1998 SUMMER RESEARCH PROGRAM FOR HIGH SCHOOL JUNIORS

AT THE

UNIVERSITY OF ROCHESTER'S

LABORATORY FOR LASER ENERGETICS

STUDENT RESEARCH REPORTS

PROJECT COORDINATOR

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Laboratory Report 300

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University of Rochester
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During the summer of 1998, 11 students from Rochester-area high schools participated in the Laboratory for Laser Energetics' Summer High School Research Program. The goal of this program is to excite a group of high school students about careers in the areas of science and technology by exposing them to research in a state-of-the-art environment. Too often, students are exposed to "research" only through classroom laboratories that have prescribed procedures and predictable results. In LLE's summer program, the students experience all of the trials, tribulations, and rewards of scientific research. By participating in research in a real environment, the students often
become more excited about careers in science and technology. In addition, LLE gains
from the contributions of the many highly talented students who are attracted to the
program.

The students spent most of their time working on their individual research
projects with members of LLE’s technical staff. The projects were related to current
research activities at LLE and covered a broad range of areas of interest including optics,
spectroscopy, chemistry, diagnostic development, and materials science. The students,
their high schools, their LLE supervisors and their project titles are listed in the table.
Their written reports are collected in this volume.

The students attended weekly seminars on technical topics associated with LLE’s
research. Topics this year included lasers, fusion, holography, nonlinear optics, global
warming, and scientific ethics. The students also received safety training, learned how to
give scientific presentations, and were introduced to LLE’s resources, especially the
computational facilities.

The program culminated with the High School Student Summer Research
Symposium on 26 August at which the students presented the results of their research to
an audience that included parents, teachers, and members of LLE. Each student spoke for
approximately ten minutes and answered questions. At the symposium an Inspirational
Science Teacher award was presented to Mr. David Crane, a chemistry teacher at Greece
Arcadia High School. This annual award honors a teacher, nominated by alumni of the
LLE program, who has inspired outstanding students in the areas of science,
mathematics, and technology.
## High School Students and Their Projects (1998)

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A total of 91 high school students have participated in the program since it began in 1989. The students this year were selected from approximately 60 applicants. Each applicant submitted an essay describing their interests in science, a copy of their transcript, and a letter of recommendation from a science or math teacher.

LLE plans to continue this program in future years. The program is strictly for students from Rochester-area high schools who have just completed their junior year. Applications are generally mailed out in February with an application deadline near the end of March. For more information about the program or an application form, please contact Dr. R. Stephen Craton at LLE.

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DESIGN AND TESTING OF A COMPACT X-RAY DIODE

by

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Design and Testing of a Compact X-ray Diode

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1998 Summer High School Research Program

Introduction

Omega, the University of Rochester's high powered laser dedicated to fusion research gives off x rays with different energy levels. Measuring the number of x rays and the energy of each is important in understanding what happens in the target chamber when Omega is fired.

Existing x-ray detectors are expensive, big, and cumbersome. Imaging detectors such as x-ray pinhole cameras which record onto film, x-ray framing cameras which make videos, and most often, x-ray streak cameras which measure time dependences of x rays. They require a lot of maintenance and are difficult to keep operational. Lawrence Livermore National Laboratory has developed the Dante Diode.¹ The Dante diode array on Omega functions as a group of 12 diodes which take up a 24" port in the target chamber, making it space-consuming and difficult to move for alternate views.

In designing a new detector, space was the main issue. The smallest possible functional diode, without losing accuracy was desired. Since the laser pulse only lasts a few nanoseconds it is important that the x-ray detector have a response time of a few tenths of a nanosecond. Other criteria include that it be easy to use for measuring the energy and number of x-ray photons and that cost be kept down.
Design Process

Before drawing anything, the gross electrical characteristics were estimated. An impedance of 50 Ω was desired so the ratio of outer potential radius to inner potential radius could be found by the following equation:

\[ Z = 60Ω \times \ln \frac{r_o}{r_i} \]

Capacitance per unit length could then be found by the following equation:

\[ C' = \frac{2\pi\varepsilon}{\ln \frac{r_o}{r_i}} \]

Overall estimated capacitance was taken to be 2 pF for calculations. Then, by simple division the overall length of the diode could be found. The inductance per unit length can also be found by the following equation:

\[ L = \frac{\mu}{2\pi} \left( \ln \frac{r_o}{r_i} \right) \]

The next step was to draw the diode. The original design was too long and thin, too fragile for it's diameter. The design was modified by shortening the diode almost fifty percent. This halved the total capacitance value, but the increase in response time balanced this reduction preserving the effectiveness of the diode. With this improved design, the diode would be more practical, less breakable, and would be easier to make.

