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Coherent Addition of Pulse for Energy (CAPE) Instrument and Data Fitting Model Study.

Michael C. Rushford, Stanley Davis[1,2,3], Antonio Lucianetti, Igor Jovanovic, Curtis G. Brown, Craig W. Siders, Wayne Brewer, Mike Taranowski, J. Hernandez, and C. P.J. Barty

National Ignition Facility, Photon Science and Applications Program,
Lawrence Livermore National Laboratory, Livermore, CA
[1]Department of Physics, St. John's University, Queens, New York
[2]NIF Photon Science and Applications Faculty Scholar, 2006
[3]Department of Physical, Environmental and Computer Science,
Medgar Evers College of the City University of New York, Brooklyn, New York

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Multi-kilojoule PW facilities with 40 cm square aperture Nd:glass amplifiers are being developed

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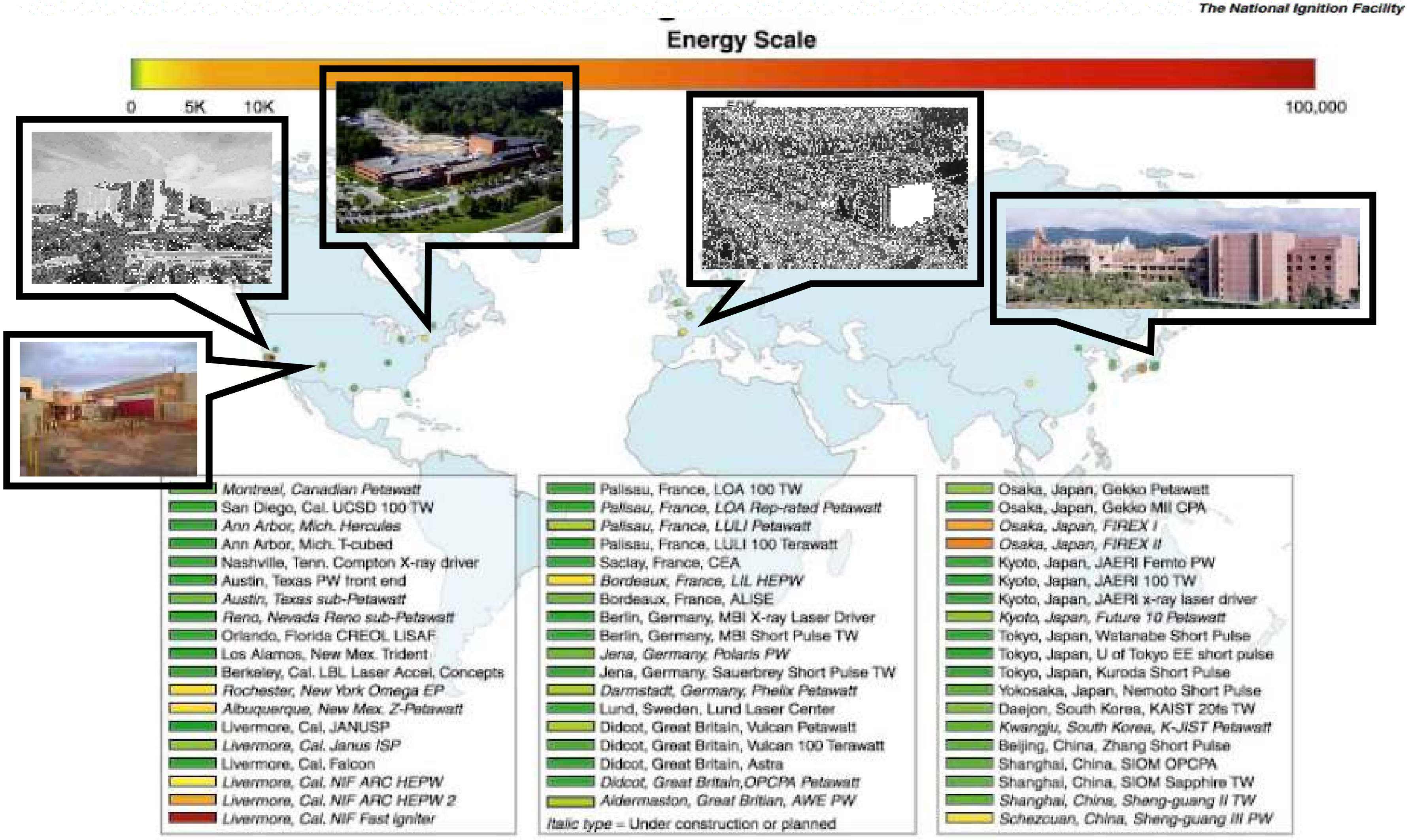
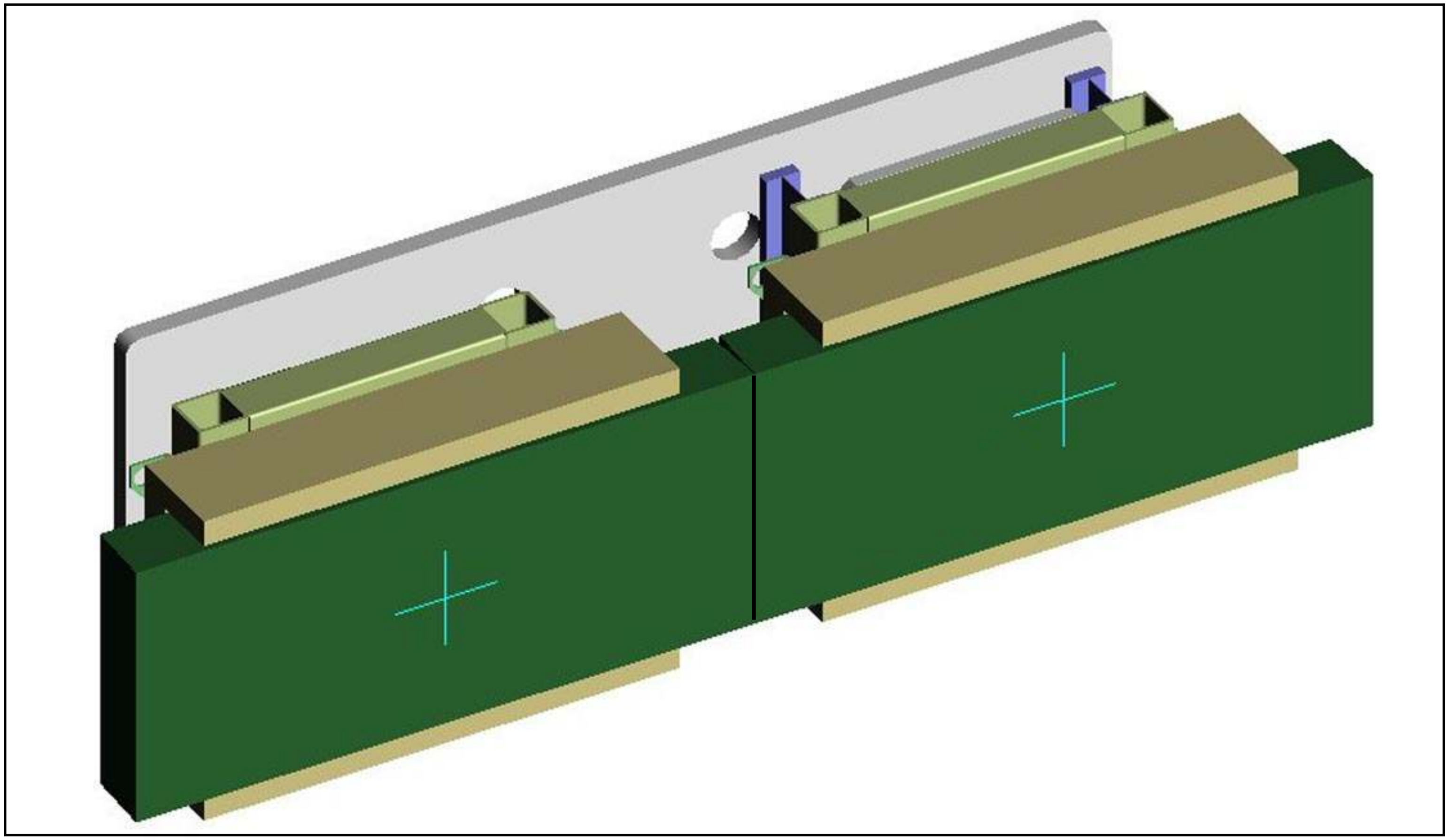


