Single Event Transients in LM124 operational amplifier Laser test report

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1 Introduction

With the Single Event Transients (SET) produced by linear devices becoming more significant, a low cost conservative test methodology is needed to characterize these effects. To this end this study has been undertaken on the LM124 operational amplifier.

The objective of this study is to collect a sufficient amount of data under many operational conditions in an attempt to understand the SET generation and characteristics. This information will then be utilized in the development of this test methodology for operational amplifiers and possibly other linear devices.

This report present the complementary results obtained during the laser tests at NRL on May 10 and May 15, 2001. The objective of this test was to make an analysis of the different transient pulse shapes obtained.

2 Tested Devices

The tested devices are described in Table 1.

Type	**Manufacturer**	**Function**
LM124	NATIONAL SEMICONDUCTORS	Operational Amplifier

Table 1 : description of the tested device.

3 Irradiation conditions

The laser irradiations have been performed in the NRL laser test facility. The laser is a dye laser pumped by by a YLF laser. The main features of this facility are presented in Table 2. The energy of the laser pulse could be varied with neutral density filters. During the experiments the laser pulse rate was 100Hz.

Wavelength	590 nm
1/e penetration depth in Si	2 µm
Maximum energy	0.5 nJ
Pulse duration	3 ps
Spot size	

Table 2: main characteristics of the NRL laser test facility

4 Identification of LM124 sensitive areas

A simplified shematics is given in Figure 1. The different sensitive areas are identified in the picture in Figure 2 and the correspondence between these regions and the electrical schematics are given in the Table 3.

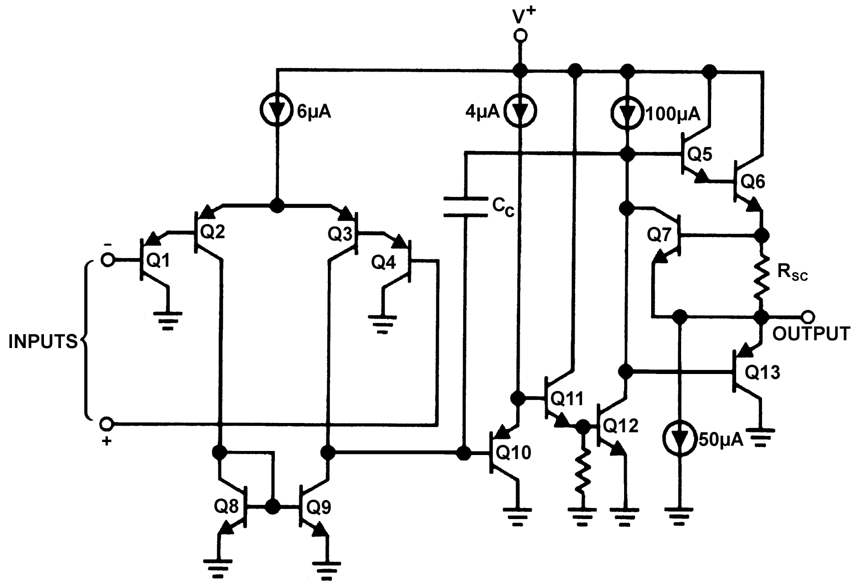

Figure 1: LM124 simplified circuit schematics

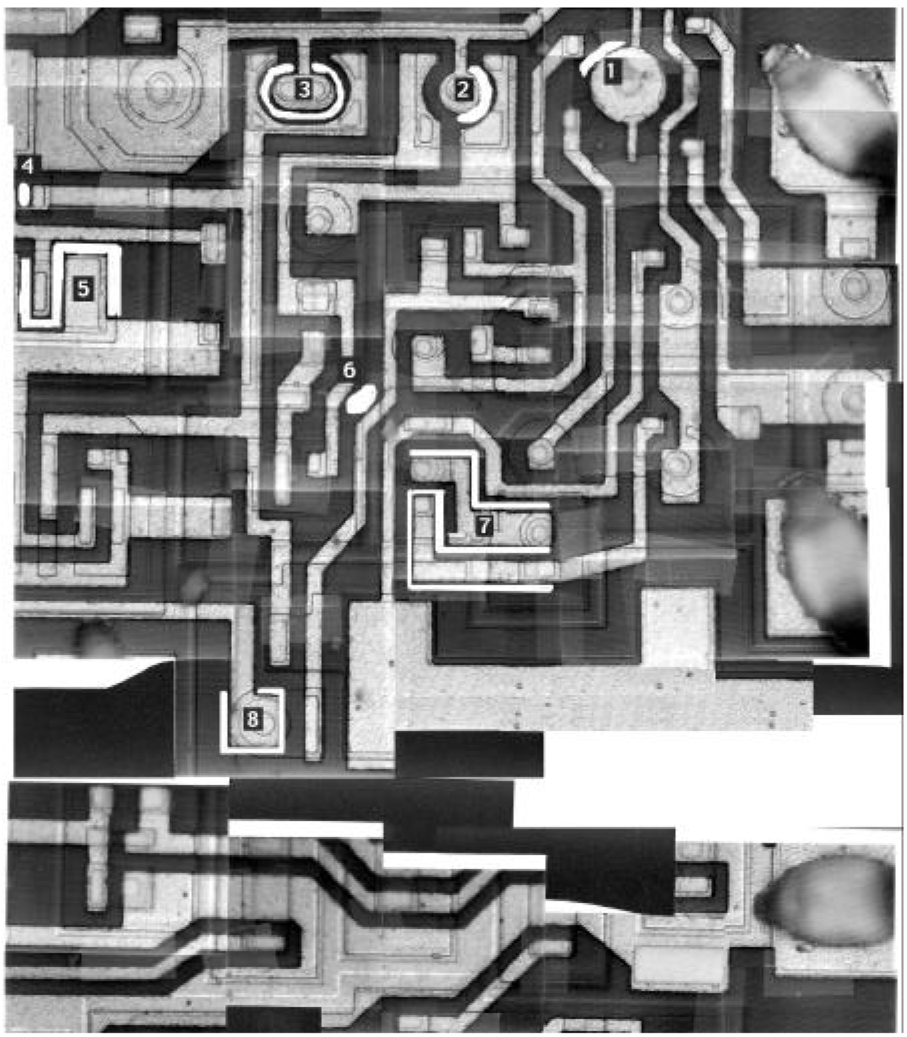

Figure 2: LM124 layout and identification of sensitive regions.

Sensitive region	Manufacturer designation
1	4 µA current source
2	Q11 collector?
3	100 µA current source
4	Q5
5	Q6
6	50 µA current source?
7	Q8 and Q9
8	Q12

Table 3: identification of sensitive areas

5 Test set-up and bias condition

Four different applications conditions have been investigated:

- Voltage Comparator
- Non Inverting Gain amplifier1 (Gain=101)
- Non Inverting Gain amplifier2 (Gain=11)
- Voltage Follower

The bias conditions are shown on Figures 3 to 7. The output of the Device Under Test (DUT) is monitored with an oscilloscope. As soon as the DUT output goes under (or above) a given trigger level (generally 50 or 100 mV), a SET is counted. SET frames are stored on a PC.

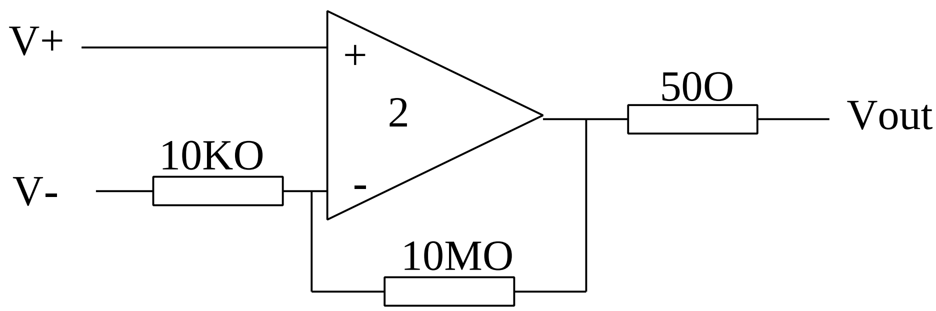

Figure 3: Voltage Comparator bias conditions.

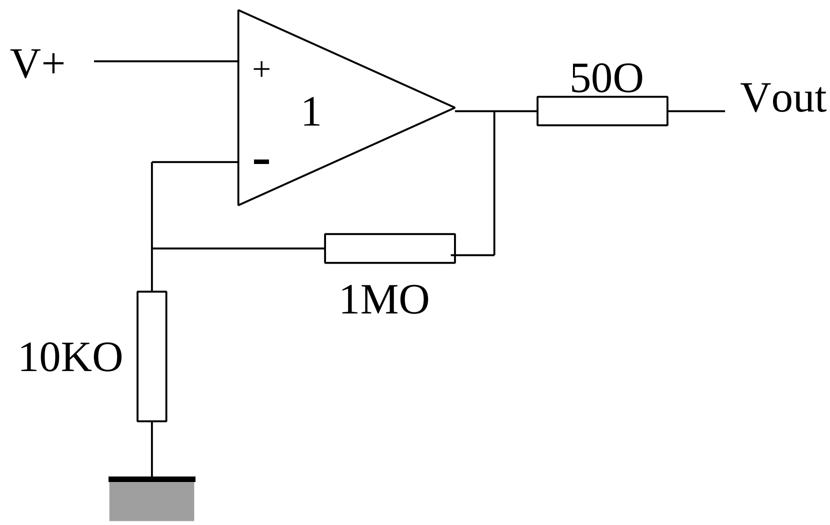

Figure 4: Non Inverting Gain 1 bias conditions.

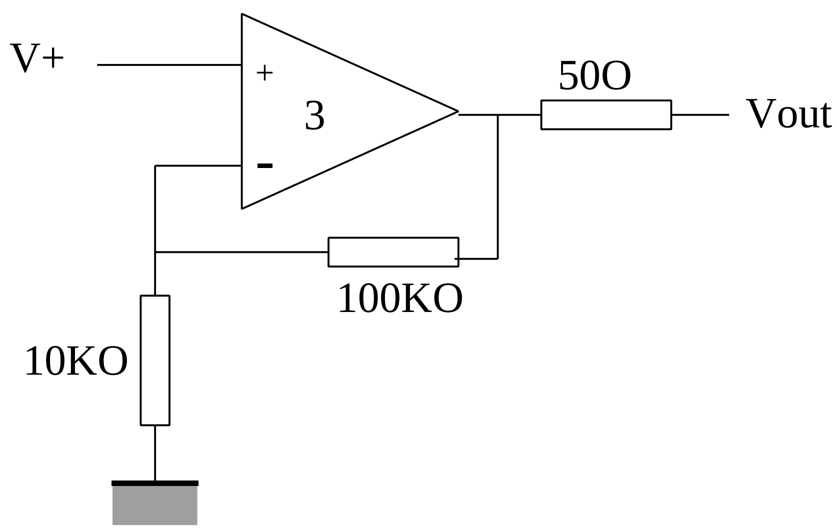

Figure 5: Non Inverting Gain 2 bias conditions.

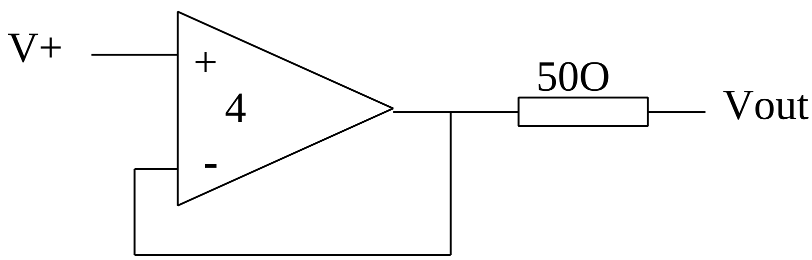

Figure 6: Voltage Follower bias conditions

6 Analysis of transient pulse shape on the comparator application

6.1 Bias conditions

A subset of the bias conditions investigated during Heavy ions experiments has been used. These test conditions are given in Table 4.

Power Supply		**Input bias**			**Output (V)**
Vcc+ (V)	**Vcc- (V)**	d**Vi(V)**	**V+(V)**	**V-(V)**	
15	**-15**	**0.05**	**0.05**	**0**	**14**
		0.1	0.1	0	
			5.1	5	
			10.1	10	
		0.6	0.6	0	
			5.6	5	
		1	1	0	
		-0.05	0	0.05	-9.5
5	0	0.1	3	2.9	4
		-0.1	2.9	3	0

Table 4: bias conditions investigated for the comparator application.

6.2 Test results

Among the eight sensitive locations irradiated, 5 have been shown as sensitive regions for the comparator application. Locations 8, 4/5 and 1 are the most sensitive regions. Then locations 2 and 6 have a significantly lower sensitivity. Locations 3 and 7 are not sensitive in this application mode.

<u>Location 8</u>

With a laser energy as low as 21 pJ, for Vcc=+/-15, V+ = 0.05V and V- = 0V, we obtained large going down pulses as shown in Figure 7 (Voltage amplitude=4.5V, FWMH = 10 µs). When the laser energy is increased to 64 pJ, the pulses have the same shape, but they are significantly much larger (Voltage amplitude=9V, FWMH= 40 µs) as shown in Figure 8.

When we change the input conditions, we do not see a significant change in the transient shape.

When we change the power supply voltage to Vcc = +5/0 V, the pulses are smaller in voltage amplitude and shorter in duration for V+ = 3V, V- = 2.9V:
- 21pJ laser energy : Voltage amplitude = 1.5V, FWMH = 5 µs (see Figure 9)
- 64pJ laser energy : Voltage amplitude = 5V (down to the 0V Vcc rail), FWMH = 12 µs (see Figure 10)

For Vcc = +5/0V, V+ = 2.9V and V- = 3V (negative differential input voltage), no event has been observed for the two laser energies.

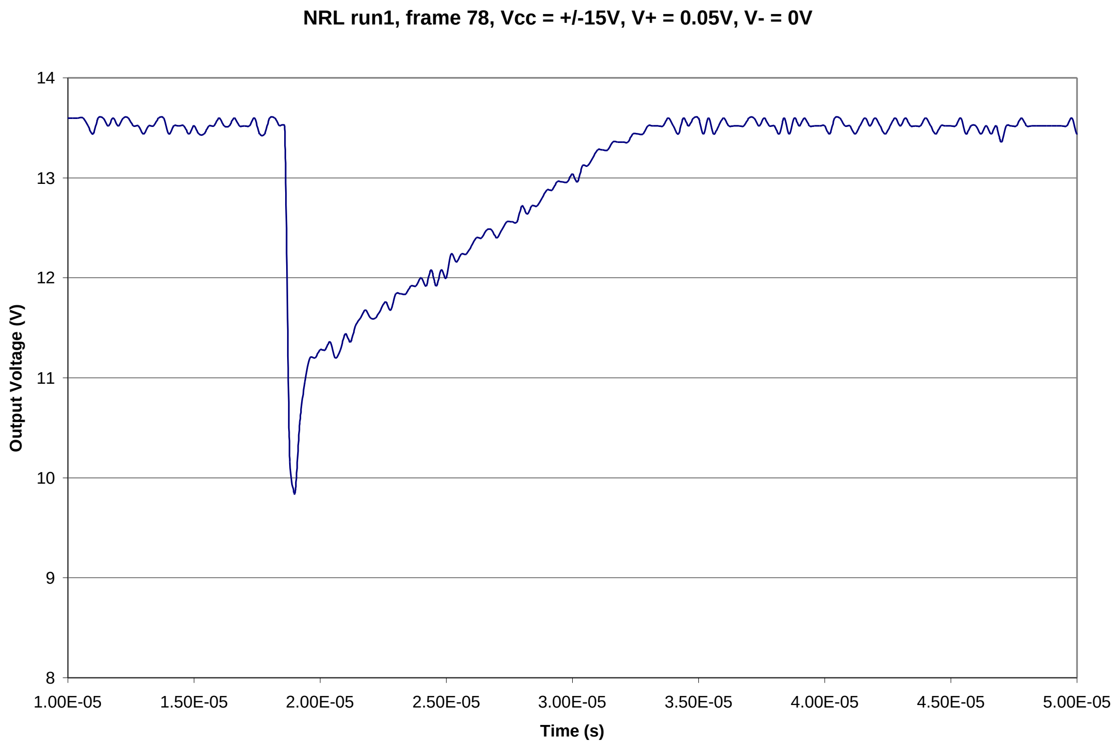

Figure 7: LM124, comparator application, typical pulse shape observed on location 8 for a laser energy =21 pJ.

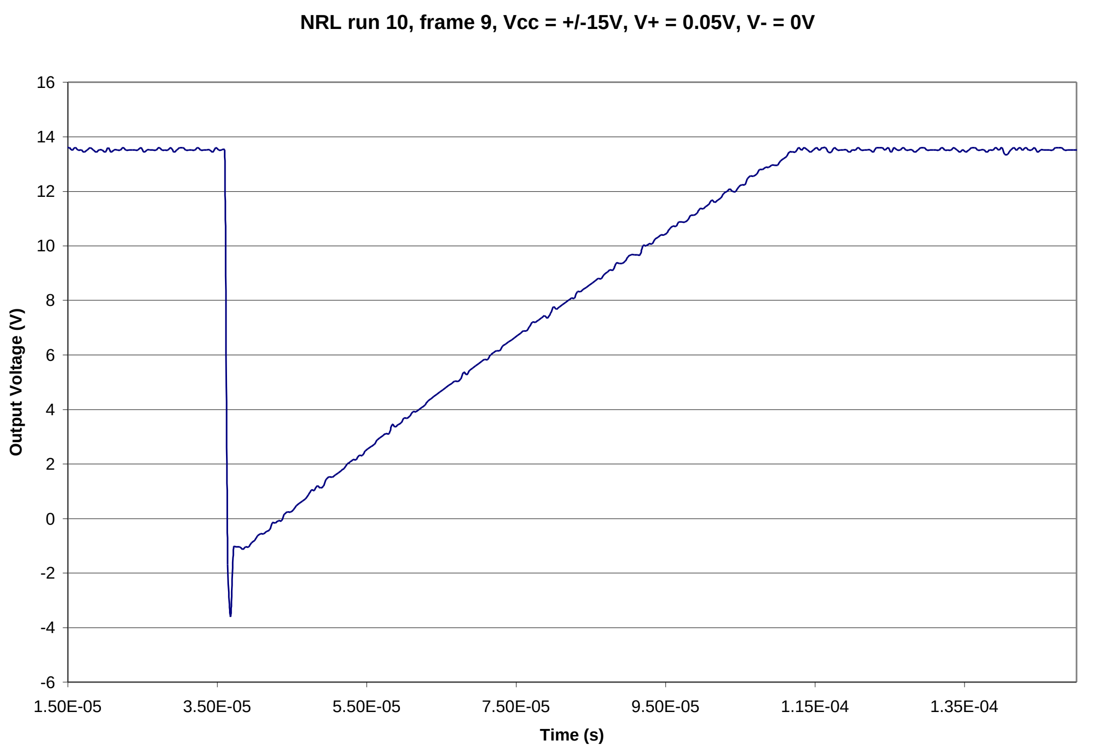

Figure 8: LM124, comparator application, typical pulse shape observed on location 8 for a laser energy = 64 pJ.

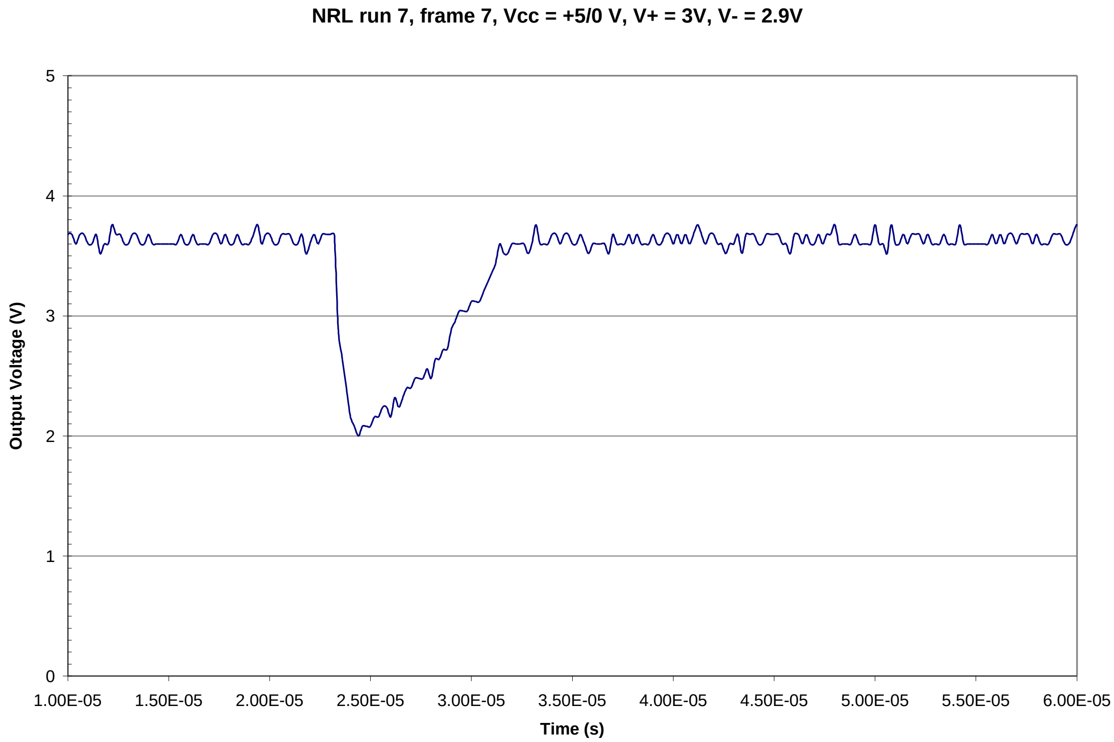

Figure 9: LM124, comparator application, typical pulse shape observed on location 8 for a laser energy = 21 pJ.

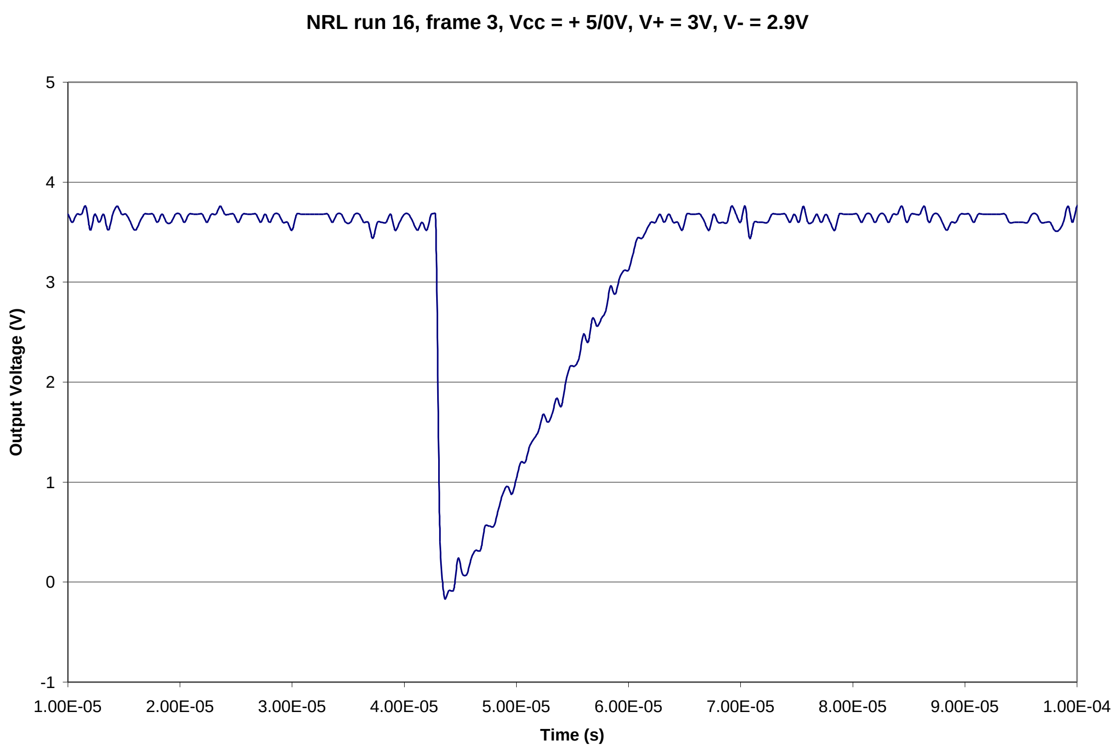

Figure 10: LM124, comparator application, typical pulse shape observed on location 8 for a laser energy = 64 pJ.

Location 4/5

With a laser energy of 64 pJ, for Vcc=+/-15, V+ = 0.05V and V- = 0V, we obtained small positive going pulses (up to + Vcc rail) as shown in Figure 11 (Voltage amplitude=2V, FWMH = 250 ns). When the laser energy is increased to 643 pJ, the pulses saturate as they reach the +Vcc rail (Voltage amplitude=2.2V, FWMH= 750 ns) as shown in Figure 12.

When we change the input conditions, we do not see a significant change in the pulse shape.

When we change the power supply voltage to Vcc = +5/0 V, the pulses have a similar shape for V+ = 3V, V- = 2.9V and a 64 pJ laser energy (Voltage amplitude = 0.8V (to +Vcc rail), FWMH = 350 ns) as shown in Figure 13.

For Vcc = +5/0V, V+ = 2.9V and V- = 3V (negative differential input voltage), no event has been observed for the 64 pJ laser energy.

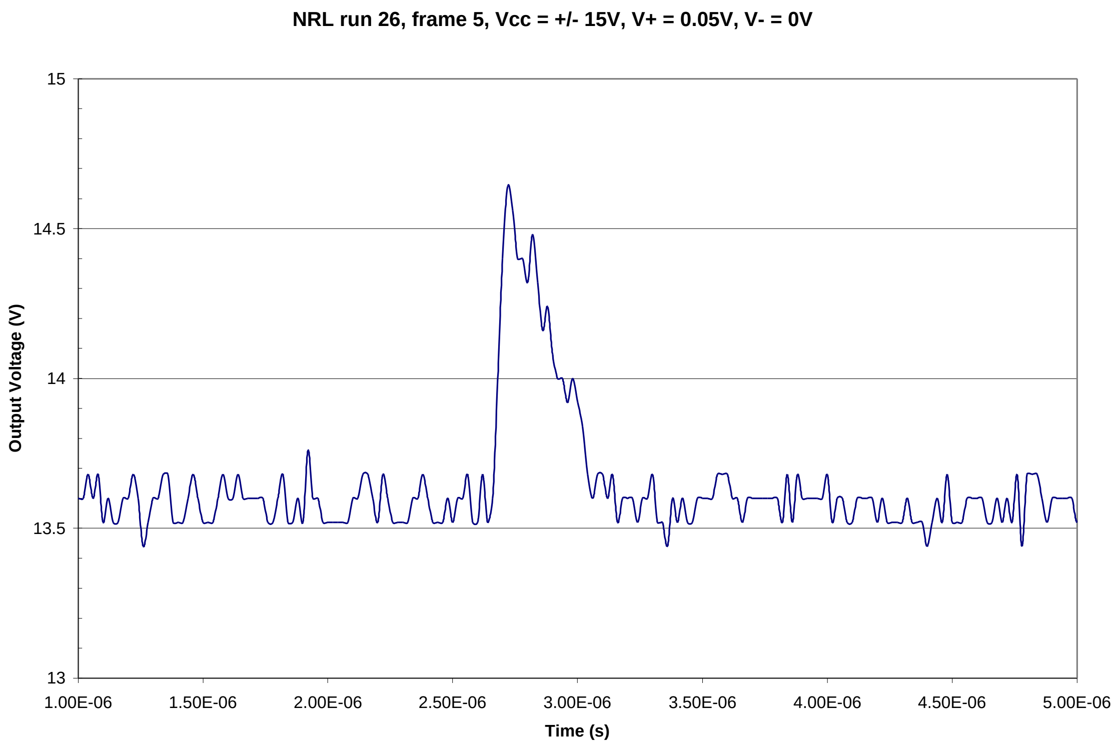

Figure 11: LM124, comparator application, typical pulse shape observed on location 4/5 for a laser energy = 64 pJ.

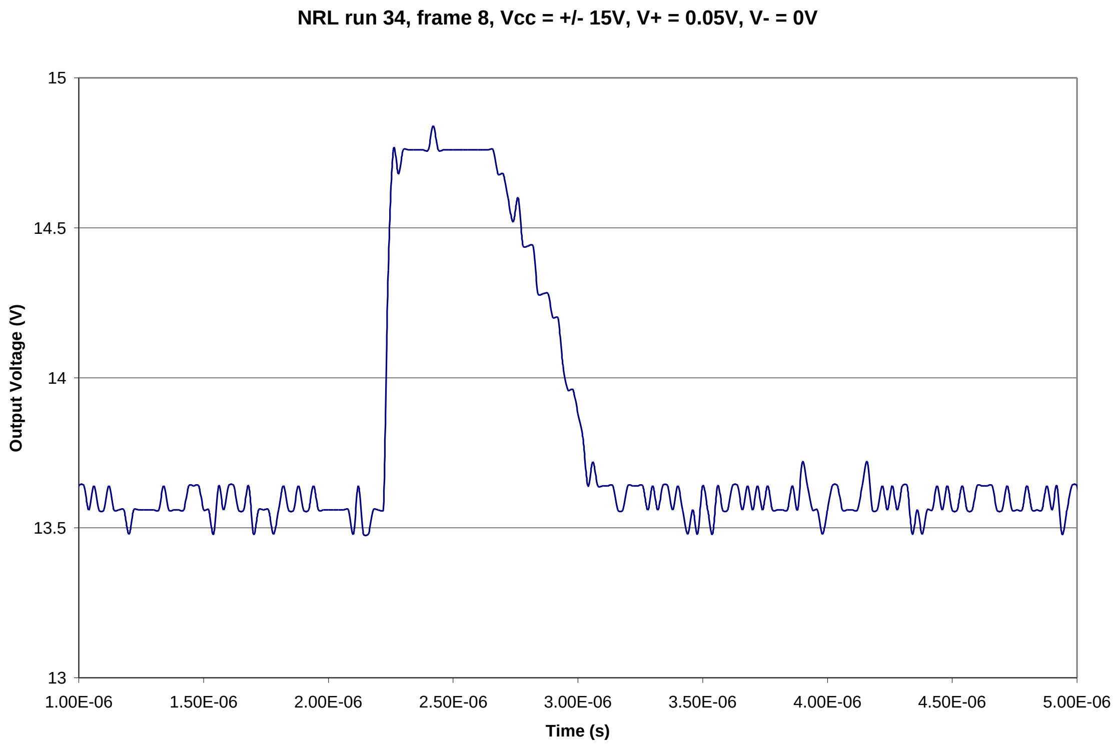

Figure 12: LM124, comparator application, typical pulse shape observed on location 4/5 for a laser energy = 643 pJ.

