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1.D Nuclear Diagnostics for the OMEGA Upgrade

The OMEGA Upgrade 60-beam glass laser facility, currently under construction at the University of Rochester, will be capable of symmetrically illuminating a direct-drive ICF target with 30 kJ of highly spatially uniform, temporally pulse-shaped, 351-nm light.[1] The OMEGA system currently employs several diagnostics to measure the flux and energy spectra of neutrons emitted from the target. These measurements have enabled us to infer fuel ion temperature, and fuel and shell areal density. Analysis of data from nuclear diagnostics has provided many insights into the performance of laser-fusion targets.

The Upgrade will include a full array of neutron diagnostics and will be constructed with special provisions to increase the usability and accuracy of the nuclear instrumentation.

In the previous article, the development of time-resolved neutron diagnostics was discussed. In this article we describe the time-integrated neutron diagnostics planned for two out of the 32 total diagnostic ports on the OMEGA Upgrade. One of these ports (the "line-of-sight" port) will have a plastic collimator mounted to it that will provide a low-scattered-neutron location for several short-path (2- to 4-m) time-of-flight detectors. These detectors will be used primarily to measure ion temperatures for high-yield ($>10^7$) DD fuel-target experiments. (Fig. 53.18). A path through this collimator is available for long-path (20-m), time-of-flight instruments that are to be housed in a separate building outside of the target-bay shield wall (Fig. 53.19). This wall serves as a 1-m-thick second collimator for this diagnostic building. The neutron-diagnostic building and target bay have provisions for the attachment of a flight tube to minimize the effects of neutron scattering along the latter part of the flight path. We are currently planning radiation-transport analysis to optimize the design of the collimators for this system. The instruments in the diagnostic room will be used to measure DT and DD ion temperature and DD secondary spectra.

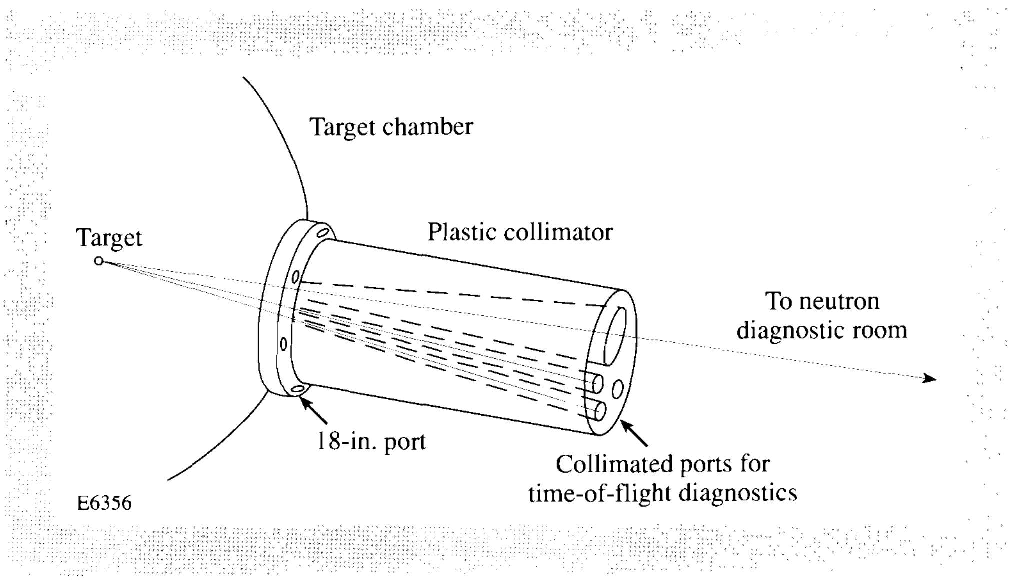

Fig. 53.18
A first collimator for time-of-flight neutron diagnostics will be mounted on the target chamber.

