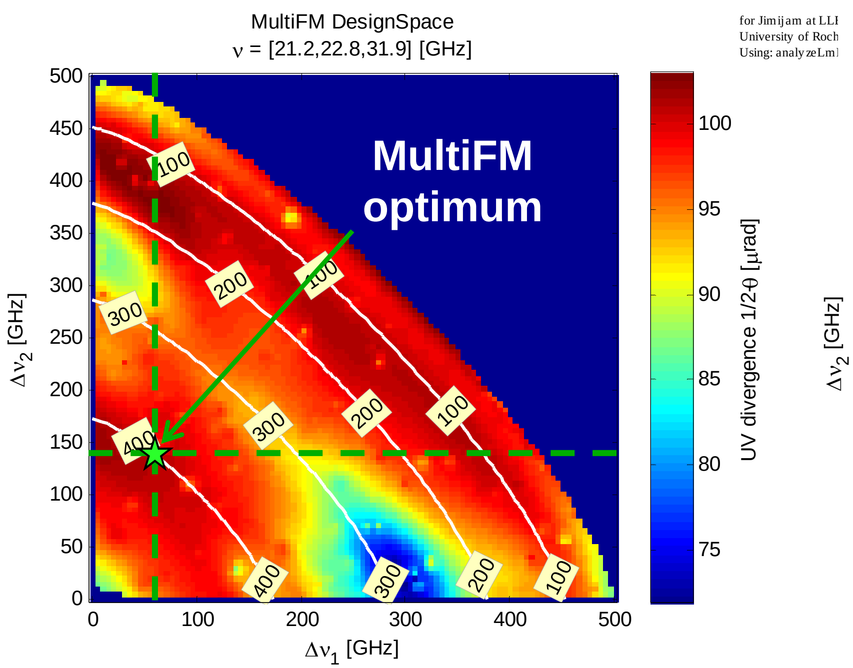
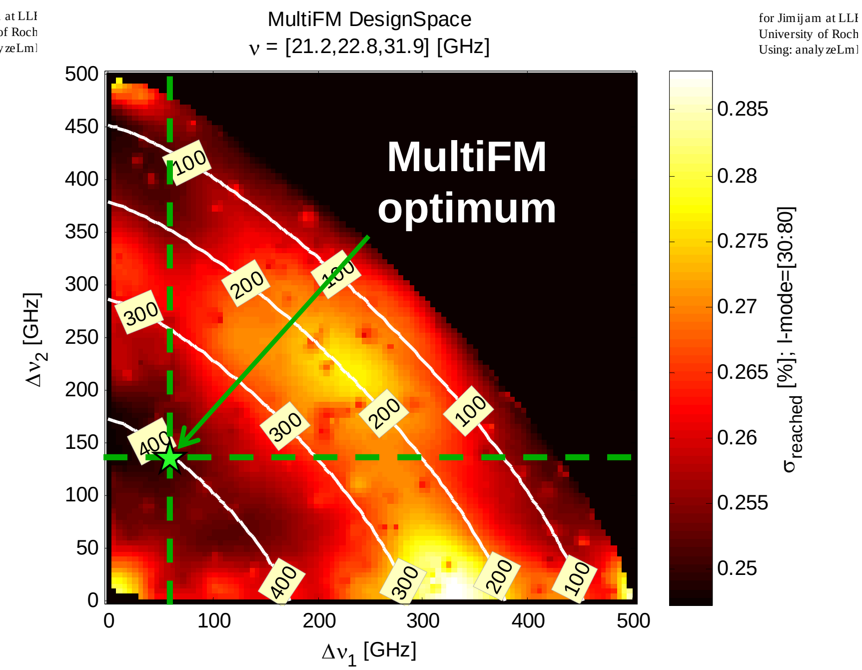
Picket Pulses with 1-D MultiFM Smoothing by Spectral Dispersion (SSD) for the NIF





mFM37b.1c = [21.2, 22.8, 31.9] GHz

International Workshop on ICF Shock Ignition Rochester, NY 8-10 March 2011

The 1-D MultiFM SSD system provides sufficient smoothing levels for igniting NIF Polar Drive (PD) targets

summary

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- A 1-D MultiFM SSD system will be deployed on Omega EP in FY11 to demonstrate laser and beam smoothing performance
- MultiFM design space surveys predict optimal MultiFM modulator combinations
- Asymptotic smoothing levels are achieved during a single NIF picket pulse

Collaborators

Tim Collins

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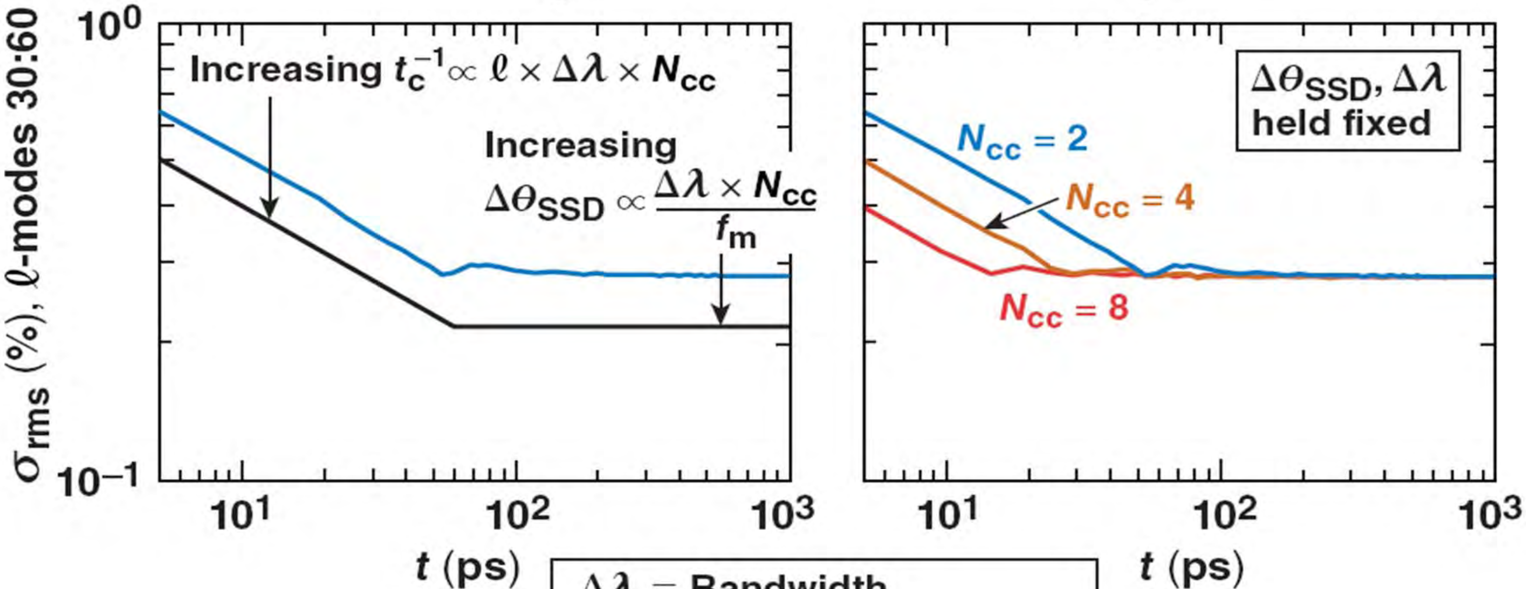
Laboratory for Laser Energetics