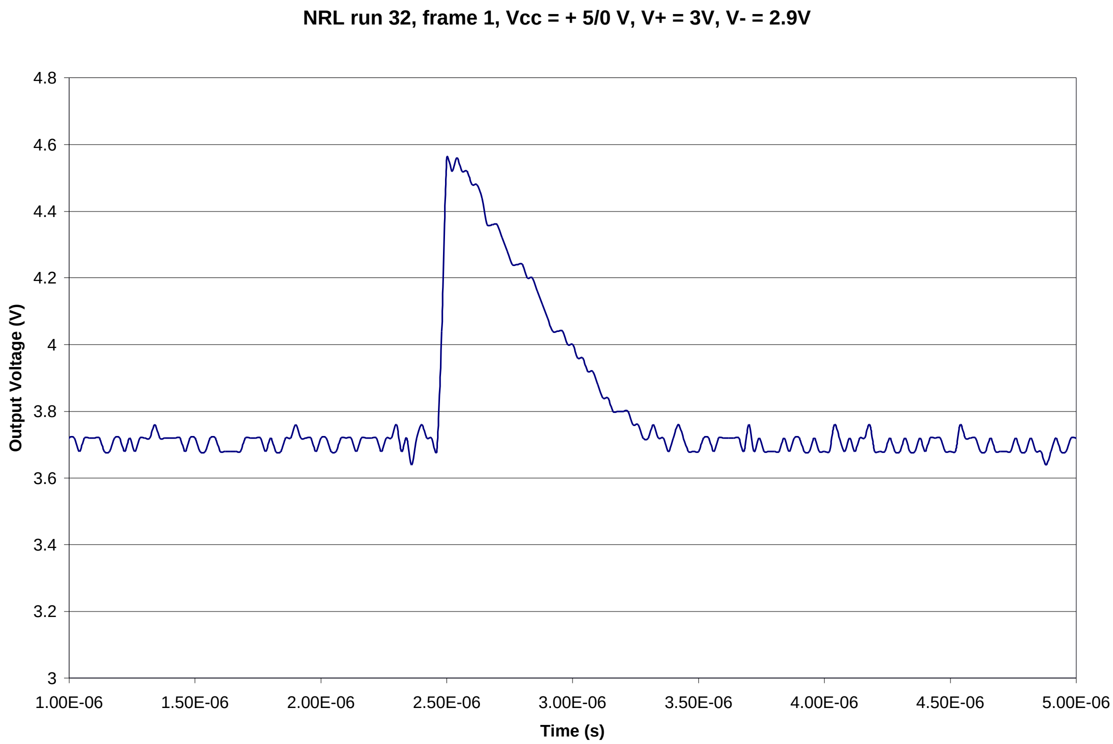

Figure 12: LM124, comparator application, typical pulse shape observed on location 4/5 for a laser energy = 64 pJ.

Location 1

With a laser energy of 129 pJ, for Vcc=+/-15, V+ = 0.05V and V- = 0V, we obtained large negative going pulses as shown in Figure 13 (Voltage amplitude=7V, FWMH = 10 µs). When the laser energy is increased to 214 pJ, the pulses have the same shape, but they are significantly much larger (Voltage amplitude=17V, FWMH= 40 µs) as shown in Figure 14.

When we change the input conditions, we do not see a significant change in the pulse shape.

When we change the power supply voltage to Vcc= +5/0 V, the pulses are smaller in voltage amplitude and shorter in duration for V+ = 3V, V- = 2.9V and a 129 pJ laser energy (Voltage amplitude= 1V, FWMH = 5 µs) as shown in Figure 15.

For Vcc = +5/0V, V+ = 2.9V and V- = 3V (negative differential input voltage), no event has been observed for the 129 pJ laser energy.

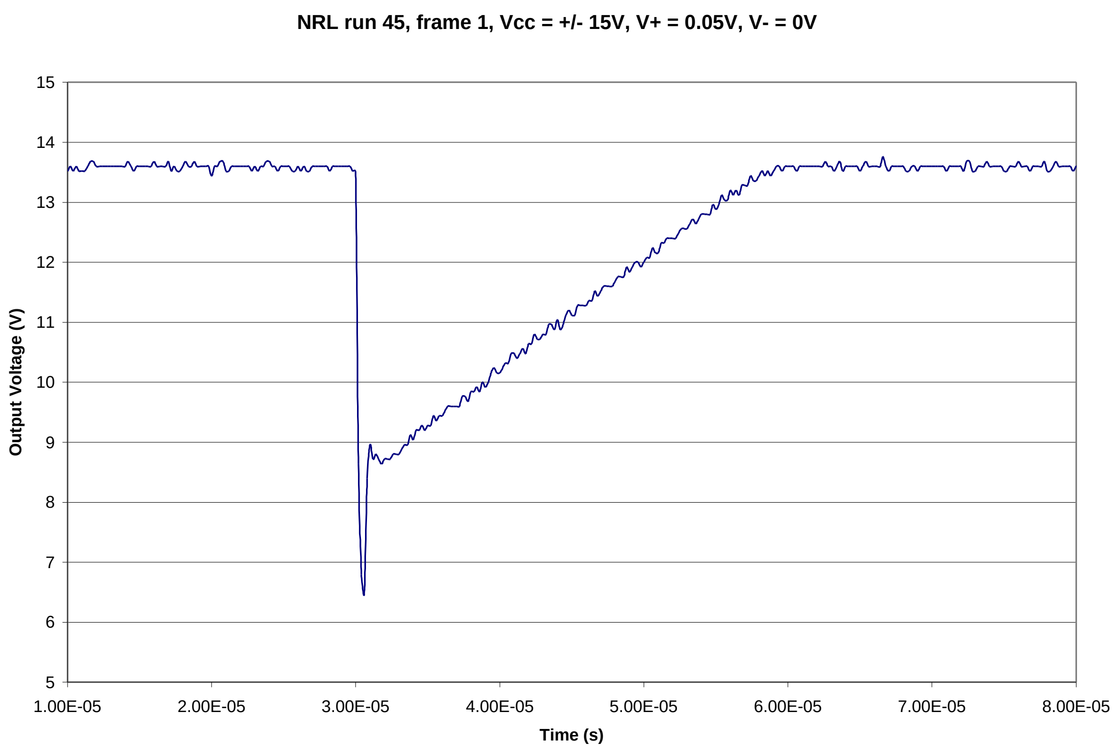

Figure 13: LM124, comparator application, typical pulse shape observed on location 1 for a laser energy of 129 pJ.

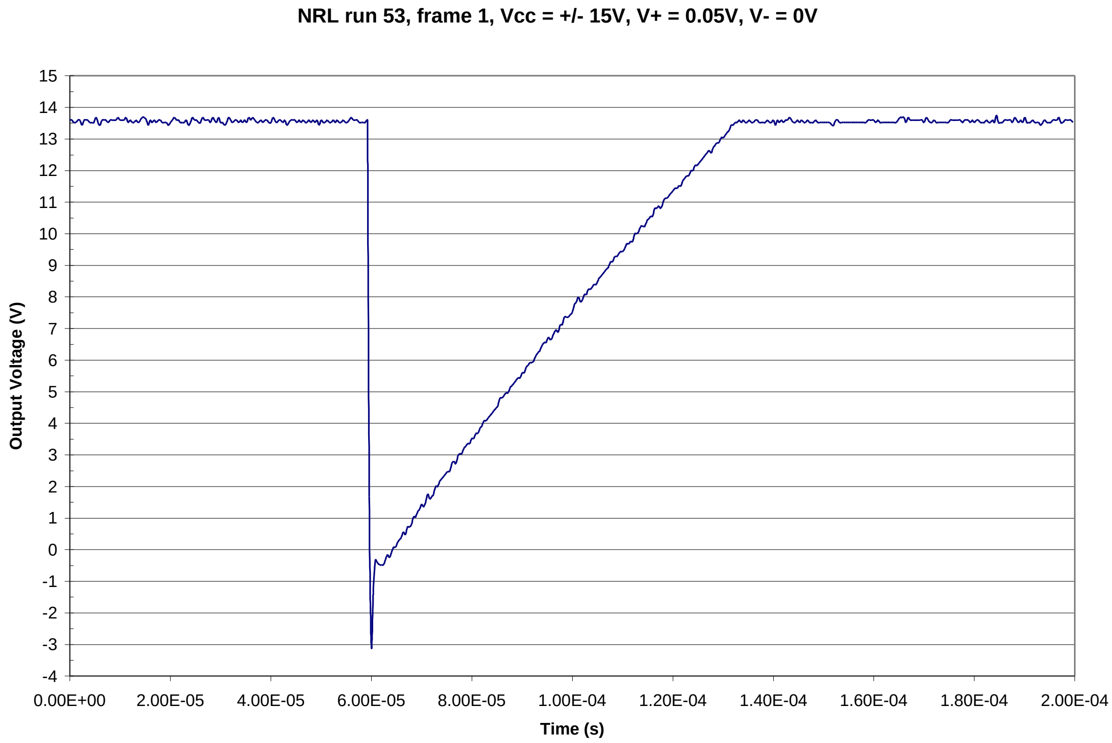

Figure 13: LM124, comparator application, typical pulse shape observed on location 1 for a laser energy of 214 pJ.

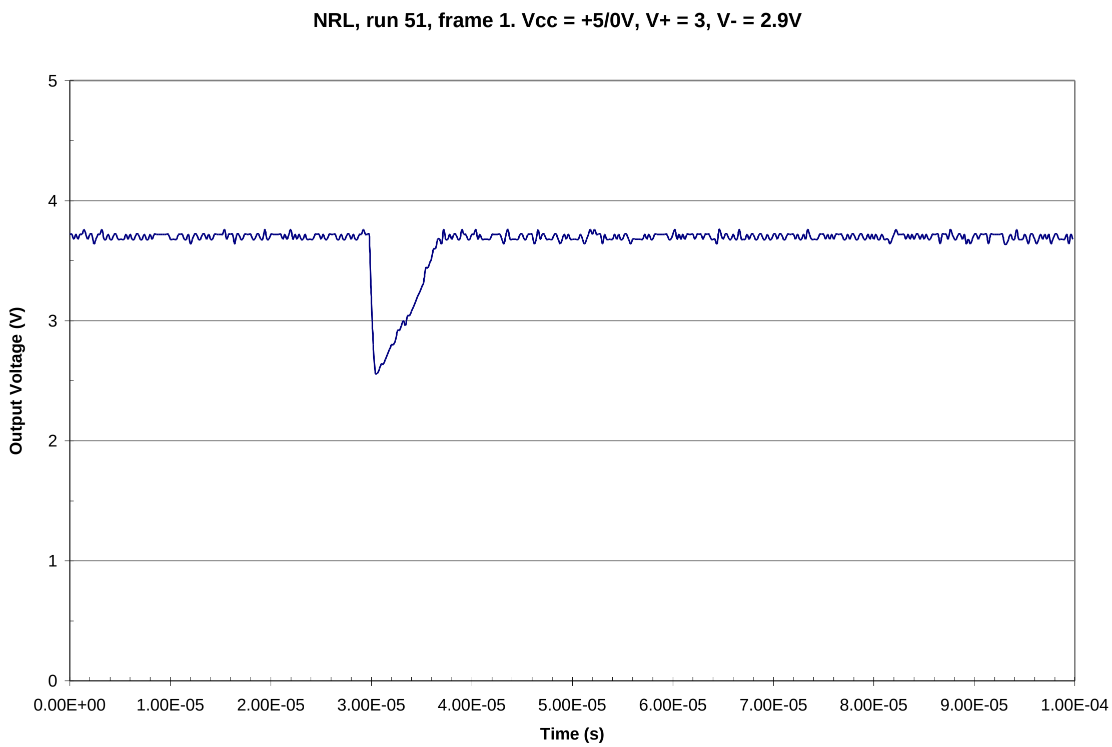

Figure 14: LM124, comparator application, typical pulse shape observed on location 1 for a laser energy of 129 pJ.

Location 2

With a laser energy of 536 pJ, for Vcc=+/-15, V+ = 0.05V and V- = 0V, we obtained large negative going pulses (Voltage amplitude=14V, FWMH = 24 µs).

When we change the input conditions, we do not see a significant change in the pulse shape. A typical pulse shape is shown in Figure 15.

When we change the power supply voltage to Vcc= +5/0 V, the behavior is completely different for V+ = 3V, V- = 2.9V :

- 536 pJ laser energy : small positive going pulse (Voltage amplitude= 0.4V (up to +Vccrail), FWMH = 400 ns) as shown in Figure 16.
- 1607 pJ laser energy : bipolar pulse (going down and then going up), (negative going component: Voltage amplitude= 0.5V, FWMH = 400ns; positive going component: Voltage amplitude= 0.5V, FWMH = 400ns) as shown in Figure 17.

For Vcc = +5/0V, V+ = 2.9V and V- = 3V (negative differential input voltage), no event has been observed for the 536 pJ laser energy.

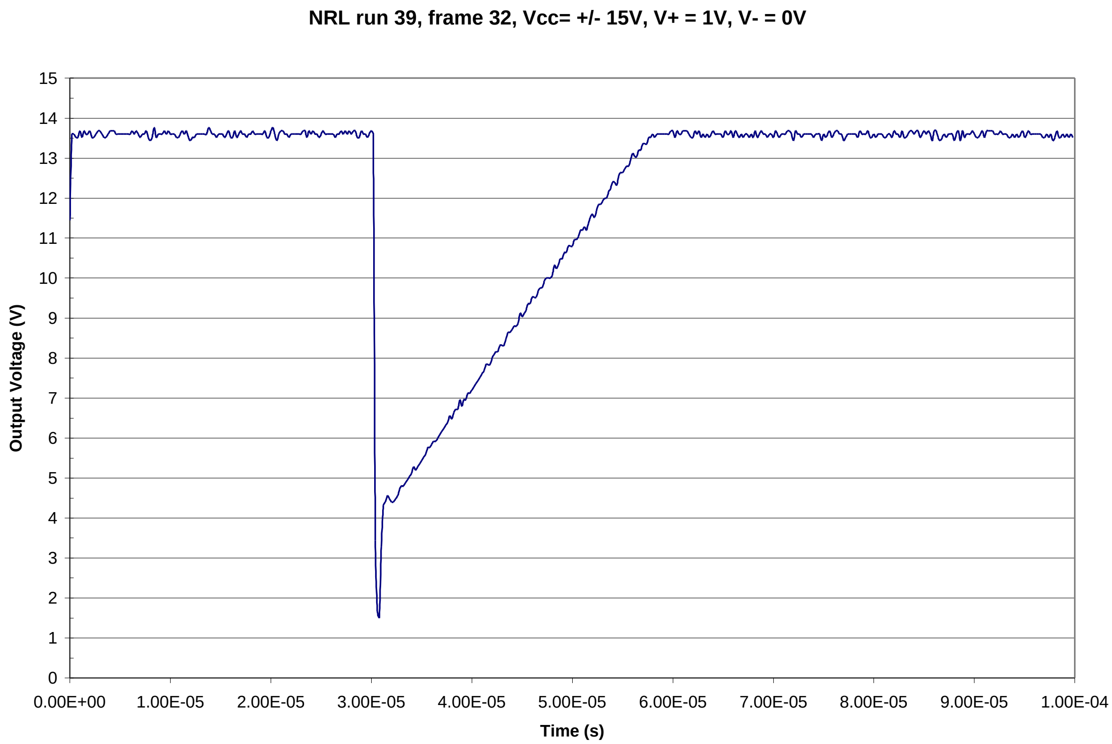

Figure 15: LM124, comparator application, typical pulse shape observed on location 2 for a laser energy of 536 pJ.

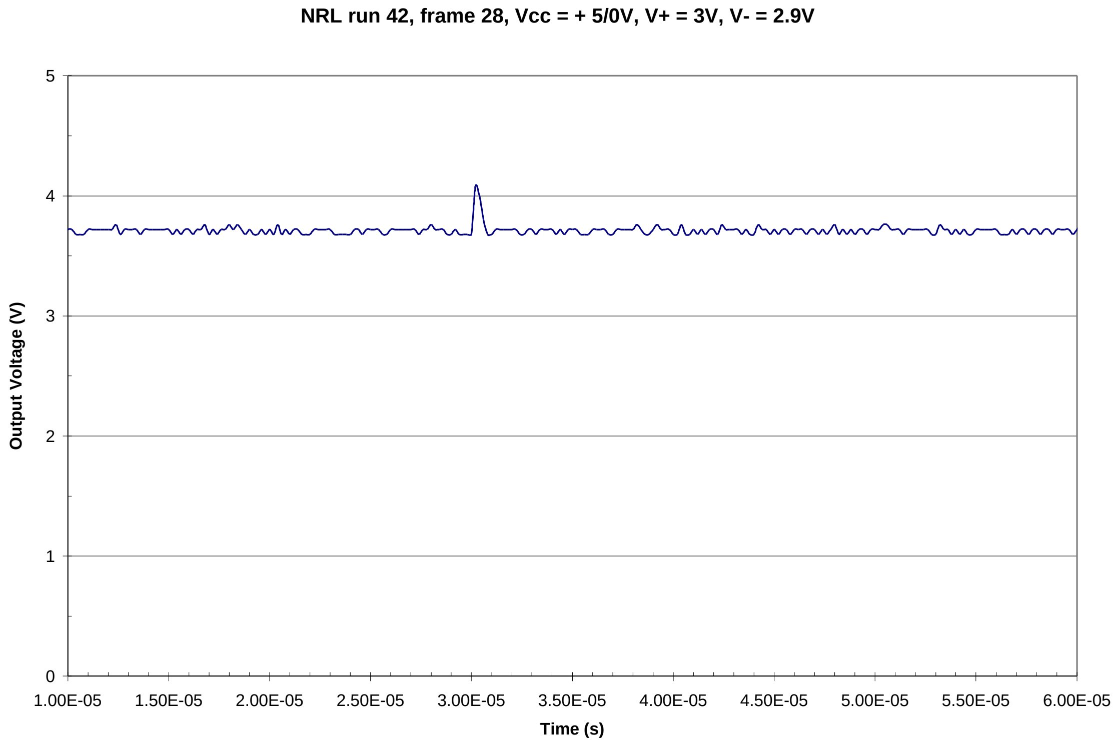

Figure 16: LM124, comparator application, typical pulse shape observed on location 2 for a laser energy of 536 pJ.

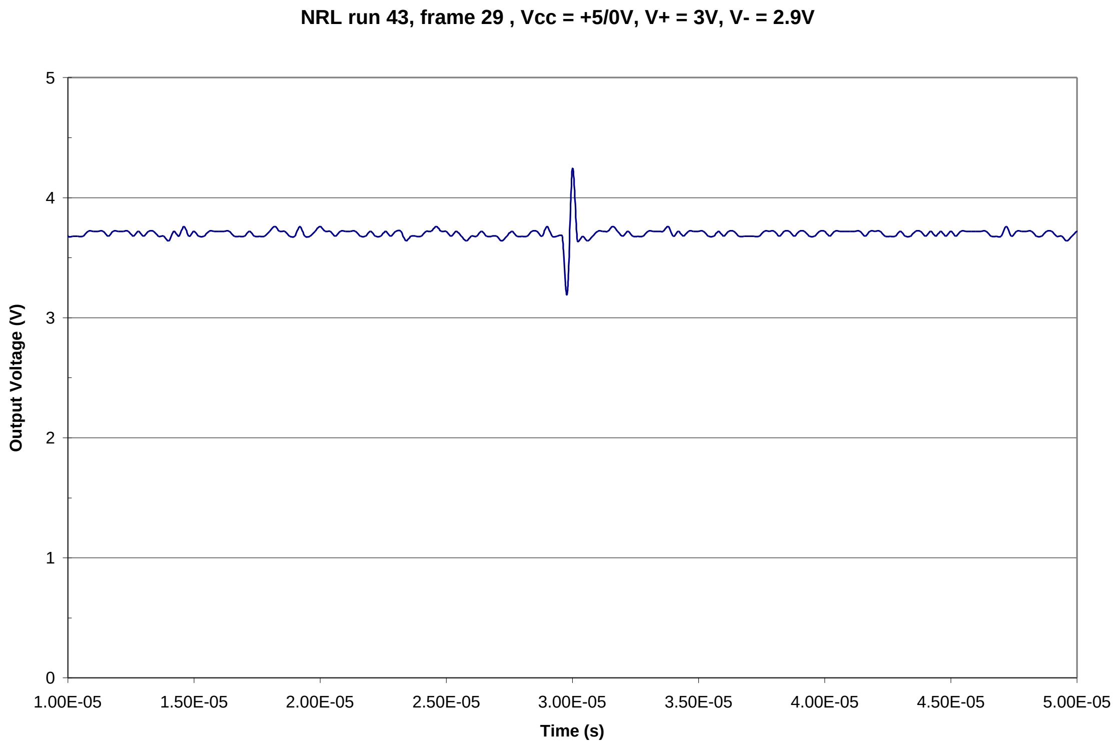

Figure 17: LM124, comparator application, typical pulse shape observed on location 2 for a laser energy of 1607 pJ.

Location 6

With a laser energy of 1714 pJ, for Vcc=+/-15, V+ = 0.05V and V- = 0V, we obtained small positive going pulses (Voltage amplitude=1V (up to +Vcc rail), FWMH = 300 ns). For some pulses, the pulse is bipolar with a very short negative going component. A typical transient is shown in Figure 18.

When we change the input conditions, we do not see a significant change in the pulse shape.

When we change the power supply voltage to Vcc= +5/0 V, the pulse shape is similar for V+ = 3V, V- = 2.9V as shown in Figure 19.

For Vcc = +5/0V, V+ = 2.9V and V- = 3V (negative differential input voltage), small negative going pulses have been observed (Voltage amplitude = 750 mV, FWMH = 1 µs) as shown in Figure 20.

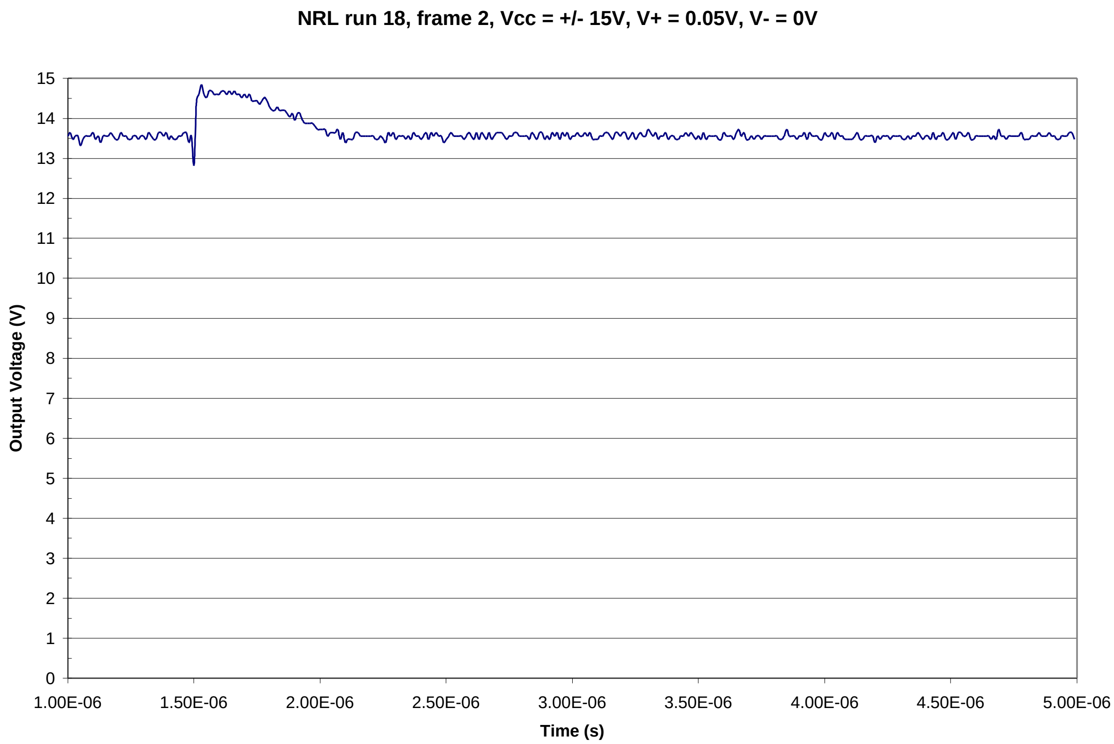

Figure 18: LM124, comparator application, typical pulse shape observed on location 6 for a laser energy of 1714 pJ.

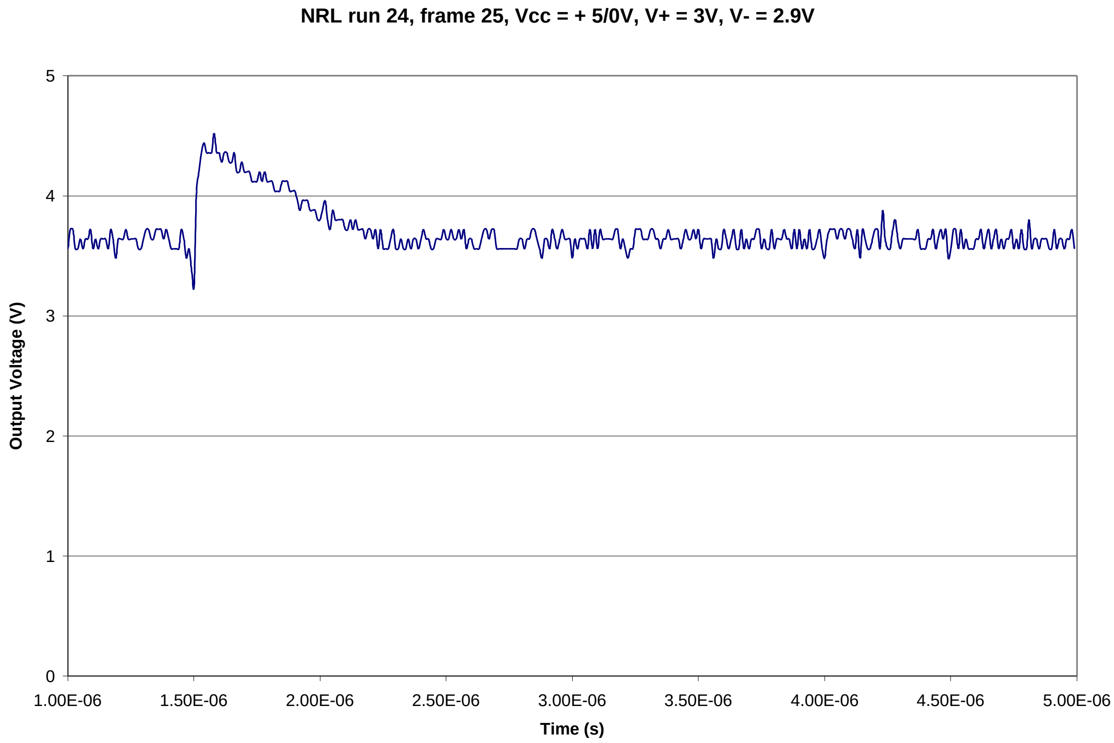

Figure 19: LM124, comparator application, typical pulse shape observed on location 6 for a laser energy of 1714 pJ.

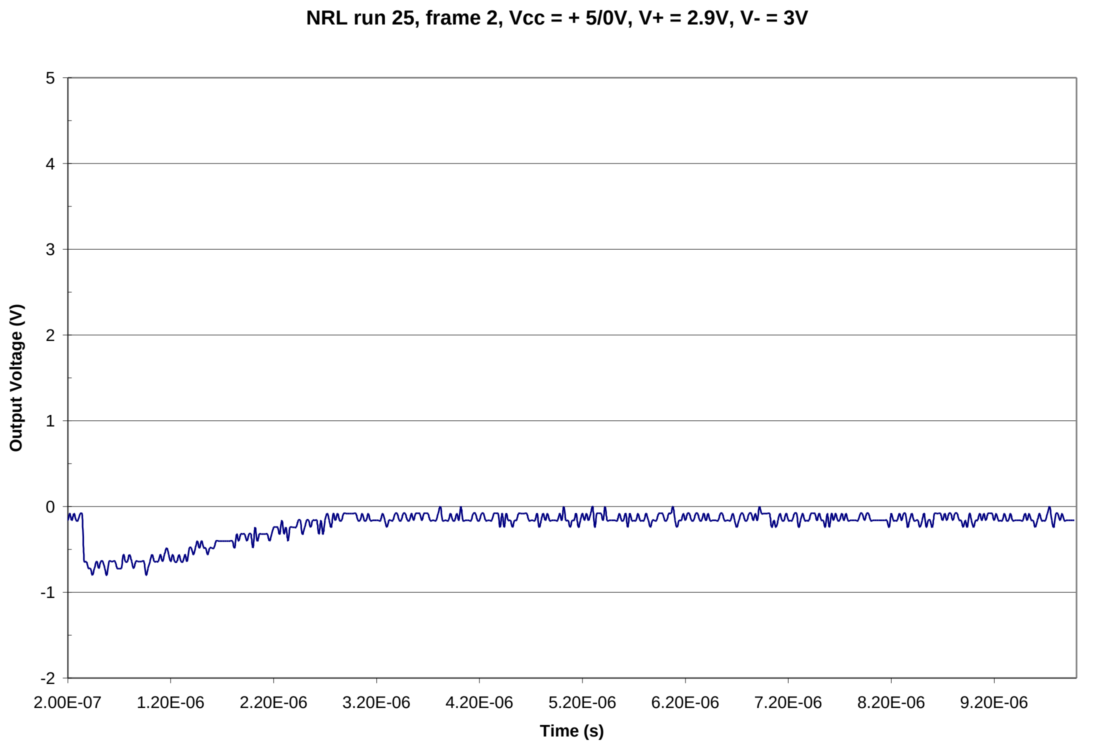

Figure 20: LM124, comparator application, typical pulse shape observed on location 6 for a laser energy of 1714 pJ.

7 Analysis of transient pulse shape on the Non Inverting Gain1 (X101) application

7.1 Bias conditions

A subset of the bias conditions investigated during Heavy ions experiments has been used. These test conditions are given in Table 5.

Power Supply		**Input**		**Output (V)**
Vcc+ (V)	**Vcc- (V)**	**V+(V)**	**V-(V)**	
15	**-15**	**0.05**	**0**	**5.1**
		0.1	0	11.5
		-0.05	0	-6
5	0	0.03	0	3.1
		2.9	3	0

Table 5: bias conditions investigated for the Non Inverting Gain1 application.

7.2 Test results

Unlike the comparator application, all the eight sensitive regions irradiated have shown SET sensitivity for the Non inverting Gain 1 application. Location 7 (which was not sensitive in the voltage comparator application), is one of the most sensitive regions with regions 1,2,4,5 and 8.