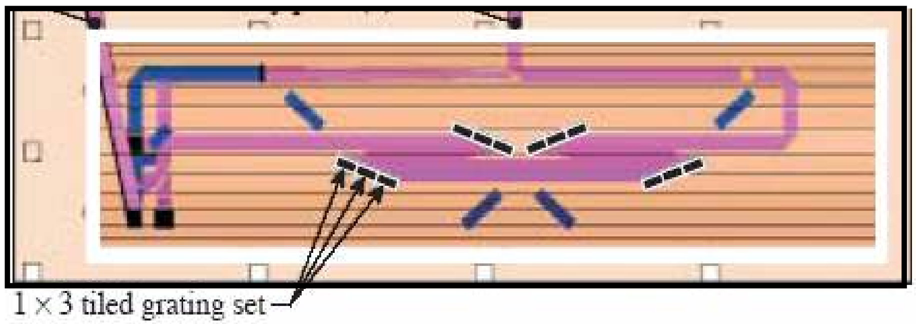
Peak irradiance will be limited to ~ 10^{21} W/cm^2

A full aperture NIF HEPW beam line would produce up to 3.3 kJ per beam, but requires 1.82 m wide grating apertures

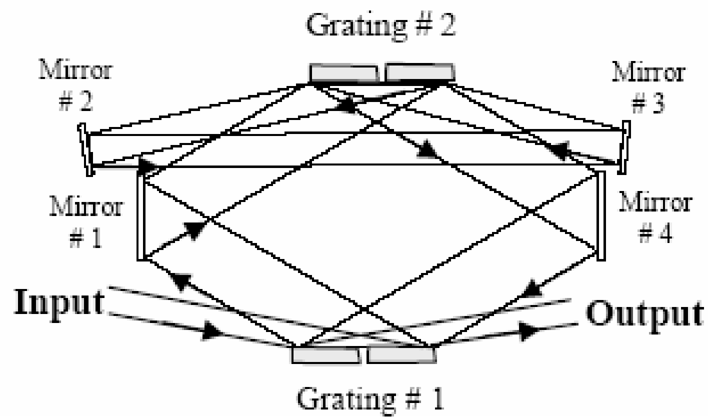


Tooling is not available for 2 meter wide grating fabrication
Segmentation reduces substrate thickness, weight, cost and lead time
2 segment "tiling" of sub-aperture gratings with 91 cm substrates is possible

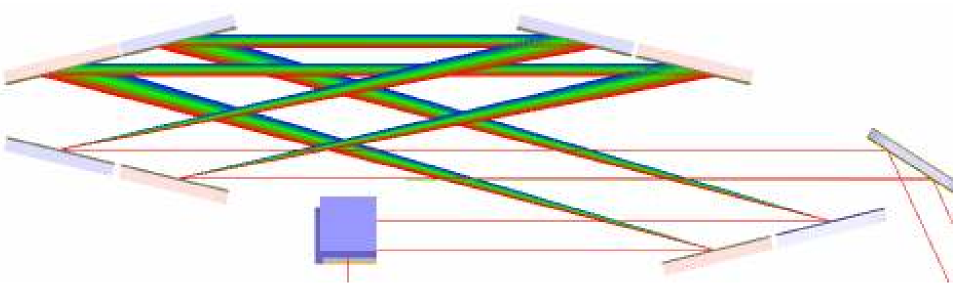
Segmented compressor designs exist for modern square aperture Nd:glass lasers



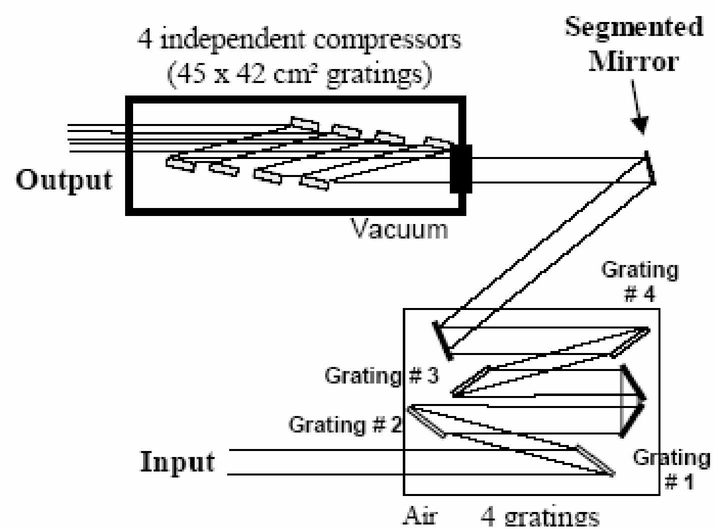
OMEGA EP



FIREX



ARC/LLNL



LIL-PW

All require ~ 2 m grating aperture

Two approaches to deal with phase errors introduced by segmentation: Coherent Grating Tiling (CGT) and CAPE

