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A METHOD FOR MAKING RPD MEASUREMENTS ON TIME-RESOLVED SPECIES*

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ABSTRACT

A pulsed electron beam retarding potential difference technique with automatic accumulation of data has been developed. This technique permits high resolution electron impact measurements to be made on species which can be resolved on the basis of their flight times from the excitation region to a detector.

The retarding potential difference (RPD) technique developed by Fox, Hickam, Grove, and Kjeldaas[1] has been extensively used to generate "monoenergetic" electron beams for the study of electron impact ionization and excitation efficiency curves.

In such experiments a retarding electrode in the electron gun is operated at a potential sufficiently negative with respect to the electron source to cause the low energy portion of the electron energy distribution to be repelled. The resulting truncated distribution can be accelerated to the desired working energy. A second truncated distribution can be formed by changing the potential applied to the retarding electrode by a small amount (e.g. 0.1 V). The difference between the two distributions is a narrow energy band of electrons corresponding to the voltage difference applied to the retarding electrode.[2]

In applying the RPD technique for measuring, e.g. ionization efficiency curves, there are two ways of obtaining high resolution data. The voltage on the retarding grid can be modulated with an amplitude appropriate to the desired resolution and the ion current detected with a detector responsive only to the AC component of the ion current.[3] Alternatively, the retarding potential can be changed from 'high' to 'low' at each electron energy setting and the arithmetical difference between the corresponding ion currents can be taken. Recently Chantry[4] devised a method of performing the latter operation automatically using a multichannel scaler.

In many experiments it is desirable or necessary to use a short pulse of electrons rather than a continuous beam.[1] For example, an experiment in progress in this laboratory uses electrons to excite species in an atomic or molecular beam to neutral metastable states.[5] The metastables are separated from the photons, which are also produced by the electron collisions, by taking advantage of the difference in flight time of the two species from the electron gun to the detector. In order to record an excitation efficiency curve for the production of metastables, it is convenient to use a pulse of electrons short with respect to the flight

time of the species and to gate open selectively the detecting system. Using an extension of Chantry's RPD method,[4] it is possible to make automatic RPD measurements with a pulsed electron beam.

DESCRIPTION OF SYSTEM

The system which was developed to make pulsed RPD measurements employs pulse counting techniques exclusively. The multichannel analyzer (MCA) is a Hewlett-Packard Model 5400A modified so that an externally applied gate can be used to switch the storage mode from add to subtract.

The pulsing scheme used is shown in Fig. 1. The times indicated in Fig. 1 are typical for the metastable experiment described above, but they are not restrictive. In cycle 1, a master clock pulse triggers the sweepstart of the MCA. A delayed clock pulse triggers a pulse train from a time-based-oscillator (TBO). These pulses are used to trigger the channel advance of the MCA and also to trigger the electron 'on' pulse. The latter pulse is applied to the retarding grid (G_3) of a 5-electrode RPD gun.[1] The maximum positive voltage of this pulse is exactly that to allow the 'high' truncated electron distribution to pass through the gun. The width of the pulse is variable from 5 μsec to continuously 'on'. The electron accelerating voltage applied to the collision chamber (G_5) is generated by amplifying the analog X output of the MCA. In the first cycle, the MCA multiscales in the 'add' mode. Counts from the electron multiplier are delivered to the MCA via a data count gate. Zero time for this gate is established by the TBO pulse. This gate is variable in delay and width, and insures that data counts are registered only in a preset time slot following (or during) the electron pulse. At the end of the MCA sweep (256, 512, or 1024

channels in this case), the analyzer produces an end-of-program pulse which is used to stop the TBO pulse train.

On receipt of the second master clock pulse to start cycle 2, the entire sequence is repeated, except that the electron 'on' voltage is decreased to the RPD 'low' value and the analyzer is automatically reset to multiscale in the subtract mode. As described by Chantry[4] these two sweeps produce one RPD curve. The complete sequence is repeated an even number of times until the signal to noise ratio of the curve is judged to be adequate.

