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Historical Perspective of the H^- Ion Source Symposia

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Historical Perspective of the H^- Ion Source Symposia

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Abstract. The International Symposium on the Production and Neutralization of Negative Hydrogen Ions and Beams is entering its third decade of providing a forum for the H^- ion source community. The first meeting was held at Brookhaven National Laboratory in 1977 and has returned there every three years to 1995. This is the eighth meeting in this series and for the first time is in Europe, hosted by CEA/Center de Cadarache. Since this Symposium is meeting in Europe many new people have had an opportunity to attend and many of these are of a younger generation. On the 20th anniversary of the First Symposium it seems fitting that a historical review should be given. The Symposium meetings and its archiving of information has been a valuable asset to this community. I hope to briefly describe the early H^- source work and provide some insight into the success of the H^- source effort.

I. INTRODUCTION

In 1951, at the University of California, Berkeley, a 2-MV generator was proposed to produce 4-MeV protons by injecting and stripping H^- ions in the HV terminal. The note describing this proposal also proposed the use of H^- ions for charge-exchange injection into synchrotrons.[1] At this time, H^- beams were obtained from the charge exchange of proton beams so only a few hundred microamperes could be expected. Nevertheless, the "swindletron", as it was called at Berkeley, became the Tandem Van de Graaff. Throughout the 60's H^- ions were obtained by charge exchange of proton beams and many sources along this line were developed[2]. Uses for H^- ions such as charge-exchange extraction from cyclotrons[3] and charge-exchange injection into synchrotrons were done[4-6].

In 1971 a Symposium on Ion Sources and Formation of Ion Beams was held at Brookhaven[7]. H^- charge-exchange ion sources were represented with papers from Los Alamos, Oxford University and the University of Wisconsin using donor gases of hydrogen, lithium and cesium. Kansas State University used a diode source for direct extraction of negative ions and Toshiba Research Center of Japan obtained H^- ions by direct extraction from a duoplasmatron. Currents of tens of microamperes to a few milliamperes were possible. Intense charge-exchange sources using a cesium canal to make H^- ions and H neutrals for fusion application were also mentioned[8].

In 1974 the Second Symposium on Ion Sources and Formation of Ion Beams was held at Berkeley[9]. A major contribution to this meeting was a paper

from Novosibirsk on "Surface-Plasma Source of Negative Ions". This was the first report of cesiated surface-plasma sources in the west although several papers had been published in Russia in 1972 and 1973. A Brookhaven report states that "first experiments (at Novosibirsk) with cesium were done in 1971!"[11] A comprehensive review of H^- source work to that time was presented[12], and papers on direct-extraction of negative ions from duoplasmatrons, major charge-exchange sources, etc. were given by the University of Washington, Los Alamos, Argonne, Brookhaven, and the Institut de Physique Nucleaire.

For the next several years H^- sources of many types were under development for accelerators and for fusion consideration. Novosibirsk and Brookhaven were actively studying the cesiated surface-plasma sources; large charge-exchange sources were under development at Livermore; and charge-exchange injection into the Argonne ZGS was successful[13] using a proton source in tandem with a hydrogen charge-exchange cell to obtain ~25 mA of H^- beam.

II. THE H^- SYMPOSIA

With the rapid rise in H^- source work, Brookhaven choose to host a Symposium on the Production and Neutralization of Negative Hydrogen Ions and Beams, September 26-30, 1977[14]. More than 50 people attended the meeting with 42 papers presented. The predominant consideration was the cesiated surface-plasma source. Several sources were already working or under development for accelerators. Fermilab was using a surface-plasma magnetron (planatron) source for injection of H^- ions onto the Linac, and Los Alamos was developing a high-duty-factor surface-plasma Penning source. Brookhaven, Berkeley, Oak Ridge, Novosibirsk, and others were considering these sources for high-power fusion use. Charge-exchange sources were still very much in the running especially for high-power fusion applications. For both the surface-plasma and the charge-exchange sources considerable effort was spent on discussing fundamental processes. Information for collision cross-sections, surface effects, space charge phenomena, etc. were necessary and represented work in progress or needed.

In the midst of all this was a paper on the "Production of Negative Hydrogen Ions in a Low Pressure Hydrogen Plasma," from Ecole Polytechnique. This paper, expounding the possibility of significant H^- ions within the volume of a plasma was rather shocking. There were cries of, "How could this be!"

