

A Mobile Instrument GRIBA for Negative Ion Studies

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Abstract. *Negative ion research is of particular interest for studies of the mechanism of forming small carbon molecules under conditions in interstellar space. A new mobile instrument is designed and will become available for measurements to explore electronic structure of negative ions in interaction of ion beam with rare or high-energy light sources located in various labs.*

Keywords: *Negative Ions, Photochemical Reactions, Mobile Instrument, Measurements of Detachment Energies, Molecules of Astrophysical Interest*

1. Introduction

Words such as exobiology, extraterrestrial or astrobiology traditionally sound more like science fiction. Yet late high-precision analyses of objects inside and in the vicinity of the Solar System (including cosmic dust samples) captured by NASA [1, 2] made at a number of laboratories show, in most of cases, positive contamination with scraps similar, as well as not similar, to Earth-life DNA sequences. Even if confirming cosmic seed-in hypothesis of life, it does not answer the question of how such DNA-like sequences were and/or are forming in interstellar space, where spectrometry shows the presence of carbon-containing molecules [3].

Therefore a need exists for more experimental research and advances in measurement instrumentation for studies of high-energy photochemical reactions of small hydrocarbon containing molecules in the interstellar environment. To evaluate the possible chemical reactions and to understand the mechanisms thereof, a good knowledge of the orbital energies and detachment energies is necessary. Most of the positive molecular ions of interest are more or less examined while very little is known about negative ions. Research of negative ion photochemistry may give a crucial answer to the riddle of the source of exobiological scraps.

Negative ion research traditions are well elaborated at Freiburg and Gothenburg (incl. Chalmers) and some other universities (Stockholm etc) [4] where equipment includes ion source, mass-spectrometric separation magnet, a quadrupole, and something like an electron energy spectrometer behind a high-vacuum photochemical reaction chamber. Usually such an experimental set-up, including a scanning laser, takes the space more than one room, and can therefore, only be used for the photochemical reactions with the existing at that place lasers or other high power radiation sources .

When the interest shifts to interstellar space shortwave light energies, the need arises for high-energy UV, VUV light source, like some unique lasers, and even synchrotron radiation sources. In this case, it is crucial to have the ability to move the installation producing ion beams to such a stationary light source, which means to have a portable instrument. Such unique apparatus is presented in this paper.

2. Subject and Methods

A cellar full of decommissioned instruments at the Gothenburg University provided the opportunity of re-using old parts to compose a new extra-low budget instrument comprised of two separate parts on wheels which are transportable in a middle-size minibus. The instrument is assembled on “Siemens” aluminum rails allowing for extremely versatile

mounting of parts. The total weight including three roughing pumps, two diffusion pumps, two turbo-molecular pumps, and one ion pump is less than one metric ton. Presently, in 2013, it is based at Gothenburg. Later it will be moved to Riga. The acronym GRIBA stands for Gothenburg-Riga Ion Beam Apparatus.

The instrument has a filament ion source [6] that may be used to generate a positive ion beam of sub-microampere scale current or negative ion beam of sub-nanoampere scale of substances of sample (inserted into it) evaporating under 2000 °C. The efforts are in progress to design laboratory made RF ICP (radiofrequency inductively coupled plasma) chamber to produce more stable ion beam with larger variability of originating ions and in particular eliminating some restrictions of the temperature while not interfering with the plans to explore molecular beams. In the extreme case, the ion head allows the implementation of a sputter source or a spray source, which is not being planned for the nearest future. Long-term expertise in ICP plasma technologies in Riga will be applied to make such innovation to perform measurements in positive and negative ion physics domain. [7].

After extracting ions from the plasma, they are focused, accelerated, and then filtered by a Wien filter (Colutron TM) - a double-focusing magnet and three-stage electrostatic field (velocity filter/mass selector) providing an uniform beam with all polluting co-substances being cleaned off. Initial MS (mass spectrometry) testing of the filter showed the sharpness of the cleaning curve ca. 100 for lightweight mass numbers. However there is enough place to mount the RF QMS (quadrupole) mass selector before photochemical reaction chamber, if pollutants occasionally will emerge at very nearby m/z ratio.

The beam then goes through a cesium vapour charge exchange chamber. If cesium is inserted and the vapour temperature stabilised, then majority of positive ions are converted to negative or even double negative ions. However the cell may not be employed, if charge reversing is not required. Cell is essential to get a better beam current.

