XMM Optical Monitor

MULLARD SPACE SCIENCE LABORATORY
UNIVERSITY COLLEGE LONDON **Author: H. Kawakami**

Quntum Efficiencies of XMM-OM intensifiers

Document Number: XMM-OM/MSSL/TC/0053.01 25-Feb-99

Distribution:

XMM-OM Project Office	A Dibbens	Orig.
ESA PX	H Eggel G Bagnasco	
DORNIER	R Schricke	
CSL	P Rochus S Roose	
UCSB	T Sasseen	
University College London	R Bingham	
University College London	J Fordham	
Mullard Space Science Laboratory	K Mason A Smith P Guttrige J Lapington A Breeveld H Kawakami	
	R Much DEP	

<< Quantum efficiencies of XMM-OM intensifiers >>

XMM-OM/MSSL/TC/0053.01

25 February 1999
Hajime KAWAKAMI
Mullard Space Science Laboratory
Holmbury St. Mary, Dorking
Surrey RH5 6NT, U.K.
Fax) 44-1483-278312
Tel) 44-1483-274111

1. Introduction

XMM-OM intensifiers employ S-20 photocathode to achieve wide spectral coverage, i.e. 1700-6000A. The two FM intensifiers were, however, delivered to ESA without measuring Q.E.s by MSSL. It was because (1) a reliable measurement system was not ready, and (2) the measurement would have taken long hours though the time for the delivery was very limited. The FM intensifiers were supplied by DEP. Their R.Q.E.s (photo-cathode sensitivity) were measured by DEP in the wavelength range of 2000A-9000A at the time of manufacturing. MSSL used DEP's R.Q.E. measurement as alternative sensitivity data. The D.Q.E. (Detectable Quantum Efficiency, overall sensitivity of a photon counting system) is not exactly same as R.Q.E. It is always lower than R.Q.E. We estimated that D.Q.E. was 70% of R.Q.E. at the time of XMM-OM delivery.

The first FM intensifier was selected from DEP's 1st batch (March 1998) and the 2nd FM intensifier was from the 2nd batch (April 1998). After the delivery of XMM-OM, two FM spare intensifiers (i.e. DEP_#6 and DEP_#7) were manufactured in the 3rd batch (June 1998). Both of R.Q.E. and D.Q.E. for the 2 spare intensifiers were measured with a newly built calibration system at MSSL.

MSSL's new R.Q.E. measurements agreed with DEP's results. MSSL measured D.Q.E as well. The ratio of D.Q.E to R.Q.E. was proven to be 70%. The measurement was carried out down to vacuum UV wavelengths, namely to 1400A. The measurement step was 100A at most of wavelengths except 20A step between 1600-1800A, where FuSi (window material of the intensifiers) cutoff is located. The wavelength of the cutoff was at 1640A. The detector showed sufficient sensitivity (D.Q.E. of >14%, R.Q.E. of >21%) at 1700A, which is the shortest wavelength required by XMM-OM.

2. Measurement system

A vacuum monochrometer system has been used for testing UV performance of the detector at MSSL since the beginning of XMM-OM project (Figures 1). The monochrometer has 2 detector ports, one is for the XMM-OM detector and the other for reference detectors (i.e. photo-multiplier and photo-diode). A light beam from a Deuterium lamp, UV light source, enters into a spectrograph and illuminates a grating. A monochromatic light is selected by the grating and is emitted towards a chopping mirror. The monochromatic light beam is redirected to one of the 2 ports by rotating

the mirror by 90 degrees (Figure 2).
Rotation of the grating, selection of filters on 2 filter wheels were controlled by a PC. While, widths of entrance and exit slits are controlled manually to tune the intensity and the band width of the input light. The Deuterium lamp has a condenser mirror to increase intensity. This, however, focus the light beam on a detector, which inhibits uniform illumination of the detector. To overcome this problem, the entrance slit was opened a little (typically 5-20um depending on wavelength) to expand the light beam by diffraction. The maximum light intensity was limited by this.

A XMM-OM detector and a reference detector was illuminated by a monochromatic light by turns to determine relative sensitivity of the XMM-OM detector, assuming the light intensity was constant in a short time. Since absolute Q.E. of a precision photodiode had been calibrated by NIST and Hamamatsu Photonics, the relative sensitivity could be converted to absolute sensitivity.

Two low noise amplifiers were newly made for reading photodiode current and for photocathode current. A photon counting readout system was also prepared for an intensifier. Fig. 3 shows schematic diagram of data acquisition. Signals from the XMM-OM intensifier and the photo-diode were transferred to an interface box. One of the two signals was selected and acquired by a computer.

Two items of the sensitivity were measured, namely,
(1) R.Q.E. (photo-cathode sensitivity)
(2) D.Q.E. (photon detection efficiency).

R.Q.E. was determined from the ratio of photocathode current to photo-diode current using brighter input light.
D.Q.E. is the ratio of input photons to photo-events detected by the readout system. D.Q.E. is always lower than R.Q.E. The D.Q.E. shows true detector sensitivity, but it is not easy to measure because the input light for the measurement must be extremely low to allow the photon counting detector to work. Assuming D.Q.E. of XMM-OM detector is 18% and Q.E. of the photodiode 50%, the input light for 50,000 events/s in the photon counting detector can create only 1.6E-19 x 1.4E5 electrons/sec = 2.2E-14 ampere =22 fA in the photodiode.

2-1. Photocathode amplifier for R.Q.E. measurement

As a bright light can be used for R.Q.E. measurement, the readout noise of this amplifier is not necessary to be extremely low. Unfortunately, our monochrometer cannot provide very bright light, therefore the target was set to 10fA, which enables to read 200fA with 5% accuracy.

A special requirement for this amplifier is to provide a large DC voltage to an image intensifier, i.e. 45volts. The photocathode of FM and spare intensifiers are electrically connected to the housing which attaches to the big lump of metal (the monochrometer) during R.Q.E. measurement. Therefore, the photocathode current cannot be measured at photocathode point (0V from the earth). The current must be measure at MCP1 input in stead, where a large DC voltage should be applied in order to accelerate photo-electrons towards MCP1. A 45V was applied to photocathode gap by integrated batteries, which achieved the best electric shielding, stability of DC voltage and compactness.

Fig. 4 shows circuit diagram of the current amplifier. A 10G Ohm is employed for the feed back resister, which converts 1fA to 0.01mV. The photocathode voltage is supplied from the inverted input of the current amplifier, which should have same voltage as the non-inverted input, i.e. 45V from the earth. The output signal is sent by frequency in stead of by voltage. The DC bias of the pulse signal is shifted to 0V through a coupling capacitor. This approach allows integration of the signal by a computer for an arbitrary length. This can also avoid measuring tiny ~0.01mV DC-signal on top of the large DC bias, 45V.

The conversion factor of the overall readout systems (current amplifier + V/F converter) was calibrated through known currents, 1pA - 10pA, supplied by Keithley 261 Picoampere Source. It was 9.53fA/Hz. The true value of the feed back resister labelled 10G Ohm was also calibrated separately and was found to be 10.18G Ohm.

Fig. 5 is the outlook of this tiny current amplifier. A DEP intensifier is connected to Raynolds connectors on a compact diecast box. The diecast box provides photocathode voltage and measures photocathode current. It sends the photocathode current data to a computer by pulse signal.

Fig.6 shows noise measurement of this amplifier without input.
Fig 7 shows photocathode current of DEP_#6 intensifier at Vc=44.8V. Because the tube was kept in dark during the measurement, the current is due to leakage through the tube body. The readout noise of the amplifier without connection is smaller than 2fA as shown in Fig 6. When an intensifier is connected to the input, major noise is originated in the leakage current thorough tube body, typically 5pA. This leakage current changes gradually, but this can be largely suppressed in chopping mode (photon v.s. dark every 10 sec) as shown by filled squares in Fig 7. It is usually less than 2.5fA. The worst error was 6fA among the 70 measurements.

Note) Noise performance test was carried out with an old 5.6G Ohm feed back resister. A new 10G Ohm resister arrived after the test, then it replaced the old one. All Q.E. measurements of the intensifiers were carried out with the 10G Ohm resister.

2-2. Photodiode amplifier for R.Q.E. and D.Q.E. measurements

Photodiode "Hamamatsu S5227-1010BN1" was calibrated by NIST blue group for 148.7-253.7nm, by NIST red group for 200-550nm and by Hamamatsu Photonics for 200-1180nm. The absolute Q.E. values showed some discrepancies among the 3 groups at overlapping wavelengths. In this report, Q.E. values by NIST blue group were employed for 150-250nm, NIST red group for 260-550nm and Hamamatsu for 560-600nm.

As Q.E. of the photodiode is more than twice as high as R.Q.E. of an intensifier, photodiode current of 500fA is expected hence readout noise of 10fA is sufficient for the R.Q.E. measurement. While, readout noise of 1fA is minimum requirement for D.Q.E., as the optimum light level for the photon counting detector is extremely low hence photodiode current of 20fA is expected.

Fig. 8 shows its circuit diagram. Photo-diode current is received by AD549LH which has a very low bias current 40fA(typ) and offset voltage 0.3mV(typ). The offset voltage is tuned further to be zero by an external potentiometer. A 25G Ohm was employed for the feedback resister, which converts 1fA to 0.025mV. The output is buffered by OPA27E, whose offset voltage is 10uV(typ). Finally the voltage signal is converted to frequency for interfacing output. Since the input voltage for the V/F converter can go negative by random noise, small DC bias of 2mV was added to the non-inverted input. In this setting, the frequency of 20Hz corresponds to 0V and 100,020Hz to 10V.

Dark current of the photo-diode is the major noise source of this photodiode detector. It is 20pA if bias voltage to the photodiode is 10mV. Fortunately, it can be reduced by tuning the offset voltage of AD549LH to zero, as the characteristics of the dark current is same as current through a resistor (Rsh=5E+8 Ohm at room temperature). Since the ratio of feedback resister to Rsh is 50, very small change of the offset voltage causes large change of output voltage, i.e. magnified by x50. For example, 1uV offset voltage causes 0.05mV at output, hence 2fA error in photodiode current. The stability of the DC offset is the key for the low noise measurement. The Rsh increases by lowering temperature, but I did not cool the photodiode for avoiding complexity.

The conversion factor of the overall readout systems (current amplifier + V/F converter) was calibrated through known currents, 1pA - 10pA, supplied by Keithley 261 Picoampere Source. It was 4.34fA/Hz.

Fig.9 is the outlook of this photodiode detector. The photodiode is held by Teflon stand from a circular PCB. The height and tilt of the photodiode is tuned by 4 brass rods. The amplifier is battery powered and all electronics components are perfectly shielded within a chamber.

Fig.10 shows noise measurement of this photo-diode detector in a dark room. Raw readout of the photodiode current decreased steeply in the beginning of power on, but slowed down in later. Its fluctuation is about 5fA. If measuring dark for the first 10sec, photon for the following 20sec and finally dark for the last 10sec, the subtraction of the photon signal by the 2 dark signals gives superb low readout noise (chopping mode). The error in the chopping mode was 1fA in typical and 1.8fA in the worst among 40 measurements.

I am not sure which component dictates the readout noise in the final design. It might be due to DC un-stability of the V/H converter. If so, applying gain of, for example, x4 to the buffer amplifier can improve the performance by the factor of 4.

3. R.Q.E. and D.Q.E. measurements and analysis

A "Hamamatsu S5227-1010BN1", whose area size is 10mm x 10mm square, was fed to the port-B of the monochrometer, and a FM intensifier to the port-A. A circular disk with a 10mmx10mm square hole was placed in front of the intensifier to receive same amount of photons as the photodiode.

The input light source was a Deuterium lamp. The input intensity was tuned by widths of the entrance and the exit slits.

The CCD camera format of 256(H)x150(V) was employed for the DEP_#6 intensifier and 256(H)x156(V) for the DEP_#7 intensifier, in order to maintain faster CCD frame rate but to cover the 10mmx10mm illumination area with sufficient margin (c.f. 10mm = 129 CCD pixel). Since the orientation of the square mask was not excellent for the DEP_#7 intensifier, the CCD window had to be larger. The pulse height distributions for the both intensifiers are shown in figures 11 and 12. The threshold level was set at 18ADU for the both intensifiers. Since the valley is very deep, particularly for the DEP_#6 intensifier, almost all photon events were captured.

Ar-gas was continuously flashed into the monochrometer to obtain transparency down to 1400A. It, however, required the rough pumping followed by 1 hour Ar-gas flash before starting measurement at VUV wavelength. Both of D.Q.E. and R.Q.E. of the DEP_#6 and _#7 intensifiers were measured in the wavelength range of 1400-5900A. These, however, used up a cylinder of Ar-gas.

Since input light must be very faint because of the photon counting detector, the measurement error is dominated by the readout noise of the photo-diode (1-2fA), even if using chopping mode. Therefore, I kept light intensity as high as possible, i.e. 30,000 - 50,000 c/s/cm^2 in the photon counting detector. This, of course, caused coincidence loss of photons, therefore needed correction. For instance, coincidence loss of 10% is expected at the input rate of 40,000 c/s for the DEP_#6 intensifier.

The detail of the correction is described in [1] XMM-OM technical report (Kawakami and Fordham 1998). Tables 1 and 2 are the extract from the report [1]. They show the relation of input to output, and coincidence loss. The coincidence loss is described by equation (A-2) in the report [1], where scale frequency of 220kHz is the best fit for the DEP_#6 and 272kHz for the DEP_#7 intensifiers.

Some of photons arriving during frame transfer period were lost. Let's assume the height of flat field image is "r"_rows (=127V, 10mm) and the number of CCD read out "R"_rows (150V or 156V). Photons that arrived during frame transfer period were spread out over 288 rows of the CCD. Those photons mis-allocated into the "R"_rows were detected by the MIC system, while those in "288-R"_rows were lost.
Frame transfer period was 0.2304ms for both intensifiers. Frame period was 6.6114ms for the DEP_#6 intensifier and 6.8526ms for the DEP_#7 intensifier. Therefore, more than 3% of photons arrived during frame transfer period. The precise event loss due to frame transfer is calculated as below,

0.2304ms x (288-150) / (6.6114ms x 288) = 0.01670 for the DEP_#6
0.2304ms x (288-156) / (6.8526ms x 288) = 0.01541 for the DEP_#7.

Above values are effectively dead time of the readout system for the photon counting detector. While, the reference photo-diode captured photons without a dead time. Therefore, D.Q.E. values must be corrected by a factor of x1.0170 for the DEP_#6 intensifier and x 1.0156 for the DEP_#7 The details of this calculation is described in Appendix-2 of the report [1].

The offset of wavelength of the monochrometer was calibrated using 0-th order light. It showed the display of the monochrometer is longer than the real wavelength by 60A. This offset was corrected in the tables and in the figures of this report.

Q.E.s were measured twice at each wavelength to evaluate accuracy. They were less accurate between 250-300nm, where the photocathode has maximum sensitivity but the photo-diode has minimum sensitivity.

