Laser Generation of Electrons in STAR Silicon Drift Detectors

N. Brandon [a], H. Dyke [a], D. Hardtke [a], T. J. Humanic [a], I. V. Kotov [a], D. Reichhold [a], E. Sugarbaker [a], J. C. Yu [a,b]

[a] *The Ohio State University, Columbus, OH 43210*

[b] *Harvey Mudd College, Claremont, CA 91711*

Abstract

A nitrogen dye laser is used to test a silicon drift detector and the results are compared to tests with an Nd:YAG laser. The results indicate certain differences in the mechanisms of electron transport and collection between creating free electrons on the surface or throughout the bulk at the near-anode region.

Introduction

We have carried out laser tests of a STAR-type silicon drift detector (SDD) using infrared and visible wavelengths to study the wavelength dependence of the SDD signal. Since infrared wavelengths deeply penetrate the bulk silicon and visible light is absorbed on the surface, electron collection should be different for different wavelengths, and thus might be used to probe the collection field at different depths in the detector.

Testing Apparatus

The infrared laser that was used for testing SDD's was a Nd:YAG laser. Since it has a wavelength of $1060nm$, which is right above the band gap of the silicon atoms, only thirty percent of the laser light is absorbed in the $300\mu m$ silicon wafer thickness, thus exciting electrons throughout its thickness like a high energy charged particle would.

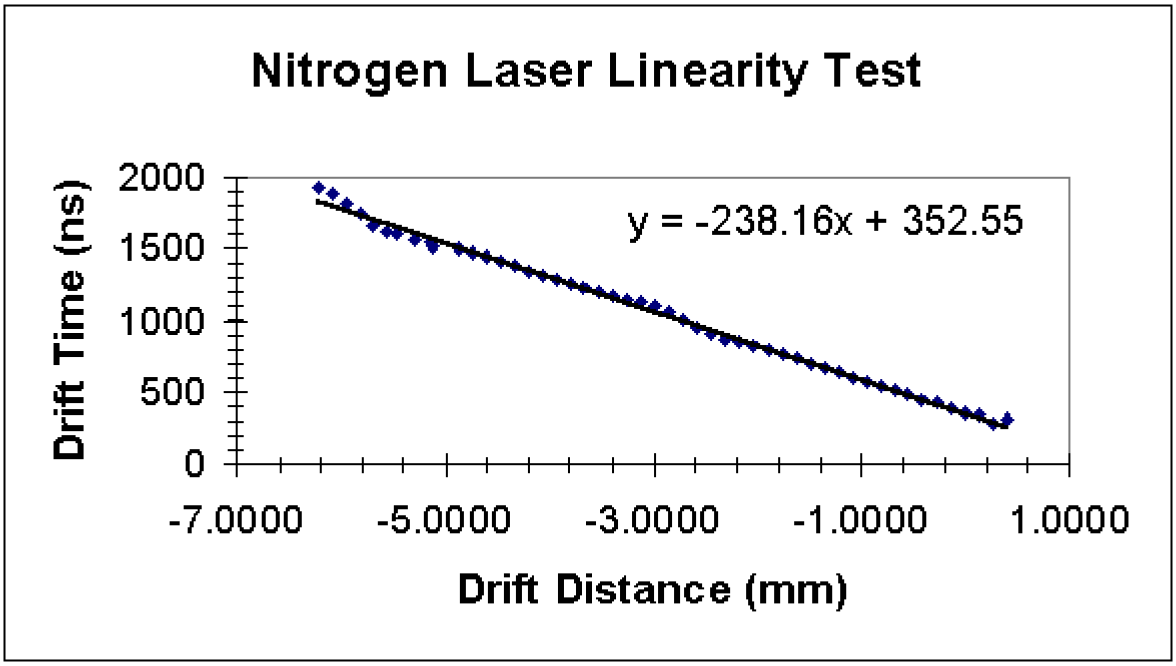
A nitrogen laser was used to provide the visible wavelength, by pumping a dye, in this case Rhodamine 590 (Rh590), which has a wavelength between

$555nm$ and $615nm$. This wavelength is below the band gap of silicon, resulting in absorption of light near the surface of the silicon. Thus, all of the excited electrons are created at the suface of the detector. Comparison of these two ways of creating electrons in an SDD should give more information about the mechanism of electron transport and collection in these detectors.

The test station which is located at Ohio State University has been described in STAR note SN0365.