A block diagram of the electronic system is shown in Fig. 2. It consists of 3 basic components: the RPD Logic unit, the time-based-oscillator and the Hewlett Packard analyzer. The TBO is a Lawrence Radiation Laboratory designed variable repetition rate oscillator.[6]

The RPD Logic unit is contained in a single 8" × 3" NIM module. The logic, timing and amplifier circuits are standard TTL and linear integrated circuits. The unit is responsible for generating and controlling the voltages and pulses illustrated in Fig. 1. A block diagram of the logic unit is shown in Fig. 3.

Referring to Fig. 3, the start pushbutton and a clock pulse delayed 6 μsec set the start flip-flop and open the start gate. Because of the delay, the first clock pulse does not pass the start gate. There is initially no output to the TBO or the MCA. The first clock pulse also sets the add/subtract flip-flop to 'add'. The second clock pulse (∿ 0.3 sec later with the times illustrated in Fig. 1) triggers the sweep trigger of the MCA and after a short delay triggers the TBO. The actual scan advance is now triggered by the TBO until the latter is stopped by an end-of-program (address overflow) pulse from

the MCA. The next clock pulse received by the Logic Unit causes the add/sub flip-flop to switch to the 'subtract' level. A wide-band operational amplifier (K_1) mixes an attenuated signal from the add-subtract flip-flop with the electron gate pulse (from an external triggered pulser) to provide the combined ΔV and electron 'on' pulse applied to the retarding grid. Both the magnitude of ΔV and the DC bias applied to the grid are variable. The width of the electron 'on' pulse is determined by the external pulser. As explained previously, the electron accelerating voltage (step sweep) is derived from the plotter X-output of the HP 5400A. This output is linear to 0.1%. The voltage is adjusted for the proper span and is biased to the desired initial value by controlling the operational amplifier K_2. To stop the pulsing sequence, the 'STOP' pushbutton is closed. The add-subtract flip-flop and the stop gate insure that the sequence does not stop until a 'subtract' cycle has been completed. Thus the sequence is stopped only after a complete RPD scan.

DISCUSSION

As mentioned previously an application of this technique is in molecular beam time-of-flight (TOF) studies. Figure 4 shows a TOF spectrum of a neon atomic beam excited by a 10 μsec pulse of electrons. The fast signal corresponds to photons generated by the electron pulse. These photons arrive during the time the electron beam is on. The photon profile illustrates the excellent rise and decay time of the electron beam. The measured width of the photon signal is within 0.1 μsec of the width of the voltage pulse applied to G_3. The slower signal corresponds to neon metastables. High resolution excitation efficiency curves for the production of Ne metastables have been published previously.[7-9] However,

the results have included a small contribution from photons. Using the pulsed RPD technique described here it has been possible to record "pure" excitation efficiency curves for both species. These curves are shown in Fig. 5. The upper curve corresponds to metastable neon atoms, the lower to photons from neon. The sharp threshold on the Ne^* curve illustrates the resolution obtained (ΔV in this case = 0.1 V). The photon signal from neon is very weak ($\sim$ 20-40 counts/MCA sweep). Many sweeps are necessary in order to produce an RPD curve for $h\nu$/Ne. However, as Chantry has pointed out,[4] the true shape of the curve should be maintained providing that the individual scans are short.

The high resolution performance of the gun used in the pulsing mode has been checked by comparing the Ne^* curve shown in Fig. 5 with a curve run in the 'DC' mode described by Chantry.[4] For neon the photons obviously do not make an important contribution to the total curve. This test showed that operation in the pulsed mode does not affect the gun performance. For experiments where high time resolution has been required, the gun has been operated with 'on' times as short as 5 μsec. 'Off' times approaching 1 msec are always used to allow the slow metastable signal to decay to an insignificant level before the next electron pulse occurs. Obviously if the duty-cycle of the gun can be increased (at the expense of time resolution), the RPD curves build-up more quickly, and fewer scans are necessary to achieve a satisfactory signal-to-noise ratio.

Mixing the 'on/off' pulse with the RPD ΔV voltage on the retarding grid appears to be highly satisfactory. The operation of the gun has been stable and reproducible, and no adverse effects from the beam pulsing have been noted in the high resolution data.

FOOTNOTES AND REFERENCES

*Work performed under the auspices of the U. S. Atomic Energy Commission.

