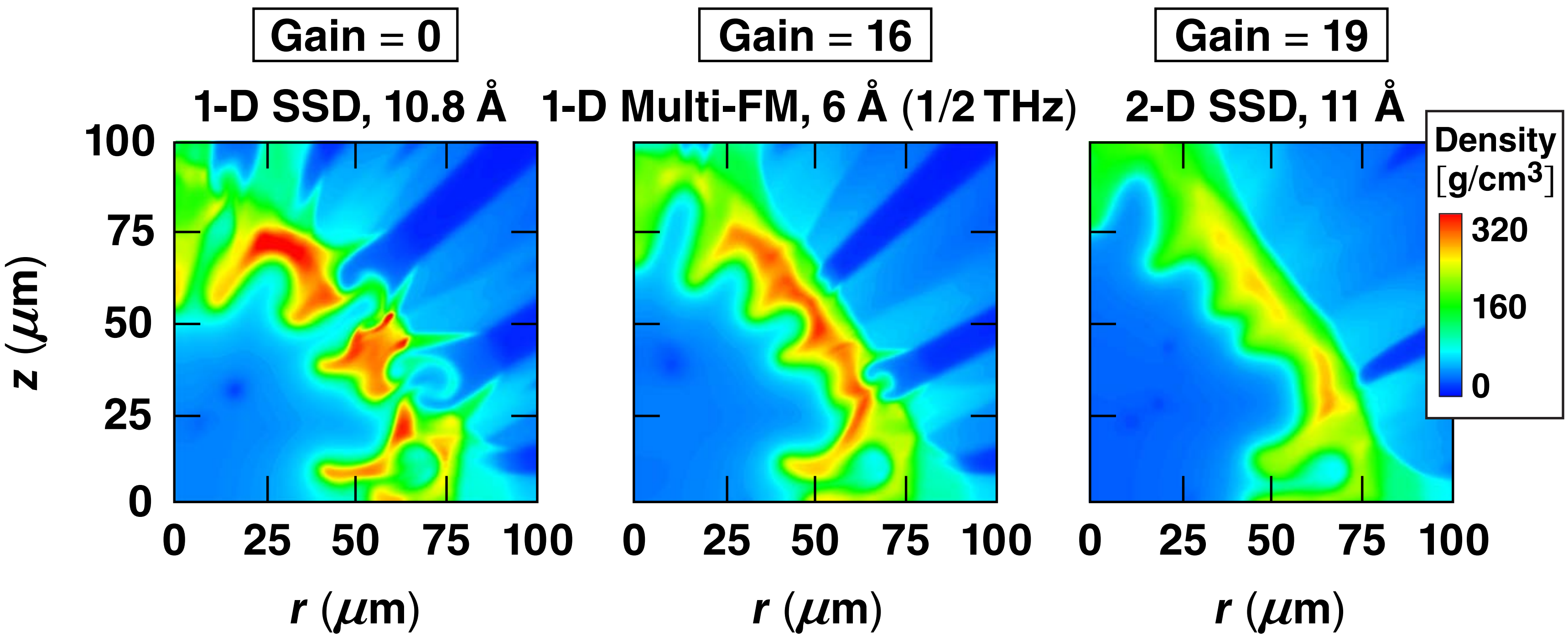
NIF Polar-Drive Simulations of a 1.2-MJ CH-Foam Ignition Target with 0.5 THz of 1-D Multi-FM SSD Using An Analytic Model

At peak compression 9.8 ns



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University of Rochester
Laboratory for Laser Energetics

51st Annual Meeting of the
American Physical Society
Division of Plasma Physics
Atlanta, GA
2–6 November 2009

Summary

A 1-D Multi-FM SSD solution was found that minimizes the nonuniformity and achieves gain

UR LLE

- An analytic model has been enhanced to handle multiple FM modulators in each orthogonal direction
- The analytic SSD model reduces the variance during a *DRACO* simulation
- The 1-D Multi-FM SSD system represents a significant savings for the NIF
  - applied in the fiber front-end, i.e. no bulk optics
  - low applied bandwidth means single frequency-conversion crystals (FCC) can be used
- Dynamic bandwidth reduction will be employed to reduce divergence and increase power during the drive pulse

1-D Multi-FM will be tested on OMEGA EP in 2010.

Collaborators

T. J. B. Collins

J. D. Zuegel

University of Rochester
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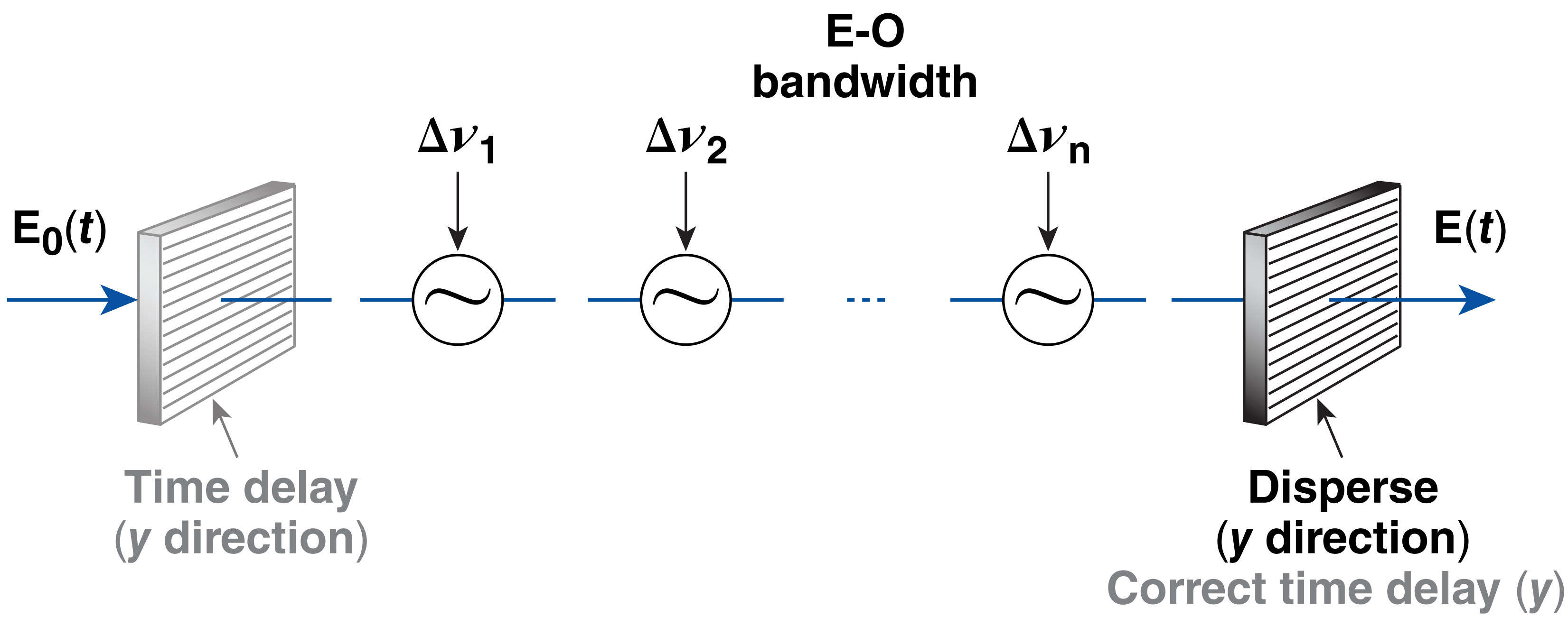
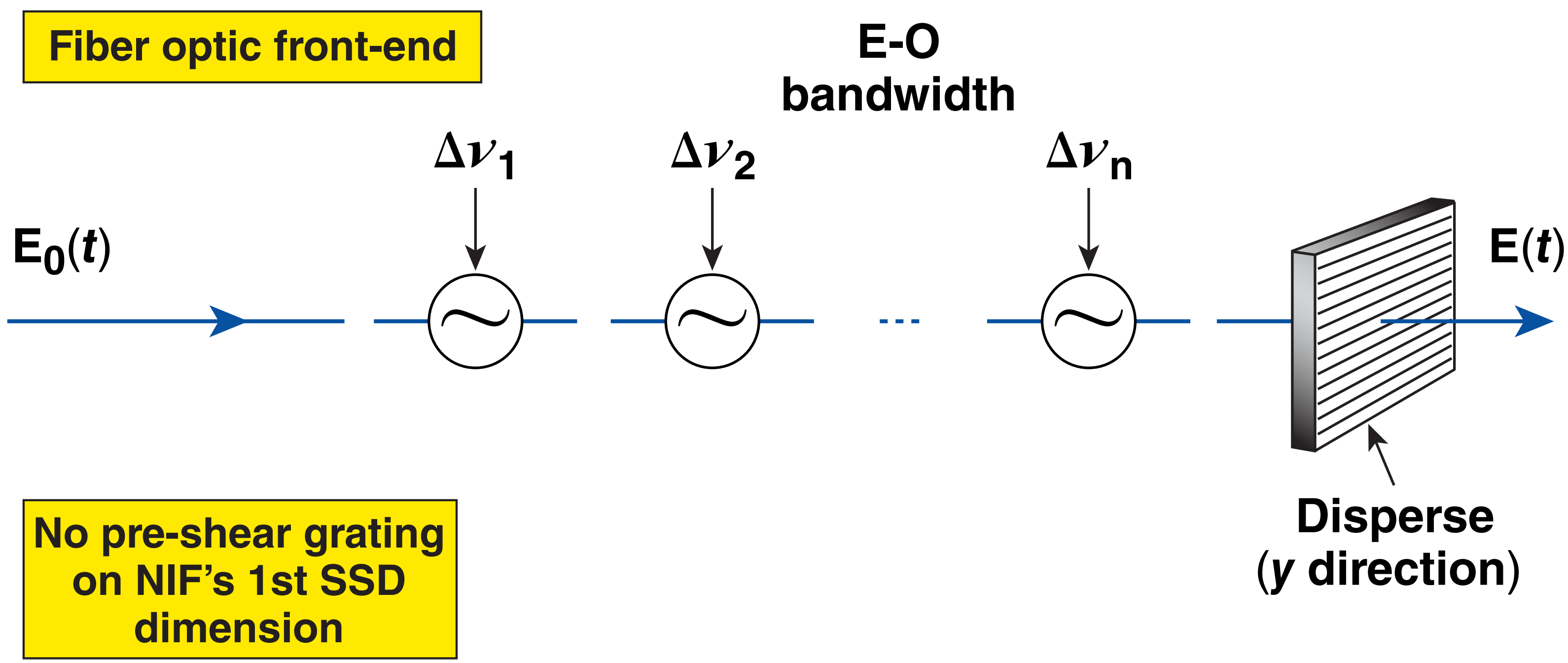
Multi-FM is produced by applying multiple FM modulators in a single dimension



- **Total bandwidth and divergence are distributed across the modulators**

TC8327_1

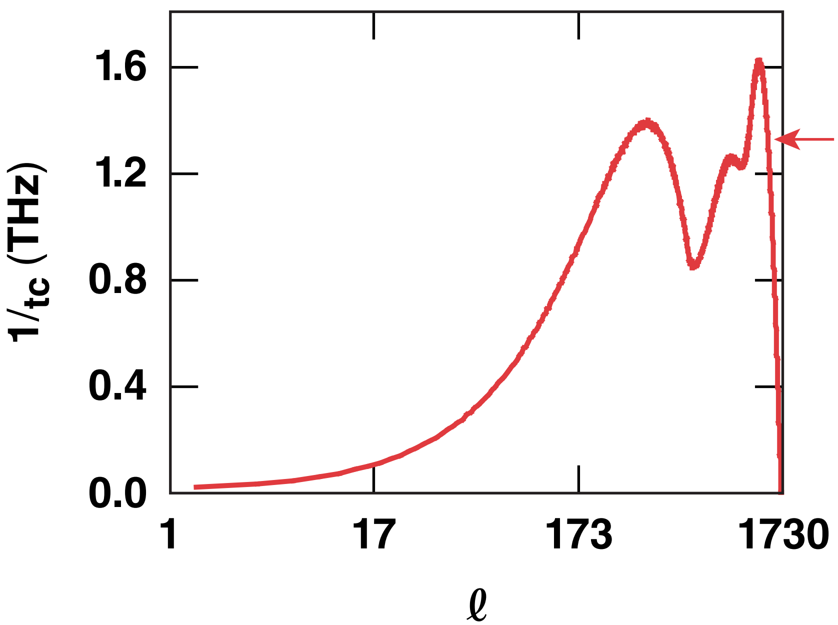
Multi-FM is produced by applying multiple FM modulators in a single dimension

