

# Dispersion Compensation in Mode-locked Thulium/Holmium Doped Fiber Laser

Kelley Daenzer  
KSU Physics REU 2016



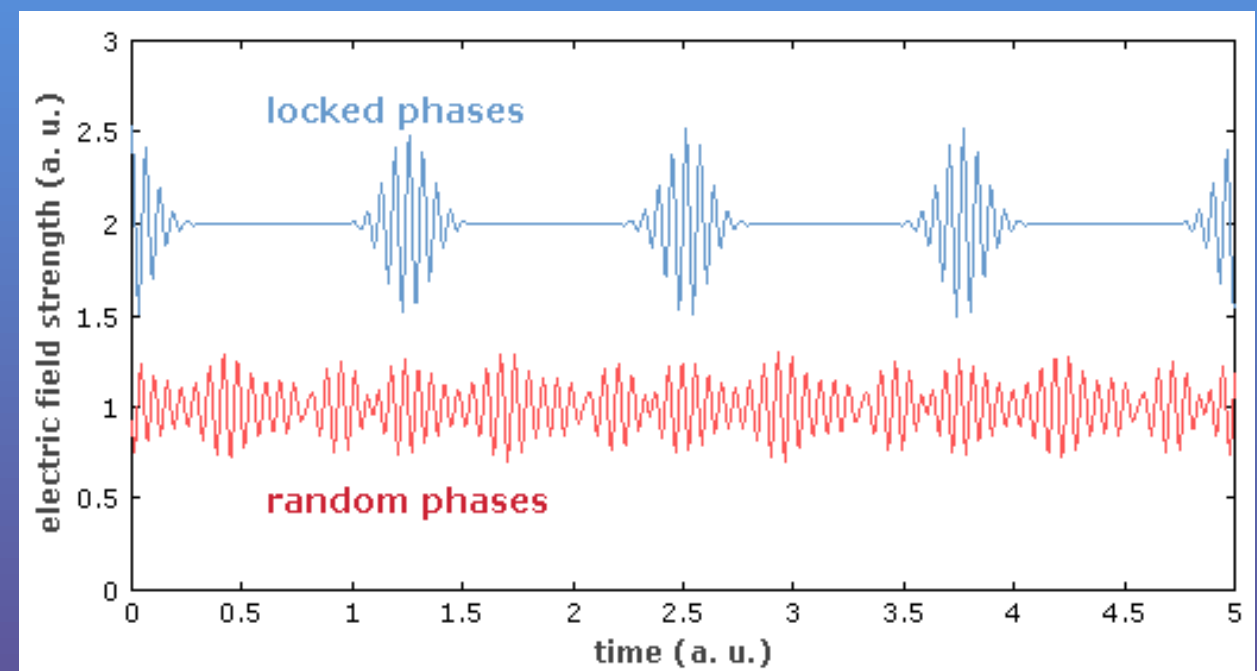
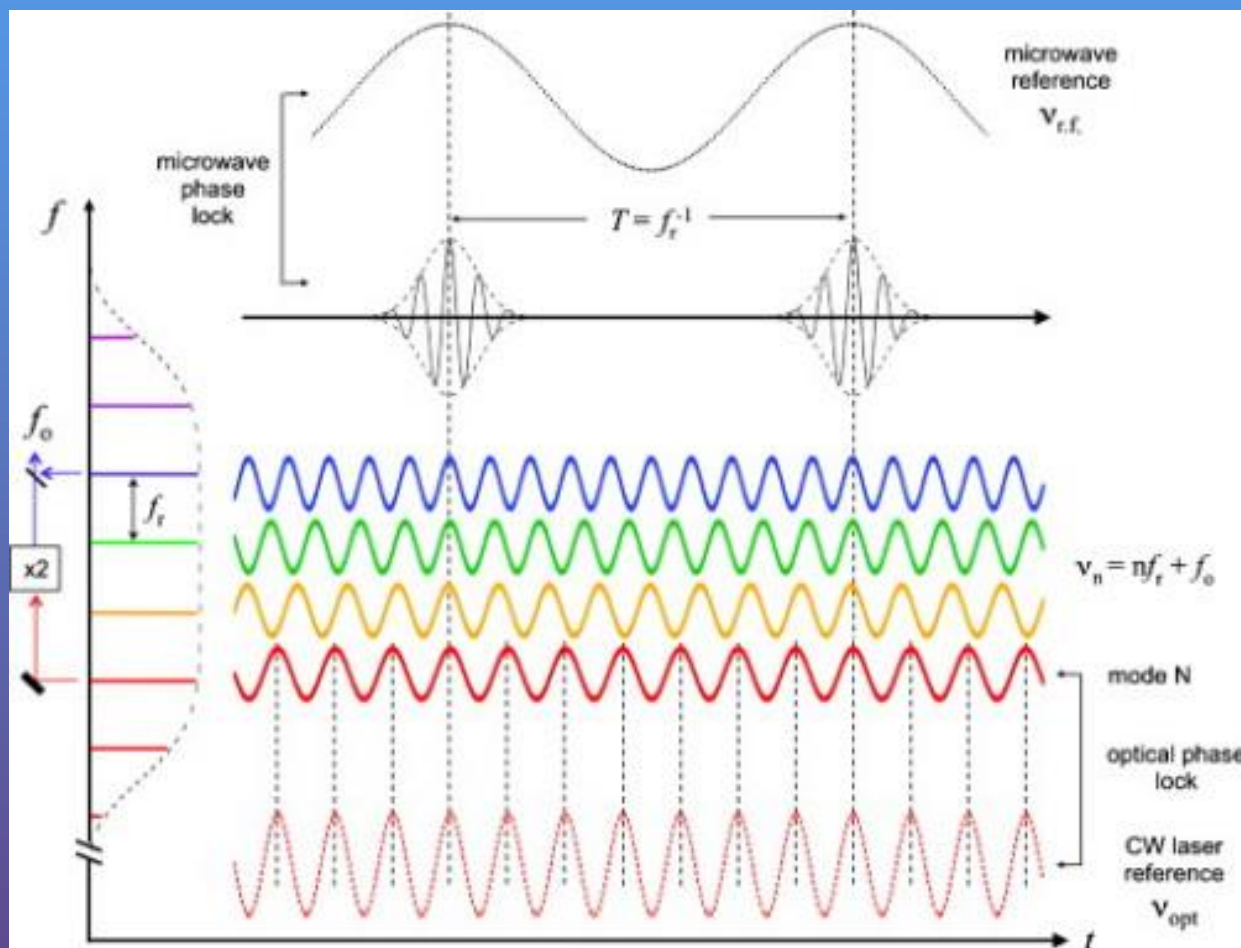
# Mid-infrared Ultra-short Pulse Lasers