Three years later, 1980, ion source people convened again at Brookhaven for the 2nd International Symposium on the Production and Neutralization of Negative Hydrogen Ions and Beams[15]. This time the symposium was titled "international" although international cooperation and participation had existed earlier. This meeting concentrated heavily on fundamental processes for both surface-plasma and volume-production sources. Yes, the production of H^- ions in the plasma volume had been further studied since the last symposium and it stood up. Now it needed to be explained and the formation of high vibrational states seemed to be part of the answer. Numerous ideas and measurements for surface-plasma and volume production came from Livermore, Berkeley, Oak Ridge, Ecole Polytechnique, FOM-Institute for Atomic Physics (Amsterdam), University of Pittsburgh, Stevens Institute of Technology, University of Ulster (Northern

Ireland), Wesleyan University, Instituto de Fisica (Mexico), the U.S. Air Force, SRI International, and others.

Ion sources with significant improvement and of new designs were presented. Berkeley had developed the converter source, which was also being studied at Culham; Novosibirsk change to a semi-planatron; Brookhaven was working on ampere surface-plasma sources; Oak Ridge had a surface-ionization source; and Nagoya University was working toward high-current surface-plasma sources. Smaller H^- sources for accelerators were doing well at Brookhaven, Fermilab, and Los Alamos.

Charge-exchange sources were presented by Livermore and Centre d'Etudes Nucleaires (Grenoble) but they were on their way out; and cluster sources were under development at the Institut fur Kernverfahrenstechnik (Karlsruhe).

The needed for multi-megawatt fusion injectors intensified research on beam lines, accelerators, neutralizers, etc.

The 3rd International Symposium on the Production and Neutralization of Negative Hydrogen Ions and Beams[16] (1983) concentrated heavily on fundamental processes for both volume and surface sources. A full day was given to each. Fundamental principles for surface-plasma sources were looking rather good and agreeing with source data, but volume processes were still uncertain. This was followed by many talks on sources themselves: sources for accelerators of good intensity and duty-factor, sources anticipating ampere and multi-ampere beams for fusion, sources based on surface effects and others based on volume principles. The magnetic filter field had been realized and it seemed to make possible a large-aperture scalable volume source for fusion. There was also many ideas on high-current accelerating and neutralizing systems in anticipation of fusion applications which was the ultimate goal for much of this effort. What fusion really needed was energetic neutral deuterium beams and much had to be done to address this matter.

At the 4th International Symposium[17] (1986) volume sources took the lead. Fundamental processes were concerned primarily with volume effects. Volume source development adopted the idea of a bucket or multi-cusp source with a magnetic-filter field to pass the low energy electrons into the extraction region. Still, these sources had low current densities, but they could apparently be scaled up to give hope for a high-current source for fusion. There were some sources of the surface-plasma and others of the volume type for accelerators. The SDI (Strategic Defense Initiative - "Star Wars") was interested in intense long-pulse H^- sources while down-to-earth accelerators were more modest and could use what was being produced. Improvements of earlier sources were occurring and new ideas based on previous concepts were being tried. Fusion continued to be interested in neutral beams so large accelerator systems and neutralizers were a part of the program. There was also some discussion on other negative ions and polarized ions.

Significant at this meeting was the introduction of cesium into a volume H^- source at the Kurchatov Institute. Cesium seeding immediately gave a large increase in the extracted H^- ions. This prompted several theories as to what might be going on, which continues to this day.

The Symposia have continued on a three year basis. At times the future seemed in doubt, especially when the fusion program was severely cut in the U.S. and when SDI ended; but, for accelerators H^- ions have become a necessity and the need for ever more intensity and duty-factor has pushed the H^- source community. Still, in other parts of the world, Japan and Europe, fusion remained and in spite of RF heating as a competitor, there was some impetus to build large sources.

At its peak, about the fourth or fifth symposium, approximately 100 participants attended, representing about a dozen countries. The atmosphere was always cordial, the presentations good, the discussion lively and the conference activities excellent. Over the several meetings there were many activities, ranging from a participants soccer match on the Brookhaven field to attending the N.Y. Metropolitan Opera.

III. CONCLUSIONS

These Symposia have undoubtedly been significant to the H^- ion source program. It has been important to bring people together in an atmosphere where all ideas could be presented and considered, and so it did. I has also been important in archiving the information and progress of this field as noted by the many references cited in these proceedings. Unfortunately the first two symposia proceedings had limited printing and are difficult to get.