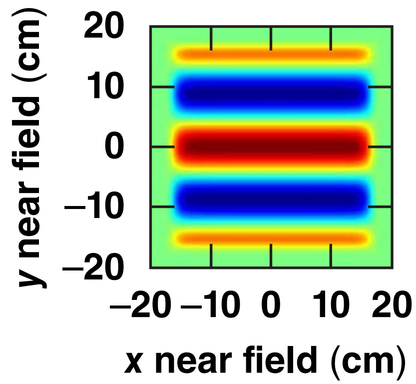


- Total bandwidth and divergence are distributed across the modulators
- Can be designed for bandwidth of $\Delta\nu_{UV}$ = 0.5 THz ($\Delta\lambda_{IR}$ = 6 Å) single frequency-conversion crystals (FCC)
- Takes advantage of multiple color cycles without detrimental resonant features that are present in single modulator systems

TC8327_2

1-D Multi-FM SSD takes advantage of multiple color cycles while reducing resonance effects





- Standard 1-D SSD
  - 900-GHz bandwidth
  - two color cycles
  - large resonances

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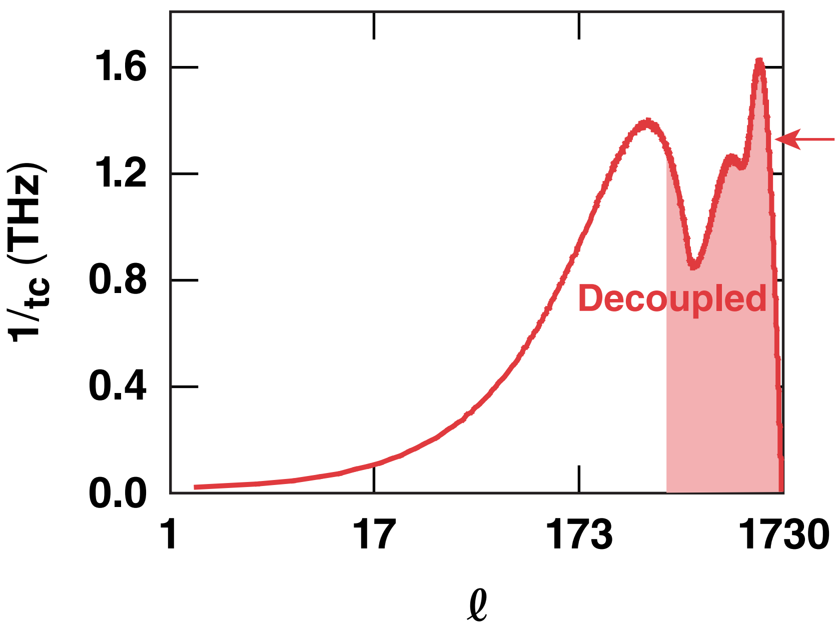

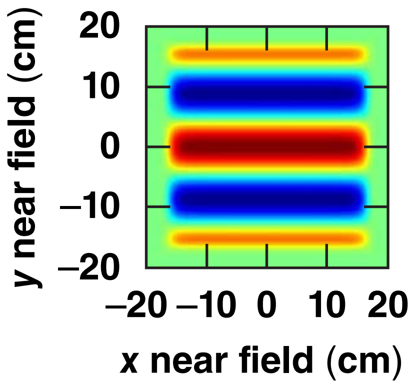

- Standard 1-D SSD
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TC8619_2

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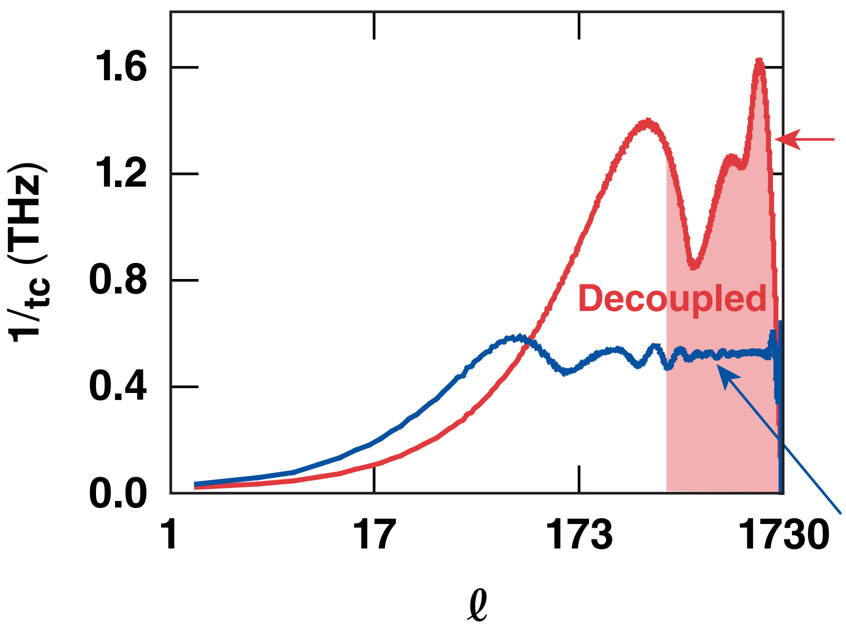

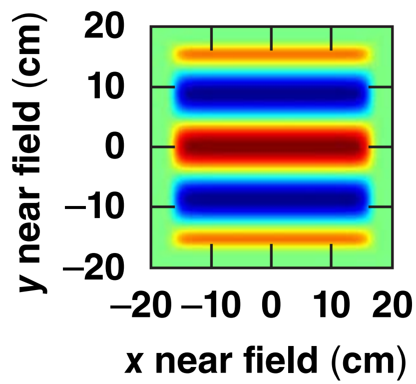

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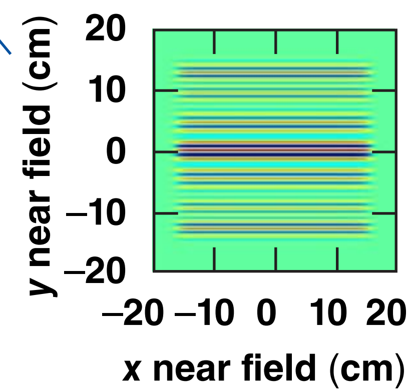
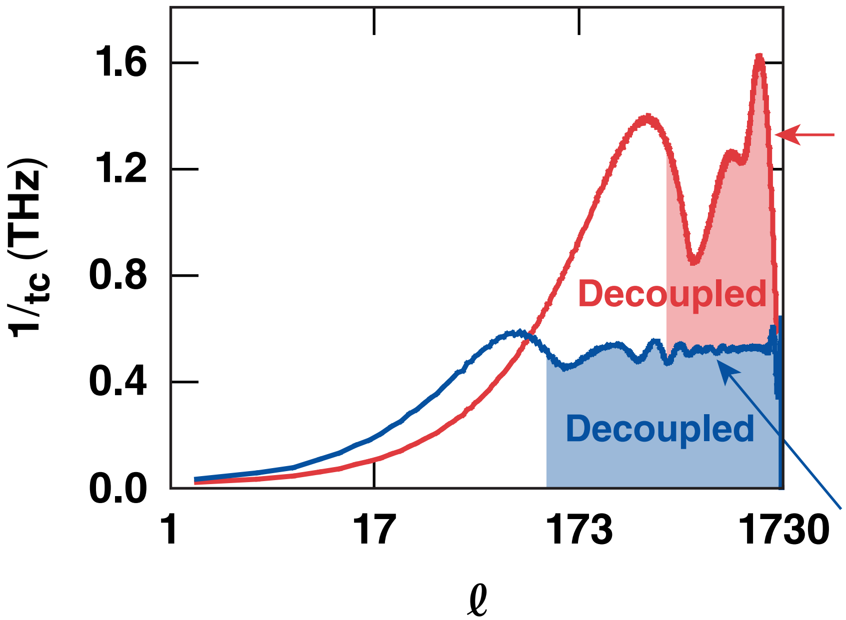


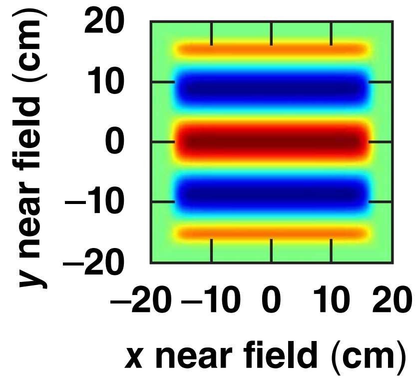
- 1-D SSD Multi-FM
  - 500-GHz bandwidth
  - many color cycles
  - resonances minimized

- Resonances are minimized because the spatial separation between the identical colors varies in time.

TC8619_3

1-D Multi-FM SSD takes advantage of multiple color cycles while reducing resonance effects





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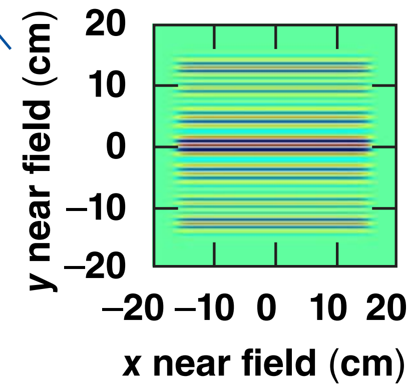

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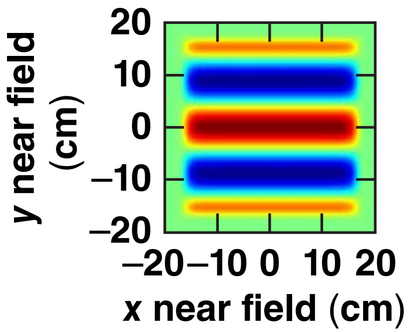
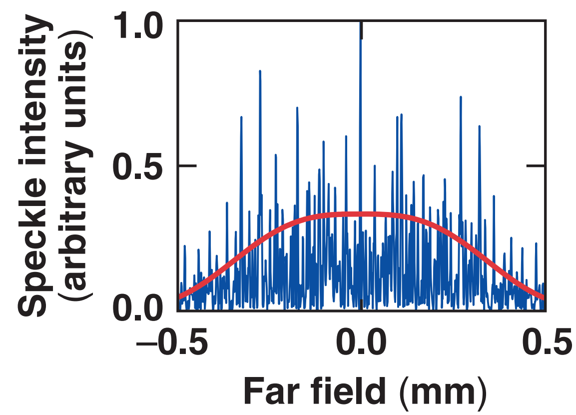
TC8619_4

The flipping and analytic models of SSD emulate the effect of smoothing during a *DRACO* simulation



<u>Far-field simulation of SSD</u>

- Models the continuously changing near-field phase front and far-field speckle pattern
- Smoothing results from temporal integration



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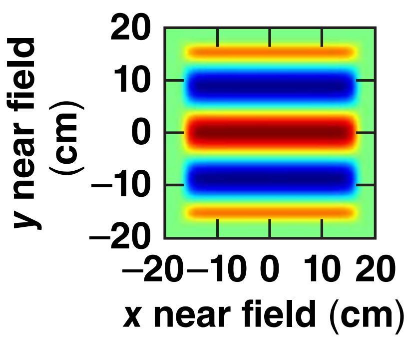
The flipping and analytic models of SSD emulate the effect of smoothing during a *DRACO* simulation



