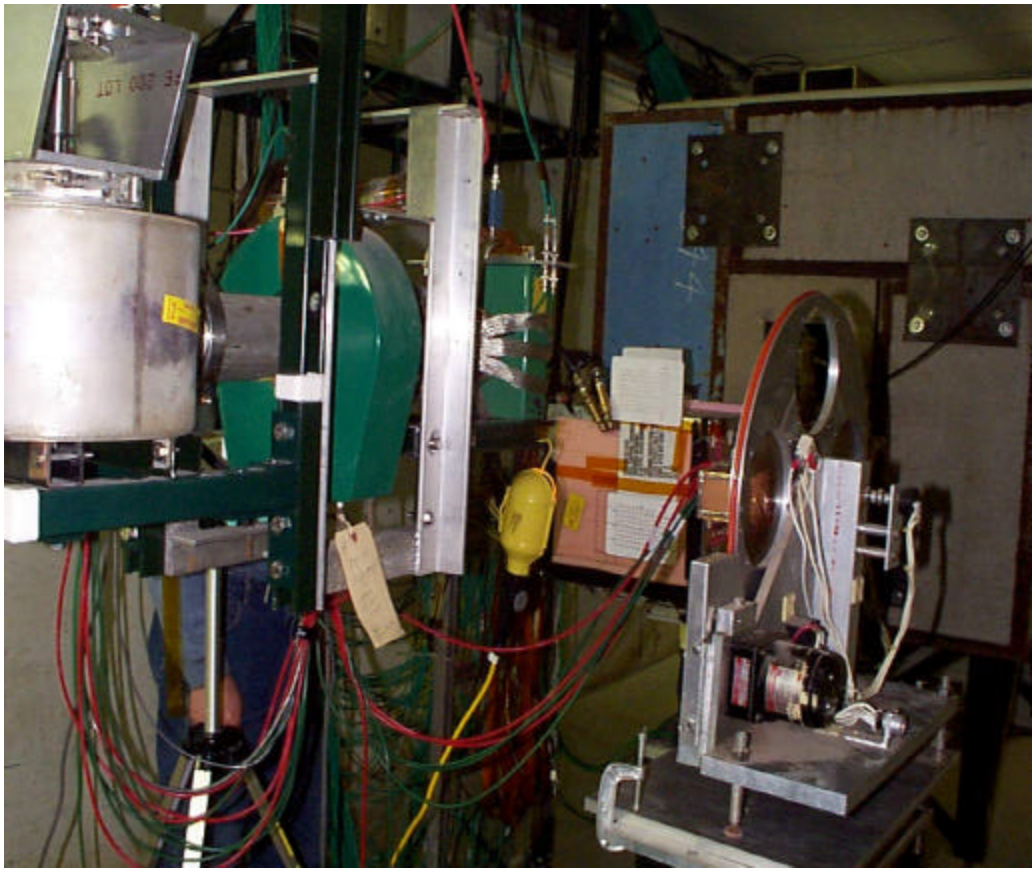
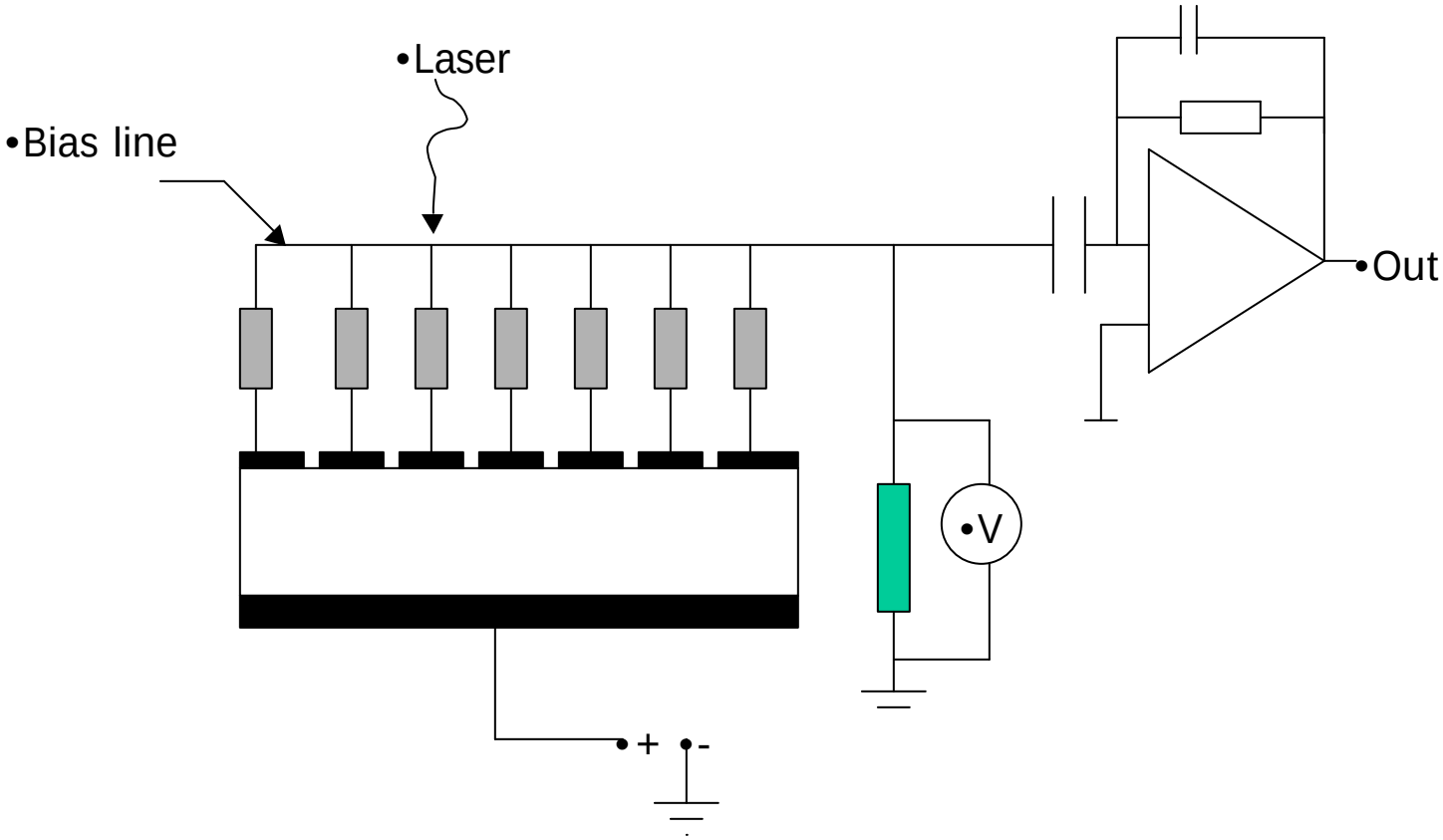
RUN 2 B sensors, 15 MRAD.

RDF (Radiation Damage Facility)

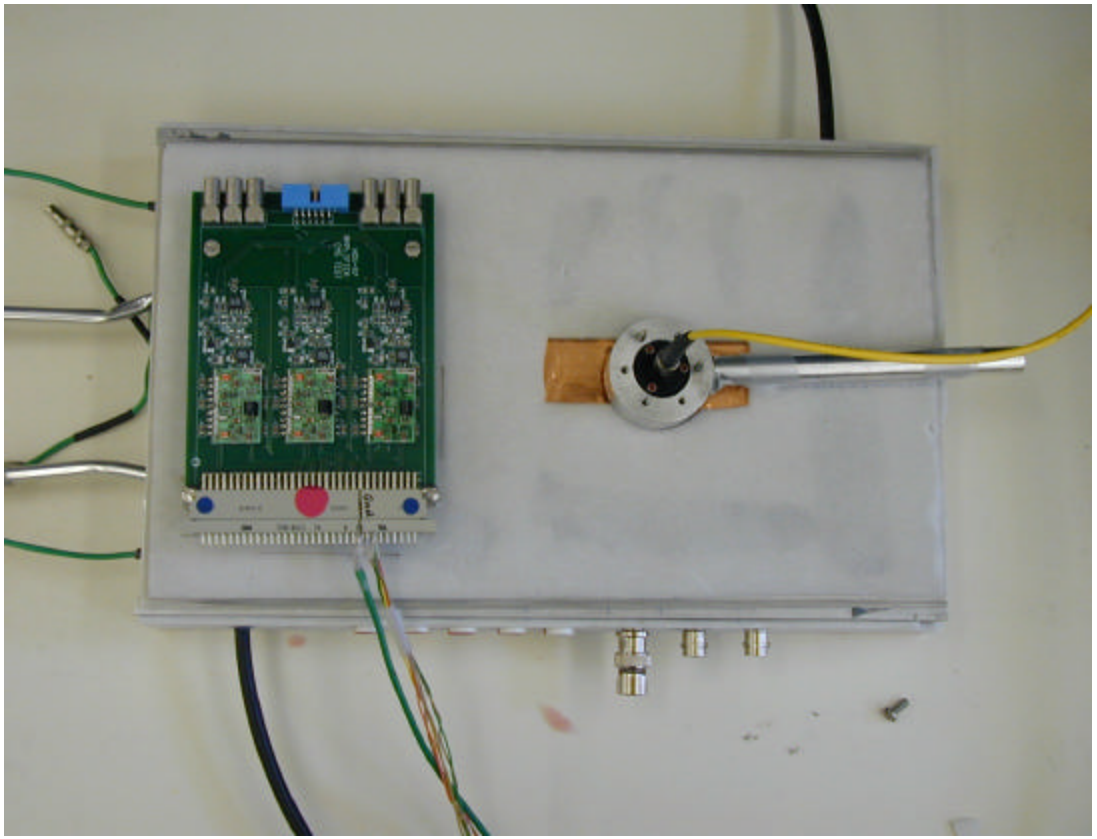
- 8 GeV.
- 1.2E12 p/cm2 every 1.5 sec.
- Toroid (proton flux control).
- Cooling box.
- Remote control.



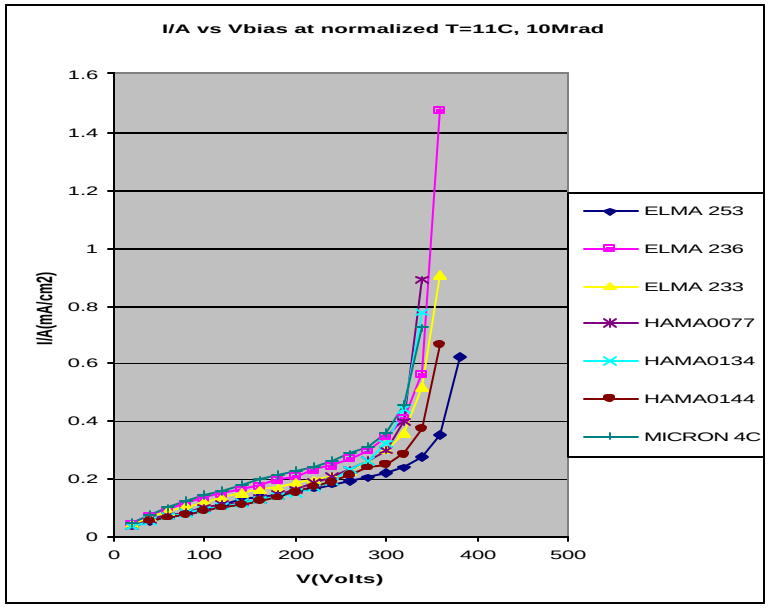
Setup for laser measurements.

