

THE USE OF NITROGEN LASER FOR OBSERVATION OF SPACE CHARGE EFFECTS IN DRIFT CHAMBERS*

J. Va'vra
 Stanford Linear Accelerator Center
 Stanford University, Stanford, California 94305

ABSTRACT

A two-stage nitrogen laser has been built and is presently being used to investigate properties of drift chambers. In this paper we present the measured parameters of this laser, the results of a study of the double track separation in a drift chamber of jet design and a measurement of the saturation effects in this chamber as a function of total gain. An understanding of the saturation effects is important for drift chambers with multiple hit capability. The laser technique reported here represents a major improvement in the simplicity of investigation of the double track separation and saturation effects.

INTRODUCTION

It is believed that in the future, experiments will be run with very high track densities. To date, there have been great efforts to improve the double hit capability of drift chambers by digitizing the waveform every 5-10 ns. Such systems are clearly very expensive and care has to be exercised in the prototyping stage to ensure a full understanding of the system. We believe that lasers, such as one presented in this paper can play an important role in the early stages of development. For instance, we have used it to check a Monte Carlo program to predict expected waveforms.¹ It can be used to study and tune the electronics at a very early stage. In this paper, we present a simple method to measure saturation effects, in which the cloud of positive ions produced by an avalanche can seriously affect the measurement of charge from a second track near the first track or even late arriving charge from the same track. This measurement is useful for determining corrections used in the above mentioned program. Also, this knowledge will be useful for high precision vertex chambers operating in a large multiplicity environment. Similar measurement in a particle beam is next to impossible.

DESCRIPTION OF THE LASER AND ITS PERFORMANCE

A pulsed, two-stage nitrogen laser has been built at SLAC. The original design[†] has been modified to improve the spark gap trigger as well as the rf noise performance. The main advantages of this particular design are small spot size and small divergence of the laser beam, very short burst duration and, as a result, a large power density per unit of time and of area. It belongs to a category of nitrogen lasers suitable for precise bench experiments rather than for a continuous long term monitoring of large experiments.

The laser obtains good divergence from the fact that it is optically long. This is achieved by combining two lasers together. The beam coming from the first cavity is returned through the right angle prism (BK-7 glass) into the second cavity - see Fig. 1. The timing of the two cavities is done through an adjustment of the cavity gaps. The second cavity is made to lase by a leading edge of the incoming wave of photons. The present work does not employ an optical expander between the two cavities to further improve the beam divergence.²

We used a RETICON linear CCD array (RL256C) to measure the beam profiles under various conditions - see Figs. 2 through 5. The beam was attenuated using neutral density filters.[§] The beam divergence was obtained by measuring spots at different distances from the laser. The smallest achieved spot size was ~50 μm vertically and ~75 μm horizontally (FWHM) using an $f = 10$ cm lens[§] with a pinhole in front of it. For measurements reported in this paper we used $f = 100$ cm and $f = 50$ cm lenses.[§] The energy of the laser was measured using an EG&G UV-444B diode. For the trigger in the precision timing measurements, we used an EG&G FND-100 diode and for the burst duration measurement, we used an ITT F4502 vacuum biplanar photodiode. Typical measured performance is listed in Table 1.