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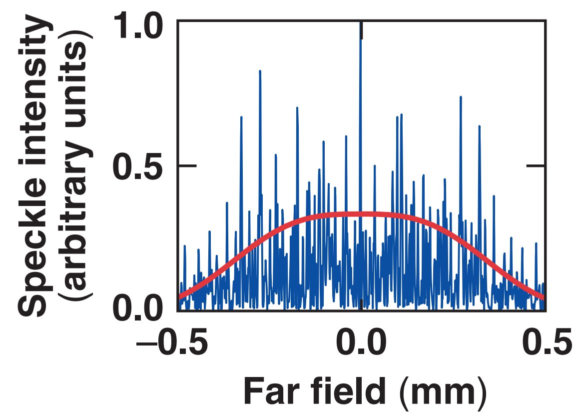

Flipping Model

- Stochastic model

Analytic Model

- Deterministic model

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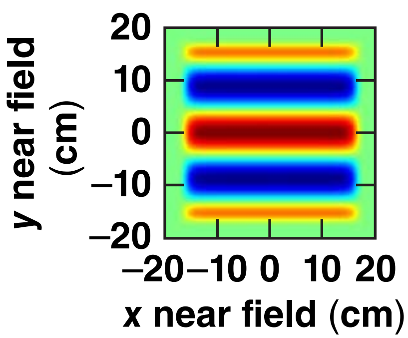

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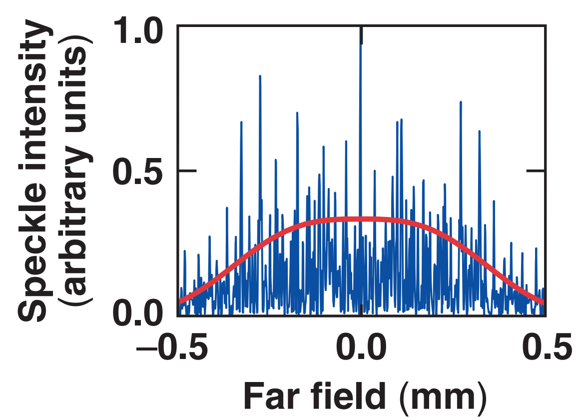


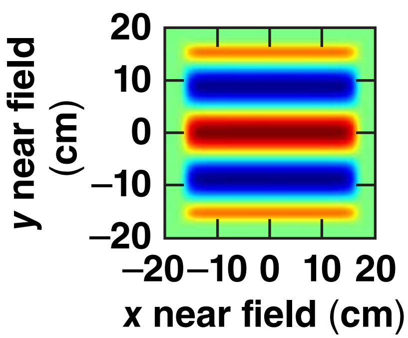
Flipping Model

- Stochastic model
- Precalculation of t_c and t_{asym}

Analytic Model

- Deterministic model
- Analytic temporal integration

The flipping and analytic models of SSD emulate the effect of smoothing during a *DRACO* simulation



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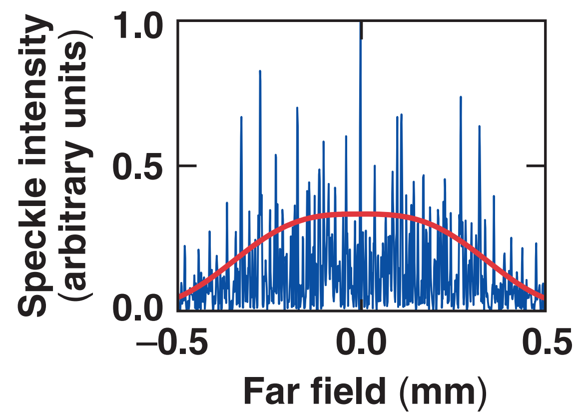

Flipping Model

- Stochastic model
- Precalculation of t_c and t_{asym}
- Pulse-shape dependent
- Initial random state of phases

Analytic Model

- Deterministic model
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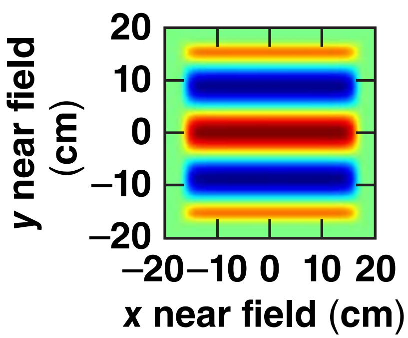
The flipping and analytic models of SSD emulate the effect of smoothing during a *DRACO* simulation



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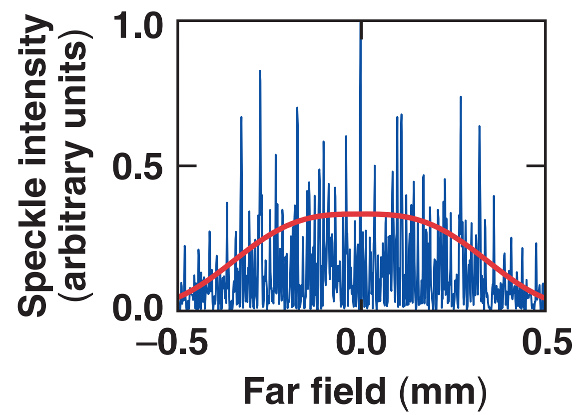


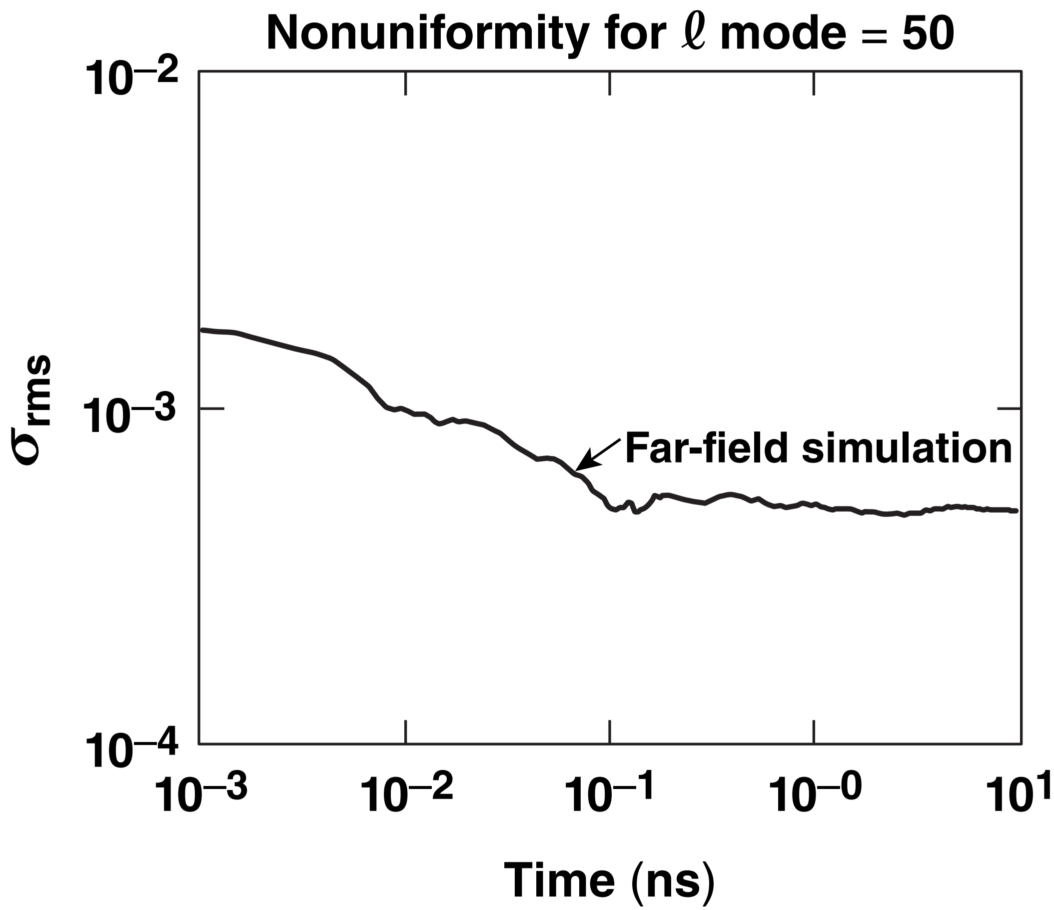
Flipping Model

- Stochastic model
- Precalculation of t_c and t_{asym}
- Pulse-shape dependent
- Initial random state of phases
- Phase can randomly flip every t_c
- Amplitude is constant
- Random phases repeat after t_{asym}

Analytic Model

- Deterministic model
- Analytic temporal integration
- Pulse-shape dependent
- Initial random state of phases
- Phase remains constant
- Amplitude varies
- Inherently models the asymptotic behavior

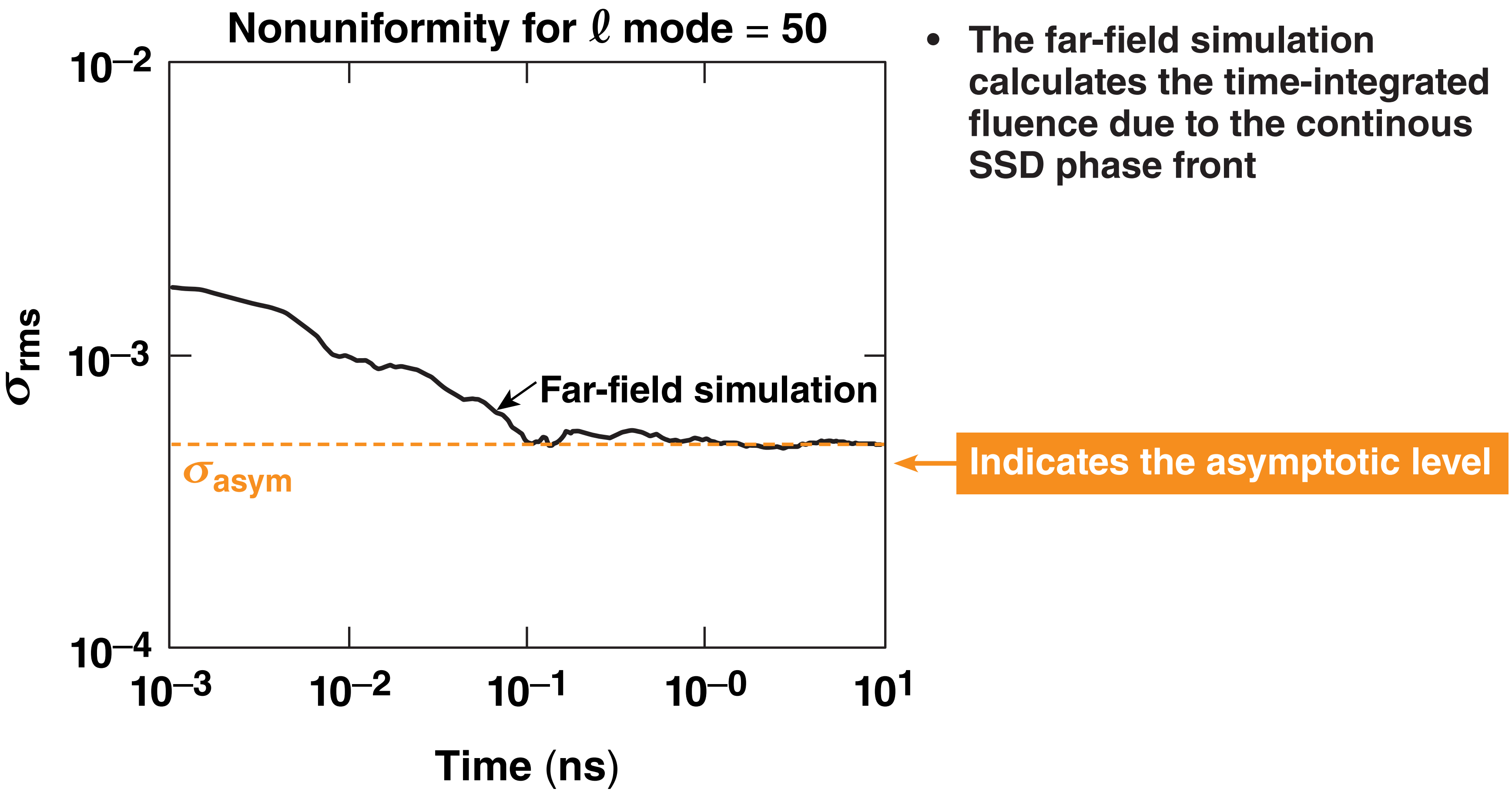
The analytic SSD model calculates the modal amplitudes deterministically