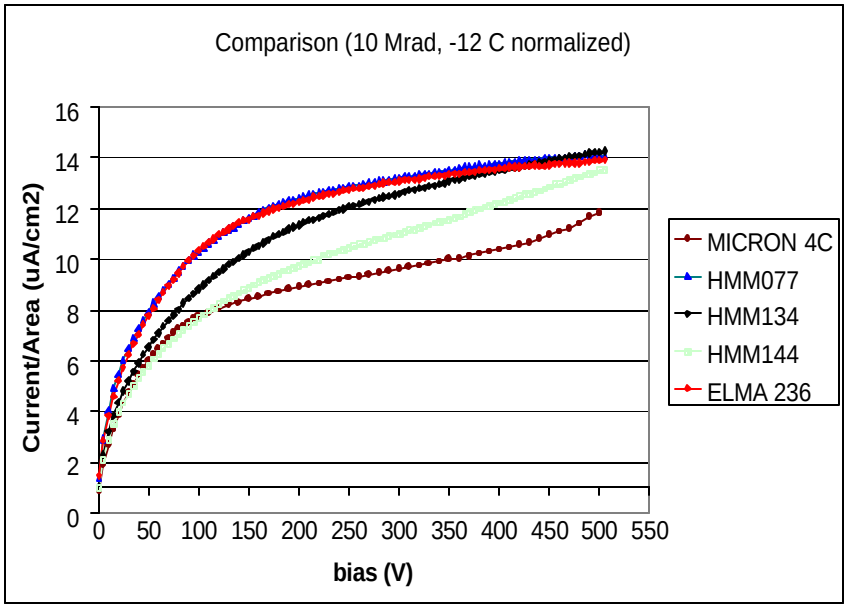


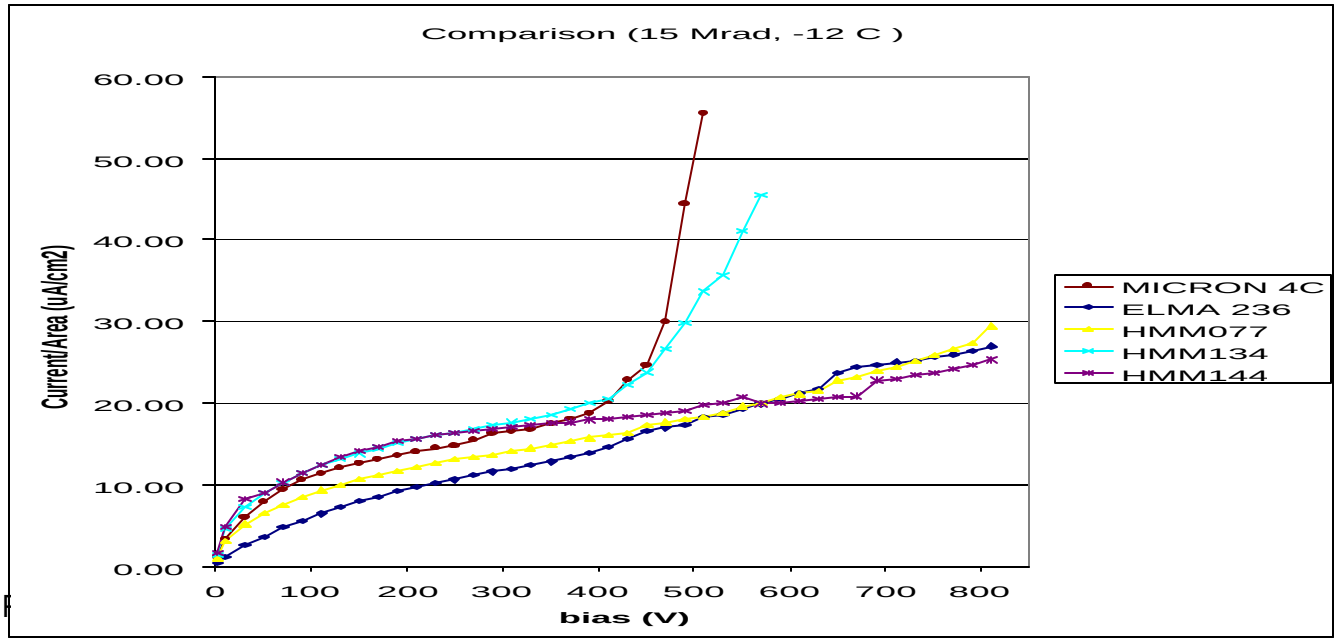
Setup for laser measurements.



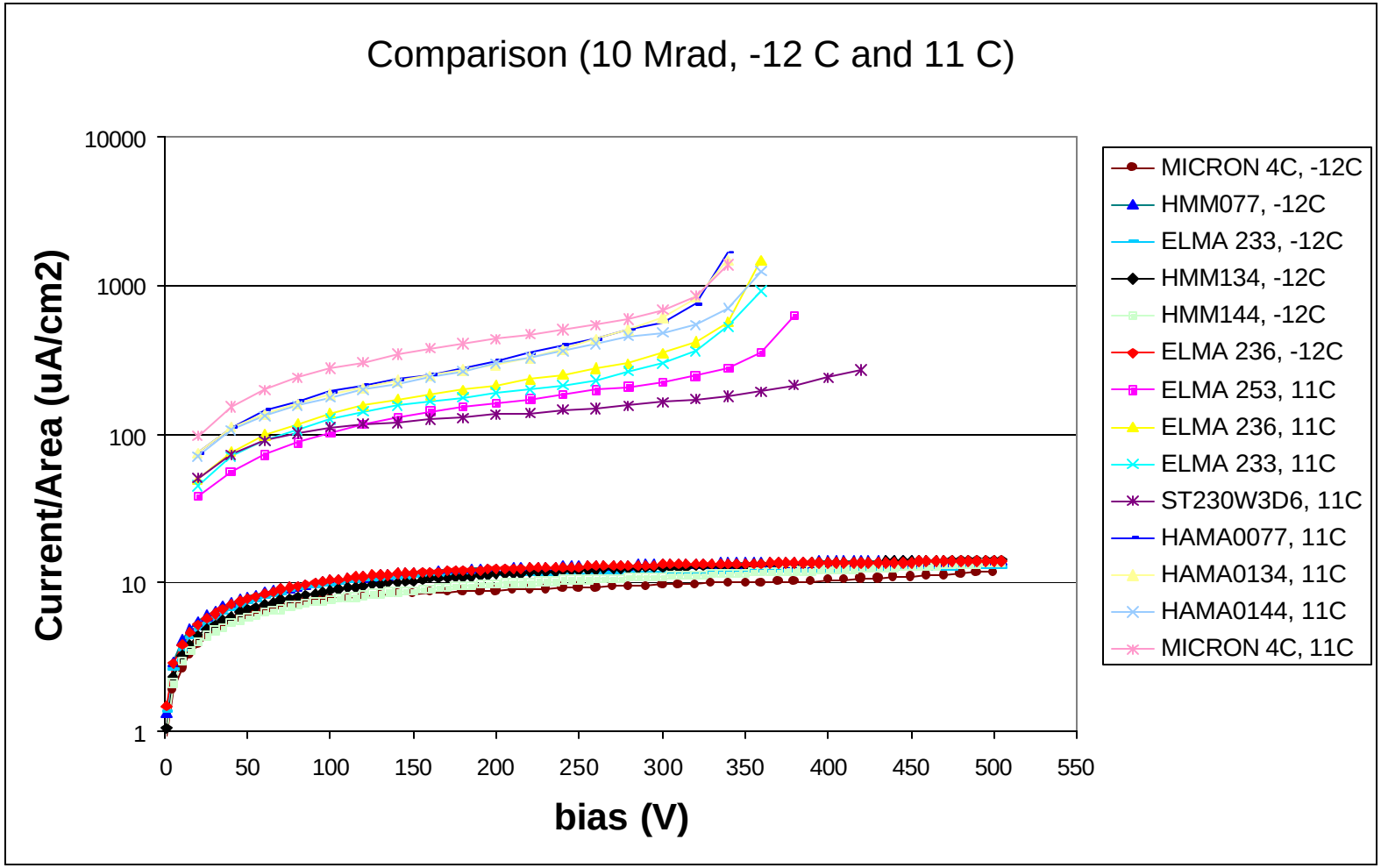
Leakage current 10 Mrad.



