Developmental Status of a Liquid-Freon Bubble Chamber for Neutron Imaging

M. C. Ghilea
University of Rochester
Laboratory for Laser Energetics

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Summary

A high-spatial-resolution neutron-imaging detector is being developed at LLE

- The neutron-induced bubble-density distribution will be measured in a chamber filled with liquid freon.*
- A prototype system is being tested at LLE for concept validation.
- Preliminary calculations and tests show promising results.

*R. A. Lerche et al., Rev. Sci. Instrum. 74, 1709 (2003).*
Collaborators

D. D. Meyerhofer, T. C. Sangster, D. J. Lonobile, and A. Dillenbeck
University of Rochester
Laboratory for Laser Energetics

R. A. Lerche
Lawrence Livermore National Laboratory

L. Disdier
Commissariat à L’Énergie Atomique
Bruyères-le-Châtel, France
Freon bubbles will be initiated by 14-MeV neutron scattering in super-critical liquid

- Freon 115 ($\text{C}_2\text{ClF}_5$) has ideal properties for a bubble-chamber working medium (temperature range of 45°C to 60°C and pressure 7 to 27 atm).

- Since the range of the recoil ions is $<5 \mu\text{m}$, the bubble-density distribution is directly related to the spatial distribution of the incoming flux of neutrons.

- Various parameters must be estimated to design a readout system for experiments on OMEGA (number of bubbles, bubble size, and bubble lifetime).
Bubbles form in the superheated freon if \( \sim 300 \text{ eV} \) of energy is deposited by incident radiation interactions.

Bubble production is a function of pressure and temperature. Slow bubble growth is preferable for high-neutron yields and fast bubble growth for low-neutron yields.
A simple model can be used to establish the requirements of a readout system

- Most of the bubbles have similar size and growth rates
- Small bubbles ⇒ higher resolution
- Bigger bubbles ⇒ easier to readout

The readout window is set by:
- bubble diameter
- bubble-growth speed
- camera sensitivity
The bubble-growth speed is determined by the freon temperature.

The temperature will be tuned to optimize the bubble size given readout duration.
General characteristics of the bubble-chamber operation

• The chamber works in single-shot mode.

• A linear motor (LIM) is used for the compression/decompression cycle.

• Parallel light is generated for bubble detection.

• An independently pulsed laser will be used to create a stream of bubbles for preliminary testing.
Only the column density of the bubble distribution can be measured for the yields on OMEGA

- In the freon detector, one bubble is created for every 10 incident neutrons.

- Schlieren imaging will be used to infer the column density of the bubbles.

- Only about $10^{-3}$ of the incident light passing through a bubble is scattered and can be detected, so a minimum pulsed-laser power of 3 mW is needed for a signal-to-noise ratio of at least 10.

- The minimum number of bubbles necessary to get a clean image is $8 \times 10^5$ and the maximum value is $\sim 10^8$. 
The LLE bubble chamber has been designed to measure the column density of bubbles instead of counting them individually as in the original Fisher experiment*.

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