Figure 13 shows R.Q.E. and D.Q.E. of the #6 intensifier for wavelength range of 1340 - 5840A with the typical measurement step of 100A. Figure 14 shows DEP's R.Q.E. measurement. Both R.Q.E. measurements agree well each other. This confirmed the R.Q.E.s for the 2 FM intensifiers which were given from DEP's measurements.

Figure 15 shows magnified Q.E. at the shorter end of wavelength. The measurements were carried out in the step of 20A between 1600-1800A, and in the step of 50A between 1800-2000nm with the band width of < 6A. The sharp cutoff due to the FuSi window is located between 1600 and 1700A. The D.Q.E. recovers to about 15% at 1700A, which is the shortest wavelength required by XMM-OM.

Figures 16, 17 and 18 are corresponding Q.E.s for the DEP_ #7 intensifier. Tables 3 and 4 show the details of D.Q.E. and R.Q.E. for the DEP_#6 intensifier, tables 5 and 6 are for the DEP_#7 intensifier.

A photo-electron is created when a photon hit the photocathode, and is emitted toward the top surface of MCP1. The travel of the photo-electron from photocathode to MCP1 is measured as photocathode current. The photo-electron is not always received by the MCP1 properly, as the aperture efficiency of MCP1 is not 100% but about 70%. Therefore, about 30% of the electron is not amplified. These electrons are, of course, not detected by the readout system. This is main reason why D.Q.E. is lower than D.Q.E.
At a short wavelength, a high energy UV photon can create 2 photo-electrons at photo-cathode, which doubles photocathode current hence doubles R.Q.E. virtually. While, the photon counting system counts the double events as one. Therefore, the ratio of R.Q.E. to D.Q.E. can become large at UV wavelengths. These characteristics of Q.E. are actually seen in the spectral response of the calibrated photodiode.

The ratio of D.Q.E. to R.Q.E. was 70% at 2000-5800A for both spare intensifiers (see figures 13 and 16). While, the ratio is lower than 70% below 2000A, which might indicate pair photo-electrons emission at S-20 photocathode in these shorter wavelengths (see figures. 15 and 18).

Acknowledgements.
The author wishes to express heartily thanks to DEP Ltd (Netherlands), who produced decent intensifiers under a hard schedule.
Mr. Phil Guttridge gave useful advices on the selection of electronic components for the low noise amplifiers.
Mr. Jon Lapington helped maintenance of the monochrometer.

Reference.
[1] Kawakami H., Fordham J., 1998, XMM-OM/MSSL/TC/0050.01
"Flat field coincidence loss in the MIC detector for XMM-OM"

//

Appendix. Current leakage through intensifier body
(By-Products of R.Q.E. amplifier)

Since the amplifier for photocathode current provides DC voltage of 45V and is capable of measuring low current, it is useful for measuring impedance along the tube body. Four Spare intensifiers were measured and the results are tabulated below. Edge emissions were often observed in photon counting mode with DEP-FM and FM Spare intensifiers when photocathode voltage was applied. The level of the emission was high in the #5 intensifier, low in the #6 intensifier and almost none in the #7 intensifier. As shown in the table, the current leakage through tube body does not relate directly with the edge emission. For example, the #7 intensifier has larger leakage than that of the #6 intensifier.

Table A-1. Resistance of tube body (unit: Ohm)

	#2	#5	#6	#7
Ph-cath gap	40.8E+12	6.9E+12	15.9E+12	9.9E+12
across MCPs	---	---	---	overflow
Anode gap	0.063E+13	2.5E+13	---	6.9E+13
Edge emission		high	low	none

Table A-2. Expected standing current through tube body

	#2	#5	#6	#7
Vc=400V	9.8pA	58pA	25pA	41pA
Va=6000V	9821pA	239pA	---	84pA

//

<< Quantum Efficiencies of DEP_#6 and #7 intensifiers >>

24 February 1999
Hajime KAWAKAMI
Mullard Space Science Laboratory
Holmbury St. Mary, Dorking
Surrey RH5 6NT, U.K.
Fax) 44-1483-278312
Tel) 44-1483-274111

Table 1.
DEP_#6 tube   CCD 256(H)x150(V)   17:03-17:33   30 Sep. 1998
Th=18ADU   3x3 Energy centroiding

	MIC Detected count rate (cnts/sec)	Ph-diode current (fA)	Detection probability relative to lowest rate	Detection probability	Fitting with a=220kHz
1	126722.50	383.20	.6858220	.6718217	.6714945
2	95072.00	254.80	.7739049	.7581064	.7622249
3	79892.10	202.50	.8181818	.8014795	.8041192
4	61496.60	145.60	.8759303	.8580492	.8534496
5	42105.00	95.60	.9134244	.8947778	.9002878
6	33377.10	72.00	.9635422	.9438725	.9237705
7	19909.35	41.70	.9901084	.9698964	.9547648
8	8920.60	18.50	1.0000000	.9795861	.9795861

Table 2.
DEP_#7 tube   CCD 256(H)x156(V)   14:34-15:16   20 Oct. 1998
Th=18ADU   3x3 Energy centroiding

	MIC Detected count rate (cnts/sec)	Ph-diode current (fA)	Detection probability relative to lowest rate	Detection probability	Fitting with a=272kHz
1	91142.55	254.75	.8326462	.8184370	.8205877
2	77139.75	207.55	.8649963	.8502350	.8503162
3	67516.25	177.25	.8862458	.8711220	.8701484
4	59707.75	154.60	.8988267	.8834881	.8854490
5	49654.20	126.40	.9145787	.8989714	.9050036
6	43139.95	109.25	.9185960	.9029201	.9170967
7	34028.05	82.75	.9566550	.9403297	.9363336
8	22261.35	52.95	.9789619	.9622558	.9586537
9	9230.30	21.50	1.0000000	.9829350	.9829350

Table 3. DEP_#6 tube D.Q.E. measurement with Deuterium Lamp
1500A - 2200A 20:08-21:19 16 Oct. 1998
2240A - 5840A 11:57-15:25 5 Oct. 1998

Wavelength (A)	Intensifier (count/s)	Ph-diode (fA)	Ratio	D.Q.E (%)	
1500	599.4	260.6	2.339	.027	73.000
1500	597.3	261.3	2.325	.027	73.000
1600	30073.7	425.1	74.167	1.011	85.100
1600	30143.3	426.8	74.047	1.010	85.100
1620	45979.8	177.7	290.430	3.947	84.820
1620	45964.9	180.1	286.479	3.893	84.820
1640	38327.4	71.0	587.423	7.957	84.540
1640	38298.1	73.1	569.454	7.713	84.540
1660	37856.6	48.4	848.342	11.453	84.260
1660	37459.9	49.3	822.662	11.106	84.260
1680	28526.2	30.4	981.312	13.204	83.980
1680	28456.4	29.9	992.957	13.360	83.980
1700	25888.5	24.7	1087.873	14.589	83.700
1700	25886.8	25.4	1059.907	14.214	83.700
1720	27991.5	27.1	1077.302	14.554	84.320
1720	28174.7	28.2	1043.034	14.091	84.320
1740	31740.0	28.9	1156.873	15.744	84.940
1740	31646.3	29.1	1144.631	15.577	84.940
1760	35653.0	32.8	1164.216	15.959	85.560
1760	35786.4	30.8	1243.638	17.048	85.560
1780	41145.2	36.5	1249.046	17.246	86.180
1780	41118.1	38.8	1171.320	16.173	86.180
1800	50905.5	48.6	1188.133	16.523	86.800
1800	50920.9	46.2	1249.913	17.382	86.800
1850	47376.8	43.2	1235.286	17.377	87.800
1850	47218.6	42.5	1249.585	17.578	87.800
1900	42601.4	36.2	1310.224	18.641	88.800
1900	41471.8	35.8	1284.474	18.275	88.800
1950	40045.9	33.9	1300.257	18.280	87.750
1950	40005.8	34.1	1290.361	18.141	87.750
2000	39100.3	32.8	1303.941	18.113	86.700
2000	39095.6	31.7	1348.395	18.730	86.700
2100	44698.7	38.4	1302.848	16.637	79.700
2100	44936.6	37.3	1348.543	17.220	79.700

2200	38150.8	29.3	1414.776	17.363	76.600
2200	38079.6	28.9	1432.747	17.584	76.600
2240	46602.4	39.1	1341.132	16.348	76.080
2240	46618.0	38.0	1379.959	16.821	76.080
2340	38536.0	29.9	1401.305	16.798	74.820
2340	38685.3	29.7	1418.302	17.002	74.820
2440	46747.4	33.0	1593.618	17.960	70.340
2440	46701.1	31.7	1657.303	18.677	70.340
2540	36076.6	20.0	1938.496	18.927	60.940
2540	36234.3	22.8	1707.544	16.672	60.940
2640	46557.9	23.7	2212.391	18.482	52.140
2640	46725.6	23.2	2262.668	18.902	52.140
2740	39747.6	17.6	2480.956	18.714	47.080
2740	39864.3	17.4	2521.159	19.017	47.080
2840	50953.6	22.8	2537.342	19.465	47.880
2840	50951.3	25.4	2276.986	17.467	47.880
2940	36676.6	18.7	2115.922	17.561	51.800
2940	37149.9	17.8	2254.261	18.709	51.800
3040	43298.6	23.9	2024.700	18.088	55.760
3040	42131.6	23.7	1983.293	17.718	55.760
3140	34842.9	22.8	1628.239	14.932	57.240
3140	34917.9	21.7	1714.107	15.720	57.240
3240	47730.6	30.6	1757.768	16.092	57.140
3240	47846.9	29.5	1827.290	16.729	57.140
3340	41375.1	26.0	1760.967	15.986	56.660
3340	41320.7	25.0	1834.487	16.653	56.660
3440	47578.8	30.4	1764.122	15.709	55.580
3440	47624.0	30.8	1741.094	15.504	55.580
3540	34787.1	20.6	1796.151	15.350	53.340
3540	34919.9	19.3	1926.097	16.460	53.340
3640	48221.9	26.7	2037.888	16.652	51.000
3640	48304.8	27.8	1962.001	16.032	51.000
3740	41182.6	23.2	1963.359	16.087	51.140
3740	41213.1	21.7	2102.752	17.229	51.140
3840	42642.8	25.8	1840.668	15.919	53.980
3840	42764.6	26.0	1831.011	15.836	53.980
3940	38289.9	25.0	1668.301	15.198	56.860
3940	38156.0	25.0	1661.104	15.133	56.860

4040	40378.1	29.3	1518.111	14.336	58.940
4040	40079.4	28.0	1574.047	14.864	58.940
4140	33214.9	23.2	1509.347	14.640	60.540
4140	35235.8	25.4	1481.222	14.367	60.540
4240	45544.9	36.9	1384.669	13.715	61.820
4240	45633.7	36.2	1412.560	13.991	61.820
4340	42040.3	34.5	1356.046	13.579	62.500
4340	42070.9	33.6	1392.321	13.942	62.500
4440	43775.3	37.8	1295.386	13.084	63.040
4440	43853.3	40.1	1220.736	12.330	63.040
4540	34279.2	32.3	1125.042	11.478	63.680
4540	34257.1	31.2	1163.202	11.868	63.680
4640	44764.1	45.4	1105.137	11.385	64.300
4640	44791.3	44.1	1138.558	11.729	64.300
4740	33098.8	37.3	935.447	9.706	64.760
4740	33085.5	35.6	980.659	10.175	64.760
4840	45222.1	55.1	919.547	9.600	65.160
4840	45248.2	54.3	934.849	9.760	65.160
4940	29957.4	32.5	964.643	10.132	65.560
4940	28065.2	34.7	843.984	8.865	65.560
5040	43387.8	58.6	826.736	8.732	65.920
5040	43402.4	59.0	820.958	8.671	65.920
5140	31070.8	43.6	748.332	7.935	66.180
5140	30916.1	42.1	771.229	8.178	66.180
5240	44049.3	72.7	677.434	7.209	66.420
5240	44483.5	70.7	703.648	7.488	66.420
5340	41969.4	71.4	653.956	6.986	66.680
5340	41254.3	70.5	647.815	6.921	66.680
5440	44945.4	84.6	594.869	6.374	66.880
5440	46230.4	85.5	607.326	6.508	66.880
5540	40887.0	80.9	558.143	6.027	67.400
5540	40704.4	80.1	561.033	6.058	67.400
5640	39382.5	84.2	512.015	5.591	68.160
5640	41726.6	89.6	517.145	5.647	68.160
5740	37925.8	90.3	455.785	5.004	68.520
5740	37878.4	90.1	456.180	5.008	68.520
5840	44715.4	116.5	429.607	4.731	68.740
5840	44655.8	116.3	429.779	4.733	68.740

Table 4. DEP_#6 tube R.Q.E. measurement with Deuterium Lamp
1340A - 2940A 17:19-18:39 16 Oct. 1998
2040A - 5840A 15:42-20:13 9 Oct. 1998

Wavelength (A)	Ph-cathode (fA)	Ph-diode (fA)	Ratio	R.Q.E (%)	
1340	5.7	431.6	.013	.967	73.000
1340	.0	418.8	.000	.000	73.000
1440	1.0	1125.6	.001	.062	73.000
1440	8.1	1199.4	.007	.493	73.000
1540	1.9	1988.8	.001	.075	77.840
1540	3.8	2110.3	.002	.141	77.840
1560	10.5	4636.0	.002	.181	80.260
1560	3.8	4763.8	.001	.064	80.260
1580	14.3	4243.2	.003	.279	82.680
1580	12.4	4345.6	.003	.236	82.680
1600	128.7	5564.7	.023	1.967	85.100
1600	132.9	5684.5	.023	1.990	85.100
1620	287.8	3650.8	.079	6.687	84.820
1620	286.9	3699.9	.078	6.576	84.820
1640	216.3	1473.0	.147	12.416	84.540
1640	224.9	1481.2	.152	12.836	84.540
1660	169.2	815.3	.207	17.483	84.260
1660	170.6	820.7	.208	17.514	84.260
1680	138.7	564.2	.246	20.639	83.980
1680	132.9	567.5	.234	19.675	83.980
1700	128.7	486.5	.264	22.134	83.700
1700	126.7	463.7	.273	22.877	83.700
1720	135.8	479.1	.283	23.899	84.320
1720	133.9	477.6	.280	23.639	84.320
1740	161.5	561.8	.288	24.422	84.940
1740	165.8	564.9	.294	24.936	84.940
1790	254.5	881.5	.289	24.967	86.490
1790	260.2	884.7	.294	25.434	86.490
1840	312.6	1051.8	.297	26.034	87.600
1840	316.4	1051.8	.301	26.351	87.600
1890	304.5	1031.4	.295	26.156	88.600
1890	307.8	1035.1	.297	26.348	88.600
1940	302.1	1015.6	.297	26.166	87.960
1940	301.6	1048.3	.288	25.308	87.960