Location 1

With a laser energy of 107 pJ, for Vcc = +/-15V, V+ = 0.05V and V- = 0V, we obtained large negative going pulses as shown in Figure 21 (Voltage amplitude=9V, FWMH = 15 µs).

When we change the input conditions to V+ = 0.1V, we do not see a significant change in the transient shape.

When the laser energy is increased to 129 pJ, the transient voltage amplitude and duration increases as shown in Figure 22.

When we change the power supply voltage to Vcc = +5/0 V, the transient shape is similar, as shown in Figure 23.

For Vcc = +/-15V and V+ = -0.05V (negative input voltage), the same type of pulse is observed, but at higher energy. The Figure 24 shows that only a 3.5V pulse amplitude has been obtained for a 643 pJ laser energy.

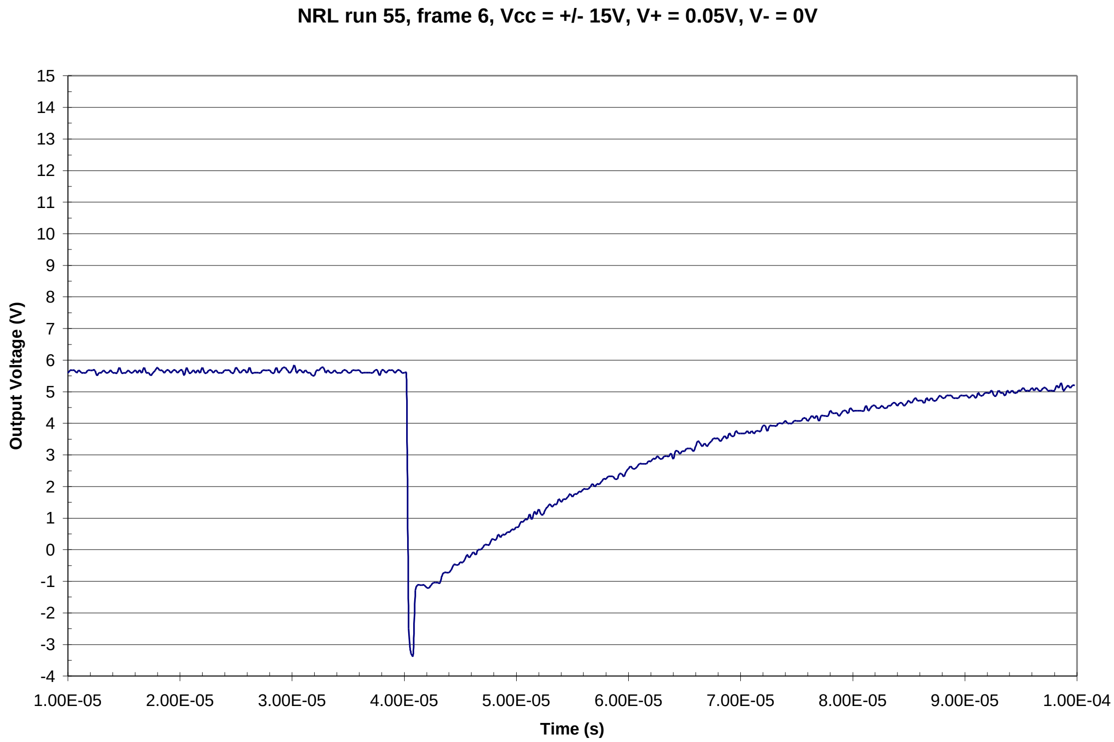

Figure 21: LM124, Non Inverting Gain1 application,
location 1, typical pulse for a laser energy of 107 pJ.

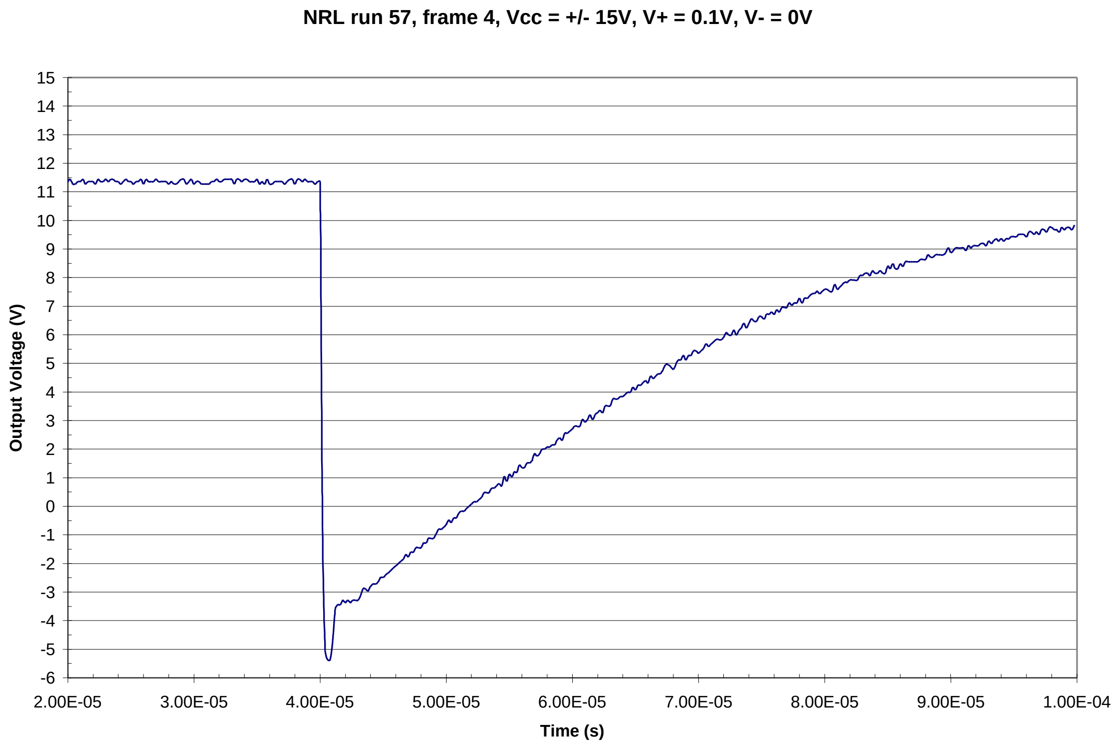

Figure 22: LM124, Non Inverting Gain1 application,
location 1, typical pulse for a laser energy of 129 pJ.

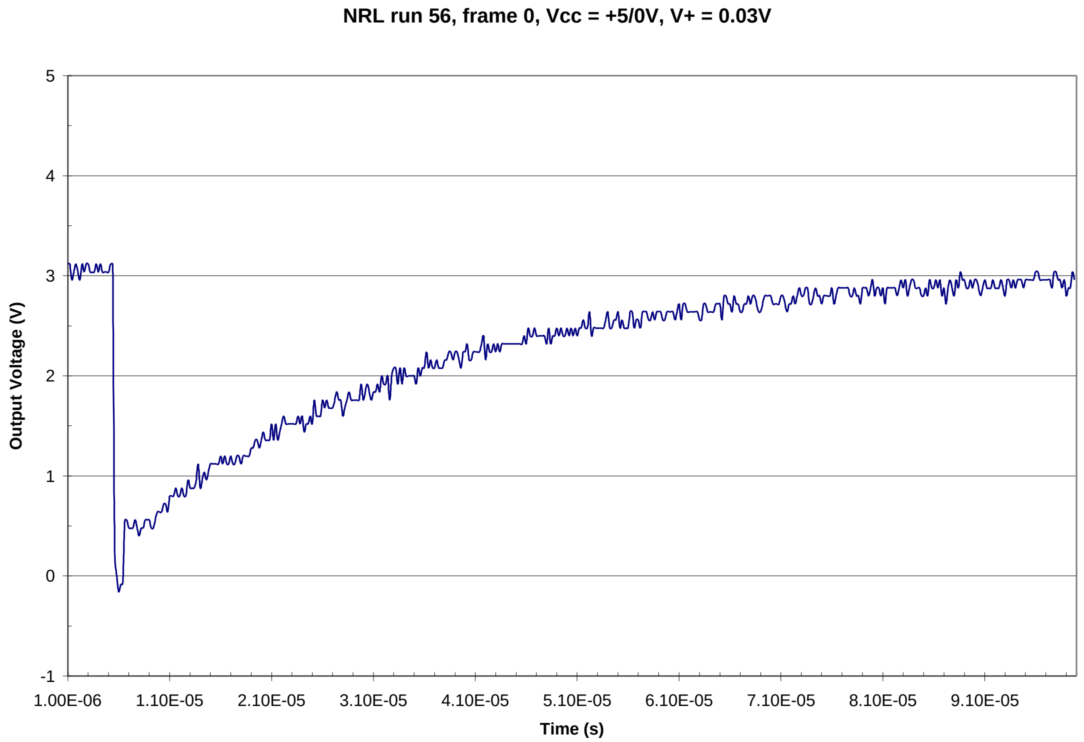

Figure 23: LM124, Non Inverting Gain1 application,
location 1, typical pulse for a laser energy of 75 pJ.

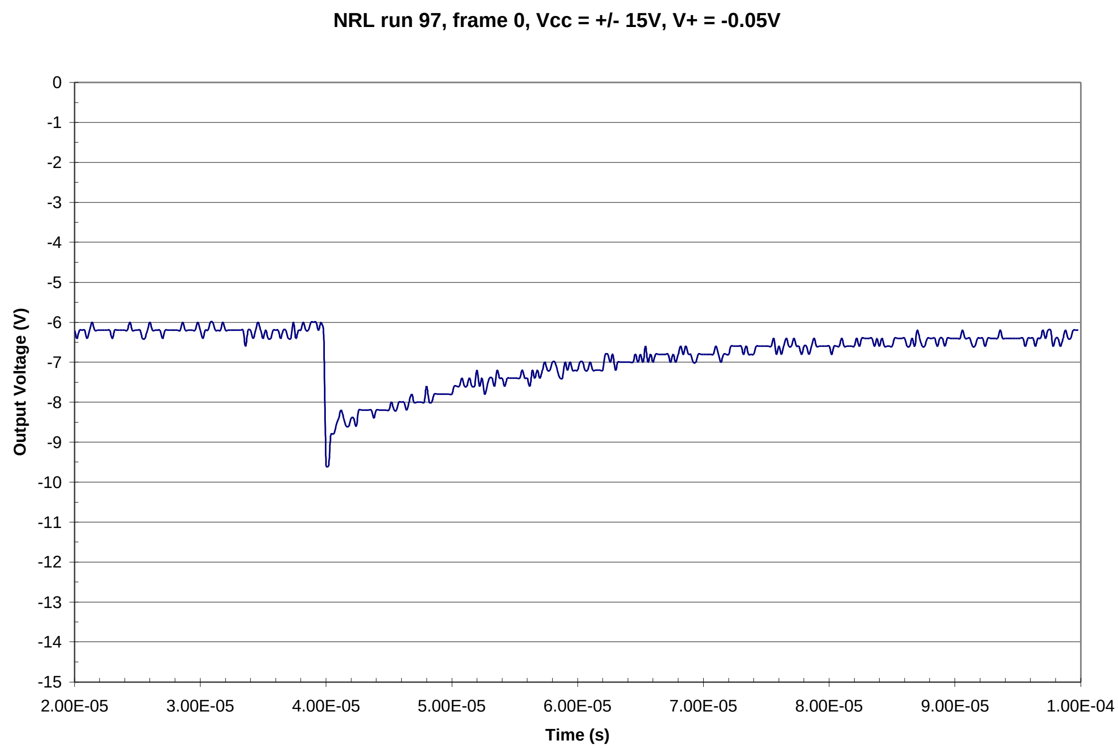

Figure 24: LM124, Non Inverting Gain1 application,
location 1, typical pulse for a laser energy of 643 pJ.

Location 2

With a laser energy of 214 pJ, for Vcc = +/-15V, V+ = 0.05V and V- = 0V, we obtained large negative going pulses as shown in Figure 25 (Voltage amplitude=8V, FWMH = 12 µs).

When we change the input conditions to V+ = 0.1V, we do not see a significant change in the transient shape.

When the laser energy is increased to 321 pJ, the transient voltage amplitude and duration increases as shown in Figure 26.

When we change the power supply voltage to Vcc = +5/0 V, the transients are smaller in voltage amplitude and shorter in duration for V+ = 0.03V, as shown in Figure 27. We could see that the pulses are bipolar with a very small and long positive going component following the main negative going component.

For Vcc = +/-15V and V+ = -0.05V (negative input voltage), small positive going type of pulse are observed at the higher energy (321 pJ). The pulse amplitude is 1.5V, and the FWMH is 400 ns. Some transients look bipolar, we can see at the beginning of the pulses a very small and short negative going component. The Figure 28 shows a typical pulse obtained for a 321 pJ laser energy.

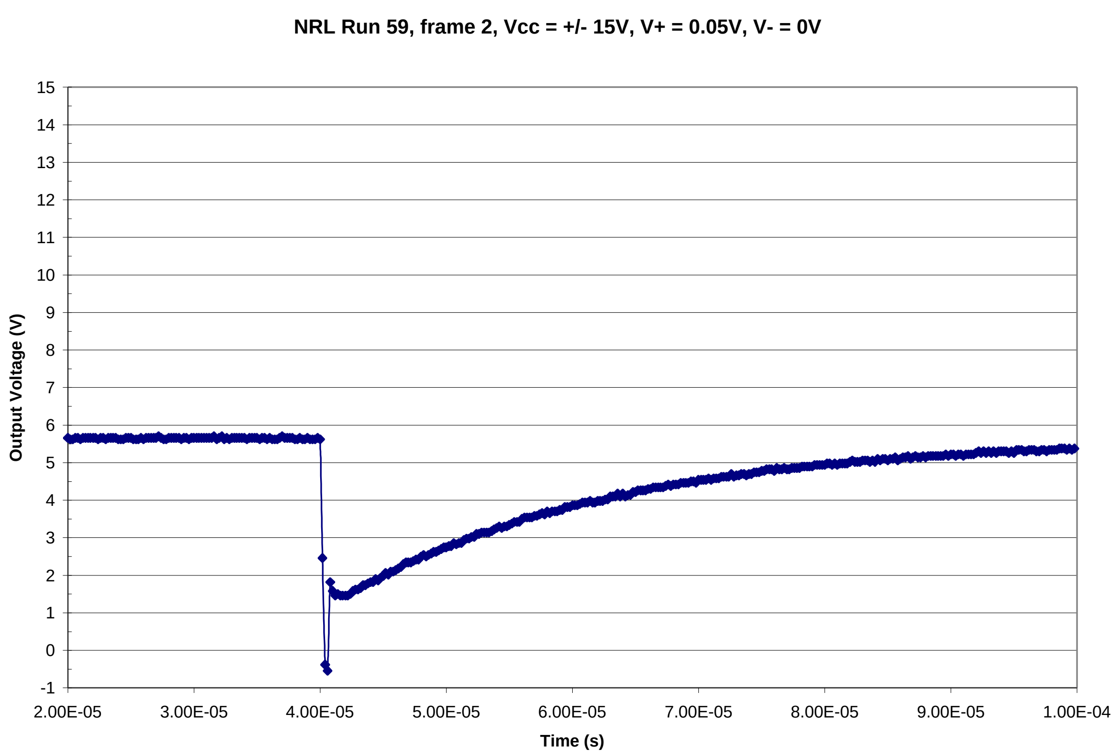

Figure 25: LM124, Non Inverting Gain1 application, location 2, typical pulse for a laser energy of 214 pJ.

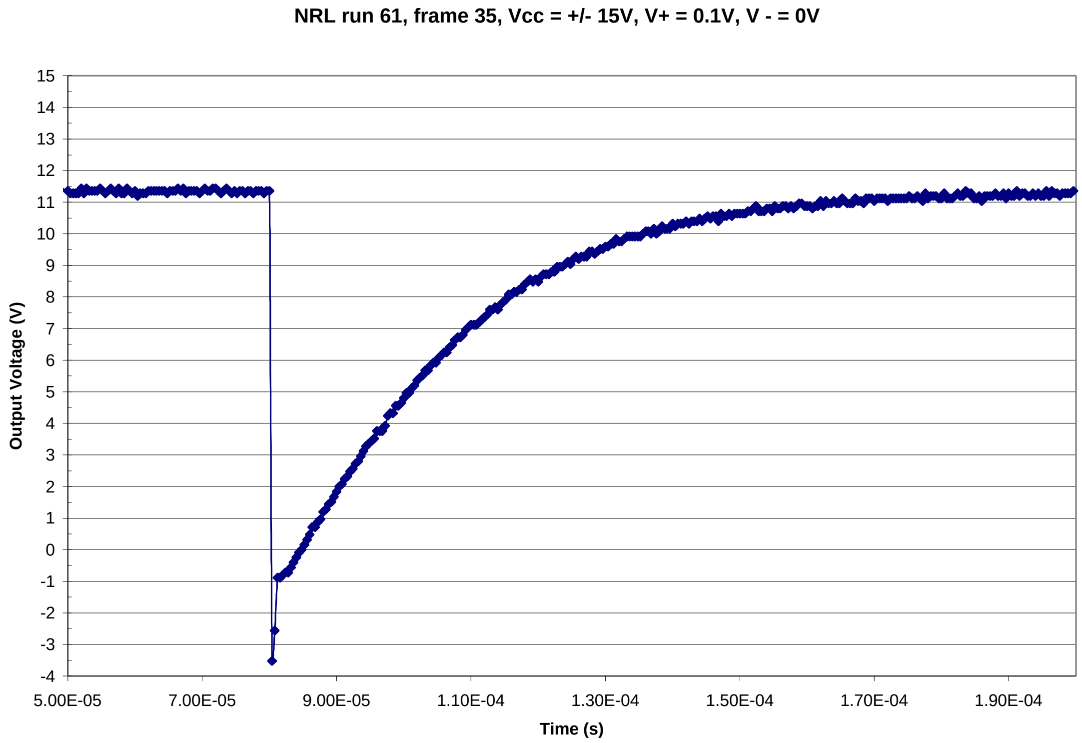

Figure 26: LM124, Non Inverting Gain1 application,
location 2, typical pulse for a laser energy of 321 pJ.

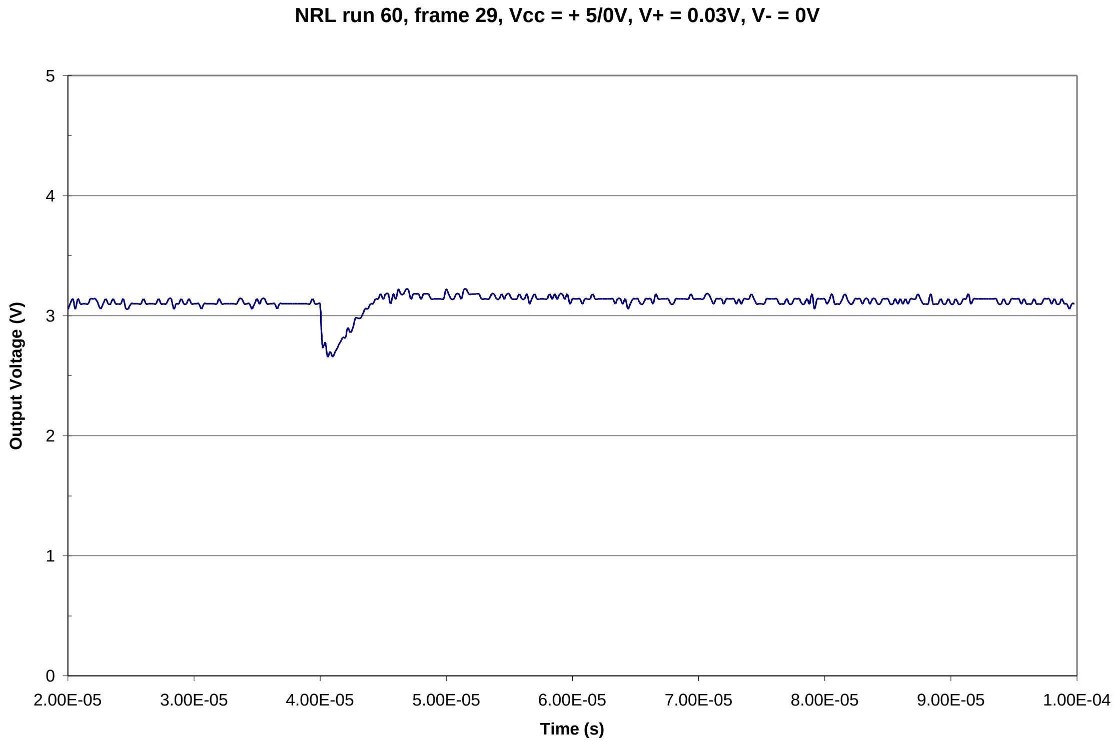

Figure 27: LM124, Non Inverting Gain1 application,
location 2, typical pulse for a laser energy of 214 pJ.

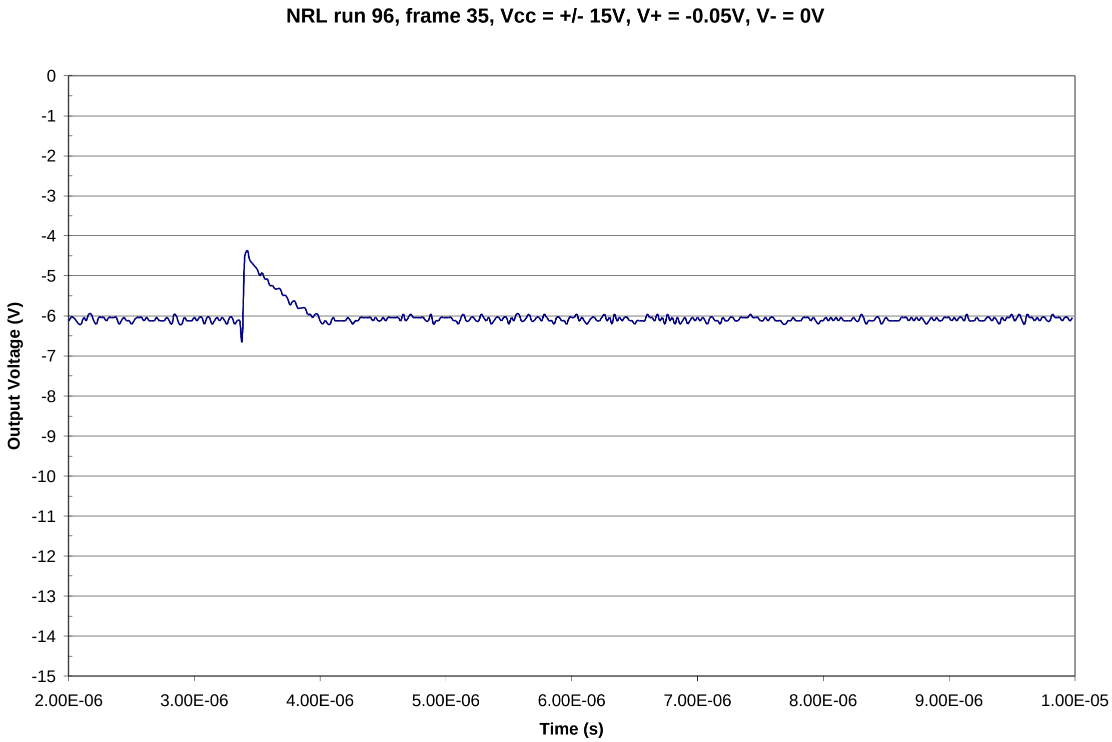

Figure 28 : LM124, Non Inverting Gain1 application, location 2, typical pulse for a laser energy of 321 pJ.

Location 3

With a laser energy of about 429pJ, for Vcc = +/-15V, V+ = 0.05V and V- = 0V, we obtained a bipolar pulse: a small and short positive going component followed by large negative going component as shown in Figure 29 (Maximum Voltage amplitude=16V, FWMH = 24 µs).

When we change the input conditions, the transient shape remains the same, but the size of the negative going component decreases with the increasing input voltage. The Figure 30 shows a typical pulse shape for V+ = 0.1V (Maximum Voltage amplitude=3V, FWMH = 15 µs).

When the energy is decreased down to 214 pJ, the pulse shape remains the same, but the amplitude of the negative going component is smaller as shown in Figure 31 for V+ = 0.05V.

When we change the power supply voltage to Vcc = +5/0 V, the pulse shapes are similar but the negative going component of the pulse is smaller in voltage amplitude and shorter in duration for V+ = 0.03V, as shown in Figure 32. As in the +/- 15V power supply case, when we decrease the input voltage, the negative going component of the transient increases in amplitude. The Figure 33 shows a typical transient for V+ = 0.01V.

For Vcc = +/-15V and V+ = -0.05V (negative input voltage), the same transient shape is observed. The Figure 34 shows a typical pulse obtained for a 171 pJ laser energy.

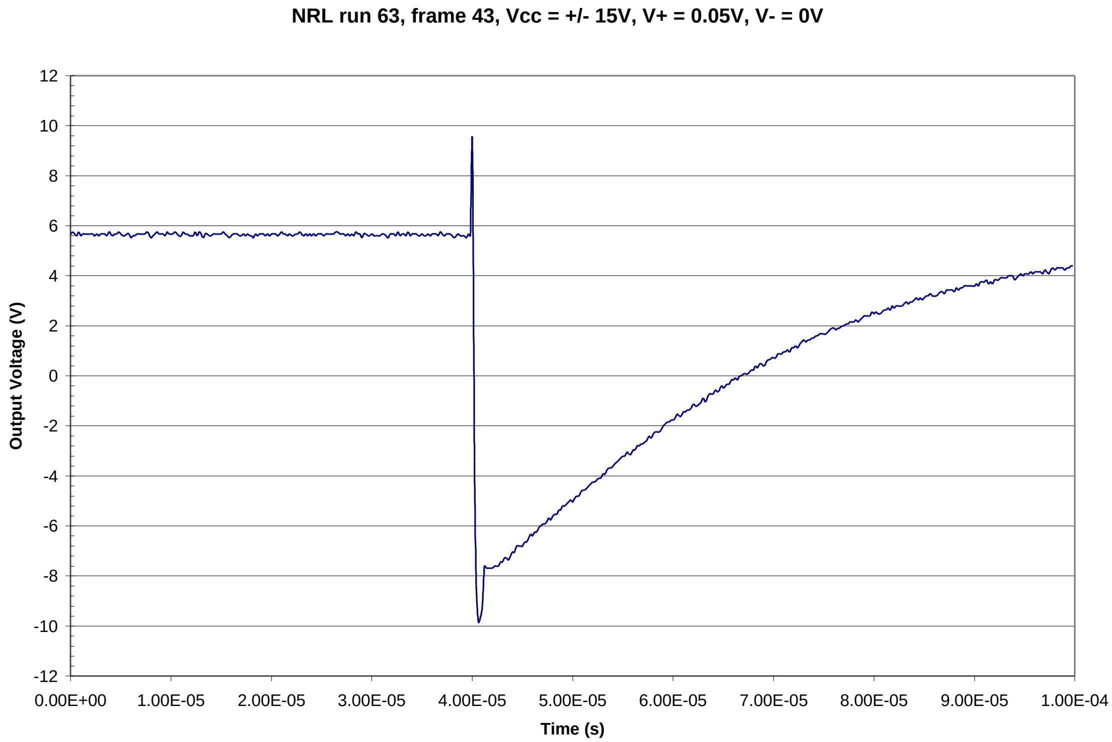

Figure 29 : LM124, Non Inverting Gain1 application, location 3, typical pulse for a laser energy of 429 pJ.

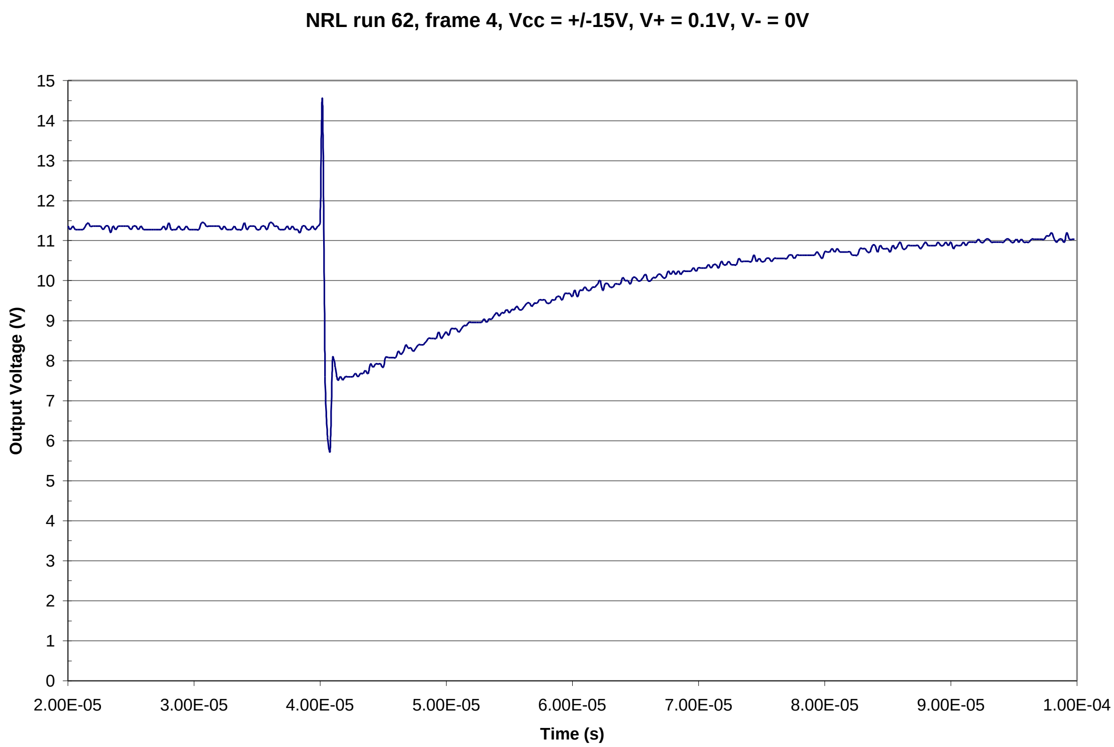

Figure 30 : LM124, Non Inverting Gain1 application, location 3, typical pulse for a laser energy of 429 pJ.