Neutron spectra will be measured to infer fuel-ion temperature and, through measurement of the secondary reaction products,[2] fuel areal density. The primary instruments used to measure neutron spectra are single scintillator/fast photomultiplier combinations ("current"-mode detectors), and arrays of scintillators and photomultipliers operated in "single-hit" mode. The current-

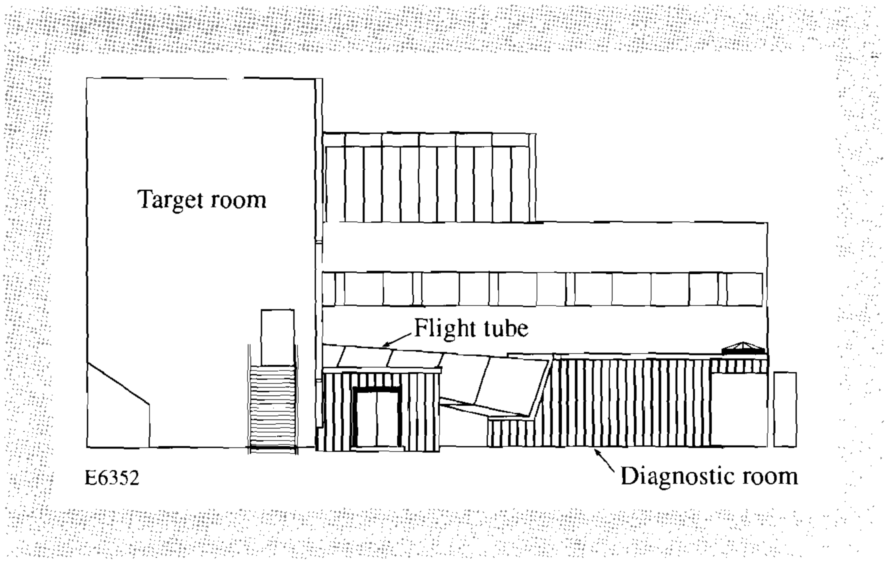

Fig. 53.19
A neutron diagnostic room is being constructed that will provide a time-of-flight path length of 20 m.

mode detectors (described in previous issues of the LLE Review[3]) have limited accuracy at low neutron yields because there are few detected events in the necessarily small scintillator volume. Increasing the size of the scintillator reduces the time resolution because of multiple light reflections within the scintillator crystal. For this reason, ion temperatures at low neutron yields and secondary neutron spectra will be measured using a multi-detector array technique developed at LLNL.[4] We have developed and tested a 96-channel prototype of the array planned for the Upgrade facility.[5] Typical ion-temperature data for this array are shown in Fig. 59.20. A single-hit array is currently being constructed that consists of 960 photomultiplier plastic-scintillator detectors. For each channel the time of arrival of the neutron event is recorded, creating an energy histogram. We also record the amplitude of the signal received in each channel, both to enable operation as a large current-mode detector and for amplitude-based timing corrections (Fig. 59.21). The neutron-diagnostic room was designed specifically to house this large detector array and two to three current-mode detectors and their associated electronics.

The other diagnostic port allocated for neutron instrumentation will contain activation diagnostics and a rapid extraction mechanism for target debris collection (Fig. 59.22). Neutron yield from the primary branch of the nuclear reaction for DD or DT fuel will be measured by indium and copper activation, respectively. Because the gamma spectrometers (counters) for these activation detectors are located in a low-background shielded area beneath the target chamber and because of the possibility of dangerous levels of radioactivity in the target chamber after a high-neutron-yield target experiment, automatic drop systems will be constructed to transport the activated samples from the target chamber to the counters (see Fig. 59.23). Measurement of activated target debris collected during a target implosion has been used to measure shell areal density[6] and fuel areal density.[7] A rapid extractor will be constructed to remove collected target debris from the vacuum of the target chamber to the counting area beneath the target chamber. The transport system will be capable of moving the sample to the counting area in under 30 s, to enable counting of short half-life isotopes.