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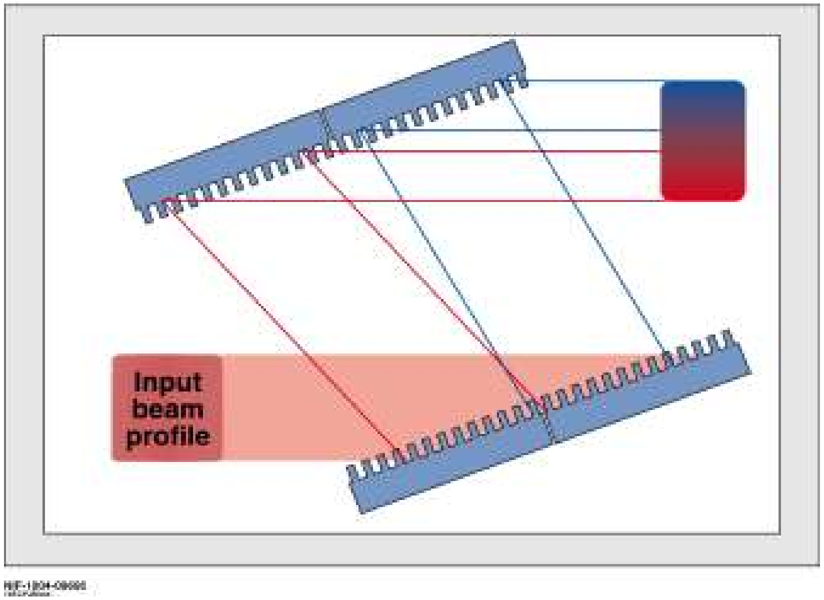
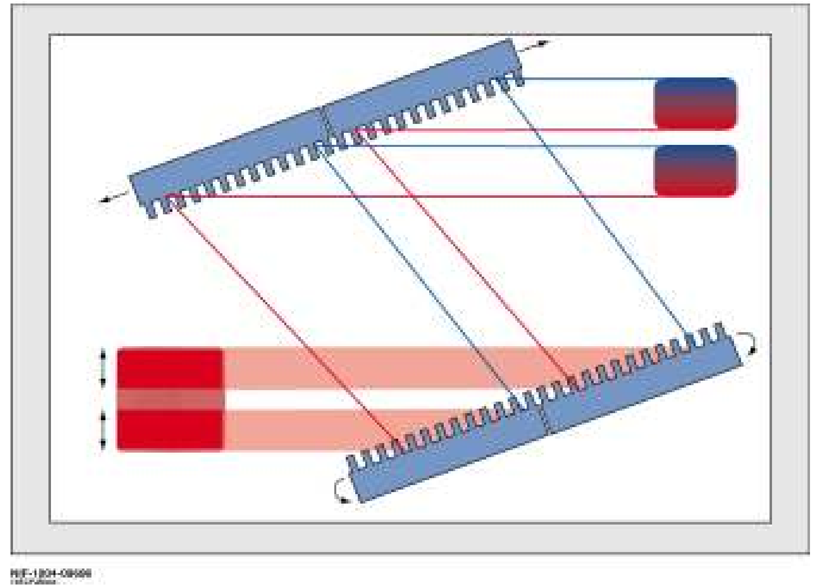




CGT[1,2,3]

Coherent Grating Tiling

CAPE[4,5]

Coherent Addition of Pulses for Energy

[1]T. Zhang et al., Opt. Comm. **145**, 367 (1998)
[2] N. Miyanaga et al., IFSA Monterey, CA (2003)
[3]T. J. Kessler et al., Opt. Lett. **29**,635 (2004)

[4] M. C. Rushford et al., ICUIL Tahoe City,CA (2004)
[5] N. Blanchot et al., Appl. Opt. (accepted -2006)

Coherent Addition of Pulse for Energy (CAPE)

- Can Coherently combine pulses.
- Want Constructive interference at the combined focal spot center.
- Examined by spectrally dispersed Young's double slit interferogram.
- Fitting fringe locations finds the *difference* in *group delay* (GD) and *group delay dispersion (GDD)*…
- Minimize differences between pulses.

For simulated Interferogram: fit and test procedures

•Calculated a Young's double slit interferogram, for various OPD(GD, GDD, TOD) conditions, try the fitting.

•Use spatial phase stepping to extract the phase of these interferogram fringes -modulo 2PI-, unwrap the 2D array **Thomas J. Flynn,** J. Opt. Soc. Am. A/ Vol. 14, No. 10/October 1997, pg. 2692 , extract the phase at Y=0 (i.e. OPD = 0) for each wavelength.

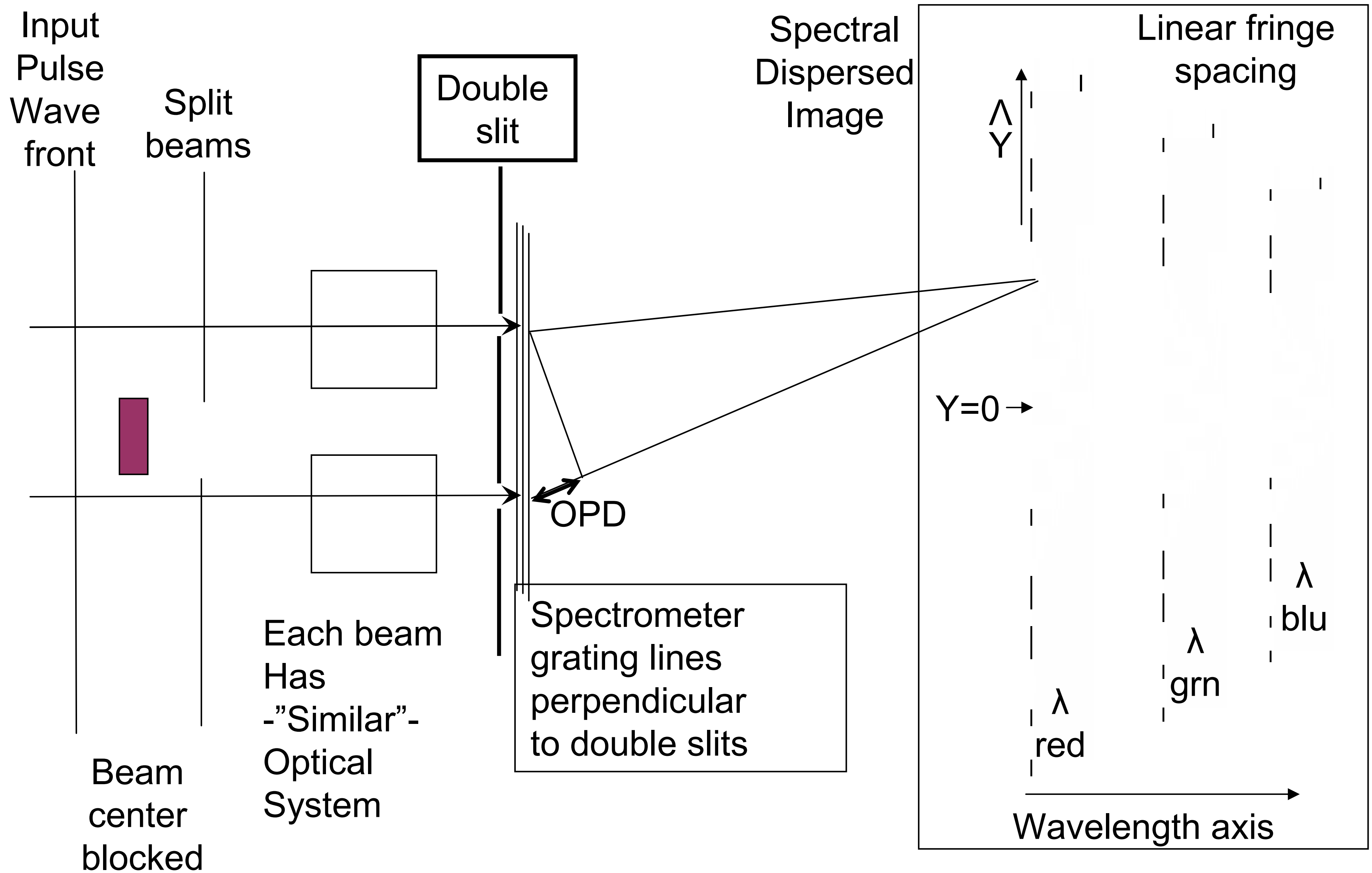
•Fit using Lab View to the phase (wavelength) as a Taylor expansion described by Tracy IEEE JOURNAL OF **QCANTUM** ELECTRONICS, **VOL. QE-5,** NO. 9, SEPTEMBER 1969

