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This report describes the progress made during the granting period in setting up the apparatus and also the work that will be undertaken in the immediate future. The studies are currently supported by a grant from the Standard Oil Company of Ohio (SOHIO), who have awarded us a

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FINAL REPORT

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

GRANT No. AFOSR-83-0280

"A PULSED LASER AND MOLECULAR BEAM APPARATUS FOR SURFACE STUDIES"

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SUMMARY

Equipment was purchased, using a grant awarded by the Air Force Office of Scientific Research under the DOD University Instrumentation Program, for the construction of an apparatus for the study of gas-surface interactions. This apparatus uses pulsed lasers both to keep the surface free of contamination and for probing surface phenomena, and pulsed molecular beam sources to dose the surface with the required gaseous samples. The experiments that will be carried out are in part described in the proposal "A Pulsed Laser and Molecular Beam Apparatus for Surface Studies" submitted by Howard University in November 1982 for review by AFOSR, under the DOD University Instrumentation Program. The Grant awarded, AFOSR-83-0280, was for the sum of $155,000 over the granting period of August 1, 1983 to July 31, 1984.

This report describes the progress made during the granting period in setting up the apparatus, and also the work that will be undertaken in the immediate future. The studies are currently supported by a grant from the Standard Oil Company of Ohio (SOHIO), who have awarded us a $225,000 three-year contract for surface studies in collaboration with the Department of Electrical Engineering.

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1. INTRODUCTION

In this laboratory we are developing a technique that will use short-timescale experiments to ensure that clean surface reactions can be studied under normal vacuum conditions. This technique uses a pulsed excimer laser (the Questek 2000), together with a pulsed molecular beam if necessary, to clean the surface of a metal, semiconductor, or insulator. We estimate that power densities of up to 300 MW/cm^2 may be obtained if the excimer laser is focussed. This may be enough to melt the surface under investigation if required. After the surface is cleaned, a reaction may be initiated with a second pulsed molecular beam, and the course of the reaction may be followed using several new pulsed surface analysis techniques under development in this laboratory.

The basis of these techniques is the use of an excimer laser, producing 5 nanosecond pulses at 193 nm, to eject photoelectrons from the surface under investigation. These electrons are analyzed with a time-of-flight (TOF) analyzer using a 200 MHz transient digitizer interfaced to an IBM XT microcomputer. In a similar experiment, the 5ns laser may be aimed at a photocathode in an electron gun, thus ejecting a short pulse of electrons that can be accelerated toward the surface sample, and used for Pulsed High Resolution Electron Energy Loss Spectroscopy (PHREELS)

or Pulsed Auger Spectroscopy (PAS). The inelastically scattered or Auger electrons, respectively, will be detected by the time-of-flight method described above. In addition, the 5ns laser may be used to photoionize molecules that are thermally desorbed from the surface by the high-power "cleaning" laser. Time-of-Flight Mass Spectrometry may then be used to determine the nature of the desorbed species.

Since all of the experimental time delays are under computer control on a pulse-to-pulse basis, it is possible to follow the kinetics of surface reactions. Another advantage of the technique is that very fast heating rates may be used that allow one to probe the surface concentrations of species by causing them to desorb before any reactions occur. The rapid rate of temperature rise on the surface will also permit high-temperature kinetic studies, especially in the case of thermal insulators such as ceramics.

The use of pulsed molecular beams with differential pumping also allows one to raise the effective gas flux on the surface to about 10^{20} molecules/cm^2-sec, equivalent to pressures of the order of a torr. Thus the new technique covers the pressure regime between those used in UHV surface physics experiments and those used in low pressure industrial catalysis processes. The pulsed valves that will be used are highly resistant to corrosive gases and particle

contamination, and thus will permit seeding of the beams by a variety of gaseous or particulate materials. In addition, the beam molecules may be excited, ionized, or dissociated by lasers in order to form species that interact with the surface in different ways.

By using a quadrupole mass spectrometer system that we have available, we hope to be able to measure the product energy distribution of Laser-induced reactions that are enhanced by gas-surface interactions.

2. VACUUM CHAMBER

Figure 1. shows the final design of the vacuum chamber constructed for carrying out the experiments. Since no commercially available off-the-shelf components could be used to construct a chamber that met with our requirements, it was decided to contract out the work to a company specialising in the custom building of high-vacuum equipment. The company finally chosen was MDC Manufacturing of Hayward, CA, who were also able to provide many of the standard vacuum accessories such as gate valves, flanges, feedthroughs, and windows.

2.1 General Description

The vacuum apparatus, shown in Fig.1, consists of a single type 304 stainless steel cylinder, 18" in diameter and 45" in length. All materials used in the construction of the apparatus are non-magnetic, to prevent perturbation of electron flight paths by stray magnetic fields. The apparatus is divided into two equal-volume cylindrical chambers by a central partition. The end flanges, which have outside diameters of 22", are mounted on hinges to enable them to swing open for easy access to the inside of each of the chambers. Since the apparatus is not designed to be UHV-compatible, all of the flanges are sealed with Viton O-rings. This greatly speeds up the cycling time for letting up to atmospheric pressure, opening the chamber, closing it

again, and pumping back down to high vacuum, as it obviates the need for copper sealing gaskets and the accompanying large number of bolts required to achieve an even seal.

Each of the two chambers has four large ports for the attachment of high-vacuum pumps and other heavy pieces of equipment, and also to provide space for large-area (9" diameter) plate glass viewports. In addition, several smaller ports are available for electrical and manipulation feedthroughs, roughing and gas inlet lines, as well as special viewports (quartz or MgF_2) for the passage of UV Laser light.