- The far-field simulation calculates the time-integrated fluence due to the continous SSD phase front

TC8620

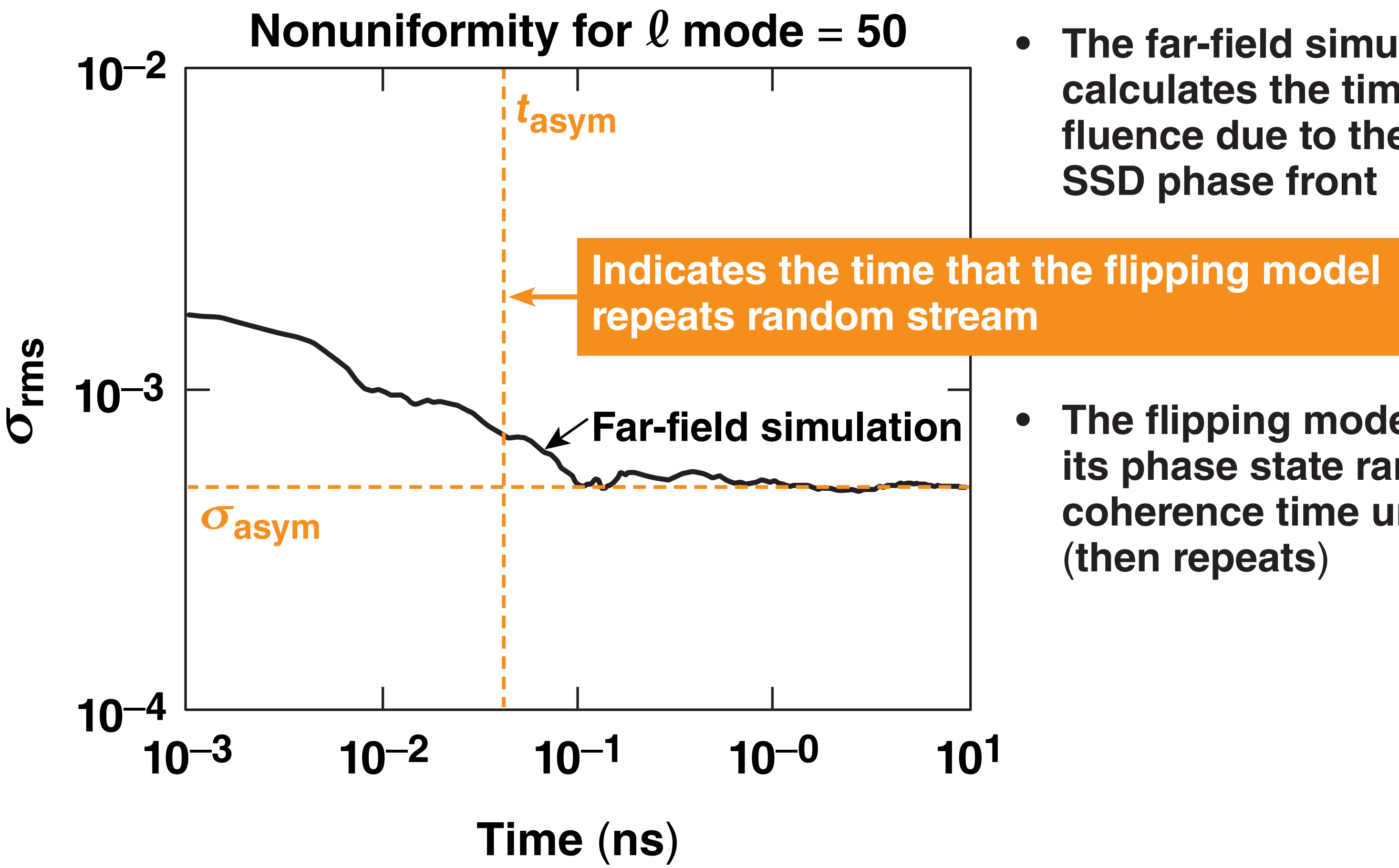
The analytic SSD model calculates the modal amplitudes deterministically



- The far-field simulation calculates the time-integrated fluence due to the continous SSD phase front

TC8620a

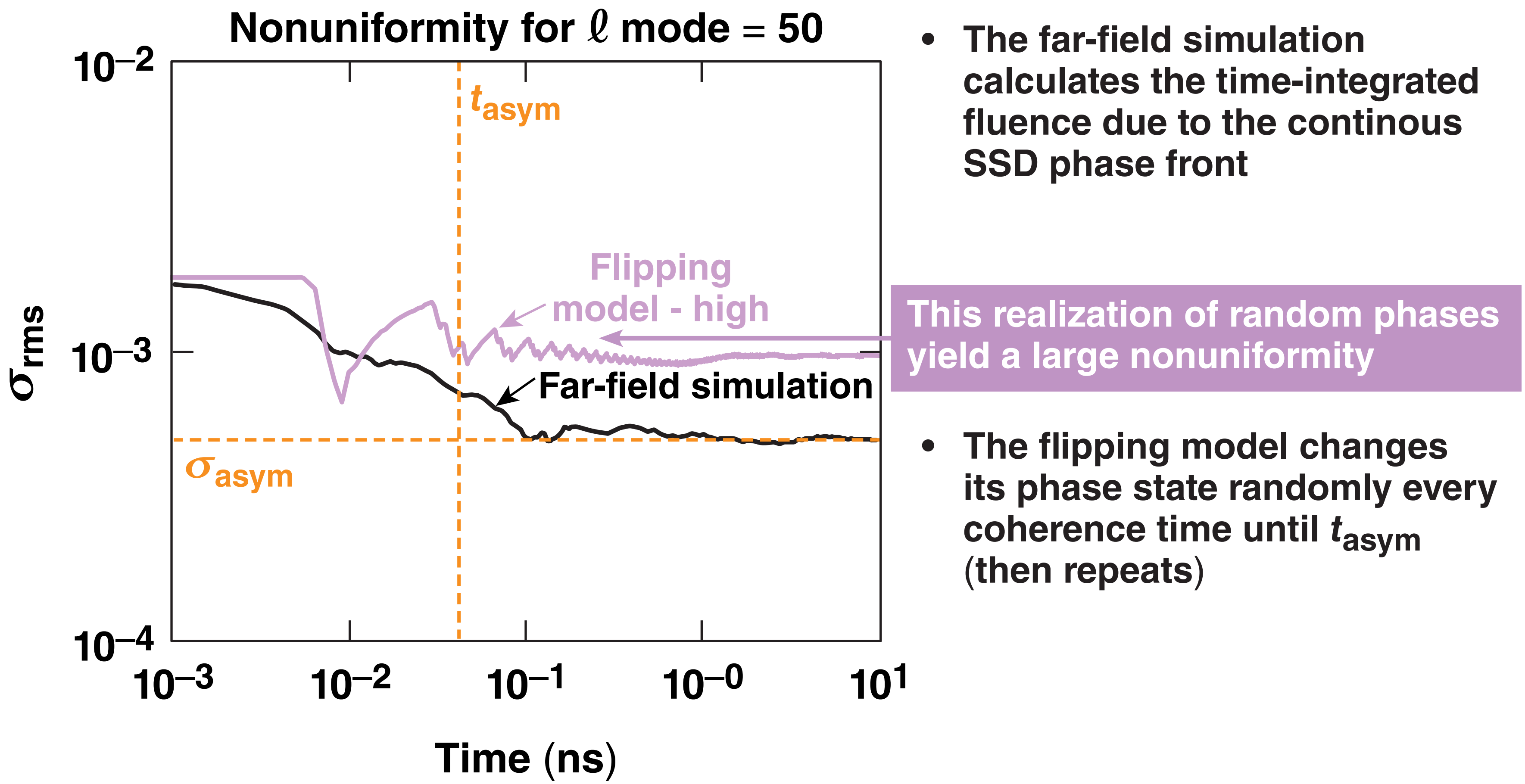
The analytic SSD model calculates the modal amplitudes deterministically



- The far-field simulation calculates the time-integrated fluence due to the continous SSD phase front
- The flipping model changes its phase state randomly every coherence time until t_{asym} (then repeats)

TC8620b

The analytic SSD model calculates the modal amplitudes deterministically



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TC8620c

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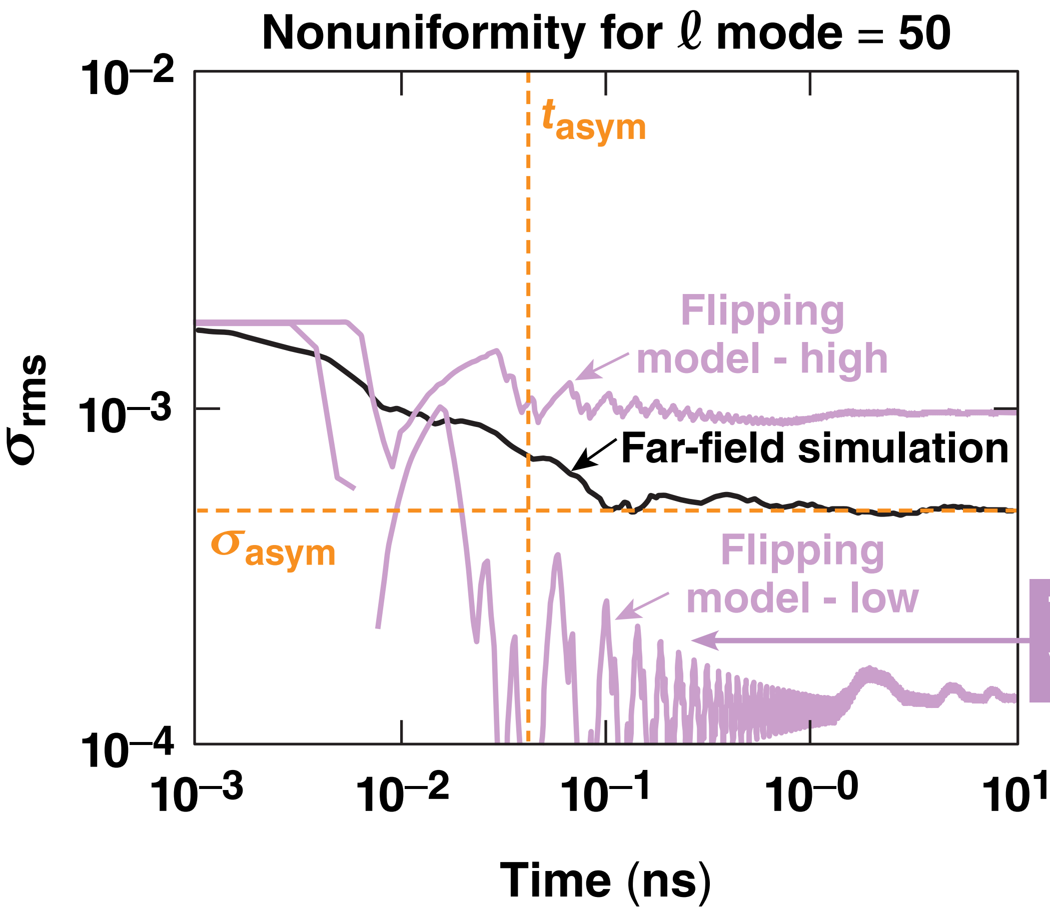
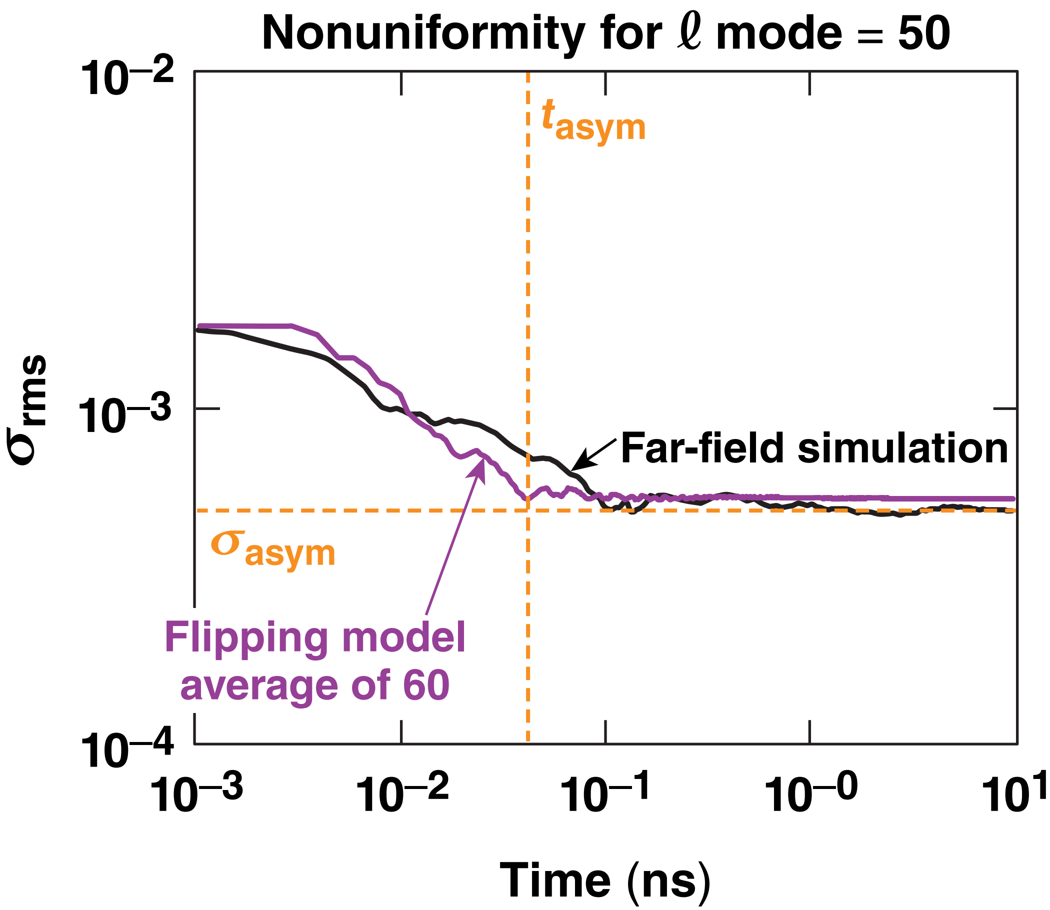