...can measure ultra-short timescales!

- Chemical reactions
- Biological processes
- etc.

...can measure absorption over a wide wavelength range!

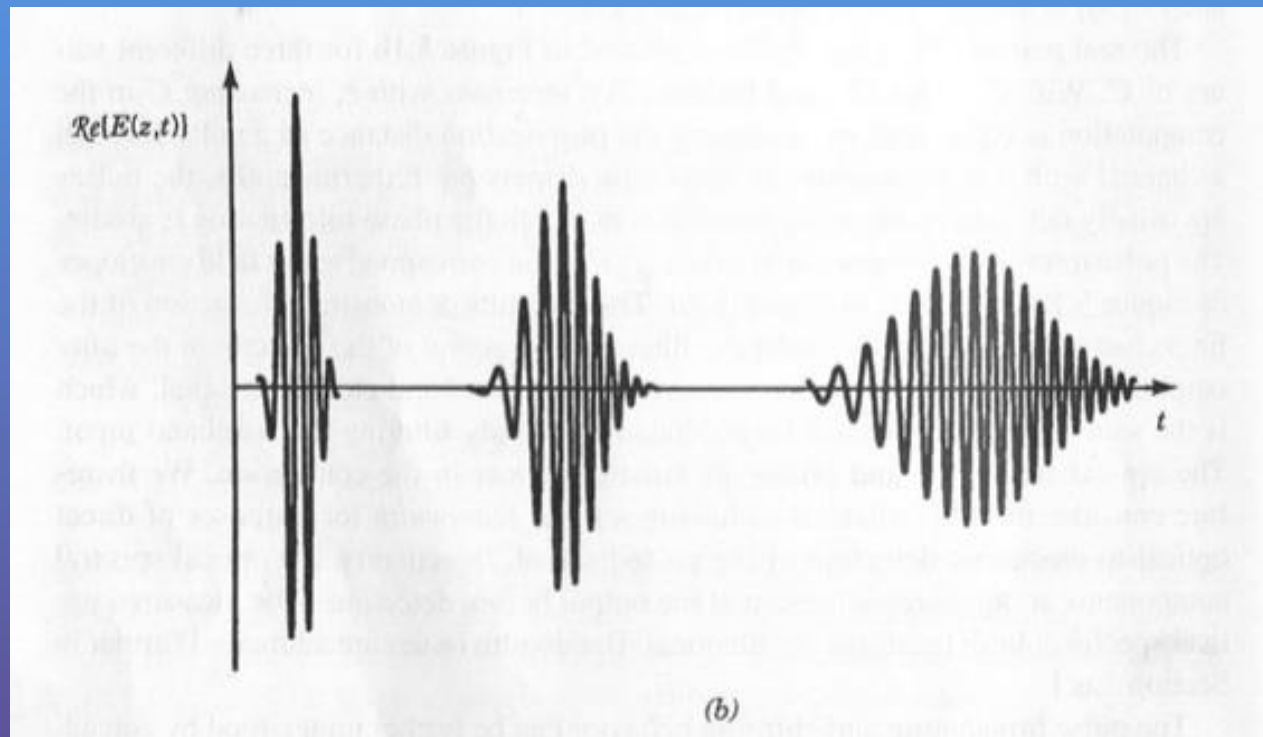
# Mode-locking



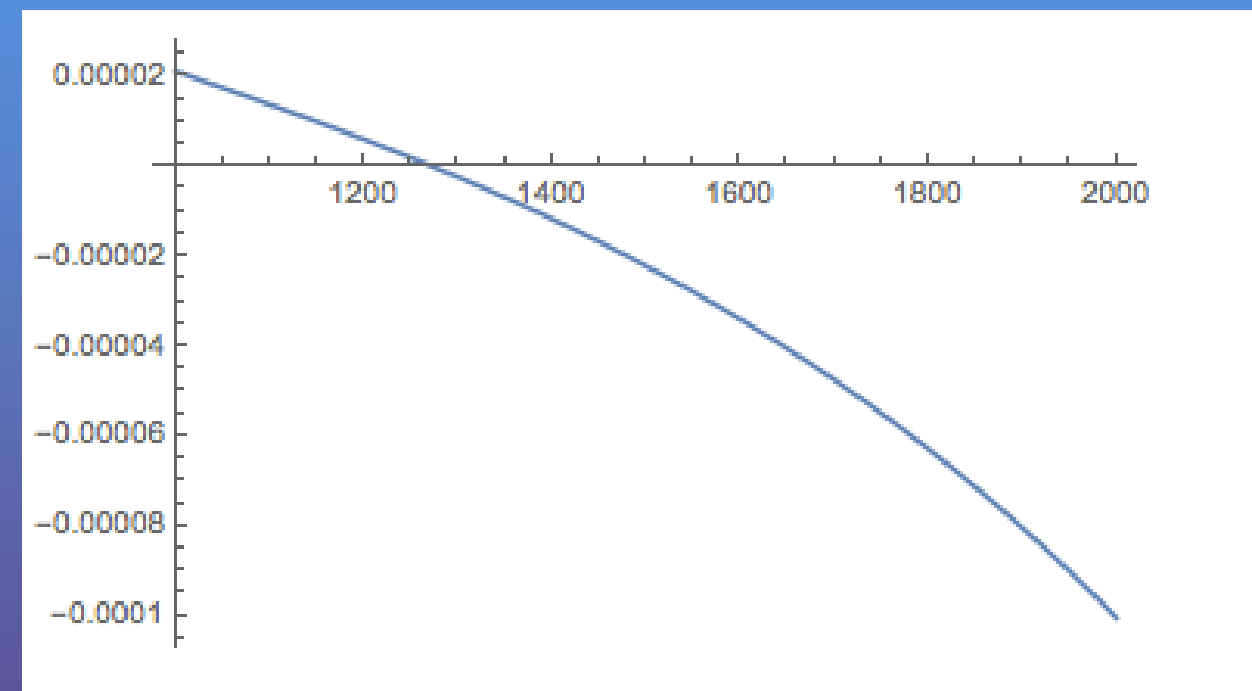
# Group Velocity and Third-order Dispersion

