New Fast Neutron Time-of-Flight Detectors with Subnanosecond Instrument Response Function for DT Implosions on OMEGA

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H4D 10.4 m
H17E 4.9 m

X-Ray IRF

H4D 10.4 m
FWHM = 553 ps
Rise time = 260 ps

H17E 4.9 m
FWHM = 362 ps
Rise time = 246 ps

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Summary

Two fast neutron time-of-flight (nTOF) detectors were recently deployed on OMEGA for hot-spot flow velocity measurements

- The detectors use 10-mm-diam Hamamatsu microchannel-plate photomultiplier tubes (MCP-PMT’s) without any scintillator
- The two PMT nTOF detectors are located along the H4D and H17E antipodal lines of sight (LOS) at 10.4 m and 4.9 m from the target chamber center (TCC)
- The PMT nTOF detectors measure hot-spot flow velocity,* DT yield, and DT ion temperature from $1 \times 10^{13}$ to $2 \times 10^{14}$ yield range

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* S. Regan et al., YO5.00002, this conference.
Collaborators


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Motivation

Reconstruction of the hot-spot velocity vector is key to understanding cryogenic implosion performance and assessing 3-D behavior

\textit{DEC3D} hydrodynamic simulations

- Low mode ($\ell = 1, m = 0$)
  - Asymmetric compression leads to incomplete stagnation and residual kinetic energy (RKE)
  - Low modes ($\ell < 10$)
    - bulk collective motion of the hot spot
  - High modes ($\ell \geq 10$)
    - variations in the flow within the hot spot

- High mode ($\ell = 12, m = 0$)

The fast PMT detectors in H4 and H17 LOS completed the 3dnTOF suite* with four quasi-orthogonal LOS to measure the hot-spot flow velocity.

The 3dnTOF detector suite uses a variety of detector technologies:

- **H10**: 22-m Petal (scintillator + PMT)
- **P2**: 5.8-m CVD and 15.8-m CVD
- **H4–H17**: 10.4-m PMT and 4.9-m PMT
- **TIM-6**: 13 m-Petal (scintillator + PMT)

Independent measurements in four separate LOS are necessary to infer the hot-spot flow velocity**

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The two 10-mm-diam Hamamatsu PMT’s were installed in the H4D and H17E antipodal LOS at 10.4 m and 4.9 m from TCC

- Each PMT was installed in a thin aluminum housing without a scintillator
- Two-stage MCP with gain up to $10^6$
- 15-m HV and signal cables
- Keysight DSOS254A 2.5-GHz, 20-Gs/s scope
- SRS PS-300 HV power supply
- SRS DG535 delay generator for gate pulse
- Signal split into three scope channels
- An optical fiducial in fourth scope channel

H4D 10.4 m
R3809U-52
ungated

H17E 4.9 m
R5916U-50
gated

HV: high voltage
The x-ray instrument response function (IRF) for H4D and H17E nTOF detectors were measured with a 100-ps laser pulse on a gold target.

- H4D 10.4 m:
  - FWHM = 553 ps
  - Rise time = 260 ps

- H17E 4.9 m:
  - FWHM = 362 ps
  - Rise time = 246 ps
The PMT nTOF detectors are sensitive to hard x rays, gammas from \((n,\gamma)\) interactions, and DT neutrons.

In order to have low signals from the x–rays and gammas and not saturate the PMT, we run the PMT at a very low gain of about 100.

Shot 93868, \(Y = 1.4 \times 10^{14}\), \(T_i = 9.2\) keV.
The hot-spot flow velocity from the H4D and H17E nTOF detectors was calculated by the forward-fitting method.

The \((n,\gamma)\) interactions with the wall produced an additional background.

There is a very small background in the H17E location.
The hot-spot flow velocity is now measured on OMEGA for DT cryogenic and room-temperature target implosions.

Exploding pusher 07/25/19 shots

- Stalk (TPS2)
- Shot 94510 flow direction (64.2 km/s)
- Shot 94512 flow direction (43.9 km/s)
- Shot 94513 flow direction (27.7 km/s)
- Shot 94514 flow direction (80.5 km/s)
- Shot 94516 flow direction (82.6 km/s)
- Shot 94517 flow direction (75.3 km/s)
- Shot 94519 flow direction (98.8 km/s)
- Shot 94520 flow direction (83.7 km/s)

Cryogenic 07/09/19 shots

- Stalk
- Shot 94341 flow direction (76.8 km/s)
- Shot 94343 flow direction (119.6 km/s)
- Shot 94346 flow direction (105.0 km/s)
- Shot 94348 flow direction (131.3 km/s)
- Shot 94350 flow direction (99.0 km/s)
The H4D and H17E nTOF detectors were calibrated for DT yield on OMEGA against the Cu activation diagnostic in room-temperature targets with high-adiabat implosions.

The operational yield range for these detectors is $1 \times 10^{13}$ to $2 \times 10^{14}$. 
The $T_i$ measured by the H4D and H17E nTOF detectors in room-temperature shots were compared with the $T_i$ measured by the Petal nTOF detector.
Summary/Conclusions

Two fast neutron time-of-flight (nTOF) detectors were recently deployed on OMEGA for hot-spot flow velocity measurements.

- The detectors use 10-mm-diam Hamamatsu microchannel-plate photomultiplier tubes (MCP-PMT’s) without any scintillator.
- The two PMT nTOF detectors are located along the H4D and H17E antipodal lines of sight (LOS) at 10.4 m and 4.9 m from the target chamber center (TCC).
- The PMT nTOF detectors measure hot-spot flow velocity, DT yield, and DT ion temperature from $1 \times 10^{13}$ to $2 \times 10^{14}$ yield range.

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Backup
Counteracting hot-spot flow velocity by imposing an $\ell = 1$ drive asymmetry with an initial target offset improves target performance at stagnation.

DT neutron yield versus hot-spot flow velocity

$T_{i,p-v}$ versus hot-spot flow velocity

3-D measurements provide insight to improve the implosion symmetry.

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