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Characteristics of the Lab-D Laser Test Setup

Selcuk Cihangir

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

Ping Hu

University of Pittsburgh
Pittsburgh, Pennsylvania

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Selcuk Cihangir
Fermi National Accelerator Laboratory

Ping Hu
University of Pittsburgh

1. Introduction

We describe the characteristics of the pulsed laser test setup at Lab-D which was constructed to test silicon strip detectors. The specifications of the laser diode and the details of the electronics driving the diode are described in another Fermilab TM note[1]. In this note, we present the system focusing the laser light on the detectors, the laser spot size after focusing and the studies we performed on a CDF SVX' ladder to characterize the setup as a whole.

2. The Focusing System

The fiber[2] which transmitted the laser light from the diode has a diameter of 6.2 μm and a numerical aperture of 0.14. Without focusing, this meant the light spot size would be 100 μm in diameter at a distance 1 mm from the tip of the fiber. For the studies we intend to do, we need a laser spot size narrower than the minimum detector pitch which is 50 μm. We should point out that, in an ideal case when the laser spot size on the detector is the same as the fiber size (6.2 μm in diameter), the refraction of light in the silicon (index of refraction of 3.2) produces a spot size of 30 μm in diameter at the bottom surface of a 300 μm thick detector.

In order to achieve the spot size desired, we constructed a focusing system composed of a barrel housing two focusing-collimating lenses[3], two mechanical motion stages and an adjustable post holder. The details of the system are depicted in Figure 1 which is not to scale. One of the stages (miniature positioning stage) which can move in a vertical plane (x-z coordinates) is for positioning the laser source (tip of the fiber) vertically (in z coordinate) relative to the lenses and centering it on the lenses horizontally (in x coordinate), while the other, which moves only vertically, is for positioning the lenses vertically relative to the detector. The adjustable post holder, which moves in the y coordinate only, is for centering the laser source horizontally (in y coordinate) on the lenses. This setup enables us to adjust the location of any component independently while the locations of the other components are fixed. Furthermore, we can move the detector in a horizontal plane (in x-y coordinates) independently with a highly sensitive motion table.

We also collimated the light by inserting rings with various size holes before, after and in between the lenses. The best result was achieved with a 1 mm hole collimation.

In the following sections, we present the studies performed to understand the behavior of the laser, to measure the laser light spot size, and to observe the response of a silicon detector to the laser.

3. The Performance of the Setup

The laser diode is derived by a pulser whose pulse shape is reproduced (the scope picture is drawn by MacDraw Pro) in Figure 2. The rise time is much less than a nsec, and the width is about 10 nsec. This pulse is attenuated within a range of 0-20 dB. In Figure 3 we plot the $\log_{10}$ of the ratio of the attenuated pulse height to the un-attenuated pulse height as a function of the attenuation. The fit indicates an expected relationship of:

$$\mathrm{dB} = 20\log_{10}\left(\frac{\mathrm{Out}}{\mathrm{In}}\right)$$

The detector response to the laser driven by this pulse was processed by the LBL SVX readout chip and the DAQ setup shown in Figure 4. The detector used is a ladder from the CDF SVX' which has a 60 μm pitch. The output of the DAQ setup can be observed on a scope and can be converted to counts. What is observed on the scope is a sequence of levels corresponding to the pulses from the strips (channels) of the detector. Figure 5 shows such a picture (reproduced). One high level is accompanied by two low levels on both sides which will be discussed later. We plot the peak level observed at a CDF SVX' detector as a function of the laser attenuation in Figure 6. The leveling off at lower attenuations (which we did not worry about at this stage) can be due to some sort of saturation and/or to laser escape at the back of the detector. To check that the detector response is reasonable, we plot the pulse height due to the laser at an attenuation of 7 dB (away from leveling off region) as a function of the bias voltage in Figure 7. The plateau is reached at the anticipated depletion voltage of 45 volts.

In order to determine the laser light spot size we made use of the fact that the laser bounces off the aluminum layer of an AC pad. We centered the laser on a strip by observing the highest level readout response on that channel. Then we moved the laser along that strip until we reached the AC pad and measured pulse level as a function of laser overlap distance over the pad. This procedure is depicted in Figure 8. The pulse levels observed on a scope before any overlap and after a complete overlap are reproduced in Figure 9a and 9b, respectively. As we see, the levels on the two neighboring strips do not change during this scan. Furthermore, at the position of complete overlap, moving the laser ±5 μm transversely did not effect this picture, indicating that the laser has a long tail and the spot size excluding the tail is about 10 μm narrower than the width (60 μm) of the AC pad.

In Figure 10 we show the pulse blocked by the aluminum as measured on a scope as a function of distance traveled into the pad. What is plotted is actually the maximum pulse measured away from the pad minus the pulse measured at the position of measurement. The solid line is a fit to guide the eye. Next, we assumed a shape (a step function or a gaussian function) for the spatial distribution of the laser light to reproduce the distribution presented in Figure 10.

a) Step Function Distribution

If the light distribution resembles a step function, a portion of it blocked by the aluminum pad would be linearly dependent on the distance along the move into the pad. This portion is the integration of a constant whose value is determined by normalizing the pulse due to this step function light to the observed laser pulse. Integration of this function is shown in Figure 11 superimposed to the measured distribution of Figure 10. As we see a step function light does not reproduce the observed distribution.

b) Gaussian Function Distribution

We tried a gaussian function distribution for the laser light with certain sigma and calculated the portion of the distribution blocked by the aluminum pad as a function of the distance along the move. The calculations were done in two dimensions rather than three, since the contribution of the third dimension to the integration to calculate the volume of the gaussian shape is a multiplicitive constant term due to the fact that the pad size in this dimension is larger than the effective laser size. This constant term is not relevant since we need to know the relative size of the light blocked by the pad.

We tried various combinations of sigma and the mean for the gaussian function representing the laser light. The best result we achieved was for a distribution with a mean of 25 μm and a sigma of 10 μm. The integration of this function, i.e. the amount of light blocked while the light moves onto the pad, is shown in Figure 12 superimposed to the measured distribution of Figure 10. Therefore, the light distribution of the laser is best described by a gaussian function with a sigma of 10 μm. The mean of the function represents the fact that the laser light is almost completely blocked by a 2x25=50 μm section of the 60 μm pad. This is consistent with the observation described above that, once the light is covered by the pad, moving the light ±5 μm transversely did not effect the pulses observed in Figure 9b.

For a better visualization of such a laser, we show in Figure 13 the three dimensional plot of the gaussian function describing the laser light.

4. Conclusions

We constructed a laser test setup at Lab-D (Silicon Detector Facility) to test silicon strip detectors. The observed responses of a CDF SVX' detector were found to be consistent with the expectations. One essential parameter, namely the spatial distribution of the laser light, was determined to be best described by a gaussian distribution with a sigma of 10 mm. The observations also indicated that the light distribution probably contained a long tail.

References

[1] M. Vaz, S. Cihangir and P. Rapidis, Fermilab-TM-1849.
[2] Corning Flexcore 1060.
[3] Melles Griot 06 GLC 004 Focusing-Collimating Multi-element Lens.

