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MEETING REPORT

SIXTH INTERNATIONAL SYMPOSIUM ON RESONANCE IONIZATION SPECTROSCOPY AND ITS APPLICATIONS

Santa Fe, New Mexico, USA, May 24-29, 1992

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The Sixth International Symposium on Resonance Ionization Spectroscopy and Its Applications (RIS-92) was held in Santa Fe, New Mexico, USA, from May 24 to 29, 1992. The host Institution was the Los Alamos National Laboratory, under the auspices of the University of California and the United States Department of Energy. Dr. C.M. Miller (LANL) served as Co-Chairman of the Symposium, whose series is coordinated, as in the past, by the Institute of Resonance Ionization Spectroscopy of the University of Tennessee, under the leadership of Dr. J.E. Parks, who acted as the other Co-Chairman of RIS-92.

SCIENTIFIC PROGRAMME

In accordance with the previous meetings (the series started in 1981 in Gatlinburg, Tennessee, USA), the scientific flavour of RIS-92 was devoted to the theory and applications of the photoionization technique in different atomic and molecular reservoirs and with different tunable laser sources. Ten scientific sessions (see below) were arranged, with over 50 contributions (Plenary Lectures, Invited Lectures and Oral Presentations). In addition, two Poster Sessions were presented, each displaying about 20 contributions.

The Plenary Lectures were given by **P. Lambropoulos**, University of Southern California and University of Crete ("The Never-Ending Richness of Resonance Ionization"), **G. Toelg**, Institute of Spectrochemistry and Applied Spectroscopy, Dortmund ("Limitations of Extreme Trace Analysis from the Standpoint of Analytical Chemistry"), **V.S. Letokhov**, Institute of Spectroscopy, Troitsk, Moscow ("Towards Laser Resonance Ionization Photoelectron and Photoion Spectroscopy"), **N. Winograd**, University of Pennsylvania ("Prospects for Sub micron Molecular Imaging with Ion Beams

and Lasers") and **A. Mooradian**, MIT, Boston, Massachusetts ("Precision Frequency and Tunable Lasers for Spectroscopic Applications").

Invited Lectures were given by J. Crawford (Montreal, Canada), H. Backe (Mainz, Germany), B. Bushaw (Richland, Washington, USA), H. Hotop (Kaiserslautern, Germany), T.F. Gallagher (Charlottesville, Virginia, USA), W.R. Garrett (Oak Ridge, Tennessee, USA), N. Omenetto (Ispra, Italy), M.G. White (Upton, New York, USA), M. Pellin (Argonne, Illinois, USA), G.I. Bekov (Troitsk, Moscow, Russia), D. von der Linde (Essen, Germany), S.W. Downey (Murray Hill, New Jersey, USA), B. Dubreuil (Orleans, France), R.A. Keller (Los Alamos, New Mexico, USA) and H. Ravn (Geneva, Switzerland).

In the following, an attempt will be made to give an overview of the scientific contents of the meeting. Since it would be impossible to cover exhaustively all the topics presented, we have tried to emphasize some applications, with special emphasis to the analytical aspects of the presentation.
As clearly pointed out by Sam Hurst in his Keynote Address, the development of RIS has been such that many of the applications anticipated in the early meetings are now met. On the other hand, if a few applications are still under development, we can also welcome pleasant surprises, notably in molecular RIS and accelerator based studies of very rare isotopes, which were not anticipated a decade ago. A similar concept was echoed by P. Lambropoulos , which entitled his lecture "The Never-Ending Richness of RIS". This certainly testifies the continuous effort of many researchers active in the field of atomic and nuclear physics, material sciences, biology and environmental analysis.

Contributions have been arranged in Scientific Sessions, namely:

- *Ultra sensitive Applications*
- *Atomic Spectroscopy*
- *RIS Dynamics*
- *Laser Techniques in Flames and Plasmas*
- *Molecular RIS*
- *Analytical Applications*
- *Surface and Bulk Analysis*
- *Biological and Medical Applications*
- *Sources and Techniques.*