The chambers are independently pumped by two 6" cryopumps (Leybold-Heraeus RPK 1500 S3), that maintain a base pressure of about 10^{-7} torr. This pressure is limited by the out-gassing rate of the Viton O-rings used in the high-vacuum seals. 6" ASA Gate Valves, mounted between each of the chambers and their respective cryopumps, may be used to seal off the chambers, either to let the chamber up to atmospheric pressure for internal access, or to regenerate the cryopumps while maintaining vacuum in the experimental chambers.

A roughing line, pumped by a Leybold-Heraeus D16A rotary pump and connected to each of the chambers and cryopumps independently via pneumatically-operated valves, is used for initial evacuation. These valves, together with the 6" Gate Valves and the pump control relays, are controlled by a dedicated Z8 single-board microcomputer,

thus allowing automatic, overnight cryopump regeneration and guaranteeing protection of the cryopumps in the event of a power failure or chamber leak. In addition, the microcomputer only permits the opening of valves in a safe sequence, once the pressures on either side of the valve have been measured, and will only allow a cryopump to be turned on if the pressure in the pump body is below crossover pressure (typically 0.1 torr).

2.2 Molecular Beam Formation Chamber

Chamber 1, the Molecular Beam Formation Chamber, contains two pulsed molecular beam valves (Newport BV-100), and must be maintained at an operating base pressure of about 10^{-4} torr in order to allow the formation of well-characterized molecular beams. When one of the beam valves is turned on, the pressure will rise to a maximum value of 3×10^{-3} torr. The molecular beam repetition rate is limited by the time taken to pump Chamber 1 back down to about 10^{-4} torr; with the chamber volume (100 l) and pumping speed (1500 l/s) given above, this time constant is about 200 msec, giving an experimental repetition rate of 5 Hz.

The partition flange separating Chambers 1 and 2 has two skimmer nozzles mounted on it, to ensure that the molecular beams are well-collimated as they enter the observation chamber. The beam valves are mounted off the flanges supporting the skimmers, to facilitate alignment.

The small nozzle aperture diameter (up to 1 mm) allows the observation chamber to be maintained at a pressure of 10^{-6} torr even when the molecular beam is on, as only a very small proportion of the molecules leaving the pulsed valve reach the observation chamber. The distances between the pulsed valves and their respective skimmers, together with the skimmer aperture diameters, are determined by the degree of beam collimation desired in the Observation Chamber, and the density of the molecular beam incident upon the surface sample.

2.3 Observation Chamber

Chamber 2, the Observation Chamber, contains the XYZ and Rotation Manipulator (Varian 9530-1111 with Offset Flip) upon which the surface sample is mounted. This manipulator is mounted on the hinged end flange in such a way that at the center of its travel locus, the sample is held at the crossing-point of all of the radial ports in the observation chamber, and also at the intersection of the two pulsed molecular beams, as determined by the geometry of the valve / skimmer assembly in the Beam Formation Chamber. A combination of Liquid N_2 cooling and resistance heating allows the sample to be maintained at a steady temperature of 77-600 K, although the regulation will depend upon the amount of energy delivered per pulse by the Excimer Laser used to keep the surface free from contamination.

A Time-Of-Flight (TOF) detector, also in Chamber 2, is used to detect either electrons, or neutral species and ions, leaving the surface. It is mounted on a rotary feedthrough manipulator, and so can be rotated about the sample to provide information concerning the angular distribution of these departing species. All components that are sensitive to stray magnetic fields, either those emanating from other pieces of laboratory equipment or the Earth's natural field, may be screened as far as practically possible by Co-Netic Mu-Metal shielding. If necessary, Helmholtz coils may have to be placed either inside or outside the chamber.

2.4 Quadrupole Mass Spectrometer System.

A Quadrupole Mass Spectrometer system (Extranuclear Labs.), that has been made available from another experiment, can be mounted on on of the side ports of the Observation Chamber. The quadrupole may be differentially pumped by using an available small ion pump to maintain the detector region at a lower pressure than the quadrupole entrance region. This may be useful in molecular beam surface scattering studies, in which the beam density entering the quadrupole may be considerably higher than the 10^{-6} - 10^{-7} torr background pressure in the Observation Chamber.

By operating the quadrupole as a mass filter, we will be able to obtain TOF spectra that will allow measurement of

the translational energy distributions of molecules scattered off the surface. We hope to be able to measure the product energy distributions from laser-induced reactions that are enhanced at the surface, and thus possibly probe catalytic processes.

If the quadrupole is used as an all-pass filter, by operating it in the RF-only mode, it may be possible to measure higher-resolution (but not angle-resolved) TOF electron energy distributions, as the electron flight path would be longer than in the case of the rotatable analyzer. (for a description of the TOF analyzer, see Section 3.1).

3. TIME-OF-FLIGHT (TOF) ANALYZER DESIGN

A TOF Electron Energy Analyzer, with additional capabilities for use as a TOF Mass Spectrometer, has been designed and constructed. Since no instrument that would meet our specifications was commercially available, it was decided to construct the analyzer from a kit of plates, cylinders, spacers, rods, and mesh (eV Parts from Kimball Physics), specifically intended for electron beam studies.

Since the initial experiments that will be carried out involve the detection and analysis of photoelectrons ejected from the sample, and a quadrupole mass spectrometer was available for mass analysis of desorbing molecules, the TOF analyzer was primarily designed for use as an Electron Energy Analyzer. Additional use as a TOF Mass Spectrometer was a secondary design consideration.