Laser nonuniformity imprint is minimized by optimizing smoothing by spectral dispersion (SSD)

Single-beam laser nonuniformity



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

- 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

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MultiFM 1-D SSD provides required beam smoothing performance with minimal impact on the facility

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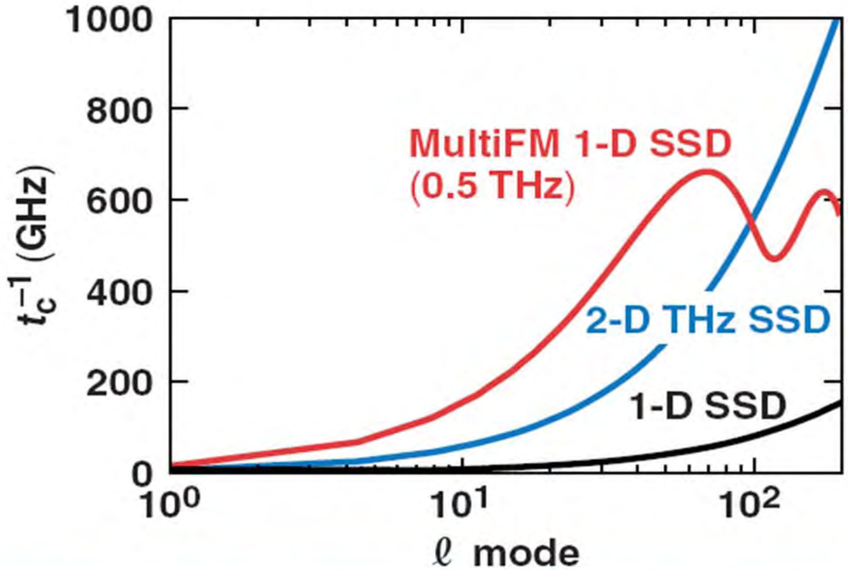
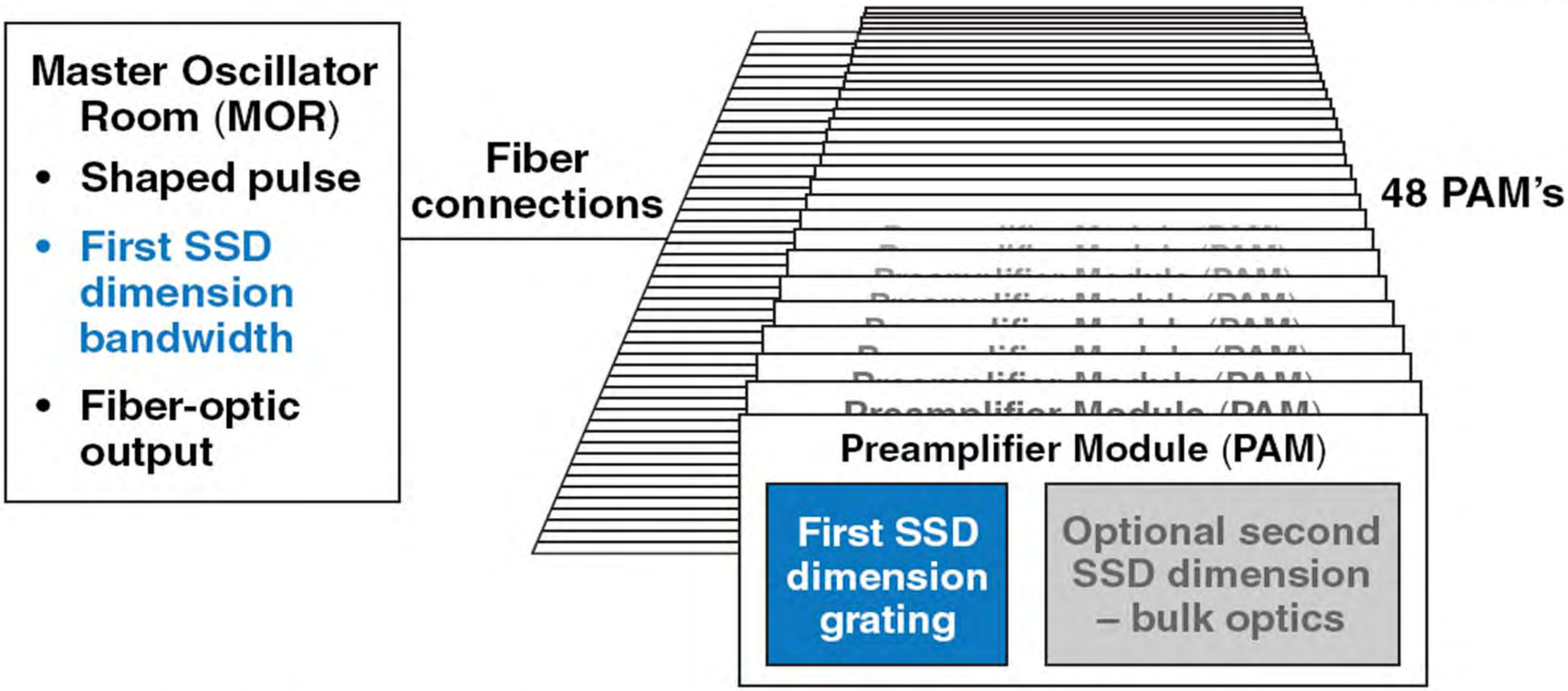
Inverse coherence time versus far-field spatial frequency