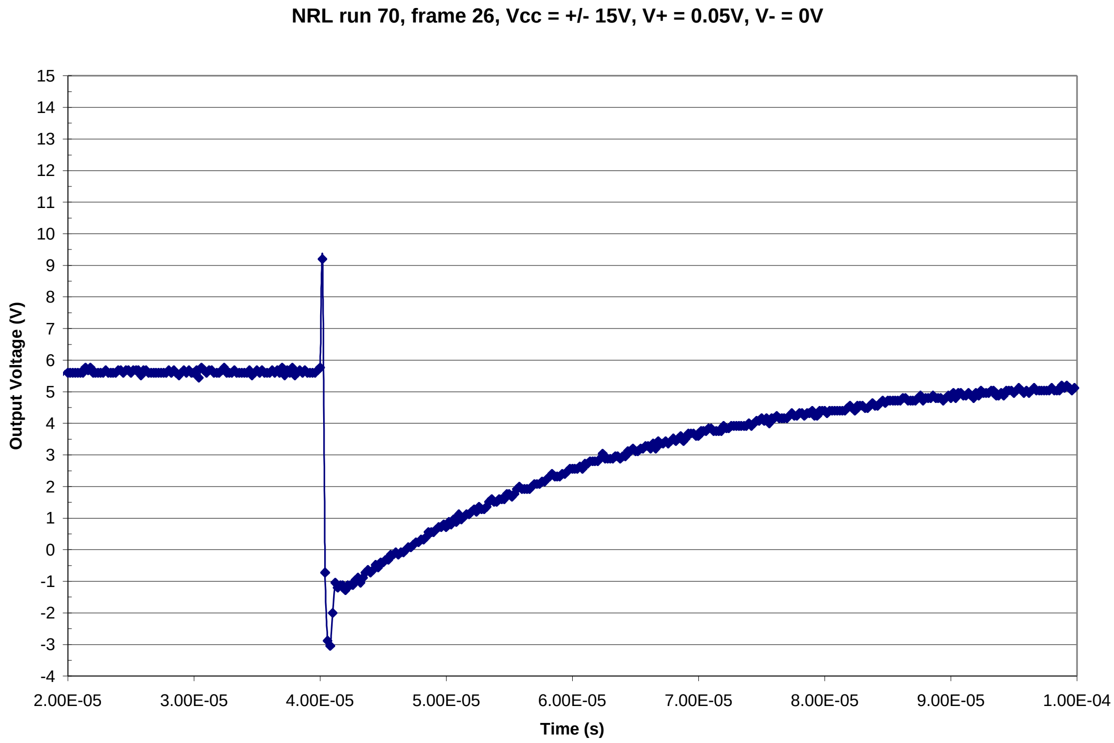

Figure 31 : LM124, Non Inverting Gain1 application, location 3, typical pulse for a laser energy of 214 pJ.

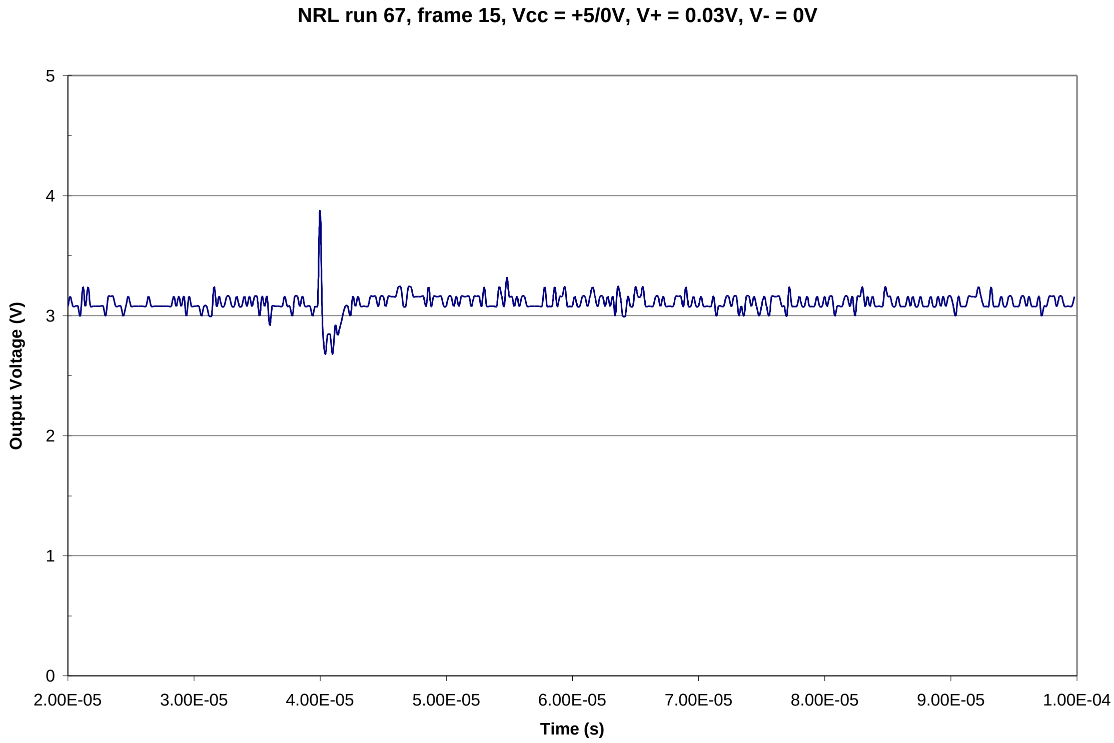

Figure 32 : LM124, Non Inverting Gain1 application, location 3, typical pulse for a laser energy of 450 pJ.

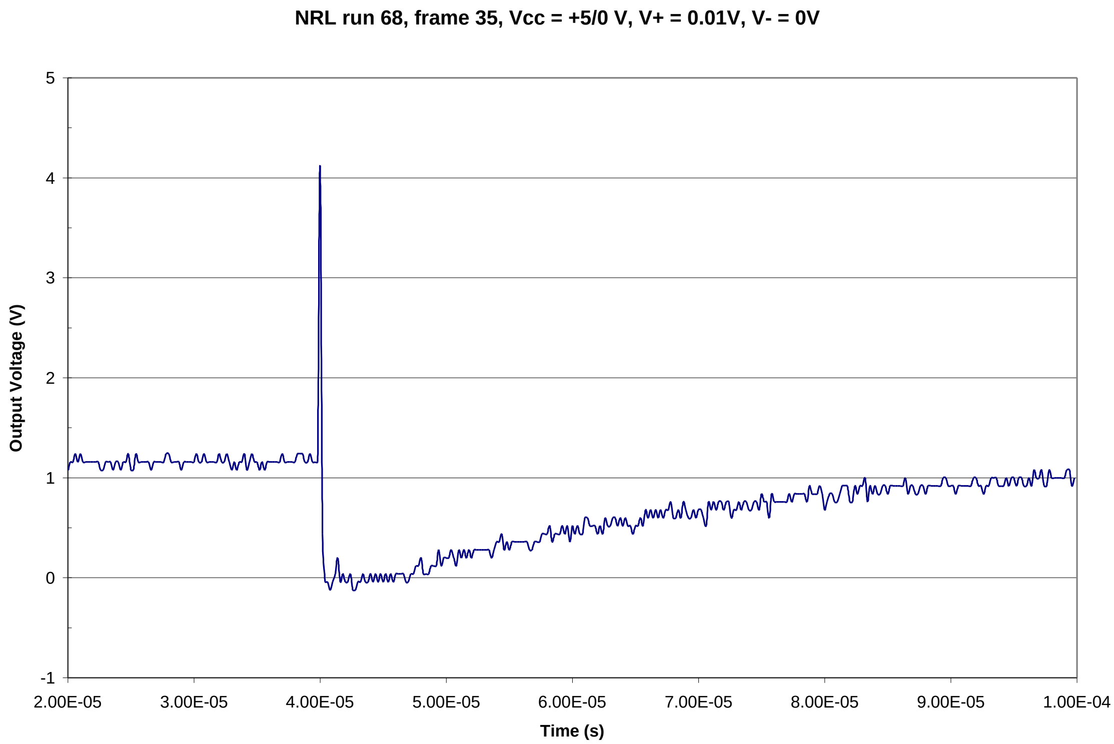

Figure 33 : LM124, Non Inverting Gain1 application, location 3, typical pulse for a laser energy of 450 pJ.

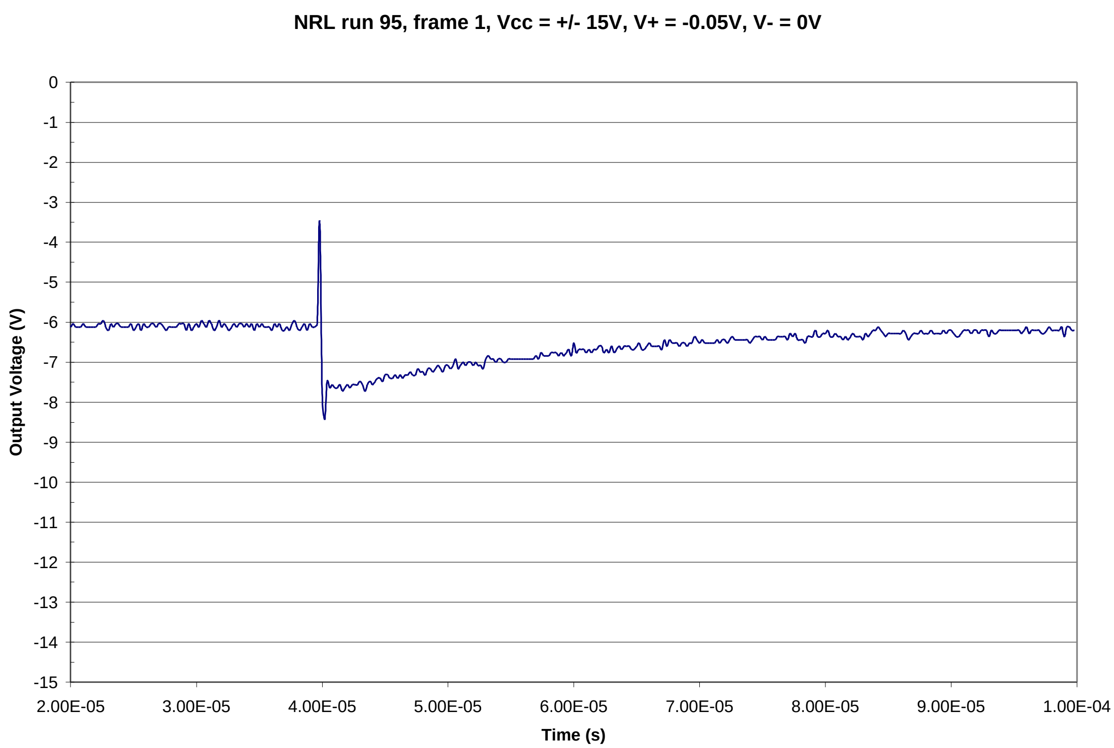

Figure 34 : LM124, Non Inverting Gain1 application, location 3, typical pulse for a laser energy of 171 pJ.

Location 4

With a laser energy of about 214 pJ, for Vcc = +/-15V, V+ = 0.05V and V- = 0V, we obtained a bipolar pulse: a large amplitude and short duration positive going component followed by large negative going component as shown in Figure 35 (Maximum Voltage amplitude=8V, FWMH = 15 µs).

When we change the input conditions, the pulse shape remains the same, but the size of the negative going component decreases with the increasing input voltage and the height of the positive going component is limited by the +Vcc rail. The Figure 36 shows a typical pulse shape for V+ = 0.1V (Maximum Voltage amplitude=5V, FWMH = 12 µs).

When the energy is decreased down to 75 pJ, the behavior is totally different. We got small positive going transients as shown in Figure 37.

When we change the power supply voltage to Vcc = +5/0 V, the transients are small positive going small pulses (2V maximum voltage amplitude, maximum FWMH = 2µs). A typical transient for a laser energy of 214 pJ is shown in Figure 38. When we increase the energy to 407 pJ, the transient shape remains the same.

When we increase the power supply to Vcc = +/- 10V, the transients become bipolar as shown in Figure 39.

For Vcc = +/-15V and V+ = -0.05V (negative input voltage), the same pulse size is observed but the size of the negative going component is smaller. The Figure 40 shows a typical pulse obtained for a 321 pJ laser energy.

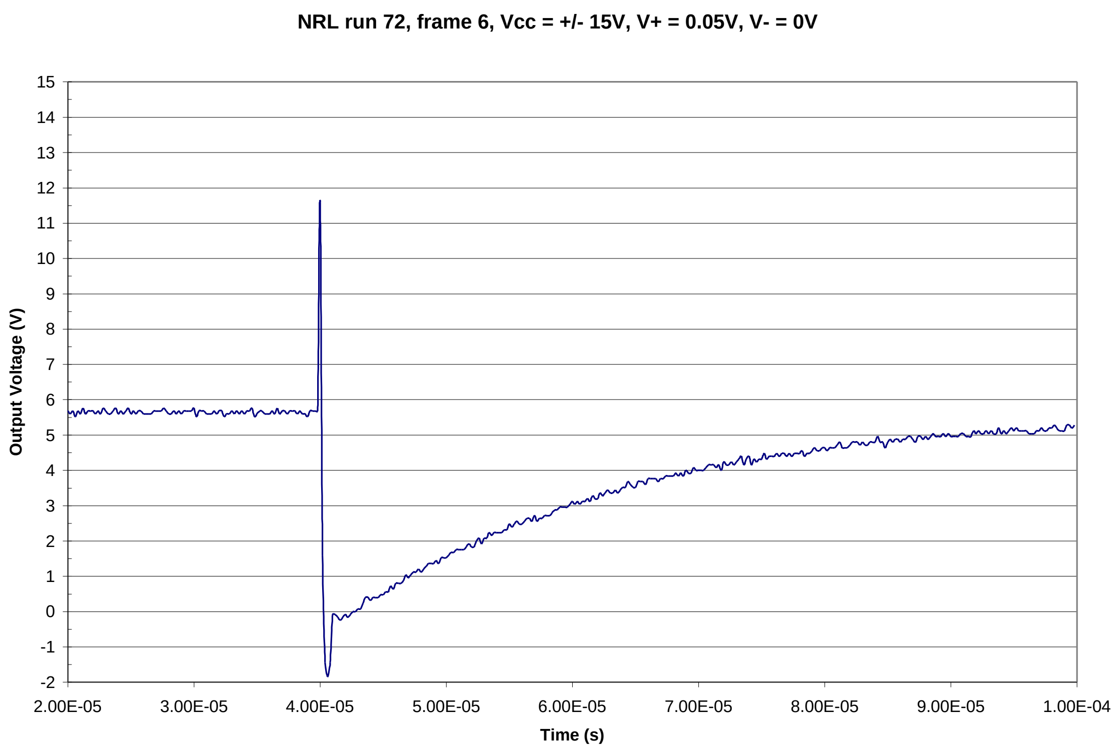

Figure 35 : LM124, Non Inverting Gain1 application, location 4, typical pulse for a laser energy of 214 pJ.

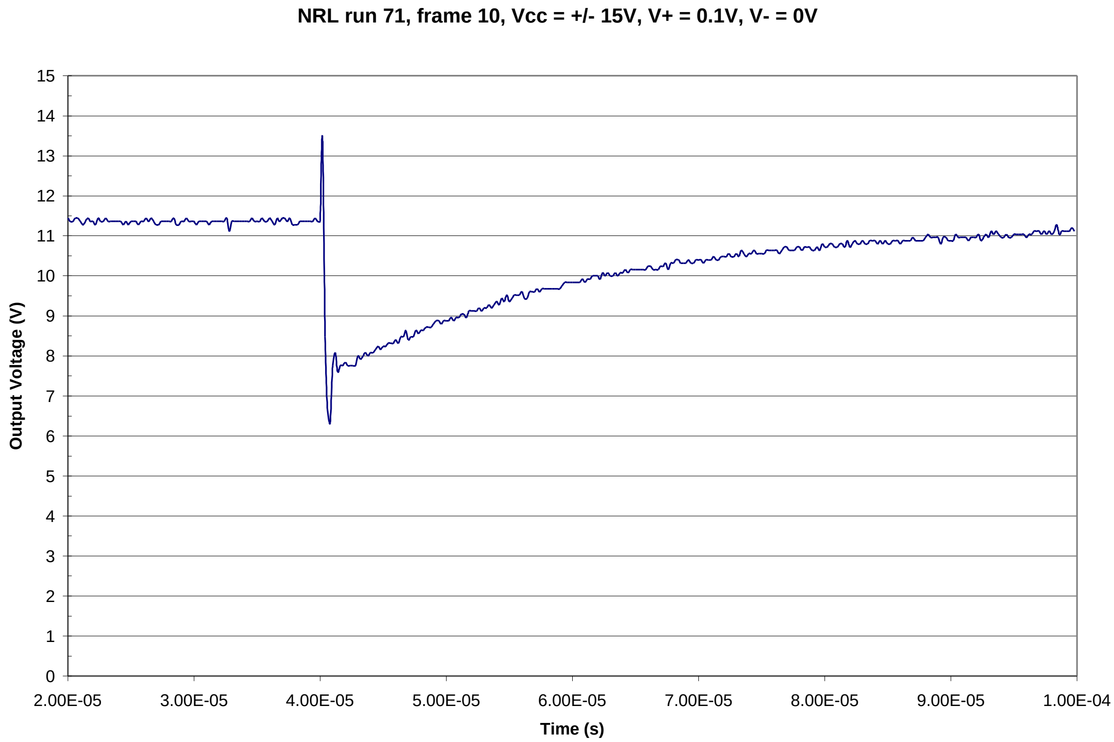

Figure 36 : LM124, Non Inverting Gain1 application, location 4, typical pulse for a laser energy of 214 pJ.

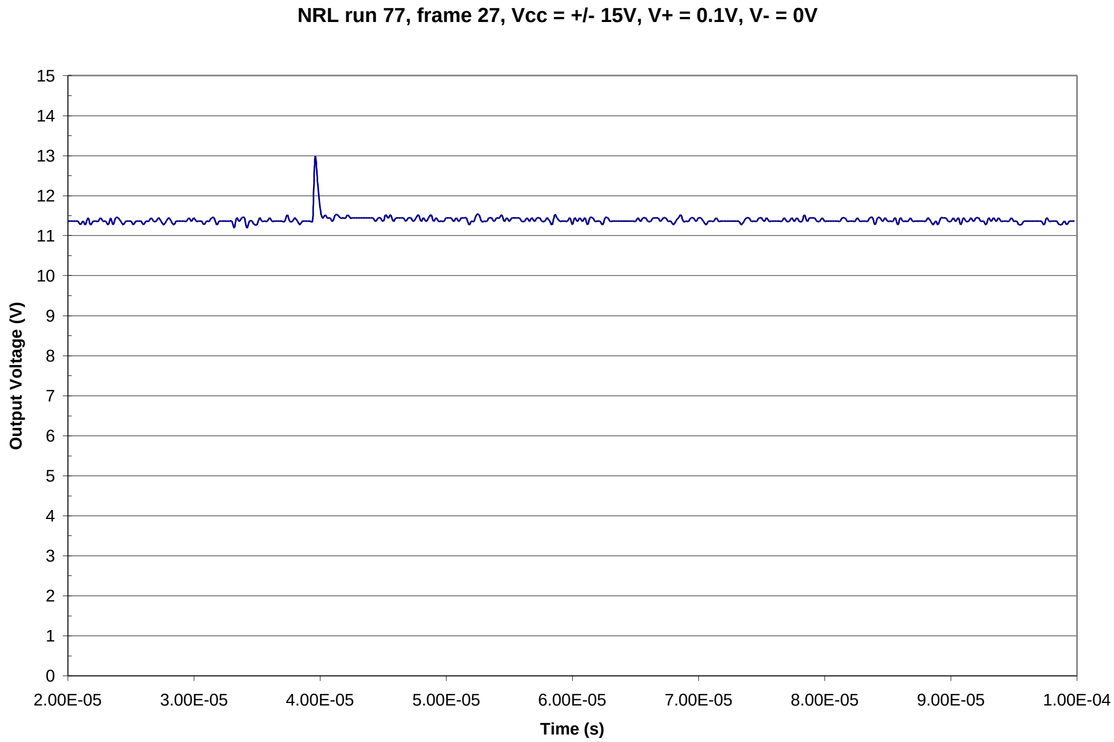

Figure 37 : LM124, Non Inverting Gain1 application, location 4, typical pulse for a laser energy of 75 pJ.

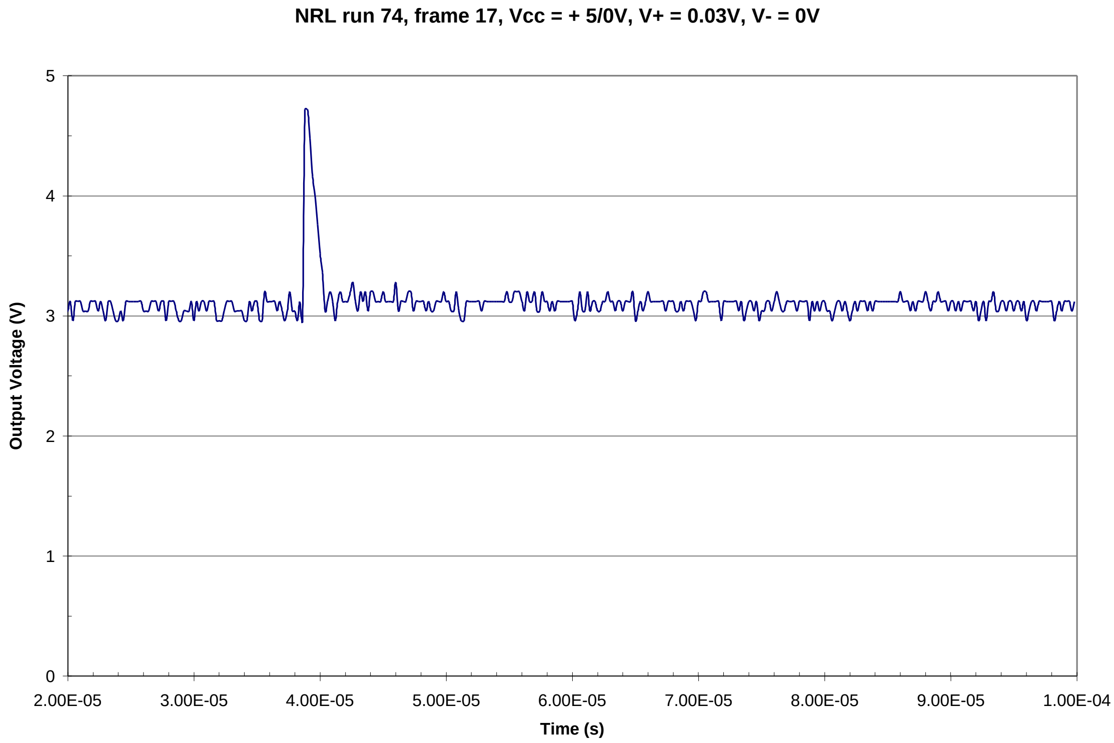

Figure 38 : LM124, Non Inverting Gain1 application,
location 4, typical pulse for a laser energy of 214 pJ.

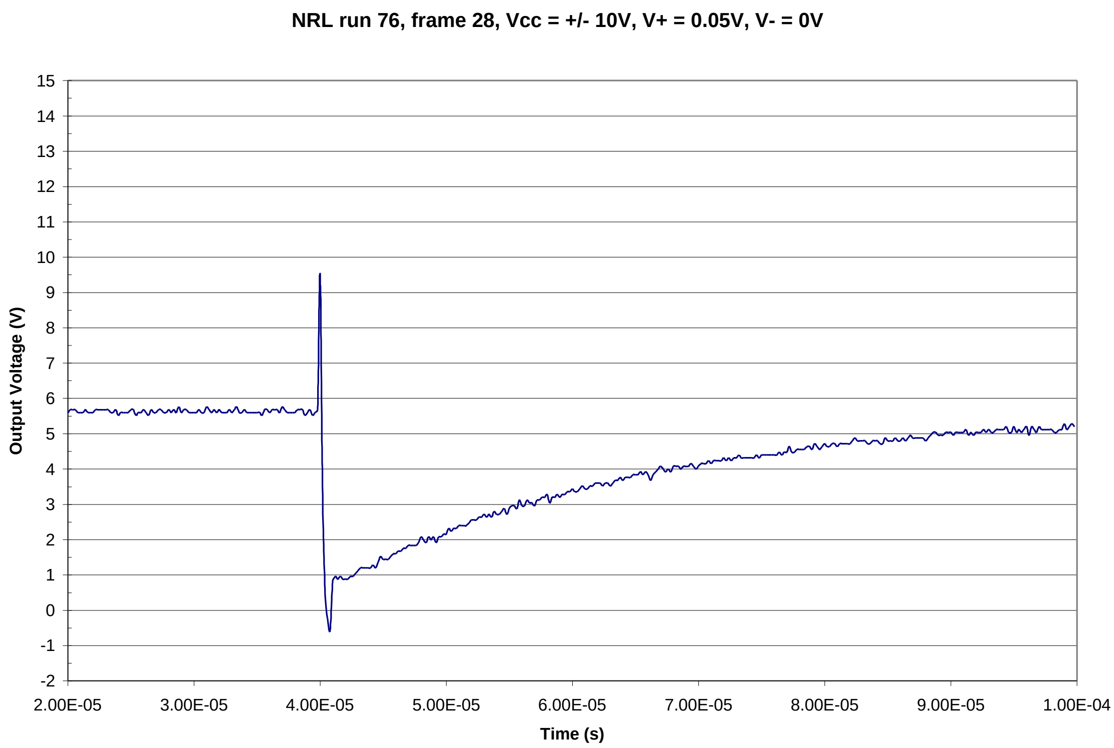

Figure 39 : LM124, Non Inverting Gain1 application,
location 4, typical pulse for a laser energy of 214 pJ.

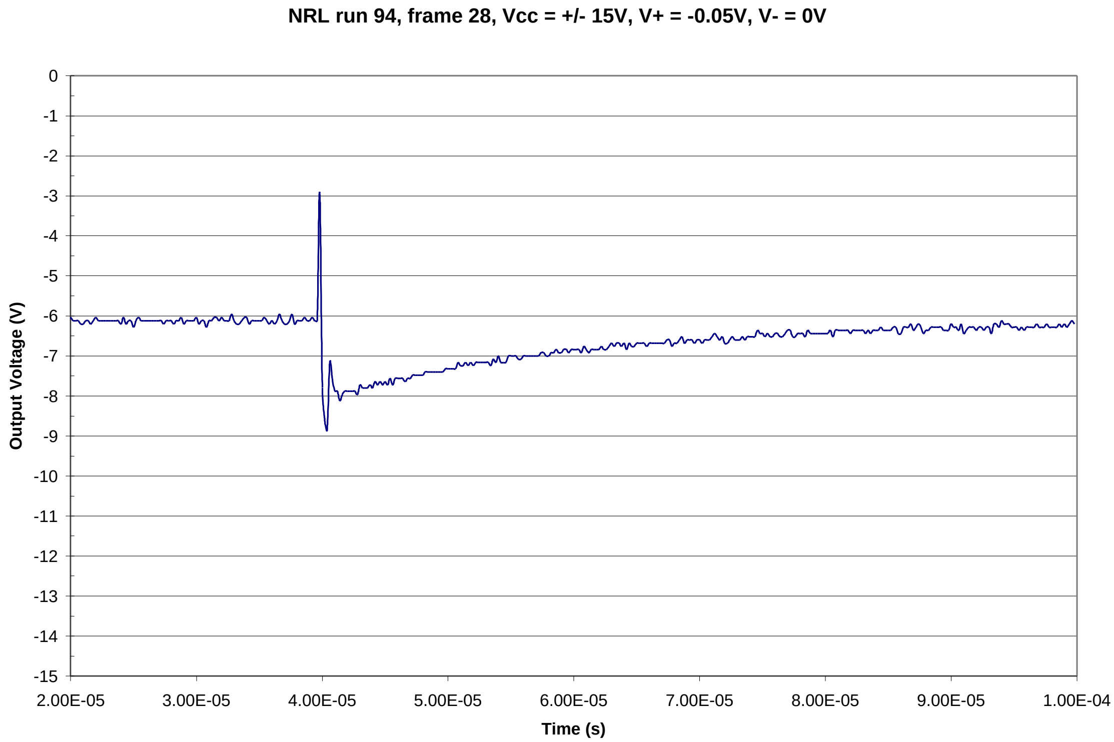

Figure 40 : LM124, Non Inverting Gain1 application,
location 4, typical pulse for a laser energy of 321 pJ.

<u>Location 6</u>

This region is only sensitive for a high laser energy. With a laser energy of 493 pJ, for Vcc= +/-15V, V+ = 0.05V and V- = 0V, we obtained a small bipolar transient: a small amplitude and short duration positive going component followed by a small negative going component as shown in Figure 41.

When we change the input conditions the transient shape remains the same.

When we change the power supply voltage to Vcc = +5/0 V, the transients have also a similar shape as shown in Figure 42.

For Vcc = +/-15V and V+ = -0.05V (negative input voltage), small positive going transients have been observed as shown in Figure 43 for a laser energy of 386 pJ.

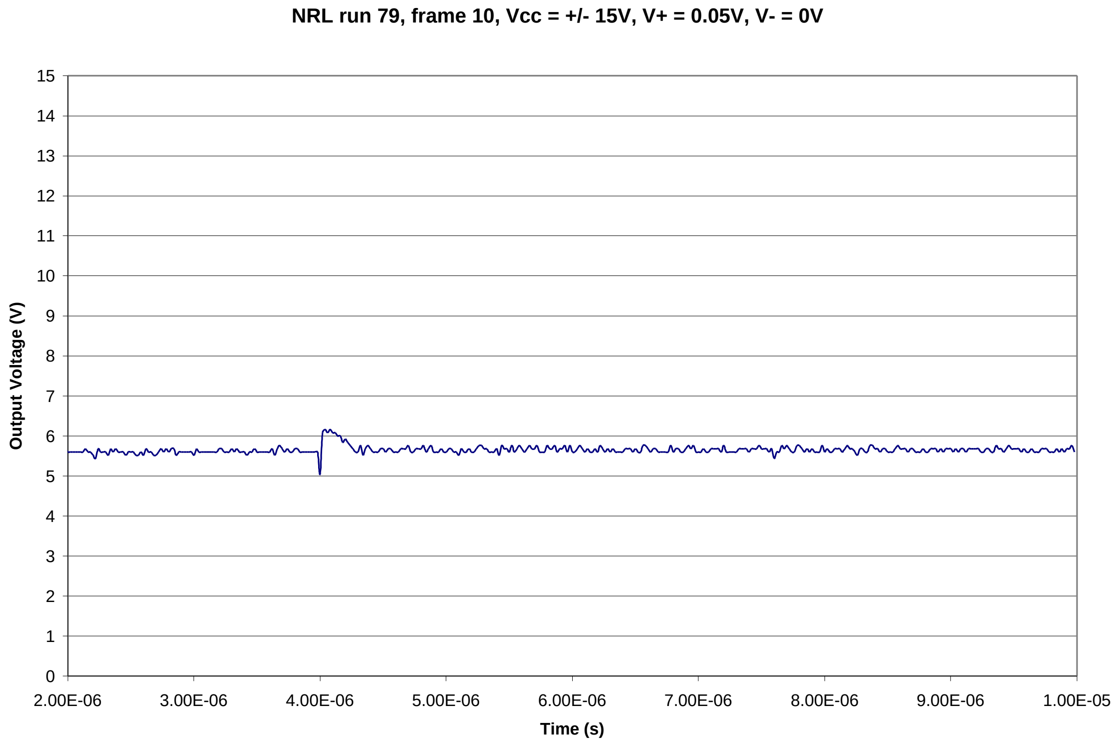

Figure 41 : LM124, Non Inverting Gain1 application, location 6, typical pulse for a laser energy of 493 pJ.