3.1 Electron Energy Analyzer

The TOF Electron Energy Analyzer was designed according to standard electro-optical calculations (References 1-3). A brief summary of the design equations used appears in Appendix 1. Aperture diameters of the various elements used, together with inter-plate spacings, were calculated according to the constraints placed upon them by the equations. Plates and spacers available off-the-shelf from Kimball Physics were chosen to fit within these

constraints. Finally, these dimensions were fed back into the design equations to derive the necessary operating potentials on for the various elements. The entire analyzer / detector assembly is supported from a rotation manipulator mounted on the top flange of the observation chamber. The final design, shown in Figure 2, consists of four main sections:

1) A Retarding Plate to reduce the energy of incoming electrons by a fixed amount, without altering the energy spread. This enables accurate energy analysis of fast electrons (8-9 eV) by decelerating them to the 1-2 eV region, where small changes in electron energy result in a greater spread in electron flight time. The aperture diameter of this plate determines the angular resolution of the energy analyzer system, and also the fraction of electrons leaving the surface that enter the analyzer. The plate is maintained at a voltage determined by the amount of energy retardation required.

2) A three-element Einzel Lens, to collimate the diverging beam of incoming electrons without altering their energies. This greatly increases the number of electrons striking the detector, while leaving the energy distribution unperturbed. The aperture diameters of the plates, and the voltages at which they are held, are determined by standard electron-optical calculations. Since the Einzel element voltages must track variations in the Retarding Plate

potential, all of the voltages will be derived by Digital-to-Analog converters interfaced to the Computer Control and Acquisition system.

3) A field-free drift tube section, 10 cm long, which serves to separate electrons traveling at different velocities. The entire tube is maintained at the same potential as the exit plate of the Einzel lens, and has stainless steel mesh (95% transmission) covering both the entrance and exit, to reduce field penetration from other elements of the analyzer. The length of the flight tube is one factor that determines the possible electron energy resolution, and in our case is limited by the size of the observation chamber and the need for rotatability about the sample. In this case, the flight tube was chosen to be 10 cm long, giving a theoretical energy resolution of 0.1 eV at an electron energy of 1 eV.

4) A Channel Electron Multiplier Assembly (CEMA). This is a Galileo Multi-Channel Plate (MCP) Detector, Model 3025, with a Dual Chevron channel plate (12 micron channel diameter), and a 50 Ohm coaxial anode to provide correct impedance matching of fast analog signals to the preamplifier and transient digitizer. For detection of electrons, the CEMA cathode (the front plate) is held at a positive potential of several hundred volts, and the anode at 1 kV above the cathode. The coupling of the output signal from the anode to the fast preamplifier must remove this DC

bias component, and so is effected by a ferrite-core toroidal transformer custom-wound for this purpose (Ref. 4). The frequency response of this coupler should extend to several hundred MHz, and thus it will not degrade the timing information contained in the output signal.

3.2 TOF Mass Spectrometer

In many cases, measurement of the the angular distribution of atoms or molecules that are desorbed from (or scattered off) the sample may yield important information concerning surface processes. However, use of the fixed-position quadrupole mass spectrometer, with the sample being rotated on its manipulator to obtain angular resolution, would yield erroneous results, as the photon flux striking the surface from the cleaning and probe lasers would vary with the angle of incidence as the surface is rotated. Thus, as in the Electron Energy Analysis experiments, the sample must be held in a fixed position and the detector rotated about it.

The Electron Energy Analyzer may be modified to allow its use as a low-resolution TOF Mass Spectrometer. In order to achieve this, the potentials on the analyzer plates must be changed. For example, the detection of positive ions requires that the plate potentials be reversed in polarity compared to the electron-detection case. Since the CEMA cathode (front plate) will need to be at a high negative

potential with respect to the flight tube, the anode may be held at near ground potential. This allows direct coupling of the CEMA output signal to the detection electronics, without requiring an isolating transformer .

4. TRANSIENT DIGITIZER AND EXPERIMENTAL TIMING SYSTEM

4.0 Transient Digitizer

The Transiac 2001 Transient Digitizer system is used for the digitization and storage of the fast analog current signal from the Channel Plate Detector. This system is based upon the Computer Acquisition, Measurement, and Control (CAMAC) bus, and physically mounted in a CAMAC crate that provides both power and Input/Output lines for additional Data Acquisition circuitry. The system purchased contained a 6001 CAMAC Crate Controller, an IBM PC/CAMAC Interface board (PC 004) and CAMAC/IBM control and acquisition software.

The experimental setup requires a transient digitizer with a digitization dwell time of 5 ns (equivalent to 200MHz), as one of the factors determining the resolution of the electron energy analysis is the accuracy with which the flight times of different electrons can be determined. However, the Transiac 2001 system has a maximum clock rate of 100 MHz, and thus can only digitize a signal with a resolution of 10 ns. Although the Transiac uses high-performance flash A-D converters and Emitter-Coupled Logic (ECL) circuits in the digitizer, these are used at close to their maximum reliable operating frequency, and thus it is impossible to modify a single 2001 unit to give the desired 5 ns resolution. Some commercially available transient

digitizer systems, such as the Tektronix 7912, have much higher digitization frequencies, but rely on exotic signal capture techniques (such as electron beam writing and storage), and thus can cost well over $40,000 for a complete system.

The solution chosen is to use two Transiac 2001 modules, having the same input signal but with their 100 MHz clocks operating in antiphase, thus producing two interleaved spectra, each of which is digitized with a 10 ns resolution, but one of which starts 5 ns after the other. These spectra are then read separately into the IBM PC XT after the acquisition is complete, and a single spectrum, with 5 ns resolution, is deconvoluted in software. This method of increasing the time-resolution of the system only costs $13,000 for the complete Dual Digitizer / CAMAC crate assembly. Initial experiment using sinewaves have shown that the input signal can be accurately reconstructed using the above interleaving technique.