$\beta_2$  - Group velocity dispersion parameter

- Related to 2nd derivative of Sellmeier equation



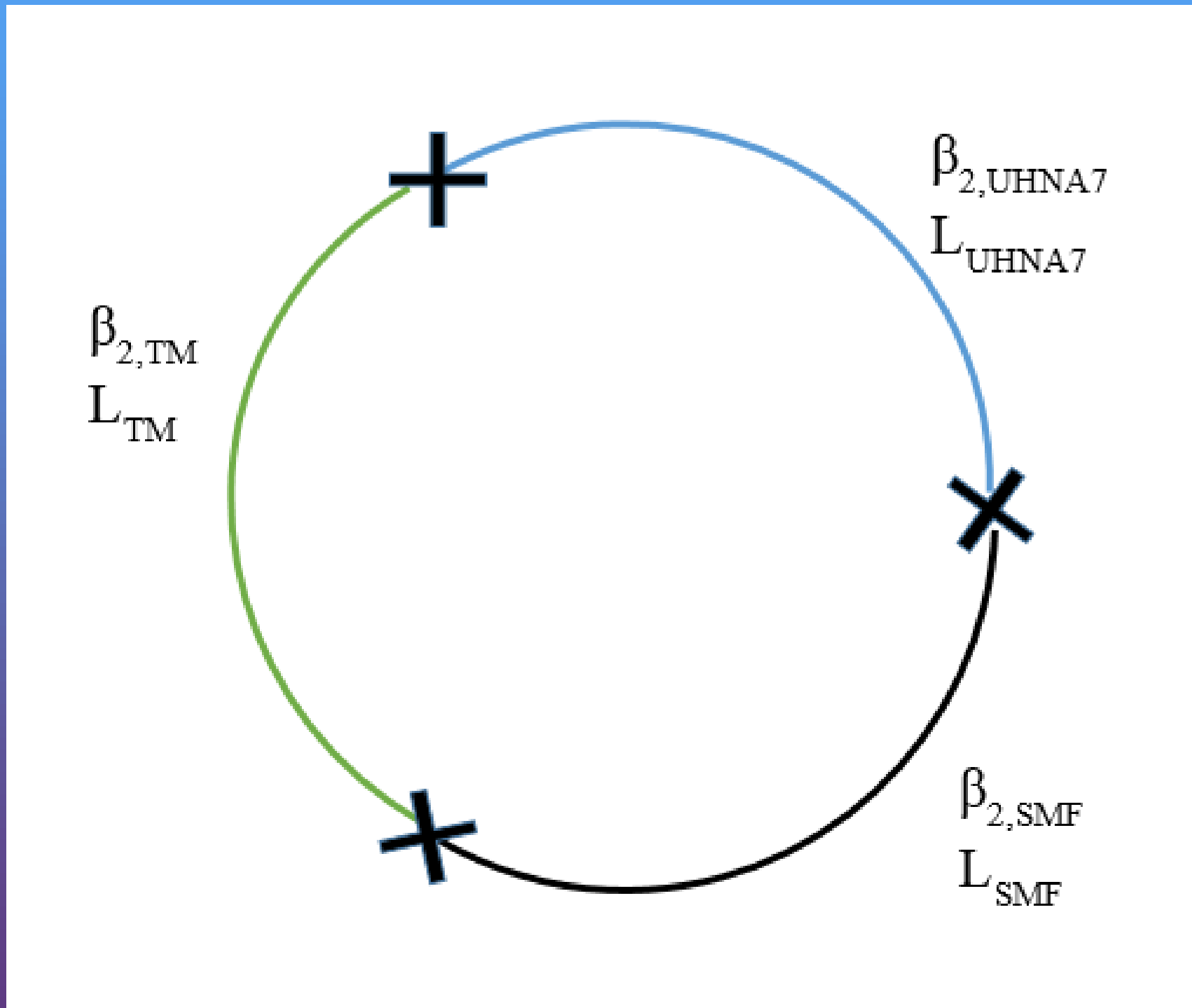
Buck, John. *Fundamentals of Optical Fibers*, ch. 5. 1995.



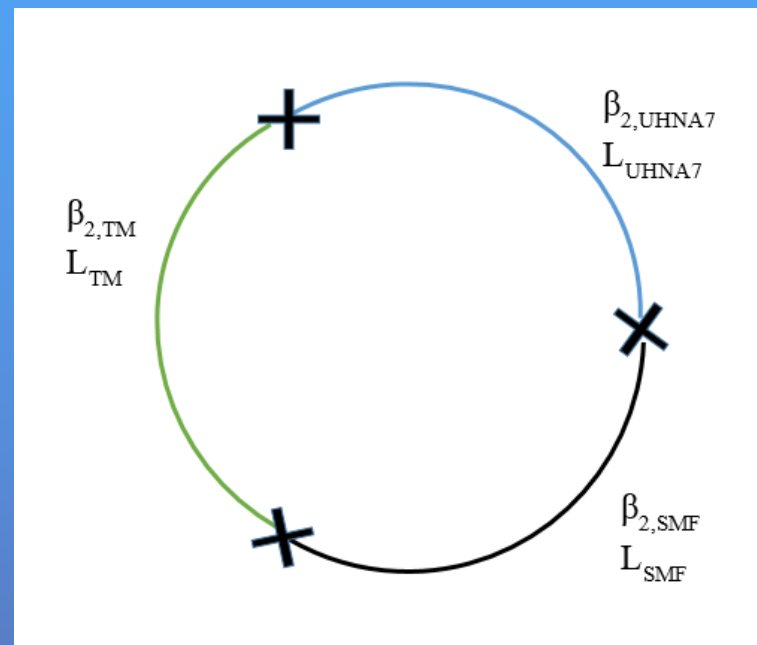
$\beta_3$  - Third-order dispersion parameter