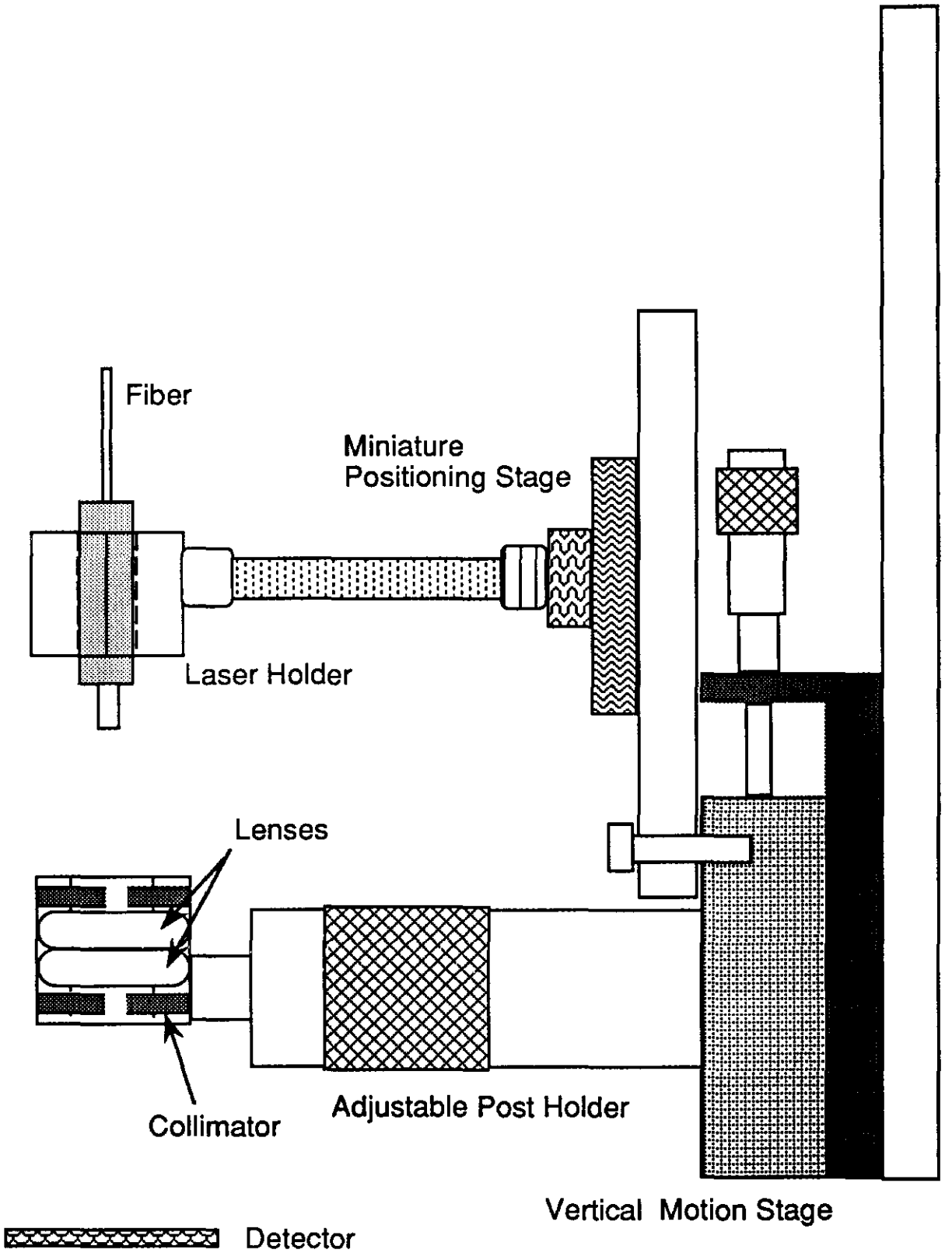


Figure 1) Laser Focusing System (not to scale)