•Plot "stationary phase ranged points" (derivative of phase across wavelength axis is close to zero) so to point out the white light interference fringe and other calculation induced noise subtleties. **Jose Calatroni …, J. Opt. A: Pure Appl. Opt. 5 (2003), s207-s210**

•Discuss and improve:

- •Accuracy of code on synthetic data (we know the correct answer).
- •Noise: compare Spatial phase stepping and FFT phase measurement.-

Fringe phase at Y=0 for each wave length λ across a split pulse



Phase measurement via Spatial phase stepping

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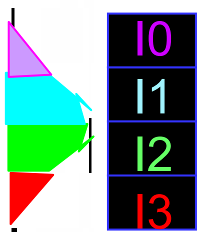
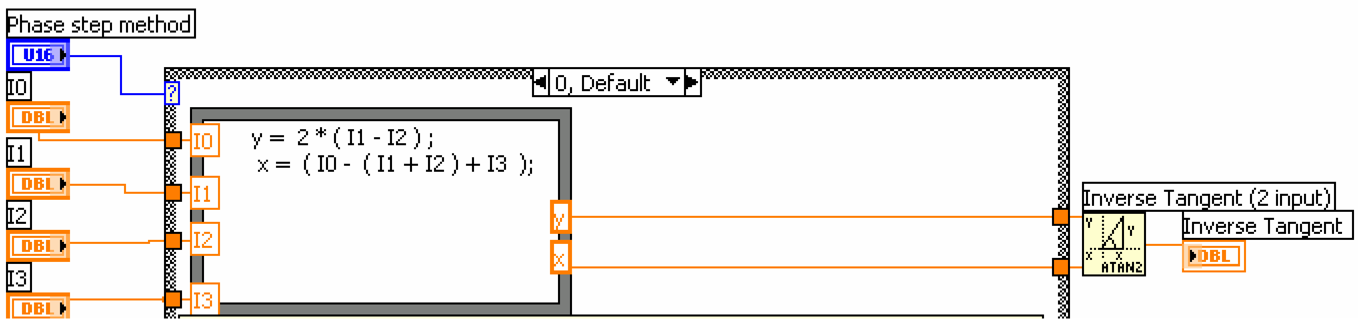
Fringe pattern line out

- **Create 4 detector that span one fringe spacing.**
- **Each quad detector sums up intensity over a minimum of one pixel wide.**

Lab View code implementation of work by:
Johannes Schwider, Oliver Falkenstörfer, Horst Schreiber, Andreas Zöller, Norbert Streibl
New compensating four-phase algorithm for phase-shift interferometry
OPTICAL ENGINEERING / August 1993 / Vol. 32 No. 8/1883





- **Quad detector spacing error makes a phase angle error that is periodic between fringe peaks and is zero error every half wave.**
- **Reduce this error using methods of** "Window function influence on phase error in phase-shifting algorithms" APPLIED OPTICS y Vol. 35, No. 28 y 1 October 1996 this reference also references spatial phase stepping.
- **Can slide the Quad detector along each pixel of the lineout to measure phase along the sinusoidal pattern.**
- **The analog Intensity difference I1-I2 is used to phase lock the fringe position to very high bandwidth feedback.**
- **Phase stepping methods utilize less computation in calculating fringe phase compared to FFT methods.**

Phase measurement via FFT

Fringe pattern line out

•Best if use a power of two number of pixels across the waveform.

•Phase error is minimum at FFT array center and increases to maximum near the array boundary due to GIBBS phenomena.

•Reduce GIBBS phenomena error by making the array edge intensity derivative = 0.

•Generally additional filtering required, increasing the computation.

•Should be a better solution for real noisy data.