- The far-field simulation calculates the time-integrated fluence due to the continous SSD phase front
- The flipping model changes its phase state randomly every coherence time until t_{asym} (then repeats)

This realization of random phases yield small nonuniformity

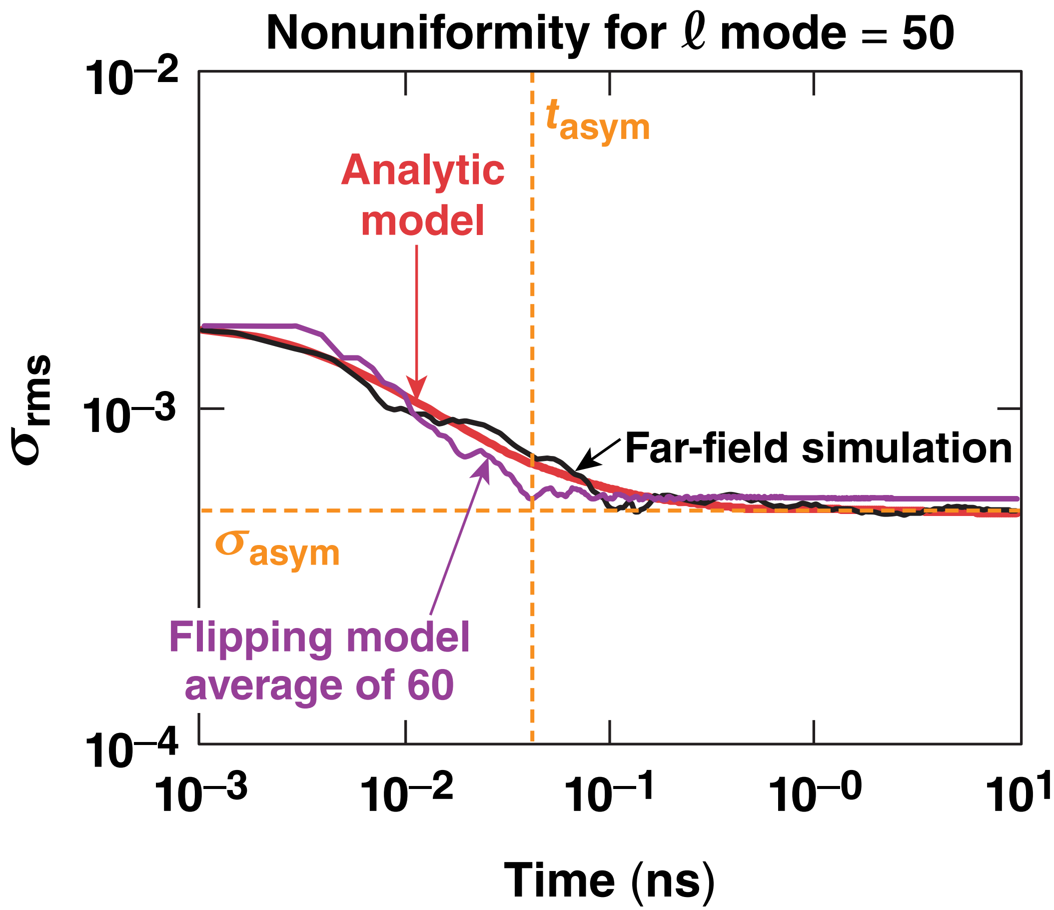
TC8620d

The analytic SSD model calculates the modal amplitudes deterministically



- The far-field simulation calculates the time-integrated fluence due to the continous SSD phase front
- The flipping model changes its phase state randomly every coherence time until t_{asym} (then repeats)
- It takes a large ensemble of flipping runs to average the variations in the far-field

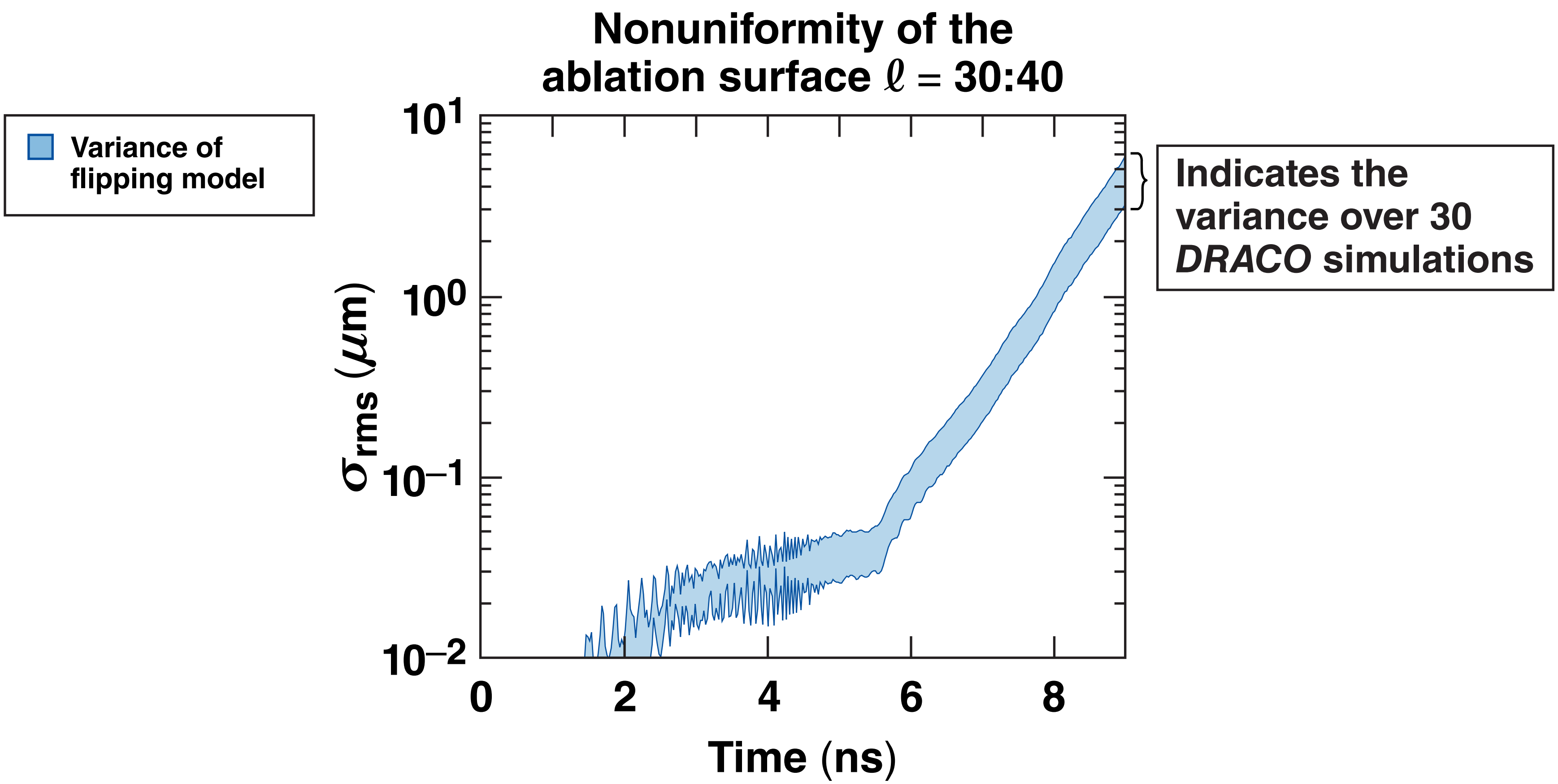
The analytic SSD model calculates the modal amplitudes deterministically



- The far-field simulation calculates the time-integrated fluence due to the continous SSD phase front
- The flipping model changes its phase state randomly every coherence time until t_{asym} (then repeats)
- It takes a large ensemble of flipping runs to average the variations in the far-field
- The analytic model emulates the modal amplitude without averaging