Being challenged as capable of single atom detection, the photoionization technique has already reached in many cases extremely high sensitivities and selectivities. For example, detection limits below hundred atoms have been achieved in the case of noble atoms with a second generation RIS-Time of Flight instrumentation (**Thonnard** *et al*, Atom Sciences Inc., Oak Ridge, TN, USA), while **Buchaw** (Pacific Northwest Laboratory, Richland, Washington, USA), using cw RIMS, has shown detection limits in the attogram range for important radioisotopes, namely for ^{210}Pb, which is an indicator of integrated radon exposure, and ^{90}Sr, because of its high yield in nuclear power generation. One drawback, related to the use of pulsed lasers, is that the duty cycle offered by most systems is very low, which means that the probing time, i.e., the time spent by the atomic/molecular target in the laser beam, is rather small. This is often alleviated using synchronized vaporization. A very intriguing approach to the solution of this problem is the use of *"trapping"* techniques, which can retain the target for a long time in the interaction volume. The use of a radio frequency quadrupole trap, suitable for the radioactive isotopes produced by nuclear accelerators, was described by **Crawford** (Mc Gill University, Montreal, Canada).

Another drawback of the RIS technique, when compared to other spectroscopic techniques such as plasma emission and plasma mass spectrometry, lies in its inability to perform multielement analysis on a simultaneous basis. **Bekov** (Institute of Spectroscopy, Troitsk, Moscow, Russia) has discussed the possibility of multielementy analysis, in which several (up to 5) dye lasers can be operated on a rapid sequential basis by a fast-acting scanner device (3-5 ms) allowing the simultaneous detection of three or more elements in a sample. This approach would be useful to other laser-based methods, such as fluorescence.

It is clear that the development of ultra sensitive methods is justified by the expanding needs of chemical analysis, when for example the micro distribution of particular elements in tissues or body fluids imply that only minute sample amounts are available. However, whenever such extremely low detection limits are reached, the question arises about their significance from the point of view of analytical precision and accuracy. As clearly stressed by **Toelg** (ISAS, Dortmund, Germany), the occurrence of systematic errors rapidly increases with decreasing concentrations and their recognition is very difficult, if sometimes not impossible. This is a fundamental problem which is faced by every technique of chemical analysis, *including RIS* and other laser-based methods. Real detection limits are limited by the blank values, which must be evaluated for the entire analytical procedure and not simply at the last measurement step.

The acronym RISM (Resonance Ionization Spectro Microscopy) was coined by **Letokhov** to describe the use of RIS in surface studies with the achievement of subwavelenght spatial resolution (approximately a nanometer). Detection of part-per-trillion impurity atoms in semiconductor targets and a variety of molecules at the attomole range from surface layers

has been discussed by **Winograd** (University of Pennsylvania, USA). The above limits correspond to just a few hundred atoms/cm^2 and a few hundred thousand molecules/cm^2. In these experiments, the species on the surface of the target are desorbed by a pulsed ion beam (one development being the possibility of using a liquid metal ion source, e.g., gallium) and then ionized with a multiphoton RIS scheme. **D. von der Linde** (University of Essen, Germany) has shown how laser photoionization with ultrashort pulses is used to study fundamental processes in surface physics and surface chemistry , which occur in that time scale. If thermal desorption can be achieved in the time frame of 1 ps, resolution at the femtosecond level will undoubtedly improve the understanding of the desorption kinetics. Moreover, these investigations are useful to achieve a better insight in the complicated processes associated with *laser ablation*, which is used more and more often as an atomic or molecular source for RIS.

In line with the long tradition of providing fundamental physical data on atoms and molecules and in continuation of the successful initiative presented at the RIS-88 Symposium in Gaithersburg, USA, **Saloman** (NIST, Gaithersburg, MD, USA) has updated his "RIS Data Service" work of providing for many elements RIS schemes and atomic data taken from available information and supplemented by calculations. Data sheets have appeared in the journal *Spectrochimica Acta B* for the elements Al, Au. B. C, Ca, Cd, Co, Cr, Cs, Cu, Fe, Ge, Hg, Kr, Mg, Ni, Pb, Si, and Zn. Other data sheets will appear for the elements Bi, Na, P, Sb and Sn.

As a final comment, it appears that there have been only a few papers dealing with *matrix-assisted laser desorption and ionization*, a popular topic, for instance, well covered in the scientific programme of the 40th ASMS

Conference, held shortly thereafter (May 31- June 5) in Washington, D.C., USA.