Put simulated Interferogram into CAPE program

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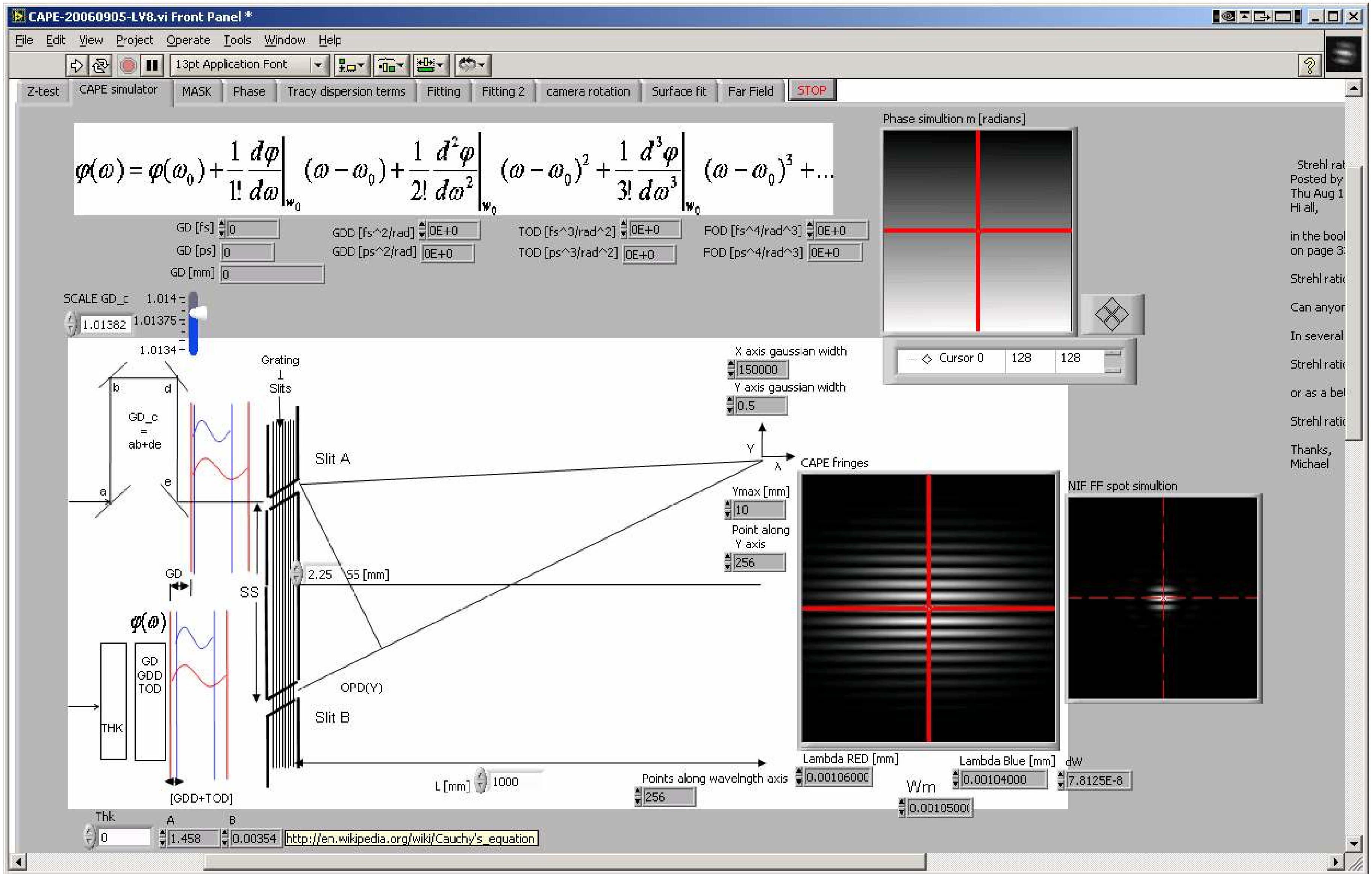
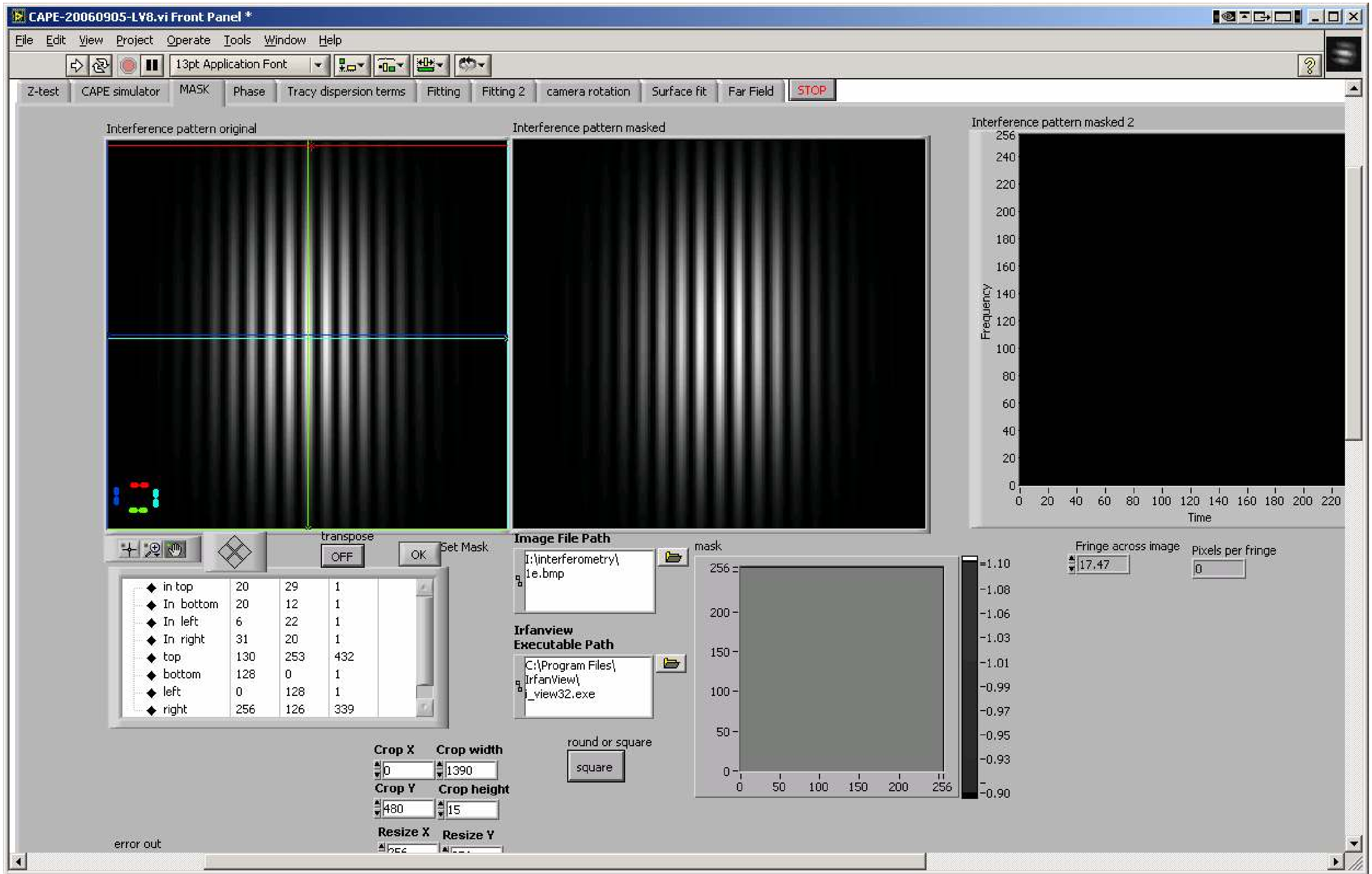
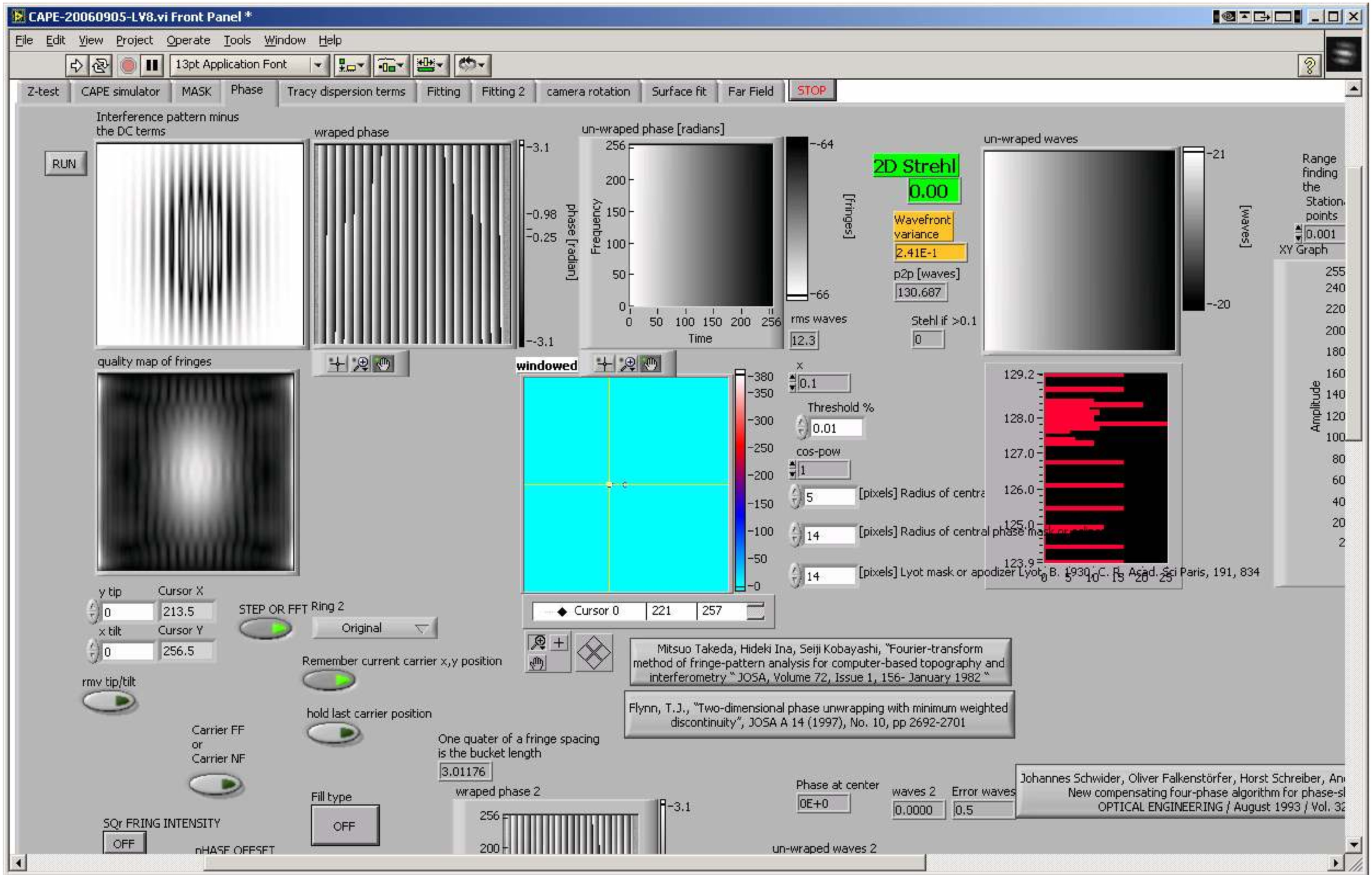