- Derivative of  $\beta_2$  with respect to frequency

# Dispersion Management



# (Dispersion Management, cont.)



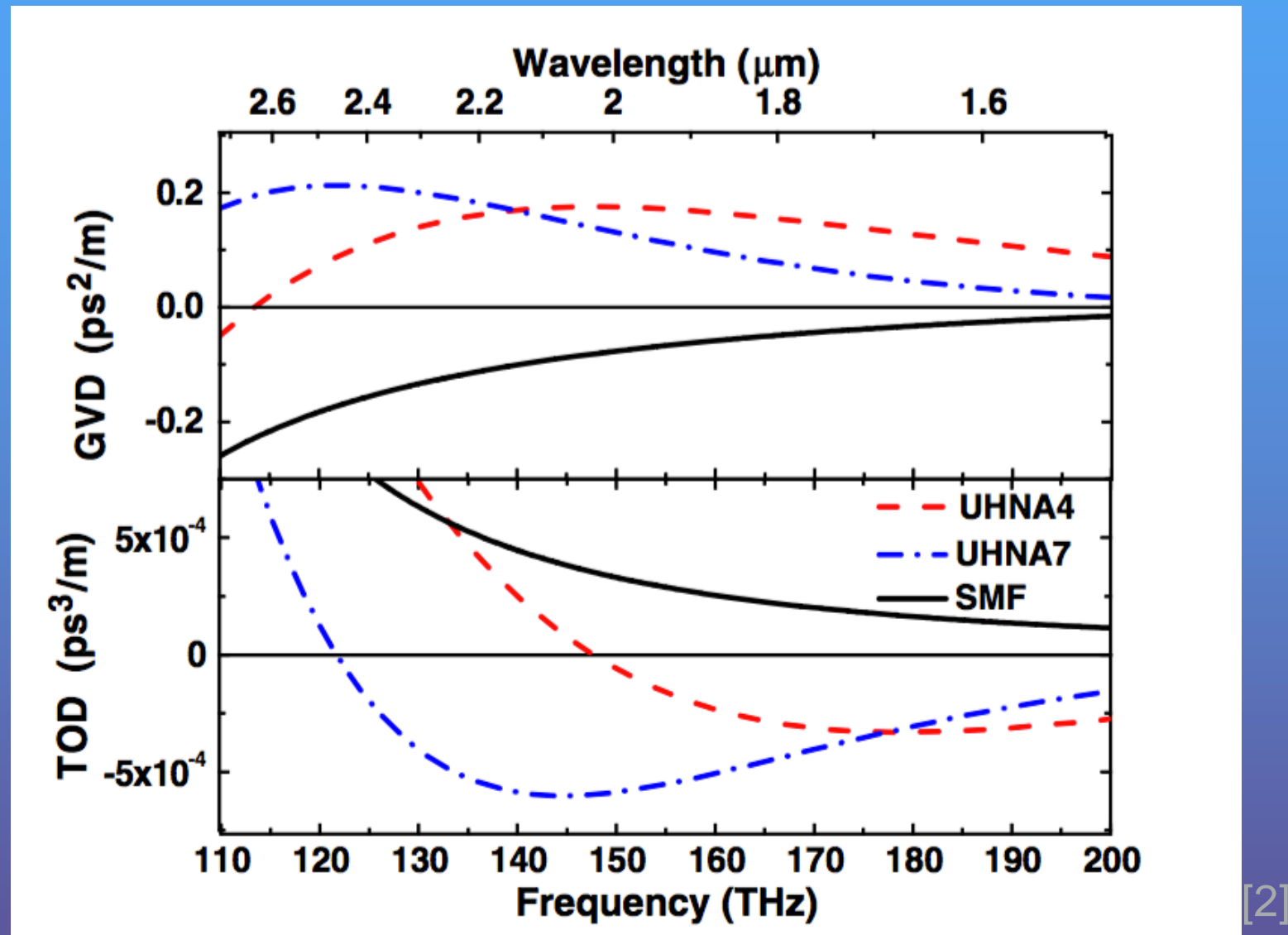
Net Cavity GVD (with no compensation fiber)

$$\beta_{2,TM} L_{TM} + \beta_{2,SMF} L_{SMF} = (0.01 \text{ ps}^2 / \text{m}) (1.24 \text{ m}) + (-0.085 \text{ ps}^2 / \text{m}) (4.46 \text{ m}) = -0.366 \text{ ps}^2$$