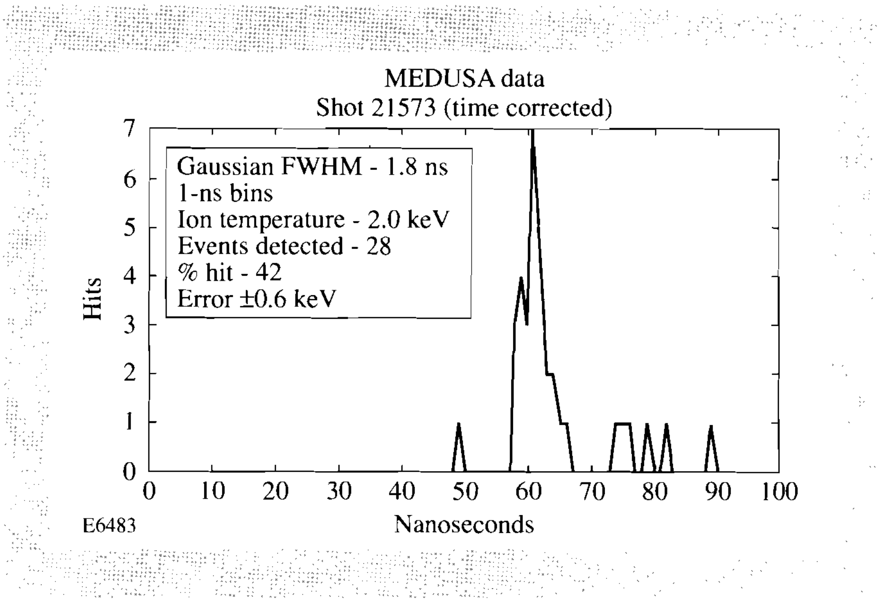

Fig. 53.20
Ion temperature data from the prototype (96-channel), single-hit detector agrees with current-mode detector.

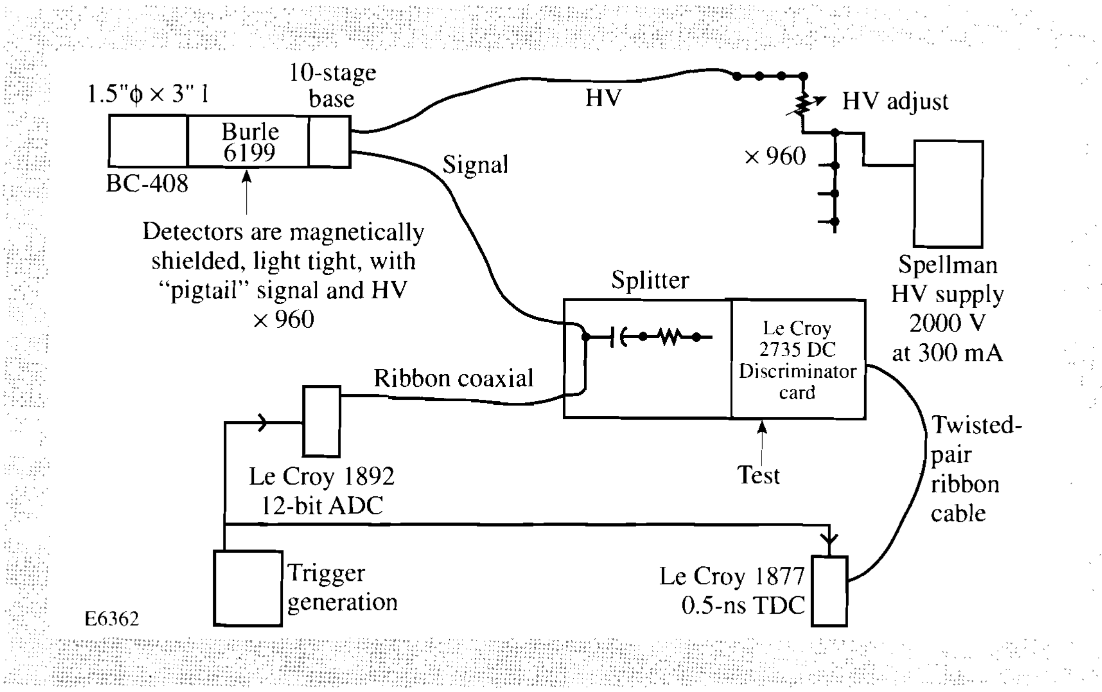

Fig. 53.21
Analog-to-digital converters and time-to-digital converters provide amplitude and time data for each of the 960 channels of Upgrade MEDUSA.