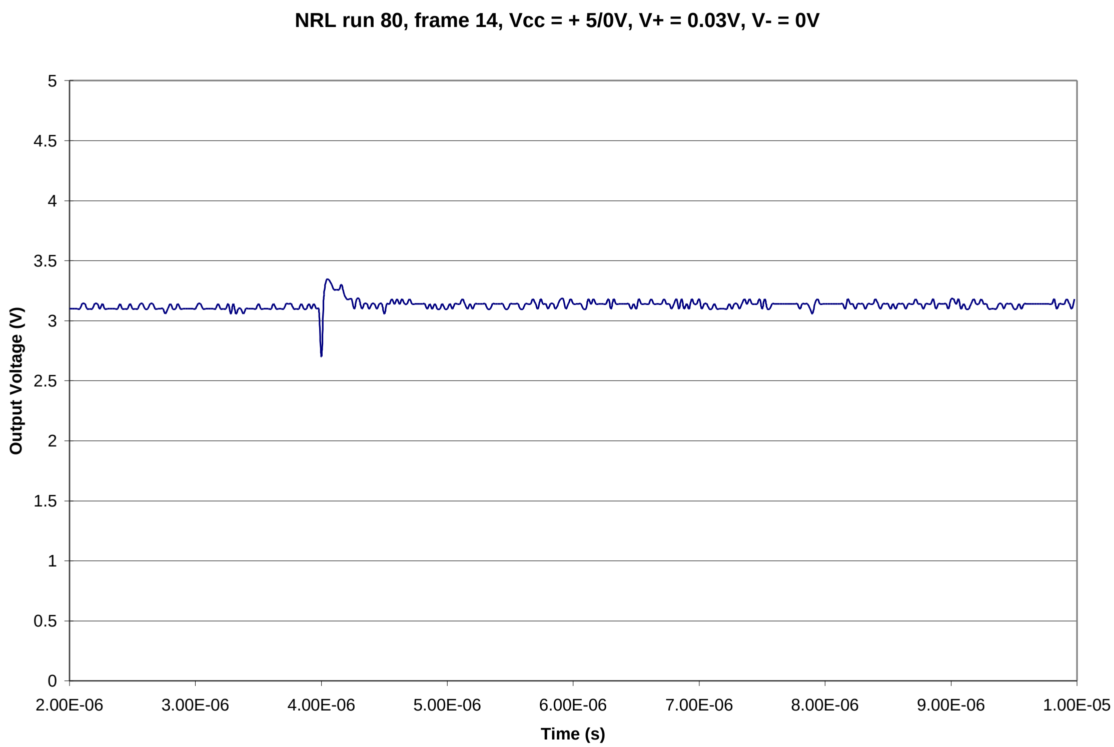

Figure 42 : LM124, Non Inverting Gain1 application, location 6, typical pulse for a laser energy of 493 pJ.

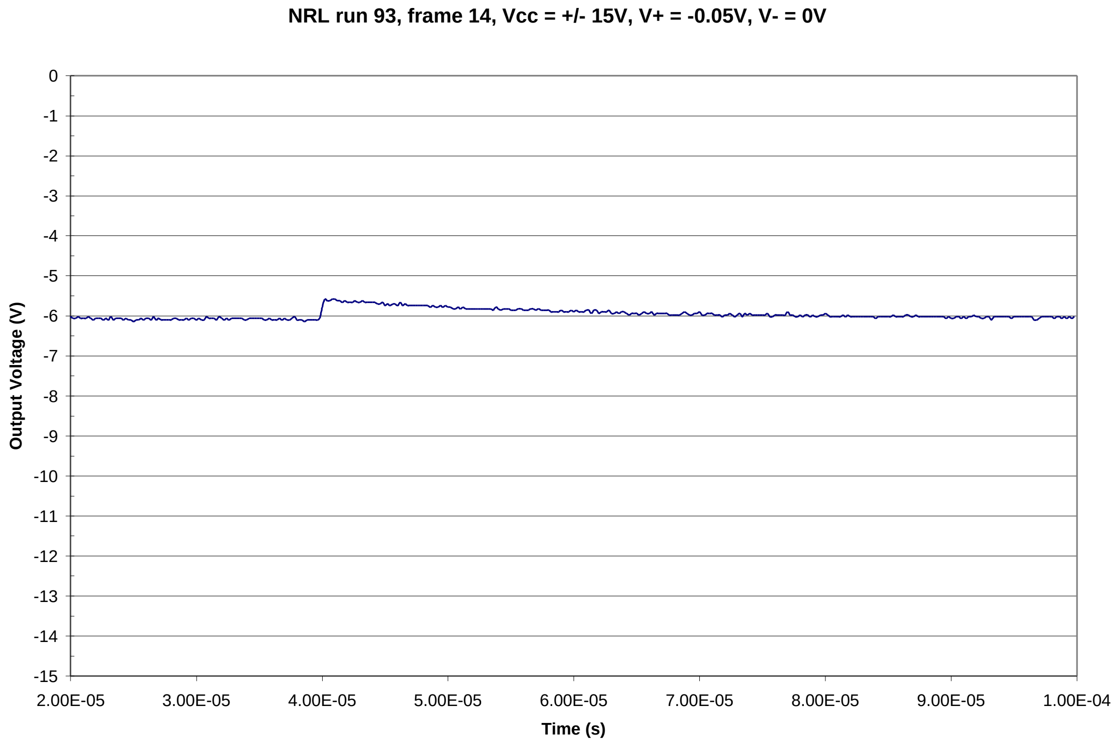

Figure 43 : LM124, Non Inverting Gain1 application,
location 6, typical pulse for a laser energy of 386 pJ.

Location 7

With a laser energy as low as 36 pJ for Vcc = +/-15V, V+ = 0.05V and V- = 0V, we obtained small positive going pulses: The pulse amplitude is about 0.8V. Two different pulses duration have been seen: short duration (FWMH=400ns) as shown in Figure 44, or longer duration (FWMH=2µs) as shown in Figure 45. About 25% of the transients have the longer duration.

When we change the input conditions to V+ = 0.1V, the pulse shapes remain the same and all pulses belong to the long duration type.

When the energy is increased to 493 pJ, the pulse amplitude is larger as shown in Figure 46 (amplitude=2V, FWMH=40µs).

When we change the power supply voltage to Vcc = +5/0 V and V+ = 0.03V, the pulse shape does not change as shown in Figure 47. When we increase the energy to 493 pJ, the transients are saturated as shown in Figure 48.

For Vcc = +/-15V and V+ = -0.05V (negative input voltage), small amplitude and long duration positive going transients have been observed as shown in Figure 49 for a laser energy of 45 pJ.

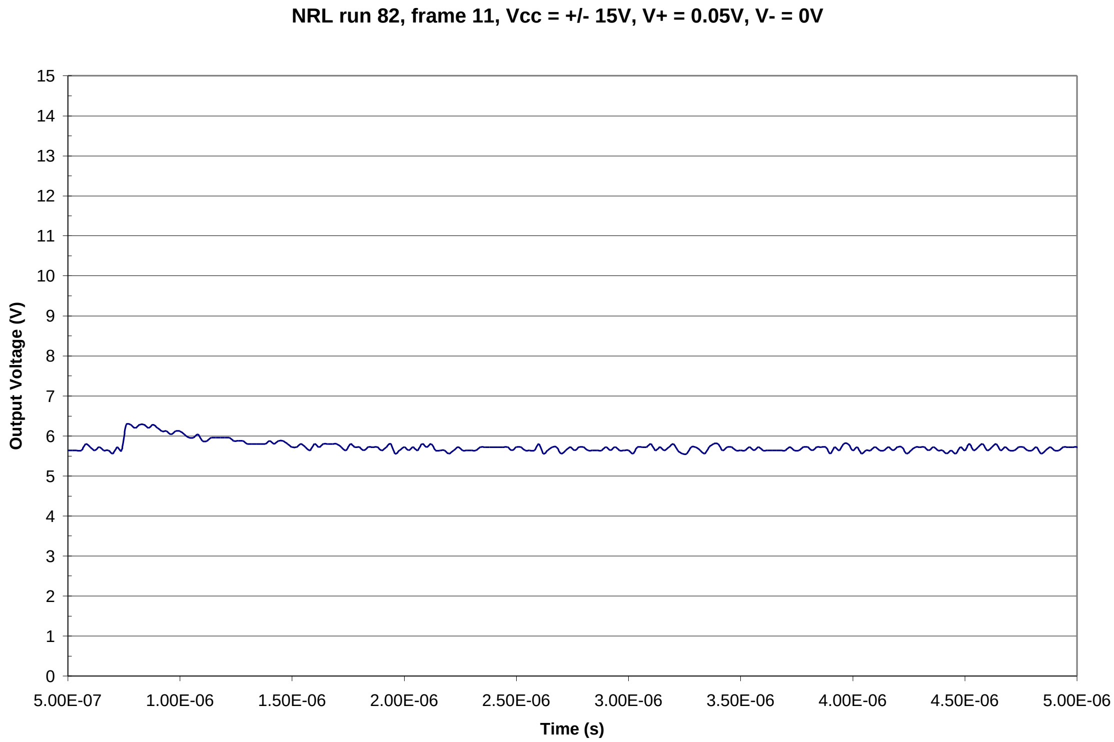

Figure 44 : LM124, Non Inverting Gain1 application,
location 7, typical pulse for a laser energy of 36 pJ.

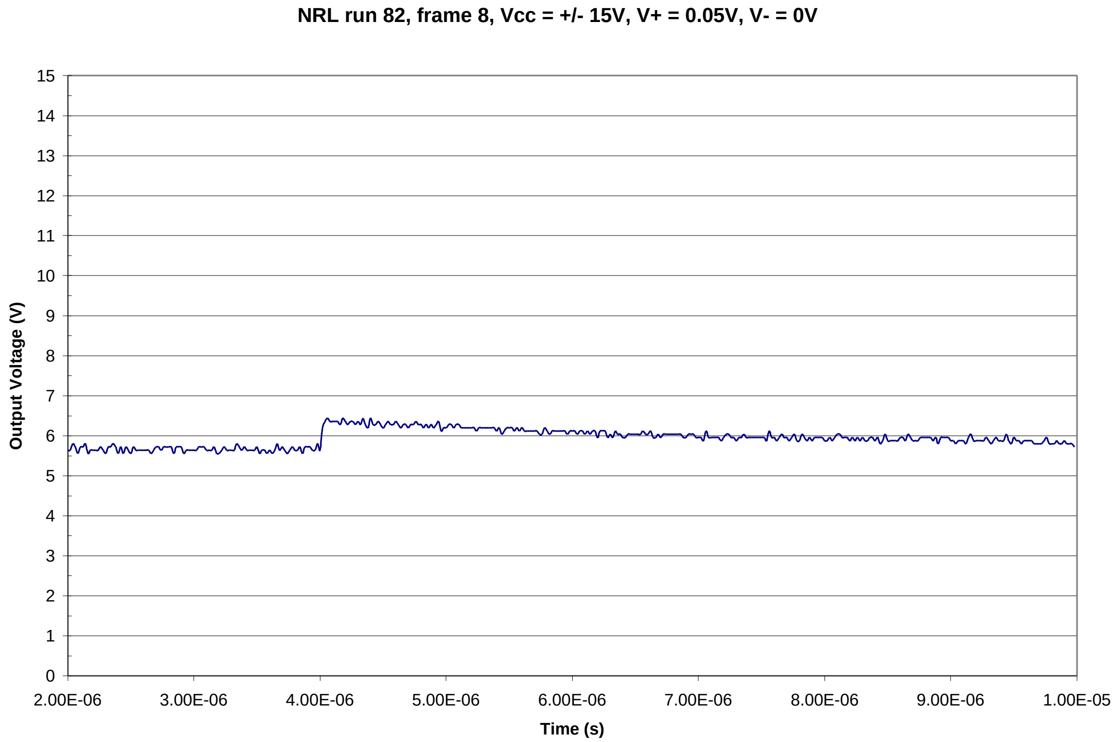

Figure 45 : LM124, Non Inverting Gain1 application,
location 7, typical pulse for a laser energy of 36 pJ.

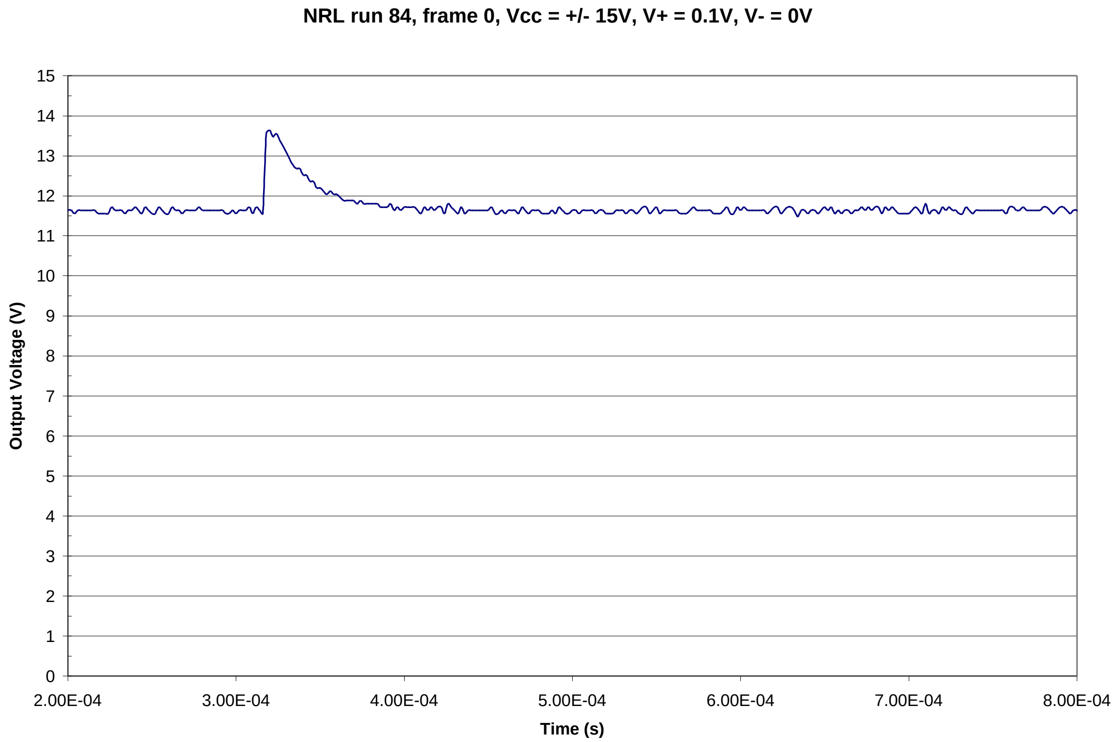

Figure 46 : LM124, Non Inverting Gain1 application, location 7, typical pulse for a laser energy of 493 pJ.

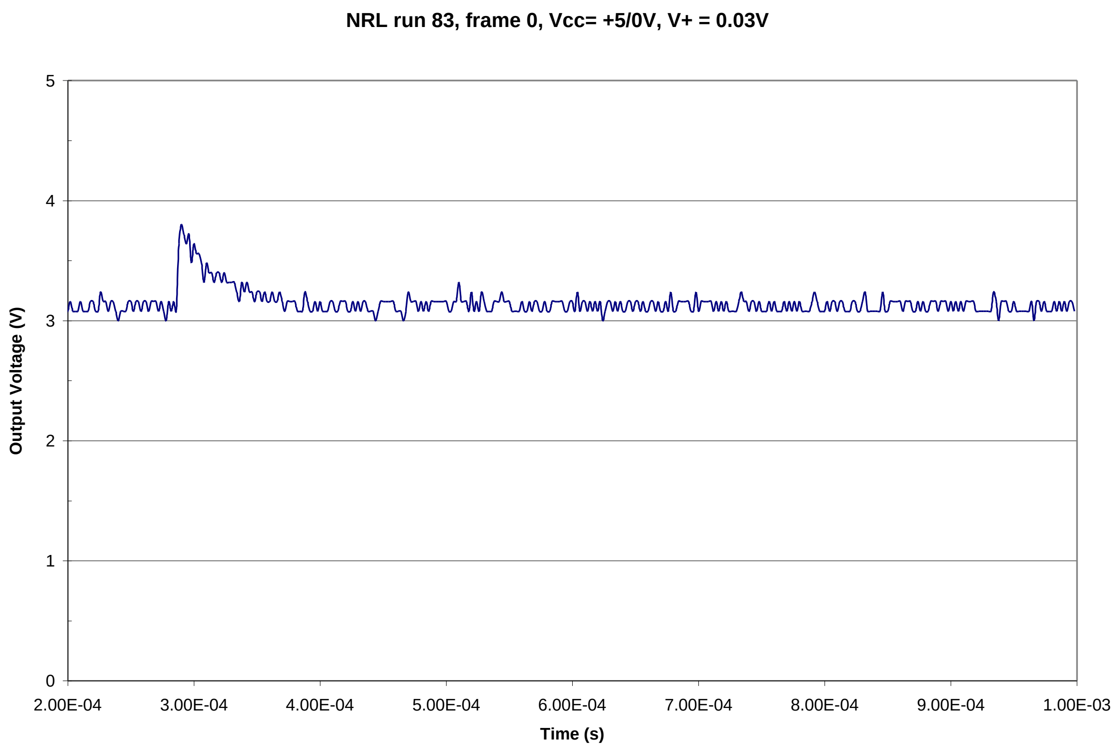

Figure 47 : LM124, Non Inverting Gain1 application, location 7, typical pulse for a laser energy of 36 pJ.

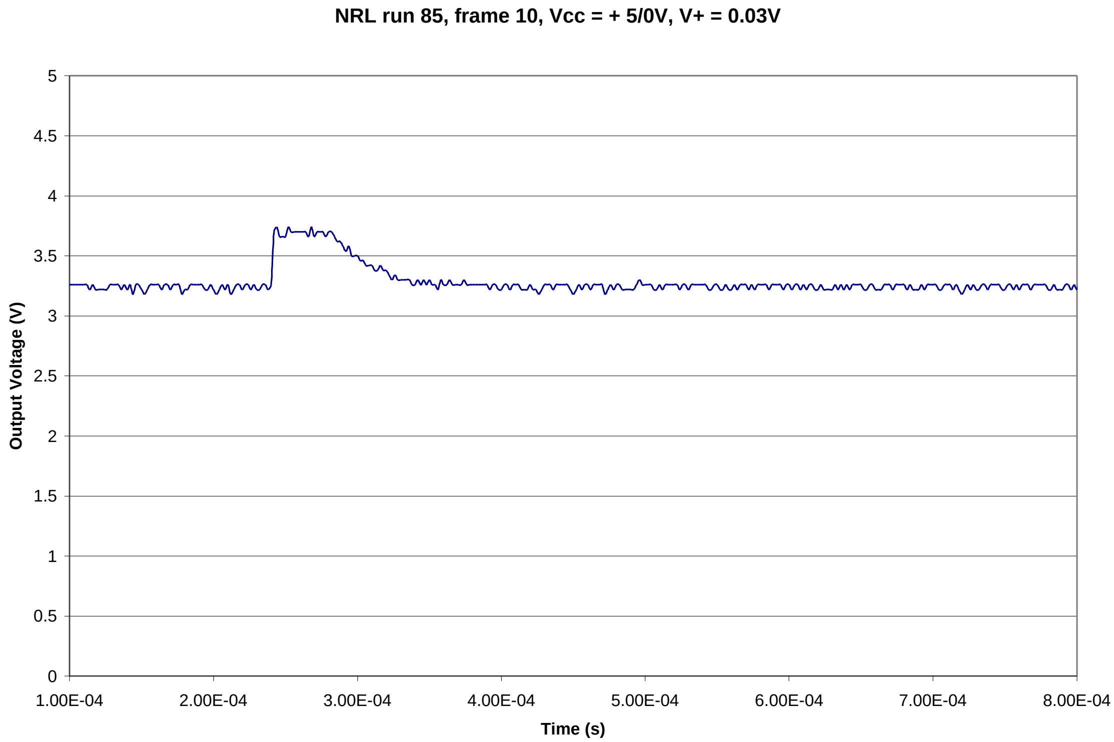

Figure 48 : LM124, Non Inverting Gain1 application,
location 7, typical pulse for a laser energy of 493 pJ.

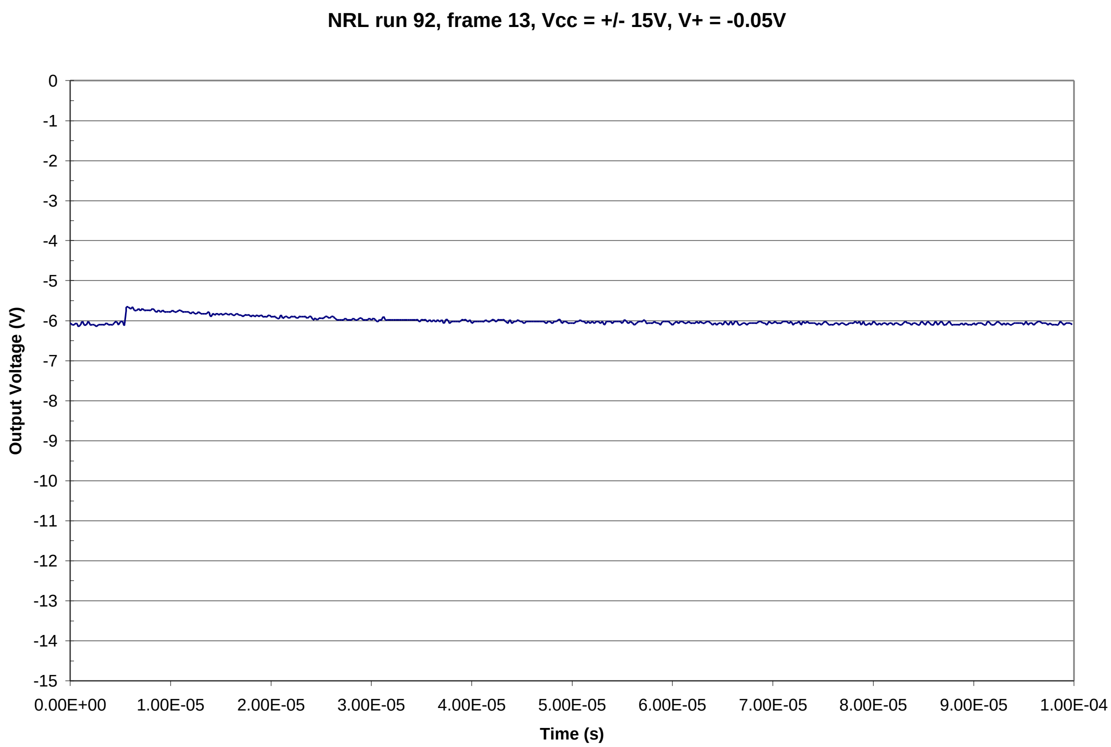

Figure 49 : LM124, Non Inverting Gain1 application,
location 7, typical pulse for a laser energy of 45 pJ.

Location 8

With a laser energy of 321 pJ for Vcc=+/-15 V, V+ = 0.05V and V- = 0V, we obtained small negative going pulses: The pulse amplitude is about 0.6V and the FWMH is about 1 µs. A typical pulse is shown in Figure 50.

When we change the input voltage to V+ = 0.1V, the transients are shorter in duration (maximum FWMH = 300 ns).

When the energy is increased to 557 pJ, the pulse amplitude is larger (maximum amplitude=1V) and longer (FWMH= 4 µs).

When we change the power supply voltage to Vcc= +5/0 V and V+ = 0.03V the transient shape does not change as shown in Figure 51. When we increase the energy to 557 pJ, the transients are larger in amplitude and longer in duration.

For Vcc = +/-15V and V+ = -0.05V (negative input voltage), we observe a significantly larger sensitivity with larger and longer negative going transients as shown in Figure 52 for a low laser energy of 39 pJ.

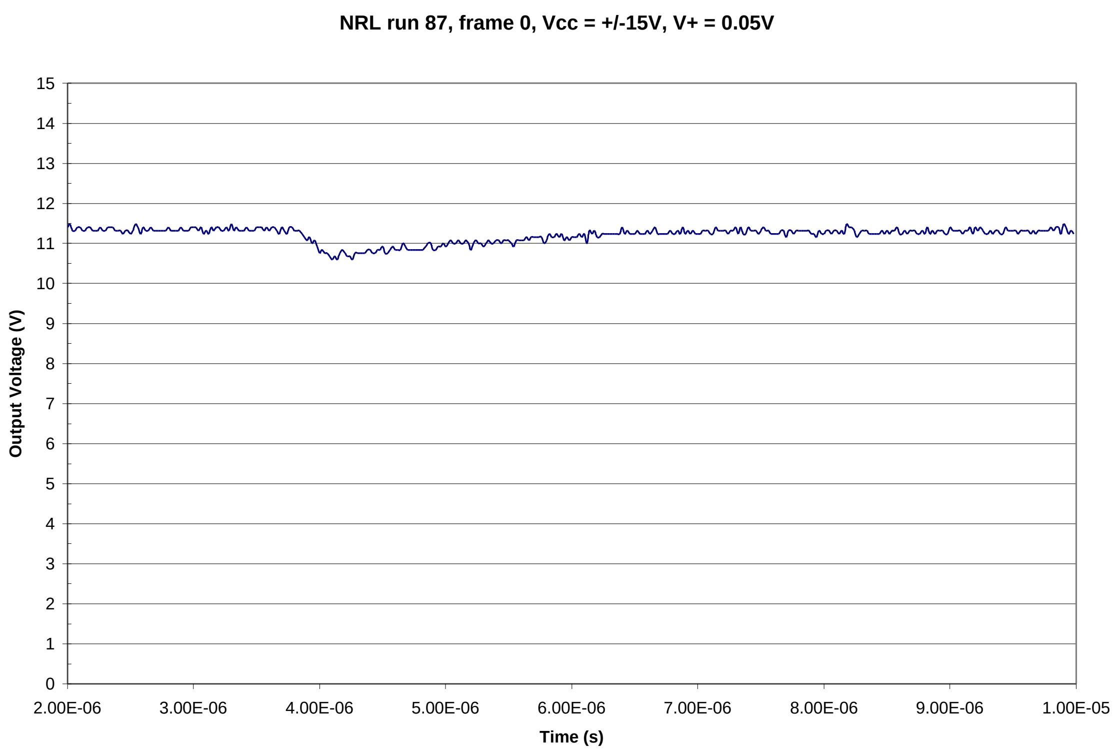

Figure 50 : LM124, Non Inverting Gain1 application, location 8, typical pulse for a laser energy of 321 pJ.

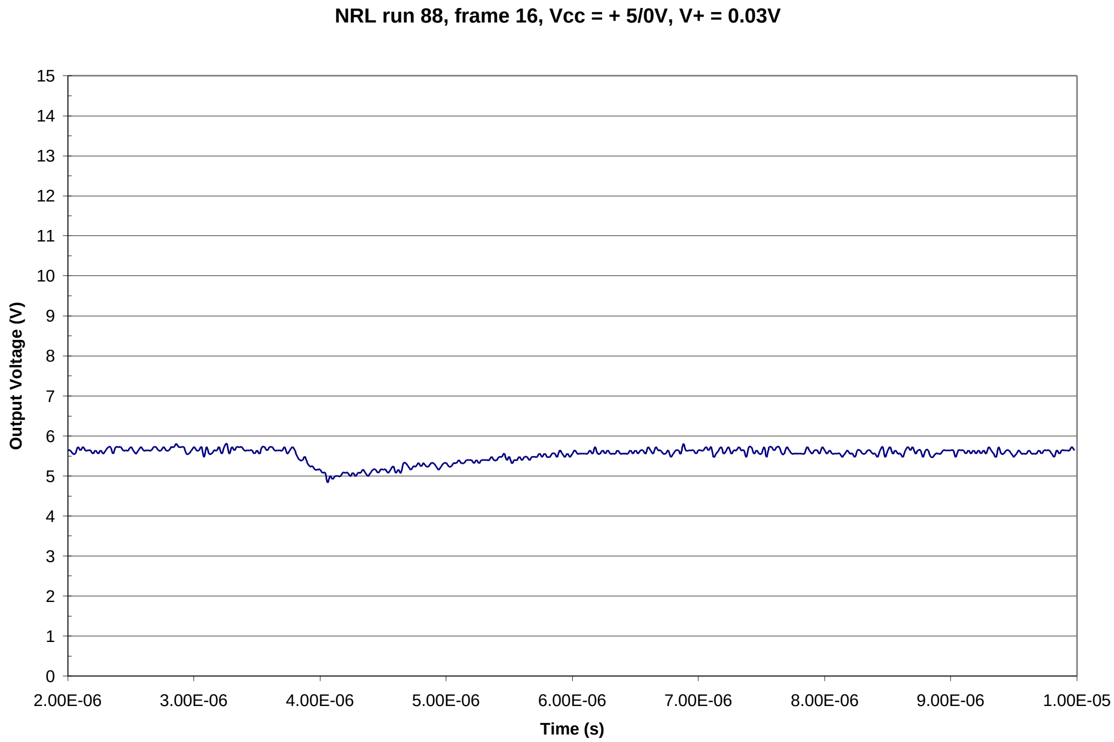

Figure 51 : LM124, Non Inverting Gain1 application,
location 8, typical pulse for a laser energy of 321 pJ.

