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ABSTRACT

This report describes work performed during the past year on DOE contract DE-AC02-78ER04971. The basic goals of this program concern the experimental determination of properties of atoms and molecules and molecular clusters that are important in a wide range of energy-related processes. In particular we are performing measurements of polarizabilities of highly polar molecules and their polymers, and of a number of important atomic elements distributed through the periodic table, as well as of the scattering of low-energy electrons by these same systems. For the scattering program we have designed and constructed an entirely new apparatus. The essential components, external and internal, of the machine are completed. At the time of this writing both the electron monochromator and the molecular beams system are being put through their final tests.

Our most significant scientific accomplishment during the past year has been the completion of our measurements of the dc electric dipole polarizabilities of a number of alkali halide dimers $[(\text{KCl})_2, (\text{RbCl})_2, (\text{CsCl})_2, (\text{KF})_2, \text{ and } (\text{CsF})_2]$. We believe that these are the first determinations of these important parameters ever made. We have also completed an experiment to measure the total cross sections for the scattering of low-energy electrons by atomic lithium, a very significant experimental test of a relatively simple, many-body system, which is amenable to elaborate computational determination.

We have finally been successful in acquiring full funding for a tunable, stabilized, single-mode ring dye laser system, including a 15 watt argon-ion pump laser, to be used on the extension of ground-state studies to excited states and on other important elements for our DOE program, including neutral beam detection and higher order polarizability determinations.

ANNUAL PROGRESS REPORT

July 1, 1981 - June 30, 1982

1. Introduction

This report describes work performed during the past year under DOE sponsorship in the Atomic Beams Laboratory of the New York University Physics Department. The senior personnel involved are Professor Benjamin Bederson and Assistant Research Professor Bernardo Jaduszliwer, assisted by Ph.D. graduate students Robert Kremens, Al Tino and Thomas Guella. The basic goals of this program concern the experimental determination of properties of atoms and simple molecules and molecular clusters that are important in a wide range of energy-related processes, as well as the study of their interactions by collisions with low-energy electrons. During the past year we have completed our first molecular polarizability experiment of the dc electric dipole polarizabilities of the alkali-halide dimers - the first determinations made of polarizabilities of such systems. We have also completed the final scattering experiment on our old scattering apparatus, the scattering of low-energy electrons by atomic lithium, while completing construction and installation of various components of our new scattering apparatus. The experiments are described in the following Sections, as is the current status of the new apparatus, and other relevant activities of our laboratory, including the status of our ring laser acquisition.

2. Polarizabilities of Alkali-Halide Molecules

It is interesting to observe that despite the importance of the induced dipole moment, generated by the interaction of a highly polar molecule with charged particles and with laboratory fields, no measurement of the molecular parameter governing this quantity, i.e., the polarizability, exists in the published literature, to our knowledge. This is partly due to the difficulty associated with unscrambling the induced moment effects from those due to the intrinsic moments of such molecules. Thus, there exists considerable uncertainty in the literature concerning the role played by polarization forces in electron-highly polar molecule scattering.¹ There are no reliable calculations of

these quantities for the alkali halide molecules, let alone reliable measurements. The difficulty in distinguishing permanent from induced effects in a molecular beam deflection experiment can be circumvented by employing the molecule dimer, because for these systems the dipole moments vanish, while the polarizabilities are attributable partly to the monomer molecular orbitals, combined of course with the appropriate dimer bond polarizabilities. Thus, the determination of dimer polarizabilities would, in addition to being of intrinsic interest in itself, contribute an important step towards the determination of the monomer polarizabilities.

Previous experimenters have found dimerization in all alkali halides at vapor pressures corresponding to source temperatures appropriate for effusive beams.² The percent of dimerization increases as molecular weight decreases towards lighter alkali halides, with lithium fluoride possessing the largest fractional dimerization.

We now briefly discuss the deflection patterns to be expected when alkali halide monomers and dimers pass between the polefaces of an inhomogeneous electric field (a detailed analysis of the deflection pattern due to molecules possessing strong electric dipole moments was presented in our previous annual report³). The geometry of the experiment is shown in Fig. 2.1.

Fig. 2.1: geometric arrangement. Shaded beam is undeflected (δ -function) beam. $I(x')$ is deflected beam.