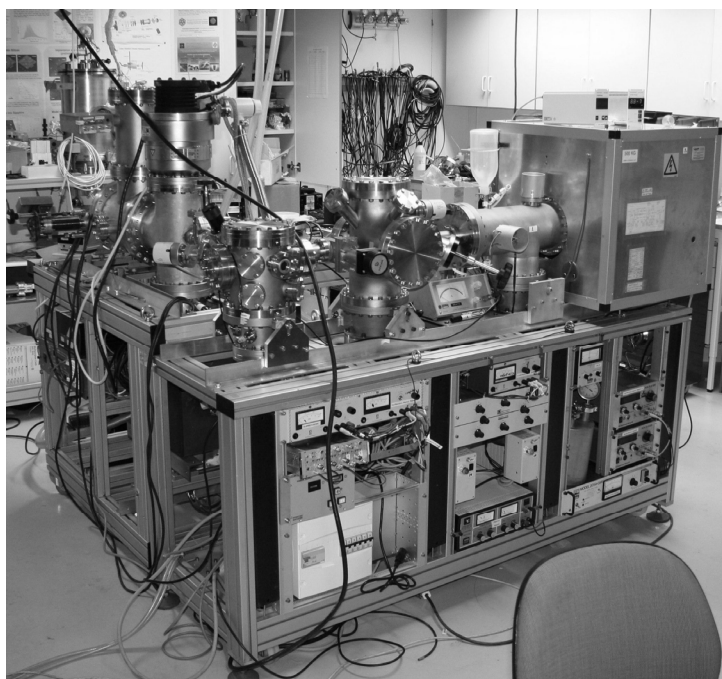


Fig. 1. View of the instrument: quadrupole in the corner, the high-vacuum station ending with TFS – at left, Colutron ending with the ion source – at right.

The first stand ends with an electrostatic deflector – a rectangle bending quadrupole. The bending angle of it is known to be mass indifferent. Thus, the ion beam may be turned to the left or right, or it may remain intact; thus particles with the wrong charge are filtered off the beam that after leaving the chamber, contain exclusively the chosen ions.

The second stand is connected here by a sylphon and vacuum valves, permitting disconnection of the stands for transportation while keeping a good vacuum. The second stand has 600 l/s turbopump in tandem with a 500 l/s ion pump to obtain ultrahigh vacuum in the photochemical reaction zone. The laser beam can be applied through windows from both ends longitudinally or transversally from both sides. A TFL (time-of-flight) electron spectrometer is mounted over the reaction zone, passed to use a transversal light source. However, a novel PEARLS [5] angle resolved spectrometer is going to be examined at autumn on. A low-grade MCP (micro-channel plate) made by newly developed ALD (atomic layer deposition) technology is placed at the end of the ion beam to enable optical adjustment of the ion beam position.

A high-grade MCP is placed above the TFL for registration. The MCP signal is pre-amplified and fixed on a high sample rate digital oscilloscope. At four positions stays Faraday cups (with easy-to-open ends for light input) for additional adjusting. Most of the ion beam adjustment, filtering and mass-spectroscopy functions are linked-in with DAQ cards and automated in a *LabView* software environment.

3. Results

The build up instrument is significant contribution to the upgrade of measurement infrastructure in the research on ion beams in EU and worldwide. The mobile instrument for negative ion energy studies at present is used in test mode and will be ready for experimental exercises early in summer 2013. The planning of experiments and selection of first target substances are in progress. SIM-ION modeling of the instrument is about ready, making the selection of experimental substances easier. By autumn the instrument will be used for cross-comparison of the TFS and PEARLS detection systems. Size of instrument at work position ca. 2*2*1,5m and of transport position 2,5*1,3*1,5m. Time scale for composing/discomposing for transport – hours. Expected life-span of sample substance loaded - with filament source 15 hr, with ICP source ca. 1000 hr. Vacuum at photochemical reaction zone expected 10E-11 Torr, already attained 10E-10 Torr. Ion beam energy already tried 50eV to 3,5 keV, yet at need is not difficult to mount a surplus accelerator for ca. 100 keV. Laser ray may be laid in from each of four direction, thus instrument is adjustable to near any kind of massive light source or accelerator geometry. Initially instrument uses Nd-YAG laser with crystal doubler.

4. Discussion

The installation described above presents a modular multiple purpose instrument with very high flexibility and transform or upgrade capacity, thus making a novel input into EU research infrastructure. It has the advantage of being relatively easily moved to permit the use of unique sources of light unavailable for ordinary negative ion research instruments. GRIBAM is designed to be conveniently rearranged to comply with different energy detectors, diverse sources of ions and charging methods. The proposed use of RF ICP plasma chamber, apart from widening the spectrum of substances for studies, also allows for higher ion currents and less polluted beam before mass selector. The team of designers in Riga and Gothenburg is open to proposals to plan and to perform joint experiments.

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