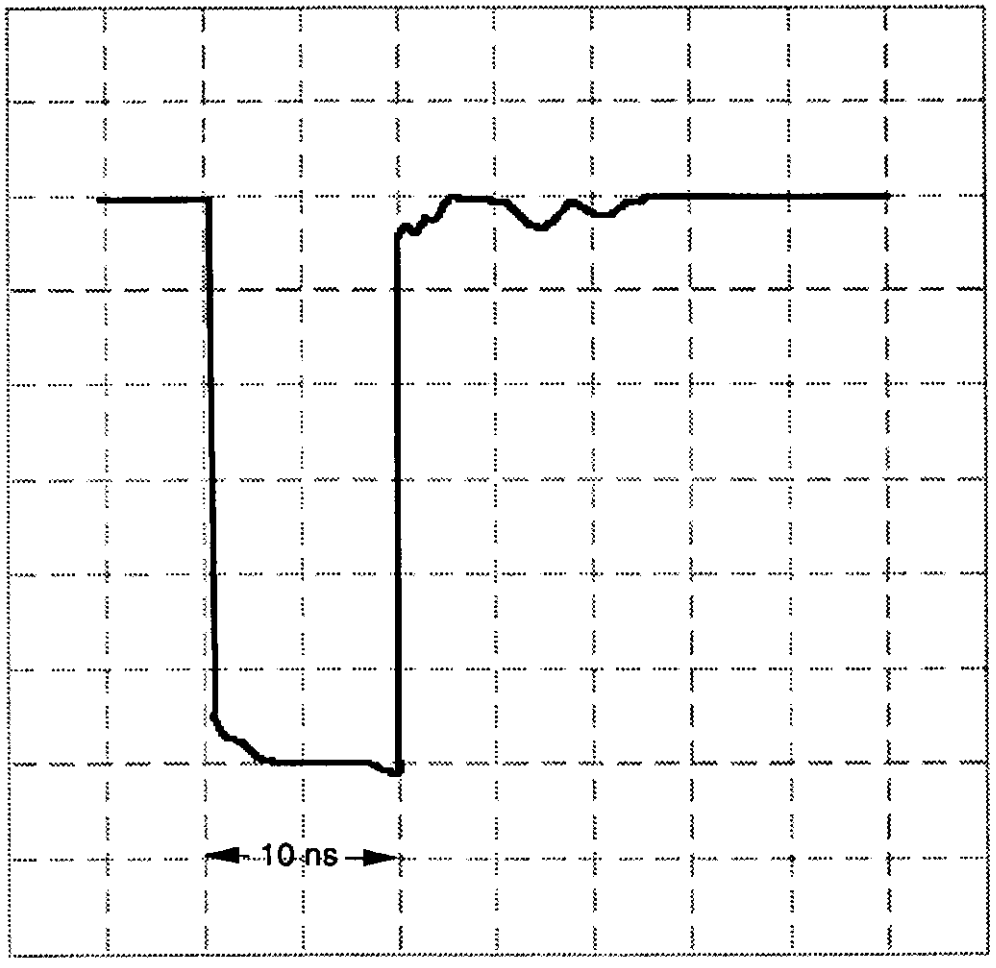


Figure 2) Shape of the pulse driving the laser diode

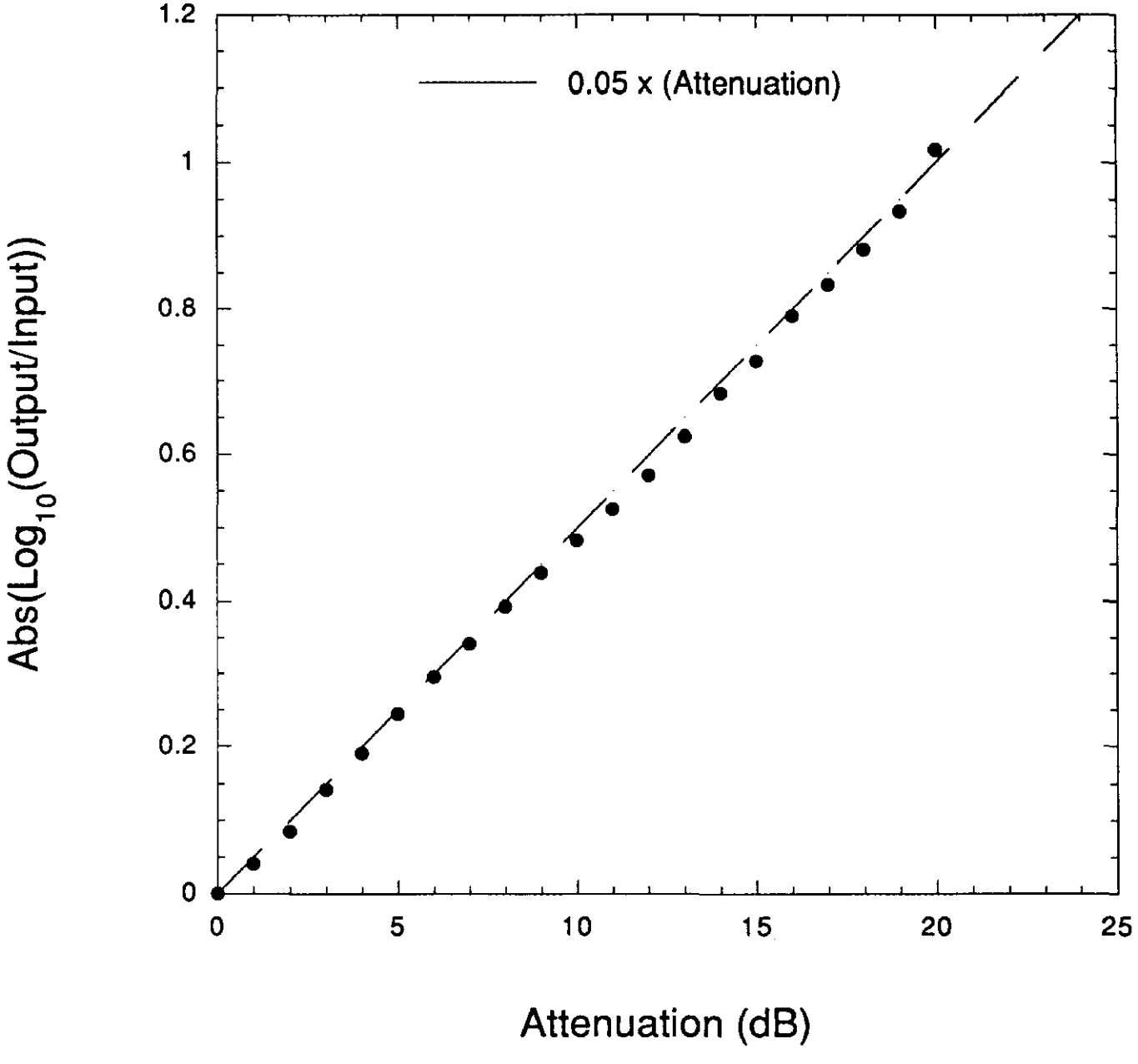


Figure 3) Ratio of attenuated laser pulse to un-attenuated pulse vs attenuation

