Technology for Polar-Drive Ignition on the NIF

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Polar-drive ignition could be tested on the NIF with a few modest modifications to the facility

- Beam-smoothing improvements:
  - Multi-FM 1-D smoothing for spectral dispersion (SSD) provides the required beam smoothing with simple modifications to the NIF facility
  - Beam smoothing is only required at the beginning of the laser pulse, which minimizes stress on the laser
  - Polar-drive phase plate and polarization-smoothing designs are underway
  - A NIF PD beam-smoothing demonstration on OMEGA EP is planned in FY12

- Direct-drive target technology:
  - NIF-scale fill-tube targets have been demonstrated and are being optimized
  - Concepts for a polar-drive ignition target insertion cryostat (PD-ITIC) are being developed
Implementing polar drive (PD) requires five changes on the NIF for an ignition demonstration:

1. Add multi-FM fiber front end and combine with existing system.
2. Add new SSD grating to 48 preamplifier modules (PAM).
3. New PD phase plates ($2\omega$) and polarization plates ($3\omega$) in final optics assembly.

Additional details:
- Far-field intensity ($\times 10^8$)
- Divergence ($\mu$rad)
Laser nonuniformity imprint is minimized by optimizing smoothing by spectral dispersion (SSD)

Single-beam laser nonuniformity

- SSD divergence ($\Delta \theta_{SSD}$) determines the asymptotic uniformity
- Increasing the inverse coherence time ($t_c^{-1}$) allows the target to experience a smoother spot for a longer period

$\sigma_{rms}$ (%), $\ell$-modes 30:60

$\Delta \lambda \equiv$ Bandwidth
$N_{cc} \equiv$ Color cycles
$f_m \equiv$ Modulator frequency

$\Delta \theta_{SSD} \propto \frac{\Delta \lambda \times N_{cc}}{f_m}$
MultiFM 1-D SSD provides required beam smoothing performance with minimal impact on the facility

- Traditional SSD systems using single-frequency phase modulation have low smoothing rates for many important spatial modes ($\ell < 150$)
- MultiFM 1-D SSD is a new approach that
  - provides better smoothing rates with lower total bandwidth (esp. for PD pulse shapes with picket prepulses)
  - can be implemented on NIF with simple modifications

Inverse coherence time versus far-field spatial frequency

- $t_c^{-1}$ (GHz)
- $\ell$ mode

- MultiFM 1-D SSD (0.5 THz)
- 2-D THz SSD
- 1-D SSD
An optimized MultiFM configuration that achieves high gain in polar drive simulations has been identified.

- MultiFM 1-D SSD employs technology developed for the telecommunications industry
  - 40-GHz phase modulators and drive electronics
  - UV bandwidth: $\Delta f_{\text{total}} = 500$ GHz (effective bandwidth)
  - SSD divergence: $\Delta \theta_{\text{SSD}} = 100 \mu\text{rad}$ (half angle at full beam)
- **DRACO** 2-D simulations with all nonuniformity sources: Gain = 32
Dynamic Bandwidth Reduction (DBWR) minimizes stress on the laser with little affect on target gain.

MultiFM 1-D SSD beam smoothing only needs to be applied to pickets in the polar-drive point design pulse shape.
A MultiFM 1-D SSD beam-smoothing demonstration on OMEGA EP will validate laser imprint performance

Integrate NIF PAM into OMEGA EP

Verify laser imprint with foil-target experiments on OMEGA EP*

Verify smoothing with equivalent target plane measurements*

### Simulation of method

**Far-field intensity ($\times 10^8$)**

<table>
<thead>
<tr>
<th>Time (ns)</th>
<th>Far-field intensity</th>
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<tr>
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<tr>
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<td>3</td>
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<tr>
<td>4</td>
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*In progress*

**Early FY12**


**Demonstrate MultiFM Seed Source**

**Divergence ($\mu$rad)**

E19672

**With SSD**

<table>
<thead>
<tr>
<th>Amplitude ($\mu$m)</th>
<th>Time (ns)</th>
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<tr>
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<tr>
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<tr>
<td>10^2</td>
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**T. R. Boehly et al., Laser Part. Beams 18, 11 (2000).**
The focal-spot conditioning strategy for polar-drive ignition includes phase and polarization plates.

The NIF final optics assembly (FOA) will include:
- Phase plate between the frequency conversion crystals ($2\omega$)
- Polarization plate ($3\omega$)
Phase plates and polarization smoothing are being designed to efficiently and uniformly couple energy to polar-drive targets.

- Phase plates efficiently deliver laser energy with a desired focal pattern to achieve required irradiation uniformity.
- Polarization smoothing instantaneously improves targeted modes of focal-spot irradiance modulation.
A NIF fill-tube target has been demonstrated that will be optimized to meet polar-drive ice layer specifications.

Facility renovations and equipment upgrades are underway at LLE to demonstrate NIF PD cryogenic layering with DT targets.
A polar-drive ignition target insertion cryostat (PD-ITIC) will minimize the impact on the NIF facility

- A polar-drive target that survives >3-s exposure to the target chamber is required to use existing “clam-shell” shroud design
- Use existing NIF space envelope and cryogenic support systems (TAS, LLCS, TARPOS)

Existing TAS and LLCS place challenging constraints on a PD-ITIC design that will limit size of the cryogenic shroud.
Summary/Conclusions

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