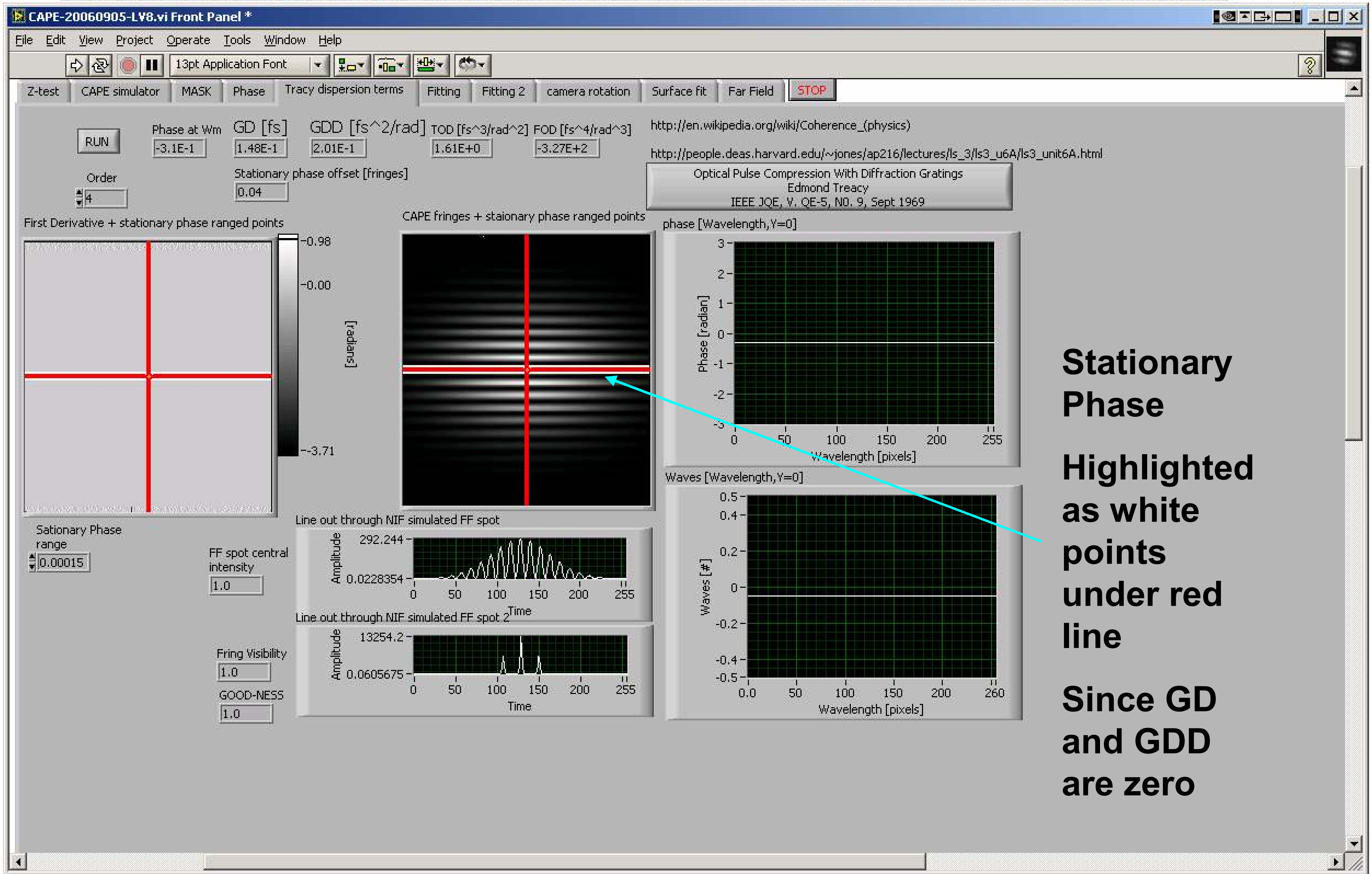
Orient and mask data



Phase measurement



Fit to simulator input of GD, GDD, TOD = 0

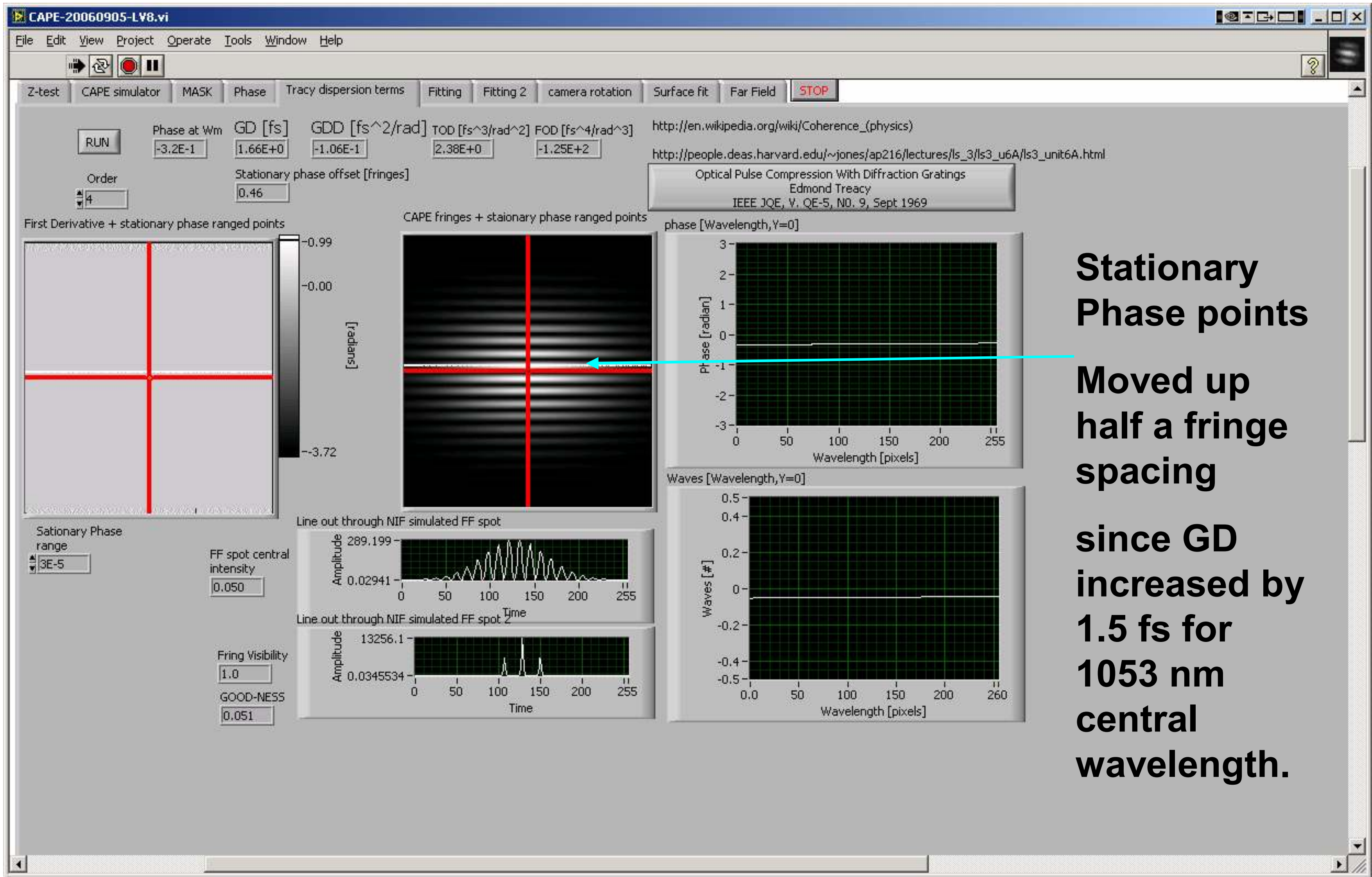


Stationary Phase

Highlighted as white points under red line

Since GD and GDD are zero

Fit to simulator input of GD = 1.5 fs