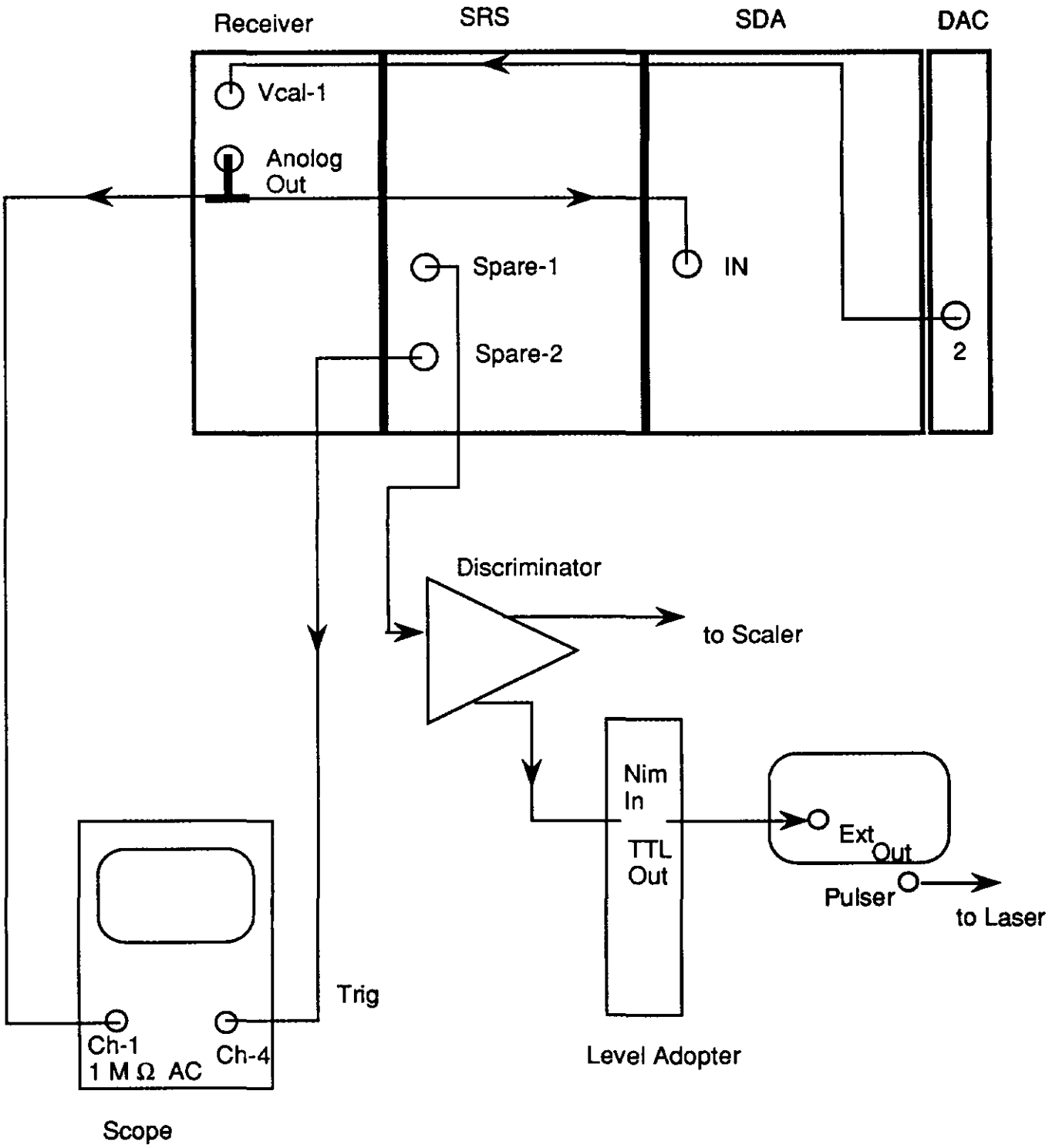


Figure 4) Laser Test Stand SVX Readout

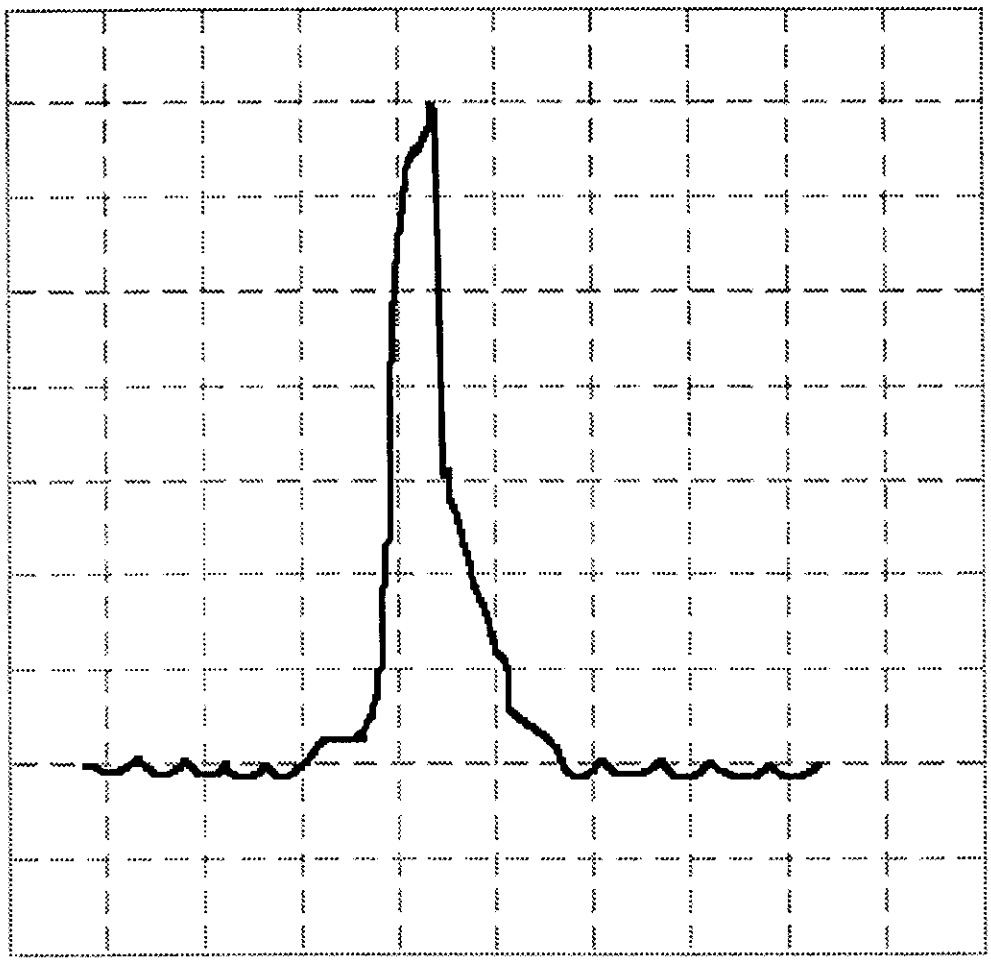


Figure 5) Detector response to the laser as observed on a scope

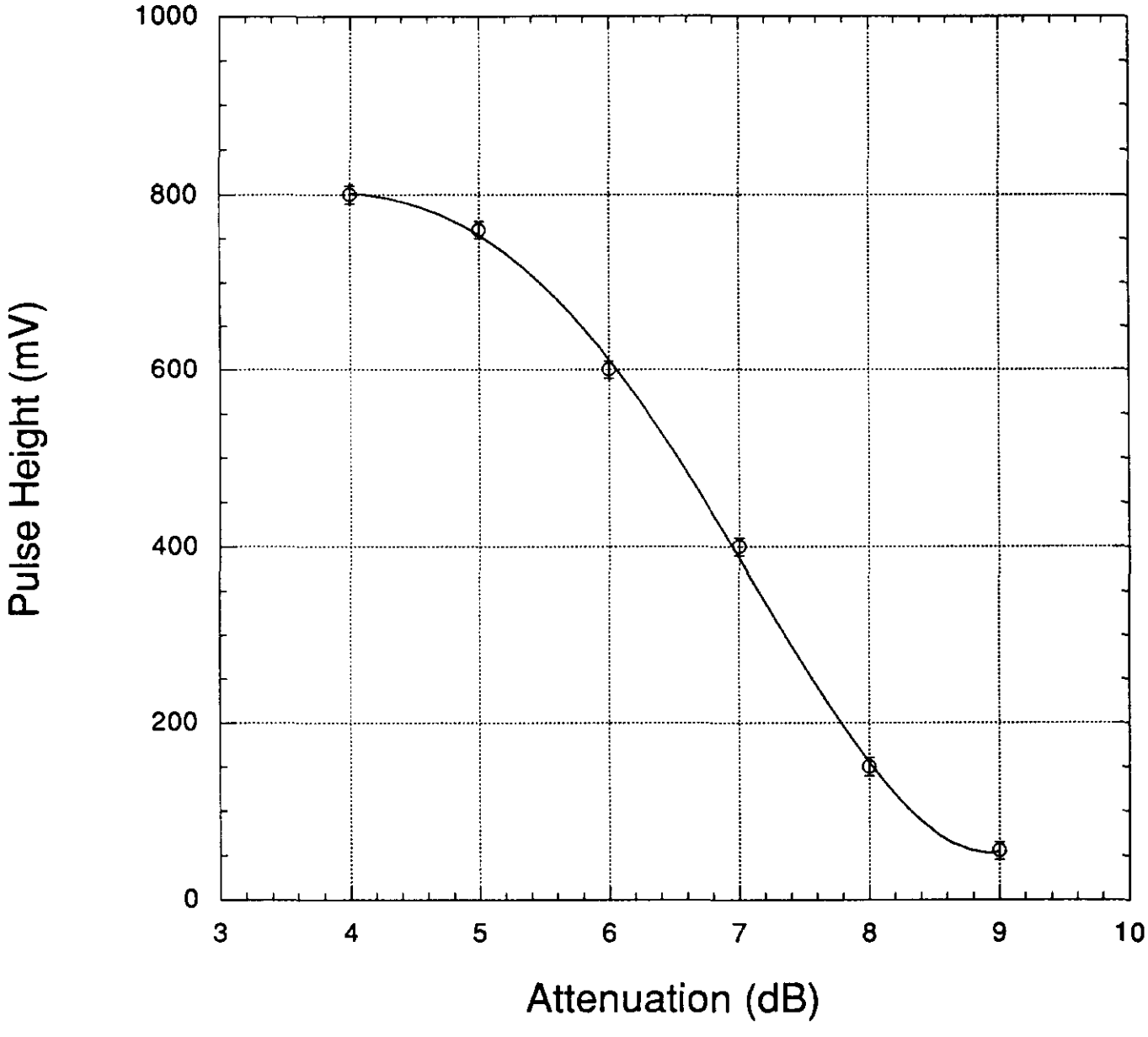