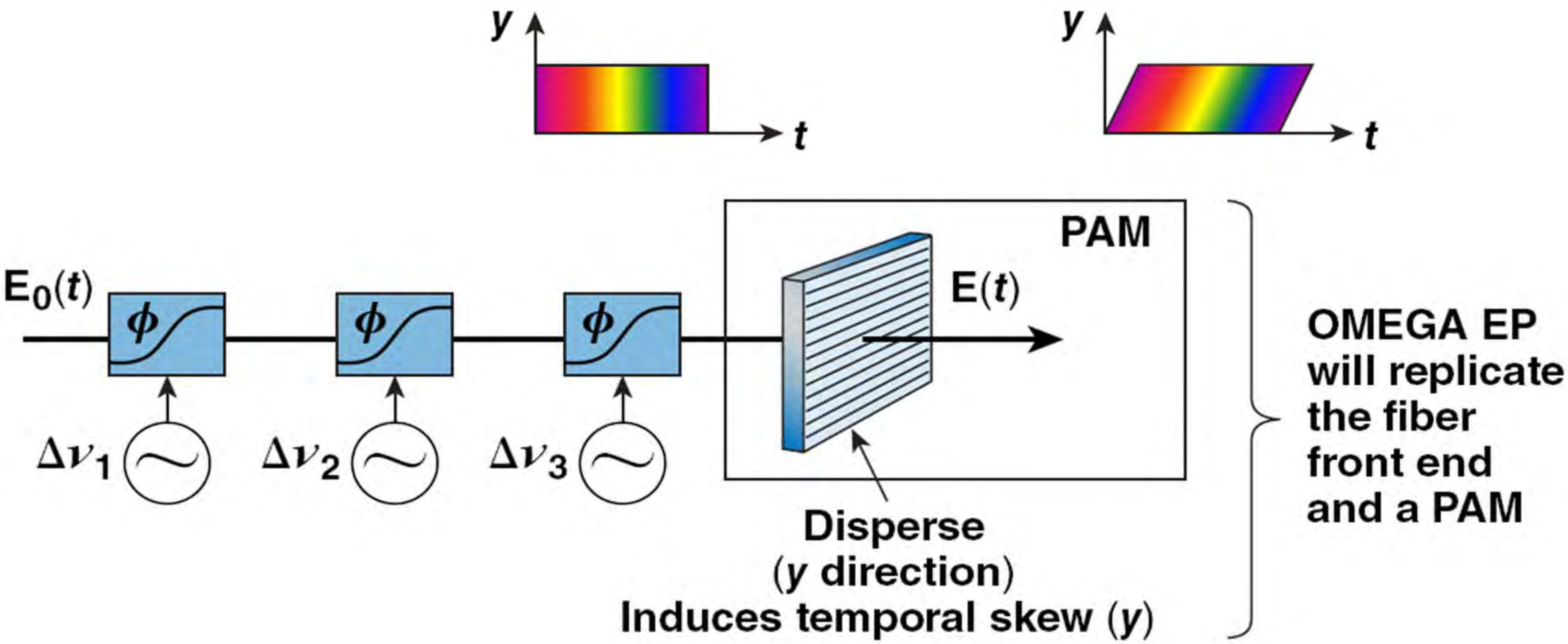
- Traditional SSD systems using single-frequency phase modulation have low smoothing rates for many important spatial modes ($\ell < 150$)
- MultiFM 1-D SSD is a new approach that
  - provides better smoothing rates with lower total bandwidth (esp. for PD pulse shapes with picket prepulses)
  - can be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

The 1-D Multi-FM SSD system is a cost-effective alternative to 2-D SSD on the NIF



- The 2-D SSD system is an expensive option because it requires duplication in 48 PAM's
- Multi-FM is generated as a fiber-based system in the MOR
- Multi-FM will be tested on OMEGA EP

The current 1-D Multi-FM SSD design employs three FM modulators



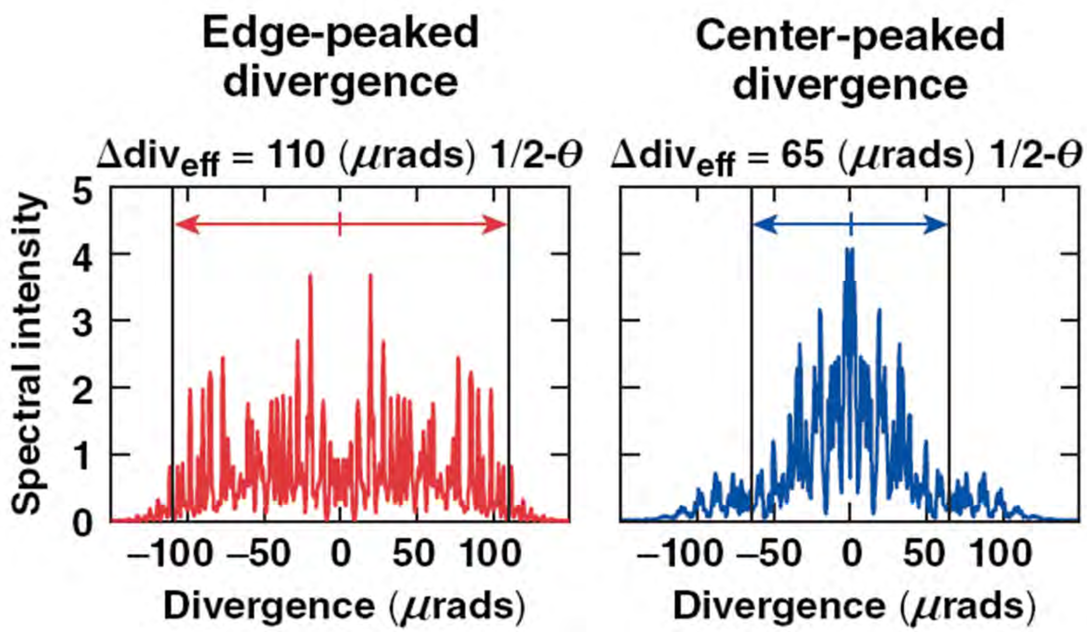
- Total bandwidth and divergence are distributed across the modulators
- Multi-FM can be designed for a bandwidth of $\Delta\nu_{UV} = 0.5$ THz ($\Delta\lambda_{IR} = 6$ Å)
  - only a single frequency-tripler crystal is needed