4.2 Experimental Timing System

Given the existing CAMAC capabilities, it was decided to base all of the laser and pulsed molecular beam timing circuitry upon the CAMAC protocol, by constructing additional delay generators and interface modules that intercommunicate via the CAMAC bus. Additional interface hardware included Programmable Timer chips (AMD 9513),

together with various Analog-Digital and Digital-Analog Converters. Optically-coupled isolating drivers were used to trigger the lasers while avoiding high levels of line-borne RF interference, and high-voltage (+80 V) pulse amplifiers were used to control the pulsed molecular beam valves. A block diagram of the experimental control and data acquisition system is shown in Figure 3.

An IBM PC XT microcomputer, interfaced to the CAMAC bus via an adapter card (PC 004) and the Transiac 6001 CAMAC Crate Controller, is used to pre-program all of the experimental parameters such as laser and molecular beam timing, Excimer laser pulse energy, and molecular beam intensity and pulse-width. This is achieved by an easy-to-operate, menu-driven BASIC program that allows the selection of various standard operating procedures. BASIC is well-suited to interactive programming, and its lack of speed is unimportant during the experimental setup cycle. Once these parameters have been loaded, and the course of the experiment decided, control passes to a machine-language program which loads up the timing delay generators, initiates the experimental control cycle, and then acquires data via the transient digitizer and the CAMAC bus. The timing diagram for a typical experimental cycle is shown in Figure 4. The high-speed performance of machine-language programs is vital during these time-critical procedures. Using the Transiac CAMAC control programs as a base, additional software was written to speed up the acquisition

and video display process, and to integrate the various modules into a single software package.

The pulse intensity of the probe laser (Quanta-Ray XL-401) is measured on a shot-to-shot basis to allow normalization of the spectra obtained to the excitation energy; this feature is especially important for an excimer laser, due to its short gas-fill lifetime and rapid roll-off of output power. However, data obtained in Pulsed Thermal Desorption Spectroscopy experiments will not be normalized to the desorbing laser (Questek 2000) pulse energy. The reasons for this are twofold. Firstly, variations in incident laser power control the surface desorption rates in an extremely complex and non-linear fashion, thus making any correction difficult. Secondly, a microprocessor-controlled "Powerlok" feature of this laser serves to compensate for the drop in laser cavity gain during the experiment, by controlling the discharge high voltage supply, thus maintaining a constant average output energy over the experimental timescale.

Once the experimental data has been acquired, processed in any desired manner, and displayed, it can be stored on the IBM PC XT's 10 Megabyte hard disk for future retrieval and processing.

5. FUTURE WORK

Over the next six months or so (up to the end of the first year of the three-year SOHIO grant), we expect to finish construction and characterization of the experimental apparatus. The computer interfaces to control the lasers and data acquisition electronics will be completed, and all the control software will be written. We will also carry out preliminary studies using the Pulsed Thermal Desorption and Pulsed Photoelectron Spectroscopy techniques. Initially, we will restrict our investigations to chemical systems that are well-characterized in the literature, such as CO on single-crystal Pt.

During the following year, we plan to continue the studies on single-crystal metal and silicon surfaces, and complete the characterization of the new techniques. We also intend to construct the pulsed photoelectron gun for the Pulsed Auger and PHREELS studies. A complete understanding of the capabilities and deficiencies of the various techniques should prepare us for the study of less well-characterized chemical systems.

During the third and final year of the SOHIO grant, we will begin experiments that simulate catalytic reactions of industrial significance. We may be able to use microcrystalline materials, such as the microsphere catalysts currently under investigation at SOHIO, as our surface sample. A satisfactory method of supporting the spheres on the sample manipulator, without risk of

contamination or modification of catalytic properties, would need to be devised. Investigation of the physical and chemical properties of semiconductor materials should be possible, since the analysis techniques described above will by then be well-characterized by their prior application to simpler systems.

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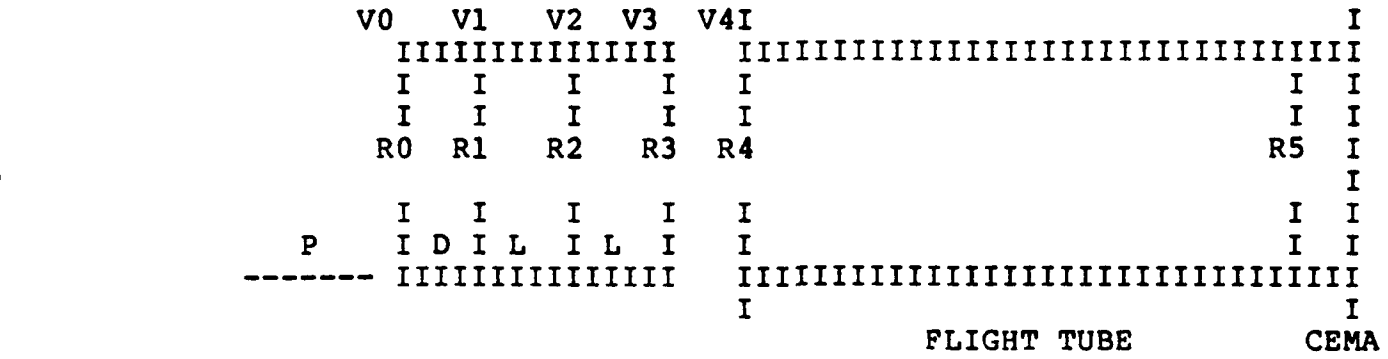
APPENDIX 1: DESIGN OF ELECTRON ENERGY ANALYZER



Retarding Plate Design

A.

$$F0 = \frac{4V0}{EB-EA} \qquad EB = \frac{(V1-V0)}{D} \qquad EA = \frac{(V0-V')}{P}$$

F0 focal length of retarding lens

V1 potential on first einzel element

V0 potential on retarding plate

V' potential of source

P distance of source from retarding plate

D distance between retarding plate and first einzel element

E electric field associated with a given region

Note that V0=V1, and V'=0, (i.e. source is grounded)

EB=0 (for a field- free region)

$$F0 = -4 \times P$$

Aperture Radius Calculations:

$$R0 = SQR(RES) \times \frac{4xDxP}{P+4xD}$$

in which RES=resolution (^E / E)

Einzel Lens Design

A. Focal Length Calculation

$$F1 = (P + D + L)$$

i. Calculate the L/F1 ratio and obtain the midfocal potential U from tables. (Ref.4)

ii. set the R1/R2 and calculate L/R2.

$$U = (1 + (L/R2) \times ARCTAN(L/R2) - R1/2 \times R2)^{-1}$$

L the spacing between the lens.

