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# HIGH SPATIAL RESOLUTION NEUTRON IMAGING OF INERTIAL FUSION TARGET PLASMAS USING BUBBLE DETECTORS

FINAL REPORT FOR THE PERIOD
NOVEMBER 1, 2002 THROUGH OCTOBER 31, 2005

by
R.K. FISHER

Prepared under the
National Nuclear Security Administration
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Grant No. DE-FG52-03SF22693
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# DISCLAIMER

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Bubble detectors, which can detect neutrons with a spatial resolution of 5 to 30μ, are a promising approach to high-resolution imaging of NIF target plasmas. Conventional gel bubble detectors were used in successful proof-of-principle imaging experiments on OMEGA. The results were presented in an invited talk at the October 2001 meeting of the Division of Plasma Physics of the American Physical Society, and published in Physics of Plasmas [1].

When this research first began, bubble detectors appeared to be the only approach capable of achieving neutron images of NIF targets with the desired 5μ spatial resolution in the target plane. In 2001, NIF significantly reduced the required standoff distance from the target, so that diagnostic components can now be placed as close as 10 cm to the target plasma. This will allow neutron imaging with higher magnification, and may make it possible to obtain 5μ resolution images on NIF using deuterated scintillators.

Having accomplished all that we could hope to on OMEGA using conventional gel detectors, we suggested that our 2003-2004 NLUF shots be used to allow experiments to test the spatial resolution of the CEA-built deuterated scintillators. The CEA data taken on OMEGA shows the spatial resolution using the deuterated scintillator detector array is ~325 microns, which should make it possible to image NIF and LMJ targets with a spatial resolution of 6 to 7μ in the target plasma [2]. This resolution requires that the scintillation detectors can be placed 25 to 40 meters from the ICF target, which is only possible on NIF and LMJ along a very small number of sightlines. Bubble detectors will still be needed in order to obtain orthogonal views of the target with spatial resolution approaching 5μ, since neither NIF nor LMJ have long diagnostic sight lines available in orthogonal directions.

Conventional gel detectors, which consist of ~10 micron diameter drops of bubble detector liquid suspended in an inactive support gel that occupies ~99% of the detector volume, were chosen for the initial tests on OMEGA since they are easy to use. The bubbles could be photographed several hours after the neutron exposure. The conventional bubble detectors that we tested should be useful for imaging the high yield NIF target plasmas. However, imaging target plasmas at neutron yields of $10^{15}$ on NIF will require a higher detection efficiency detector, and being able to image these unsuccessful implosion experiments will be very useful in terms of understanding how to achieve higher yield implosions. I had proposed using a liquid bubble chamber detector, which should increase the neutron detection efficiency by a factor of ~1000 over that of the conventional gel bubble detectors used in our tests on OMEGA. A pressure-cycled liquid bubble detector would require a laser scattering or flash x-ray system to record the bubble locations a few microseconds after the neutron exposure when the bubbles have grown to be ~10 microns in diameter. Installing a pressure-cycled liquid bubble chamber and recording the bubble distribution in real-time are major development tasks, and would require funding significantly larger than that possible under an NLUF research grant. We propose to collaborate with the University of Rochester Laser Laboratory for Energetics. Marian Ghilea, a graduate student at the University of Rochester, is working with Prof. David Meyerhofer and Dr. Craig Sangster at UR/LLE on proposed tests of a liquid bubble chamber for neutron imaging of OMEGA target plasmas [3].

## HIGHER SENSITIVITY BUBBLE DETECTORS RECENTLY DEVELOPED

Recently there has been a significant advance in the techniques used in making gel bubble detectors. New DEFENDER series detectors have been developed by Bubble Technologies, Inc. (BTI) to allow detection of contraband nuclear material at customs entry ports and border crossings. These new high efficiency detectors have a neutron sensitivity εA that is up to 10,000 times larger than the conventional BDS gel bubble detectors used in our earlier studies.

The gel bubble detectors used in our proof-of-principle tests on OMEGA consisted of ~ 20,000 five to forty micron diameter drops of a superheated liquid suspended in an elastic polymer matrix gel, so that the neutron-induced bubbles last indefinitely rather than a few milliseconds. Only ~ 0.1% of the volume of these conventional gel bubble detector consists of active detector liquid drops, resulting in a very low neutron detection efficiency. BTI has developed a new manufacturing technique that allows them to increase the fraction of active detector liquid in the detector, increasing the neutron detection efficiency to $\sim 3 \cdot 10^{-4}$ b/n per cm of detector thickness. Hence a 10 cm thick detector would have a neutron detection efficiency of 0.3%, making them potentially useful for high-resolution neutron imaging of lower yield target plasmas on NIF. The diameter of the drops of active detector liquid in the presently available DEFENDER series detectors is between 90 and 130 microns. Since a neutron induced bubble grows to vaporize an entire drop of active detector liquid, the bubble size is determined by the liquid to gas density ratio. The final bubble diameter is approximately six times the drop diameter, or between 540 and 780 microns. With a bubble diameter this large, the spatial resolution of these off-the-shelf DEFENDER series detectors can not expected to be significantly better than the 325 microns achieved using deuterated scintillators in the CEA tests on OMEGA. Research would need to determine if detectors with a smaller increase in the average diameter of the active liquid drops, but with a larger number of these drops, can be developed…. so that a significant portion of the increase in the neutron detection efficiency of today's DEFENDER series detectors can be obtained.

### References

[1] R.K. Fisher, et al., Phys. Plasmas **9**, 2182 (2002).
[2] L. Disdier, et al. "Inertial Confinement Fusion Images," Invited Talk presented at the APS/DPP Meeting in Denver (Oct. 2005); to be published in Phys. Plasmas.
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