2040	291.1	959.1	.304	25.467	83.900
2040	289.7	960.7	.302	25.302	83.900
2140	257.8	837.4	.308	24.153	78.460
2140	254.0	837.2	.303	23.802	78.460
1840	253.5	860.8	.294	25.796	87.600
1840	261.6	859.1	.305	26.674	87.600
1940	240.6	821.6	.293	25.763	87.960
1940	237.8	783.4	.304	26.698	87.960
2040	446.0	1480.8	.301	25.270	83.900
2040	447.9	1476.9	.303	25.445	83.900
2140	392.2	1277.0	.307	24.094	78.460
2140	390.7	1276.2	.306	24.022	78.460
2240	310.7	1036.6	.300	22.802	76.080
2240	322.6	1065.5	.303	23.035	76.080
2340	265.9	879.5	.302	22.619	74.820
2340	275.4	879.1	.313	23.442	74.820
2440	360.7	1032.9	.349	24.564	70.340
2440	367.4	1031.8	.356	25.044	70.340
2540	282.6	690.9	.409	24.922	60.940
2540	283.0	692.7	.409	24.902	60.940
2640	237.8	478.7	.497	25.898	52.140
2640	239.2	479.6	.499	26.007	52.140
2740	204.4	359.1	.569	26.798	47.080
2740	204.9	358.1	.572	26.942	47.080
2840	338.3	638.0	.530	25.390	47.880
2840	344.0	638.2	.539	25.811	47.880
2940	244.0	534.3	.457	23.655	51.800
2940	254.5	535.1	.476	24.631	51.800
....					
2040	199.7	653.2	.306	25.646	83.900
2040	199.7	646.0	.309	25.930	83.900
2040	463.6	1579.3	.294	24.630	83.900
2040	492.7	1610.6	.306	25.666	83.900
2140	423.6	1401.0	.302	23.724	78.460
2140	431.7	1405.9	.307	24.092	78.460
2240	353.1	1146.8	.308	23.423	76.080
2240	357.9	1147.5	.312	23.726	76.080
2340	288.3	911.0	.316	23.677	74.820
2340	287.3	909.7	.316	23.633	74.820

2440	335.9	956.5	.351	24.703	70.340
2440	337.4	944.2	.357	25.133	70.340
2540	259.7	633.4	.410	24.984	60.940
2540	260.6	647.1	.403	24.546	60.940
2640	232.5	465.2	.500	26.060	52.140
2640	231.1	462.9	.499	26.033	52.140
2740	200.1	351.8	.569	26.786	47.080
2740	200.6	353.5	.567	26.718	47.080
2840	357.9	664.9	.538	25.770	47.880
2840	359.3	664.2	.541	25.898	47.880
2940	262.6	552.5	.475	24.616	51.800
2940	262.1	552.7	.474	24.562	51.800
3040	217.3	501.3	.433	24.170	55.760
3040	214.9	501.5	.429	23.895	55.760
3140	180.1	434.7	.414	23.720	57.240
3140	180.6	434.7	.415	23.783	57.240
3240	315.0	777.7	.405	23.141	57.140
3240	317.3	776.9	.409	23.342	57.140
3340	273.5	673.1	.406	23.022	56.660
3340	264.5	673.1	.393	22.260	56.660
3440	214.4	552.5	.388	21.571	55.580
3440	224.4	547.1	.410	22.802	55.580
3540	159.2	366.1	.435	23.189	53.340
3540	157.7	368.5	.428	22.832	53.340
3640	238.3	545.1	.437	22.291	51.000
3640	242.1	543.2	.446	22.729	51.000
3740	199.7	463.7	.431	22.018	51.140
3740	206.3	461.1	.447	22.882	51.140
3840	188.2	450.3	.418	22.564	53.980
3840	185.4	444.6	.417	22.503	53.980
3940	160.6	419.2	.383	21.779	56.860
3940	162.5	422.9	.384	21.845	56.860
4040	249.2	704.8	.354	20.840	58.940
4040	245.4	673.4	.364	21.480	58.940
4140	197.7	574.0	.345	20.858	60.540
4140	196.8	593.5	.332	20.074	60.540
4240	186.8	578.1	.323	19.975	61.820
4240	183.9	565.1	.325	20.122	61.820
4340	162.0	538.2	.301	18.815	62.500

4340	163.4	538.4	.304	18.974	62.500
4440	270.2	984.5	.274	17.300	63.040
4440	274.0	960.4	.285	17.984	63.040
4540	193.0	738.5	.261	16.642	63.680
4540	192.5	742.8	.259	16.504	63.680
4640	162.5	669.9	.243	15.597	64.300
4640	163.9	674.9	.243	15.618	64.300
4740	119.1	547.9	.217	14.080	64.760
4740	121.5	547.3	.222	14.378	64.760
4840	268.7	1327.6	.202	13.190	65.160
4840	271.1	1328.9	.204	13.294	65.160
4940	175.4	915.7	.191	12.554	65.560
4940	177.3	909.2	.195	12.781	65.560
5040	148.2	819.8	.181	11.916	65.920
5040	148.7	815.7	.182	12.014	65.920
5140	101.0	611.9	.165	10.925	66.180
5140	104.4	646.9	.161	10.676	66.180
5240	165.8	1105.4	.150	9.964	66.420
5240	168.2	1104.1	.152	10.119	66.420
5340	156.3	1119.1	.140	9.313	66.680
5340	156.3	1119.3	.140	9.311	66.680
5440	153.4	1193.7	.129	8.596	66.880
5440	151.1	1191.5	.127	8.478	66.880
5540	129.1	1071.8	.120	8.121	67.400
5540	127.2	1060.9	.120	8.083	67.400
5640	122.0	1157.9	.105	7.181	68.160
5640	125.8	1168.1	.108	7.340	68.160
5740	299.2	3163.9	.095	6.481	68.520
5740	304.0	3171.7	.096	6.568	68.520
5840	347.8	3995.6	.087	5.984	68.740
5840	349.3	4014.7	.087	5.980	68.740

Table 5. DEP_#7 tube D.Q.E. measurement with Deuterium Lamp
1340A -5840A 11:53-18:17 20 Oct. 1998

Wavelength (A)	Intensifier (count/s)	Ph-diode (fA)	Ratio	D.Q.E (%)	
1340	553.1	30.4	18.493	.216	73.000
1340	554.8	28.2	19.975	.234	73.000
1440	582.6	206.2	2.870	.034	73.000
1440	606.7	214.6	2.871	.034	73.000
1540	733.7	195.7	3.807	.047	77.840
1540	726.7	196.2	3.762	.047	77.840
1560	903.8	367.4	2.498	.032	80.260
1560	922.8	366.3	2.559	.033	80.260
1580	3532.5	265.4	13.519	.179	82.680
1580	3556.6	266.5	13.556	.180	82.680
1600	28930.7	328.5	92.555	1.262	85.100
1600	28846.3	327.7	92.514	1.261	85.100
1620	52924.4	189.2	312.351	4.245	84.820
1620	52674.3	184.0	319.535	4.342	84.820
1640	24581.5	44.3	578.698	7.838	84.540
1640	24675.4	42.3	607.833	8.233	84.540
1660	28425.4	38.6	772.716	10.432	84.260
1660	28482.6	36.9	810.800	10.946	84.260
1680	30052.8	34.3	923.313	12.423	83.980
1680	31754.5	35.4	948.844	12.767	83.980
1700	29472.5	28.6	1082.604	14.518	83.700
1700	29623.1	29.5	1056.444	14.167	83.700
1720	32534.8	30.6	1125.579	15.206	84.320
1720	32349.0	31.9	1073.076	14.497	84.320
1740	39186.6	37.5	1133.742	15.429	84.940
1740	39223.6	37.3	1141.599	15.536	84.940
1790	46968.3	43.8	1187.767	16.459	86.490
1790	46935.8	45.1	1152.680	15.973	86.490
1840	55439.9	52.9	1174.419	16.483	87.600
1840	56054.7	54.3	1160.177	16.283	87.600
1890	54785.5	49.9	1229.806	17.457	88.600
1890	54761.7	50.1	1223.899	17.374	88.600
1940	53151.7	48.0	1238.222	17.450	87.960
1940	53179.3	47.5	1250.239	17.619	87.960
2040	48828.9	42.5	1274.217	17.128	83.900

2040	48785.9	42.1	1286.181	17.289	83.900
2140	47795.1	41.2	1285.729	16.163	78.460
2140	47212.4	40.8	1283.063	16.129	78.460
2240	39461.3	32.1	1336.180	16.287	76.080
2240	39682.8	31.5	1372.840	16.734	76.080
2340	51392.3	43.0	1332.267	15.971	74.820
2340	51312.4	42.5	1343.586	16.106	74.820
2440	43241.2	30.2	1585.159	17.864	70.340
2440	43350.4	31.9	1502.787	16.936	70.340
2540	51840.4	31.9	1811.525	17.687	60.940
2540	51711.8	31.9	1806.630	17.639	60.940
2640	52675.4	27.1	2167.783	18.109	52.140
2640	52554.4	26.0	2252.448	18.816	52.140
2740	52164.6	23.7	2459.713	18.554	47.080
2740	51983.2	23.2	2496.199	18.829	47.080
2840	52327.9	25.6	2279.864	17.489	47.880
2840	52581.9	25.2	2331.446	17.885	47.880
2940	49520.7	26.3	2094.238	17.381	51.800
2940	49504.5	27.1	2026.535	16.819	51.800
3040	45474.0	25.2	2000.537	17.872	55.760
3040	43578.4	25.4	1898.338	16.959	55.760
3140	51842.7	32.1	1799.372	16.502	57.240
3140	53550.8	35.6	1682.265	15.428	57.240
3240	45519.2	29.7	1695.620	15.523	57.140
3240	46733.5	28.9	1794.675	16.430	57.140
3340	50701.7	33.6	1677.006	15.224	56.660
3340	50765.4	34.5	1637.050	14.861	56.660
3440	42228.5	28.4	1635.681	14.566	55.580
3440	43569.4	28.2	1708.143	15.211	55.580
3540	66641.0	43.2	1765.749	15.090	53.340
3540	68158.6	44.5	1758.707	15.030	53.340
3640	64694.8	42.3	1743.183	14.244	51.000
3640	64769.4	40.1	1839.776	15.033	51.000
3740	54159.7	31.0	1953.300	16.004	51.140
3740	53884.6	33.2	1815.497	14.875	51.140
3840	46640.0	29.9	1726.082	14.928	53.980
3840	46894.6	28.9	1801.055	15.577	53.980
3940	42478.4	28.0	1672.760	15.239	56.860
3940	44525.5	29.5	1669.684	15.211	56.860

4040	43657.3	30.8	1567.037	14.798	58.940
4040	43590.1	31.5	1532.188	14.469	58.940
4140	36307.3	26.7	1458.683	14.149	60.540
4140	36343.0	26.7	1460.350	14.165	60.540
4240	47957.8	38.2	1392.882	13.796	61.820
4240	47953.6	39.1	1361.804	13.488	61.820
4340	42213.8	36.2	1282.545	12.843	62.500
4340	39699.8	33.0	1310.278	13.121	62.500
4440	44176.1	40.4	1210.981	12.231	63.040
4440	44362.1	39.1	1256.772	12.694	63.040
4540	33570.4	32.1	1108.744	11.312	63.680
4540	33339.3	32.3	1093.218	11.154	63.680
4640	41778.9	40.8	1125.330	11.593	64.300
4640	39346.9	40.8	1048.302	10.800	64.300
4740	28507.0	30.6	978.444	10.152	64.760
4740	28351.2	30.4	979.748	10.166	64.760
4840	47489.1	59.2	888.918	9.280	65.160
4840	47654.9	56.9	929.577	9.705	65.160
4940	29905.4	38.6	815.315	8.564	65.560
4940	30171.8	37.5	846.795	8.895	65.560
5040	43497.4	60.3	797.412	8.422	65.920
5040	43716.1	63.6	760.505	8.032	65.920
5140	32382.2	47.7	717.792	7.611	66.180
5140	32404.2	47.5	721.591	7.651	66.180
5240	43520.5	71.4	674.170	7.174	66.420
5240	43770.9	71.2	680.230	7.239	66.420
5340	44054.1	69.2	704.080	7.522	66.680
5340	40741.4	71.6	622.259	6.648	66.680
5440	39298.1	73.8	578.804	6.202	66.880
5440	39337.3	72.7	588.132	6.302	66.880
5540	35923.4	75.3	510.725	5.515	67.400
5540	39336.3	80.1	533.926	5.766	67.400
5640	39520.4	85.9	500.261	5.463	68.160
5640	39395.8	85.3	502.211	5.484	68.160
5740	33608.4	81.6	436.946	4.797	68.520
5740	33723.3	81.4	439.709	4.827	68.520
5840	38723.4	103.7	404.642	4.456	68.740
5840	38695.8	103.5	405.151	4.462	68.740

Table 6. DEP_#7 tube R.Q.E. measurement with Deuterium Lamp
1340A - 4440A 17:43-20:33 17 Oct. 1998
4540A - 5840A 12:00-12:51 19 Oct. 1998

Wavelength (A)	Ph-cathode (fA)	Ph-diode (fA)	Ratio	R.Q.E (%)	
1340	2.9	521.5	.005	.400	73.000
1340	-1.0	536.2	-.002	-.130	73.000
1440	3.8	1253.0	.003	.222	73.000
1440	2.9	1369.9	.002	.152	73.000
1540	13.8	2613.3	.005	.412	77.840
1540	4.8	2739.0	.002	.135	77.840
1560	5.7	5643.7	.001	.081	80.260
1560	1.4	5842.1	.000	.020	80.260
1580	17.6	5353.0	.003	.272	82.680
1580	20.5	5519.2	.004	.307	82.680
1600	173.4	7302.7	.024	2.021	85.100
1600	179.2	7297.7	.025	2.089	85.100
1620	362.6	4777.3	.076	6.438	84.820
1620	357.9	4843.9	.074	6.266	84.820
1640	253.0	1920.5	.132	11.138	84.540
1640	279.2	1942.6	.144	12.152	84.540
1660	200.6	1003.0	.200	16.853	84.260
1660	211.6	1012.3	.209	17.610	84.260
1680	162.5	698.7	.233	19.529	83.980
1680	166.3	703.1	.237	19.864	83.980
1700	158.2	616.5	.257	21.478	83.700
1700	156.8	620.4	.253	21.150	83.700
1720	180.6	666.2	.271	22.858	84.320
1720	181.5	674.9	.269	22.683	84.320
1740	234.0	825.3	.284	24.081	84.940
1740	224.0	828.9	.270	22.948	84.940
1790	414.6	1420.0	.292	25.249	86.490
1790	401.7	1424.8	.282	24.383	86.490
1840	498.4	1738.8	.287	25.110	87.600
1840	493.2	1738.6	.284	24.849	87.600
1890	482.2	1690.2	.285	25.278	88.600
1890	429.3	1579.3	.272	24.085	88.600
1940	432.2	1565.7	.276	24.281	87.960
1940	462.7	1626.2	.285	25.026	87.960