Figure 6) Pulse due to laser vs attenuation

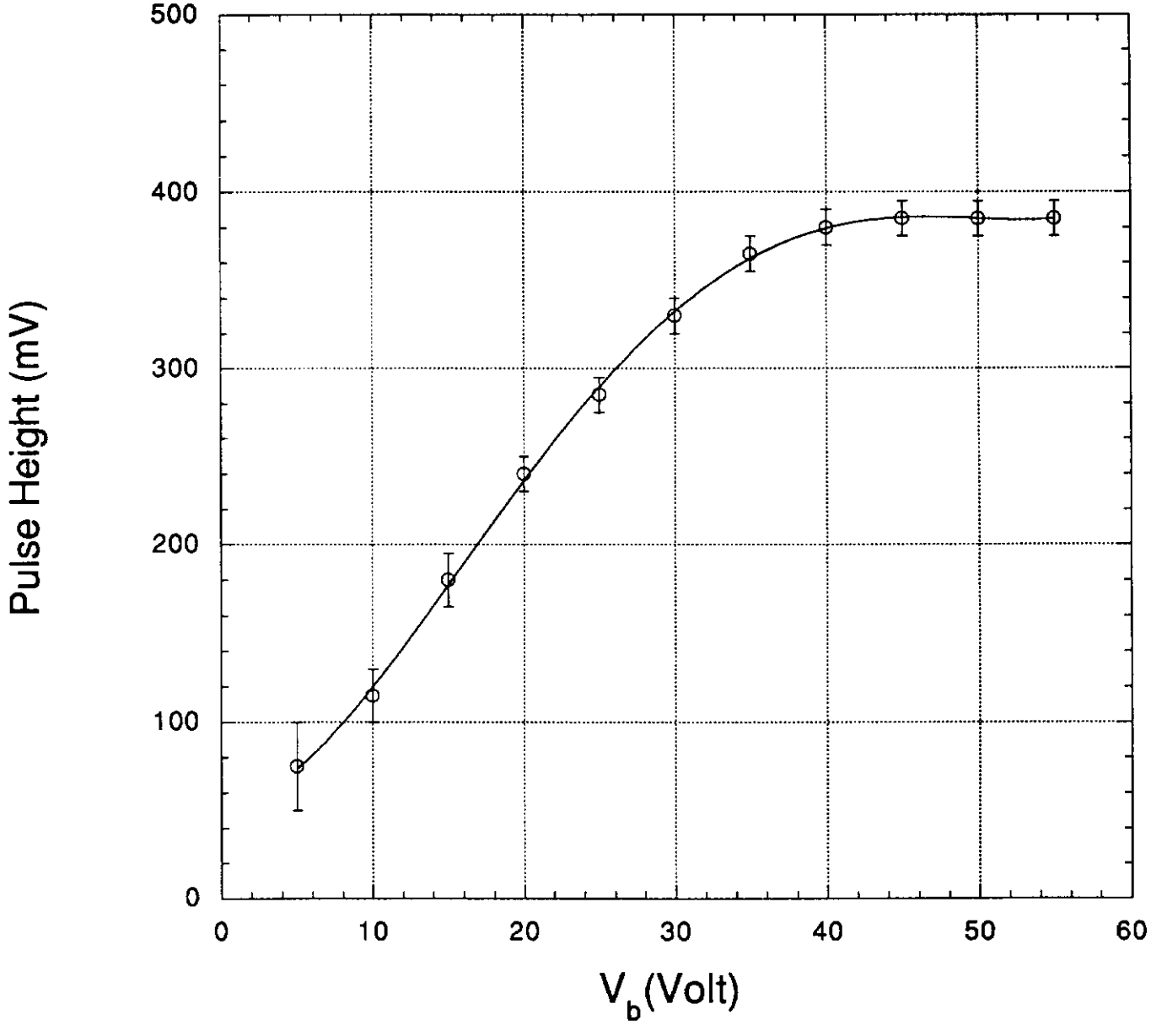


Figure 7) Pulse due to laser vs bias voltage

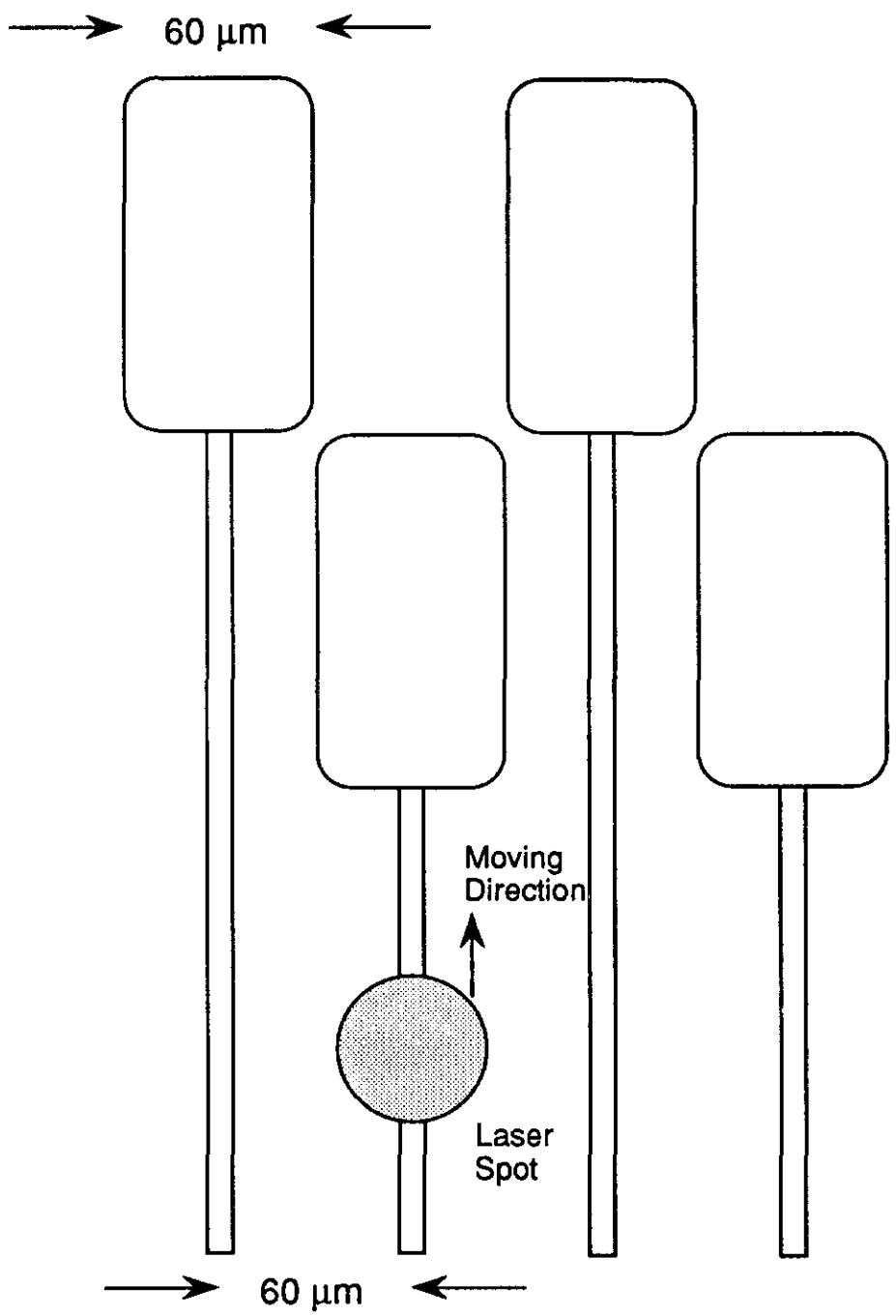
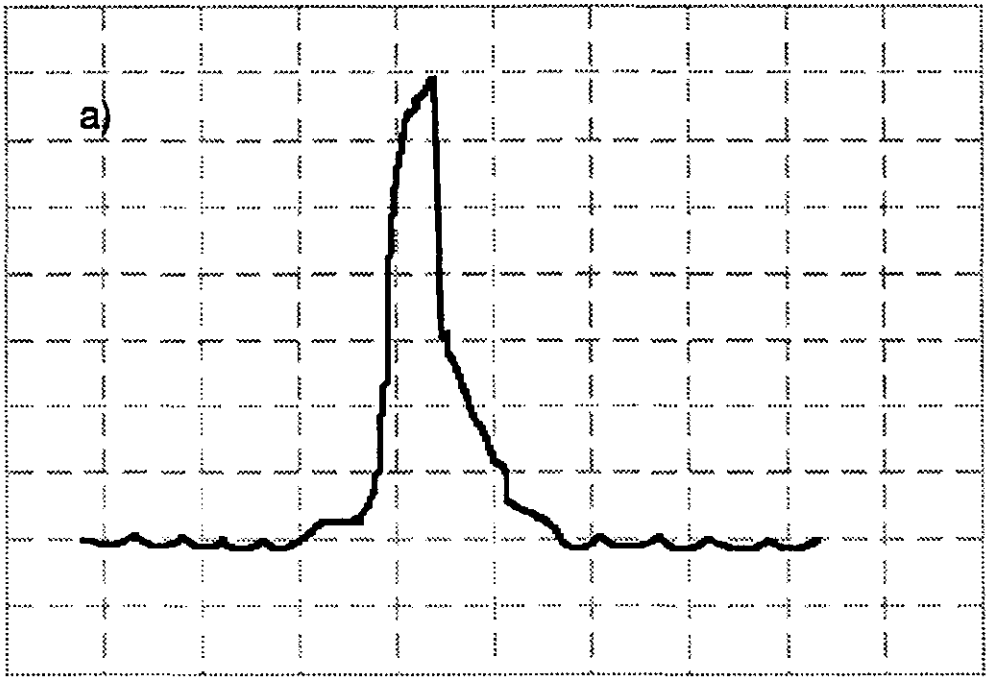