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3. C. R. Bowman and W. D. Miller, J. Chem. Phys. 42, 681 (1965); H. H. Brongersma and L. J. Oosterhoff, Chem. Phys. Letters 1, 169 (1967).

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5. R. Clampitt and Amos S. Newton, J. Chem. Phys. 50, 1997 (1969); University of California, Lawrence Radiation Laboratory Report UCRL-18032.

6. A description of this unit is available from the Lawrence Radiation Laboratory as drawing No. 15X1810.

7. R. Dorrestein, Physica. 9, 447 (1942).

8. F. M. J. Pichanik and J. Arol Simpson, Phys. Rev. 168, 64 (1968).

9. John Olmsted III, Amos S. Newton, and K. Street, Jr., J. Chem. Phys. 42, 2321 (1965).

FIGURE CAPTIONS

Fig. 1. Timing diagram for the pulse scheme used to make RPD measurements on time-resolved species.

Fig. 2. Block diagram of the electronic system showing the connections of the RPD Logic Unit, the TBO and the MCA.

Fig. 3. Block diagram of the RPD Logic Unit.

Fig. 4. Time-of-flight spectrum of a neon atomic beam excited by a 10 μsec, pulse of electrons.

Fig. 5. Upper curve: Electron impact excitation efficiency curve for the production of neutral metastable atoms in neon.

Lower curve: Electron impact excitation efficiency curve for the production of U. V. photons from neon.