2040	437.0	1484.7	.294	24.692	83.900
2040	427.4	1488.6	.287	24.090	83.900
2140	376.4	1295.3	.291	22.802	78.460
2140	376.9	1296.4	.291	22.812	78.460
2240	624.2	2139.0	.292	22.202	76.080
2240	632.3	2055.0	.308	23.410	76.080
2340	497.0	1659.8	.299	22.403	74.820
2340	494.1	1655.5	.298	22.332	74.820
2440	406.0	1169.2	.347	24.424	70.340
2440	396.4	1166.6	.340	23.904	70.340
2540	306.4	783.4	.391	23.835	60.940
2540	304.5	783.2	.389	23.693	60.940
2640	260.6	540.5	.482	25.141	52.140
2640	264.9	540.5	.490	25.555	52.140
2740	223.0	408.6	.546	25.694	47.080
2740	224.4	419.5	.535	25.190	47.080
2840	360.7	719.6	.501	24.002	47.880
2840	366.0	731.7	.500	23.946	47.880
2940	270.2	609.6	.443	22.960	51.800
2940	270.2	607.6	.445	23.033	51.800
3040	220.6	557.9	.395	22.050	55.760
3040	229.2	569.8	.402	22.427	55.760
3140	187.7	491.5	.382	21.864	57.240
3140	188.2	488.7	.385	22.046	57.240
3240	159.6	419.9	.380	21.722	57.140
3240	157.2	424.5	.370	21.168	57.140
3340	132.0	347.2	.380	21.540	56.660
3340	130.1	349.4	.372	21.097	56.660
3440	277.3	777.1	.357	19.835	55.580
3440	290.7	777.7	.374	20.772	55.580
3540	208.2	539.7	.386	20.581	53.340
3540	209.7	543.4	.386	20.581	53.340
3640	195.4	480.7	.406	20.729	51.000
3640	195.8	479.1	.409	20.846	51.000
3740	167.3	393.9	.425	21.717	51.140
3740	164.4	394.7	.416	21.299	51.140
3840	147.7	387.1	.382	20.597	53.980
3840	148.2	385.4	.385	20.756	53.980

3940	135.8	376.9	.360	20.486	56.860
3940	133.9	378.0	.354	20.140	56.860
4040	346.4	1067.2	.325	19.132	58.940
4040	359.3	1056.1	.340	20.050	58.940
4140	298.8	945.5	.316	19.130	60.540
4140	303.1	977.6	.310	18.768	60.540
4240	293.5	983.7	.298	18.447	61.820
4240	295.4	984.7	.300	18.546	61.820
4340	244.4	877.8	.278	17.405	62.500
4340	232.1	815.7	.284	17.780	62.500
4440	218.2	830.7	.263	16.562	63.040
4440	218.7	827.0	.264	16.672	63.040
4540	480.8	1888.8	.255	16.210	63.680
4540	461.3	1871.6	.246	15.694	63.680
4640	379.8	1780.3	.213	13.717	64.300
4640	390.7	1778.7	.220	14.124	64.300
4740	305.4	1367.3	.223	14.466	64.760
4740	291.6	1382.7	.211	13.658	64.760
4840	366.4	1868.8	.196	12.776	65.160
4840	385.0	1978.2	.195	12.682	65.160
4940	228.7	1262.9	.181	11.873	65.560
4940	231.1	1260.3	.183	12.021	65.560
5040	232.5	1322.2	.176	11.593	65.920
5040	223.5	1312.0	.170	11.229	65.920
5140	158.7	990.2	.160	10.605	66.180
5140	156.3	988.2	.158	10.467	66.180
5240	127.7	863.7	.148	9.821	66.420
5240	127.7	865.2	.148	9.804	66.420
5340	138.7	897.3	.155	10.304	66.680
5340	121.0	937.0	.129	8.613	66.680
5440	122.9	996.2	.123	8.253	66.880
5440	130.6	1071.5	.122	8.149	66.880
5540	113.9	1005.1	.113	7.636	67.400
5540	112.5	1004.3	.112	7.547	67.400
5640	115.3	1116.2	.103	7.041	68.160
5640	113.9	1117.8	.102	6.944	68.160
5740	299.2	3248.1	.092	6.313	68.520
5740	300.2	3244.2	.093	6.340	68.520

5840	319.7	3781.4	.085	5.812	68.740
5840	316.9	3738.9	.085	5.826	68.740

Table A-1. Resistance of tube body (unit: Ohm)

	#2	#5	#6	#7
Ph-cath gap	40.8E+12	6.9E+12	15.9E+12	9.9E+12
across MCPs	---	---	---	overflow
Anode gap	0.063E+13	2.5E+13	---	6.9E+13
Edge emission		high	low	none