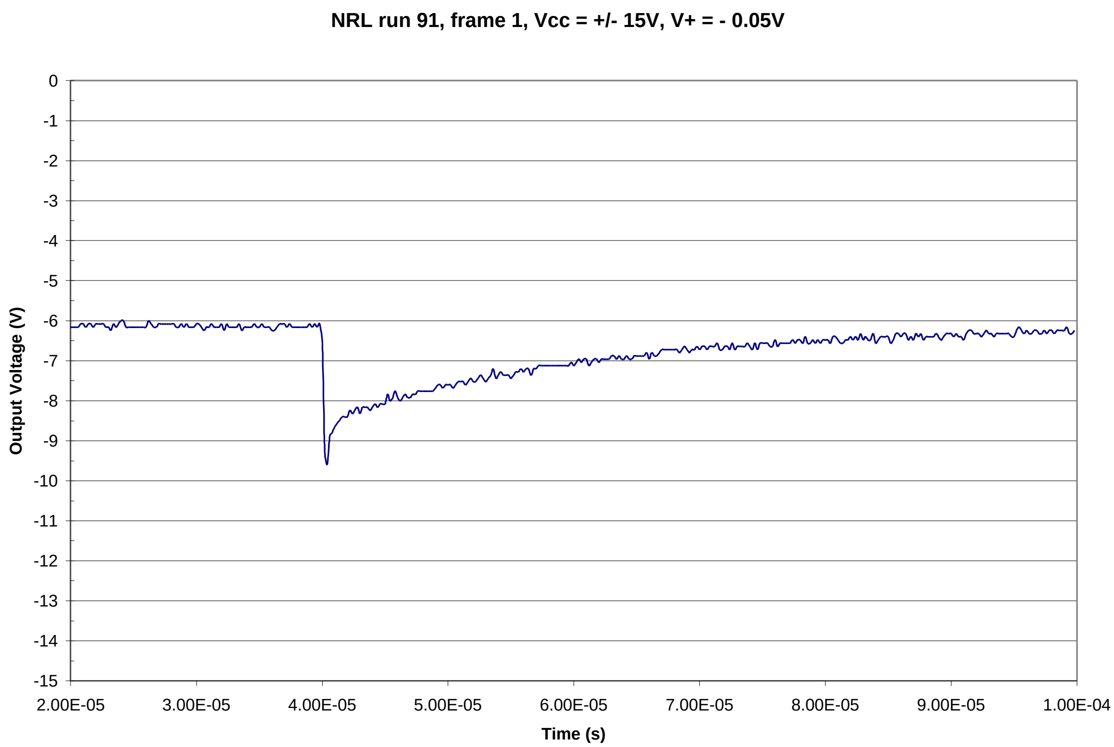

Figure 52 : LM124, Non Inverting Gain1 application,
location 8, typical pulse for a laser energy of 39 pJ.

8 Analysis of transient pulse shapes on the Non Inverting Gain2 (X11) application

8.1 Bias conditions

Only one of the bias conditions investigated during Heavy ion experiments has been used. This test condition is given in Table 6.

Power Supply		Input		Output (V)
Vcc+ (V)	Vcc- (V)	V+(V)	V-(V)	
15	-15	1	0	11

Table 6: bias conditions investigated for the Non Inverting Gain2 application.

8.2 Test results

Among the eight sensitive regions irradiated, 6 have shown SET sensitivity for the Non inverting Gain 2 application with the bias condition investigated. Regions 1, 4&5 and 2 are the most sensitive regions.

Location 1
With a laser energy of 13 pJ, we obtained large negative going transients as shown in Figure 53 (Voltage amplitude=4V, FWMH = 4 µs).

Location 2
With a laser energy of 246 pJ, we obtained small bipolar pulses as shown in Figure 54.

Location 3
With a laser energy of 3214 pJ, no event has been observed.

Location 4&5
With a laser energy of 214 pJ, we obtained small positive going transients as shown in Figure 55.

Location 6
With a laser energy of 386 pJ, we obtained small positive going transients as shown in Figure 56.

Location 7
With a laser energy of 3214 pJ, no event has been observed.

Location 8
With a laser energy of 386 pJ, we obtained small negative going transients.

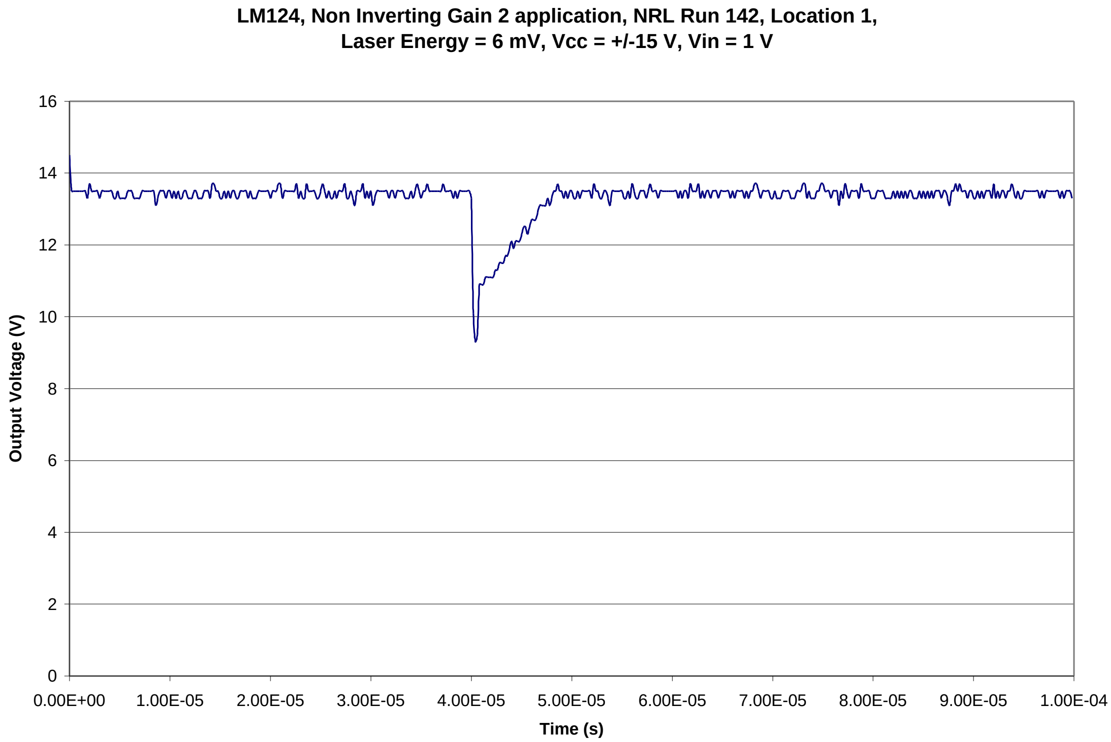

Figure 53 : LM124, Non Inverting Gain2 application, location 1, typical pulse for a laser energy of 13 pJ.

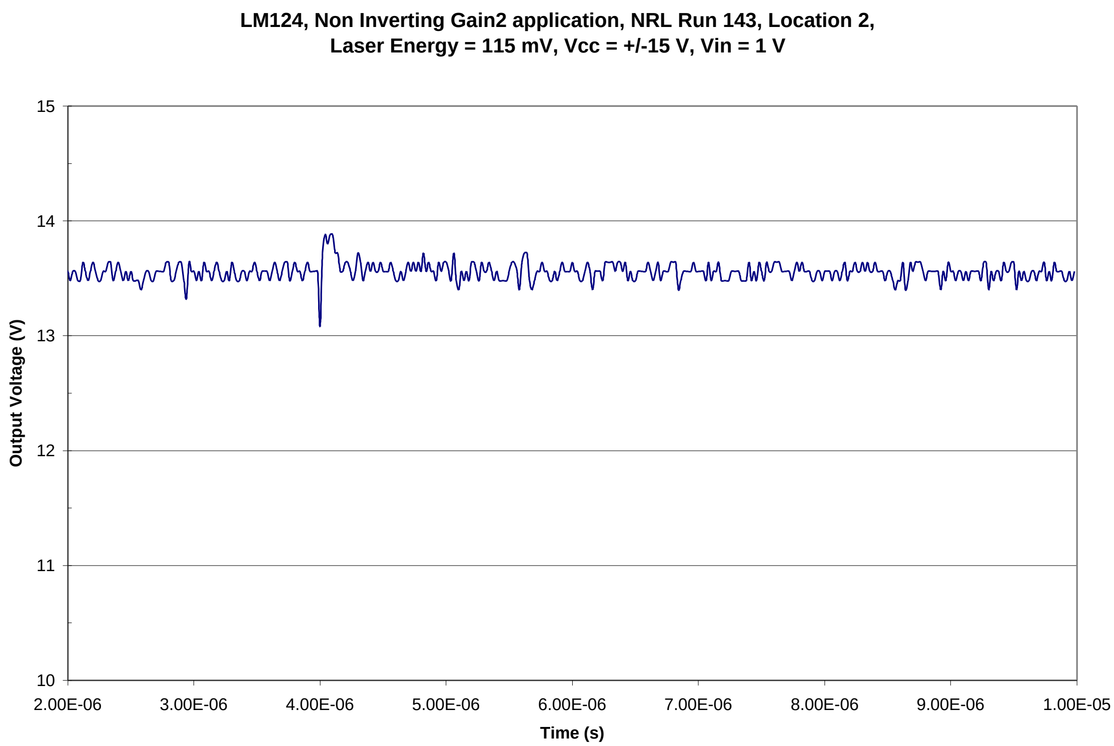

Figure 54 : LM124, Non Inverting Gain2 application, location 2, typical pulse for a laser energy of 246 pJ.

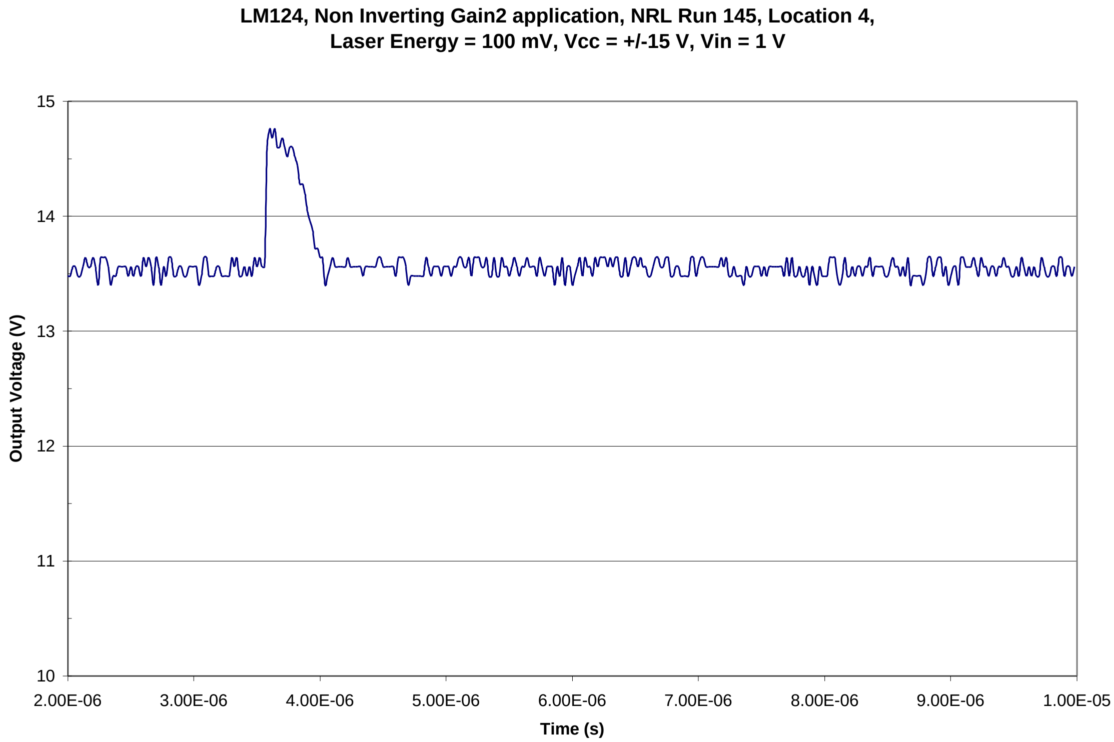

Figure 55 : LM124, Non Inverting Gain2 application, location 4, typical pulse for a laser energy of 214 pJ.

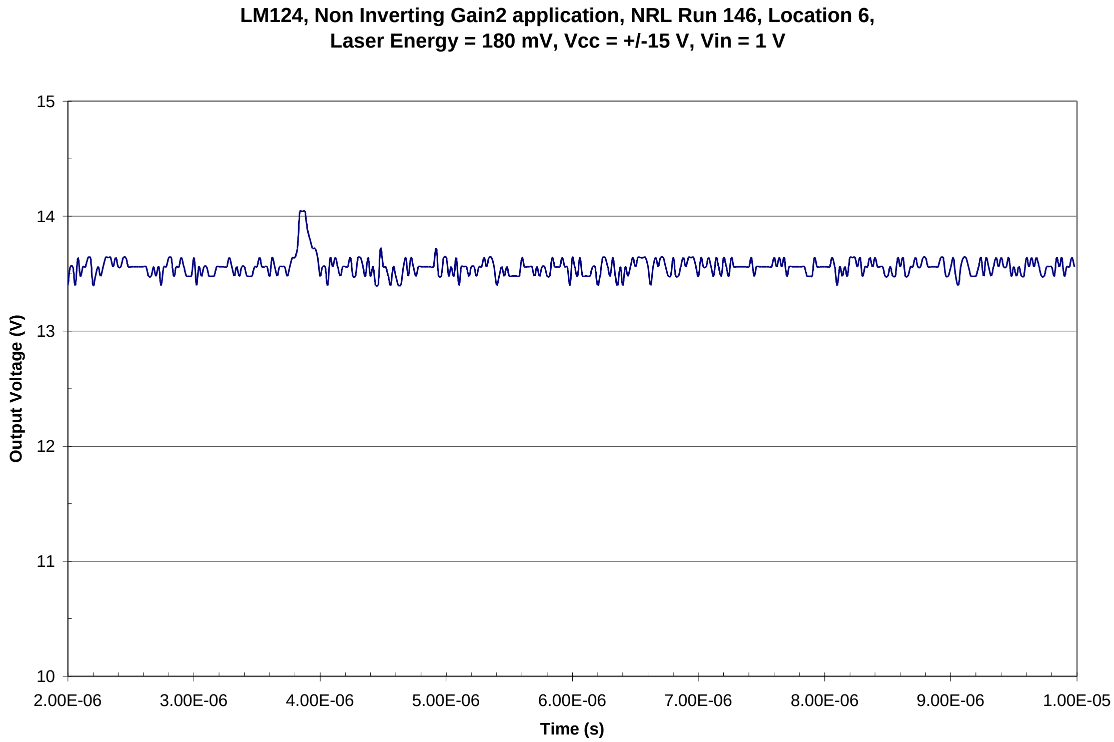

Figure 56 : LM124, Non Inverting Gain2 application, location 6, typical pulse for a laser energy of 386 pJ.

9 Analysis of transient pulse shape on the Voltage Follower application

9.1 Bias conditions

A subset of the bias conditions investigated during Heavy ions experiments has been used. These test conditions are given in Table 7.

Power Supply		Input bias		Output (V)
Vcc+ (V)	**Vcc- (V)**	**V+(V)**	**V-(V)**	
15	**-15**	**5**	**0**	**5**
		10	0	10
		-5	0	-5
5	0	0.3	0	0.3
		3	0	3

Table 7: bias conditions investigated for the Voltage Follower application.

9.2 Test results

All the eight sensitive regions irradiated have shown SET sensitivity. Regions 1, 8, 4&5, 3 and 7 are the most sensitive regions.

<u>Location 1</u>

With a laser energy of 39 pJ, for Vcc=+/-15V, V+ = 5V and V- = 0V, we obtained small negative going transients as shown in Figure 57 (Voltage amplitude=2V, FWMH = 4 µs).

When we change the input voltage to V+ = 10V, we do not see a significant change in the transient shape.

When the laser energy is increased to 96 pJ, the transient voltage amplitude and duration increases as shown in Figure 58.

When we change the power supply voltage to Vcc = +5/0 V, we observe similar pulses for V+ = 3V as shown in Figure 59. But for V+ = 0.3V, we observe bipolar pulses as shown in Figure 60.

For Vcc = +/-15V and V+ = -5V (negative input voltage), the same type of pulse is observed, but at lower energy. The Figure 61 shows that a 4.5V pulse amplitude has been obtained for a 54 pJ laser energy.

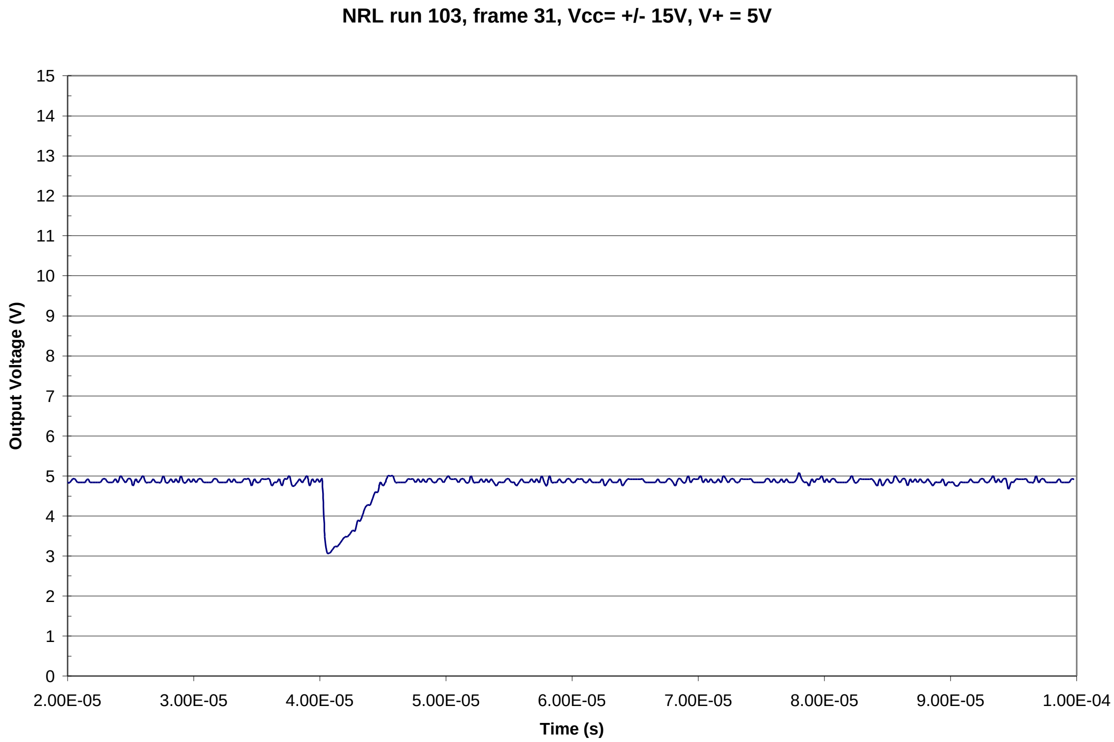

Figure 57: LM124, Voltage Follower application,
location 1, typical pulse for a laser energy of 39 pJ.

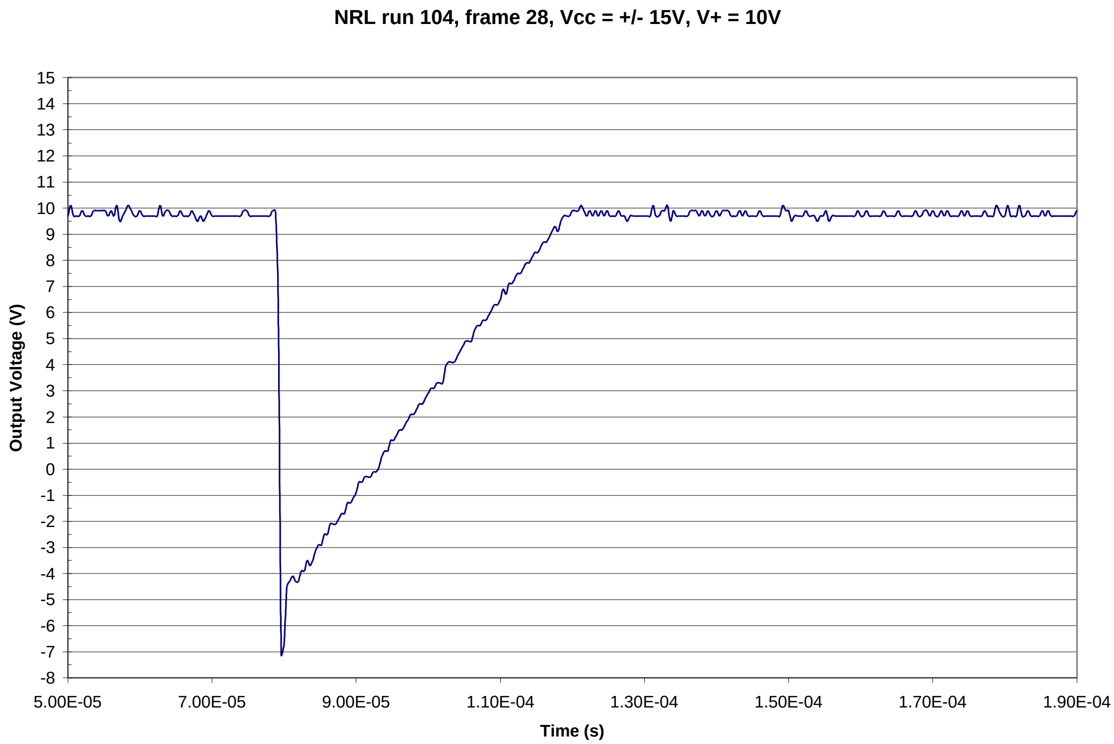

Figure 58: LM124, Voltage Follower application,
location 1, typical pulse for a laser energy of 96 pJ.

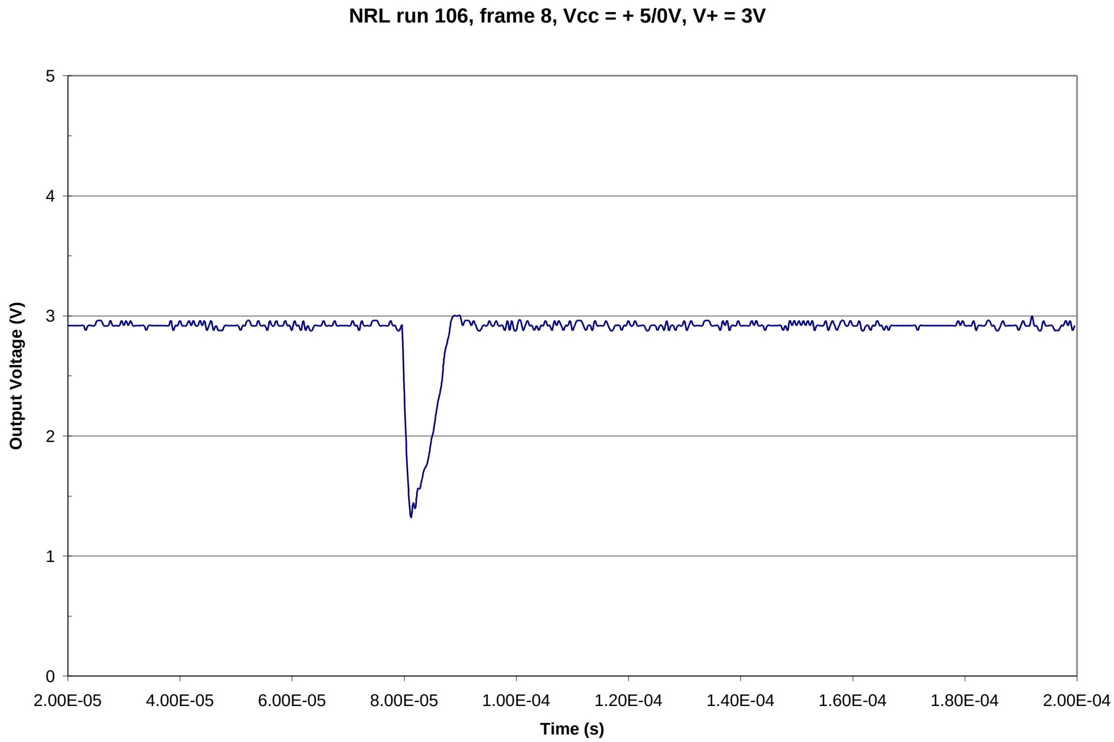

Figure 59: LM124, Voltage Follower application,
location 1, typical pulse for a laser energy of 43 pJ.

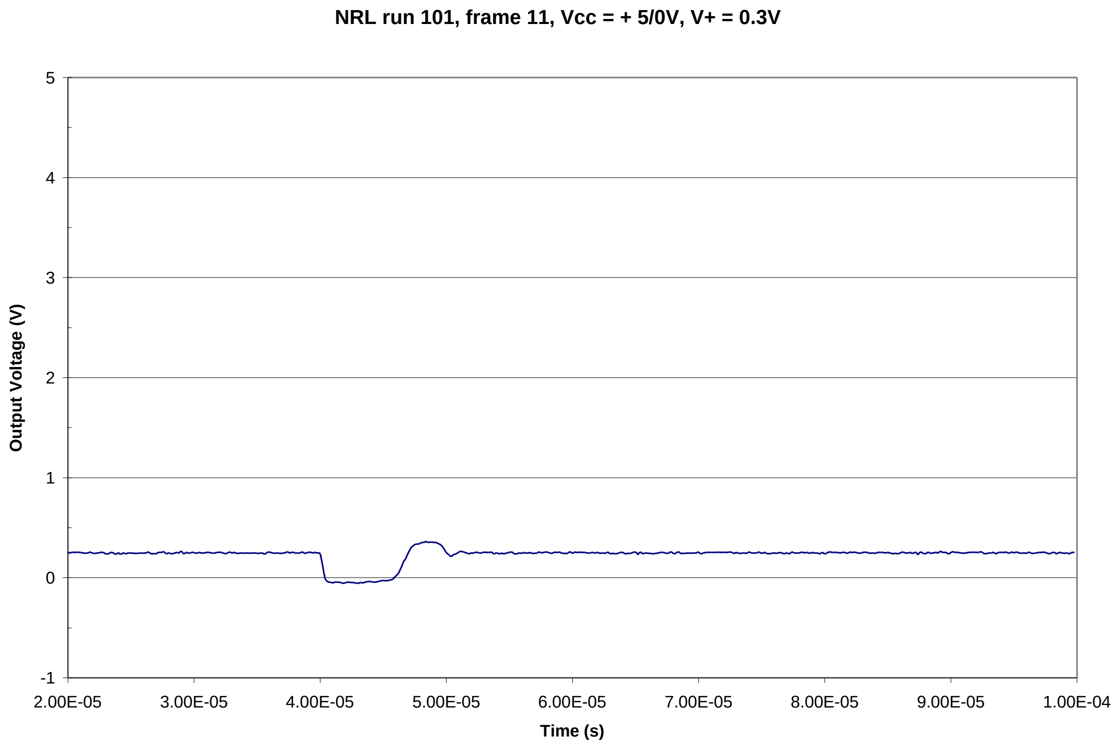

Figure 60: LM124, Voltage Follower application,
location 1, typical pulse for a laser energy of 39 pJ.

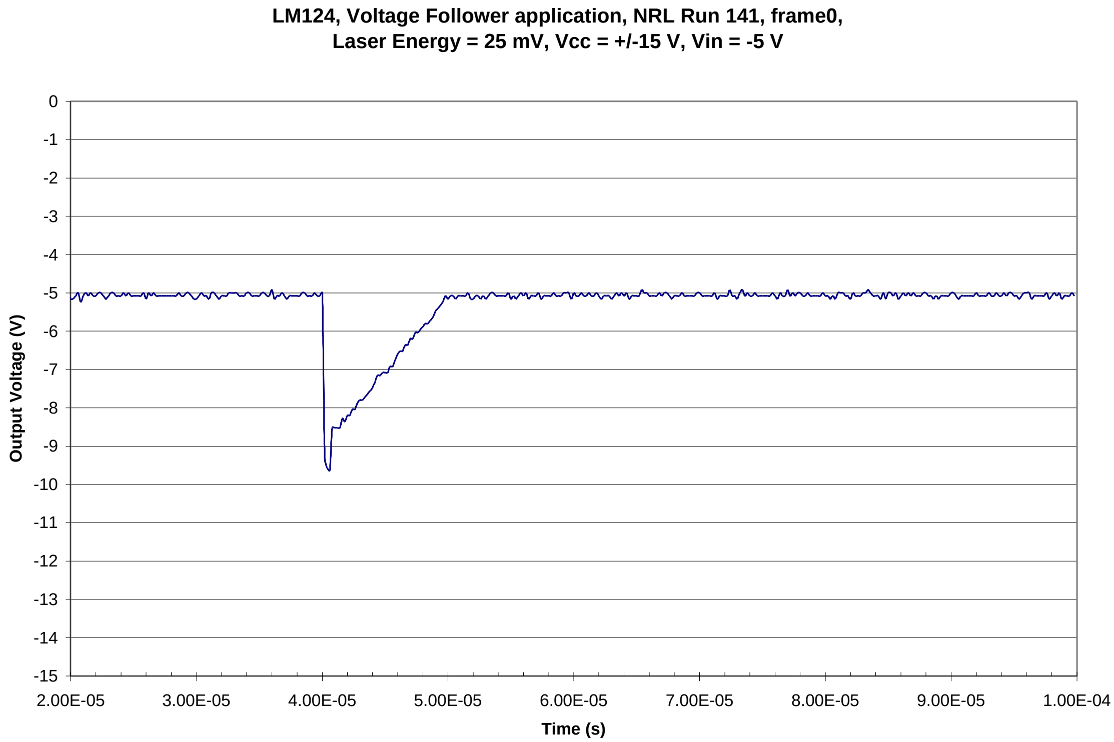

Figure 61: LM124, Voltage Follower application
Location 1, typical pulse for a laser energy of 54 pJ.

Location 2

With a laser energy of 300 pJ, for Vcc=+/-15V, V+ = 5V and V- = 0V, we obtained large negative going pulses as shown in Figure 62 (Voltage amplitude=7V, FWMH = 6 µs).

When we change the input voltage to V+ = 10V, we do not see a significant change in the transient shape.

When the laser energy is increased to 429 pJ, the transient voltage amplitude and duration increases as shown in Figure 63.

When we change the power supply voltage to Vcc = +5/0 V and V+ = 3V, we observe small bipolar transients as shown in Figure 64. When we increase the energy to 429 pJ, the transient shape does not change significantly.

For Vcc = +/-15V and V+ = -5V (negative input voltage), we obtained a small bipolar pulse, but at a lower energy (86 pJ) as shown in Figure 65.