TC9144

Two performance metrics are used to predict the smoothing of 1-D Multi-FM SSD designs

- The autocorrelation width is used to measure both the effective temporal bandwidth $\Delta\nu_{eff}$ and the effective divergence Δdiv_{eff} in the far field
- The values of effective bandwidth $\Delta\nu_{eff}$ and divergence Δdiv_{eff} distinguish between edge-peaked and center-peaked spectra

ν_1 = 29 (GHz)
ν_2 = 35 (GHz)
ν_3 = 36 (GHz)



ν_1 = 28 (GHz)
ν_2 = 32 (GHz)
ν_3 = 36 (GHz)

TC9145

Monte Carlo simulations are used to survey the large design space available for 1-D Multi-FM SSD

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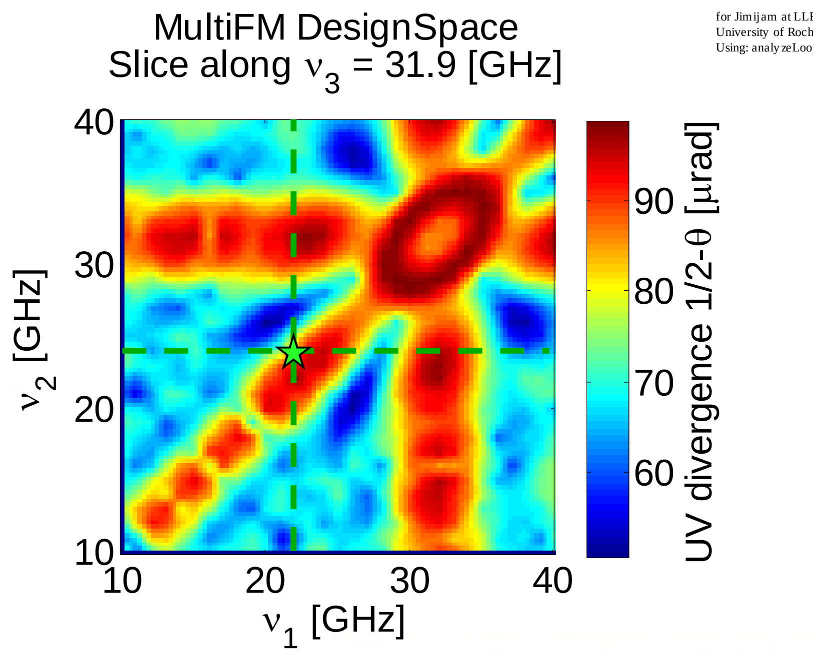
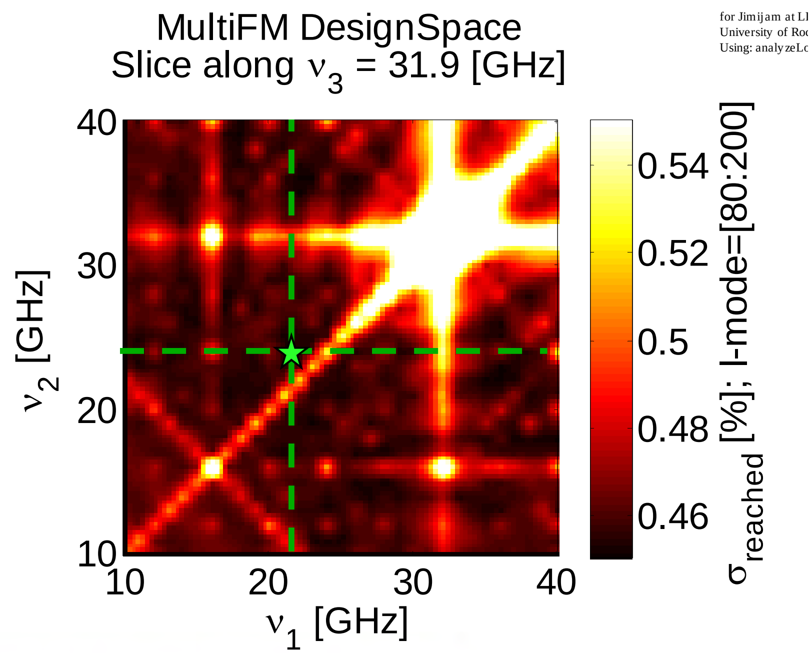
- **The frequency design space for the FM modulators is 20 to 40 GHz**
- **This is guided by commercial RF modulators and amplifiers**