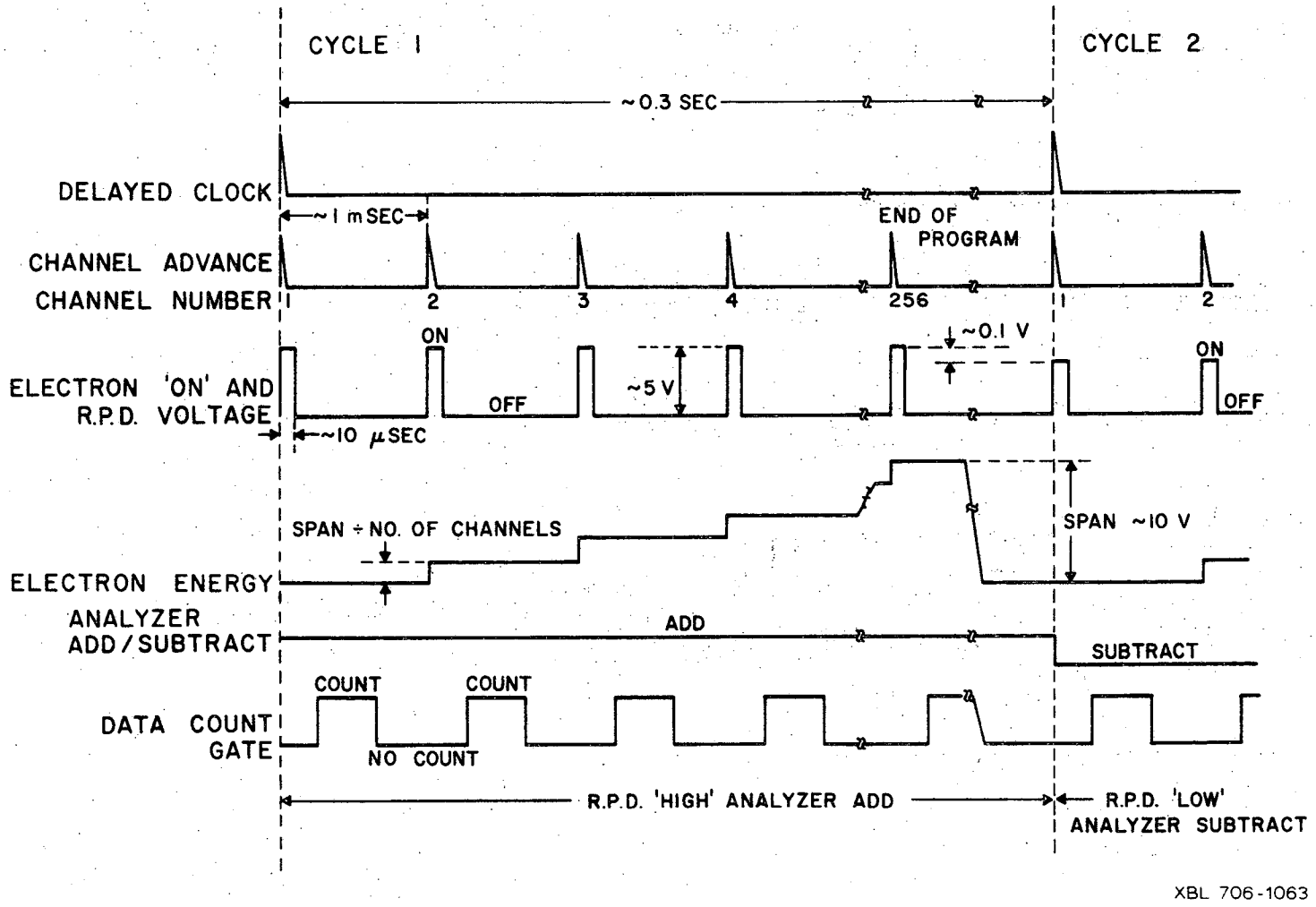
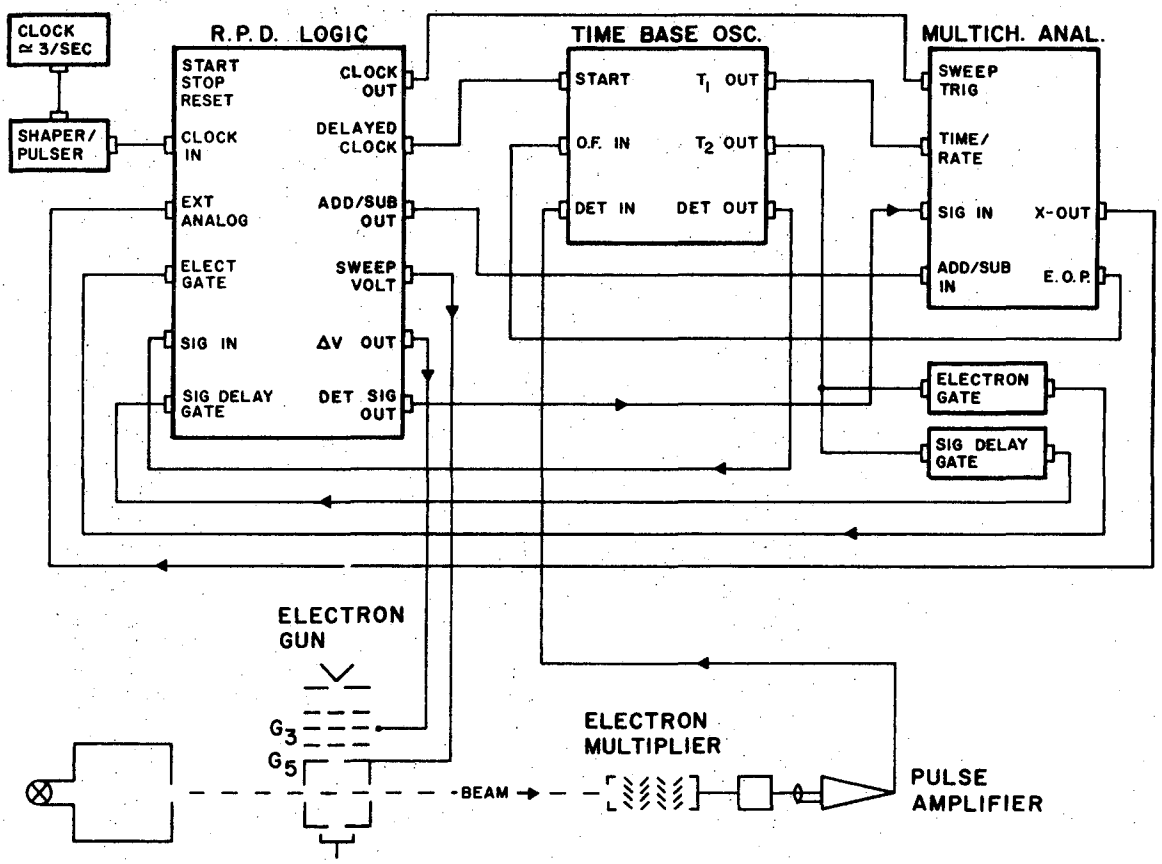