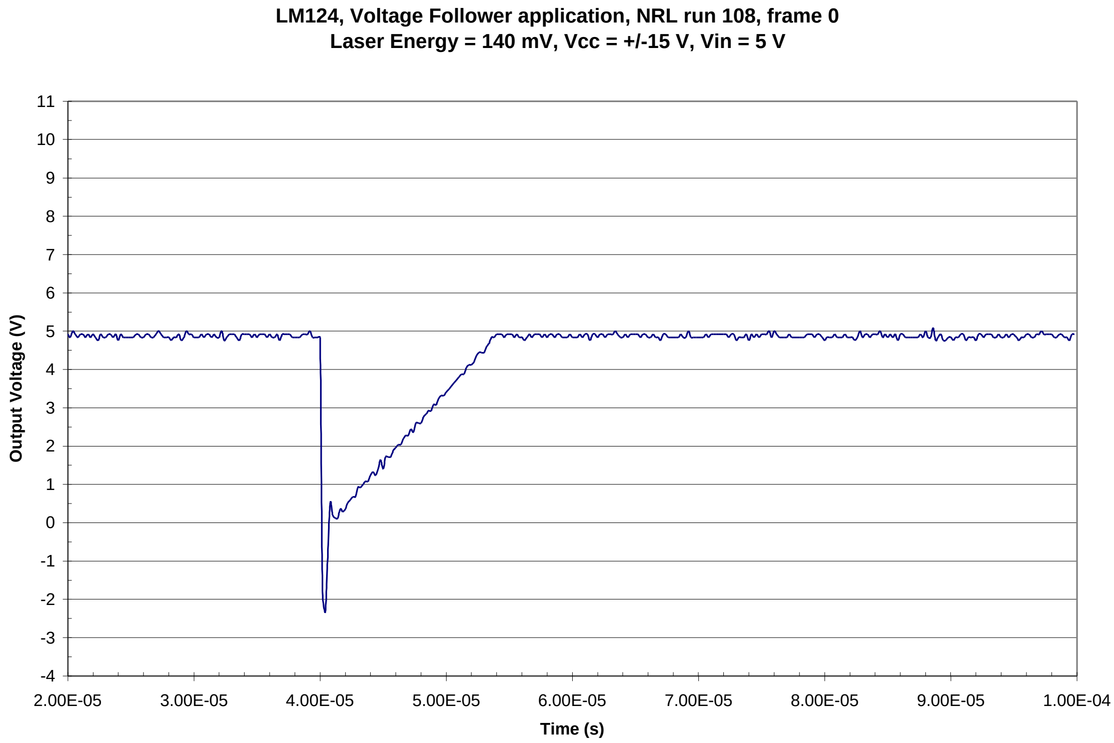

Figure 62: LM124, Voltage Follower application
Location 2, typical pulse for a laser energy of 300 pJ.

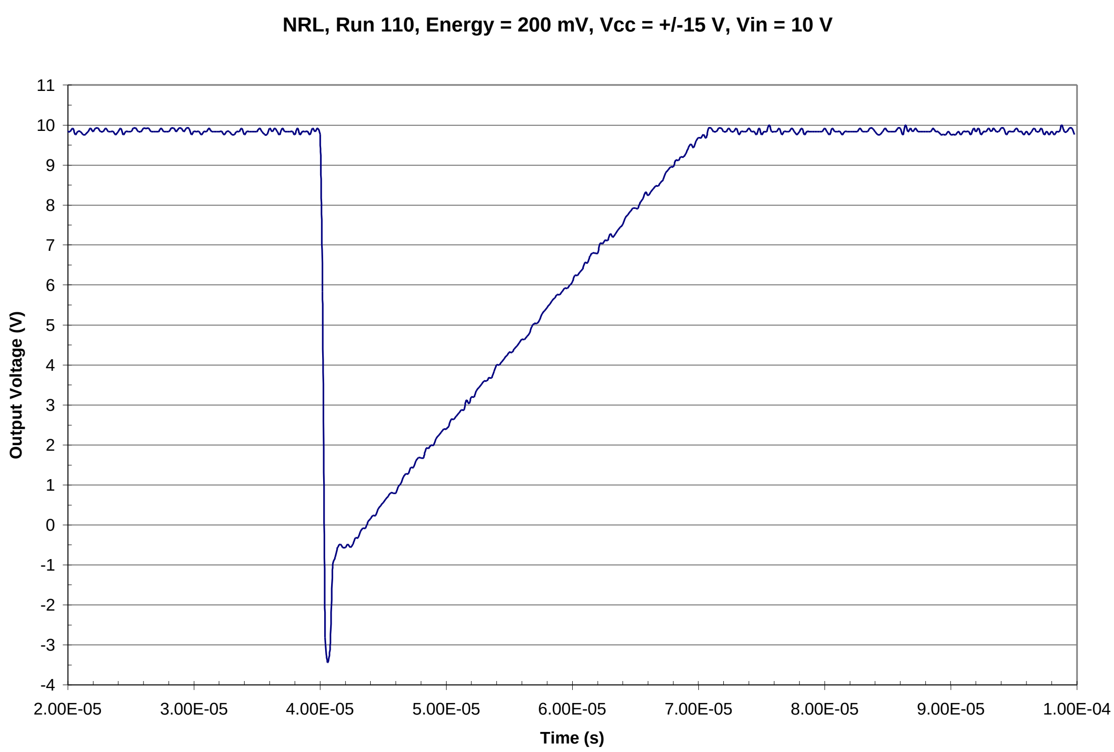

Figure 63: LM124, Voltage Follower application
Location 2, typical pulse for a laser energy of 429 pJ.

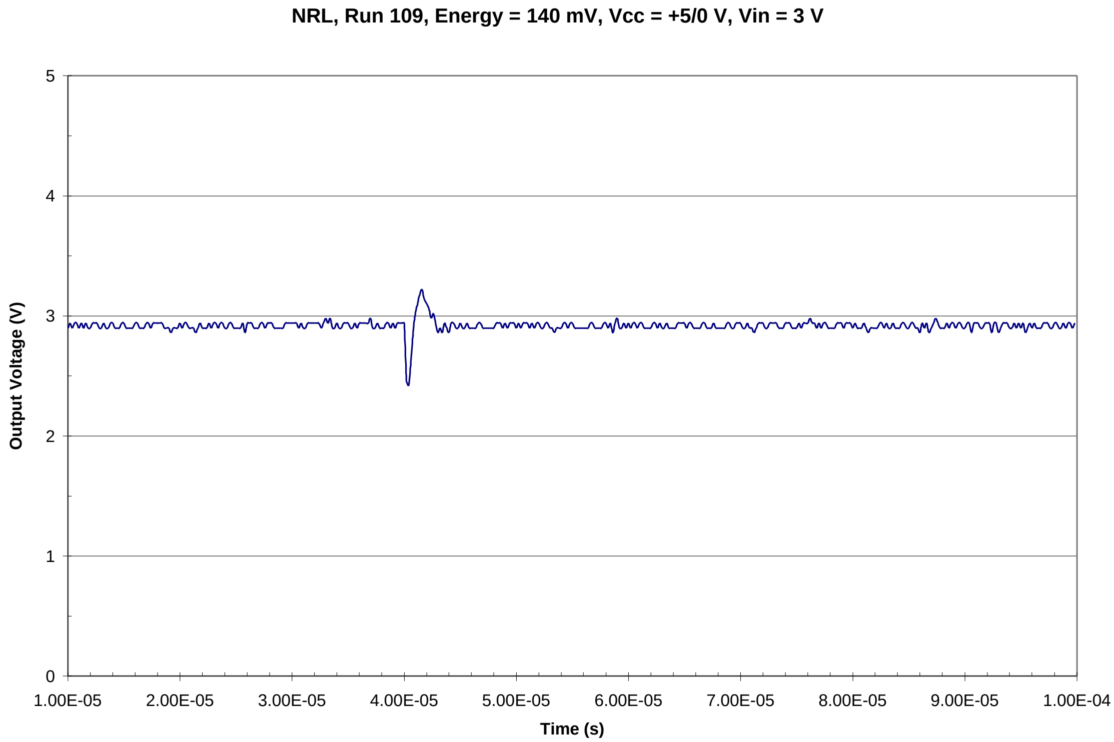

Figure 64: LM124, Voltage Follower application
Location 2, typical pulse for a laser energy of 300 pJ.

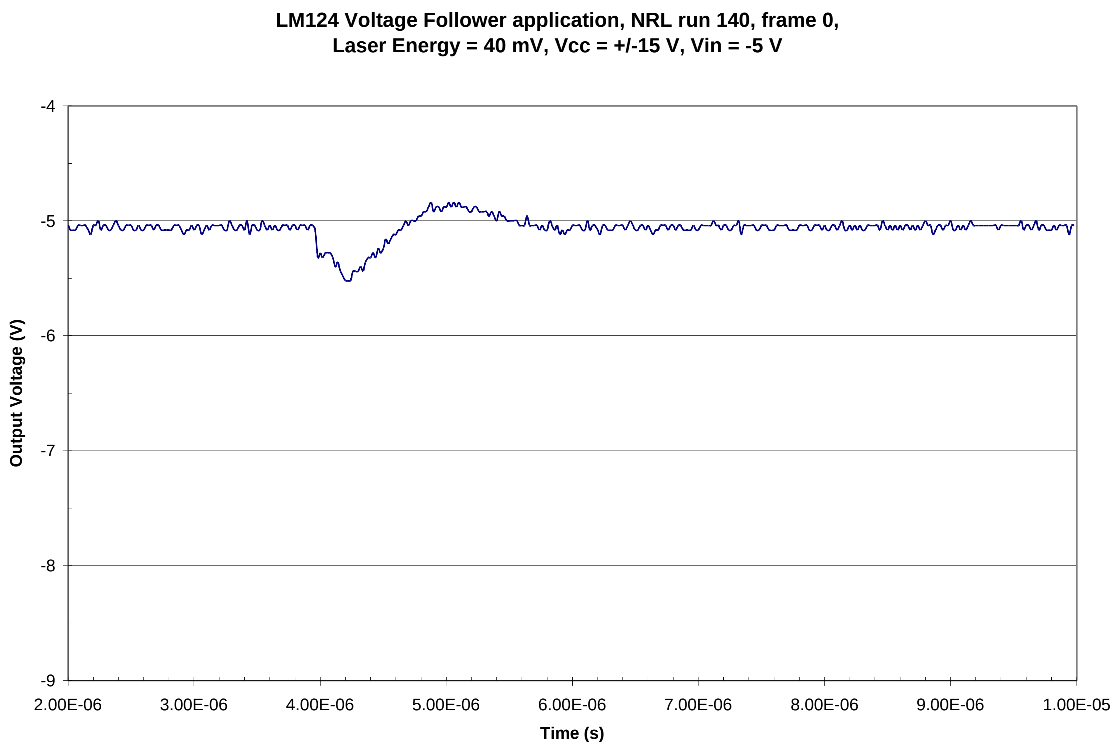

Figure 65: LM124, Voltage Follower application
Location 2, typical pulse for a laser energy of 86 pJ.

Location 3

With a laser energy of 45 pJ, for Vcc=+/-15V, V+ = 5V and V- = 0V, we obtain small bipolar transients as shown in Figure 66.

When we change the input voltage to V+ = 10V, we do not see a significant change in the transient shape.

When the laser energy is increased to 321 pJ, we observe bipolar transients with a large negative going component as shown in Figure 67.

When we change the power supply voltage to Vcc = +5/0 V and V+ = 3V, we observe small bipolar pulses as shown in Figure 68. When we increase the energy to 321 pJ, the pulse shape does not change significantly.

For Vcc = +/-15V and V+ = -5V (negative input voltage), we obtain a similar transient shape as shown in Figure 69 for a laser energy of 86 pJ.

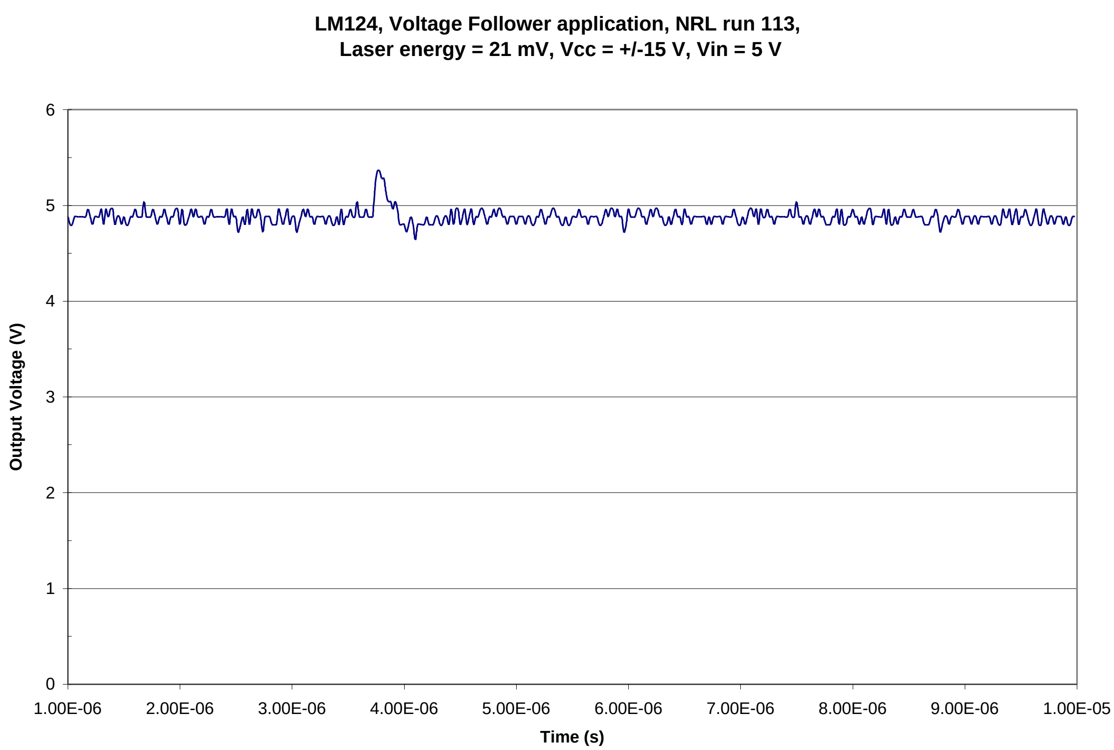

Figure 66: LM124, Voltage Follower application
Location 3, typical pulse for a laser energy of 45 pJ.

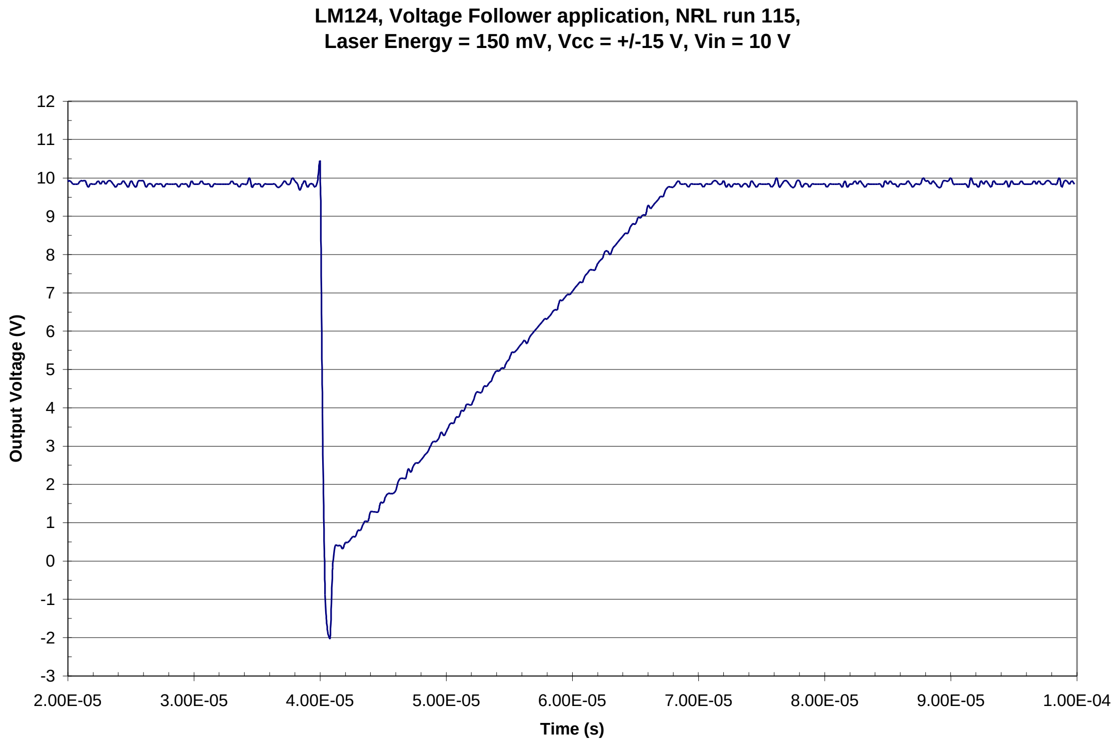

Figure 67: LM124, Voltage Follower application
Location 3, typical pulse for a laser energy of 321 pJ.

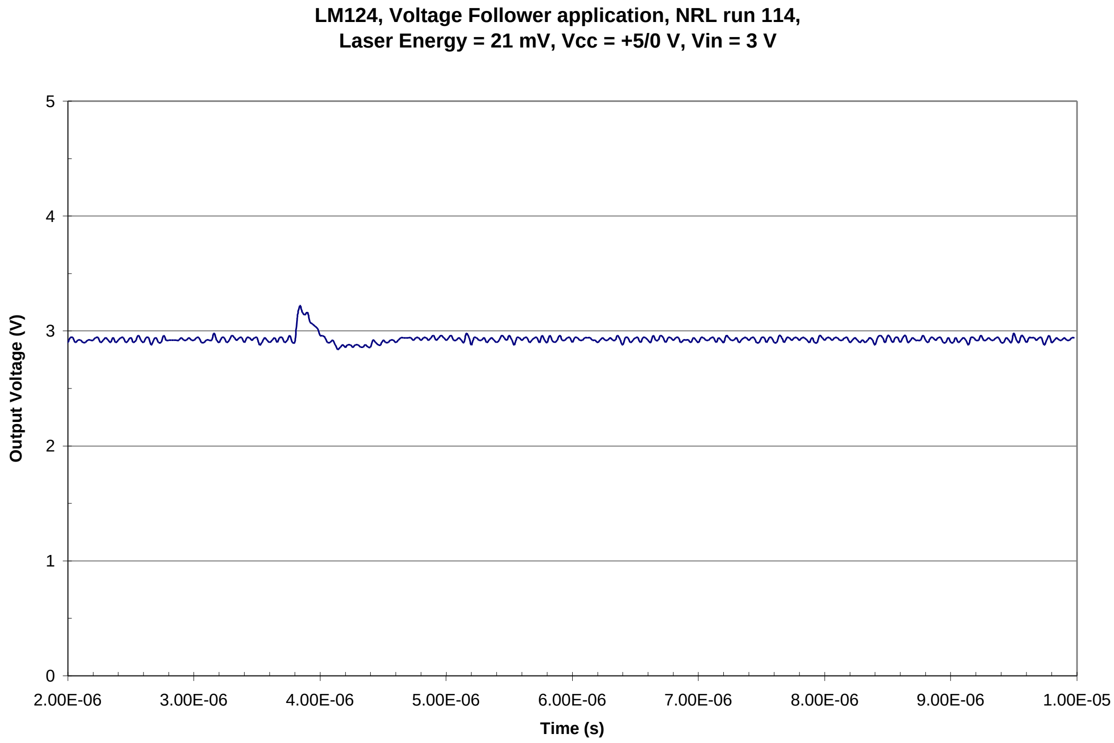

Figure 68: LM124, Voltage Follower application
Location 3, typical pulse for a laser energy of 45 pJ.

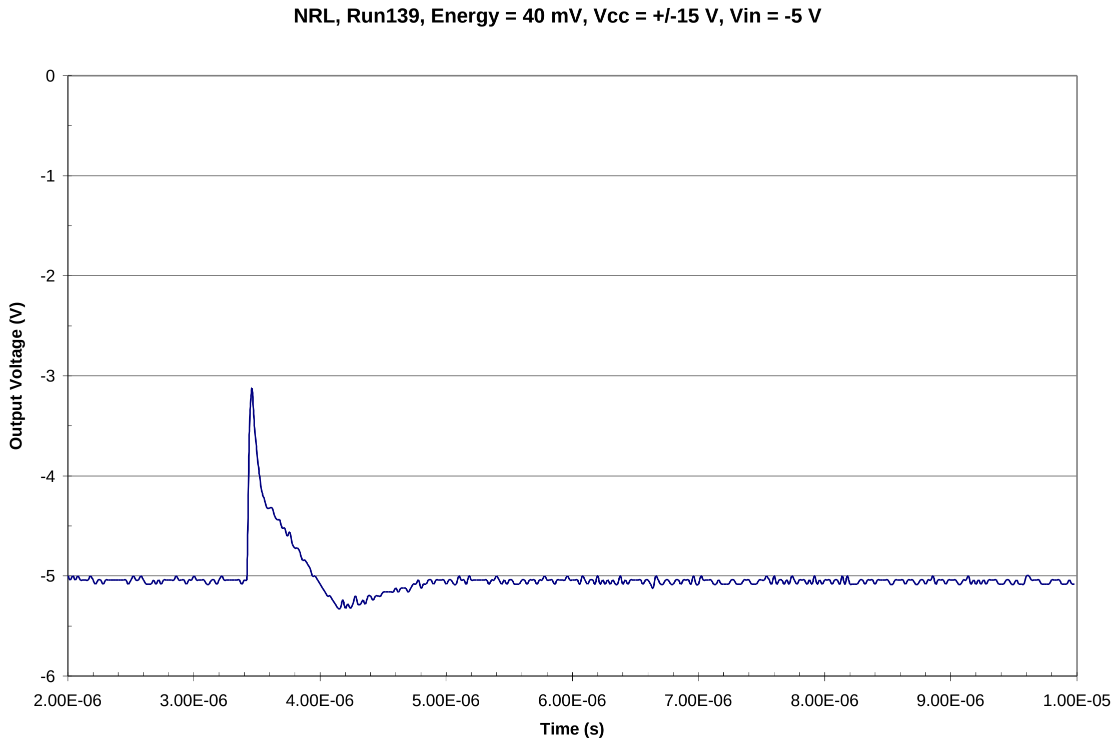

Figure 69: LM124, Voltage Follower application
Location 3, typical pulse for a laser energy of 86 pJ.

Location 4

With a laser energy of 43 pJ, for Vcc=+/-15V, V+ = 5V and V- = 0V, we obtain small bipolar pulses as shown in Figure 70.

When we change the input voltage to V+ = 10V, we do not see a significant change in the transient shape.

When the laser energy is increased to 429 pJ, we get a larger bipolar transient as shown in Figure 71. The voltage amplitude is 2V and the FWMH 1.5 µs.

When we change the power supply voltage to Vcc = +5/0 V and V+ = 3V, we observe a similar bipolar pulse. When we increase the energy to 150 mV, the pulse shape does not change significantly but the size increases in the same proportions than for +/-15V power supply case.

For Vcc = +/-15V and V+ = -5V (negative input voltage), we obtain a similar transient shape as shown in Figure 72 for a laser energy of 86 pJ.

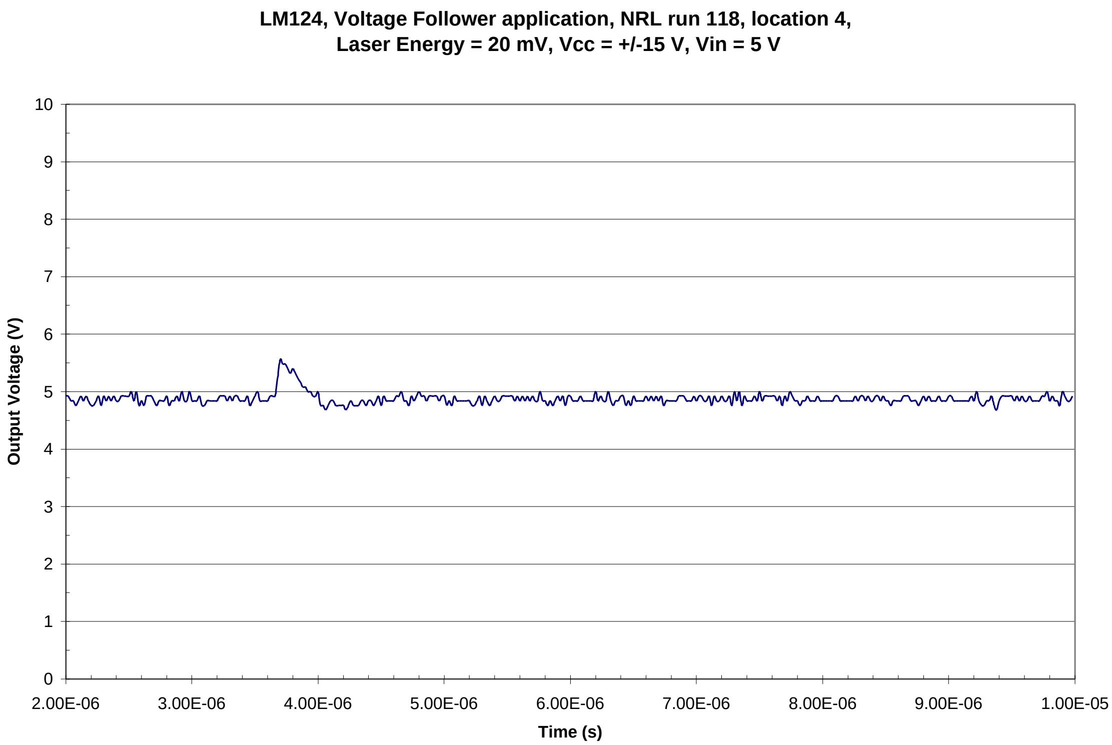

Figure 70: LM124, Voltage Follower application
Location 4, typical pulse for a laser energy of 43 pJ.

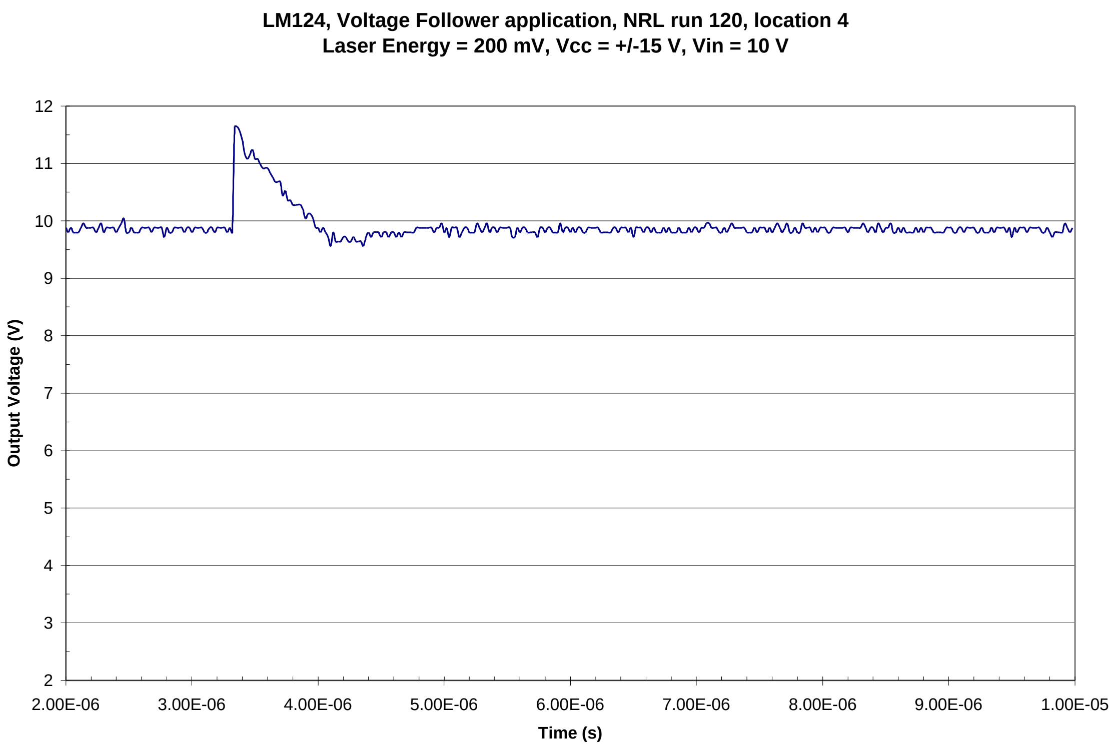

Figure 71: LM124, Voltage Follower application
Location 4, typical pulse for a laser energy of 429 pJ.

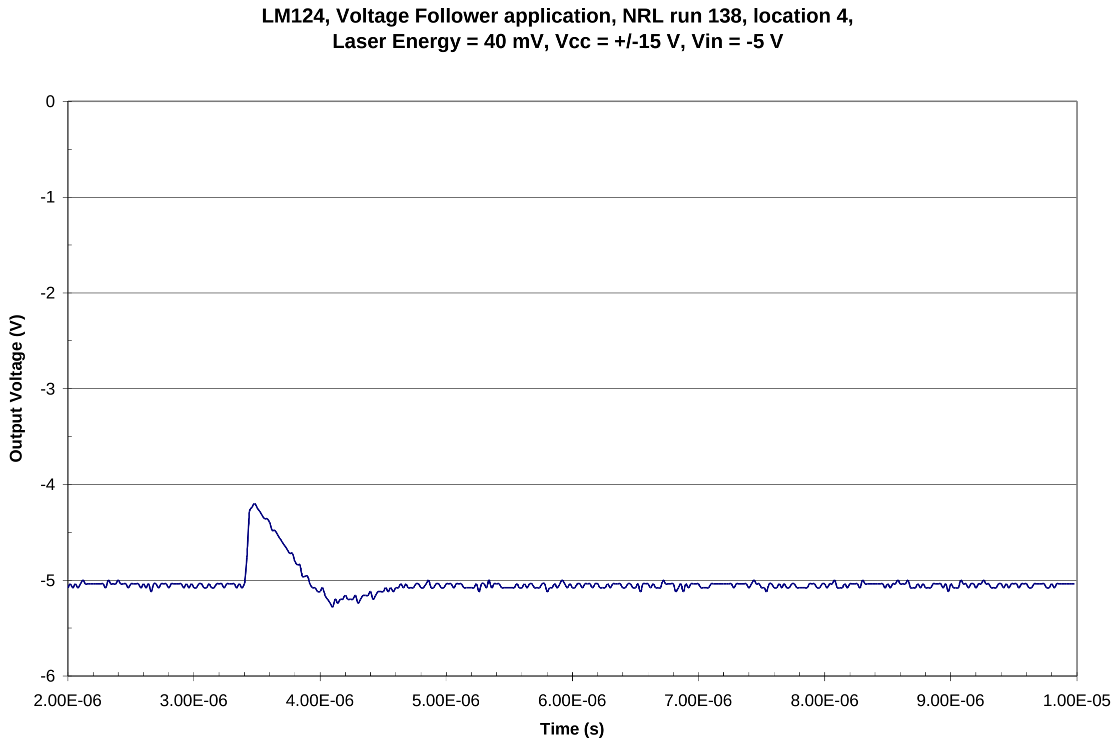

Figure 72: LM124, Voltage Follower application
Location 4, typical pulse for a laser energy of 86 pJ.