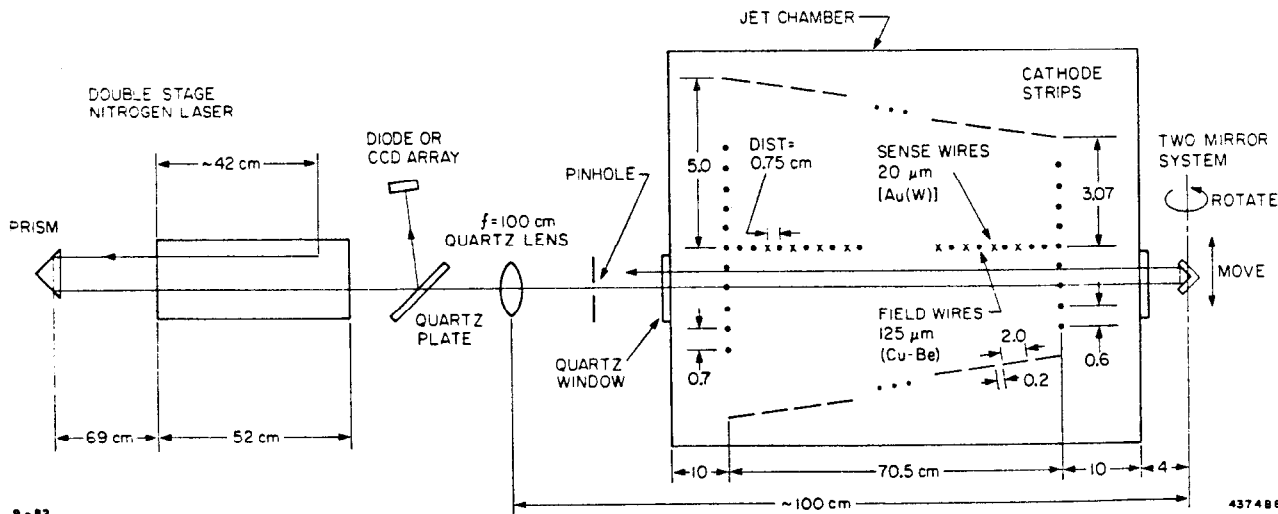


Fig. 1. Experimental setup to observe the double tracks.

*Work supported by the Department of Energy, contract DE-AC03-76SF00515.

†MOPA 1000 from Multilasers, Grand-Sacouneux, Switzerland.

§Standard fused silica quartz made by Melles Griot or Rolyn Optics Companies.

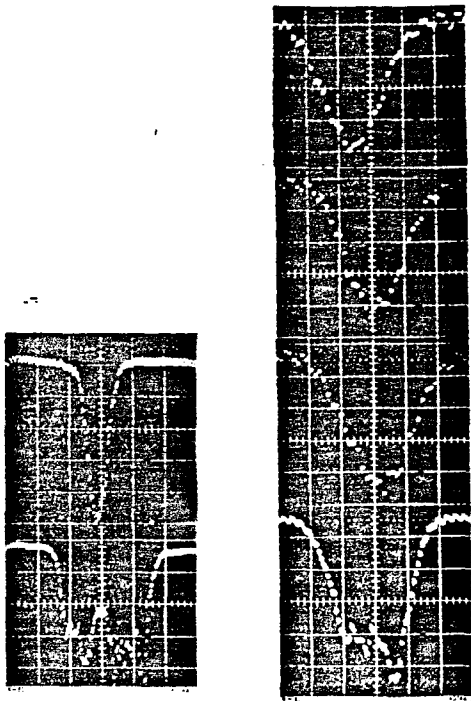


Fig. 2. a) Unfocused vertical beam shape 53 cm away from the exit of the laser box. (Point to point distance is $25.4 \mu\text{m}$.) b) Unfocused horizontal beam shape 24 cm away from the exit of the laser box.

Fig. 3. Beam shape obtained using $f = 100 \text{ cm}$ lens; a) vertical at focus, b) vertical at focus -9 cm , c) vertical at focus $+20 \text{ cm}$, d) horizontal at focus.

DETECTOR

The tracks were generated in a jet chamber prototype³ operating at normal pressure and with 90% Argon + 9% CO_2 + 1% CH_4 gas. The chamber had 47 sense wires, each sampling 1.5 cm of track length. Between the $20 \mu\text{m}$ diameter sense wires are $125 \mu\text{m}$ diameter guard wires. The chamber operated with the cathode at ground potential and the sense and guard wires at positive voltage. Different gains were obtained by varying the voltage on the guard wires and the voltage on the sense wires. The wires were arranged so that the vertical edge of the beam was aligned with a drift direction. The chamber was connected to an amplifier with a $\sim 10 \text{ ns}$ rise-time and $\sim 50 \text{ ns}$ fall-time.

EXPERIMENTAL RESULTS

The typical experimental setup can be seen in Fig. 1. Figures 6 through 8 show typical pulse height distributions in the chamber, the diode and their correlations. To create double tracks in the chamber, we reflected the beam through an orthogonal system of two mirrors. The mirror system was mounted on a precision table allowing transverse and rotational motion. Figure 9 shows a typical single track as measured on several wires in the chamber. The pictures are multiple exposures of typically 40 shots. The chamber operated at a total gain of $\sim 2 \times 10^5$ and the ionization created by the laser was typically 3 times that of a minimum ionizing particle. Figure 10 shows the typical double tracks. The total length is about 1.5 m. Figures 11 and 12 show typical double tracks on wire #4 as a function of a distance between the two tracks, with and without a two zero-pole filters⁴ to suppress the 1/t tail from positive ion motion. The two zero-pole filters were tuned for maximum tail cancellation while the laser was running. Although the results were