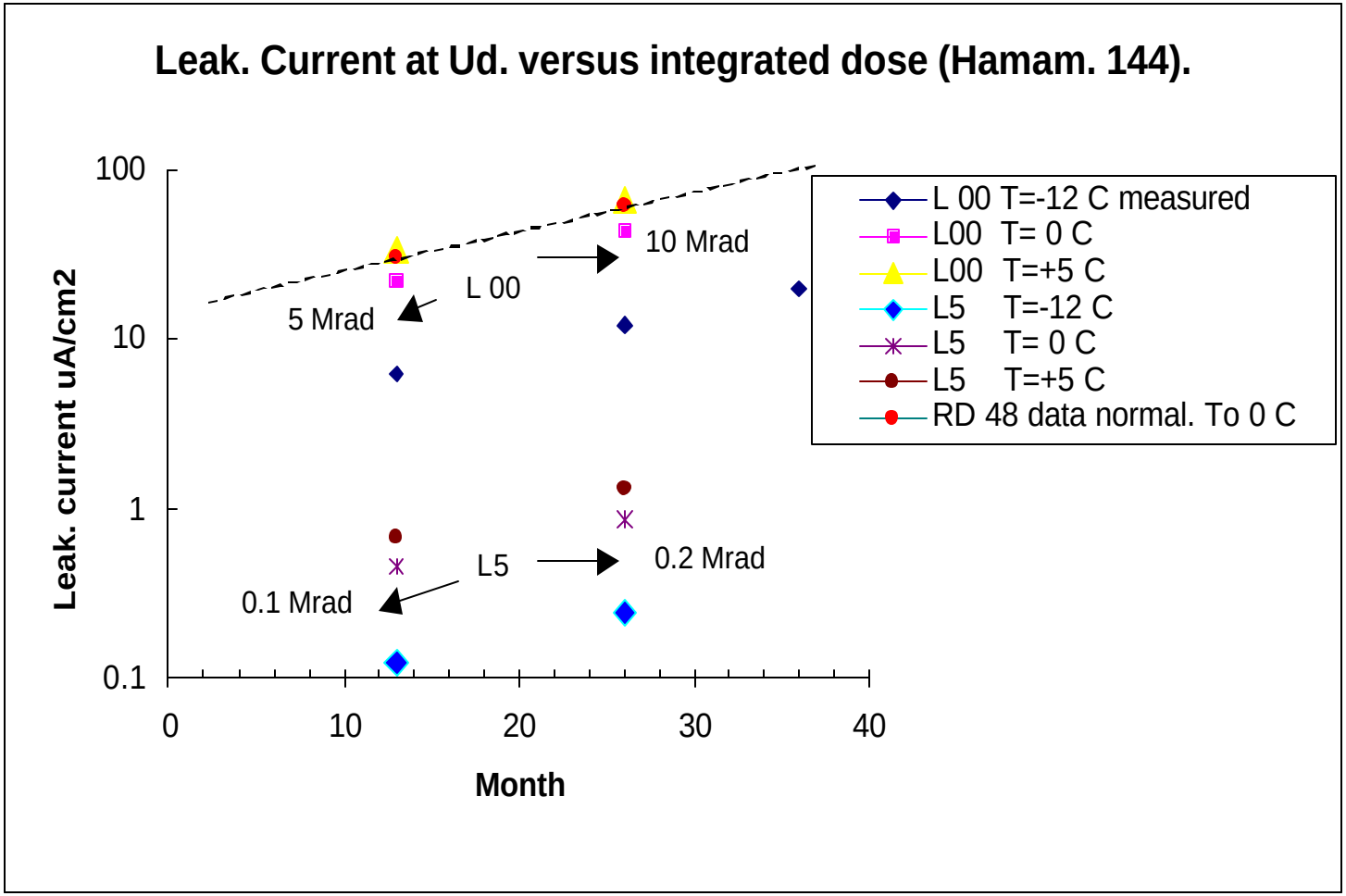




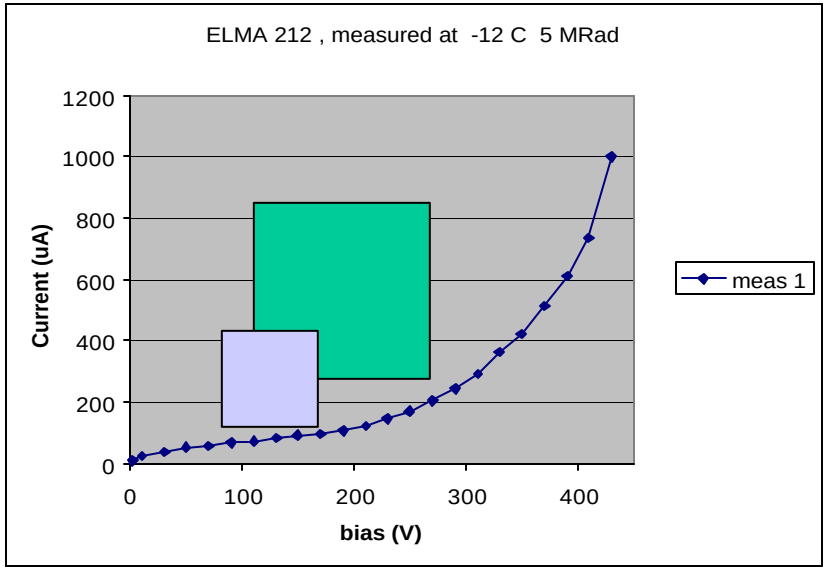
Leakage current 10 Mrad.

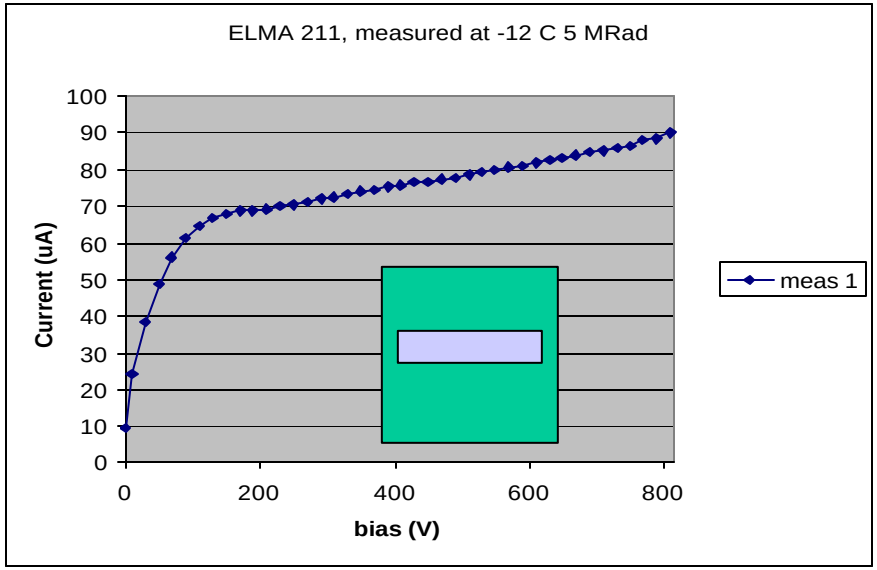


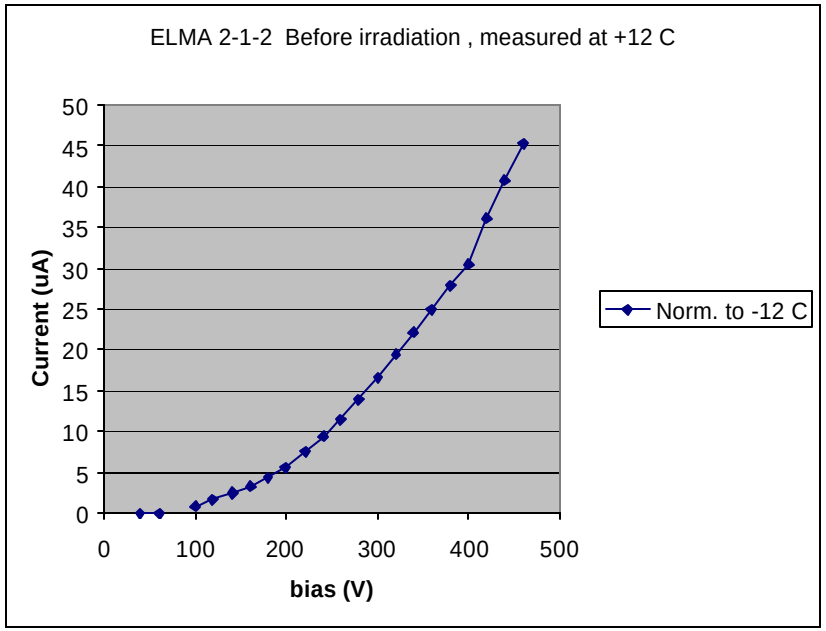
Leakage current 10 Mrad.

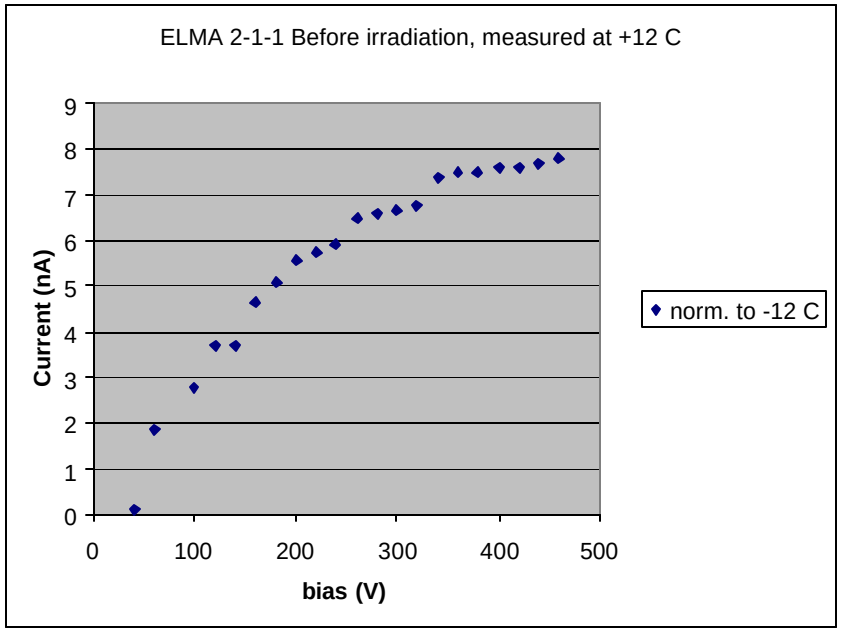


Leakage current when Be glued to Si.