The essential elements of the experiment are a) an effusive molecular beam source, b) inhomogeneous deflecting electric polefaces, c) surface

ionization detector, capable of translation in order to obtain the deflected beam pattern. l_1 , l_2 , l_3 are the distance from the source to the front of the polefaces, the length of the polefaces, and the distance from the back of polefaces to detector, respectively.

Consider the monomer, which possesses a permanent dipole moment μ . Then it can be shown that the deflection x' of a molecule of speed v and rotational state J , M_J is

$$x'(v, J, M_J) = \frac{b^2 \mu^2 \gamma A E^2}{4 m \hbar^2 v^2 J^2} \left(1 - 3 \frac{M_J^2}{J^2} \right) \quad (2.1)$$

where $b^2 = l_1 (2 l_2 + l_3)$, γ is the gradient constant, equal to the ratio of electric field gradient to electric field in the poleface gap, A is the molecular moment of inertia perpendicular to the internuclear axis, E is the electric field strength, and it is assumed that $\mathcal{E}_\mu \ll kT$ (low field case), where $\mathcal{E}_\mu$ is the Stark energy of the permanent dipole moment. Averaging over M_J , and integrating over J we obtain the intensity pattern

$$I(v, x') = \frac{\sigma^{3/2} v^2 I_0(v)}{\sqrt{3\pi} \beta} \int_0^{J_{\max}} \frac{J^4 e^{-\sigma J^2} dJ}{\sqrt{1 - x' v^2 J^2 / \beta}} \quad (2.2)$$

where $J_{\max}$ depends on whether $x > 0$ or $x < 0$, $\sigma = \hbar^2 / 2AkT$ and $\beta = b^2 \mu^2 \gamma A E^2 / 4m\hbar^2$, and it is assumed that the undeflected beam is infinitesimally narrow, i.e., $I_0(v, 0) = I_0(v) \delta(x)$. On the other hand, the polarizability deflection is

$$x'/(v; \text{pol}) = b^2 \alpha \gamma E^2 / v^2 \quad (2.3)$$

where α is the (space-averaged) electric dipole polarizability, and the intensity pattern caused by the induced (polarizability) dipole moment at a given beam speed v is

$$I(v, x'; \text{pol}) = I_0(v) \delta \left(x' - \frac{b^2 \alpha \gamma E^2}{2mv} \right) \quad (2.4)$$

that is, the molecular beam is simply displaced in the detector plane by the amount $x' = b^2 \alpha \gamma E^2 / 2mv$. The actual intensity pattern will depend on the velocity distribution, but will always possess a peak in the direction of the stronger field, that is, towards the convex poleface. On the other hand,

integrating Eq.2.4 over the velocity distribution always results in a beam deflection pattern that monotonically decreases as $|x^*|$ increases, when moving in the direction of stronger field. Accordingly, should a peak be observed experimentally on the strong-field side of the deflection pattern, it must be caused by polarizability forces. (that the polarizability deflection pattern is attributable to the dimer is proved by use of our mechanical velocity selector).

To obtain reliable values for the polarizabilities it is necessary to normalize to a known polarizability. By this means all systematic errors that are associated with imperfect knowledge of the electric field and gradient parameters as well as of the precise position of the beam with respect to the polefaces cancel. The best "test system" for this purpose is atomic potassium, whose polarizability is well-known from earlier measurements on the same apparatus.⁴ In Fig. 2.2 we show a pair of beam profiles for potassium, with zero electric field and with a field corresponding to a potential difference of 3620 V, and in Fig. 2.3 we show a typical deflection pattern for one of the alkali halide-dimer combinations (RbCl). The results of our measurements are summarized below:

$$\bar{\alpha}(\text{K}_2\text{Cl}_2) = 38.4 \times 10^{-24} \text{ cm}^3$$

$$\bar{\alpha}(\text{Rb}_2\text{Cl}_2) = 42.6$$

$$\bar{\alpha}(\text{Cs}_2\text{Cl}_2) = 24.9$$

$$\bar{\alpha}(\text{K}_2\text{F}_2) = 19.5$$

$$\bar{\alpha}(\text{Cs}_2\text{F}_2) = 18.8$$

While quantitative calculations are unavailable for comparison with these results, rough estimates can be made for qualitative comparison, by using bond polarizabilities obtained from calculations of dimer vibrational constants.⁵ Berkowitz⁶ has calculated the normal vibrational frequencies for many of the alkali halide dimers assuming an ionic model. Using these frequencies and assuming simple spring models for the potentials we can calculate the equilibrium positions of the ionic centers in an external electric field, thence the induced dipole moments and, finally, the polarizabilities.