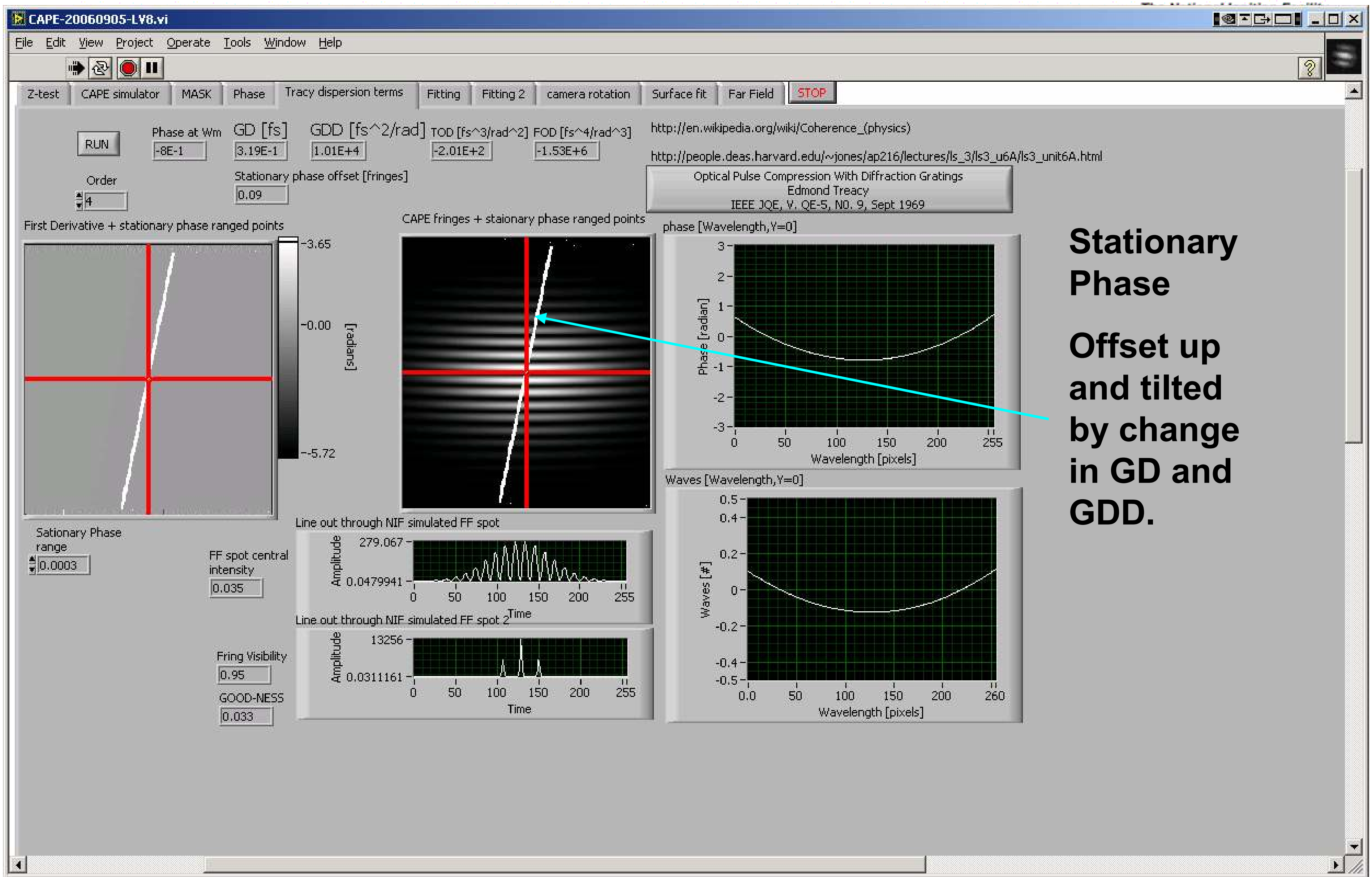


Stationary Phase points

Moved up half a fringe spacing

since GD increased by 1.5 fs for 1053 nm central wavelength.

Fit to simulator input of GD = 1.5 fs, GDD = 1E+4 fs^2/rad



Stationary Phase

Offset up and tilted by change in GD and GDD.