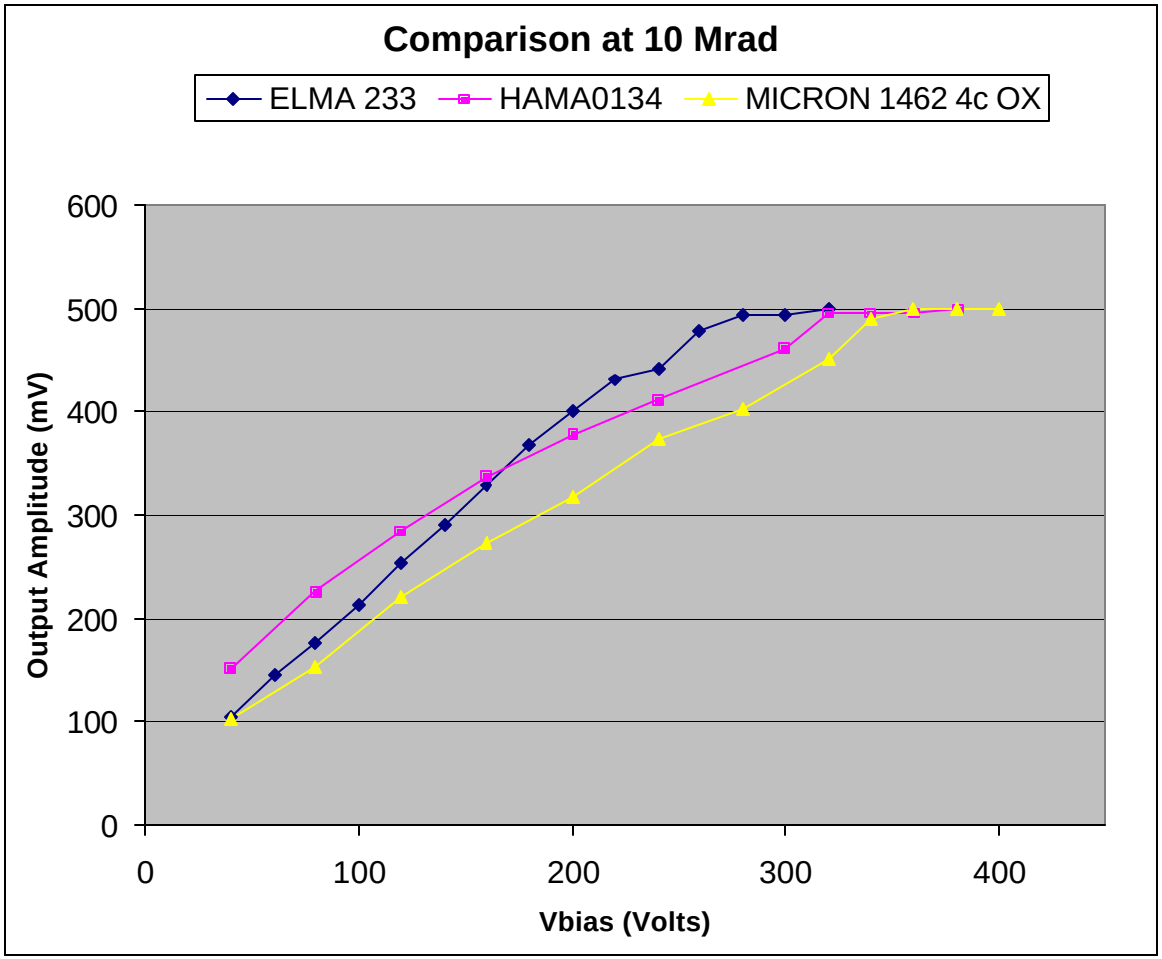




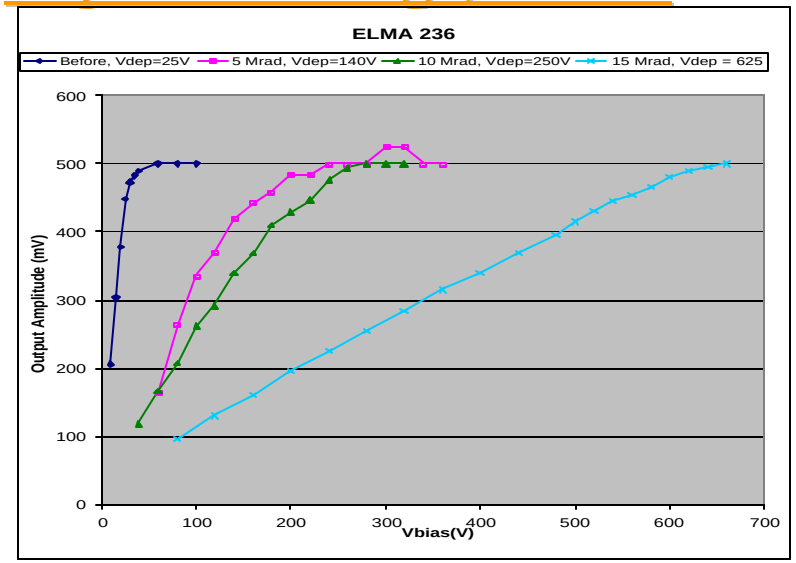


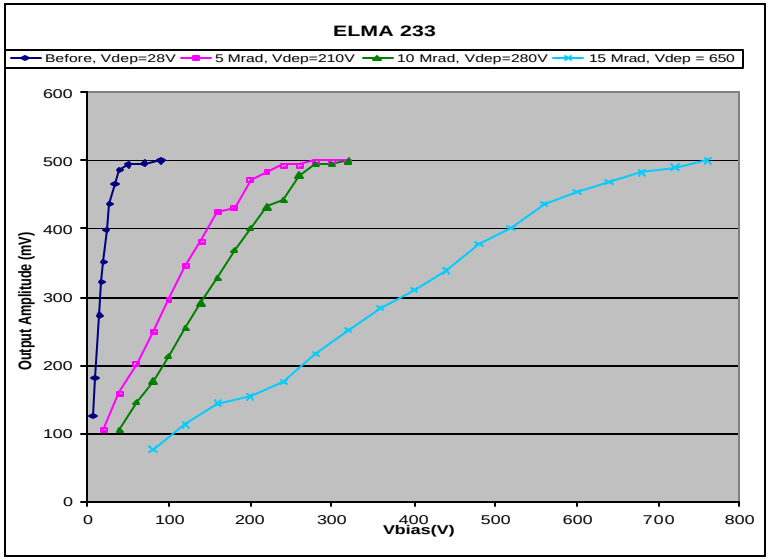


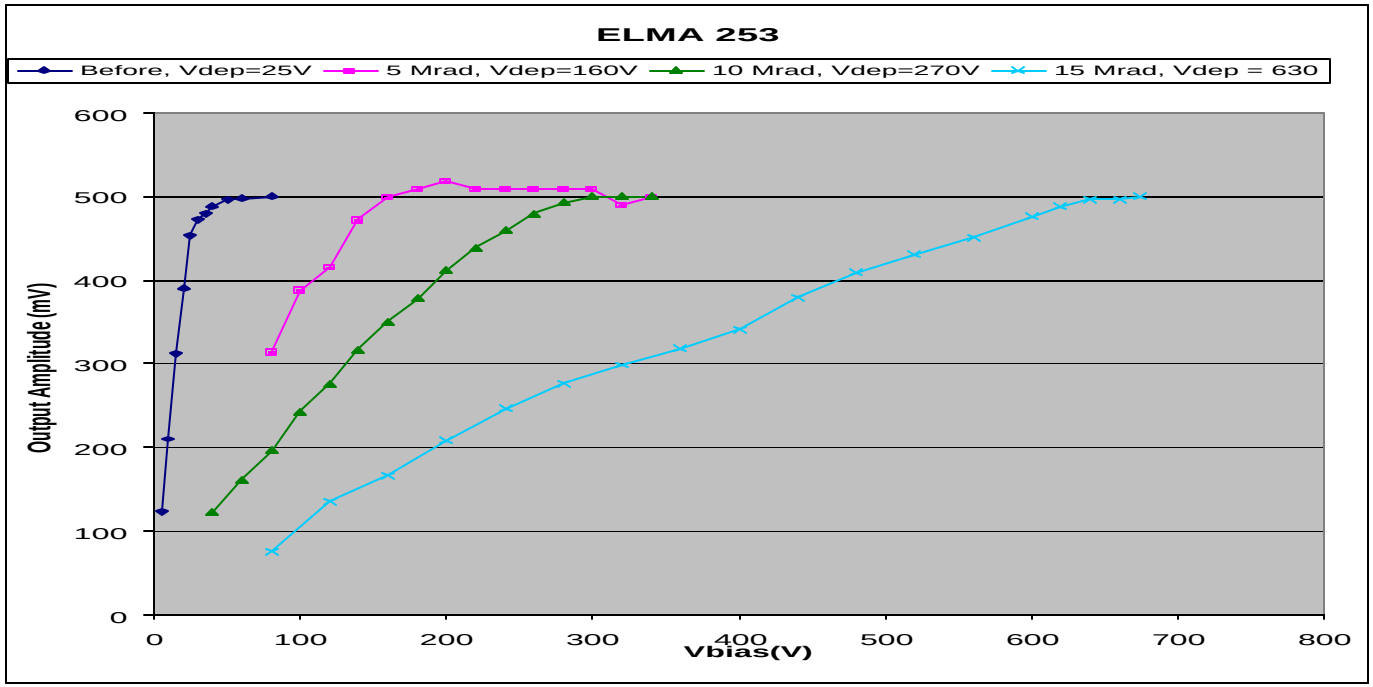
Depletion voltage.