3620 V

B

A

B

A

Fig. 2.2: Beam vs detector position, for atomic potassium. Curve A - no applied voltage. Curve B: $V = 3620$

RbCl
1020 K° 2.08 KV.

Fig. 2.3: Beam vs detector position,
for RbCl and (RbCl)₂. Lower
curve: undeflected beam.
Upper curve: deflected curve
for applied voltage of 2.08
KV. Peak on right is attri-
buted to dimer polarizability.

We assume that the dimer system possesses a rhomboidal shape, corresponding to the minimum energy configuration of two contiguous dipoles possessing finite, repulsive cores. The dimer system possesses six normal modes, but for our purposes we consider only those in which all the charges move parallel to one another. There are three such modes, as shown in Fig.2.4.

Fig. 2.4: three of the normal modes for alkali halide dimer (rhomboidal configuration)

Berkowitz refers to these modes as B_{1u} , B_{2u} , and B_{3u} . M refers to the positive alkali ion and x to the negative halide ion. The motion in mode B_{1u} is out of the plane of the molecule (and paper). Assuming only small deviations from the equilibrium positions we can describe the motion in each mode as follows:

We now calculate the vibrational frequencies for each mode:

$$\omega = \sqrt{\frac{k_1}{2\mu}}, \quad \mu = \frac{m_X m_M}{m_X + m_M}$$

$$\omega = \sqrt{\frac{k_2}{\mu}}$$

We now calculate the equilibrium positions of the molecules in an electric field.

$$2Ee = k\Delta x$$

$$\text{so } \mu = 2e\Delta x = \frac{4e^2}{k_1} E$$

$$\alpha = \frac{4e^2}{k_1} = \frac{4e^2}{[2\pi\nu]^2 2\mu} = \frac{2e^2}{[2\pi\nu]^2 \mu}$$

Mode $B_{2\mu}$
or $B_{3\mu}$

$$Ee = \Delta x_1 k_2$$

$$\Delta x_1 k_2 = E2e + k_2 \Delta x_2$$

$$\Delta x_2 k = -Ee; \quad \Delta x_2 = -\frac{Ee}{k_2}$$

$$\Delta x_1 = -\Delta x_2 = \frac{Ee}{k_2}$$

$$\mu = 2e\Delta x_1 = \frac{2e^2}{k} E$$

$$\text{so } \alpha = -\frac{2e^2}{[2\pi\nu]^2 \mu}$$

Thus from Berkowitz's calculated frequencies we can determine the three diagonal components of the polarizability tensor, α_{zz} , α_{yy} , and α_{xx} . The z-axis is chosen to be perpendicular to the molecular plane, y is parallel to a line joining the alkali ions, and x is parallel to a line joining the halide ions. The calculated polarizabilities are:

$$\begin{aligned} \text{Cs}_2\text{Cl}_2 \quad \alpha_z &= 48.3 \times 10^{-24} \text{ cm}^3 \\ \alpha_y &= 12.2 \\ \alpha_x &= 11.5 \\ \bar{\alpha} &= 24.0 \times 10^{-24} \text{ cm}^3 \end{aligned}$$

$$\begin{aligned} \text{Rb}_2\text{Cl}_2 \quad \alpha_z &= 45.2 \times 10^{-24} \text{ cm}^3 \\ \alpha_y &= 12.8 \\ \alpha_x &= 10.8 \\ \bar{\alpha} &= 22.9 \times 10^{-24} \text{ cm}^3 \end{aligned}$$

$$\begin{aligned} \text{K}_2\text{Cl}_2 \quad \alpha_z &= 38.8 \\ \alpha_y &= 12.4 \\ \alpha_x &= 9.9 \\ \bar{\alpha} &= 20.4 \end{aligned}$$

$$\begin{aligned} \text{K}_2\text{F}_2 \quad \alpha_z &= 27.1 \\ \alpha_y &= 9.39 \\ \alpha_x &= 9.17 \\ \bar{\alpha} &= 15.2 \end{aligned}$$

