High-stability high-voltage power supply for MRTOF†

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Achieving the highest possible mass resolving power in a multi-reflection time-of-flight (MRTOF) mass spectrometer requires very high-stability power supplies. To this end, we have developed a programmable high-voltage power supply that can achieve long-term stability on the order of parts-per-million. We have demonstrated that in the 1 Hz–200 Hz band the output stability is on the level of 1 part per million (ppm) during one hour, with only slightly more output variation across 3 days. We have further demonstrated that the output is largely free of noise in the 1 Hz–200 Hz band. We have also demonstrated settling to the ppm level within one minute following a 100 V step transition.

In order to achieve a fast-settling, high-precision, long-term stable high-voltage power supply for driving our MRTOF, we have extended the concept laid out in the Voltage Multipliers, Inc, application note “AN-0300 - High Voltage Op-Amp Application Using Opto-Couplers,1)” which describes the use of infrared LEDs and high-voltage photodiodes to emulate an operational amplifier with up to 15 kV power supply span. A conceptual circuit diagram of our design, separated into functional blocks, is given in Fig. 1.

A crate of 16 power supplies was built to bias the electrodes of an MRTOF the measured time-of-flight is stable on the ppm-level for at least one hour.

Electrodes of 50 cm MRTOF-MS in the E3 (KISS) vault. The voltages were adjusted until a time resolution of 0.1 ns raw bin size MRTOF-MS operated with a PID stabilization scheme. The data for the PID stabilization was obtained using a 30 ms cycle period, yielding a minimum Allan deviation of 0.1 ppm, which coincides with the 0.1 ns raw bin width from the TDC.

Fig. 2 shows the result of an analysis of time-of-flight data from a several-hours-long measurement using our newly developed power supplies with the MRTOF in E3 along with a similar analysis using pre-existing hours-long duration data from our full-size MRTOF-MS operated with a PID stabilization scheme. The data for the PID stabilization was obtained using a 30 ms cycle period, yielding a minimum Allan deviation’s sampling period of 80 ms. The data for the present system was obtained using a 15 ms cycle period, yielding a minimum Allan deviation sampling period of 40 ms. These analyses shows that in terms of long-term stability the voltage stabilization circuit of the present work exceeds the performance of our RC filter enhanced PID regulation system. Using our new power supplies, the MRTOF exhibits white noise in the ion time-of-flight over a much wider duration than with the PID-based regulation systems.

References