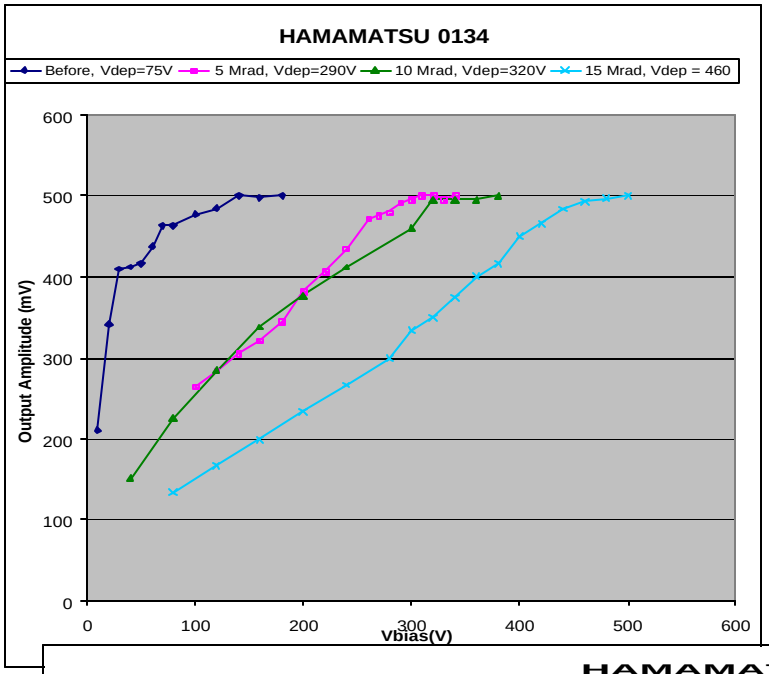
Depletion voltage, ELMA

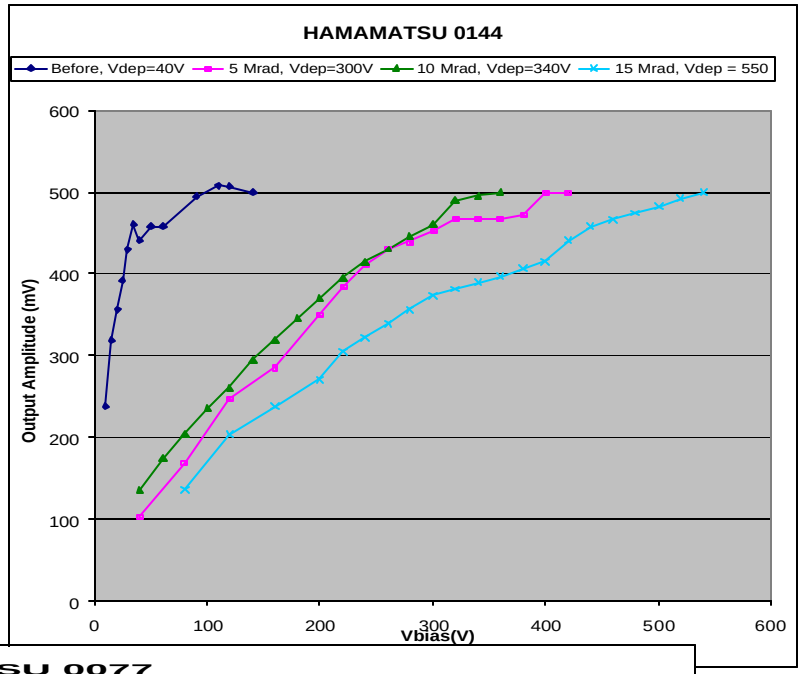


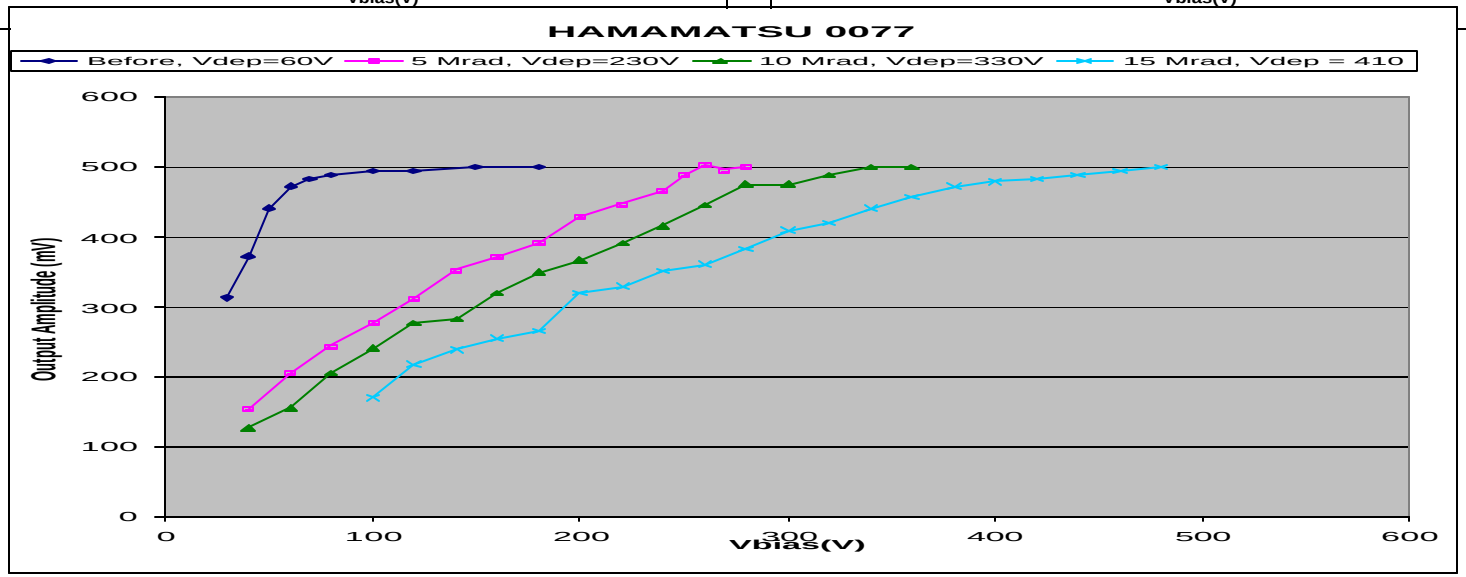




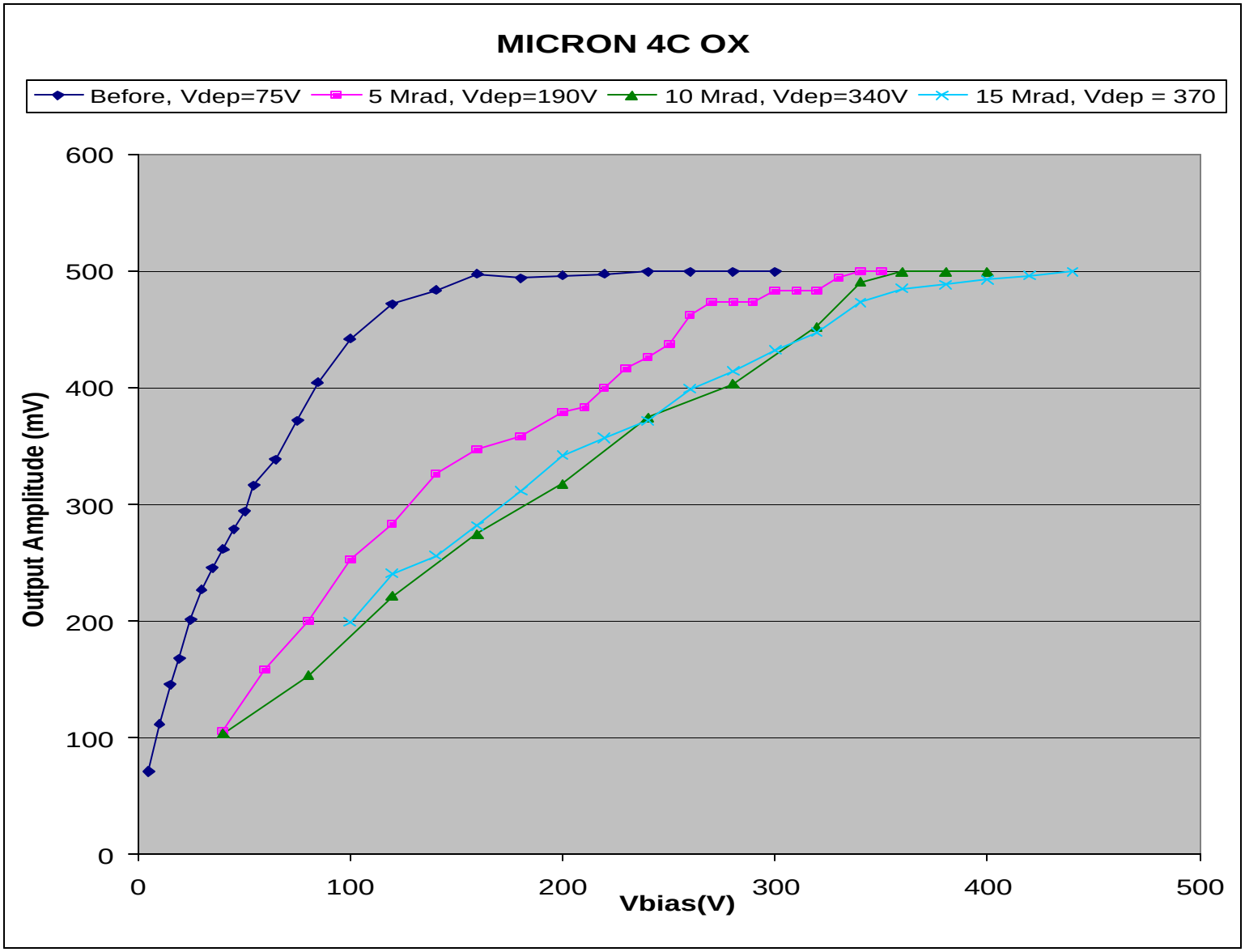
Depletion voltage, Hamamatsu.