Since in our experiment the orientation of the dimer molecule is assumed to be totally random the average polarizability is just the arithmetic mean of the diagonal elements, α_{zz} , α_{yy} , and α_{xx} . The polarizabilities we have calculated so far are due to shifts in the ionic charge centers. To this we have to add the contributions of the ions themselves. We use the values given by Tessman et al.⁷

$$\begin{aligned} \text{K}^+ &= 1.20 \times 10^{-24} \text{ cm}^3 \\ \text{Rb}^+ &= 1.80 \\ \text{Cs}^+ &= 3.14 \\ \text{F}^- &= 0.76 \\ \text{Cl}^- &= 2.97 \end{aligned}$$

Thus the additional electronic polarizability for each of the dimers is

$$\text{Cs}_2\text{Cl}_2 = 12.2; \text{K}_2\text{Cl}_2 = 8.3$$

$$\text{Rb}_2\text{Cl}_2 = 9.5; \text{K}_2\text{F}_2 = 3.9$$

So the total average polarizabilities which are to be compared with our measurements are

		<u>Experiment</u>
Cs_2Cl_2	$\bar{\alpha}_T = 36.2 \times 10^{-24} \text{ cm}^3$	24.9
Rb_2Cl_2	= 32.4	42.6
K_2Cl_2	= 28.7	38.4
K_2F_2	= 19.1	19.5

As can be seen, there is fair qualitative agreement with the measured values, though of course it is unreasonable to expect quantitative agreement, considering the crudity of the model.

These final results are being presented at an ACS symposium on high temperature chemistry, to be held in Atlanta in late March, and the work is also being prepared for publication.

3. Electron Scattering by Lithium

While we were completing construction of the electron monochromator and other components of the new scattering apparatus (see Section 4), we undertook and completed a final experiment on our old scattering machine. This experiment consisted of the measurement of the total cross sections for the scattering of electrons by atomic lithium. Lithium is the most simple of the alkali elements, possessing only a helium-like core, and accordingly it should be the one most amenable to critical testing of collision theory. However, it happens that while theoretical calculations abound, there is very little experimental work reported in the literature. This is due primarily to the fact that lithium is much more difficult to work with than the rest of the alkalis. Hotter sources are required, and hot lithium vapor is very corrosive. Lithium is also somewhat more difficult to detect than the other alkalis.

Some years ago we measured electron-lithium total cross sections between 0.25 and 10.0 eV, relative to those of potassium. An attempt by us to

measure the absolute total scattering cross sections by the recoil technique yielded some preliminary results⁹, but the lack of a direct measurement of the average atomic beam velocity (essential for the recoil technique) cast some doubt on the validity of those results.

Several approaches have been followed by theorists to study the electron-lithium system. Inokuti and McDowell¹⁰ (Born approximation) Sarkor et al.¹¹ (polarized-Glauber) and Walters¹² (frozen core-Glauber) have extended their total cross sections to fairly low energies. Sinfailam and Nesbet¹³ calculated variational phase shifts below the 2P threshold. The few-state close coupling method had been very successful in describing low energy electron collisions with potassium and sodium atoms. Lithium is, of course, quite similar to sodium and potassium, but on the other hand there are enough differences to leave the extension of the close-coupling approach to lithium a very tantalizing, open question. As an example of those differences, while the oscillator strength of the resonant transition for all the heavier alkalis is near unity, it is only 0.75 for lithium. Two-state close coupling calculations for the electron-lithium system have been performed by Karule, and Karule and Peterkop¹⁴ (below and above the 2P threshold, respectively), by Burke and Taylor¹⁵, and, at very low energies, by Norcross.¹⁶

The other approach that has been followed to study electron-lithium collisions is the polarized orbital method¹⁷, in which the target polarization caused by the colliding electron is specifically included in the interaction. Stone¹⁸ determined the polarization potential variationally, rather than by perturbation theory, and Vo Ky Lan¹⁹ used Stone's method in an otherwise conventional polarized orbitals calculation. Bhatia et al.²⁰ modified the polarized method by demanding that the polarized orbital yields the correct value of atomic polarizability, the correct electron affinity of the negative Li ion and the proper number of nodes of the zero-energy scattering orbital. In this way, they obtained phase shifts for elastic electron-lithium scattering which are qualitatively similar to (but still differing from) the close-coupling calculations.¹⁵

The atomic recoil technique for the study of low-energy electron-atom collisions is fully described in our earlier reports. The main difference between this and the other experimental techniques is that observations are made on the atoms downstream from the collision region, rather than on the

The atomic recoil angles are much smaller than the electron scattering angles, but because the angular resolving power for the (neutral) atomic beam is quite high, they are sufficiently large to allow not only the determination of total cross sections by measuring the attenuation of the atomic beam when cross-fired by electrons ("scattering-out" experiment) with generally excellent angular resolution, but also the study of differential scattering by selectively collecting atoms recoiled away from the beam axis ("scattering-in" experiment).