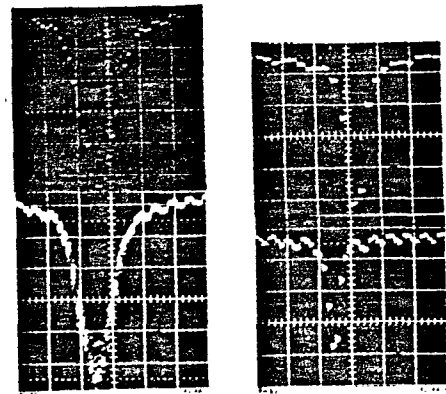


Fig. 4. Vertical beam shape at focus of $f = 50 \text{ cm}$ lens; a) single shot, b) 40 shots to see reproducibility.

Fig. 5. Smallest achieved beam size at a focus of $f = 10 \text{ cm}$ lens; a) vertical, b) horizontal. (Point to point distance is $25.4 \mu\text{m}$.)

Table 1

Beam divergence:	$\sim 0.7 \text{ mrad}$ vertical
Beam size (FWHM):	$\sim 1.1 \text{ mrad}$ horizontal
a) Unfocused beam at exit:	$\sim 0.6 \text{ mm}$ vertical $\sim 2.1 \text{ mm}$ horizontal
b) At focus of $f = 50 \text{ cm}$ lens:	$\sim 250 \mu\text{m}$ vertical
c) At focus of $f = 100 \text{ cm}$ lens:	$\sim 375 \mu\text{m}$ vertical
Smallest achieved beam size (FWHM):	$\sim 50 \mu\text{m}$ vertical $\sim 75 \mu\text{m}$ horizontal
Positional Edge Stability (At focus of $f = 50 \text{ cm}$ lens)	$< 20 \mu\text{m}$ vertical
Light yield stability (σ):	$\leq 10\%$
Pulse Time Duration	$\sim 0.5 \text{ ns}$
Typical Light Output Energy/Burst	$\sim 50\text{--}100 \mu\text{J}$
Total stored electrical energy/burst	$\sim 0.34 \text{ J}$
Laser wavelength	337 nm
Typical operating pulse frequency	$5\text{--}10 \text{ Hz}$
Typical operating high voltage	$\sim \pm 17 \text{ kV DC}$

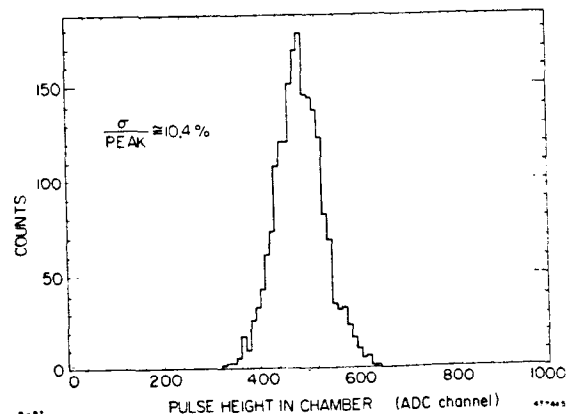


Fig. 6. Pulse height distribution in the chamber.

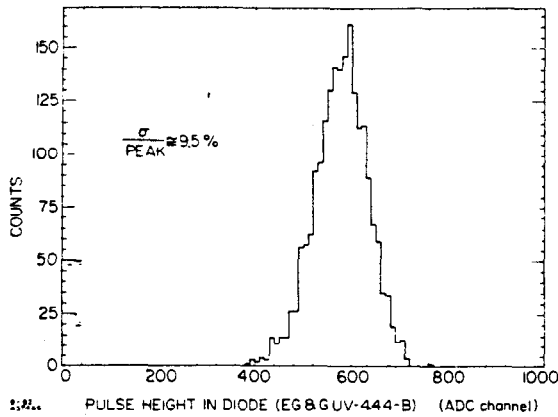


Fig. 7. Pulse height distribution in the monitoring diode.