Fit to simulator input of
GD = 1.5 fs, GDD = 1E+4 fs^2/rad, TOD = 5E+6 fs^3/rad^2

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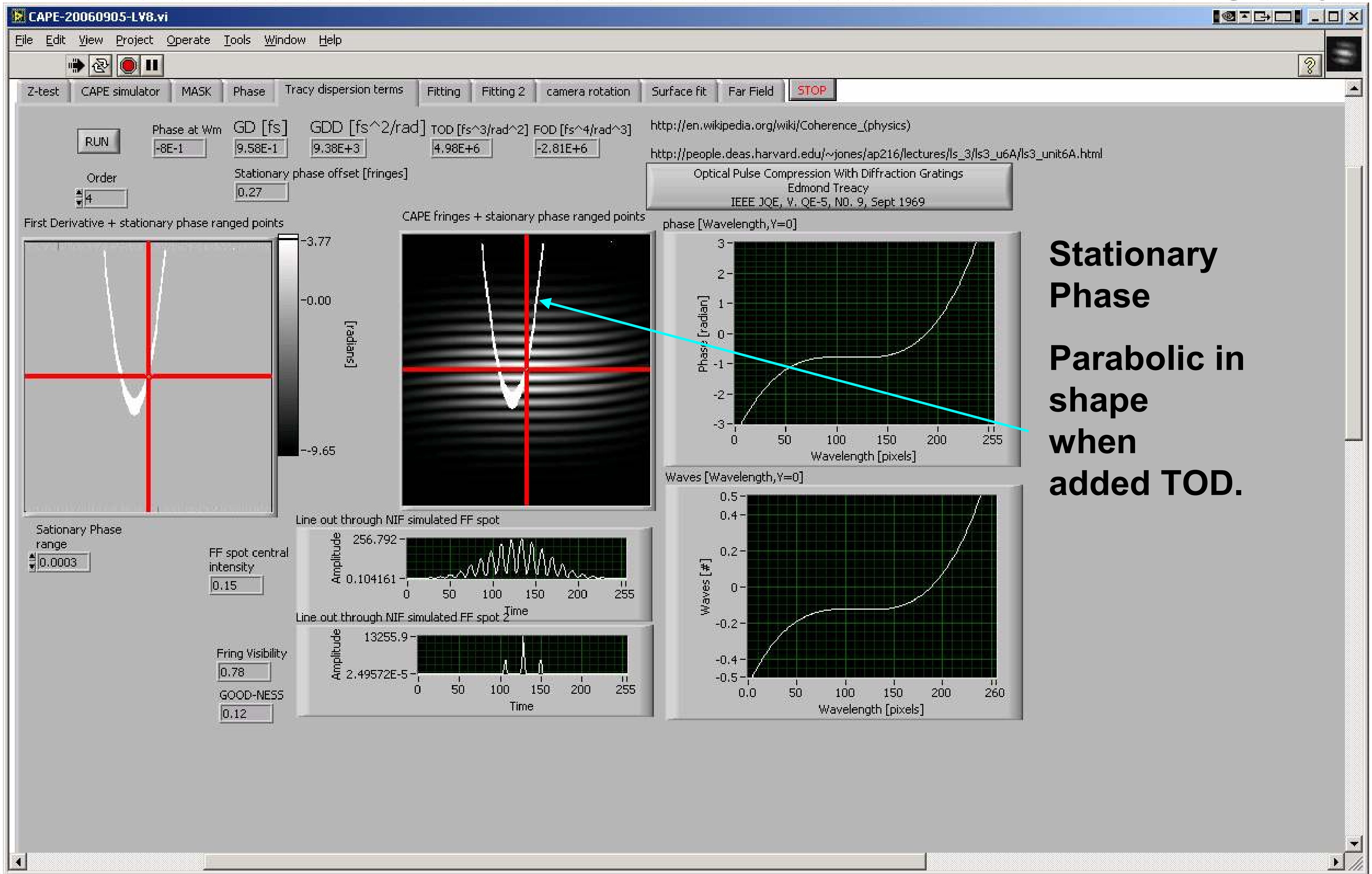

Stationary Phase

Parabolic in shape when added TOD.

Phase measurement method and Fit (error) study.

the accuracy of code on synthetic data (for which we know the correct answer).

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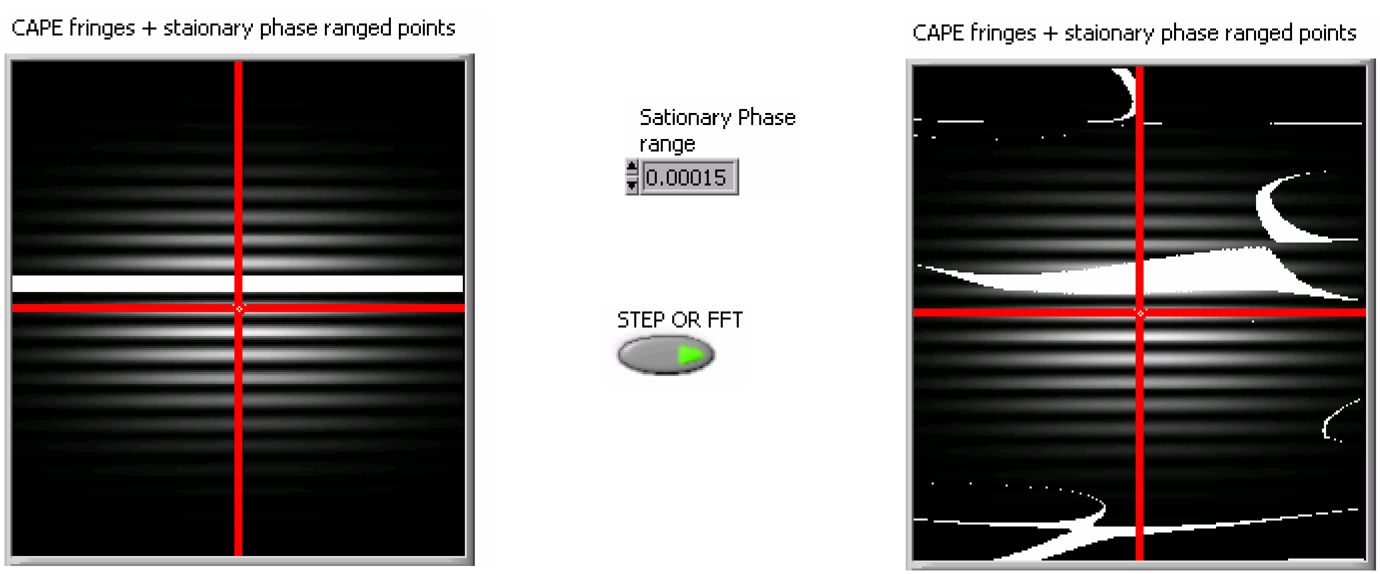
	GD [fs]	GDD [fs^2/rad]	TOD [fs^3/rad^2]	FOD [fs^4/rad^]
Simulator request	0.0000	0.00	0.00	0.00
fit in simulator	0.0000	0.00	0.00	0.00
fit from simulated fringes use phase stepping	0.1480	0.20	1.61	-327.00
fit from simulated fringes use FFT	0.0103	-52.70	-716.00	3630000.00
	Evidence GD can be measured accurately	Why is there cross talk into the higher order terms and the FFT so much worse?		

To do..

•GD effects GDD, TOD and FOD and visa versa, why.

•This higher order cross talk is eliminated if the phase is measured along the Y axis which is the stationary phase offset at the central wavelength?

•Can the FFT methods be made more precise like seen with phase stepping?



Results for the code on some real lab data
Shows a very “noisy” stationary phase - with no filtering applied.

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