CYCLE 1
CYCLE 2
~0.3 SEC
DELAYED CLOCK
~1 mSEC
END OF PROGRAM
CHANNEL ADVANCE
CHANNEL NUMBER
1
2
3
4
256
1
2
ON
OFF
~5 V
~0.1 V
ON
OFF
ELECTRON 'ON' AND R.P.D. VOLTAGE
~10 μSEC
SPAN ÷ NO. OF CHANNELS
SPAN ~10 V
ELECTRON ENERGY ANALYZER ADD/SUBTRACT
ADD
SUBTRACT
COUNT
COUNT
NO COUNT
DATA COUNT GATE
R.P.D. 'HIGH' ANALYZER ADD
R.P.D. 'LOW' ANALYZER SUBTRACT
XBL 706-1063

Fig. 1

R. P. D. CONTROL BLOCK DIAGRAM



XBL 706-1065

Fig. 2

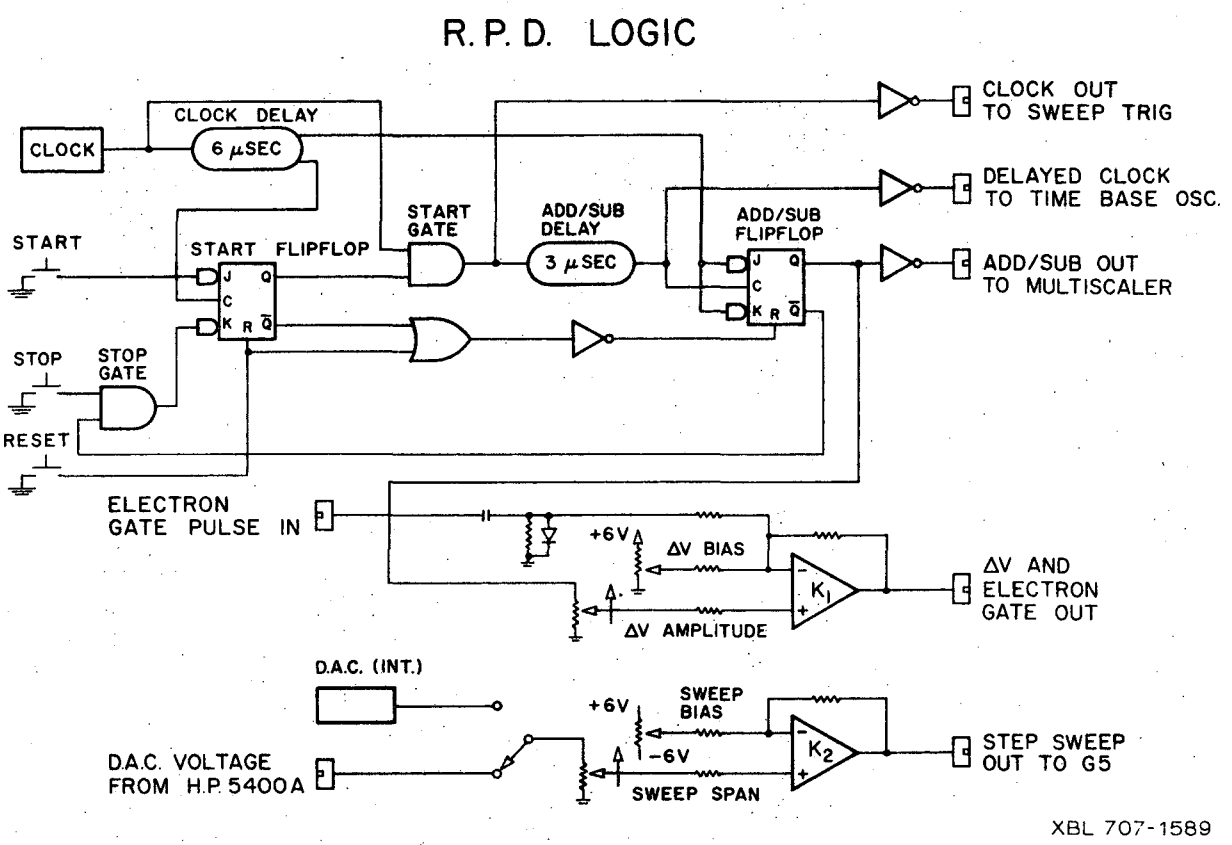