Figure 8) Pad and strip configuration of CDF SVX' Silicon Detectors



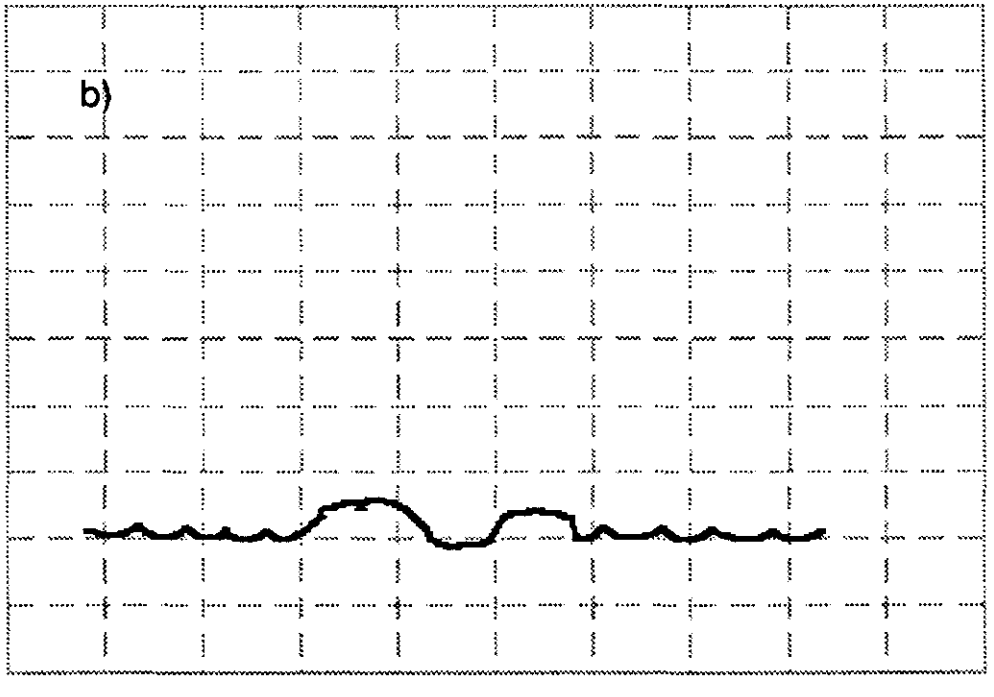


Figure 9) Scope picture before the laser is moved into aluminum pad (a) and after (b)