Table A-2. Expected standing current through tube body

	#2	#5	#6	#7
Vc=400V	9.8pA	58pA	25pA	41pA
Va=6000V	9821pA	239pA	---	84pA

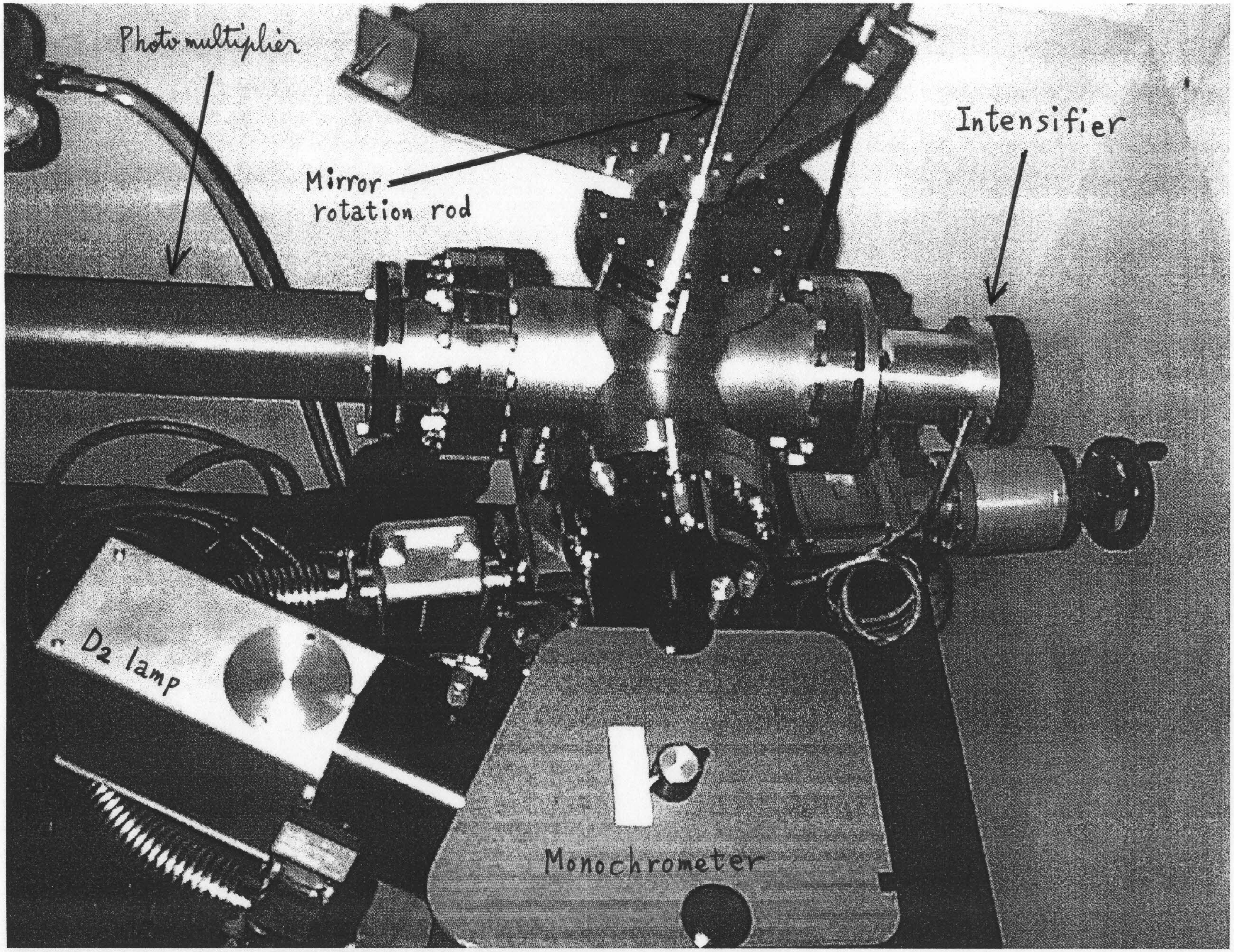


Fig. 1 Outlook of monochrometer system

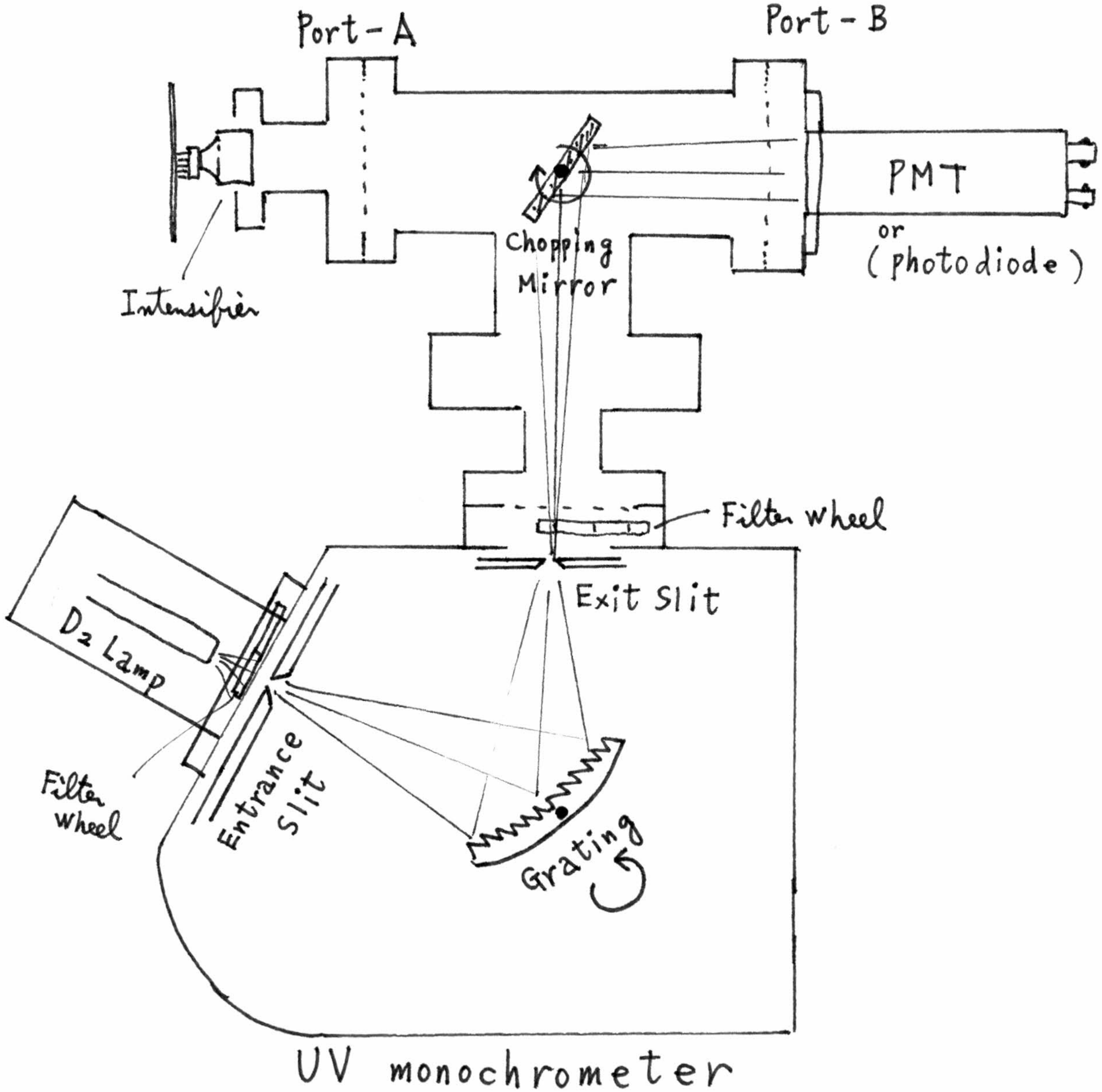


Fig. 2 Optics configuration of Q.E. measurement

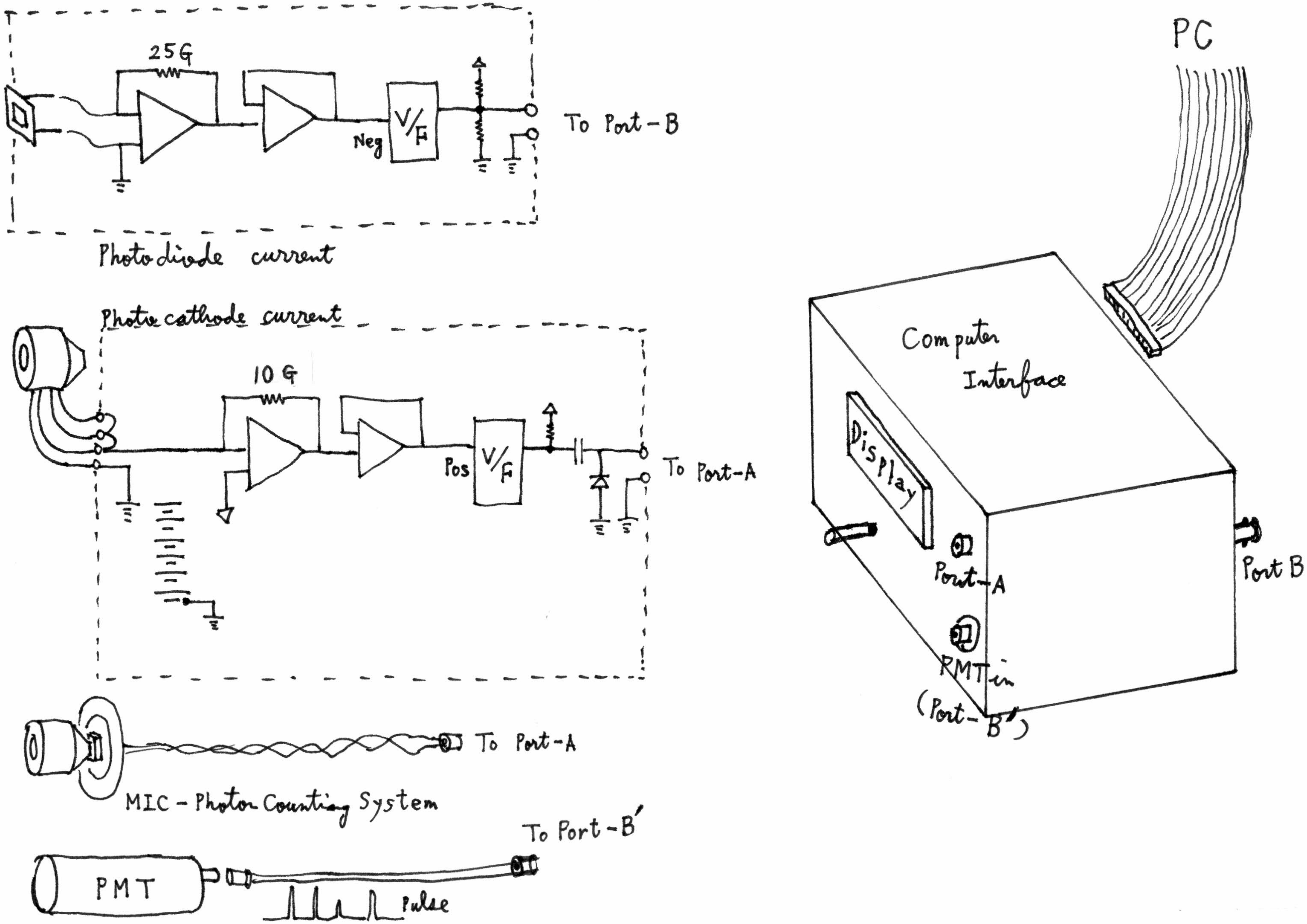


Fig. 3 Electronics configuration of Q.E. measurement

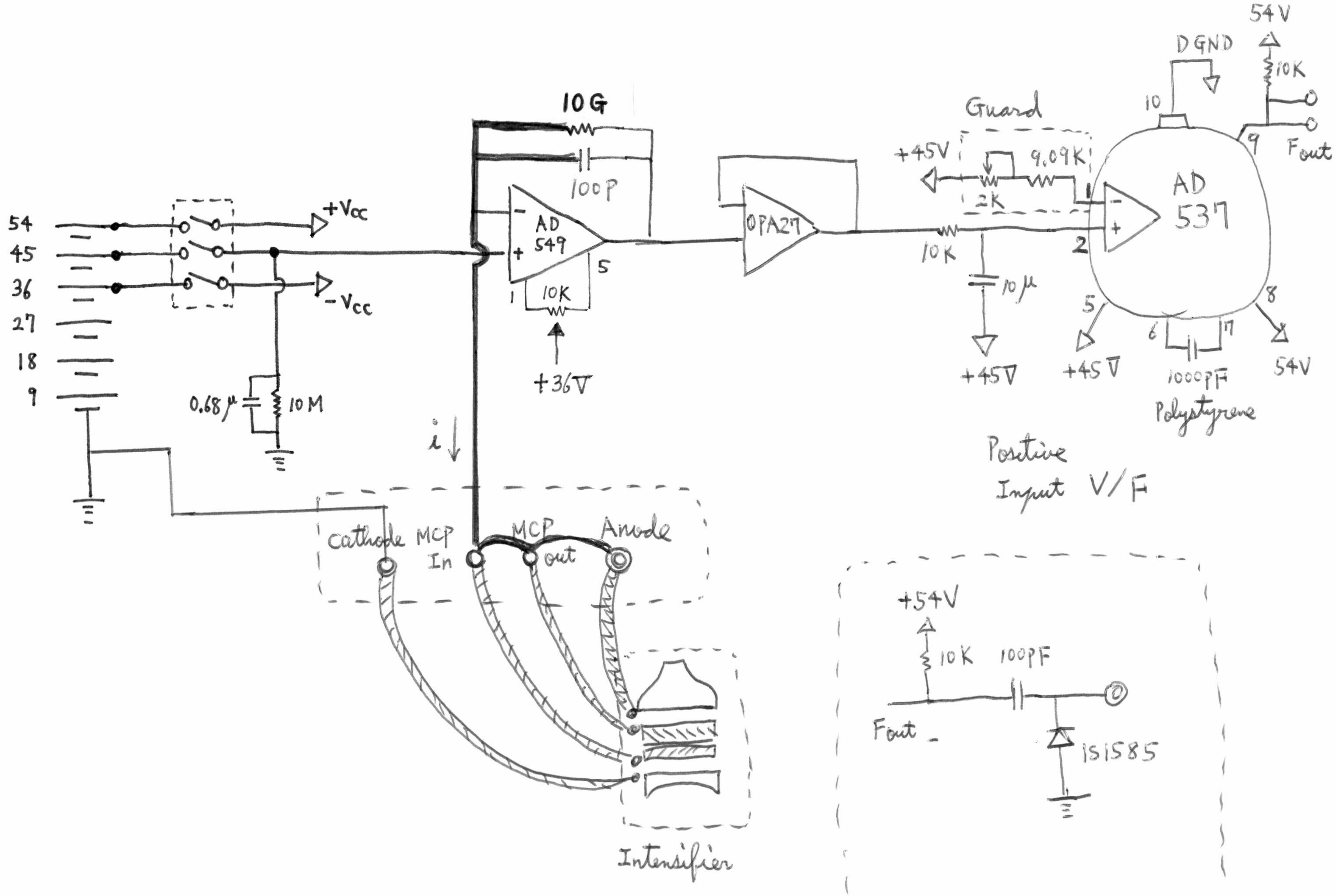


Fig. 4 Photocathode current amplifier

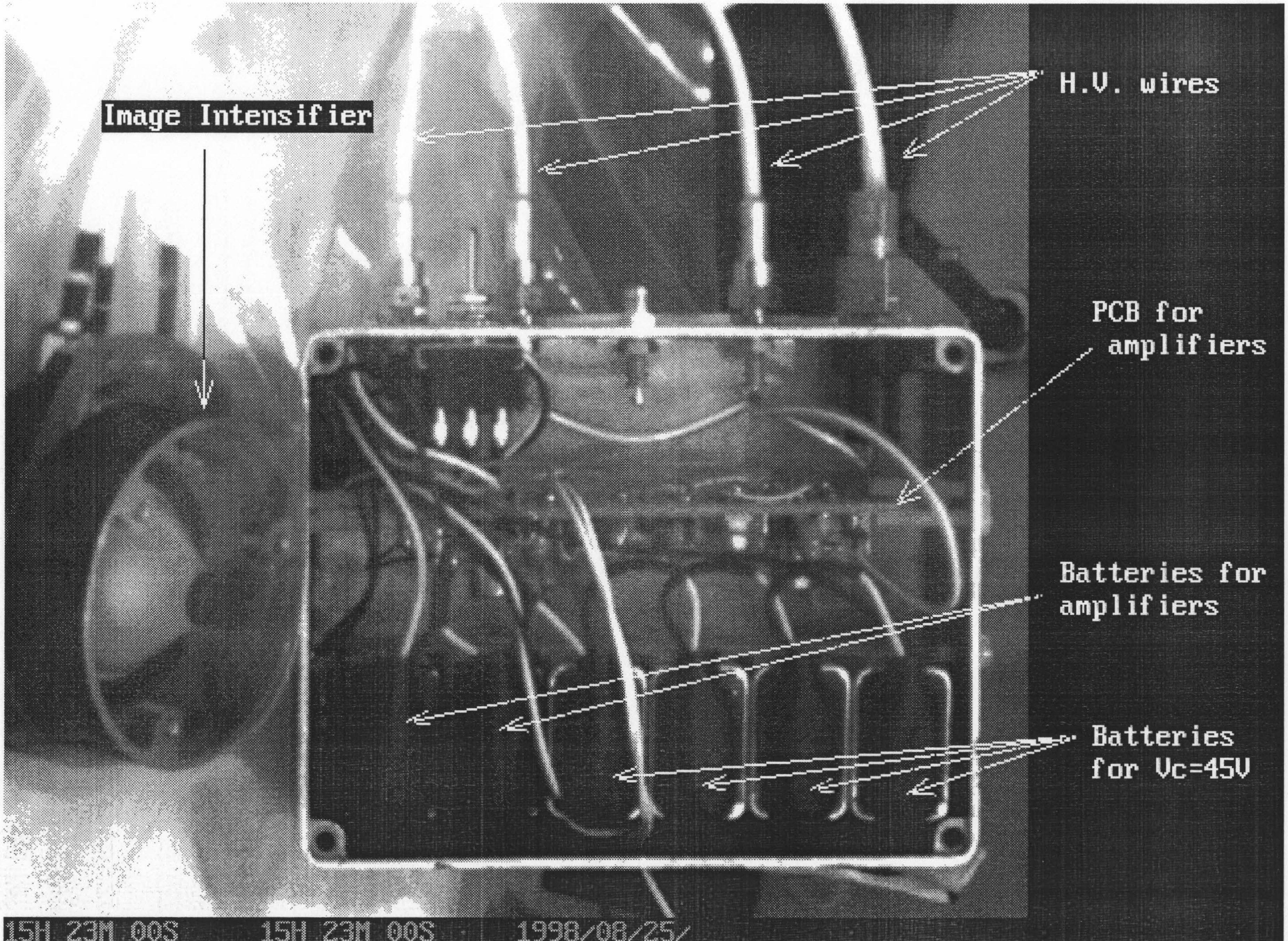
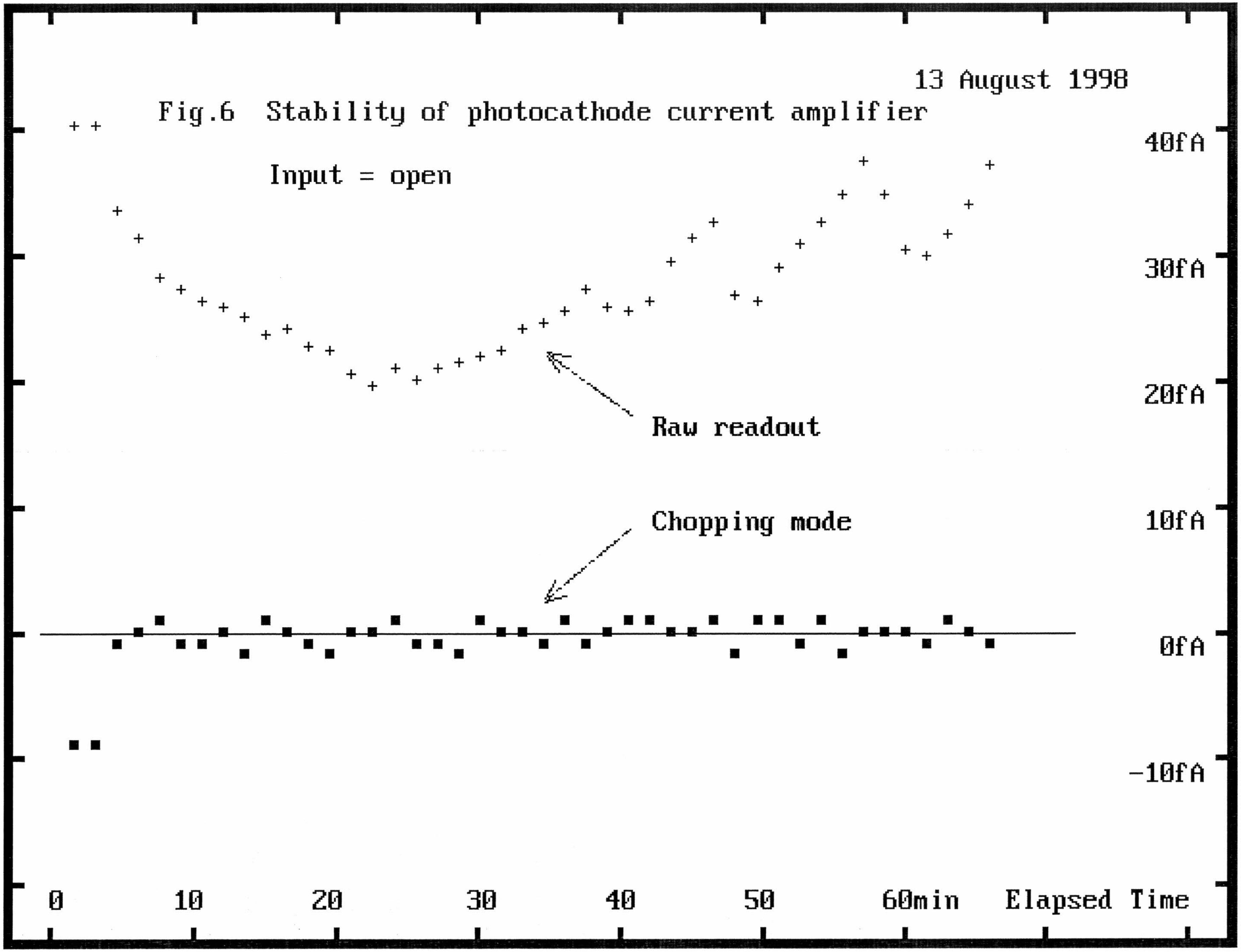
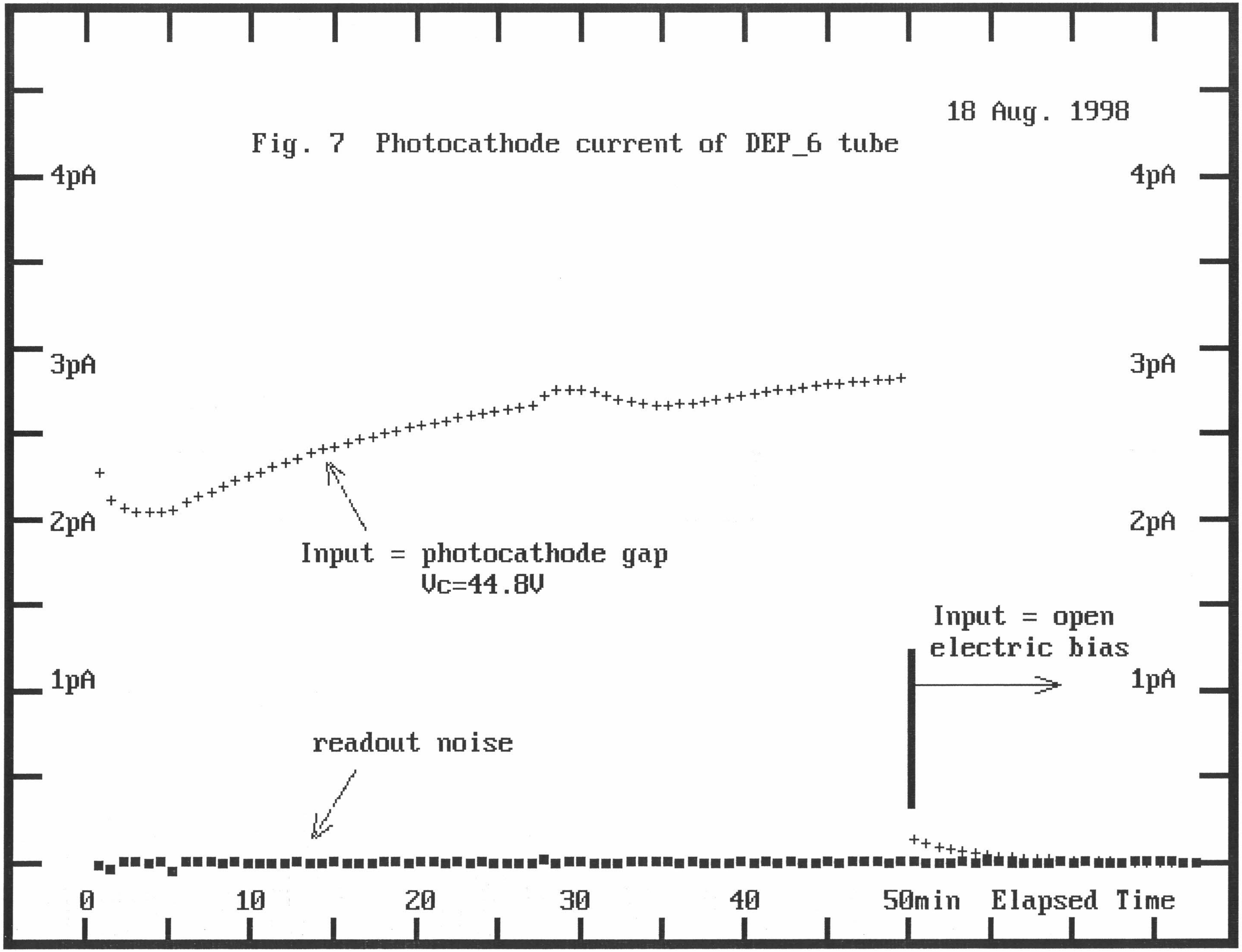