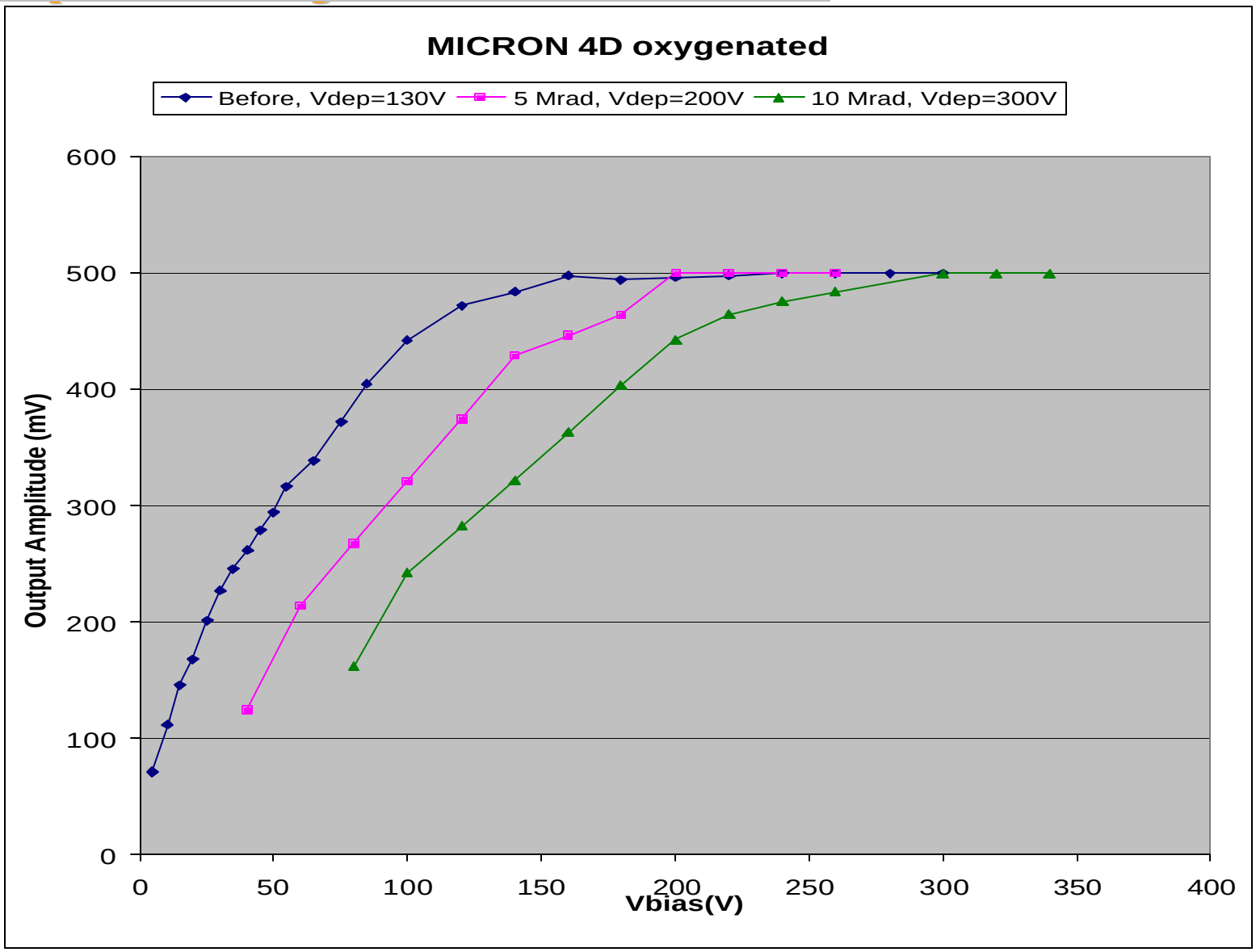




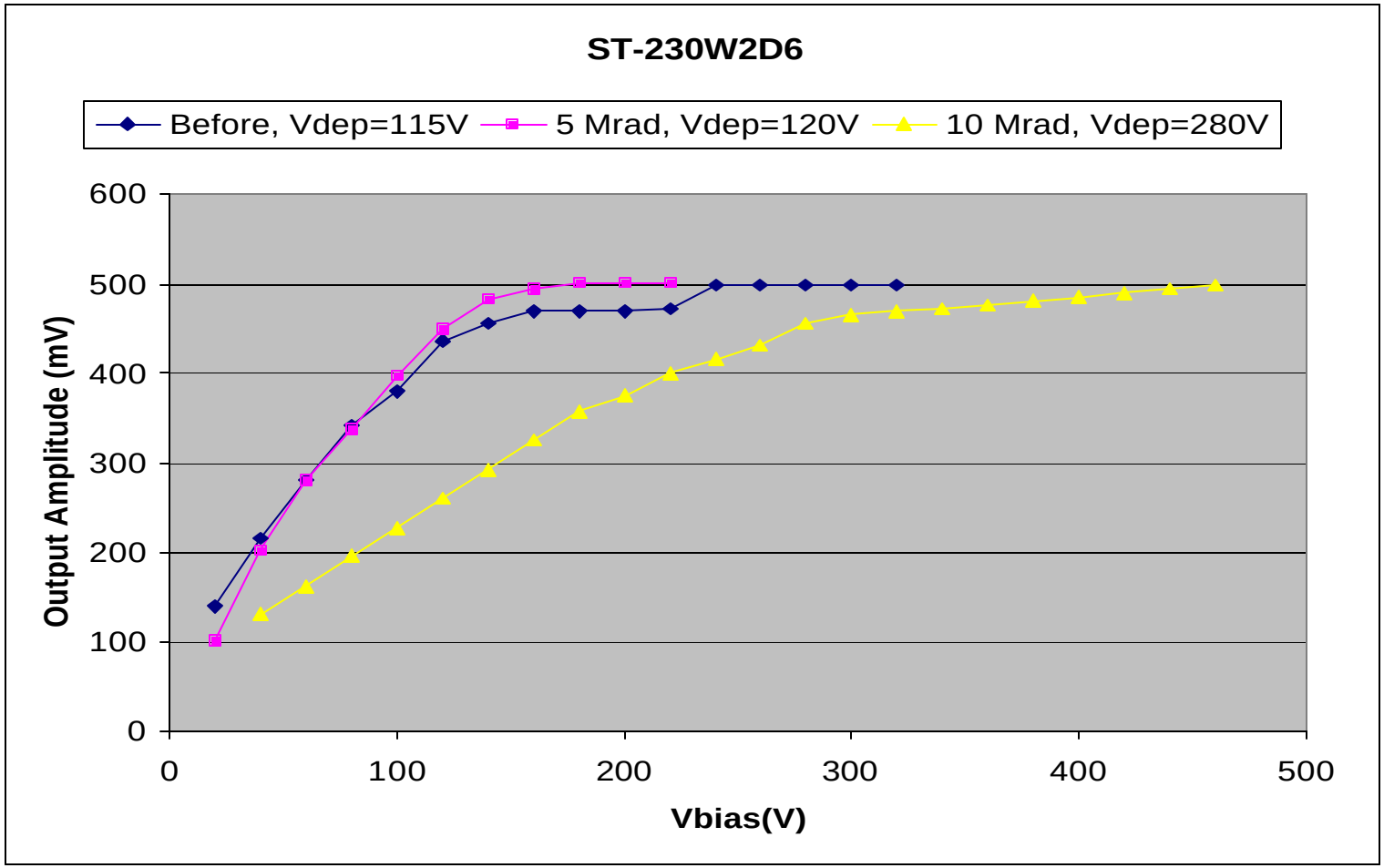
Depletion voltage, Micron .



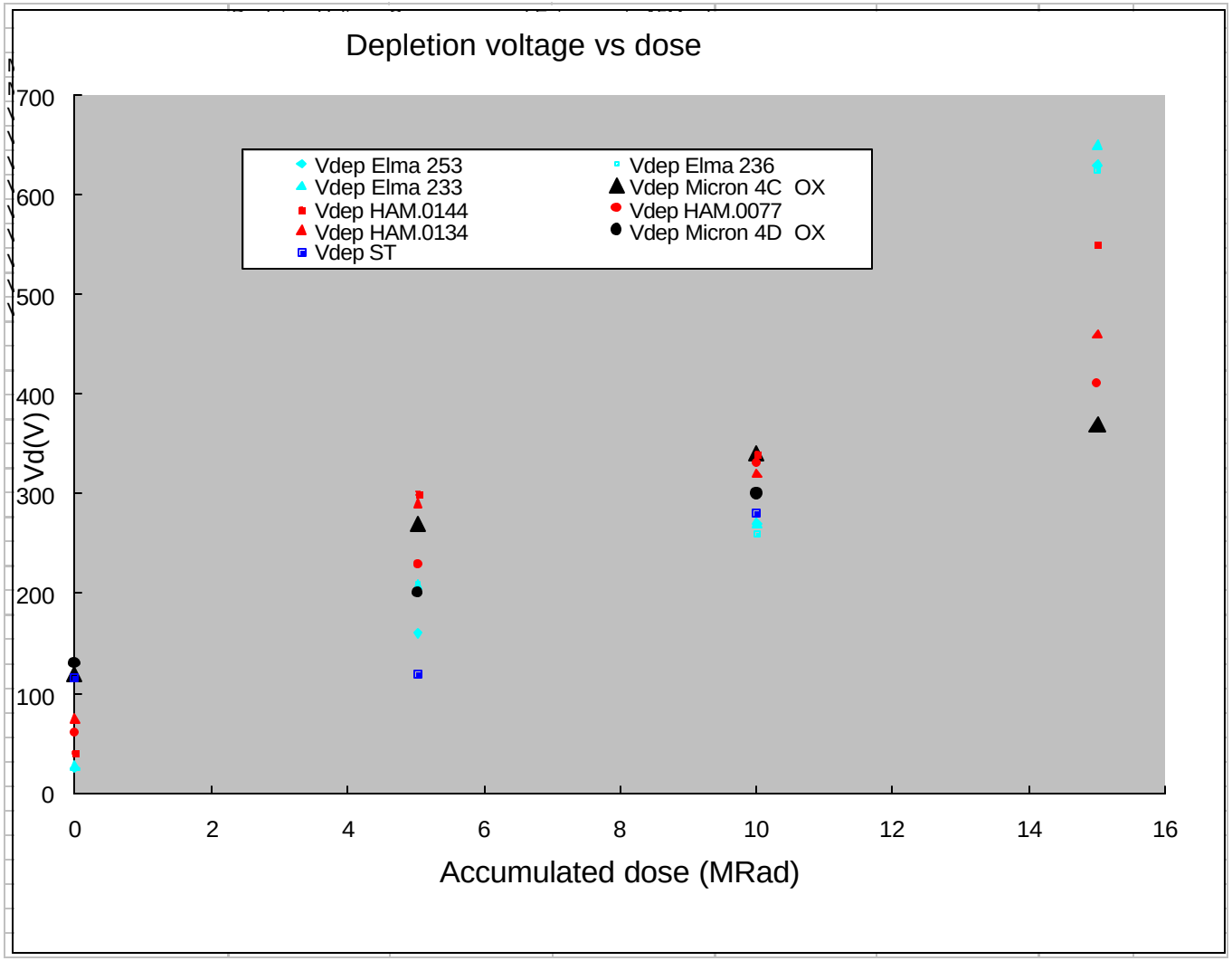
Depletion voltage Micron 4 D, 10 MRad



Depletion voltage ST



Depletion voltage vs accumulated dose



Depletion voltage at different temperatures, calculations.

From RD48 3 Status Report CERN/LHCC 2000-009, N_A corresponds to the short term beneficial annealing phase, N_C corresponds to the stable damage part and N_Y is for long term reverse annealing.

$V_{dep} = q_o / (2 \varepsilon \varepsilon_o) \, | N_{eff} | \, d^2$

$\Delta N_{eff} (\Phi_{eq} , t (T_a)) = N_A (\Phi_{eq} , t (T_a)) + N_C (\Phi_{eq}) + N_Y (\Phi_{eq} , t (T_a))$

The solution of this equation for $V_{fd}(t)$ is based on this RD48 approximation,

$V_{fd}(t) = V_S + V_1 \exp(-t / \tau_S) + V_2 (1 - \exp(-t / \tau_L)), \quad t \equiv$ time in days

V_S corresponds to N_C (Φ_{eq}) ==➔ Stable damage.
V_1 = 80V corresponds to N_A ➔ Short term beneficial annealing.
V_2 = 480V corresponds to N_Y ➔ Reverse annealing component.

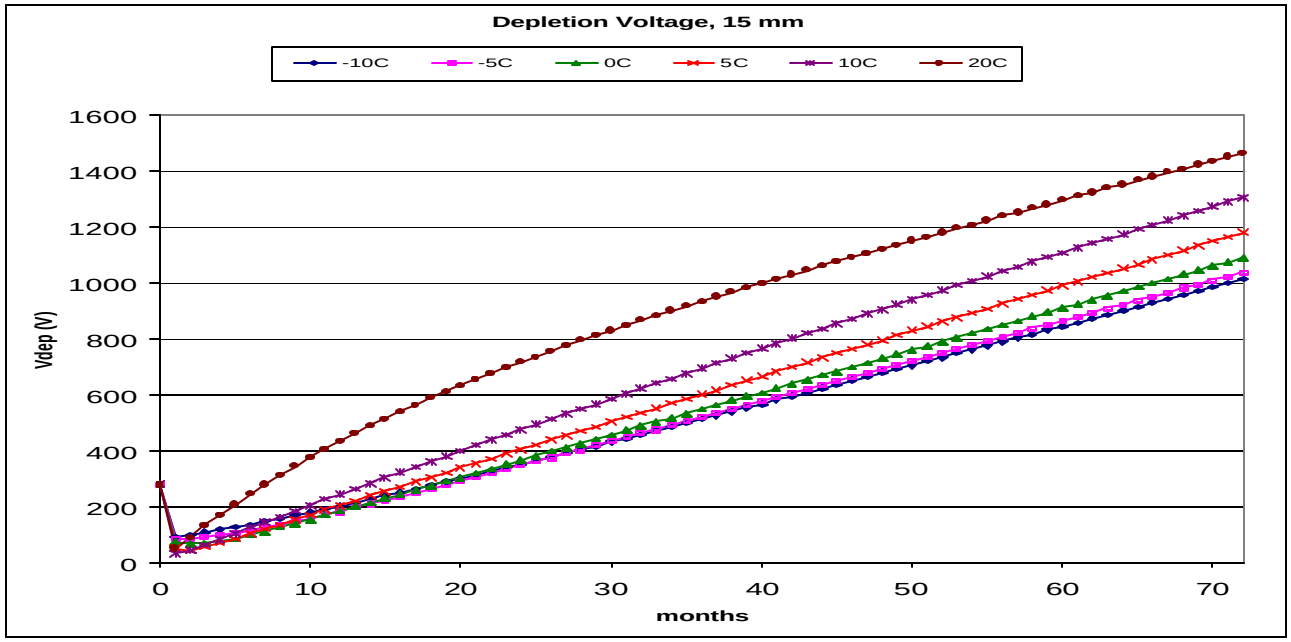
$V_S = V_0 \exp(-3 * 10^{-13}) F) + b F$ with V_0 = 200V and $b = 1 * 10^{-12}$ is based on the INP MSU Preprint 2000 – 7/611.