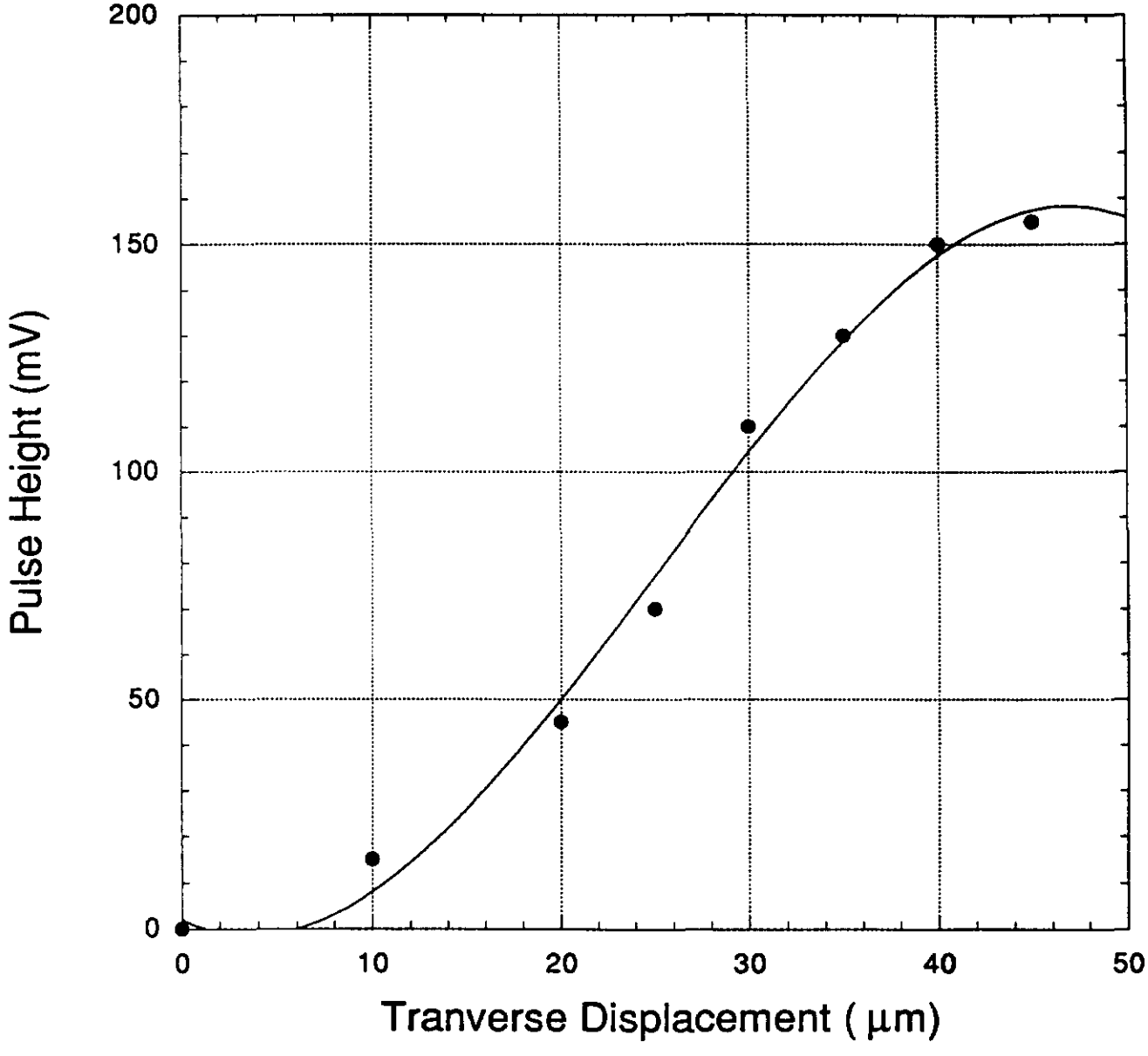


Figure 10) Measured laser spot: Laser pulse blocked by the aluminum vs displacement into the pad