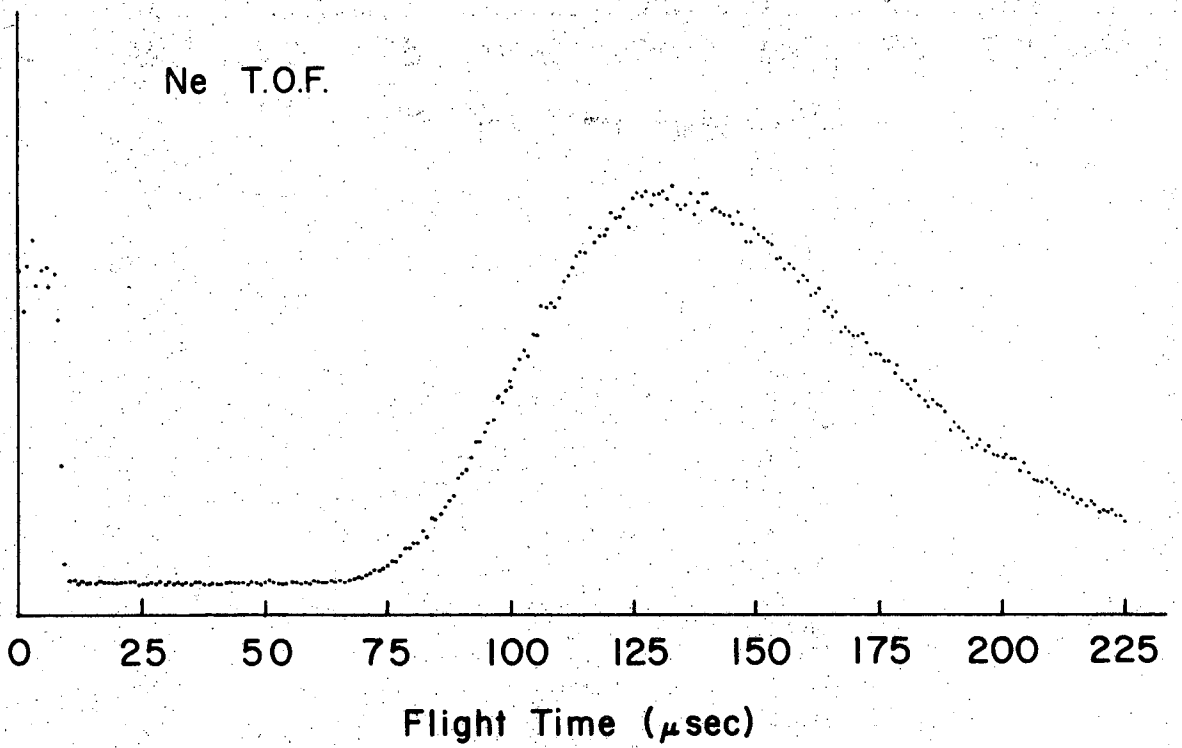

R. P. D. LOGIC
CLOCK
CLOCK DELAY
6 μSEC
START
START FLIPFLOP
START GATE
ADD/SUB DELAY
3 μSEC
ADD/SUB FLIPFLOP
STOP
STOP GATE
RESET
CLOCK OUT TO SWEEP TRIG
DELAYED CLOCK TO TIME BASE OSC.
ADD/SUB OUT TO MULTISCALER
ELECTRON GATE PULSE IN
+6V
ΔV BIAS
ΔV AMPLITUDE
K1
ΔV AND ELECTRON GATE OUT
D.A.C. (INT.)
D.A.C. VOLTAGE FROM H.P. 5400A
+6V
SWEEP BIAS
-6V
SWEEP SPAN
K2
STEP SWEEP OUT TO G5
XBL 707-1589