Fig. 3.1 shows schematically our experimental arrangement. The lithium beam source is an effusive oven constructed from stainless steel pipe fixtures and surrounded by a helical tantalum filament mounted on insulating posts. It reaches a temperature of about 700° C by a combination of radiation and electron bombardment heating. The oven is normally offset from the beam axis; a Stern-Gerlach magnet selects in high fields one of the two m_j states present in the lithium beam, acting in this experiment as a velocity filter ($\Delta V/V \approx 0.08$). The magnet also effectively removes all lithium dimers from the beam.

The electron gun is similar to the one described by Collins et al.²¹ (This is the predecessor to our electron monochromator.) The electron beam is shaped like a ribbon, about 25mm in width and 0.8mm in height. The energy width of the electron beam is 0.425 eV FWHM. The mean electron energy is corrected for space charge and contact potentials. The electron current through the interaction region is monitored by a digital microammeter. In this experiment we have used currents between 150 μ A and 500 μ A.

After passing through the interaction region the atoms are surface-ionized on a hot wire (92% Pt, 8% W). The ions are mass-analyzed by a 60° sector magnet and detected by a Channeltron multiplier operated in the current mode.

To measure a total cross section, the detector is kept on axis, and a "scattering-out" experiment is performed, measuring the difference between the atom current I_o , reaching the detector when the electron beam is turned off, and I , reaching the detector when the electron beam is turned on. The total cross section σ_o is related to the other parameters of the experiment by

$$\sigma_o = \frac{(I_o - I)}{I_o} \cdot \frac{v_h}{I_e} \quad (3.1)$$

Fig. 3.1: Schematic of the experimental arrangement.

where h is the height of the atomic beam, V is the mean speed of the atoms and I_e is the electron current through the interaction region (electrons/sec). It is important to stress that in this technique it is not necessary to measure absolute atomic beam densities or fluxes. The only requirements that have to be satisfied for the method to yield absolute cross sections are that the atomic detector must be linear, and the measurement of the electron current must be absolute. This, in turn, means that the height of the electron beam must be smaller than the height of the atomic beam.

"Scattering-out" experiments are performed by connecting the detector output to an electrometer; the electrometer output is fed to the analog-to-digital converter of a DECLAB-03 computer which is programmed to sample repetitively the beam signal with the electron gun off, turn the gun on and sample again, then turn the gun off and start the cycle anew. At the end of a preset number of cycles the data accumulation is stopped, and the computer performs a least-squares linear fit to both halves of the data, the first half with the electron gun off and the second half with the electron gun on. From the results of these fits $(I_0 - I)/I_0$ is computed, and a value for σ_0 is obtained using Equation 3.1.

Equation 3.1 explicitly requires knowledge of the atomic beam mean speed. This is accomplished by a technique described by Rubin et al.²², in which inelastic scattering at threshold, where the excitation energy is uniquely determined, is used to directly measure this quantity to better than 3%.

Measurements were made of total cross sections for the scattering of electrons by lithium atoms between 2 and 10 eV. Since the 2P threshold is at 1.85 eV, inelastic processes will contribute to the cross sections over the whole energy range investigated in this experiment.

Our results are presented in Table 3.1. The errors incorporate standard statistical errors and an allowance for systematic errors, to a 68% confidence level. Possible sources of systematic errors in our measurements have been discussed extensively elsewhere.²³ These will be discussed in detail for the present experiment in an article now in preparation. Suffice it to note here that we estimate that the combination of all known systematic errors will affect our results at most by 3%.

Our data are to be compared with theoretical calculations for the quantity $\sigma = \sigma_{EL} + \sigma_{2S-2P}$ where σ_{EL} is the elastic scattering contribution

TABLE 3.1: Total cross sections for the scattering of electrons by lithium.

Energy (eV)	Cross Section (10^{-16} cm^2)	Standard Error (10^{-16} cm^2)
2	115.4	6.2
3	109.8	6.5
4	87.7	5.0
5	82.5	4.9
7	76.1	3.5
10	72.1	3.3

to the total cross section, and σ_{2S-2P} is the contribution from the excitation of the 2P state. We are assuming here that the total cross section is overwhelmingly dominated by those two processes, and that the sum of contributions from other channels is smaller than the errors present in the experiment.