Fig. 5 Photocathode current amplifier 0.01mV=1.8fA


13 August 1998
Fig.6 Stability of photocathode current amplifier
Input = open
Raw readout
Chopping mode
40fA
30fA
20fA
10fA
0fA
-10fA
0
10
20
30
40
50
60min
Elapsed Time


18 Aug. 1998
Fig. 7 Photocathode current of DEP_6 tube
4pA
3pA
2pA
1pA
Input = photocathode gap
Vc=44.8V
Input = open
electric bias
readout noise
0
10
20
30
40
50min Elapsed Time

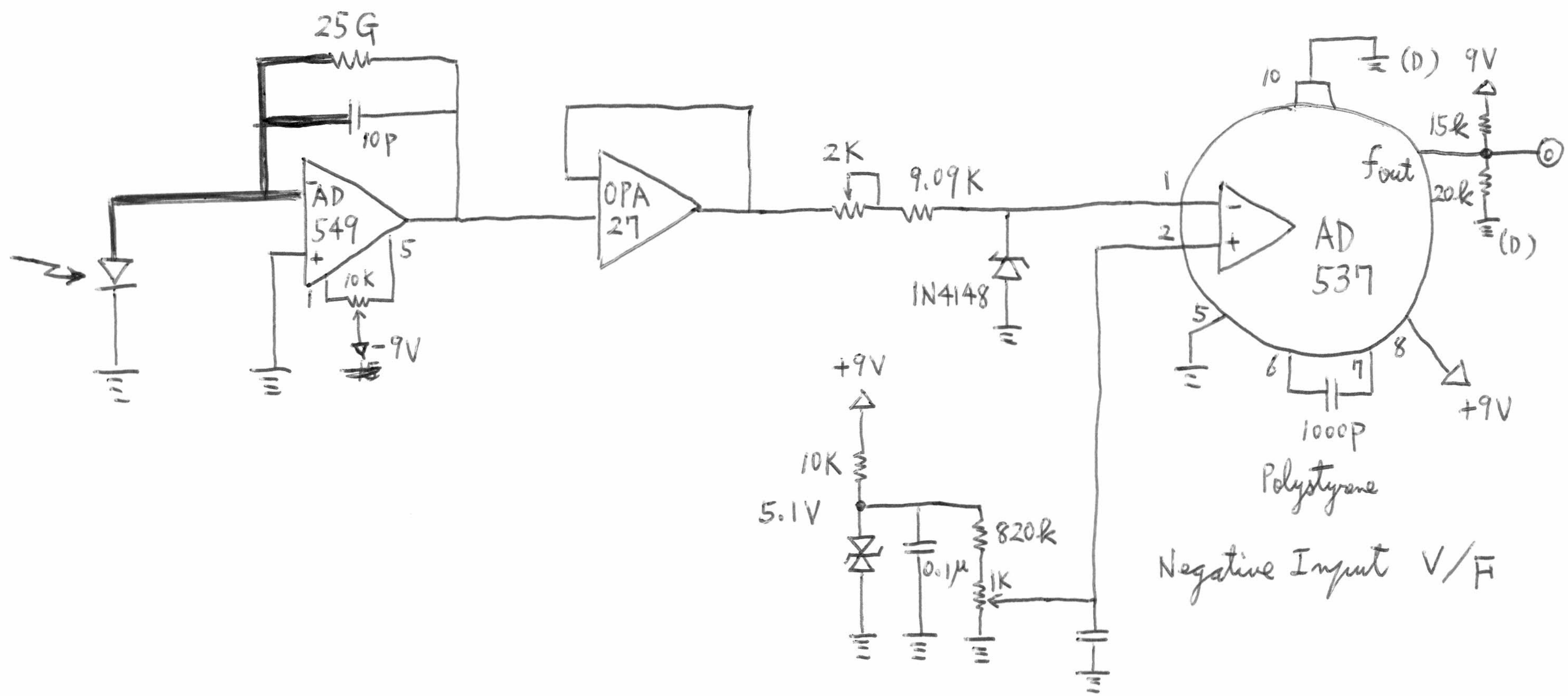


Fig. 8 Photodiode current amplifier

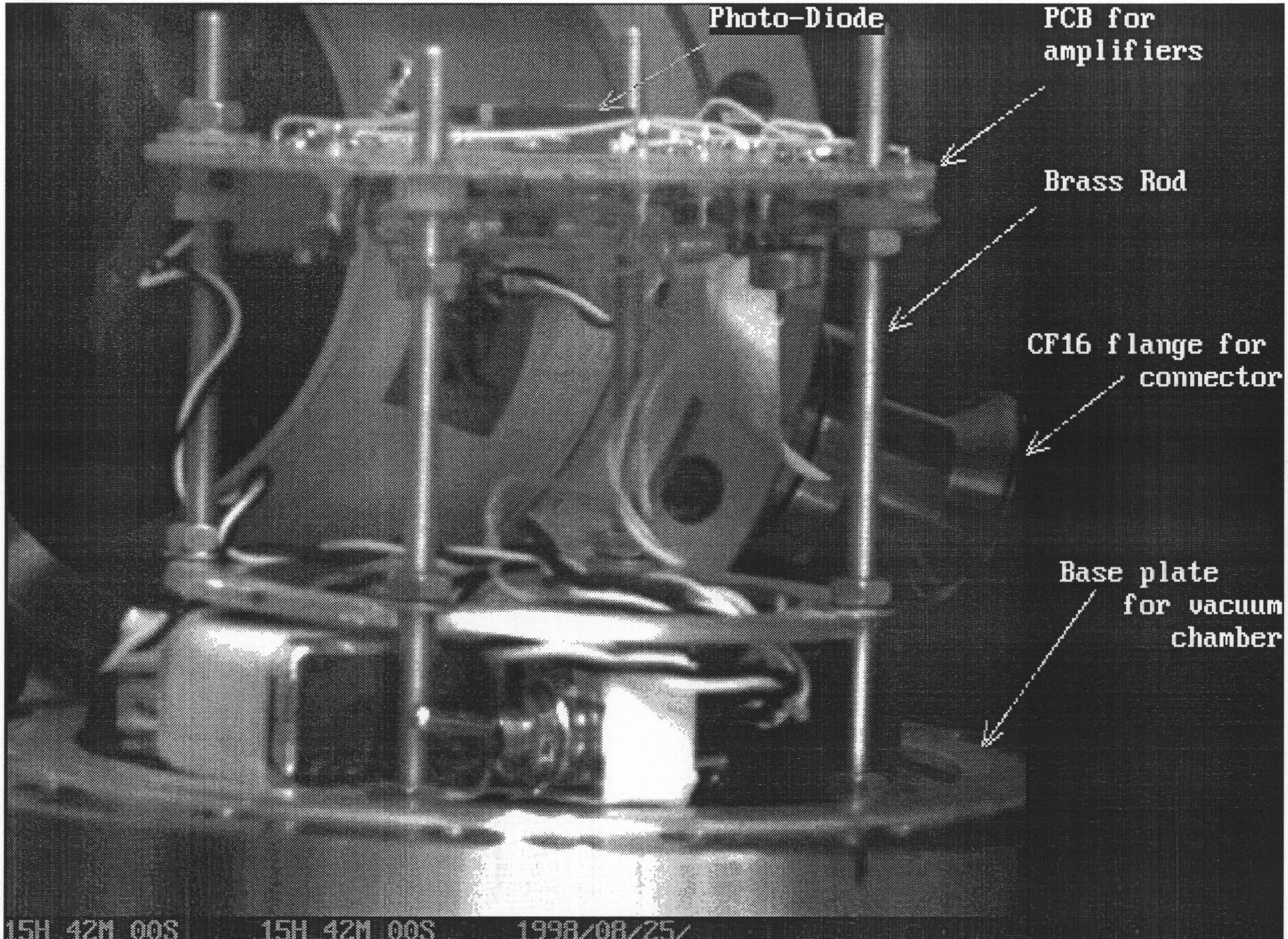


Fig. 9 Photodiode current amplifier 0.01mV=0.43fA

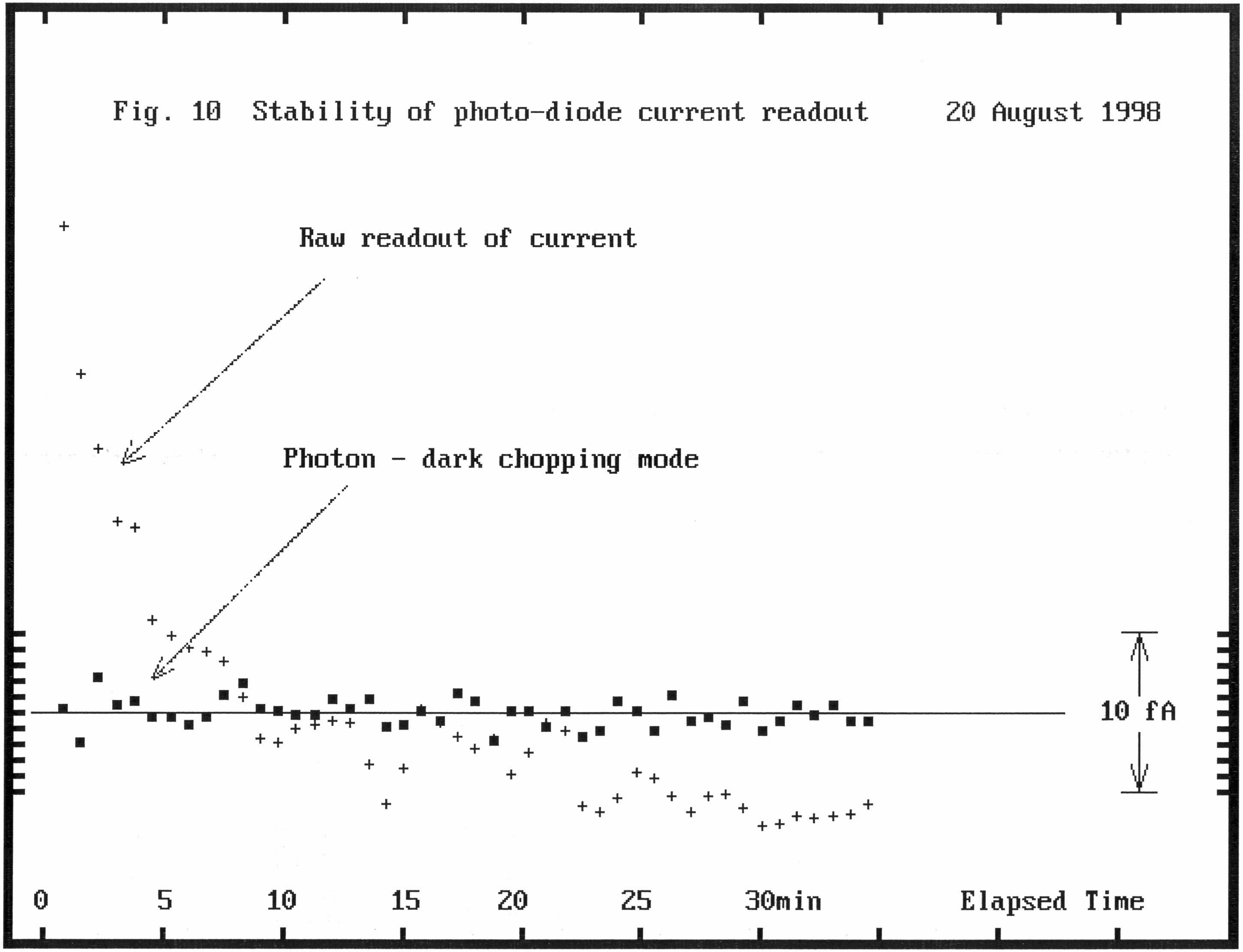


Fig. 10 Stability of photo-diode current readout 20 August 1998
Raw readout of current
Photon - dark chopping mode
10 fA
0
5
10
15
20
25
30min
Elapsed Time