The cathode end needed to be changed. Instead of tapering all the way to the end, a cylindrical screw-on section was added. This would allow for testing of different cathode materials (for different energy x rays) more easily. Cathode ends also tend to get damaged with time and use. This new way of attaching it would make it easier and less expensive to replace.

The final design costs only a quarter of what the Dante diode is estimated to cost. Seven diodes are able to fit in a 2" diameter circle, rather than 12 in a 24" one. The final values for impedance,
capacitance, and inductance are 50 Ω, 1.34 pF, and 3.34 nH, respectively.

FIG. 1. An as built drawing of the new LLE Diode shows 8 out of 10 parts (2 O-rings missing) assembled.

Modeling

In order to find out the expected response and signals from the diode, Paul Jaanimagi's modified SLAC "lens" program was used while the diode was being manufactured. This program maps equipotentials and calculates electron trajectories for electric fields, as shown at right.²

The cathode was set at potential -500 V and the anode at 0. The boundaries were set as in the actual diode. Voltage for the equipotentials was set in increments of 100 V.

FIG. 2. Map of electric field with electron trajectories is shown. The trajectories have combinations of the following energies, initial positions, and initial angles: 0eV, 3.5eV, 10eV; (30, -25), (30, 0), (30, 25); -45, 0, 20, 45, 60, 75, 85
50 V. Then the different electron trajectories could be simulated. Different initial positions, initial energies and initial angles were entered for calculation. The program is designed to output final electron positions, energies and angles, as well as the paths followed. It also gives the transit time for each electron from cathode to anode. The actual diode is not a hundred percent efficient, but it can be compared with these ideal values. The transit times ranged from 241.49 ps to 296.91 ps. This shows that even in ideal conditions where all the x rays arrive at the same time there is 54 ps difference in when the electrons will reach the anode.

**Testing**

The diode was tested using T-cubed, a test laser with a one picosecond pulse of varied energy, usually around 300 mJ. The LLE diode was compared to Lawrence Livermore’s Dante Diode. The area of Dante’s cathode is about ten times the area of the new diode. The signal levels were proportional to this ratio, as would be expected.

Although the rise times in FIG. 3 look identical, they are not. The LLE diode has a rise time of .141 +/- .008 ns and the LLNL diode has a rise time of .181 +/- .005 ns. This is a full 40 ps faster. The decay times of the two are almost identical at 1.09 +/- .17 ns for the LLE diode and 1.03 +/- .08 ns for the LLNL diode. This shows that the two diodes have

![FIG. 3. Temporal response of both diodes is shown.](image-url)
similar electrical characteristics and couple similarly into the transmission cables.

The Fourier transform of FIG. 3. (FIG. 4.) shows a hump around 2.5 GHz representing a resonance, or ringing in the LLNL diode. The plus signs, representing the LLE diode continue downwards without the unwanted resonance.

![Fourier transform](image)

**FIG. 4.** Fourier transform shows a resonance at 2.5 GHz

Conclusions

The LLE diode (FIG. 5) costs $450, which is estimated to be a quarter of Dante’s cost. It is very compact, having a total length of 4.13 cm and a total diameter of 1.5 cm. Seven of these new diodes can fit in a 2" port in the target chamber, compared with the 24" port that is currently used for the Dante diode array. The Dante diode exhibits a resonance around 2.5GHz where as the LLE diode does not. The LLE diode has a faster rise time by 40ps.

The signal levels in the new diode are one tenth of the Dante diode, that just improves the versatility of the

![Photograph](image)

**FIG. 5.** A Photograph shows the finished, assembled x-ray diode with the SMA connector attached.
The Dante diode’s cathode responds at a certain signal level such that it must be set back from Omega’s target wall. This compact x-ray diode has a cathode and a signal level one tenth the size of Dante. ideal for use at the target wall, making it easier to use.

The new LLE diode will continue to be tested. Future work will attempt to install an array of these diodes in the Omega system.

Acknowledgments

I would like to thank the Laboratory for Laser Energetics and Dr. R. Stephen Craxton for the remarkable opportunity to participate in this year’s Summer Research Program for High School Juniors. Many thanks to Oscar Lopez-Raffo, Mark Romanofsky, Dick Fellows, and Mark Russell for all their help concerning the diode’s fabrication. I would also like to thank Yoram Fisher and Kenton Green for their help with the diode’s testing. Most of all, I would like to thank my advisor, Dr. James Knauer for his endless patience and firm dedication to my success.

References


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