Figure 3.2 shows our data together with the values of σ obtained from the results of two-state close-coupling calculations by Karule and Peterkop¹⁴ (squares) and Burke and Taylor¹⁵ (full line). The line of dashes is a hybrid curve showing the values of σ obtained by adding σ_{EL} results from the modified polarized orbitals calculation of Bhatia et al.²⁰ and the σ_{2S-2P} results from the close-coupling calculations by Burke and Taylor. The differences between the elastic contributions to the total cross section calculated by the modified polarized orbitals and the close-coupling methods are of the order of 20% in the energy range we have explored. Of course, adding to both of them the same 2P impact excitation contribution makes the difference between the total cross sections to appear smaller, especially at higher energies, where the impact excitation contribution is dominant.

Our results seem to fit much better the hybrid curve obtained using the elastic cross sections of Bhatia et al. At the higher energies they become larger than both theoretical curves, probably reflecting the increasing importance of contributions from channels other than the elastic and 2S-2P excitation.

Aside from the intrinsic importance of these measurements, we believe that this work is also significant because it shows our ability to perform these difficult, low-energy cross section measurements at the $\pm 10\%$ error level. Measurements on our new machine should possess even smaller error limits for atomic systems that can be detected with good efficiency and that possess reasonably large cross sections.

4. New Machine

In our previous Annual Report we described the design and construction of our new beams apparatus in detail, and we will not repeat this description here, although for convenience we reproduce a schematic diagram of the machine in Fig. 4.1. It is about 5 meters long; it is vibrationally isolated from the laboratory floor by means of a pair of commercial air-cushion mounts (all external fittings, including vacuum and water connections contain flexible vibration-isolation sections). The principle components are: source

Fig. 3.2: Total cross sections for the scattering of electrons by lithium.

Fig. 4.1: Schematic diagram of new scattering apparatus.

A: Hexapole magnets. B: Two turntable ball bearings, centered at the scattering region, one in the vertical plane and the other in the horizontal plane. C: Counterweight system for the scanning arm. D: Computer-driven positioning devices for the detector chamber. E: Electron spectrometer chamber.

chamber (with pumping speed adequate for either condensable or non-condensable beams), buffer chamber containing a 6-disc mechanical velocity selector, hexapole focussing magnets and state selectors (these are labelled A in Fig. 4.1), the interaction chamber containing the electron monochromator, state analyzer, beam drift tube, counterweight system and detector chamber. The source and buffer chambers are pumped by oil diffusion pumps, and the rest of the apparatus is pumped by ion pumps. All external and internal components, except the state selector and magnet polefaces, are now constructed and are in place. Our first beam was successfully run in July, 1980. The electron monochromator has been constructed, and is now in the process of being tested. Some idea of its complexity is indicated in Figs. 4.2 and 4.3, which show its machined components (made of OHFC copper) disassembled and assembled. The monochromator has been designed to operate as low 1 eV, with good energy resolution and high electron current capability; this accounts for its complexity. Installed, it is surrounded by a commercially fabricated and annealed μ -metal shield. For gross magnetic shield cancellation the entire experimental room is wired with three pairs of rectangular coils, made from two pairs each of 50-conductor telephone cable, wired in series-parallel for impedance matching with 100V - 20A power supplies.

A photograph of our "Mark II" high temperature source oven is shown in Fig. 4.4. This source was designed to serve two essential purposes, first, to perform satisfactorily with refractory beam materials, as for example the alkali halides, and such atomic elements as bismuth and uranium. Second, for less refractory materials, such as the alkalis, it should be capable of producing sufficiently high vapor pressures so that we could generate supersonic beams. It is for this latter reason that we did not use electron bombardment as has been done in our polarizability and old scattering machines. While electron bombardment is a very efficient method for heating metal components, a high voltage must be applied between a filament and the object to be heated. This would cause an electric discharge at the high ambient pressures which exist when using supersonic beams.

Instead, we have used direct heating of a ceramic cylinder, by ohmic resistance (the large cylinder in the photograph). The beam source is a cylindrical, stainless steel container that fits inside the oven, aligned horizontally. For some purposes (e.g., to eliminate dimers or for supersonic beams) the region at the exit slit must be superheated. For this

Fig. 4.2: Photograph of components of electron monochromator.