Location 6

This location is only sensitive at high energy. With a laser energy of 471 pJ, for Vcc=+/-15V, V+ = 5V and V- = 0V, we obtain small positive going transients. Voltage amplitude is 0.5V and FWMH is 1.2 µs.

When we change the input voltage to V+ = 10V, we do not see a significant change in the transient shape. A typical transient is shown in Figure 73.

When we change the power supply voltage to Vcc= +5/0 V and V+ = 3V, we observe a similar pulse shape.

For Vcc = +/-15V and V+ = -5V (negative input voltage), we observe a similar pulse shape for a laser energy of 857 pJ.

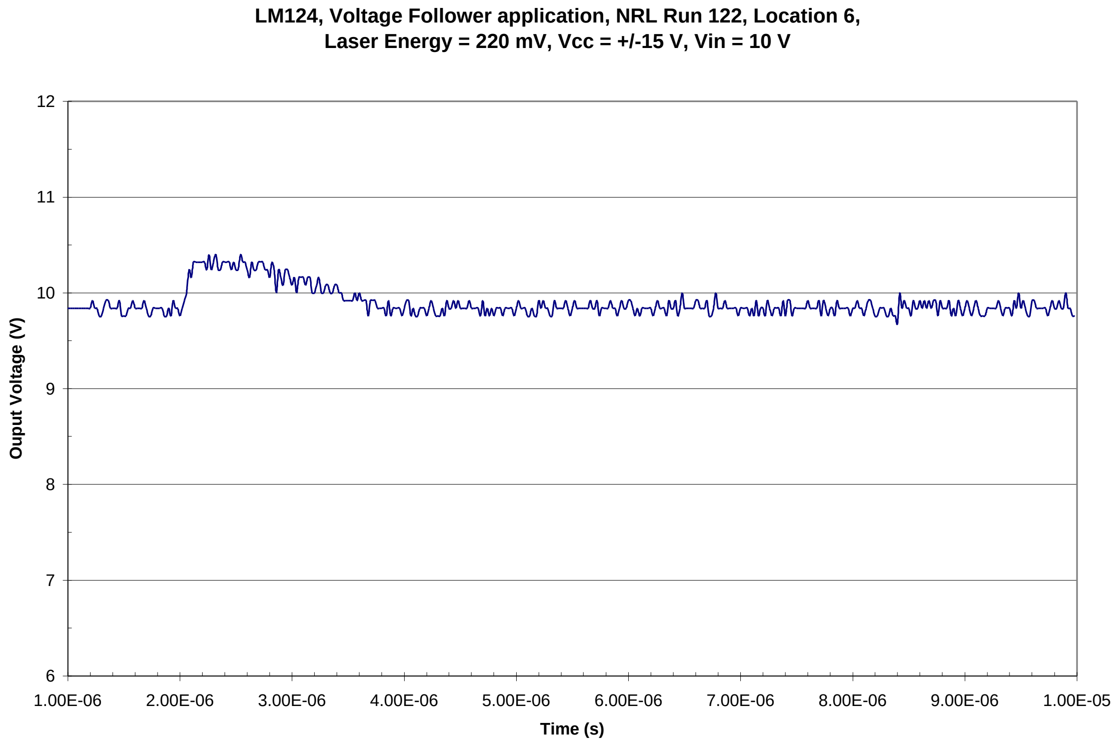

Figure 73: LM124, Voltage Follower application
Location 6, typical pulse for a laser energy of 471 pJ.

Location 7

With a laser energy of 43 pJ, for Vcc=+/-15V, V+ = 5V and V- = 0V, we obtain small positive going transients as shown in Figure 74. The Voltage amplitude is 0.7V and the FWMH is 1.2 µs.

When we change the input voltage to V+ = 10V, we do not see a significant change in the transient shape.

When the laser energy is increased to 429 pJ, we observe the same transient shape but of larger amplitude as shown in Figure 75. The voltage amplitude is 3.2V and the FWMH 5 µs.

When we change the power supply voltage to Vcc = +5/0 V and V+ = 3V, we observe a similar bipolar pulse but of small amplitude. At the energy of 429 pJ, the voltage amplitude is 0.8V and the FWMH is 4 µs.

For Vcc = +/-15V and V+ = -5V (negative input voltage), we observe a similar transient shape. For a laser energy of 86 pJ, the voltage amplitude is 0.6V and the FWMH 1.6 µs.

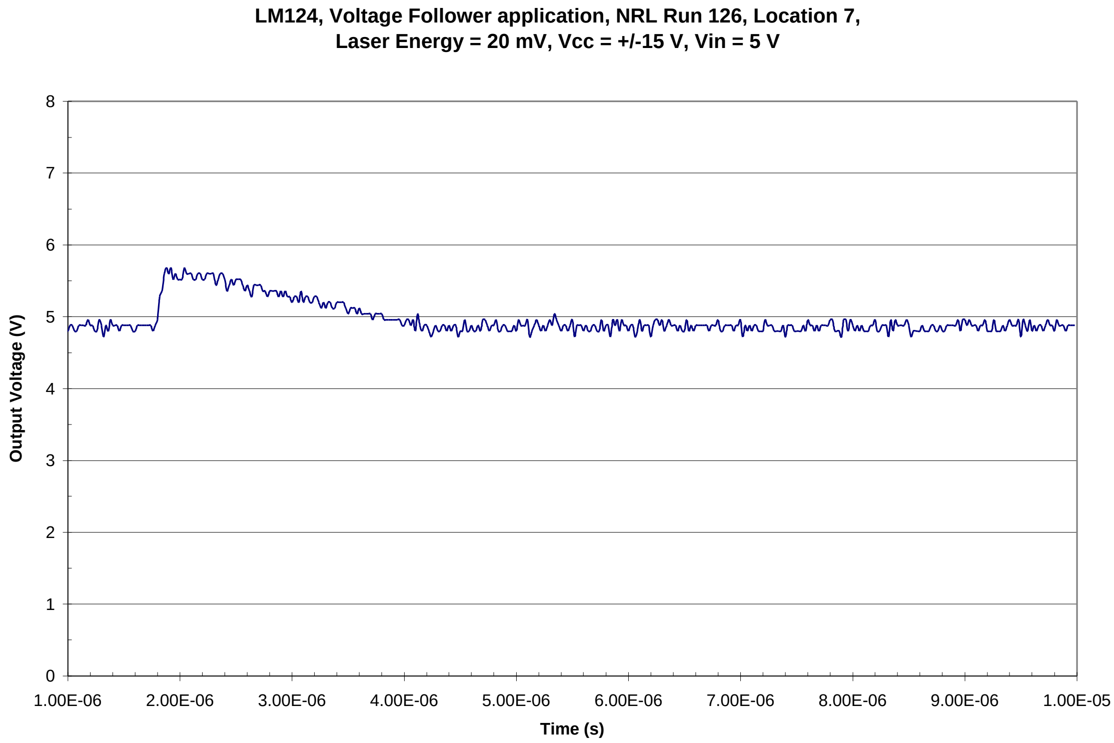

Figure 74: LM124, Voltage Follower application
Location 7, typical pulse for a laser energy of 43 pJ.

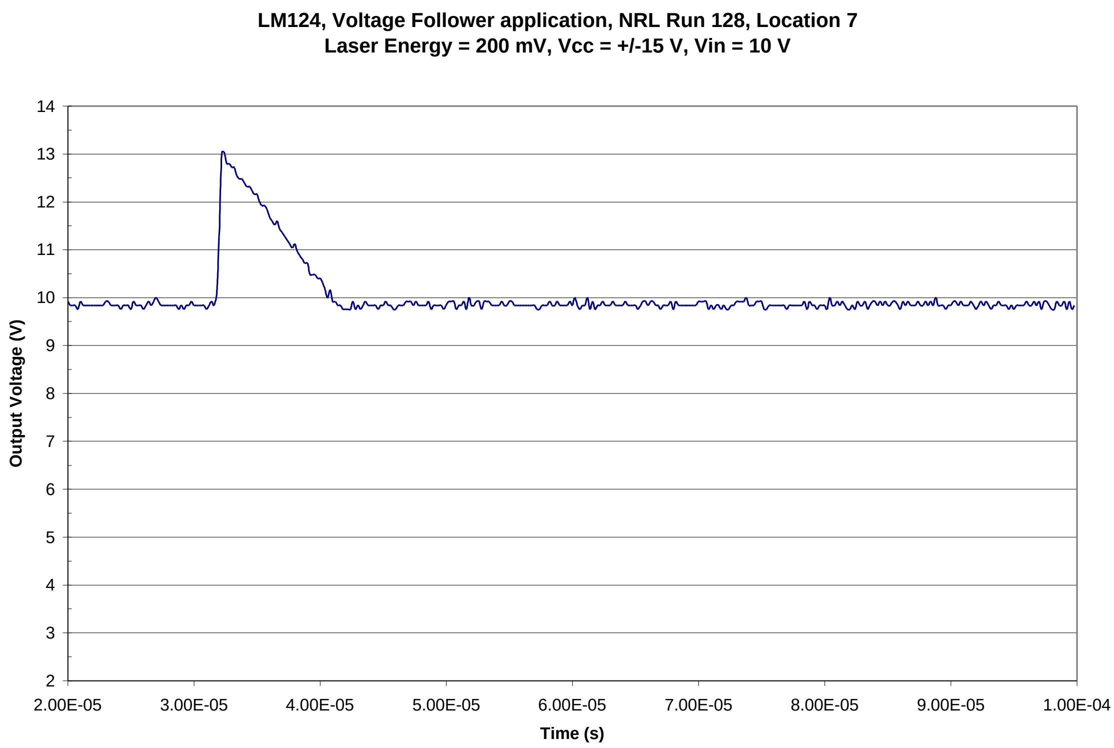

Figure 75: LM124, Voltage Follower application
Location 7, typical pulse for a laser energy of 429 pJ.

Location 8

With a laser energy of 43 pJ, for Vcc=+/-15V, V+ = 5V and V- = 0V, we obtain small negative going pulses as shown in Figure 76. Voltage amplitude is 1.8V and the FWMH is 2 µs.

When we change the input voltage to V+ = 10V, the transient amplitude is larger (5V) and the pulse duration is longer (4.5 µs) as shown in Figure 77.

When the laser energy is increased to 86 pJ, we get the same transient shape but of larger amplitude as shown in Figure 78. The voltage amplitude is 20V and the FWMH 13 µs.

When we change the power supply voltage to Vcc = +5/0 V and V+ = 3V, we observe a bipolar pulse as shown in Figure 79. At the energy of 86 pJ, the transient shape is the same but the voltage amplitude is greater (3V) and the FWMH is longer (7 µs) as shown in Figure 80.

For Vcc = +/-15V and V+ = -5V (negative input voltage), we obtain a similar pulse shape but of smaller size. For a laser energy of 86 pJ, the voltage amplitude is 3V and the FWMH 3 µs, as shown in Figure 81.

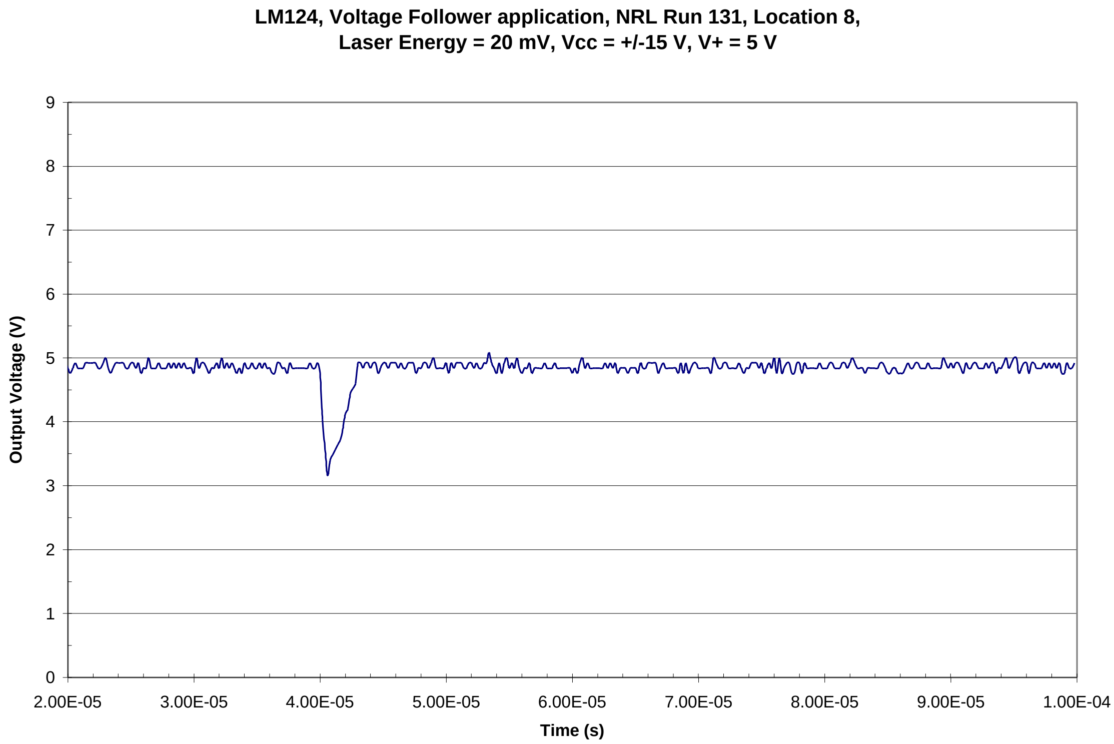

Figure 76: LM124, Voltage Follower application
Location 8, typical pulse for a laser energy of 43 pJ.

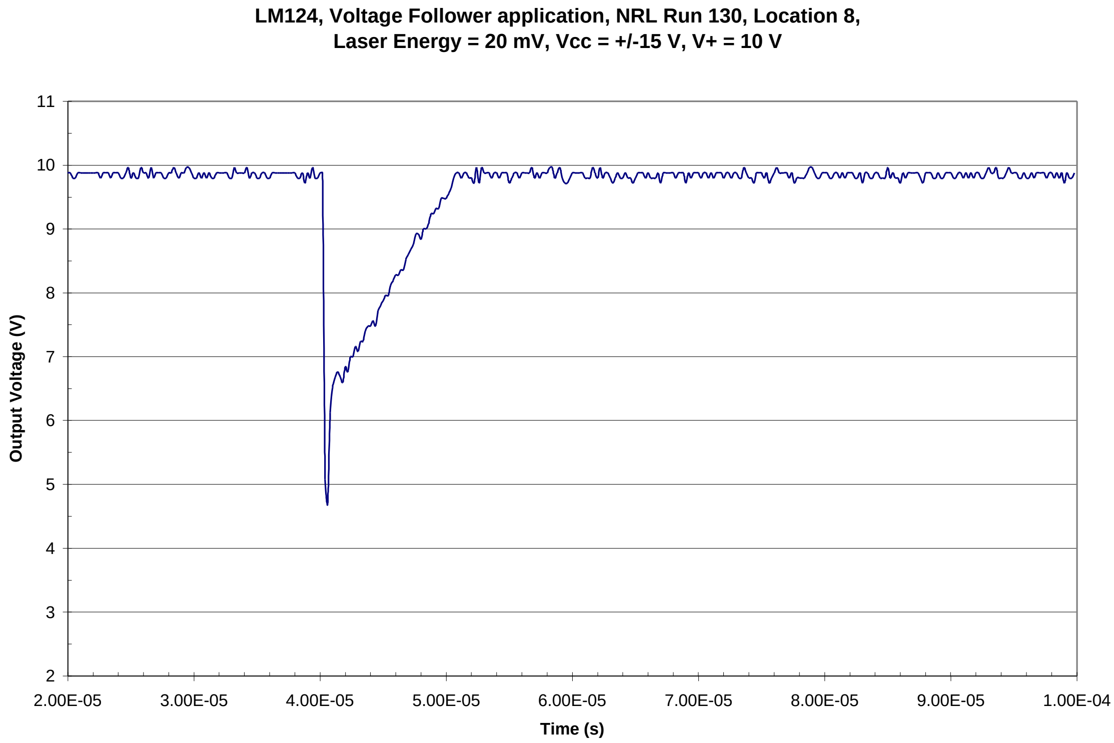

Figure 77: LM124, Voltage Follower application
Location 8, typical pulse for a laser energy of 43 pJ.

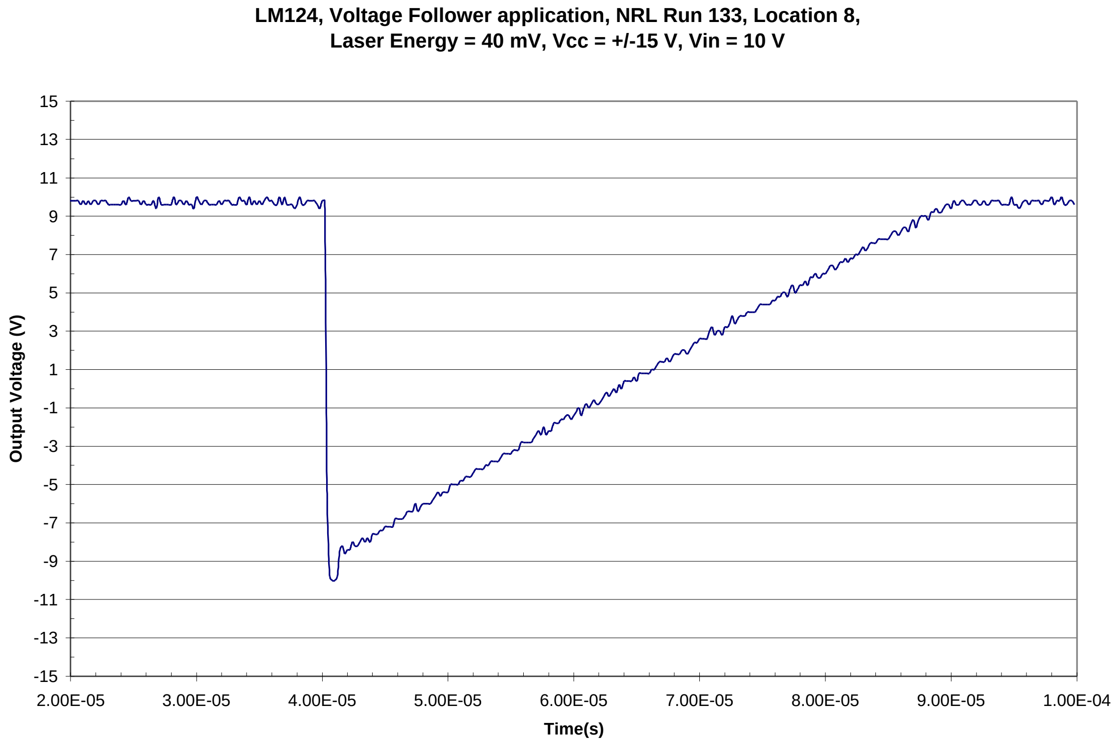

Figure 78: LM124, Voltage Follower application
Location 8, typical pulse for a laser energy of 86 pJ.

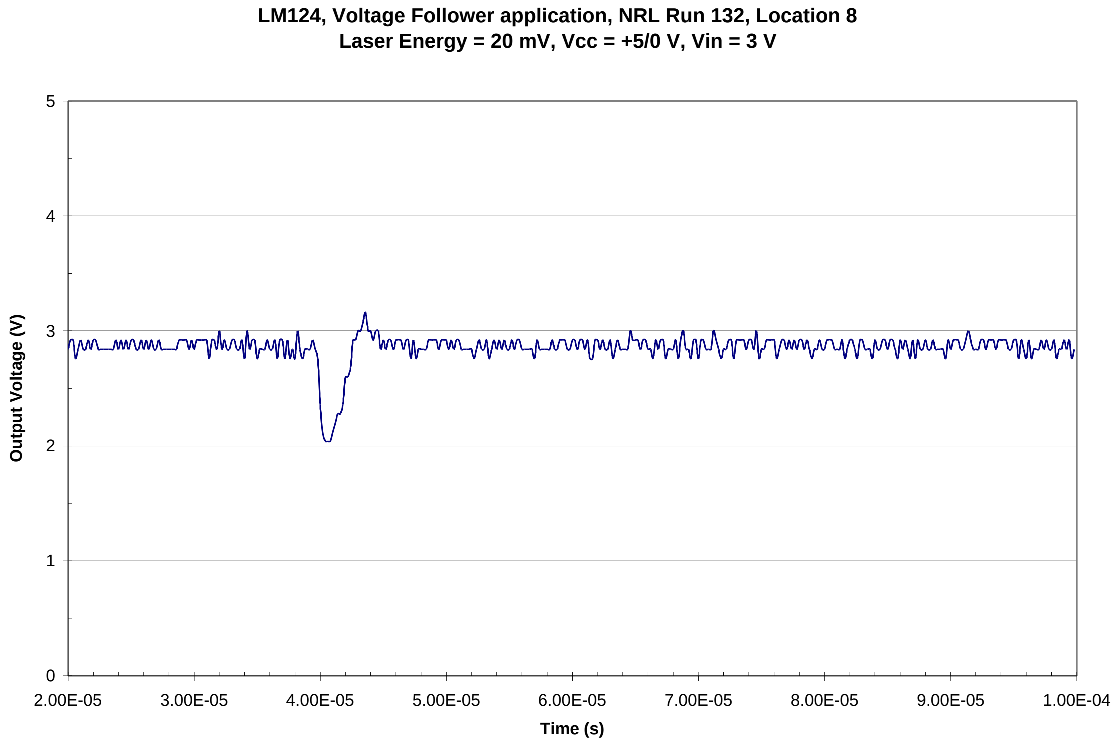

Figure 79: LM124, Voltage Follower application,
Location 8, typical pulse for a laser energy of 43 pJ.

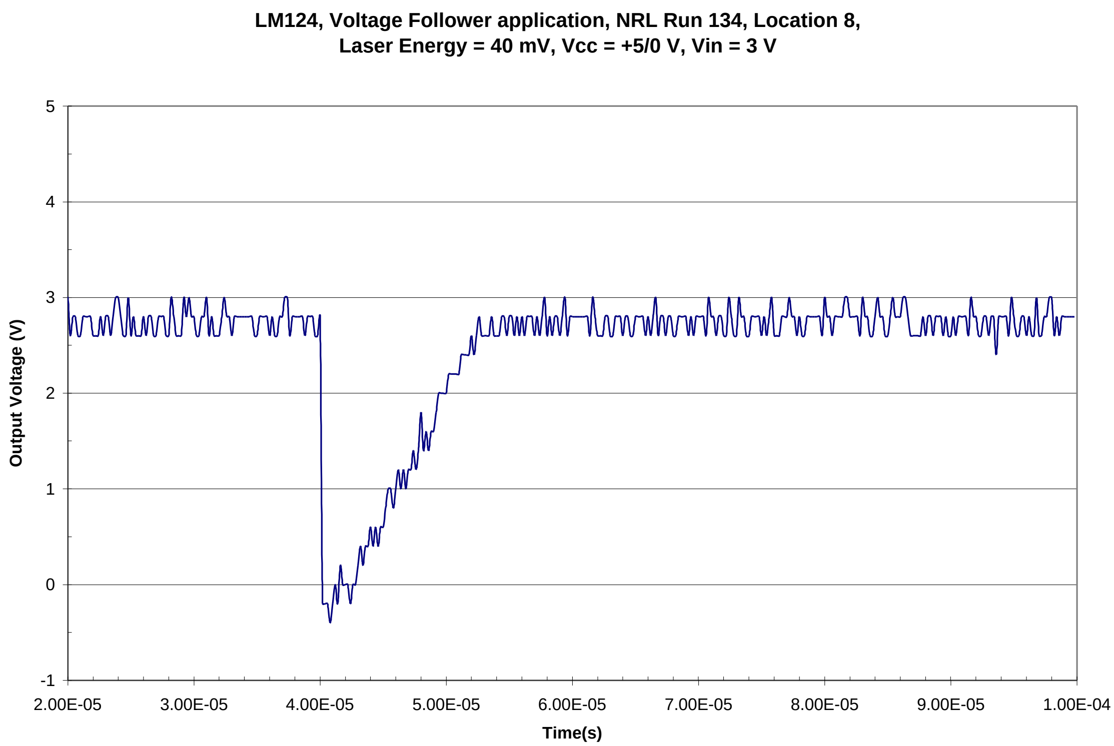

Figure 80: LM124, Voltage Follower application,
Location 8, typical pulse for a laser energy of 86 pJ.

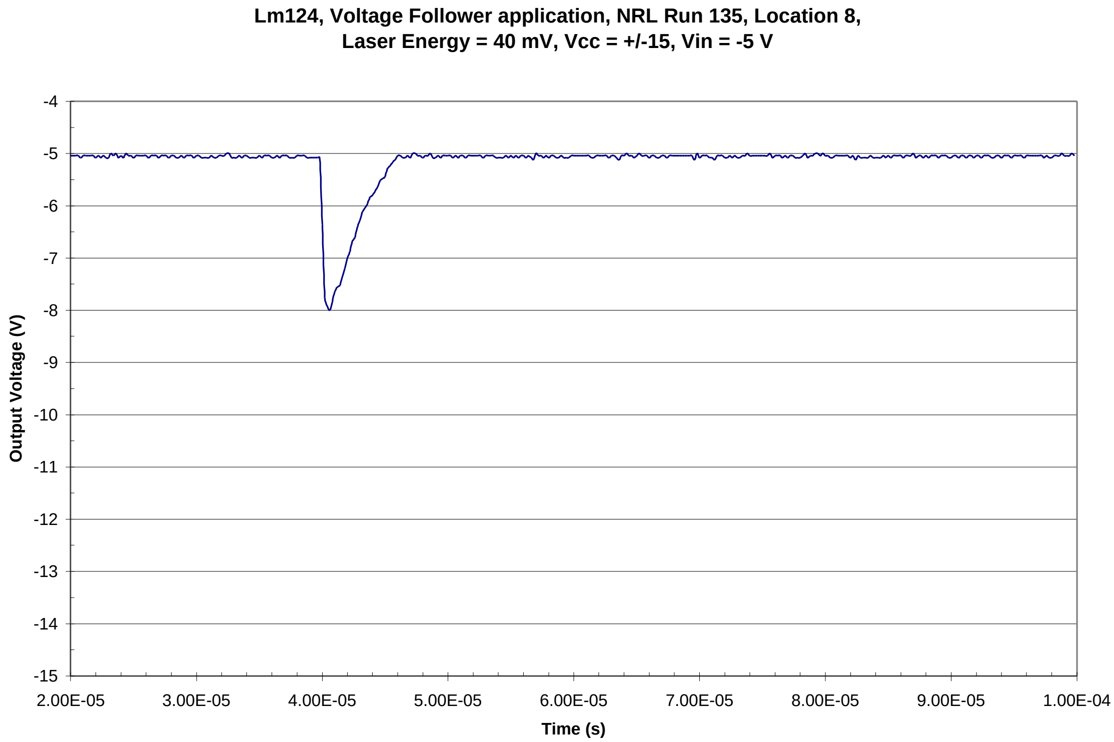

Figure 81: LM124, Voltage Follower application,
Location 8, typical pulse for a laser energy of 86 pJ.

10 Analysis of transient pulse shape on the Inverting Gain application (x 100)

10.1 Introduction

At the end of the experiment, we have looked quickly at the SET sensitivity of the inverting gain configuration.

10.2 Bias conditions

The inverting gain (x100) configuration irradiated is showm in Figure 80. Only one bias condition has been investigated. The bias conditions are shown in Table 8.

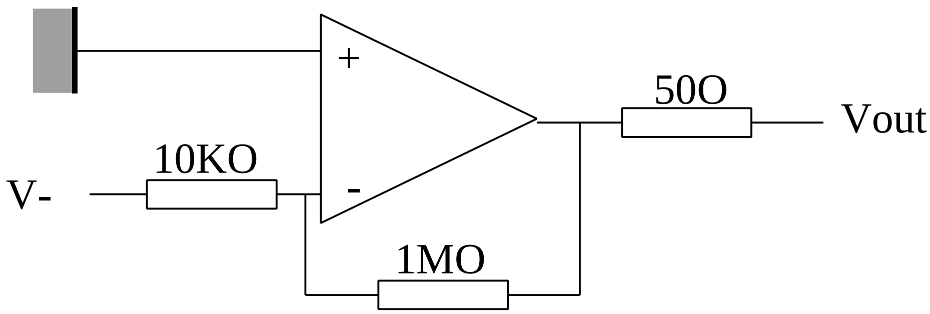

Figure 80

Power Supply		Input bias		Output (V)
Vcc+ (V)	Vcc- (V)	V+(V)	V-(V)	
15	-15	0	0.1V	-10

Table 8: bias conditions investigated for the Voltage Follower application.

10.3 Test results

Only four regions are sensitive to SET: Locations 6, 7 and 4&5. Regions 4&5 are the most sensitive regions.

<u>Location 4&5</u>
For a laser energy of 471 pJ, we observe positive going transients (transient amplitude ~ 3V).

<u>Location 6</u>
We observe only small bipolar transients (transient amplitude < 200 mV).

<u>Location 7</u>
We observe onlySmall positive going transients (transient amplitude < 200 mV).

11 Conclusions

Various transient shapes have been observed depending on the application and bias conditions. Some regions are not sensitive for some applications and are very sensitive for other applications. But for all conditions, we observe a consistent behavior for each region but region 6:

- large positive going or bipolar (large positive going component and large negative going component) transients: regions 4&5 and 3.
- Small long duration positive going transients: region 7.
- Large negative going transients: regions 1 and 8.
- Large negative going transient or small bipolar transient (negative going and then positive going): region2

On region 6, we have observed only small transients, but of various shape (long duration positive going, short duration positive or negative going, bipolar (negative going, then positive going). This region is only sensitive at high laser energy levels.

Depending on the application and bias conditions, all the other 7 regions could be very sensitive to SET. But regions 4&5 and 7 have a significantly larger area, the transients coming from these regions dominate the heavy ion response.

It is surprising to see that the transistors Q1 to Q4 of the input differential amplifier are not sensitive to SET. It is possible that these transients are filtered by the second stage amplifier. Therefore the behavior of a high speed operational amplifier could be significantly different and closer to the one observed on LM139 comparator.

The transients on the Q8 and Q9 transistors of the input differential amplifier give small long duration transients, they appear at high LET or high laser energy and give a significant contribution (up to 50%) of the overall device response. The long duration of these transients is attributed to the internal compensation capacitor Cc.

All the other 7 sensitive regions are located in the second stage amplifier. The response is dominated by the transients in the Q5 and Q6 outputs transistors.