RIS SHORT COURSE

For the second time, following the successful initiative presented at the RIS-90 Symposium in Varese (Italy), a Short Course on RIS was presented. This Course, which was extremely well attended by the participants, was presented by four Lecturers, and covered a general introduction to the technique (*J.E. Parks*), the concept of selectivity in the photoionization process (*P. Lambropoulos*), high resolution resonance ionization (*T. Whitaker*) and the application of the technique to molecular studies (*J.C. Miller*).

AWARDS

As in the previous Symposium, in an effort to recognize outstanding efforts in the research and development in RIS, two awards were also given at this meeting, namely the *Excellence Award for RIS Research and Development* performed by a graduate student and the *Excellence Award for Poster Presentation*. The former was made possible by an endowment fund initiated by the Institute of Resonance Ionization Spectroscopy at the University of Tennessee, Knoxville, USA, while the last one was sponsored by a private donation, the Institute of Physics Publishing, and by the Institute of Resonance Ionization Spectroscopy. The Excellence Award for graduate research and development went to L. Monz for his work entitled "Collinear RIS for the detection of Sr-90 and Sr-89 in Environmental Samples". L. Monz is a graduate student of Prof. H.J. Kluge of the Institute of Physics at the

Johannes Gutenberg University in Mainz (Germany). Mr. Monz helped develop an experimental scheme for the fast, sensitive and selective detection of small amounts of the hazardous radioactive isotope Sr-90 in air. The second award went to Dr. G. Petrucci of the University of Florida, Gainesville (USA), recognizing the work (coauthored by R. Badini and J.D. Winefordner) entitled "Resonance Detection of Photons". This new technique demonstrated the feasibility of using the ionization scheme in flames to detect Raman photons from several samples. This award resulted from a strong competition between many good presentations. For example, the work of Franzke *et al.* (ISAS, Dortmund, Germany) is certainly worth of being mentioned. Also, it is necessary to emphasize that many poster contributions had to be withdrawn, because economical difficulties have prevented their authors from attending the meeting.

In addition to these awards, the research group of Dr. R. Estler at the Department of Chemistry in Fort Lewis, Durango, Colorado, USA, earned an honorable mention for proving that undergraduates on a very restricted budget can make important contributions to RIS research, normally carried out with million-dollar projects. The three student of Dr. Estler were J. Zoller, R. Lewis and G. Rothschopf. The honorable mention given to this group illustrates that RIS research at the undergraduate level can provide meaningful and valuable experience for the undergraduate students.

Finally, N. Omenetto received an award, on behalf of the Commission of the European Communities, Joint Research Centre of Ispra, Italy, for the successful organization of the RIS-90 Symposium in Varese.

EXCURSION

A relaxing break was taken on Wednesday afternoon, where a tour was arranged to Los Alamos and its surroundings, including a visit to Bandelier

National Monument. This scenic tour, a step back in time among the Indian culture and their traditional Pueblos, has been attractive also for European people, who are accustomed with antiquities.

SPONSORING INSTITUTIONS

Thanks are due to many sponsors for their support. These were: 1) *United States Department of Energy, Office of Health and Environmental Research*, Washington D.C., USA ; 2) *Atom Sciences, Inc.*, Oak Ridge, Tennessee, USA; 3) *Coherent Inc.*, Palo Alto, California, USA; 4) *Continuum*, Santa Clara, California, USA; 5) *Kratos Analytical*, Ramsey, New Jersey, USA; 6) *Lumonics Inc.*, Kanata, Ottawa, Ontario, Canada; and 7) *Spectra Physics Lasers Inc.*, Mountain View, California, USA>

PROCEEDINGS

The Proceedings of RIS-92 will be published in hardback form by IOP Publishing Ltd., Bristol, England and will be available from the Publisher or through the American Institute of Physics.

CONCLUSIONS

In concluding this brief Report, one can certainly state that the various laser ionization techniques illustrated in this Symposium combine the characteristics of selectivity and sensitivity which makes them extremely attractive in many areas of science, from nuclear physics to environmental chemistry. Therefore, fundamental studies and analytical applications were

both covered and will still be developed. On the other hand, these techniques do not seem yet to attract from the analytical community all the attention and interest that they deserve. To our opinion, this cannot only be attributed, as often done, to the complexity and to the cost of the instrumentation required. It is therefore important that, in the future, the RIS community tries to expand and to reach the majority of chemists, now involved with other more conventional methods, so that the unique potential of the technique in solving particularly difficult problems of chemical analysis can be fully appreciated. We firmly believe that this effort is well worth of being pursued.