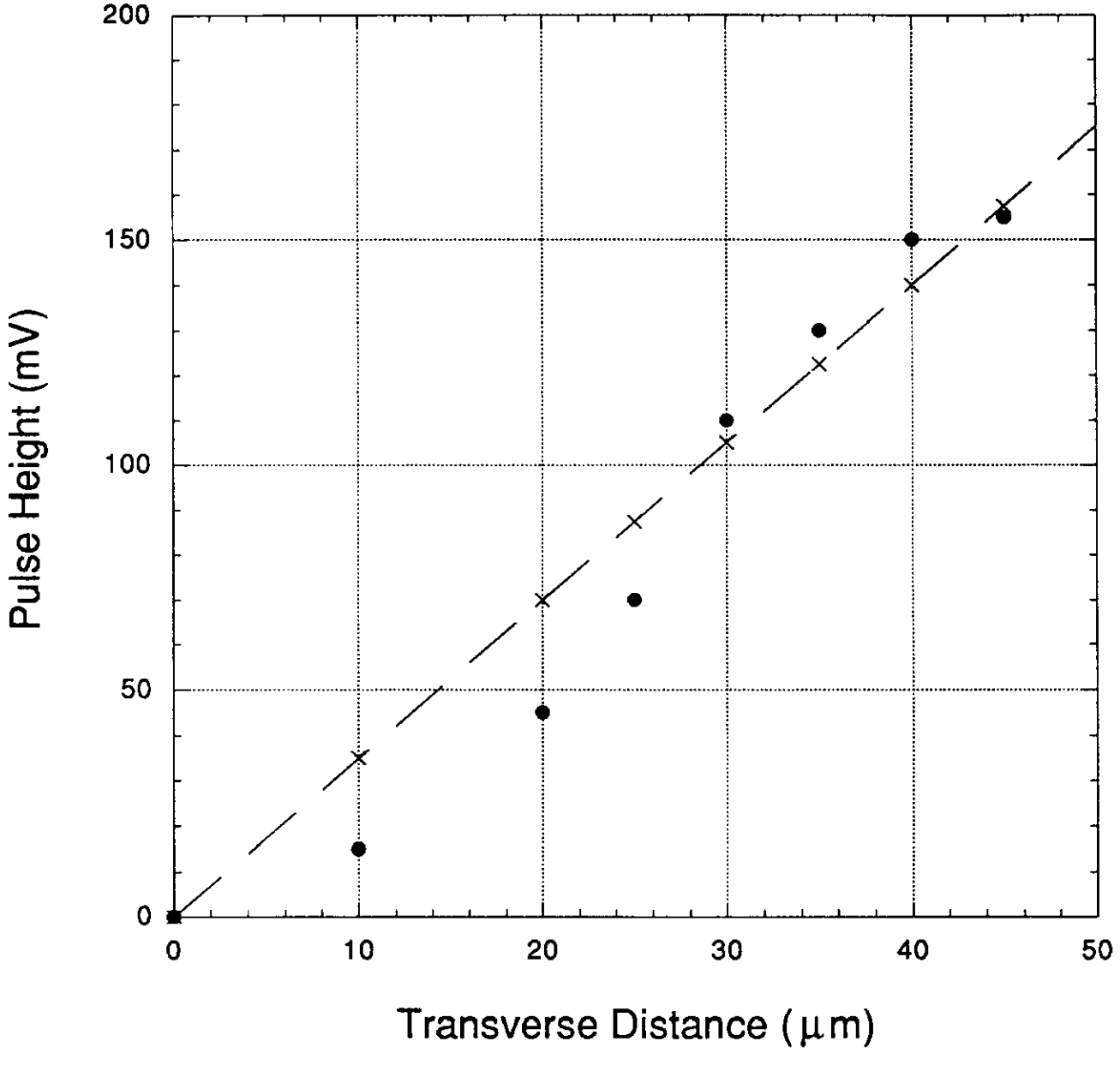


Figure 11) Measured laser spot size compared to step function laser spot size

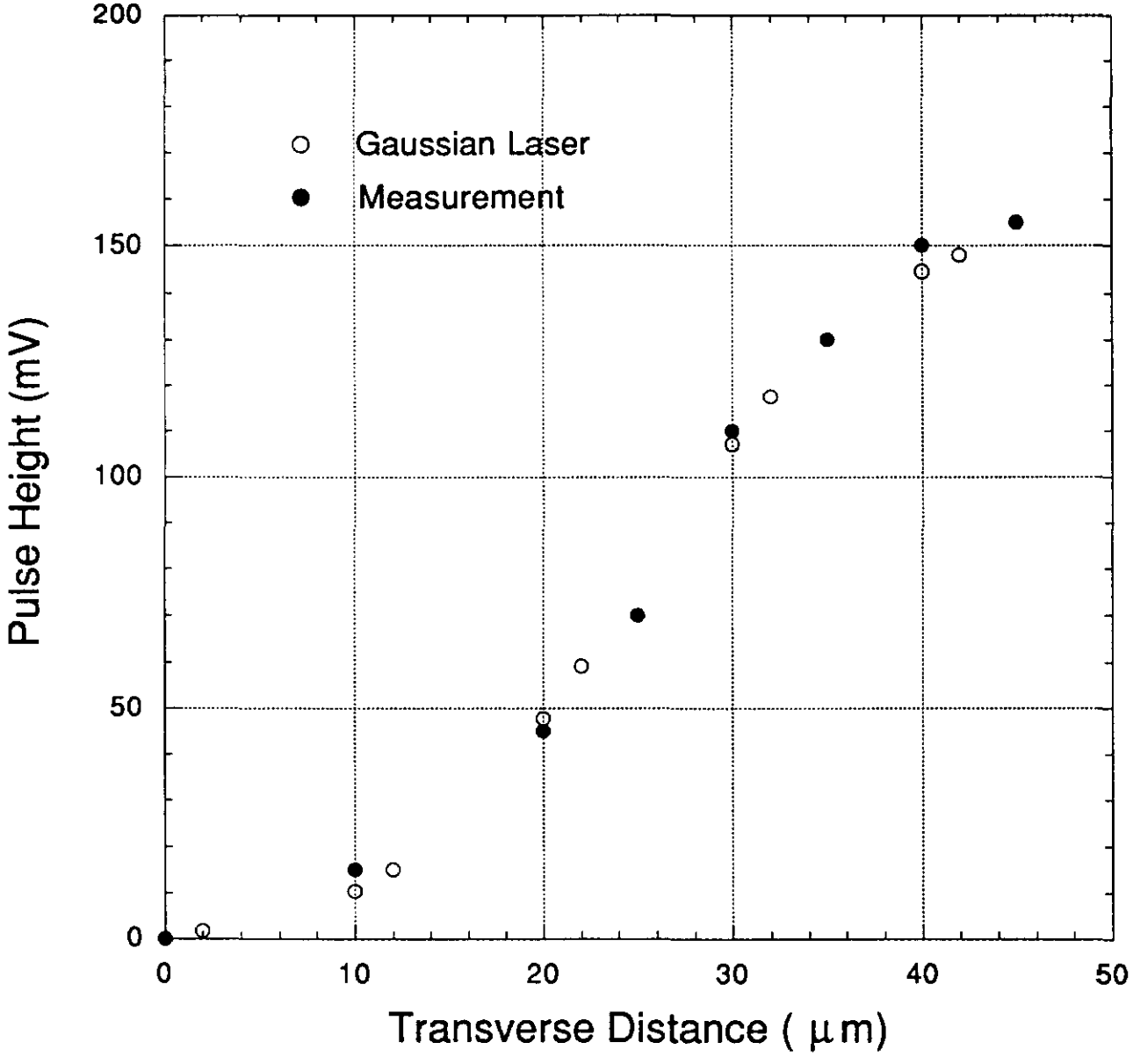


Figure 12) Measured laser spot size compared to gaussian laser spot size

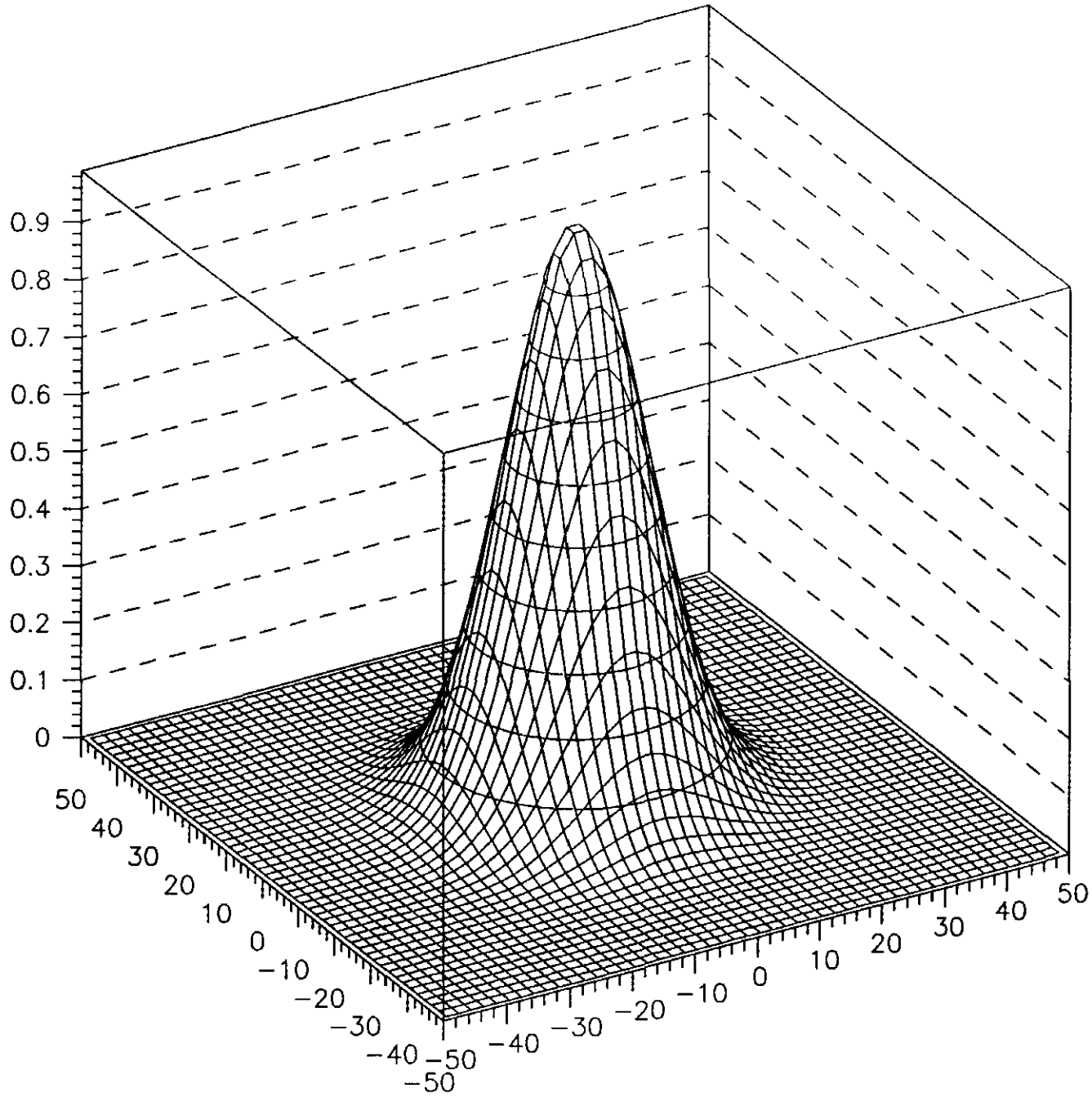


Figure 13) Three dimensional view of the gaussian function describing the laser light