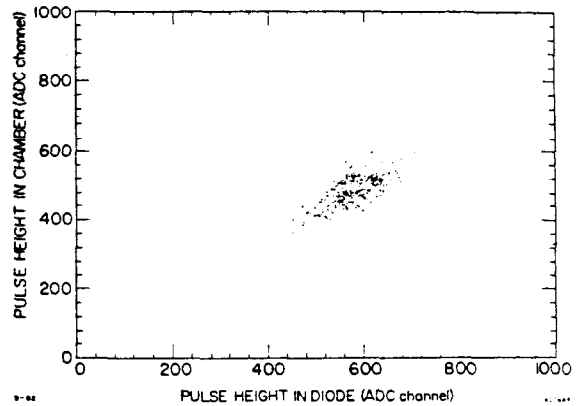


Fig. 8. Correlation of pulse height between the chamber and diode.

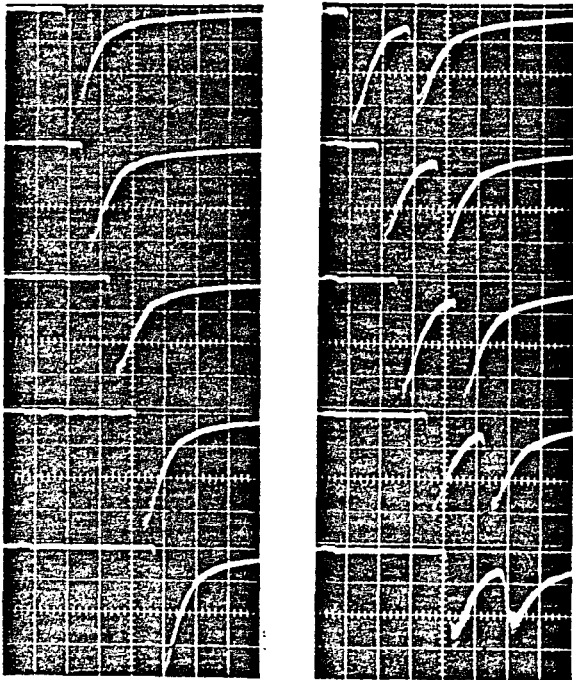


Fig. 9. Single track in the chamber, 200 mV/div, 100 ns/div, 40 exposures, no zero-pole filter, wires 4, 12, 24, 36, 44.

Fig. 10. Double tracks 9 mm apart, 200 mV/div, 100 ns/div, no zero-pole filter, wires 4, 16, 24, 36, 44. Total length of ionization corresponds to ~ 1.5 m long track.

better with two filters, one would obtain a reasonable tail cancellation with only one zero-pole filter. It can be seen that it is possible to separate two tracks down to 2-3 mm if the waveform is digitized every ~ 10 ns. This would be improved in a chamber with smaller wire spacing. In the case of real particles, clustering effects will tend to confuse some small fraction of hits.

Figure 13 represents the concept of the measurement of saturation effects. The tracks are separated by 10 mm and we used the zero-pole filters to clearly determine the amplitude of the second pulse. By rotating the system of two mirrors, we find a position where the second pulse is at a minimum in amplitude. At that point, we fix the rotating table and proceed to vary the gain in the chamber. At lower gains, one retains

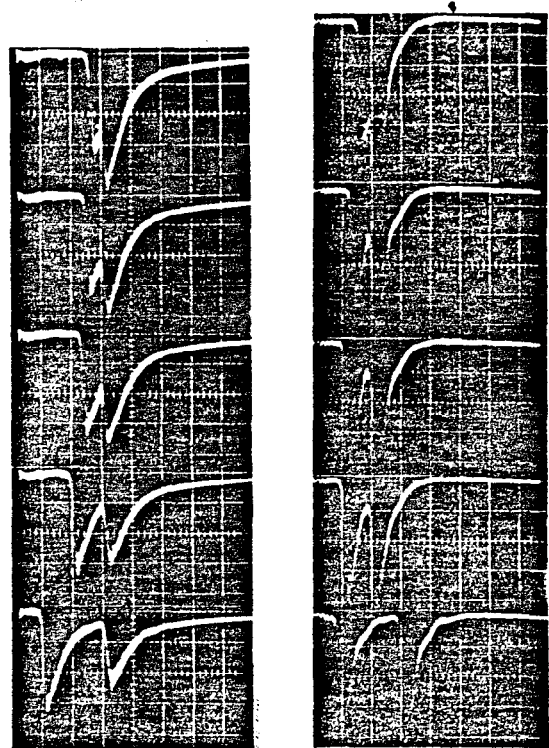


Fig. 11. Double tracks on wire #4 as a function of their distance, 200 mV/div, 100 ns/div, no zero-pole filters, distances 2, 3, 4, 5, 10 mm.