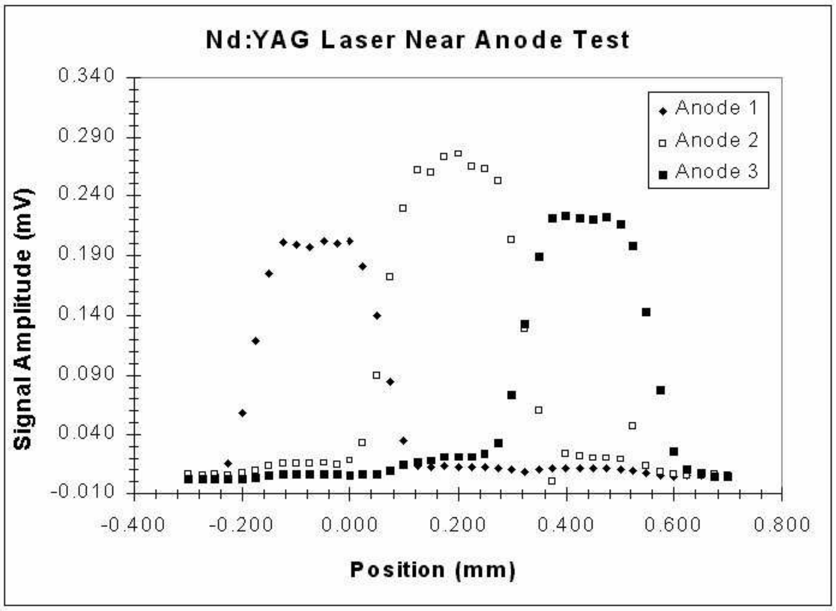
Data–Results

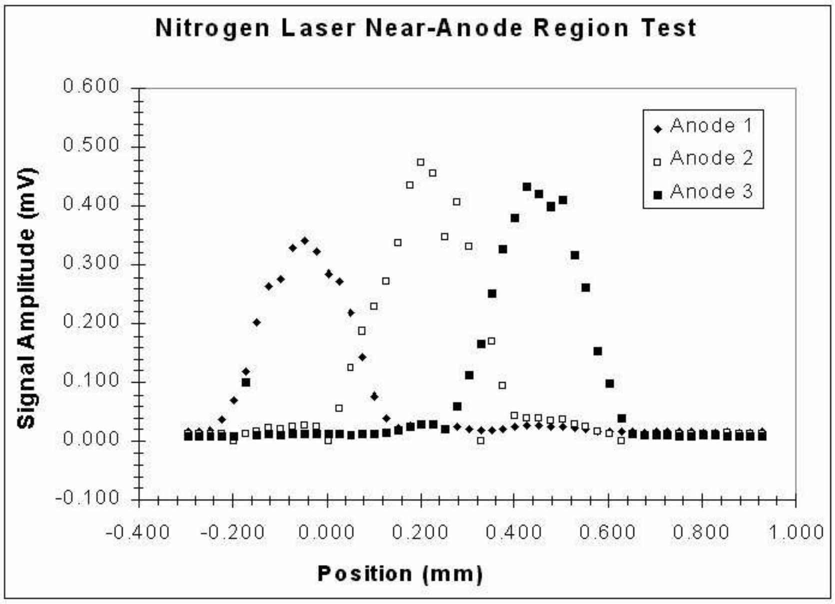
The first test was to see if there is any difference in the electron transport and collection mechanism at the far-anode region, that is, whether the excited electrons are created on the surface or throughout the whole bulk. To do so, the yellow laser light lased from the Rh590 dye is directed on the SDD, and the wafer is moved from one end to the other.



From the signal level plot, there seems to be no difference between the two different methods of creating electrons. Electrons created on the surface of the wafer would also fall into the middle of the wafer as an electron cloud, and be transported to the anode by the electric field. The small osciallation about the fitted line comes from the fact that the steps of the laser light across the wafer were not perfectly consistent.

To check the uniformity of the anodes' sensitivity, a second test was performed: the wafer was moved parallel to the anodes, with the laser shining on the near-

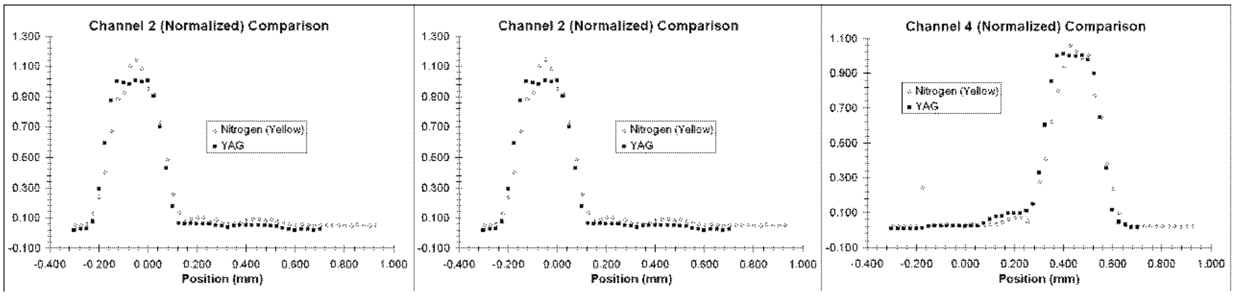




anode region. The test performed with the Nd:YAG laser looks satisfying, with plateaus appearing right above the location of each anode, and only ±10% in the amplitude of the signals among the three anodes (see next page).

However, when the excited electrons are created only at the surface in the near-anode region, as the nitrogen laser pumps through the Rh590 dye, the plot of the amplitude looks bizarre. Not only did the expected plateaus above the anodes disappear, but it also seems like not all the electrons being created are collected by the anode.

A possible answer to this observation can be found on the potential plot of the near-anode region [1]. Imagine an electron that rolls down along the potential



graph. As it gets close to the anode to be collected, it has to “roll over” several “valleys.” If this electron does not have enough energy to make it over any one of these potential valleys, it will sit there and not be collected by the anode. Therefore, it is possible that when the electrons are created on the surface of the wafer instead of throughout the bulk, some of the electrons are stuck in the valleys instead getting collected by the anodes.

Another comparison made was the shapes of the two near-anode region plots. If the shapes of the amplitude peak curve turn out to be different between the two, then there is something else interesting to know besides the “missing plateaus” in the case of the nitrogen laser. To do so, the average value of the peaks were calculated to normalize all six curves (3 anodes for each type of laser). Then, the resulting plots of corresponding channels are mapped over each other.

From the plots, there seem to be no significant differences between the two lasers used.

Conclusion

In summary, it was observed that when free electrons are created on the surface of SDD at far-anode region, the electron transport and collection mechanism act as if the free electrons are created throughout the bulk. However, once the laser beam, used to mock up ionized particles, is moved to the near-anode region, there is a significant difference. Not only is the uniformity of the signals lost, but it appears that some of the electrons created are lost in the wafer and not being collected.

References

[1] I. V. Kotov and the STAR-SVT Group, “Anode region design and focusing properties of STAR Silicon Drift Detectors,” submitted for publication.