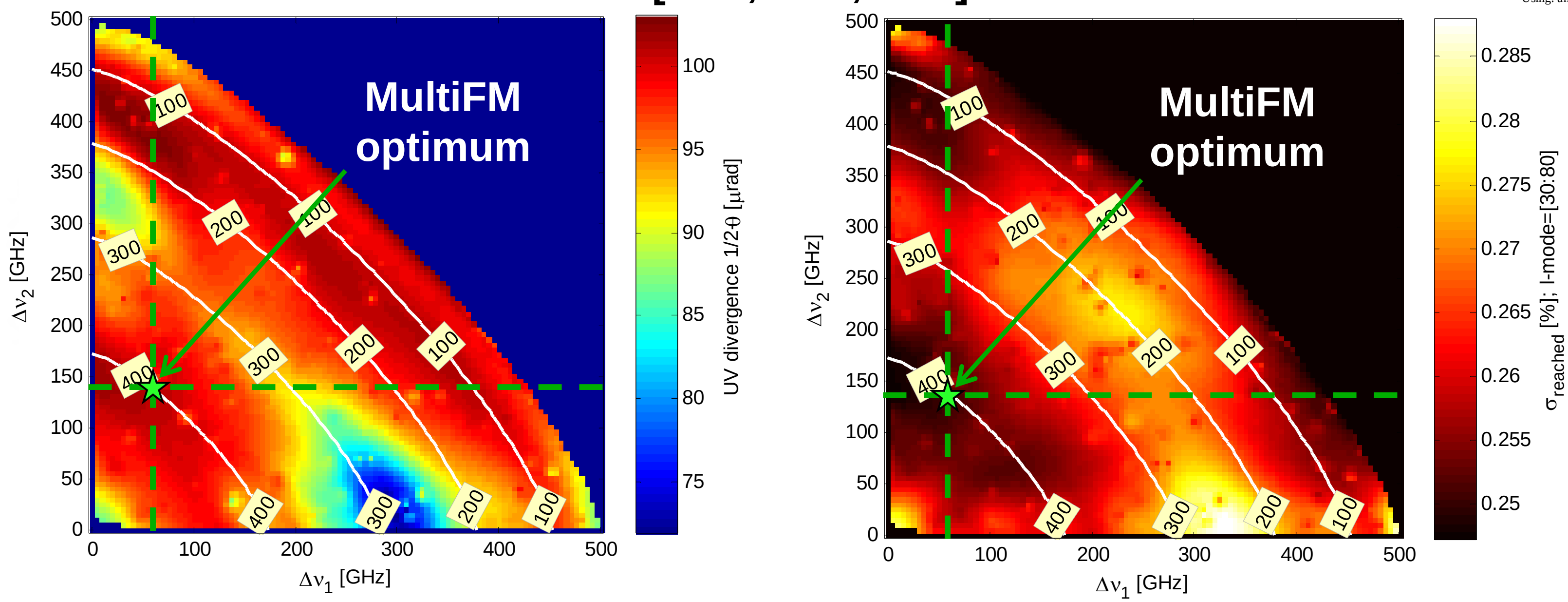


These performance metrics are optimized when two frequencies are similar and one is not.

TC9146

An optimized MultiFM configuration that achieves high gain in polar drive simulations has been identified

mFM37b.1c = [21.2, 22.8, 31.9] GHz



- **MultiFM 1-D SSD employs technology developed for the telecommunications industry**
  - **40-GHz phase modulators and drive electronics**
  - **UV bandwidth: Δf_{total} = 500 GHz (effective bandwidth)**
  - **SSD divergence: $\Delta\theta_{SSD}$ = 100 μrad (half angle at full beam)**
- ***DRACO* 2-D simulations with all nonuniformity sources: Gain = 40**

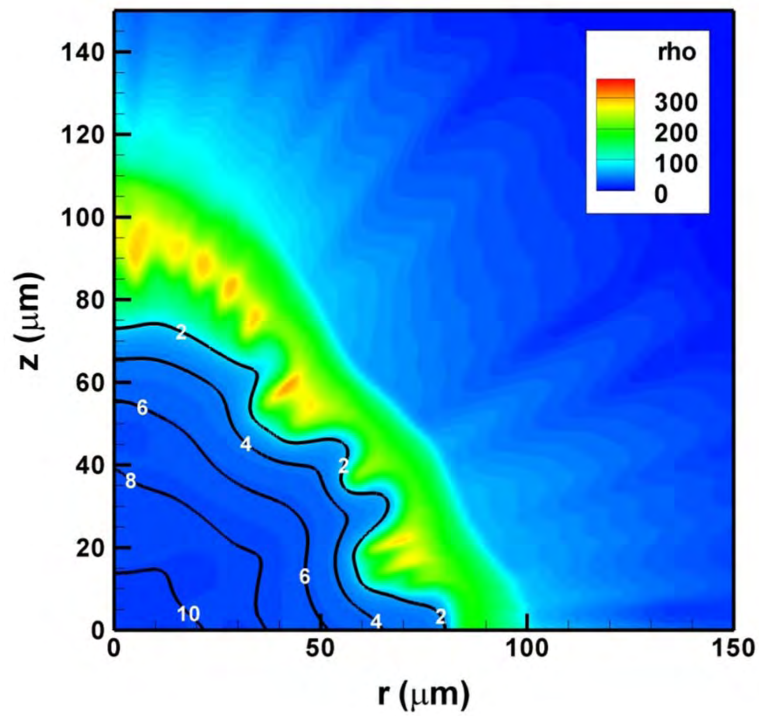
A triple picket PD design for the NIF attains a gain of 40 using the proposed 1-D Multi-FM SSD system

1.5MJ Triple Picket PD HotSpot Point Design; shown near peak compression, 10.3 ns; with nonuniformity sources; Gain = 40*

Nonuniformities:

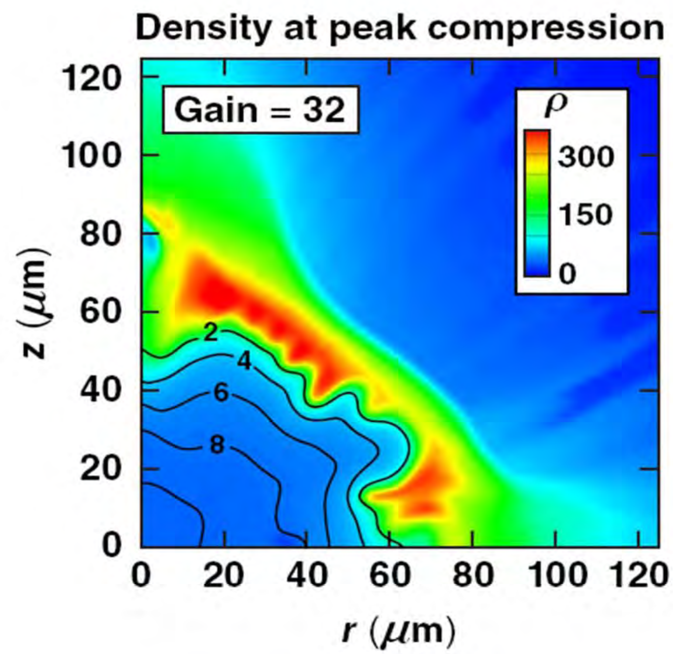
- **Imprint; l-modes 2:100**
- **Ice roughness; 1um rms**
- **Mistiming; 30ps rms**
- **Power imbalance; 8% rms**
- **Mistiming; 50 ps rms**