Net Cavity TOD (with compensation fiber)

$$\beta_{3,TM} L_{TM} + \beta_{3,SMF} L_{SMF} + \beta_{3,UHNA7} L_{UHNA7} = 0$$

# Ultra-high Numerical Aperture Fiber

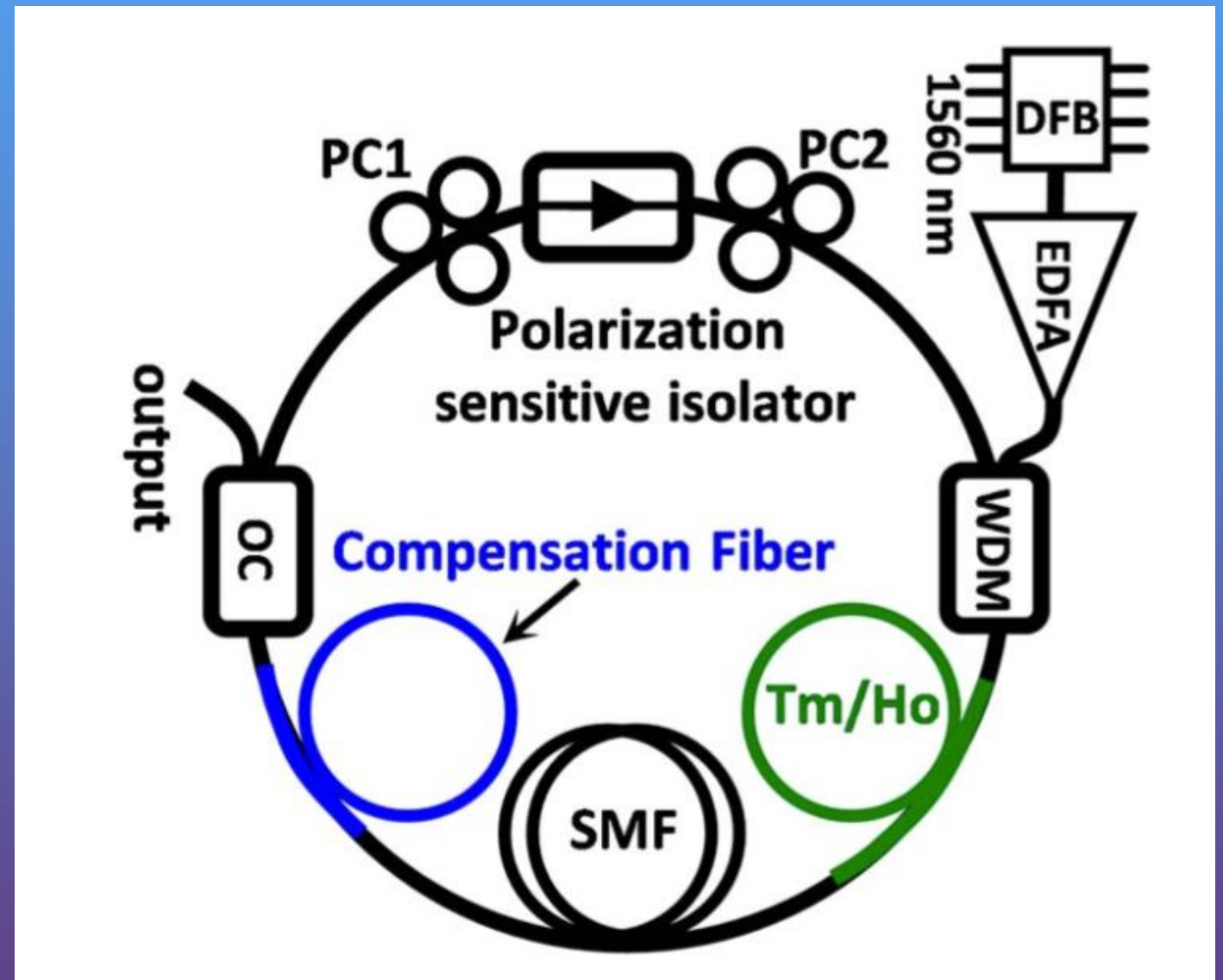
