# Ion source development of H-rich molecular beam operation for production of high-intensity proton beams at the UNILAC

*A. Adonin and R. Hollinger*

GSI, Darmstadt, Germany.

The operation of UNILAC high current injector with light ions (M/Q < 8) is strongly limited due to high transmission losses in the LEBT and RFQ. Another limitation is the low extraction voltage applied at the ion source due to the fixed specific ion energy of 2.2 keV/u at the RFQ entrance. These factors make the HSI operation with proton beams extremely inefficient. However the situation can be dramatically improved by production of singly charged heavy (up to M = 50 a.m.u.) molecular ion beams with a high content of hydrogen atoms. These molecular ions can be accelerated in the HSI with much lower transmission losses and when converted into a proton beam at the gas stripper [1].

For the experimental investigations the first two elements from alkane group: methane ($CH_4$) and ethane ($C_2H_6$) have been considered because they are non-toxic and could be used in the ion sources under the same safety requirements as a hydrogen gas. The first experiments have been performed with methane gas using high current MUCIS ion source. The mass spectrum of extracted beam is shown on Figure 1. It contains several different molecule species (including higher order alkane chain). However by tuning the operation parameters of the ion source it was possible to optimize the spectrum and get the maximum output of $CH_3^+$ ions.

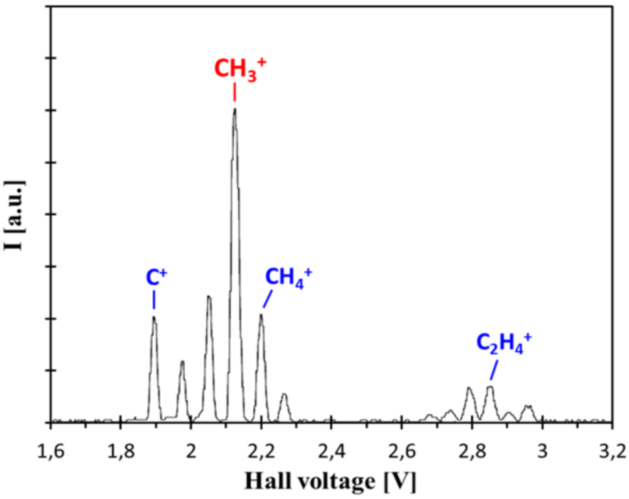


Figure 1: Mass-spectrum of methane gas optimized for $CH_3^+$ production

The operation was performed with duty cycle of 2 Hz and the pulse length from the ion source of 1 ms. The maximum beam currents achieved in the tests were 11 mA for unanalysed beam and 4 mA for $CH_3^+$ ions.

Tests with ethane gas have been performed with the same ion source and under the same conditions as with methane. The mass spectrum is more complex than for methane (Fig.2). The production maximum was achieved for $C_2H_4^+$ ions and maximum beam current in front of the RFQ was 2 mA.

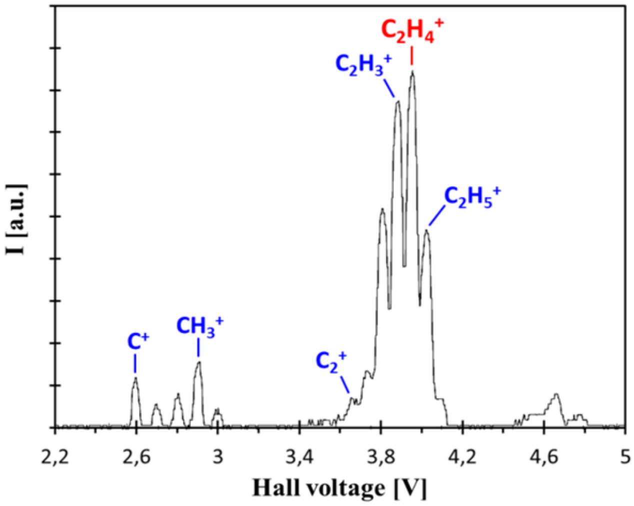


Figure 2: Mass-spectrum of ethane gas optimized for $C_2H_4^+$ production

A notable disadvantage in operation with $CH_4$ and $C_2H_6$ gases is strong and relatively fast contamination of the plasma chamber and the extraction system of the ion source with carbon. The carbon ions embedded in the heating filaments make them more fragile and reduce their durability and lifetime. Carbon deposits on the extraction electrodes causes sparking and breakdowns in the extraction system. Thus the operation with alkanes requires a full service of the ion source with cleaning of the plasma chamber once a week. While hydrogen operation requires only a filament service every 7-10 days.

The HSI operation with molecular $CH_3^+$ ion beam results in proton intensity up to 3 mA behind the gas stripper that is more than 1 order of magnitude higher (at transferline to SIS) than the intensity achieved with hydrogen operation. For further performance improvement of the ion source the optimization of the extraction system for singly-charged molecular beam production and reduction of carbon contamination effect are foreseen. Besides using of more heavy H-rich gases (such as propane, butane, trimethylamine, etc.) could provide better transmission and even higher yield of protons behind the gas stripper for future proton operation.

## References

[1] W. Barth et al., LINAC-2014 proceedings.


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