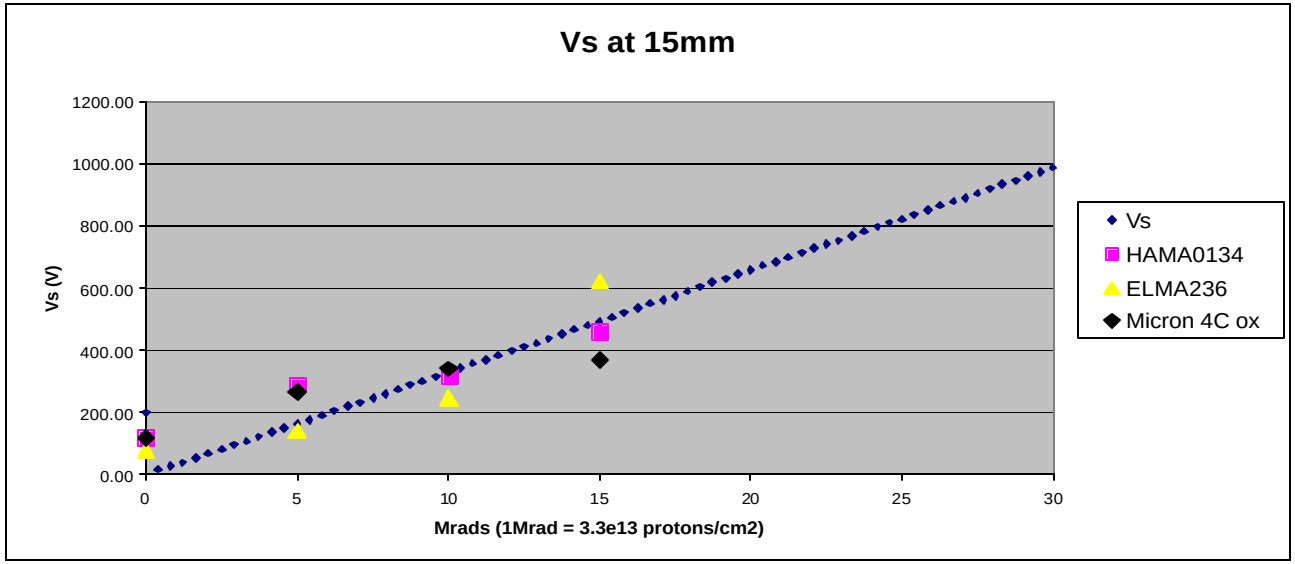
The time constants are taken from ATLAS R&D report.

$\tau_S = 70 \exp(-0.175 \, T(°C))$, $\tau_L = 9140 \exp(-0.152 \, T(°C))$

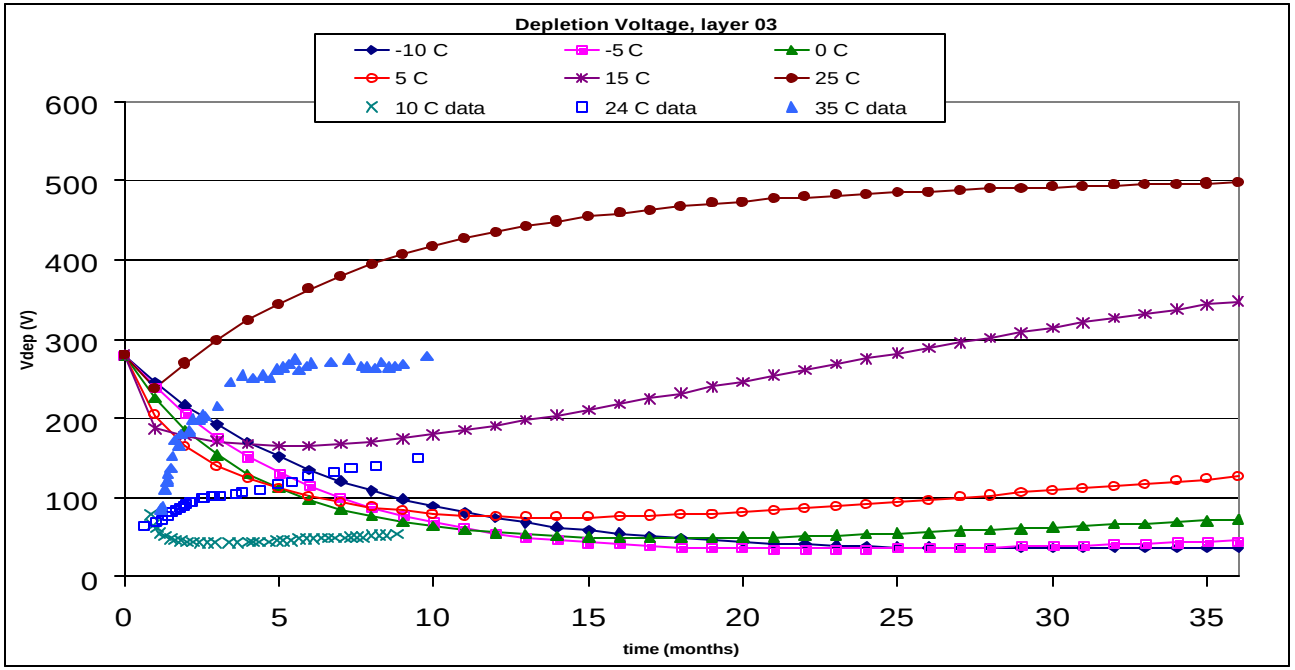
T(°C)	τ_S	τ_L
-10	403	41800
-5	168	19500
0	70.0	9140
5	29.2	4270
10	12.2	2000
15	5.07	935

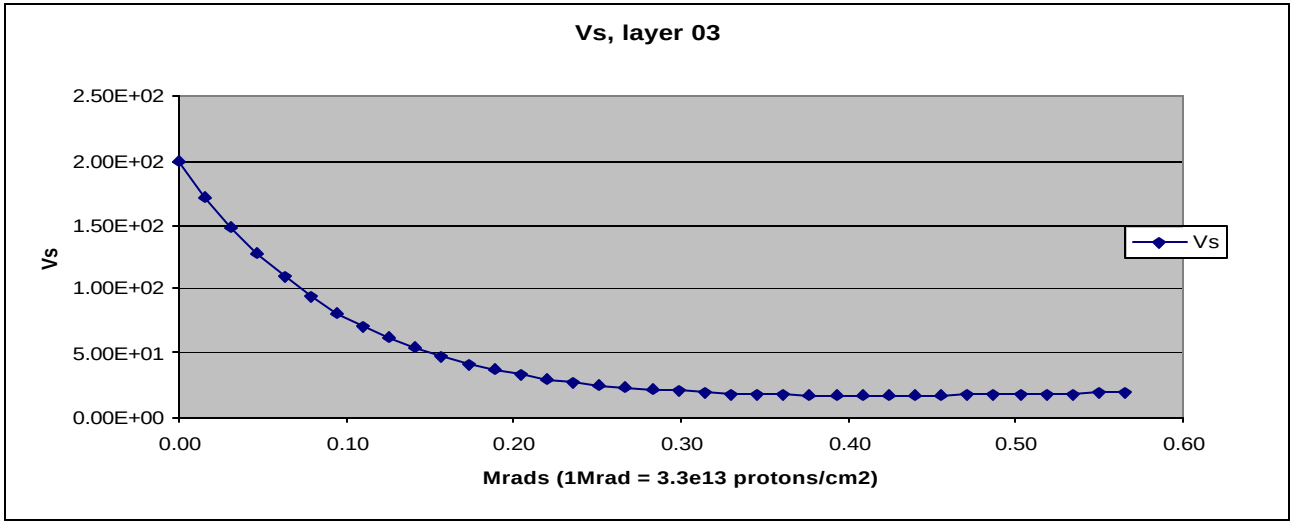
Depletion voltage at different temperatures, calculations.



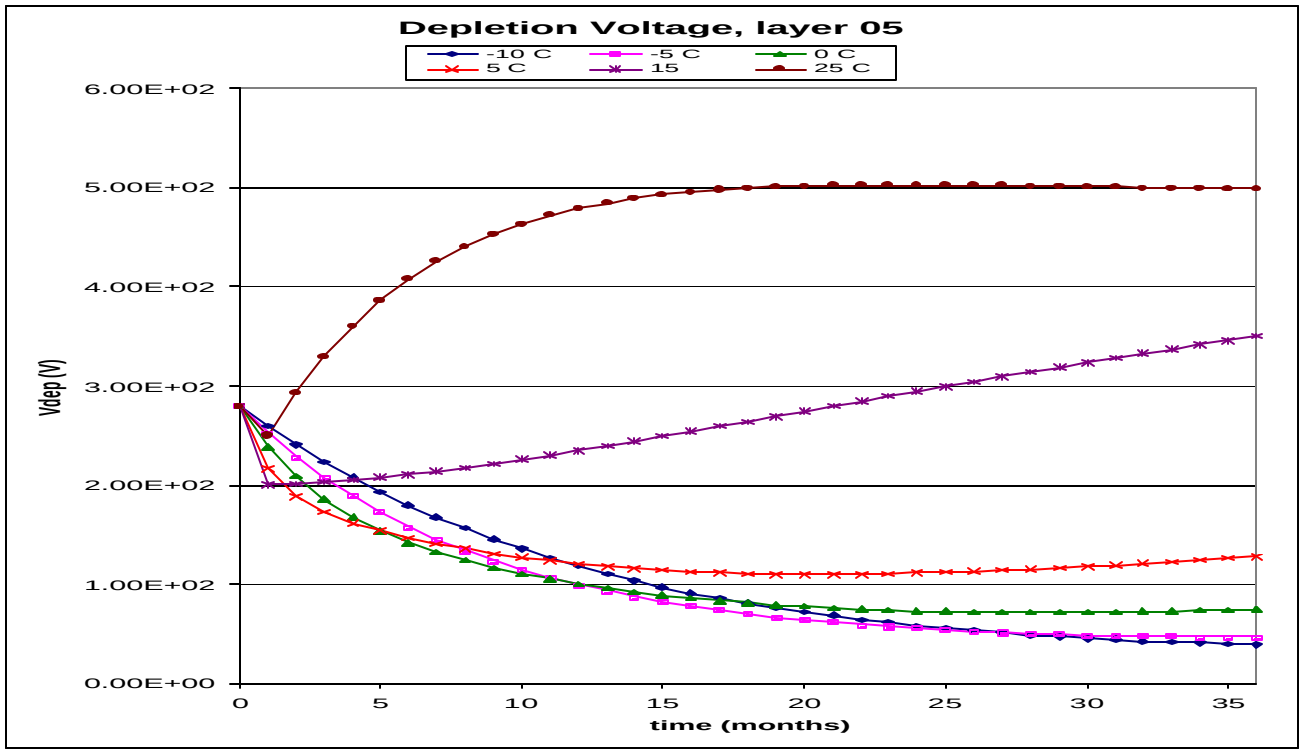


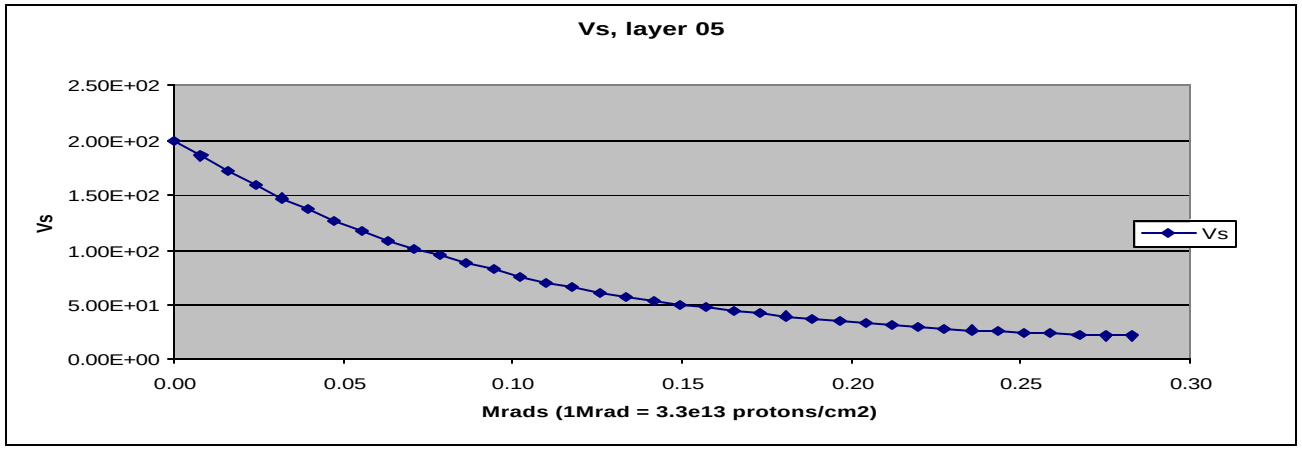
Depletion voltage at different temperatures, calculations.