Fig. 4.3: Photograph of electron monochromator, assembled.

Fig. 4.4: Refractory atomic and molecular beam source, Mark II (ceramic oven). Small cylinder is superheater of snout.

Fig. 4.5: Surface-ionization detector and magnetic mass spectrometer.

reason the beam container can be fitted with a snout, which fits inside the small ceramic cylinder that can be seen in the photograph.

The surface ionization detector is shown in Fig. 4.5. It is of conventional design. The hot wire is oriented at an angle of 45° to the atomic beam; the surface-ionized beam is accelerated with some simple optics through a small mass spectrometer and is deflected by a channeltron, for either electrometer or particle counting.

A PDP11/03 computer serves to data-process and to control the experiment. D/A output circuits are being programmed to control the mechanical motions that determine the range of atomic recoil scattering angles being investigated.

5. Ring Laser Acquisition

Our plans to exploit recent cw tunable laser technology has been discussed in detail in previous proposals. It was our belief that the commercially available system that would best serve our overall needs would be a cw, tunable, stabilized ring laser pumped by a high-powered argon ion laser. The approximate cost of this system was estimated to be \$70,000 (including some essential optics components). Our plan to acquire the necessary funding involved substantial cost-sharing with New York University, as well as sharing most of the remaining cost between our ongoing DOE contract and our NSF grant, as well as a request from the NSF for a Capital Equipment grant for \$25,000 to complete the funding package.

During the past year we assembled the first half of the package with a \$15,000 contribution by NYU (\$10,000 from a Challenge grant and \$5,000 from the Physics Department), and purchased the Coherent Model 699, stabilized ring laser. We have just received word that the NSF Capital Equipment grant request for \$25,000 has been approved, and accordingly we have now ordered the argon pump laser (15 watt), thereby completing the laser system.

6. Laboratory and Personnel Activities

Mr. Robert Kremens has completed his Ph.D. experiment (on the polarizabilities of alkali halide dimers), and is now writing his dissertation. He is expected to have his final oral exam in April, and obtain a June degree.

A contributed paper on this work was presented at the annual DEAP meeting (Dec. 1980) at Los Angeles.

A summary of our polar molecule work is also being presented at the

American Chemical Society Symposium on High Temperature Chemistry to be held in Atlanta, March 31 - April 2, 1981. A paper on this work, to be published in June in an ACS Supplement, is now in preparation. The lithium experiment is being written up for submission to Physical Review A.

Professor Bederson presented an interdisciplinary seminar at Yale University in December 1980, on "Physics of Highly Polar Molecules", and he is giving a Colloquium at the University of Massachusetts at Amherst in March, 1981 on a "Review of Electron Scattering by Simple Atoms and Molecules."

During Spring, 1980, Professor Bederson was on Sabbatical leave. He visited and gave talks on DOE-related research at a number of European laboratories, including: Max-Planck Institute for Laser Physics, Garching; Max Planck Institute for Gas Dynamics, Göttingen, Free University, Berlin; University of Münster; University of Bielefeld; University of Paris South (Polytechnic Institute), CNRS (Orsay) - Laboratoire Aimé Cotton; FOM, Amsterdam.

In October, Professor Bederson visited the USSR as a guest of the USSR Academy of Sciences. He visited and gave lectures at the Ioffe Physical-Technical Institute, Leningrad; the Chemical Physical Institute and the Lebedev Institute, both in Moscow; Leningrad State University; Latvian Academy of Sciences (Riga), and the Laser Institute, Minsk.

In June 1980, Professor Bederson presented an invited paper on our polar molecule work, at the Canadian Association of Physicists meeting in Hamilton Ontario.

Other personnel involved with our project include Mr. Al Tino, who is performing scattering of electrons by alkali halide molecules for his Ph.D. dissertation, and Mr. Thomas Guella, who is measuring polarizabilities of heavy atoms for his Ph.D. dissertation. Drs. Thomas Miller (University of Oklahoma) and John Stockdale (ORNL) are associated with our DOE work and visit our laboratory from time to time, although they are not supported by the DOE contract.

Professors Jaduszliwer and Bederson both attended the Seventh International Conference on Atomic Physics held in Cambridge Mass., August 1980, and the annual DEAP - APS meeting held in Los Angeles, December 1980.

New York University will serve as host of the 1981 DEAP meeting. Professors H. Stroke and B. Bederson will organize the meeting.

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