R1 the radius of the first einzel element.

R2 the radius of the second einzel element.

$$R1=R3 \qquad R5 = .75 \times R4$$

iii. calculate the potential ratio V2/V1 of the first and second einzel elements.

$$K = 3.14 \times L + R2 - 2 \times R3 \times L \times (ARCTAN(L/R2))$$

$$C = 3.14 \times L - 2 \times R1$$

$$\frac{V2}{V1} = 1 - ((3.14 \times L) \times (((U-1)/C)) / ((U \times K) - 1))$$

$$V0 = V1 = V3 = V4 = V5$$

EXAMPLE CALCULATIONS (Dimensions in mm.)

P = 50 , D = 2 , L = 4 , R1/R2 = .5 , V0 = .9 , U =.7

R0 = 1.37 , R1 = 3 , R2 = 6 , R3 = 3 , RES = .01

$$\frac{V2}{V1} = .9687$$

TABLE OF CALCULATED VALUES

D0	D1	D2	D3	L	D	P	V2/V1	R1/R2
.7	4	8	4	4	1	50	.96	.5
.7	5	5	5	4	1	50	.94	1
1.4	4	8	4	4	2	50	.96	.5
1.4	5	5	5	4	2	50	.94	1
3.0	5	5	5	4	5	50	.94	1
3.0	4	8	4	4	5	50	.96	.5
4.2	4	8	4	4	12	50	.96	.5
2.6	7.4	14.8	7.4	9.52	4.4	50	.993	.5
2.6	11.6	11.6	11.6	9.52	4.4	50	.991	1
1.2	4.0	8	4.0	4	1.8	50	.96	.5
1.2	4.4	4.4	4.4	4	1.8	50	.94	1
3.0	4.0	8	4.0	4	5.77	50	.96	.5
3.0	4.4	4.4	4.4	4	5.77	50	.94	1

APPENDIX 2: BUDGETARY CONSIDERATIONS

The original Howard University Proposal to the DOD Instrumentation Program requested $250,695 to purchase equipment to set up the Surface Study apparatus. Since the final grant award was $155,000, the apparatus outlined in the proposal was completely re-designed to allow the acquisition of sufficient equipment to carry out the desired experiments, within the constraints of the available finances.

Appendix 3 shows the Equipment Budget throughout the various stages of the granting cycle. Appendix 3A contains the Budget as outlined in the original proposal, and Appendix 3B the Revised Budget submitted after the grant was awarded. Appendix 3C reflects slight changes made in this revised budget, with AFOSR permission. Finally, Appendix 3D contains the breakdown of equipment purchased according to the Budget Categories of Appendix 3C. It may be seen that the estimated categorical expense breakdown correlates reasonably well with that anticipated in the revised budget.

APPENDIX 3A: ORIGINAL EQUIPMENT BUDGET
(as outlined in proposal)

A. Apollo Model 570 CO_2 Laser with Q-switch	$ 27,320
B. CVC TOF Mass Spectrometer with Turbo Pump	63,600
C. Ircon Modline Two-Color Pyrometer	4,200
D. Allied Alexandrite Laser with accessories	90,000
E. Observation Chamber	14,500
F. Laser Technics Valve (2 ea.)	3,200
G. Hewlett-Packard Pulse Generator	3,895
H. Biomation 8-bit Transient Digitizer	18,980
I. Varian VHS 6 inch Pumping Stack	8,500
J. Windows, Vacuum Hardware, etc.	16,500
	$ 250,695

APPENDIX 3B: REVISED EQUIPMENT BUDGET
(after award of Grant)

A. Apollo Model 570 CO_2 Laser with Q-switch	$ 27,320
B. Math Sciences North West XL-401 Excimer Laser	18,000
C. Ircon Modline Two-Color Pyrometer	4,200
D. Vacuum Chambers, Pulsed Valves, Pumping Systems	50,890
E. Channel Plate Detector, High Voltage Power Supplies, Photomultipliers, Misc. Optics	13,500
F. Tektronix 7912 Transient Digitizer System	29,700
G. Programmable Sequence Control System based on IBM Personal Computer with Data Acquisition development system	11,390
	$155,000

APPENDIX 3C: FINAL APPROVED EQUIPMENT BUDGET
(modified with AFOSR permission)