TC8620f

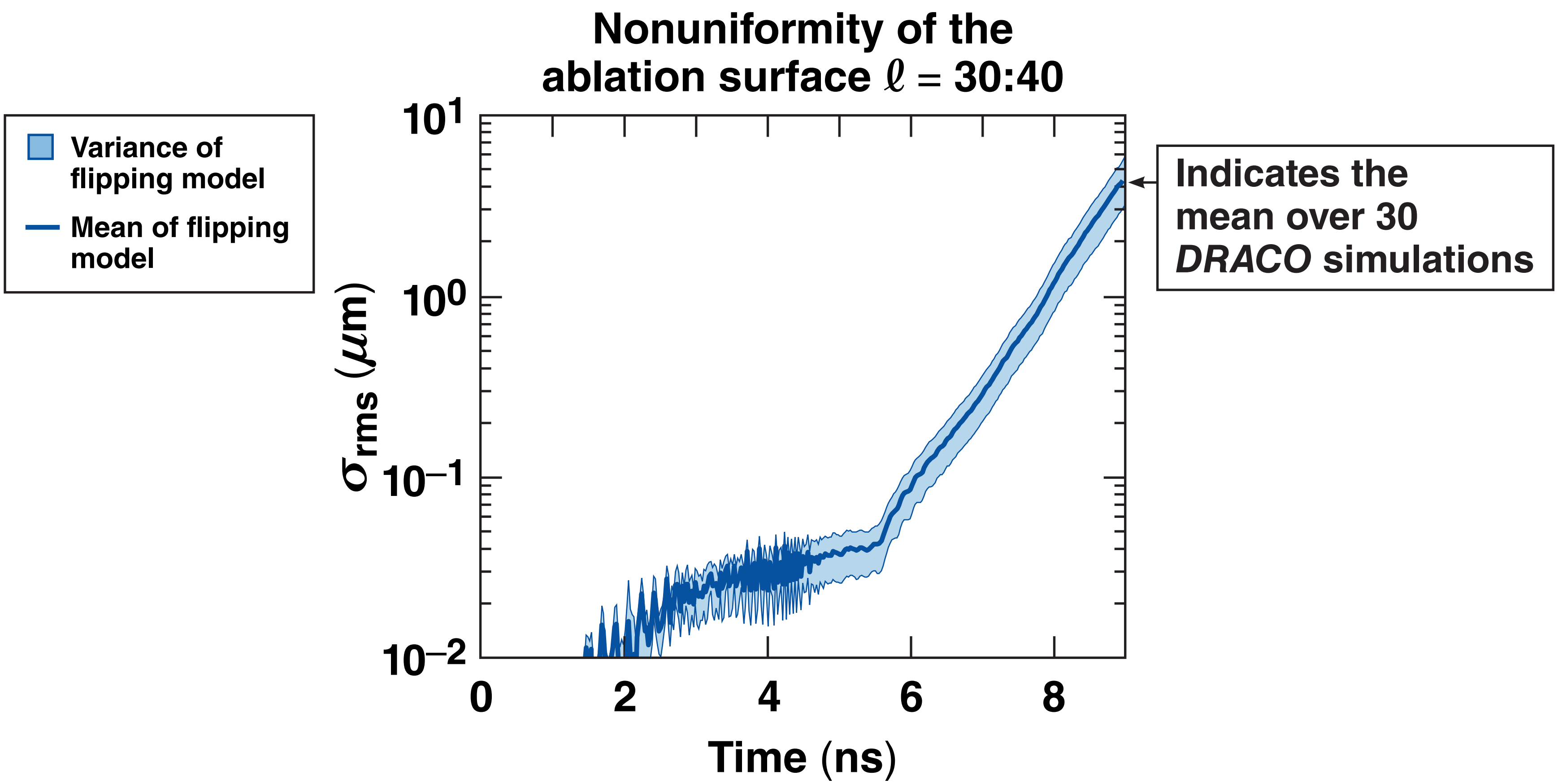
An ensemble of multiple *DRACO* simulations illustrate the advantage of the analytic model



- The sum of the Fourier modes of the ablation surface shows that the flipping model has a large variance
- This variance is sufficient to lead to ignition failure for some targets

TC8681_1

An ensemble of multiple *DRACO* simulations illustrate the advantage of the analytic model



- The sum of the Fourier modes of the ablation surface shows that the flipping model has a large variance
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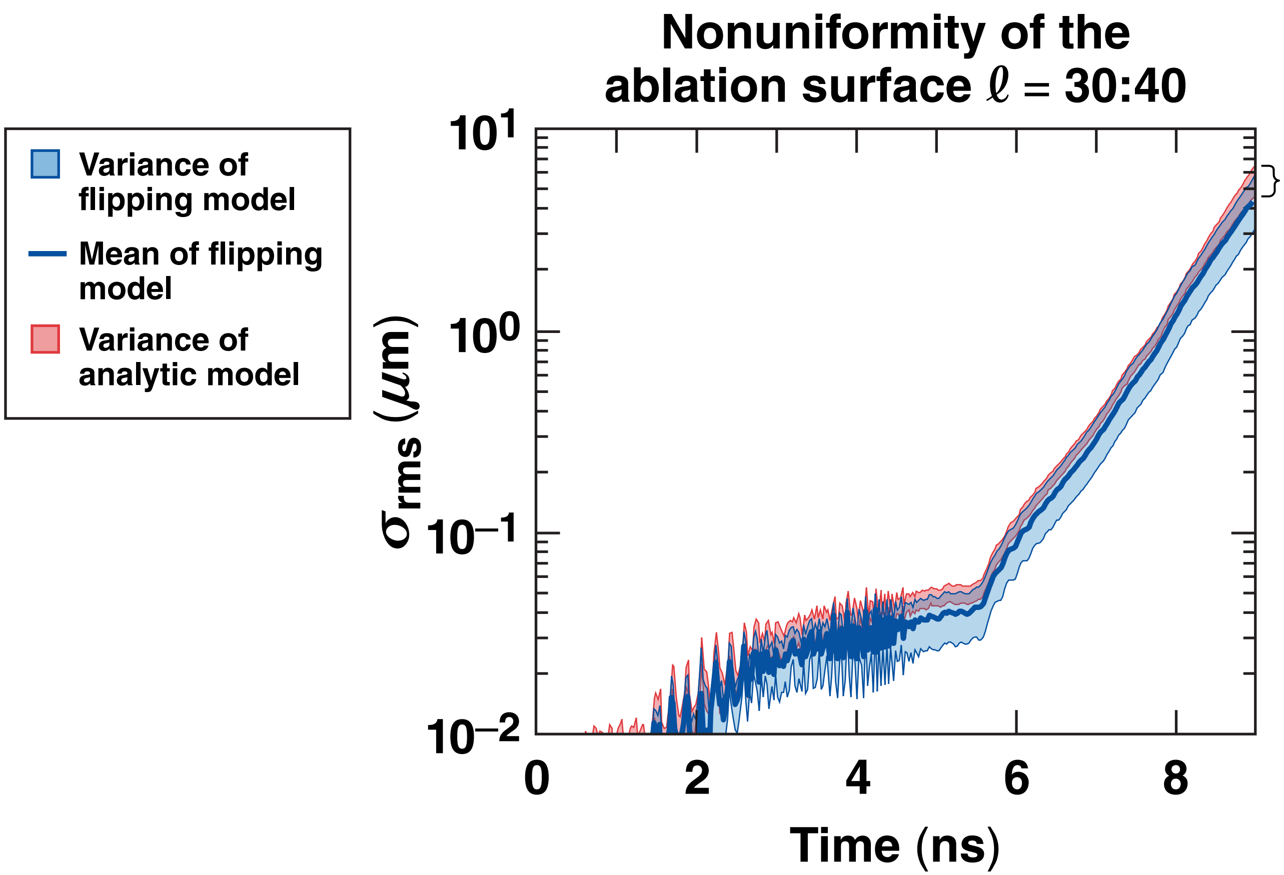
TC8681_2

An ensemble of multiple *DRACO* simulations illustrate the advantage of the analytic model



The variance of the analytic model is smaller by a factor of 2

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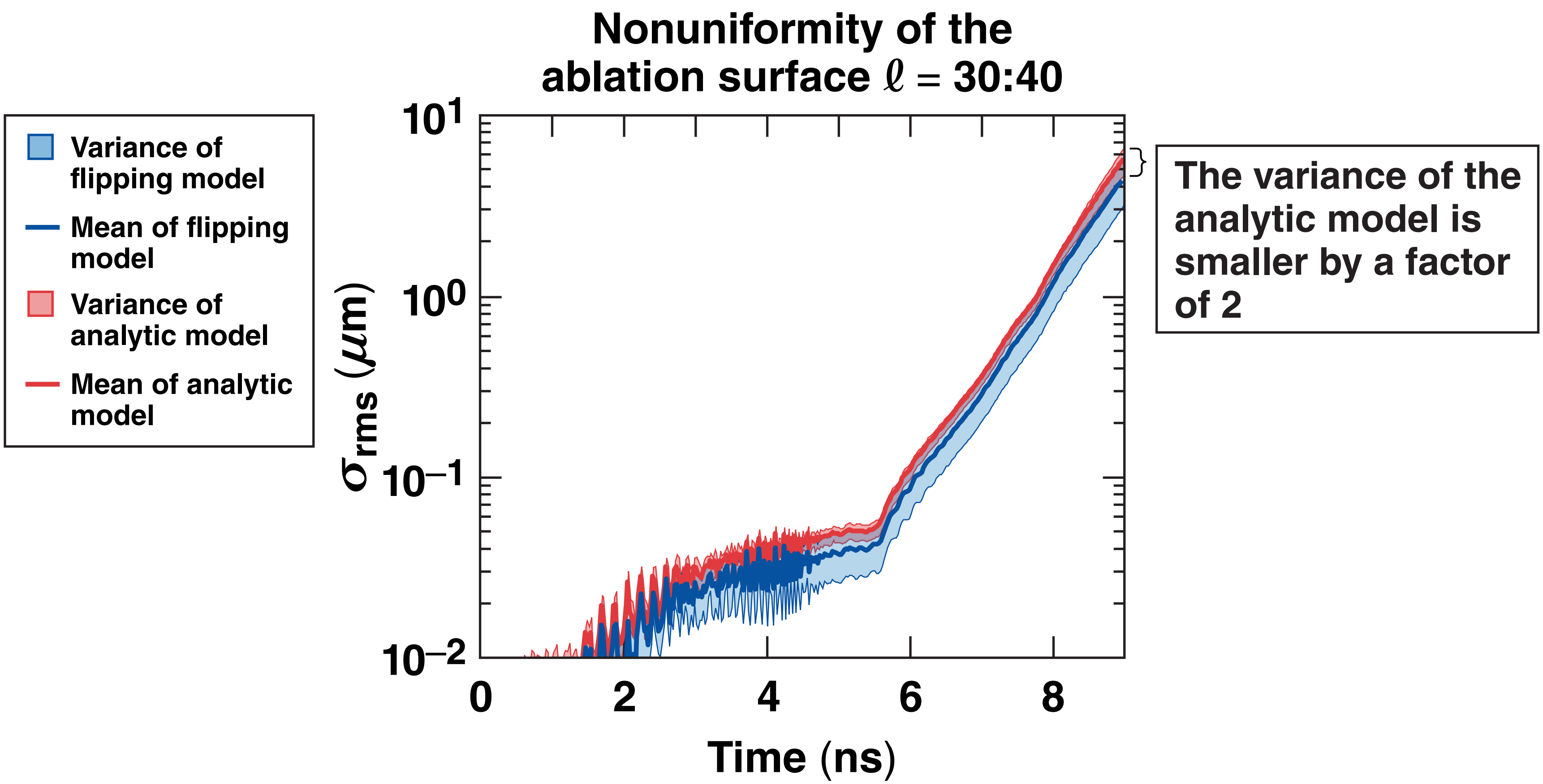
An ensemble of multiple *DRACO* simulations illustrate the advantage of the analytic model