Fig. 12. The same as in Fig. 11, except 50 mV/div and amplifier with two zero-pole filters.

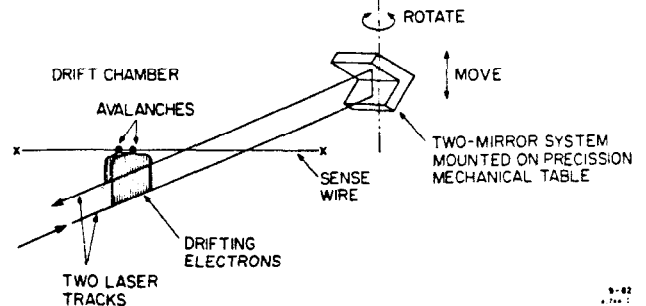


Fig. 13. Principle of the saturation effects measurement.

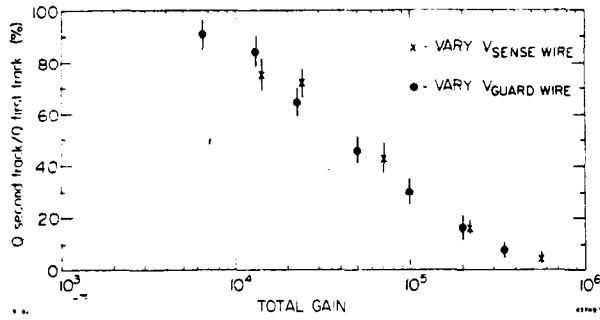


Fig. 14. The relative saturation effect as a function of total gain.

the full amplitude of the second pulse. Figure 14 shows the results of the saturation measurement. Two different sets of points were obtained by either lowering the gain through the sense wire or guard wire voltages. Either of these two conditions will alter the collecting characteristics of the chamber. Nevertheless, in both cases one gets the same result. To minimize the spot size, the two mirrors were located at the focus plane of an $f = 100$ cm quartz lens and wire #4 was 24.5 cm from the focus. The results were insensitive to lens position. As can be seen in Fig. 3, the vertical distribution doesn't change near the focus of the $f = 100$ cm lens. Similar results were obtained when the wire plane was between the two tracks, i.e., the two avalanches came from opposite directions toward the wire. However, the onset of the saturation came at a voltage ~ 100 volts higher.

FINAL COMMENTS

Our experience with this type of laser indicates that it can be made reliable. However, because of using a spark gap, periodic downtimes are to be expected. For this reason, we believe, this is not the type of laser to use for long-term monitoring of large experiments.

The rf shield should be properly designed right from the beginning, employing proper rf gaskets, feed-throughs, etc. In our case, we built a high voltage pulser right in the laser box, and used three Faraday cages around the laser. Even then some additional shielding was needed at the detector end.

We are presently using the laser to investigate properties of a high pressure drift chamber. With the $f = 50$ cm lens and a small prototype of a micro-jet chamber with 1 mm wire spacing,⁵ we succeeded in measuring tracks as close as 1 mm from the sense wires. Preliminary results indicate resolution ≤ 25 μ m. The stability of an edge of the laser has been measured by fitting a straight line to three wires and the error in intercept is consistent with ~ 25 μ m resolution.

ACKNOWLEDGEMENTS

We would like to thank Dr. L. Keller and H. Weidner for interest and support during this project. We appreciate discussions with Drs. H. Hilke and C. K. Sinclair. We thank Dr. D. Freytag for help with his CCD array. We would like to thank K. Hughes for excellent machining work and J. Nicol for help during the construction of the laser.

REFERENCES

- ¹J. Va'vra and L. Roberts, Computer Simulation of Drift Chamber Pulse Shapes - to be published.
- ²J. C. Guo, F. G. Hartjest and J. Konijn, The Use of Laser Induced Electron Clusters for Drift Chamber Tests. NIKHEF H/82-5.
- ³J. Va'vra and D. Rust, dE/dx Prototype Test - SLAC-PUB-2635 (1980).
- ⁴R. A. Boie, A. T. Hrisoho and P. Rehak, Nucl. Instrum. and Methods 192 (1982) 365-374.
- ⁵J. Va'vra, Stanford Linear Collider Workshop, Note 60 (1982).