Depletion voltage at different temperatures, calculations.





Parameters : before and after 15 MRad irradiation (Annealing--5days at 5°C and 4 days at room temperature).

Detector's ID	I_L(Ud)/cm2 before (+11 C)	$I_{L/cm2}$(Ud) after(-12 C)	Ud before	Ud after 15 MRad (+ 5 C)
Elma 236(ox)low	0.68 nA	22 μA	25 V	625 V
Elma 233(ox)low	0.68 nA	14 μA	28 V	650 V
Micron 1962 4-C (ox)	8.8 nA	18 μA	120 V	370 V
HAM.0144 No info	26.6 nA	20 μA	40 V	550 V
HAM.0077 No info	2.7 nA	18 μA	60 V	410 V
HAM.0134 No info	70 nA	24 μA	75 V	460 V
St 230W3D4 10 Mrad	0.5 nA	14 μA	125 V	280 V
Elma 6-2 (non. Ox.) 10 Mrad	3.3 nA	11.6μA	70 V	300 V

Table 1, 30 MRad

30 MRAD					30 MRAD							30 MRAD				
I ~ T^2 exp(-Eg/(kT)), Eg = 1.12ev, k = 8.614e-5 ev/K																
I2/I1 = (T2/T1)^2 * exp(-Eg/(2k*T2))/exp(-Eg/(2k*T1))																
Eg/(2k)=	6501.045															
		I at -12C =	720													
T = -10C						T = -5C						T = 0C				
d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-
15	29.97	1013.66	883.5	900.0		15	29.97	1039.33	1455.0	1155.0		15	29.97	1090.14	2354.4	1469.1
20	18.49	634.58	544.9	706.8		20	18.49	660.25	897.4	907.0		20	18.49	711.05	1452.0	1153.8
30	9.35	333.24	275.7	502.8		30	9.35	358.91	454.1	645.2		30	9.35	409.71	734.8	820.7
40	5.77	214.93	170.1	394.8		40	5.77	240.60	280.1	506.7		40	5.77	291.41	453.2	644.5
50	3.97	155.41	116.9	327.4		50	3.97	181.08	192.5	420.1		50	3.97	231.89	311.5	534.4
60	2.92	120.89	86.1	280.9		60	2.92	146.56	141.7	360.4		60	2.92	197.36	229.3	458.5
75	2.01	90.77	59.2	232.9		75	2.01	116.44	97.4	298.8		75	2.01	167.25	157.6	380.1
100	1.24	65.39	36.5	182.9		100	1.24	91.06	60.1	234.7		100	1.24	141.87	97.2	298.5
145	0.66	46.71	19.5	133.8		145	0.66	72.38	32.2	171.8		145	0.66	123.19	52.1	218.5
165	0.53	43.18	15.7	120.1		165	0.53	68.85	25.9	154.1		165	0.53	119.65	41.9	196.0
T = 5C						T = 10C						T = 20C				
d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-
15	29.97	1179.52	3746.6	1853.3		15	29.97	1306.19	5869.0	2319.6		15	29.97	1465.67	9665.0	2976.7
20	18.49	800.43	2310.7	1455.5		20	18.49	927.10	3619.6	1821.6		20	18.49	1086.59	5960.8	2337.7
30	9.35	499.09	1169.3	1035.3		30	9.35	625.76	1831.6	1295.8		30	9.35	785.25	3016.3	1662.9
40	5.77	380.79	721.1	813.1		40	5.77	507.46	1129.6	1017.6		40	5.77	666.94	1860.3	1305.9
50	3.97	321.27	495.7	674.1		50	3.97	447.94	776.5	843.7		50	3.97	607.43	1278.7	1082.7
60	2.92	286.75	364.9	578.4		60	2.92	413.41	571.6	723.9		60	2.92	572.90	941.3	929.0
75	2.01	256.63	250.8	479.5		75	2.01	383.30	392.9	600.2		75	2.01	542.78	647.0	770.2
100	1.24	231.25	154.7	376.6		100	1.24	357.92	242.3	471.3		100	1.24	517.41	399.1	604.9
145	0.66	212.57	82.9	275.6		145	0.66	339.24	129.8	345.0		145	0.66	498.73	213.8	442.7
165	0.53	209.04	66.7	247.3		165	0.53	335.70	104.5	309.5		165	0.53	495.19	172.1	397.2

Table 2, 20 MRad

20 MRAD					20 MRAD							20 MRAD			
T= -10 C					T = -5C						T = 0C				
Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-
19.98	677.90	883.5	900.0		15	19.98	693.52	1455.0	1155.0		15	19.98	729.37	2354.4	1469.1
12.32	425.18	363.3	577.1		20	12.32	440.79	598.2	740.6		20	12.32	476.65	968.0	942.0
6.24	224.29	183.8	410.5		30	6.24	239.90	302.7	526.8		30	6.24	275.76	489.8	670.1
3.85	145.42	113.4	322.4		40	3.85	161.03	186.7	413.7		40	3.85	196.89	302.1	526.3
2.64	105.74	77.9	267.3		50	2.64	121.35	128.3	343.0		50	2.64	157.21	207.7	436.3
1.95	82.72	57.4	229.3		60	1.95	98.33	94.5	294.3		60	1.95	134.19	152.9	374.4
1.34	62.65	39.4	190.1		75	1.34	78.26	64.9	244.0		75	1.34	114.11	105.1	310.4
0.83	45.78	24.3	149.3		100	0.83	61.39	40.1	191.6		100	0.83	97.25	64.8	243.7
0.44	35.60	13.0	109.3		145	0.44	51.21	21.5	140.2		145	0.44	87.07	34.7	178.4
0.36	36.15	10.5	98.0		165	0.36	51.76	17.3	125.8		165	0.36	87.62	27.9	160.0
T=+5 C					T = 10C						T = 20C				
Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-
19.98	796.69	3746.6	1853.3		15	19.98	905.85	5869.0	2319.6		15	19.98	1121.59	9665.0	2976.7
12.32	543.97	1540.5	1188.4		20	12.32	653.12	2413.1	1487.4		20	12.32	868.86	3973.9	1908.7
6.24	343.07	779.5	845.4		30	6.24	452.23	1221.1	1058.0		30	6.24	667.97	2010.9	1357.8
3.85	264.20	480.8	663.9		40	3.85	373.36	753.1	830.9		40	3.85	589.10	1240.2	1066.3
2.64	224.52	330.5	550.4		50	2.64	333.68	517.6	688.9		50	2.64	549.42	852.5	884.0
1.95	201.51	243.3	472.3		60	1.95	310.66	381.1	591.1		60	1.95	526.41	627.6	758.5
1.34	181.43	167.2	391.5		75	1.34	290.59	261.9	490.0		75	1.34	506.33	431.4	628.9
0.83	164.57	103.1	307.5		100	0.83	273.72	161.5	384.8		100	0.83	489.47	266.0	493.9
0.44	154.39	55.2	225.0		145	0.44	263.54	86.5	281.7		145	0.44	479.28	142.5	361.5
0.36	154.93	44.5	201.9		165	0.36	264.09	69.7	252.7		165	0.36	479.83	114.7	324.3

Table 3, 15 MRad

15 MRAD					15 MRAD							15 MRAD				
T = -10C						T = -5C						T = 0C				
d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-
15	14.99	512.28	883.5	900.0		15	14.99	520.49	1455.0	1155.0		15	14.99	548.05	2354.4	1469.1
20	9.24	322.74	272.5	499.8		20	9.24	330.95	448.7	641.4		20	9.24	358.51	726.0	815.8
30	4.68	172.07	137.9	355.5		30	4.68	180.28	227.0	456.2		30	4.68	207.84	367.4	580.3
40	2.88	112.91	85.0	279.2		40	2.88	121.12	140.0	358.3		40	2.88	148.68	226.6	455.8
50	1.98	83.16	58.4	231.5		50	1.98	91.36	96.3	297.1		50	1.98	118.93	155.7	377.9
60	1.46	65.89	43.0	198.6		60	1.46	74.10	70.9	254.9		60	1.46	101.66	114.7	324.2
75	1.00	50.84	29.6	164.7		75	1.00	59.05	48.7	211.3		75	1.00	86.61	78.8	268.8
100	0.62	38.58	18.2	129.3		100	0.62	46.79	30.0	165.9		100	0.62	74.35	48.6	211.1
145	0.33	36.18	9.8	94.6		145	0.33	44.39	16.1	121.5		145	0.33	71.95	26.0	154.5
165	0.27	40.78	7.9	84.9		165	0.27	48.99	13.0	109.0		165	0.27	76.55	21.0	138.6
T = 5C						T = 10C						T = 20C				
d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-		d(mm)	Mrad	Vdep(V)	I_L/strip(nA)	ENC_L e-
15	14.99	601.72	3746.6	1853.3		15	14.99	694.91	5869.0	2319.6		15	14.99	933.96	9665.0	2976.7
20	9.24	412.18	1155.4	1029.2		20	9.24	505.37	1809.8	1288.1		20	9.24	744.42	2980.4	1653.0
30	4.68	261.51	584.6	732.1		30	4.68	354.70	915.8	916.3		30	4.68	593.75	1508.1	1175.8
40	2.88	202.36	360.6	574.9		40	2.88	295.54	564.8	719.6		40	2.88	534.60	930.1	923.4
50	1.98	172.60	247.8	476.7		50	1.98	265.78	388.2	596.6		50	1.98	504.84	639.3	765.6
60	1.46	155.34	182.5	409.0		60	1.46	248.52	285.8	511.9		60	1.46	487.57	470.7	656.9
75	1.00	140.29	125.4	339.1		75	1.00	233.47	196.5	424.4		75	1.00	472.53	323.5	544.6
100	0.62	128.03	77.3	266.3		100	0.62	221.21	121.2	333.3		100	0.62	460.26	199.5	427.7
145	0.33	125.62	41.4	194.9		145	0.33	218.81	64.9	243.9		145	0.33	457.86	106.9	313.0
165	0.27	130.23	33.3	174.9		165	0.27	223.41	52.2	218.8		165	0.27	462.47	86.0	280.8