (ns) during the ion detection. High-speed digitizer with an analog bandwidths of $>$GHz distinguish a pulse from another. Extracted ions by single spatter are about ten thousand less than those by continues beam because pulse width of the primary beam is 300 ns. The low extraction rate leads directly to a low signal output. A pulse counting method in common use can dramatically increase a signal-to-noise ratio and deal with signal intensity quantitatively.

The detection system of LIMAS is composed of two steps MCP and preamp to amplifier the introduced electrical signal. A pulse width from the preamp is 6 ns and the pulse energy is distributed to 58 +/- 48 mV (3sigma). Because the noise level is -6 +/- 7 mV (3sigma), the pulse can be distinguished from noise. The output signal is recorded by using NI PXIe-5185 (hereafter 5185) digitizer of 1.25 x 10^{10} samples per second (S/s) and 8-bit vertical resolution. Two 5185s record the same signal which is split by distributer. One is for recording the analog output with wide input range (0.8 V full scale), another is for pulse counting with higher resolution (0.2 V full scale). A timing synchronization of each component is adjusted by using delay generator (BNC model-575).

The wave forms are recorded for several micro second by 1 kHz post-trigger, which are described as arrays in 8-bit. In pulse counting, the recorded array is simultaneously transformed to 1/0 one. An algorism of the deconvolution is as follows. When a center value of three arbitrary consecutive points is lower than the other two ones and lower than a threshold which is previously determined from pulse height distribution, the value of the center index is 1. The other cases are 0. A time resolution of this method depends on the sampling rate of 5185 (currently 3 GS/s) and responsively of the MCP (0.5 ns). Consequently, it is about 2 ns. In case of constant recurrence timing the system acquires ions from one to 5 x 10^8 cps. Since there is statistical fluctuation for incident ions, the ions are detected up to 5 x 10^7 cps for practical purpose. The system for a single triggered event cannot determine 1.7 ions or more due to counting loss. Another 5185 is used for digitizing the large analog signal.

[1] Yurimoto et al. (2011) Oyo Butsuri (Japanese), 80, 979. [2] Okumura et al. (2005) Eur. J. Mass Spectrom., 11, 261.

Keywords: NI PXIe-5185, High-speed digitizer, Pulse counting, TOF-MS