Fig. 3



XBL 706-1053

Fig. 4

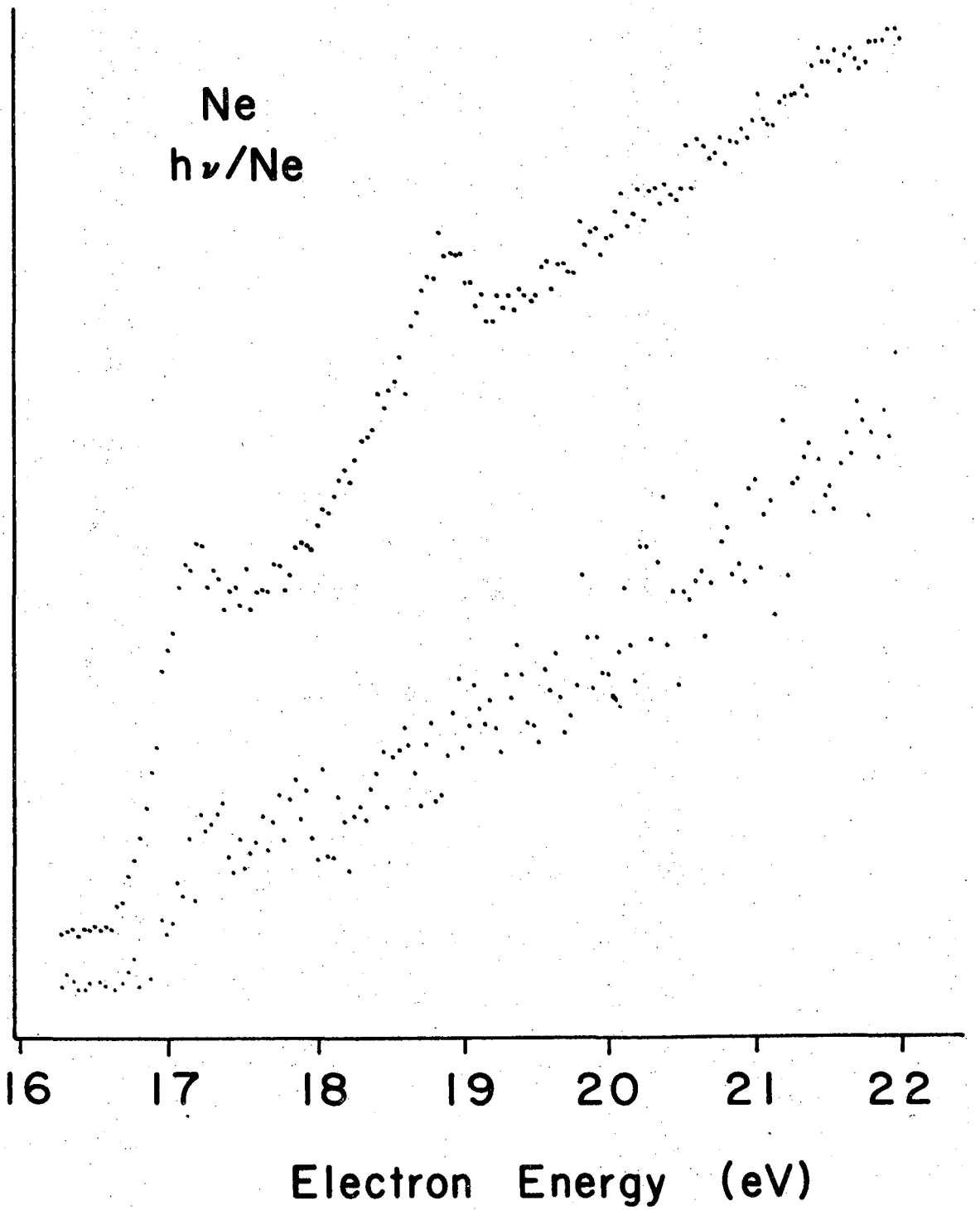


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Fig. 5

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