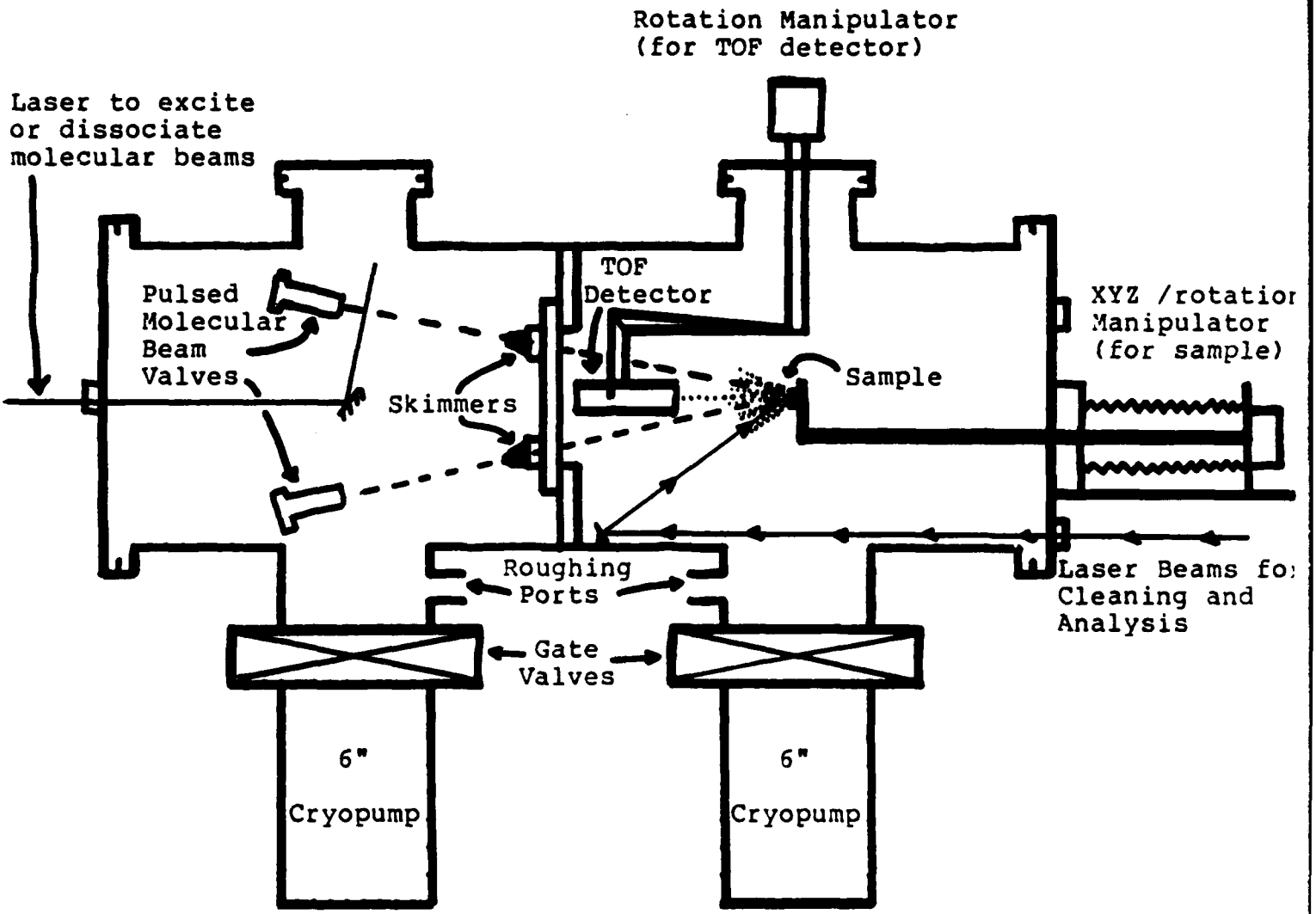
A. Questek Model 2000 Excimer Laser	$ 31,520
B. Math Sciences North West XL-401 Excimer Laser	18,000
C. Vacuum Chambers, Pulsed Valves, Pumping Systems	50,890
D. Channel Plate Detector, High Voltage Power Supplies, Photomultipliers, Misc. Optics	13,500
E. Tektronix 7912 Transient Digitizer System	29,700
F. Programmable Sequence Control System	11,390
	$ 155,000

APPENDIX 3D: CATEGORIZATION OF PURCHASES MADE

A. Questek Model 2000 Excimer Laser with optics	$35,530
B. Quanta-Ray (MSNW) XL-401 Laser with spare optics	$19,850
C. Vacuum Chamber, Pulsed Valves,etc.:	
1. MDC Custom-Built Vacuum Chamber, Valves, etc.	$18,542
2. Varian 981-1111 Sample Manipulator (LN_2 cooled)	10,600
3. Leybold-Heraeus RPK 1500S-3 Cryopumps (2)	16,251
4. Leybold-Heraeus D-16A Rotary Pump, Accessories	2,176
5. Newport BV-100 Pulsed Beam Valves (2)	3,280
6. Granville-Phillips Vacuum Gauge Controllers (2)	1,657
7. Beam Dynamics Beam Skimmer Nozzles	1,160
8. Huntington Rotary Manipulator, Ion Gauge	915
9. Chamber Support Framework Pipe and Connectors	634
10. Cryogenic Temperature Sensor Diodes	235
11. Relays, Magnetic Shielding, Heaters, etc.	762
	$ 56,212
D. Channel Plate Detector, Power Supplies, Optics, etc.:	
1. Galileo Chevron Channel Plate Detector	$ 1,550
2. E G & G Ortec HV Power Supplies, Nim Bin	2,430
3. Pacific Instruments Dual High Voltage Power Supply	800
4. Analog Modules Programmable HV Power Supplies	780
5. Heathkit Power Supply, Chart Recorder	460
6. Lens Holders, Translators, Optical Mounts	1,705
7. Spare Mirrors for Quanta-Ray XL-401 Laser	900
8. He-Ne Lasers for alignment, spare plasma tubes	1,155
9. Photodiodes, Lenses, Misc. Optics	432
	$ 10,212
E. Transient Digitizer System:	
1. Transiac Model 2001 Transient Digitizer Modules	$11,490
2. BiRa Model 5000 CAMAC Crate	1,615
3. Philips PM 3262 100 MHz Oscilloscope	1,495
	$ 14,600
F. Programmable Sequence Control System:	
1. IBM PC XT Microcomputers (2) with Color Cards	$8,430
2. PGS HX-12 and Amdek 300A Video Monitors	729
3. NEC 3550 Spinwriter Printer with Tractor Feed	2,474
4. AST Megaplus and I/O-Plus Expansion Boards	698
5. Tecmar Labmaster Data Acquisition Board	963
6. Sysgen Streaming Tape Backup Drive for Hard Disk	1,120
7. CAMAC Prototype Modules,EPROM Blaster Board	629
8. Lehmann Z8 Microcomputer Boards, Software	1,015
9. Evans 4130 Gated Integrator, 4145 Delay Generator	375
10. PC/FORTH Software with Graphics Extension	200
11. Kodak Video Monitor Camera Adapter	245
12. Miscellaneous Electronics, Connectors, Cable, etc	1,718
	$ 18,596
TOTAL SPENT:	$ 155,000

Figure 1.