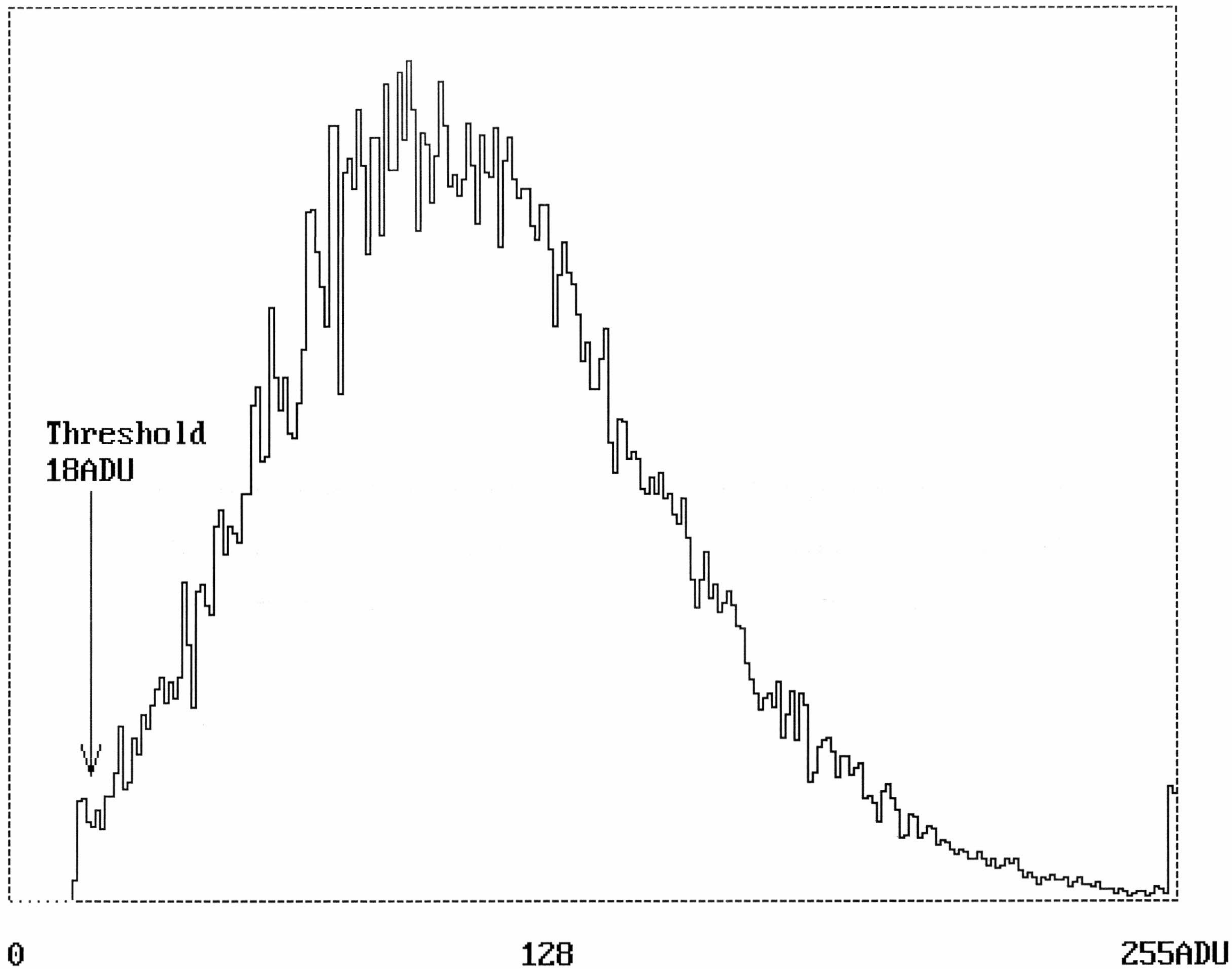


Fig. 11
Pulse Height Distirbution of DEP_#6 intensifier   400-2400-5220 Volts

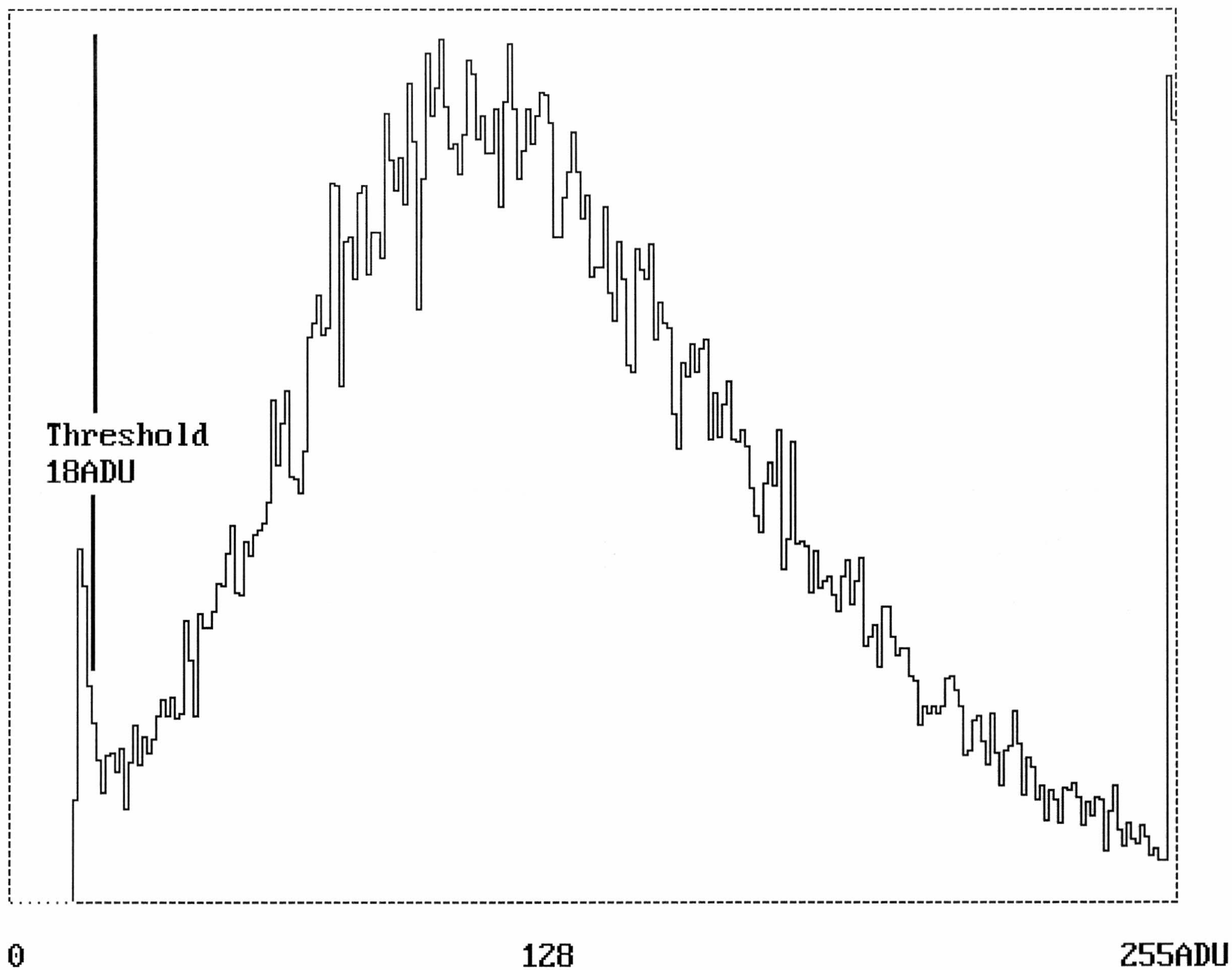


Fig. 12
Pulse Height Distirbution of DEP_#7 intensifier   400-2420-5250 Volts

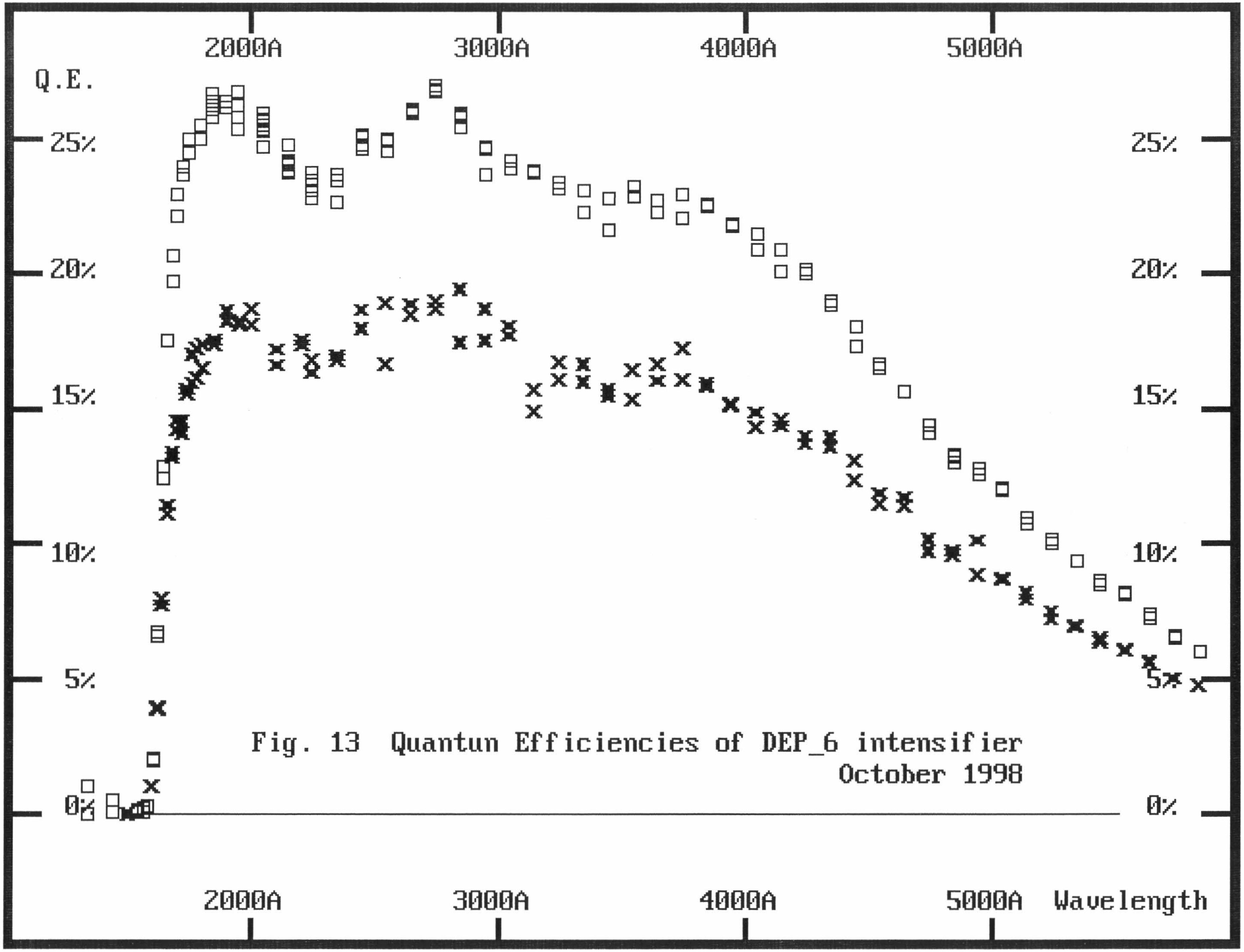


Fig. 13 Quantun Efficiencies of DEP_6 intensifier
October 1998

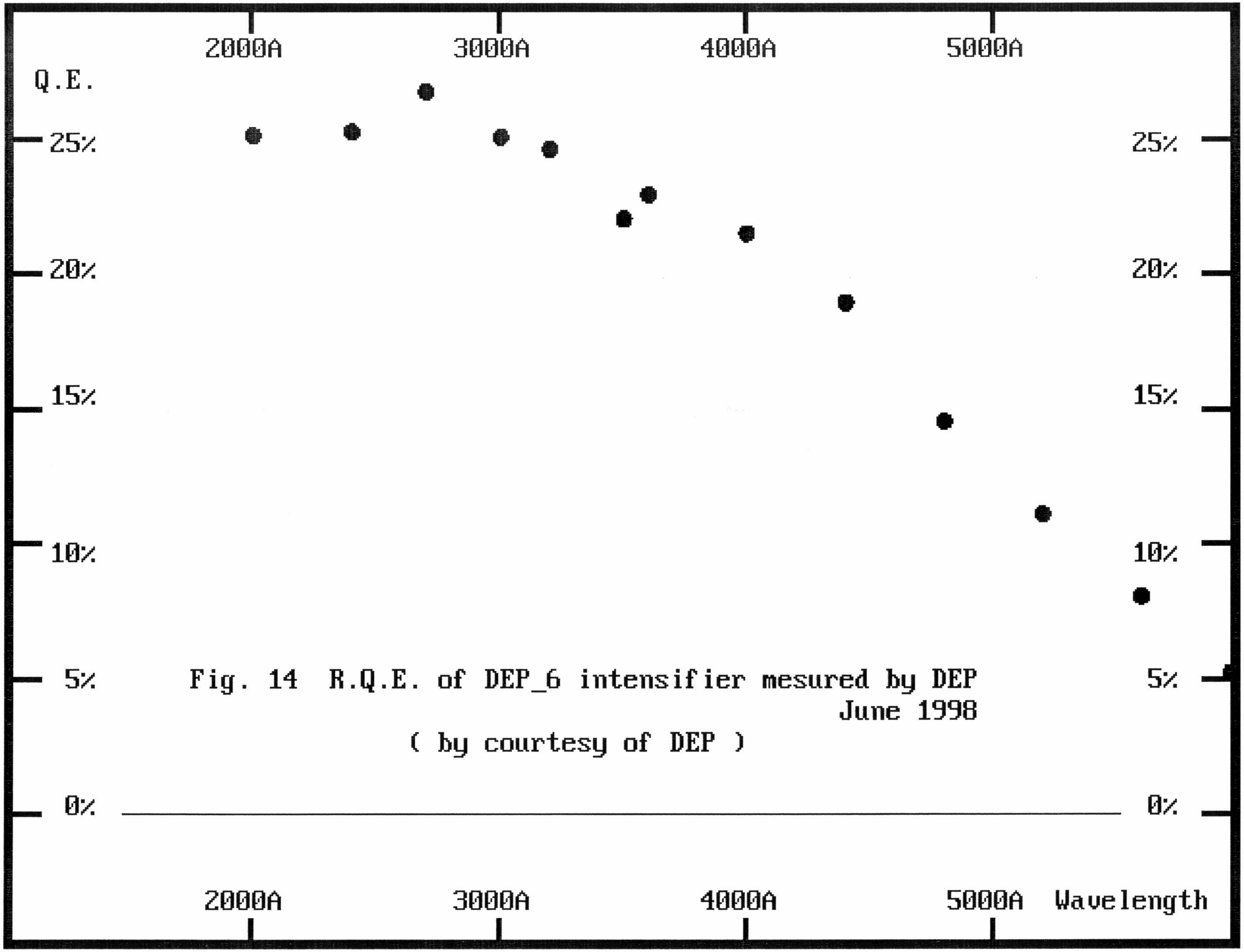
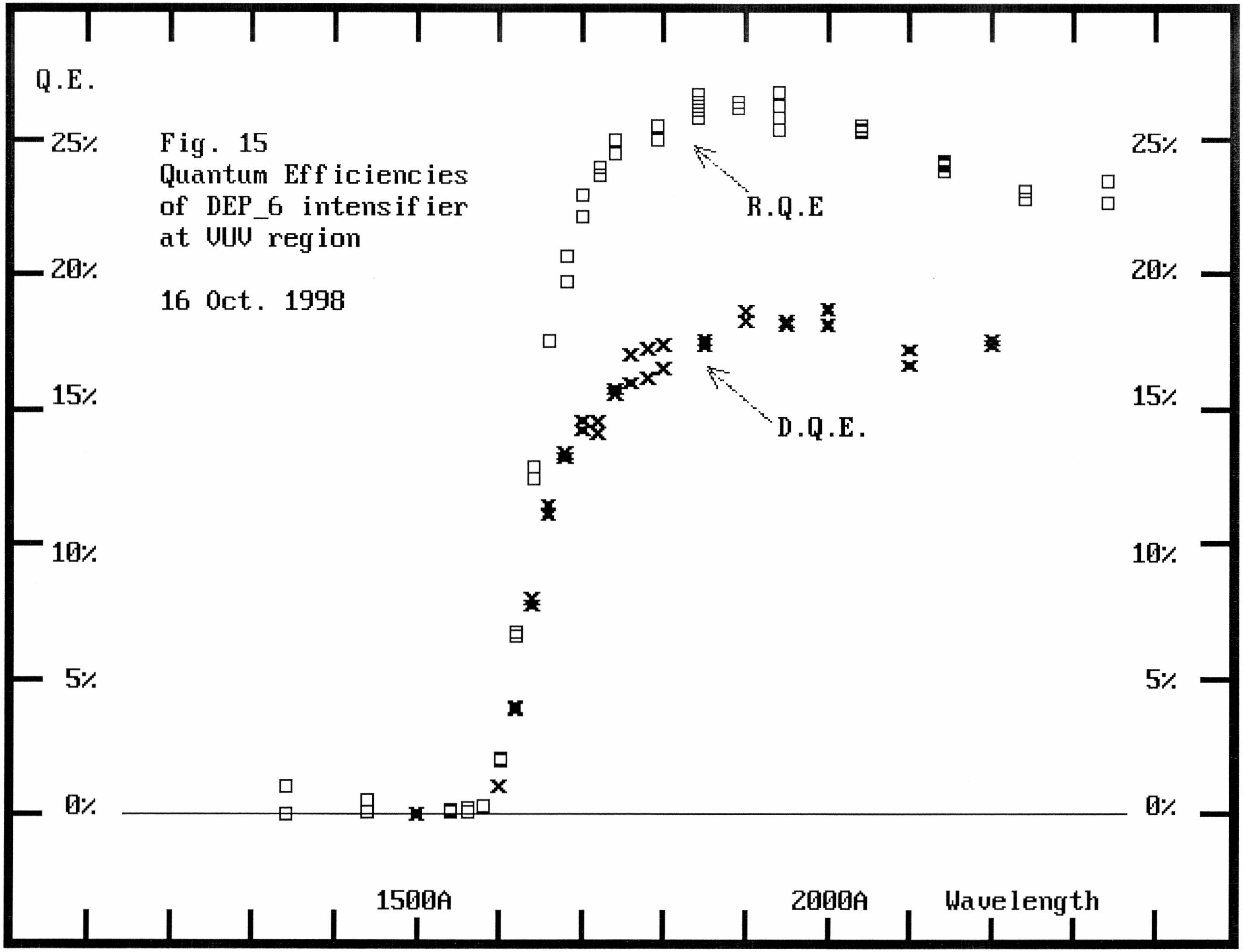