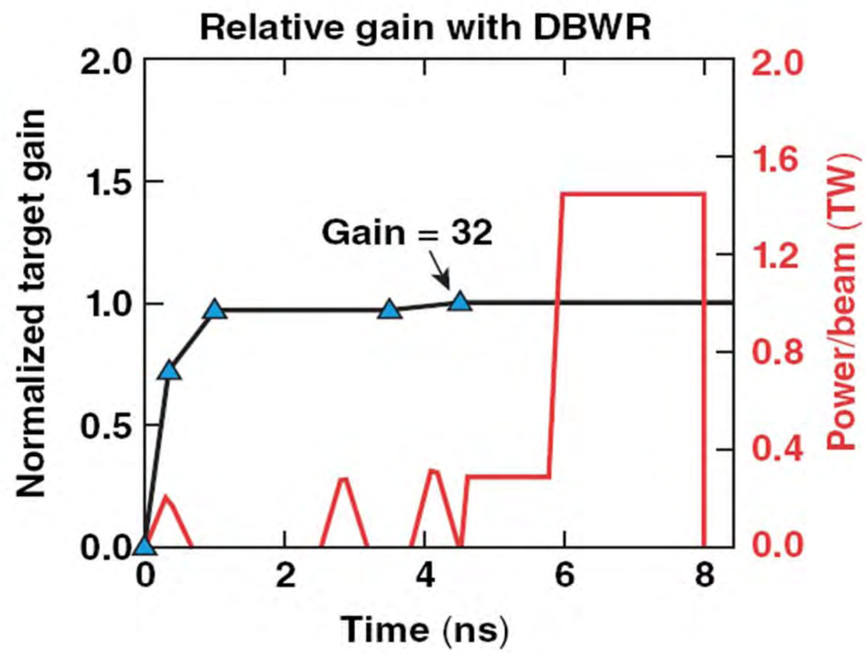
0.5 THz 1-D Multi-FM SSD; mFM37b.1c



*<Ref. to Tim Collins’ talk>

Dynamic Bandwidth Reduction (DBWR) minimizes stress on the laser with little affect on target gain



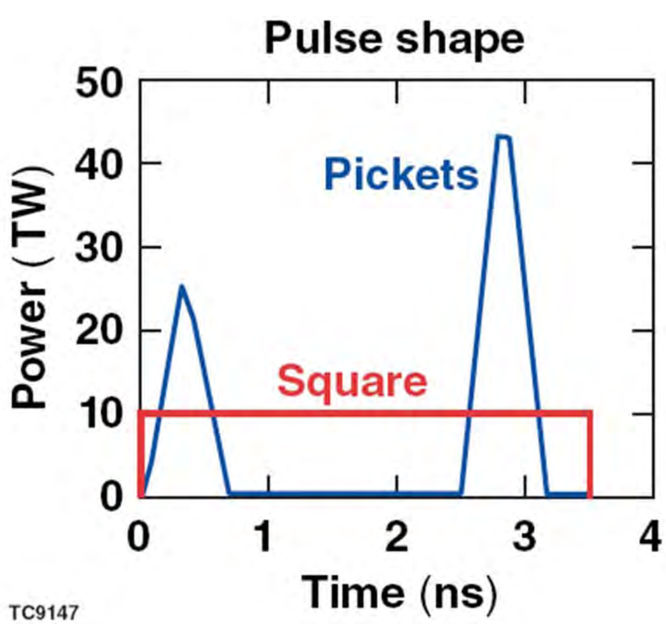


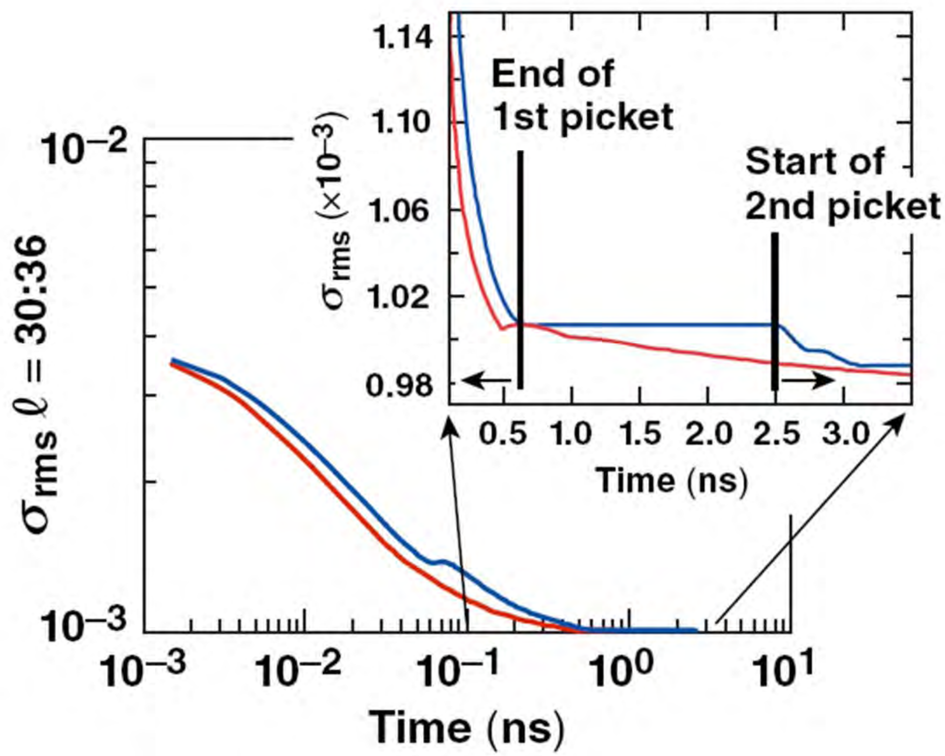
MultiFM 1-D SSD beam smoothing only needs to be applied to pickets in the polar-drive point design pulse shape.