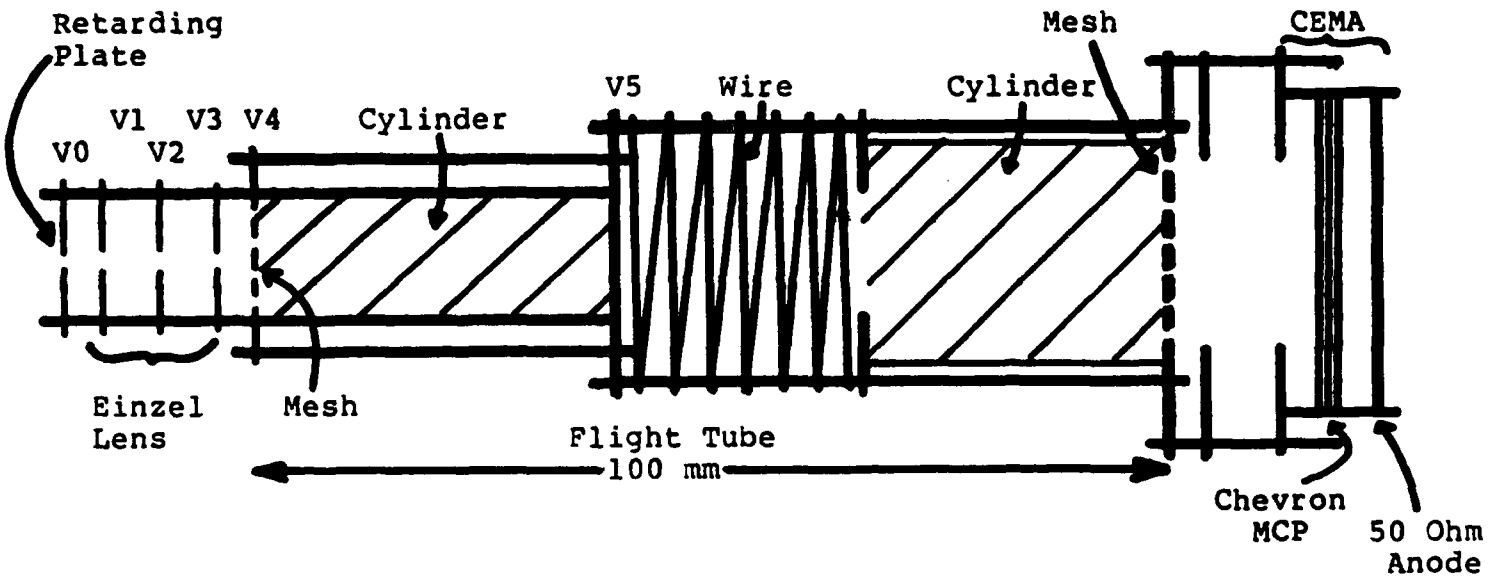
Experimental Apparatus



If used, the quadrupole Mass Spectrometer System would be mounted on a port coming directly out of the plane of the paper from the sample.

Fig. 2

Time-of Flight Electron Energy Analyzer



V0 = V1 = V3 = V4 = V5 = V6

Figure 3.