Fig. 14 R.Q.E. of DEP_6 intensifier mesured by DEP
June 1998
(by courtesy of DEP)


Q.E.
25%
20%
15%
10%
5%
0%
Fig. 15
Quantum Efficiencies
of DEP_6 intensifier
at VUV region
16 Oct. 1998
R.Q.E
D.Q.E.
1500A
2000A
Wavelength

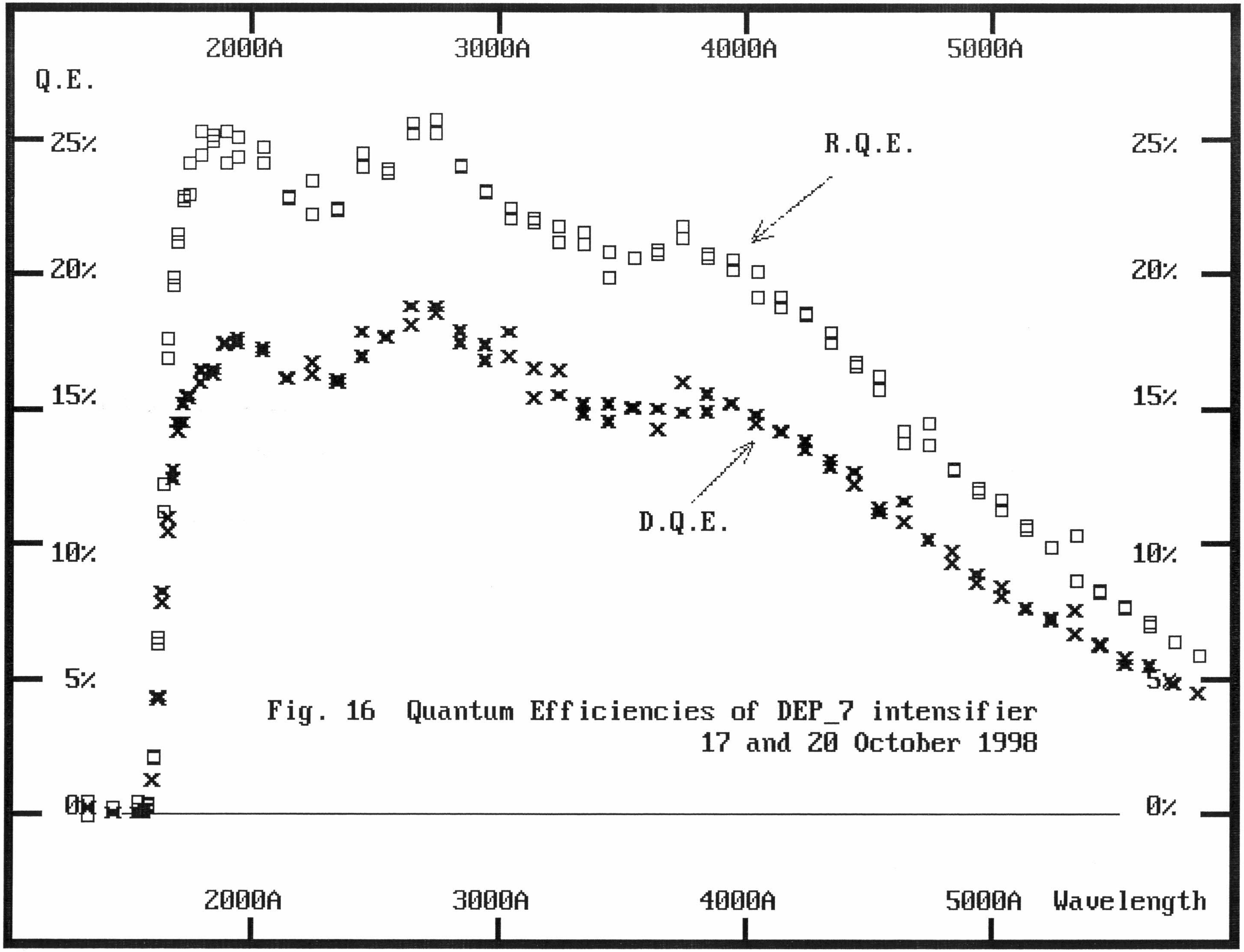


Fig. 16 Quantum Efficiencies of DEP_7 intensifier
17 and 20 October 1998

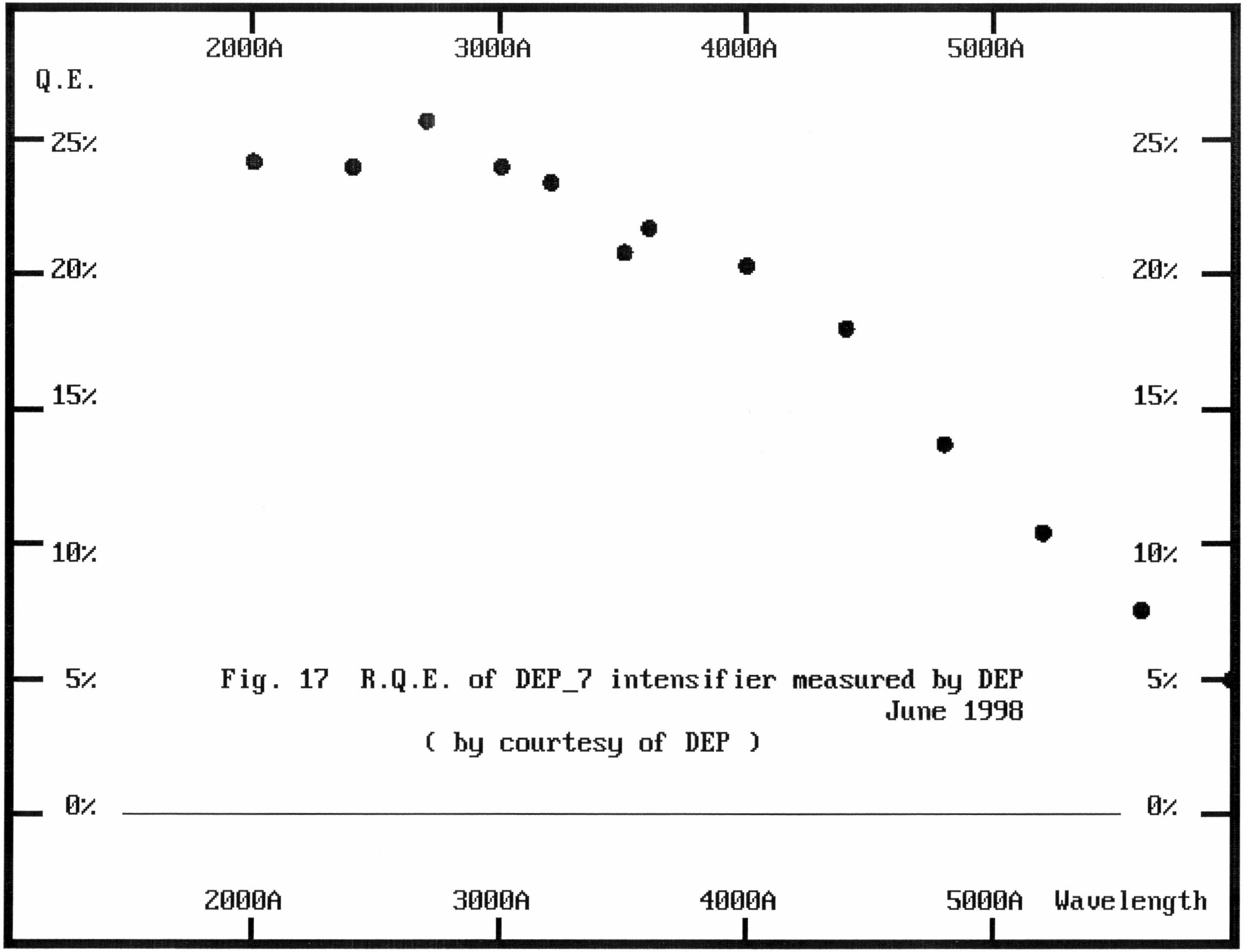


Fig. 17 R.Q.E. of DEP_7 intensifier measured by DEP
June 1998
(by courtesy of DEP)

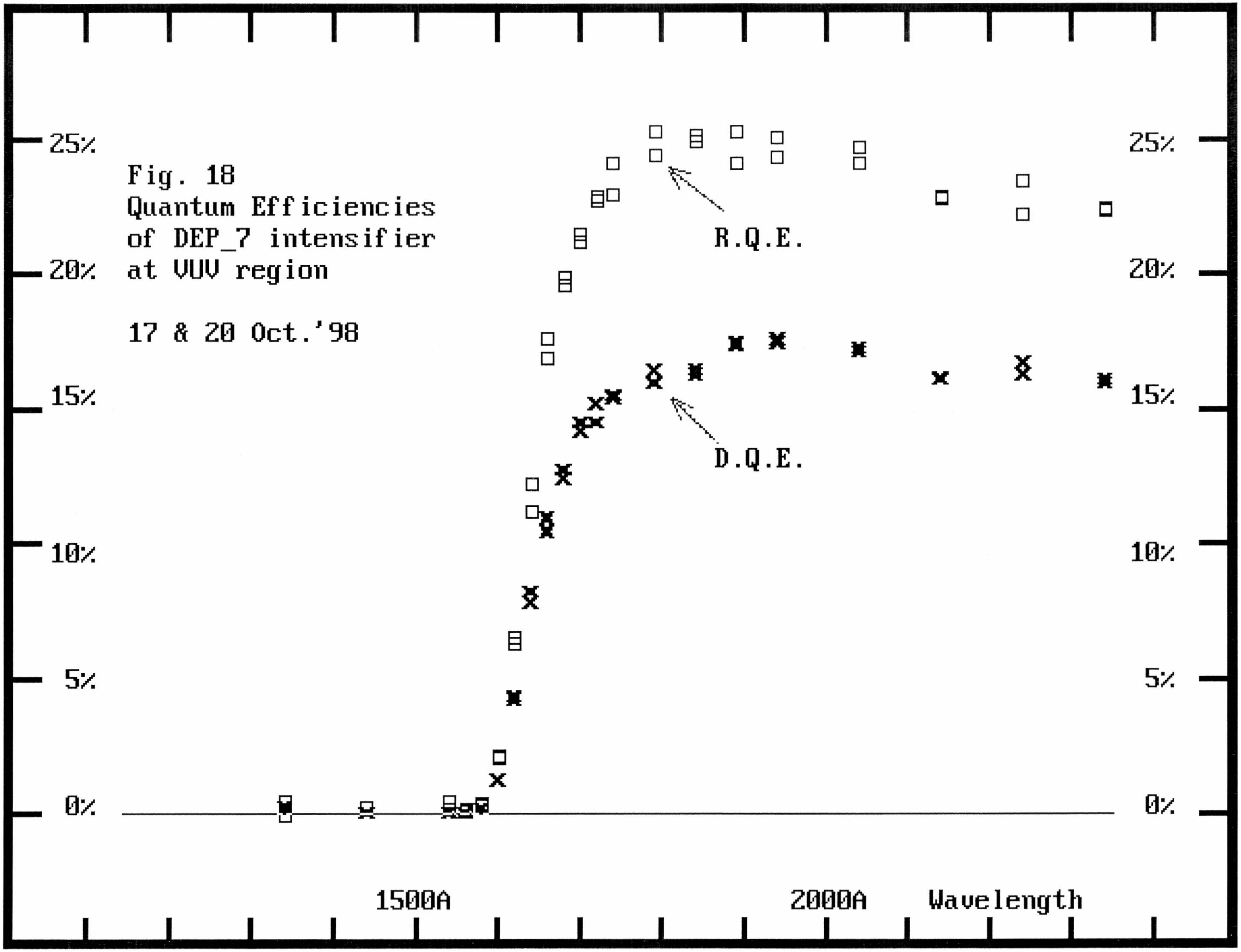


Fig. 18
Quantum Efficiencies
of DEP_7 intensifier
at VUV region
17 & 20 Oct.'98
R.Q.E.
D.Q.E.
25%
20%
15%
10%
5%
0%
25%
20%
15%
10%
5%
0%
1500A
2000A
Wavelength