NIF scale picket pulses have similar smoothing characteristics to a square pulse

- **Asymptotic levels are reached by the end of the first picket**

$\nu_1 = 20$ (GHz) $\quad \nu_2 = 22$ (GHz) $\quad \nu_3 = 28$ (GHz)
$\Delta\nu_{eff} = 508$ (GHz) $\quad \Delta div_{eff} = 101$ (μrads) 1/2-θ
mFM32





TC9147

The 1-D MultiFM SSD system provides sufficient smoothing levels for igniting NIF Polar Drive (PD) targets

conclusion

UR LLE

- A 1-D MultiFM SSD system will be deployed on Omega EP in FY11 to demonstrate laser and beam smoothing performance
- MultiFM design space surveys predict optimal MultiFM modulator combinations
- Asymptotic smoothing levels are achieved during a single NIF picket pulse

•===
•================== getSSDparms Report ==================
•================== NIFmFM37b.1c ==================

•Temporal shear report for each modulator [whether or not a pre-shear grating is employed]:
• temporal shear y-dir = {360.763, 360.763, 360.763} [ps].

•Modulator frequencies:
• mod. freq. y-dir = {21.165, 22.837, 31.881} [GHz].

•Modulator depth:
• mod. depth y-dir = {0.450, 1.040, 2.071}.

•Number of Color Cycles:
• Ncc y-dir = {7.636, 8.239, 11.502}.

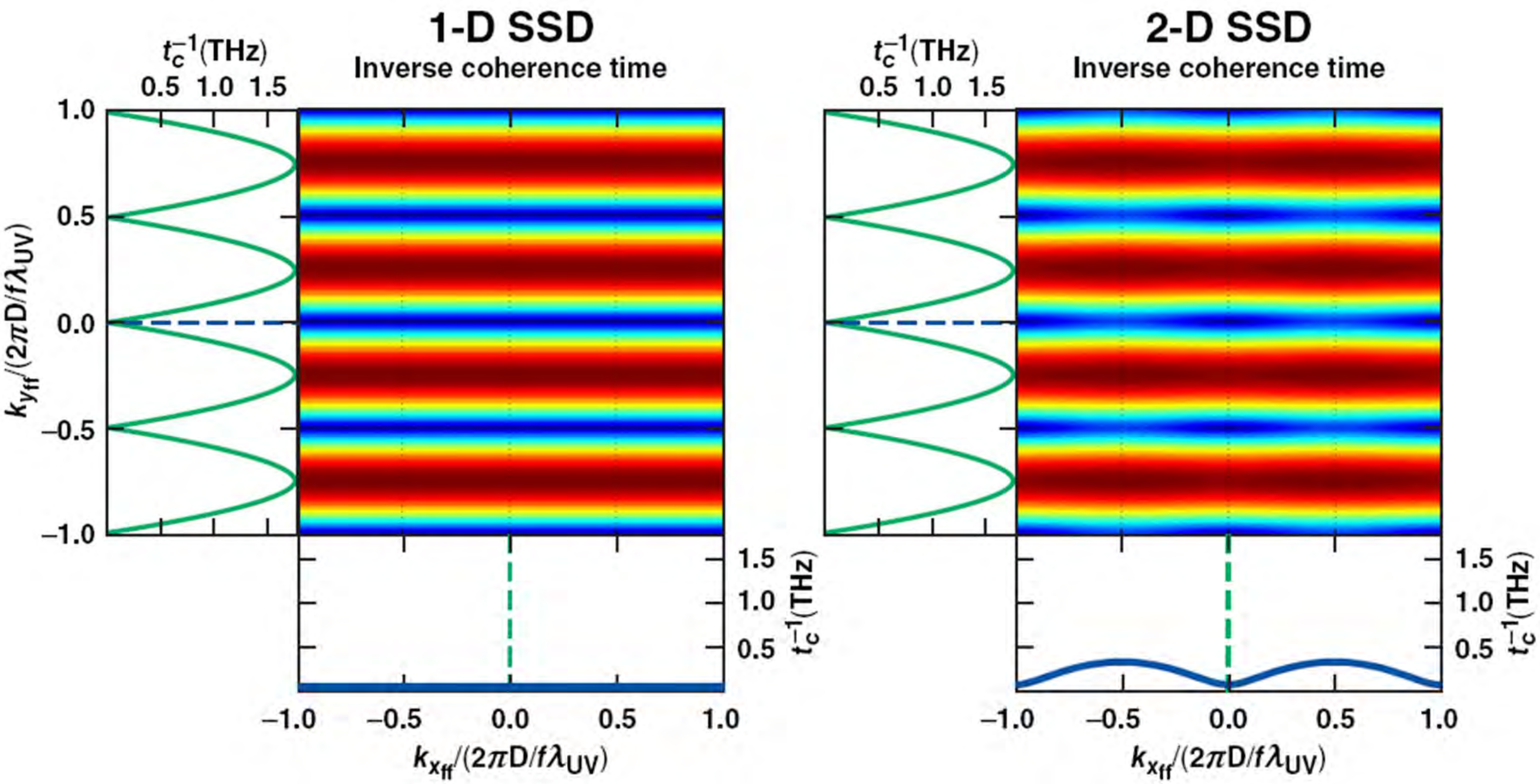
•Magnification on the grating at the standard 44mm beam size:
• Mag_grating y-dir = {1.187, 1.187, 1.187}.

•Grating dispersion at beam_diam_SSD = 35.100 [cm] in the IR:
• y-dir:
• dTheta/dLambda = { 29.3, 29.3, 29.3} [urad/Å].
• dTheta/dLambda*Lambda0/c = {1.03e-009, 1.03e-009, 1.03e-009} [rad*s/m].
•
•Bandwidth report in the IR:
• mFM Per modulator bandwidth y-dir:
• IRbandwidth = {0.705, 1.757, 4.884} [Å]; Using the 2BetaNu definition.
• IRbandwidth = {1.566, 1.757, 4.884} [Å]; Using the 2max(Beta,1)Nu Modified definition.
• IRbandwidth = {2.271, 3.446, 7.242} [Å]; Using the 2(Beta+1)Nu Carson definition.
• IRbandwidth = {3.836, 5.135, 9.600} [Å]; Using the 2(Beta+2)Nu Carlson definition.