Block Diagram of Data Acquisition System

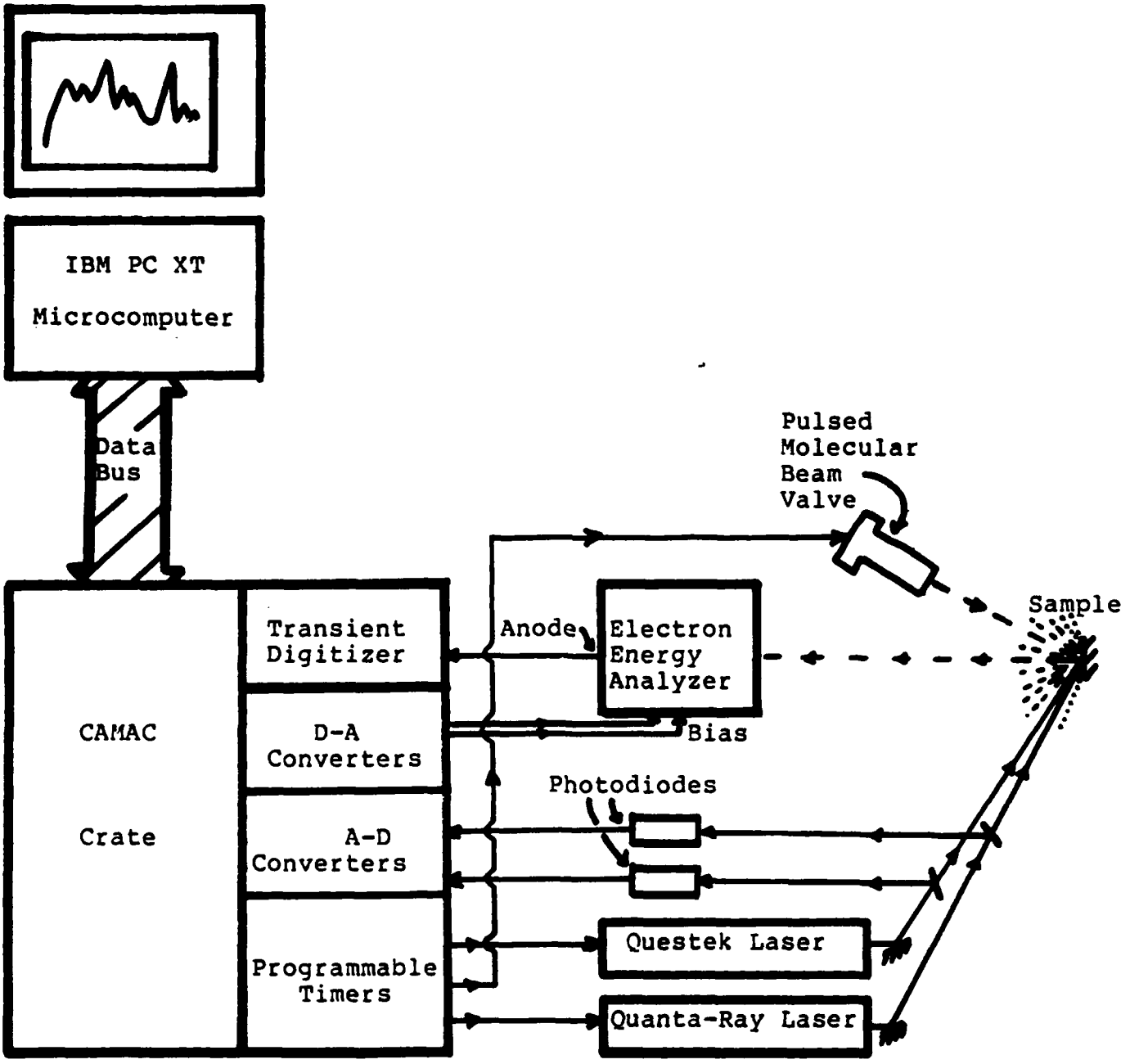
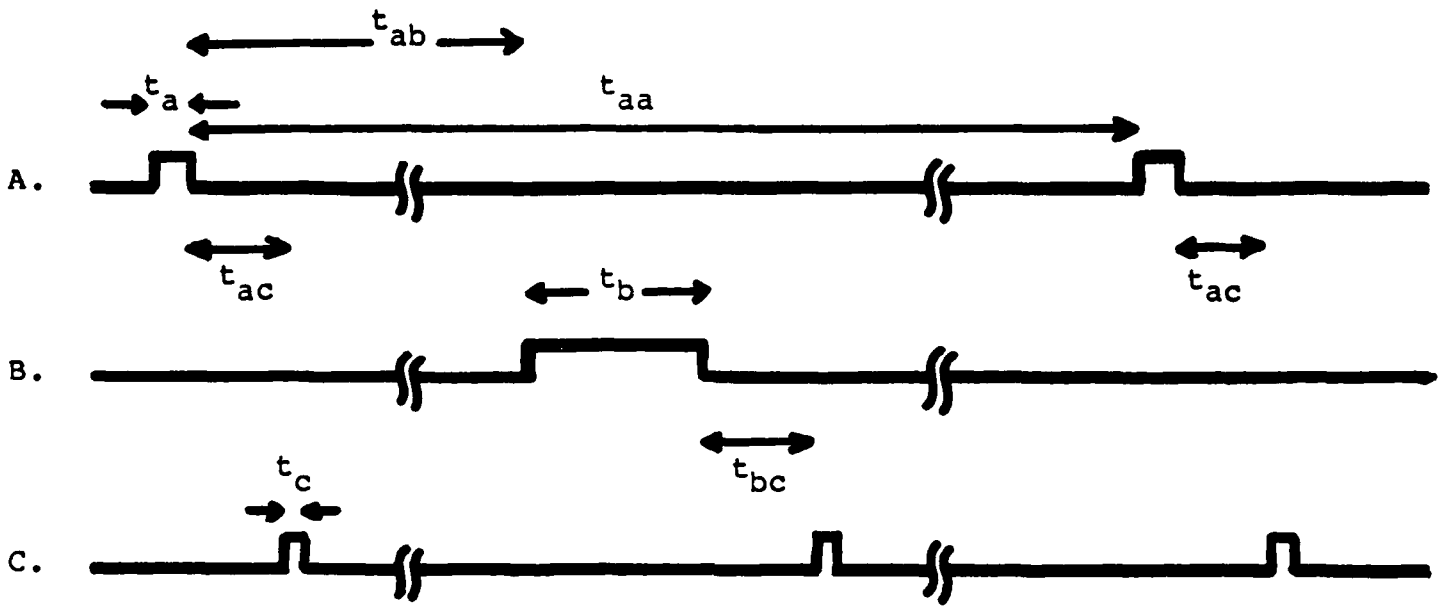


Fig. 4

Experimental Timing Cycle



A. is Excimer Laser used to clean the surface (Questek 2000)
B. is Pulsed Molecular Beam striking surface
C. is Pulsed Laser (Quanta-Ray XL-401) or Electron Beam to probe surface

t_a is pulsewidth of Questek, 20 nsec.
t_b is pulsewidth of molecular beam valve, 0.1-10 msec.
t_c is pulsewidth of Quanta-Ray, 3-5 nsec.

t_{aa} is time between successive cleaning laser pulses (20 msec. min.)
t_{ab} is delay between cleaning laser and arrival of molecular beam
t_{ac} is delay between cleaning and probing of surface
t_{bc} is delay between end of molecular beam pulse and probing of surface

All delays, the molecular beam pulsewidth t_b, and the intensities of the Questek laser and the molecular beam,are under software control and can be pre-programmed on a shot-to-shot basis.