The ion source community has had great success in developing H^- sources for numerous applications and in making new hardware work. This has been our forte. Understanding the fundamental processes, however, has developed at a somewhat slower pace. This has been due in part to the difficulty of the problem, and the lack or disparity of the information. Different investigators often found different effects. It seems that no sooner was one idea resolved than two more came up. For the most part, we were so busy building sources that we seldom had time to study them in detail, and given that they worked, we had to get on with using them.

IV. FINAL REMARKS

This review has covered the early years prior to the Brookhaven H^- Symposium and has gone essentially through the first decade, the first four sessions, of the Symposia. With this, the 8th Symposium, the second decade has come to a close and in another ten years someone can hopefully look back and review the second decade. The first decade was highly productive and I think it is clear that the second decade is as well.

During the present panel session on fundamental processes and ion sources there was some discussion about the early Symposia and their significance. Since this meeting was being held for the first time in Europe have been many new people attending this meeting, many of whom are young, so there appeared to be a need and purpose for this review.

In giving this review I have avoided persons names. It is clear that many people are important to the development of H^- ion sources and since it would be impossible to recognize everyone I have chosen not to give names. Still, many

people will know who the players are and if not, one can go to the proceedings to find some of the major people. I use institution names where possible and I apologize if I did not include some places. It should also be pointed out that in addition to this Symposia there were other ion source conferences that paralleled the information presented here. Note worthy among these is the European Workshop on the Production and Application of Light Negative Ions, with which this Symposium has merged. This merger will hopefully allow these combined meetings to be held in different parts of the world thereby reaching a broader audience and continuing to serve the world community.

Everyone who has worked on the H^- source problem, from the machinist and the lab technician to the senior scientists and the funding support personnel should feel pleased at a job well done. We have come a long way and it has been fruitful and good. At the first few symposia there were some people who stood tall among the group. Some of them are still amongst us, in the laboratories and at the meetings. Some have had to move to other areas. And some have retired but are not forgotten. The effort has gone on for many years. Unfortunately, some are no longer with us except in memory, but what a pleasant memory it is. On this the 20th anniversary of the first symposium (1977-1997), we should all be pleased with the progress that has been made and with our contribution, whether big or small. We should also take time to remember our colleagues.

REFERENCES

1. L. Alvarez, R.S.I., 22, 705 (1951).
2. K. Ehlers, N.I.M., 32, 309 (1965).
3. K.W. Ehlers, B.F. Gavin and E.L. Hubbard, N.I.M., 22, 87 (1963).
4. G.I. Budker and G.I. Dimov, *International Conf. on High Energy Accel.*, Dubna, USSR, August 21-27, 1963.
5. G.I. Dimov, et al, *USSR National Conf. on Part. Accelerators,* Moscow, October, 9-16, 1968.
6. R.L. Martin, IEEE Trans. on Nucl. Sci., NS-18, No. 3, 953, (June 1971).
7. *Proceedings of the Symposium on Ion Sources and Formation of Ion Beams,* Th. Sluyters, Editor. Brookhaven, Upton, N.Y., BNL 50310, October 19-21, 1971.
8. J.E. Osher, ibid, 137.
9. *Second Symposium on Ion Sources and Formation of Ion Beams*. Berkeley, LBL-3399, October 22-25, 1974.
10. Yu.I. Belchenko, G.I. Dimov and V.G. Dudnikov, ibid, VIII-1-1.
11. K. Prelec, AGS Division H- Technical Note, No 35, 1976.
12. Th. Sluyters, ibid, VIII-2-1.
13. C.W. Potts, IEEE Trans. on Nucl. Sci., NS-24, No. 3, 1385, (June 1977).
14. *Proceedings of the Symposium on the Production and Neutralization of Negative Hydrogen Ions and Beams*. Brookhaven, September 26-30, 1977, BNL 50727.
15. *Proceedings of the Second Symposium on the Production and Neutralization of Negative Hydrogen Ions and Beams*. Brookhaven, October 6-10, 1980, BNL 51304.
16. *Proceedings of the Third Symposium on the Production and Neutralization of Negative Hydrogen Ions and Beams.* Brookhaven, 1983, AIP Conference Proceedings, No. 111.
17. *Proceedings of the Fourth Symposium on the Production and Neutralization of Negative Hydrogen Ions and Beams.* Brookhaven, 1986, AIP Conference Proceedings, No. 158.