• mFM Combined bandwidth:
• Total IRbandwidth = 6.136[Å]; (1.3-norm) Waist definition.
• Total IRbandwidth = 6.646[Å]; (1.3-norm) Waist Modified definition.
• Total IRbandwidth = 7.345[Å]; (1-norm) Transmission definition.
• Total IRbandwidth = 8.206[Å]; (1-norm) Transmission Modified definition.
•
•Bandwidth report in the UV:
• mFM Per modulator bandwidth y-dir:
• UVbandwidth = {57.183, 142.479, 396.116} [GHz]; Using the 6BetaNu definition.
• UVbandwidth = {57.183, 142.479, 396.116} [GHz]; Using the 2max(3Beta,1)Nu Modified definition.
• UVbandwidth = {99.514, 188.154, 459.878} [GHz]; Using the 2(3Beta+1)Nu Carson definition.
• UVbandwidth = {141.845, 233.829, 523.640} [GHz]; Using the 2(3Beta+2)Nu Carlson definition.
•
• mFM Combined bandwidth y-dir:
• Total UVbandwidth = 424.827[GHz]; (2-norm) Waist definition.
• Total UVbandwidth = 424.827[GHz]; (2-norm) Waist Modified definition.
• Total UVbandwidth = 506.747[GHz]; (2-norm) Waist Carson definition.
• Total UVbandwidth = 590.758[GHz]; (2-norm) Waist Carlson definition.
• Total UVbandwidth = 497.680[GHz]; (1.3-norm) Waist definition.
• Total UVbandwidth = 497.680[GHz]; (1.3-norm) Waist Modified definition.
• Total UVbandwidth = 611.910[GHz]; (1.3-norm) Waist Carson definition.
• Total UVbandwidth = 727.622[GHz]; (1.3-norm) Waist Carlson definition.
• Total UVbandwidth = 595.778[GHz]; (1-norm) Transmission definition.
• Total UVbandwidth = 595.778[GHz]; (1-norm) Transmission Modified definition.
• Total UVbandwidth = 747.546[GHz]; (1-norm) Transmission Carson definition.
• Total UVbandwidth = 899.314[GHz]; (1-norm) Transmission Carlson definition.
•
•Divergence report {1/2 angle @ Full beam diameter = 35.1 [cm]}:
•
• mFM Per modulator y-dir:
• UVdivergence y-dir = {10.315, 25.701, 71.452} [urad]; Using the 2BetaNccLambdaIR/D_ssd definition.
•
• mFM Combined Divergence y-dir:
• Total UVbandwidth = 99.768[urad]; (1.1-norm) Waist definition.

•================== getSSDparms Report ==================
•===

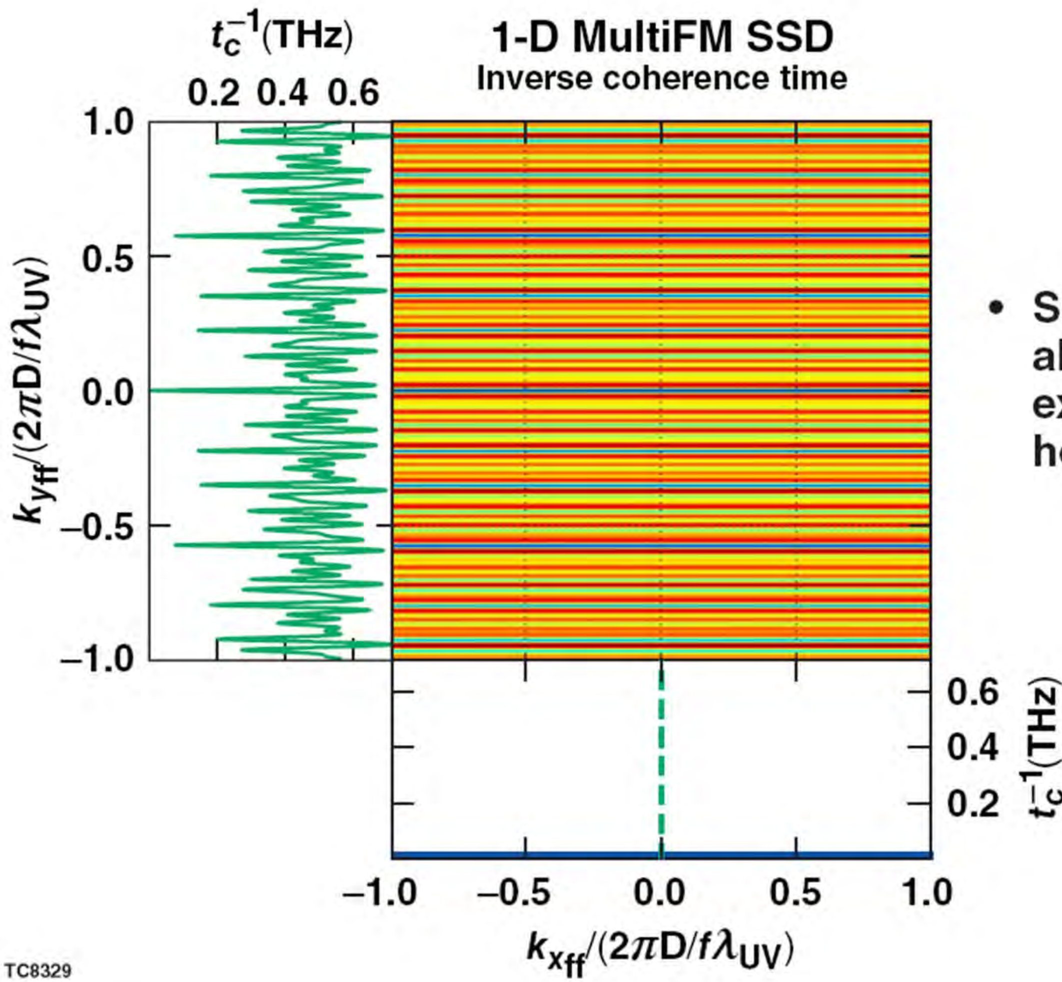
The inverse coherence time is a 2-D function of the far-field spatial frequency



- The traditional SSD systems have large regions with very low values of t_c^{-1}.

TC8328

The inverse-coherence-time distribution for MultiFM does not go to zero (except along the central horizontal axis)



- Smoothing results at all spatial wavelengths except along the central horizontal axis.

TC8329