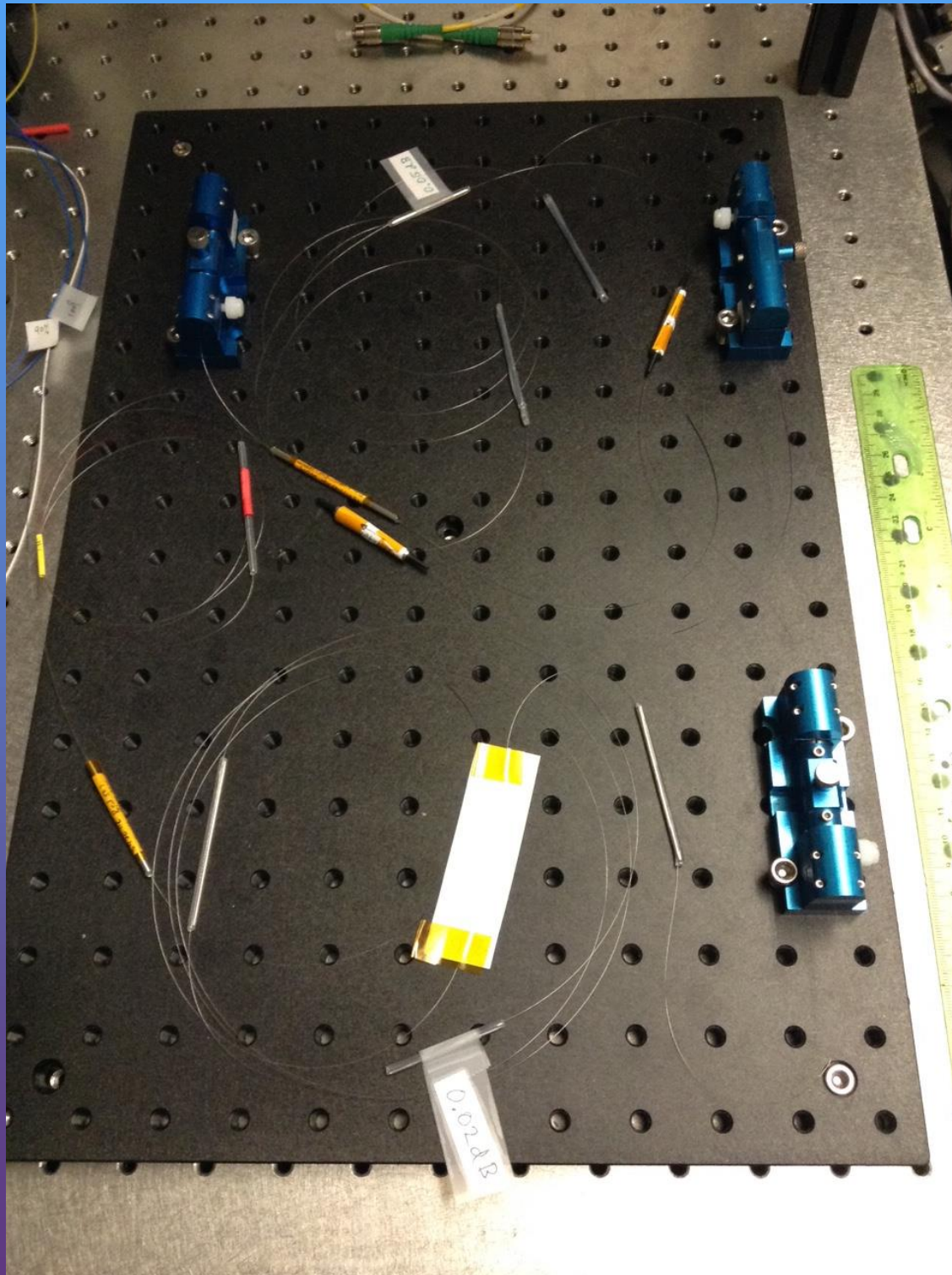


Required UHNA-7 Length

$$L_{\text{UHNA7}} = \frac{\text{NCD} - \beta_{2,\text{TM}} L_{\text{TM}} - \beta_{2,\text{SMF}} L_{\text{SMF}}}{\beta_{2,\text{UHNA7}}}$$