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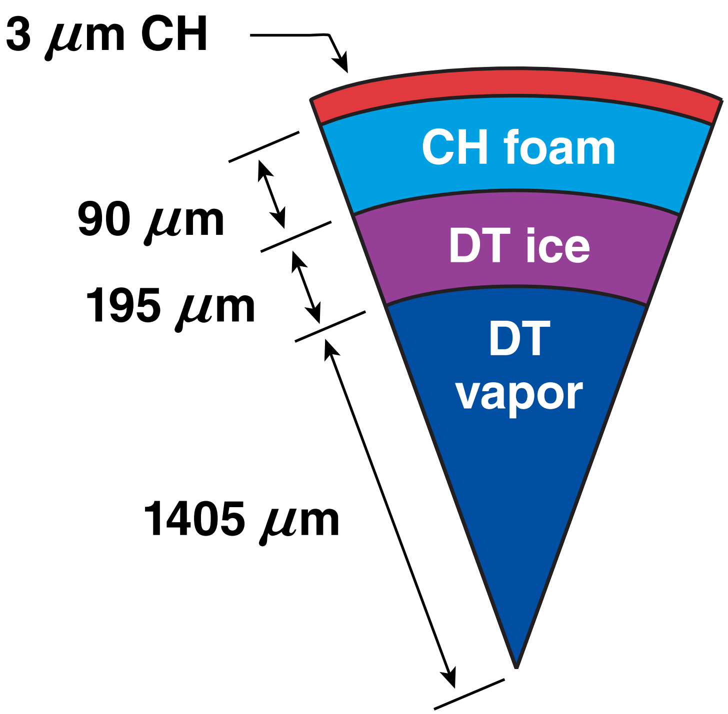
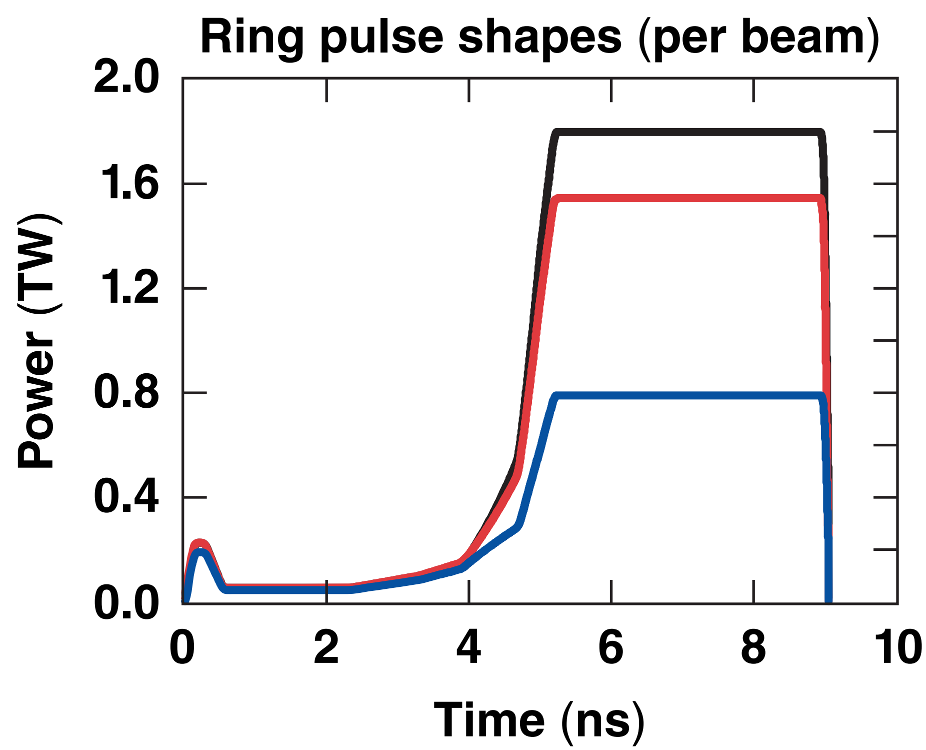
TC8681_4

The 1-D Multi-FM case achieves a gain of 16, whereas the 1-D SSD case fails to ignite





TC8623a

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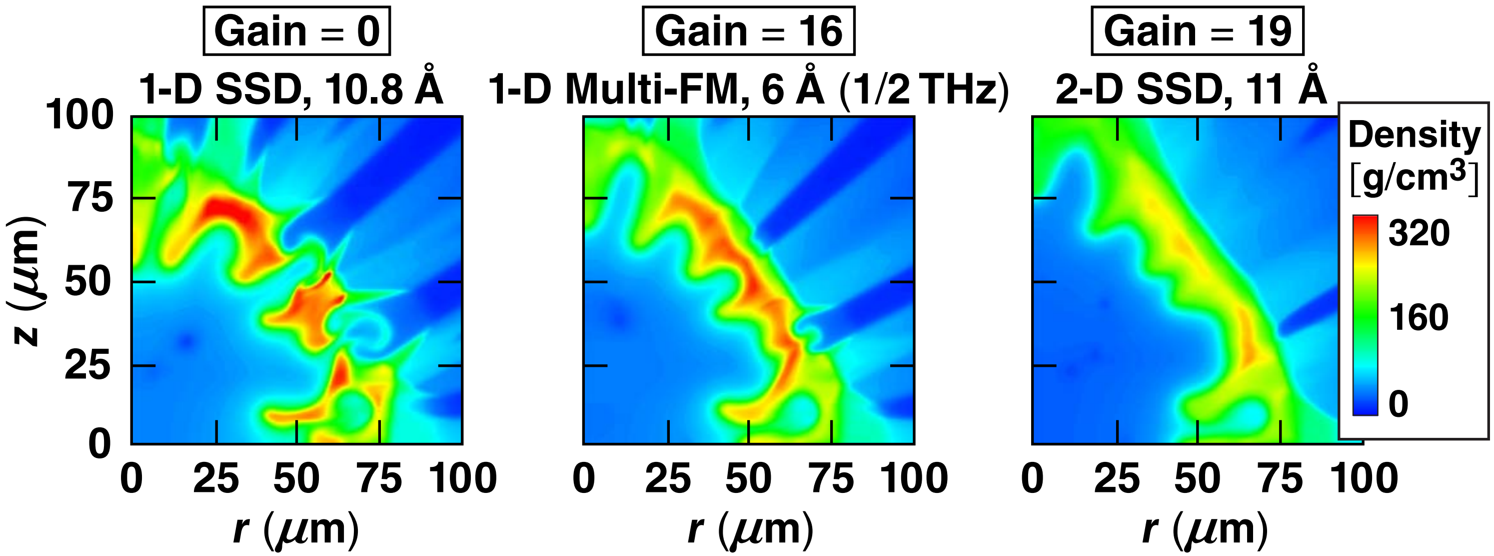
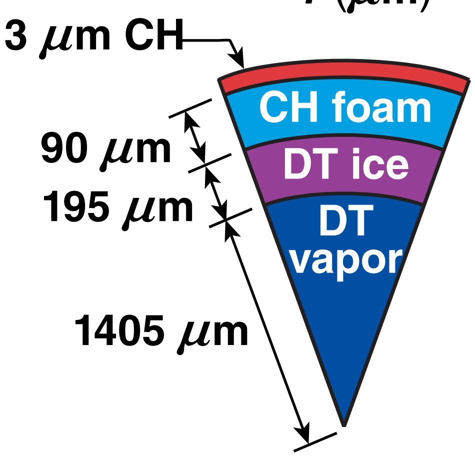
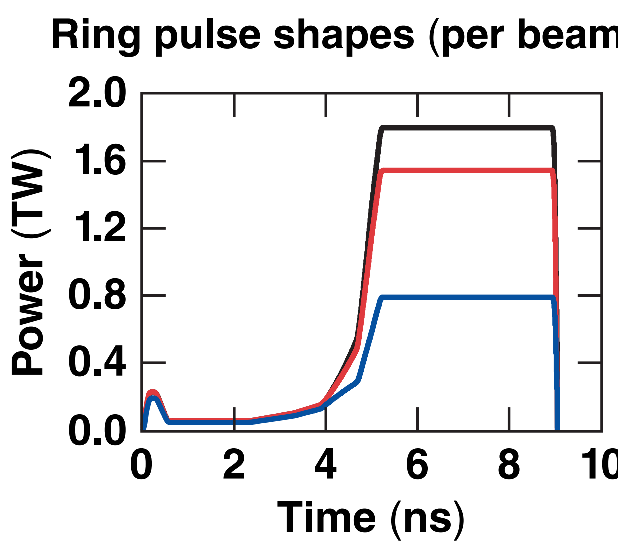
Polar-drive simulations of 1.2-MJ CH-foam ignition target







- At peak compression, t = 9.8 ns

TC8623b

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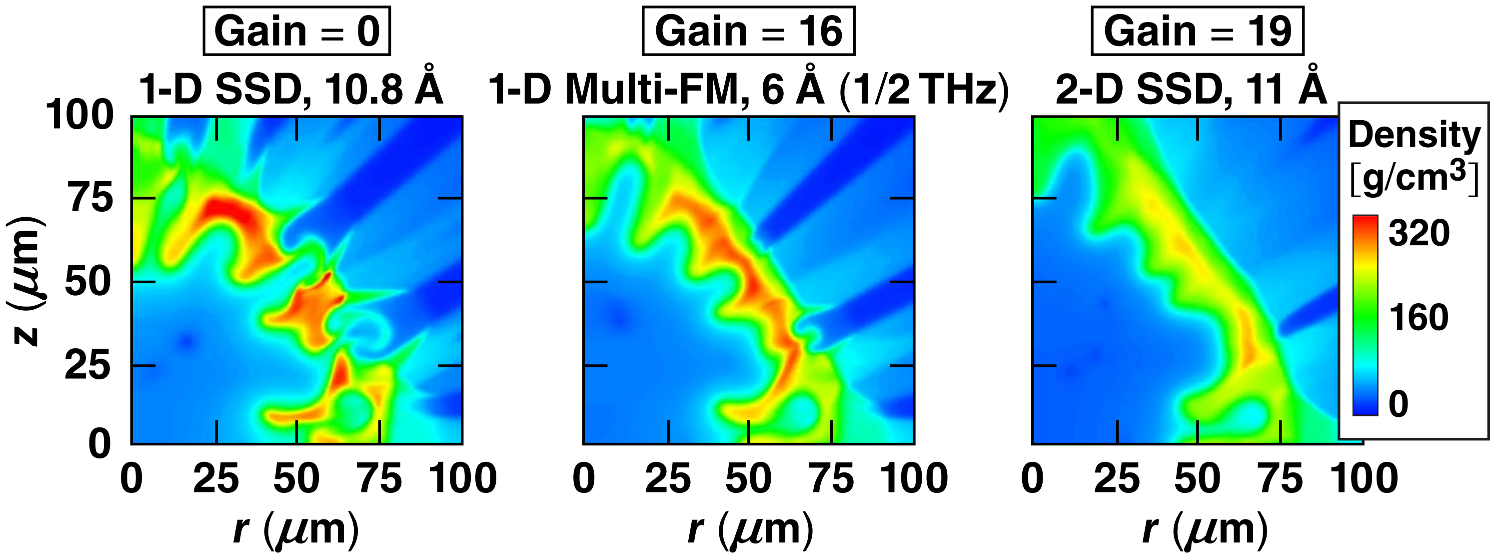
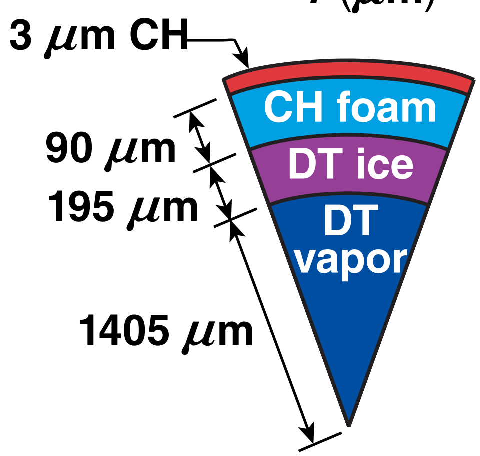
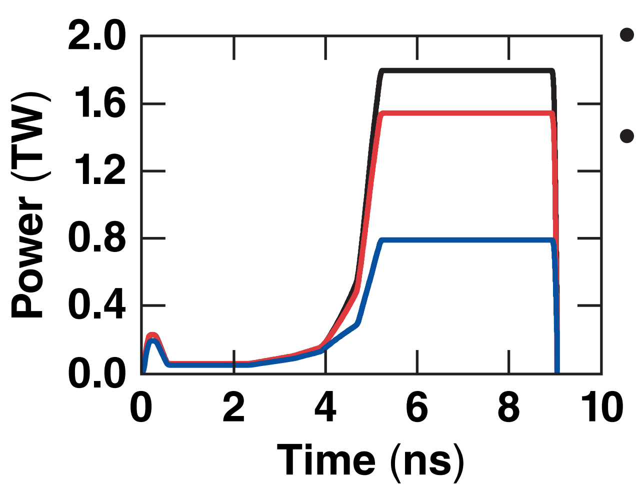




Ring pulse shapes (per beam)



- At peak compression, *t* = 9.8 ns
- Includes sources of nonuniformity
  - imprint ℓ = 2:100
  - inner/outer shell roughness
  - mistiming 30-ps rms
  - energy imbalance 8%