We have three detectors for gamma spectroscopy: a large (25 cm × 25 cm) sodium iodide detector for high-sensitivity, low-resolution requirements, and two high-purity germanium detectors for high-resolution spectroscopy.

A measurement of the response function of the previously mentioned detectors to single neutrons is essential for unambiguous unfolding of the measured data.

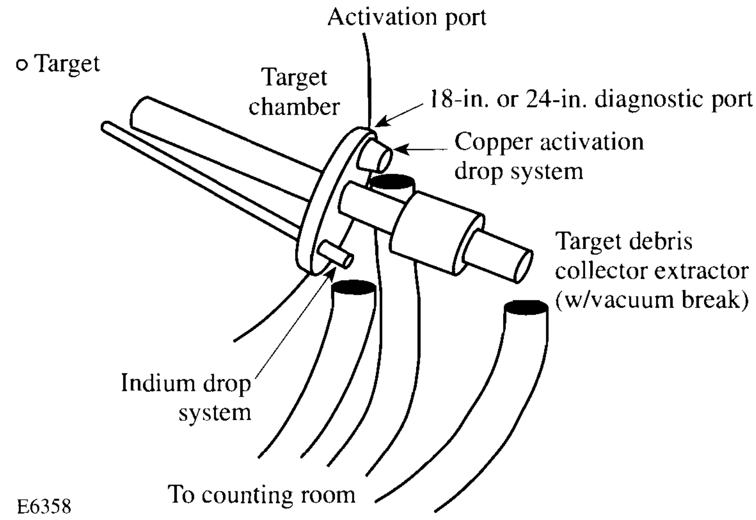

Fig. 53.22
A chamber will contain activation diagnostics and a radiation-chemistry collector extractor.

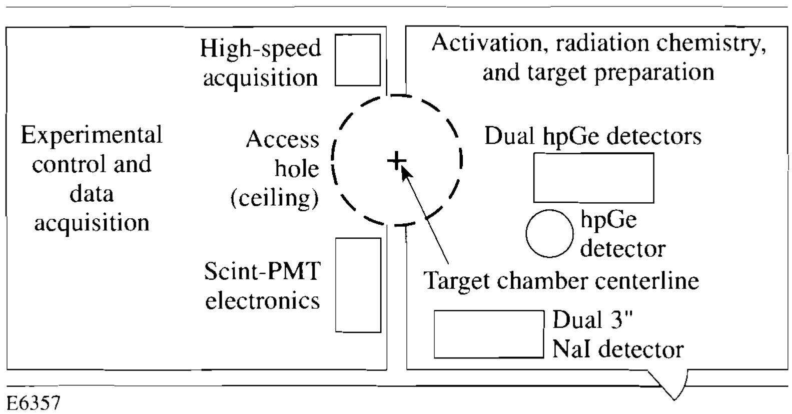

Fig. 53.23
Activated material will be analyzed in a low-background counting room beneath the target chamber.

A calibration facility capable of producing 2.45-MeV (DD) and 14.1-MeV (DT) neutrons is essential. We have begun a collaboration with SUNY Geneseo to construct a calibration facility capable of producing sub-5-ns bursts of neutrons from the Geneseo 2-MV VanDeGraff accelerator. Short bursts of neutrons are highly desirable since the effects of neutron scattering in the accelerator, experiment room, and surrounding materials may then be eliminated by time gating of the signal from the detector under calibration. This VanDeGraff is capable of stable operation at accelerating voltages as low as 100 kV, which is important to the optimization of neutron yield in each calibration pulse, since the