TC8623c

Summary/Conclusions

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UR LLE

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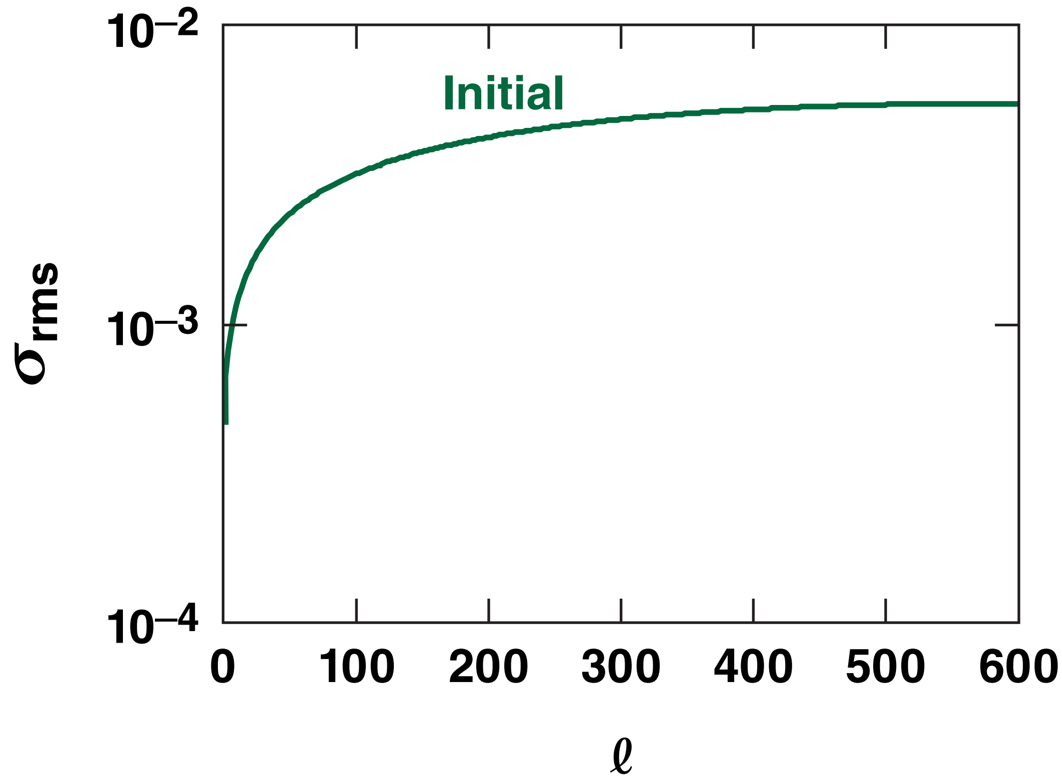
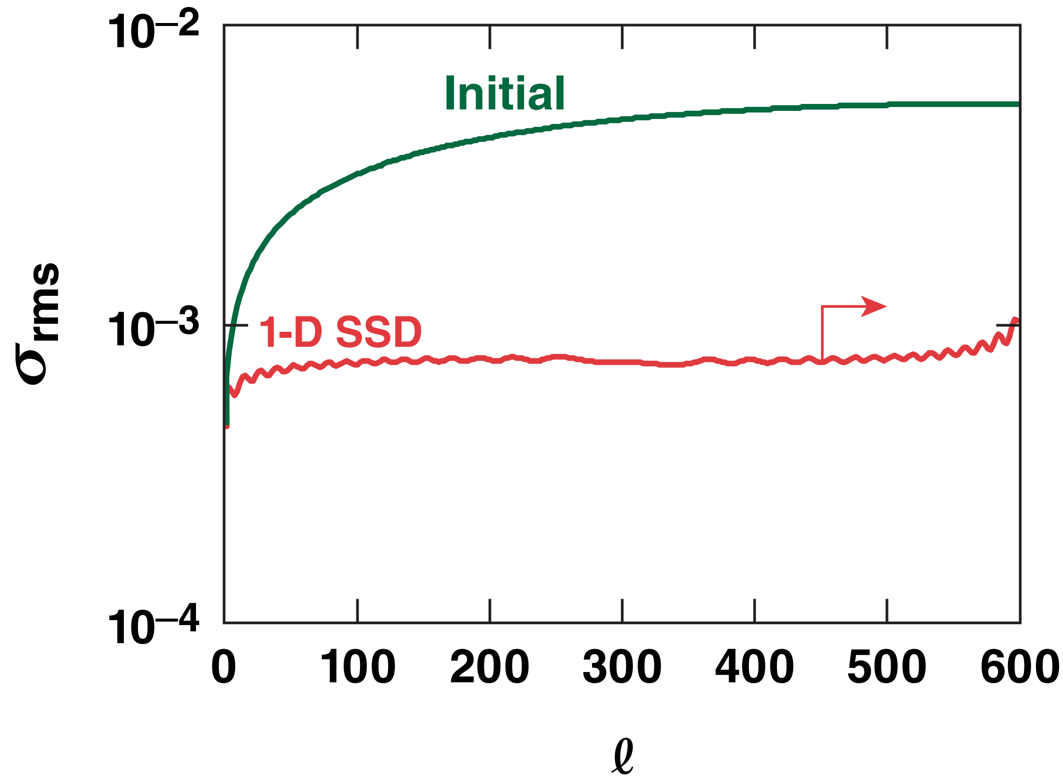
1-D Multi-FM will be tested on OMEGA EP in 2010.

The analytic model was used to find a 1-D Multi-FM SSD system that optimized for asymptotic levels



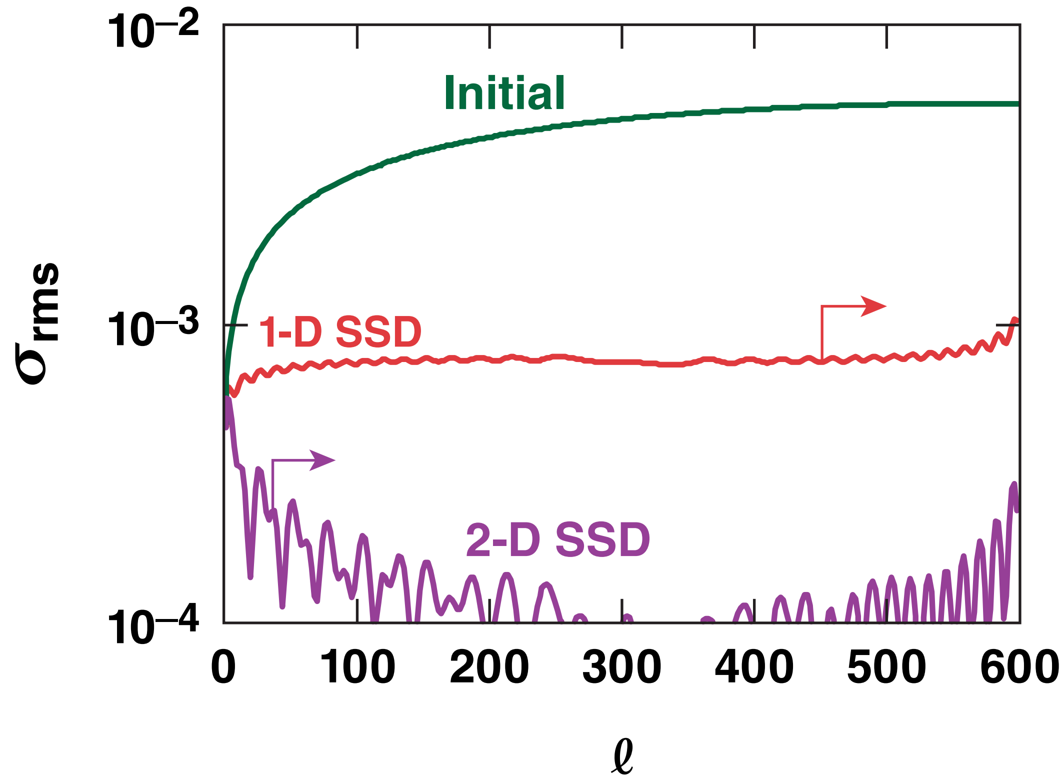
TC8621_1

The analytic model was used to find a 1-D Multi-FM SSD system that optimized for asymptotic levels



TC8621_2

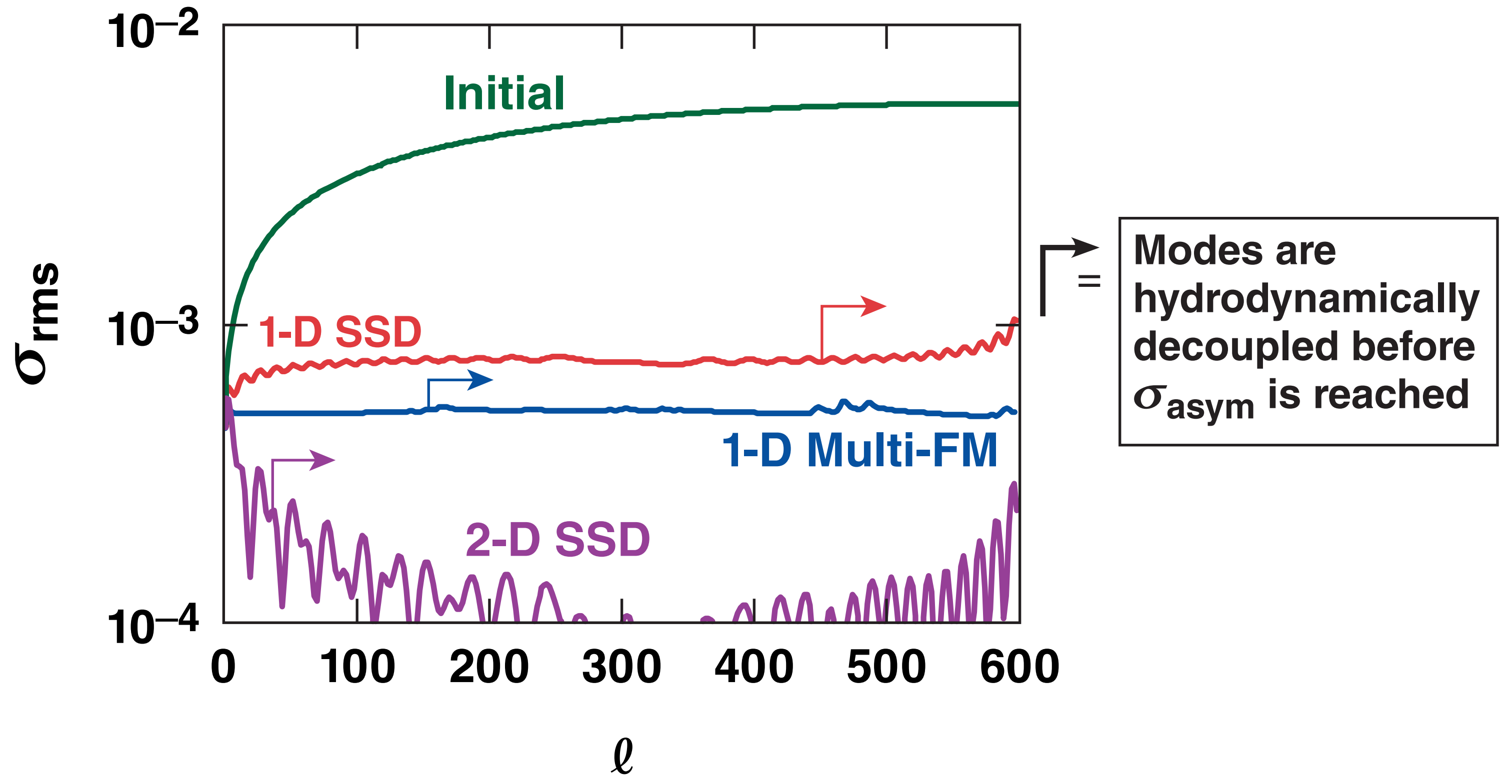
The analytic model was used to find a 1-D Multi-FM SSD system that optimized for asymptotic levels



- Most modes for the 2-D SSD system decouple before the asymptotic limits are reached.
- The levels reached by the 1-D Multi-FM system are about a factor of 2 larger than the 2-D SSD system when decoupling is included.

TC8621_3

The analytic model was used to find a 1-D Multi-FM SSD system that optimized for asymptotic levels



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TC8621_4