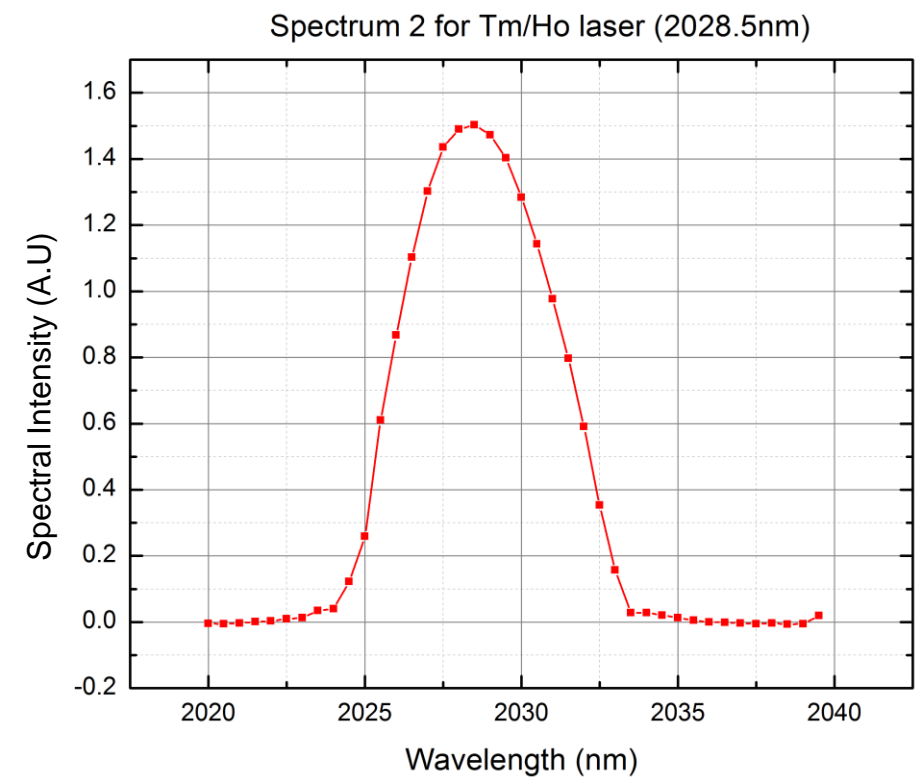
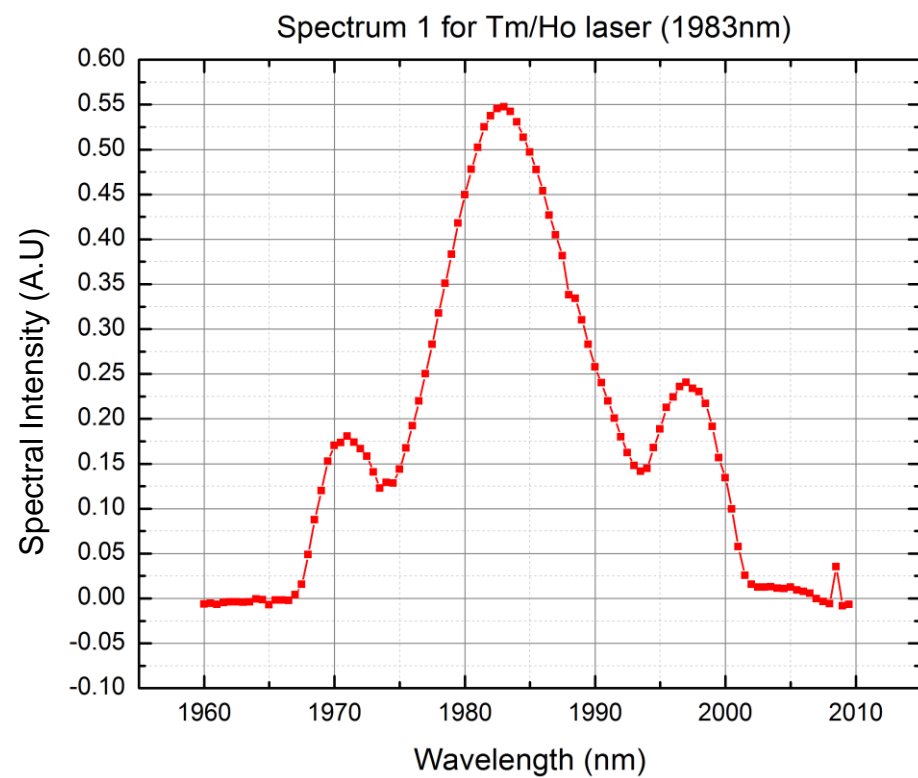


# Laser Setup

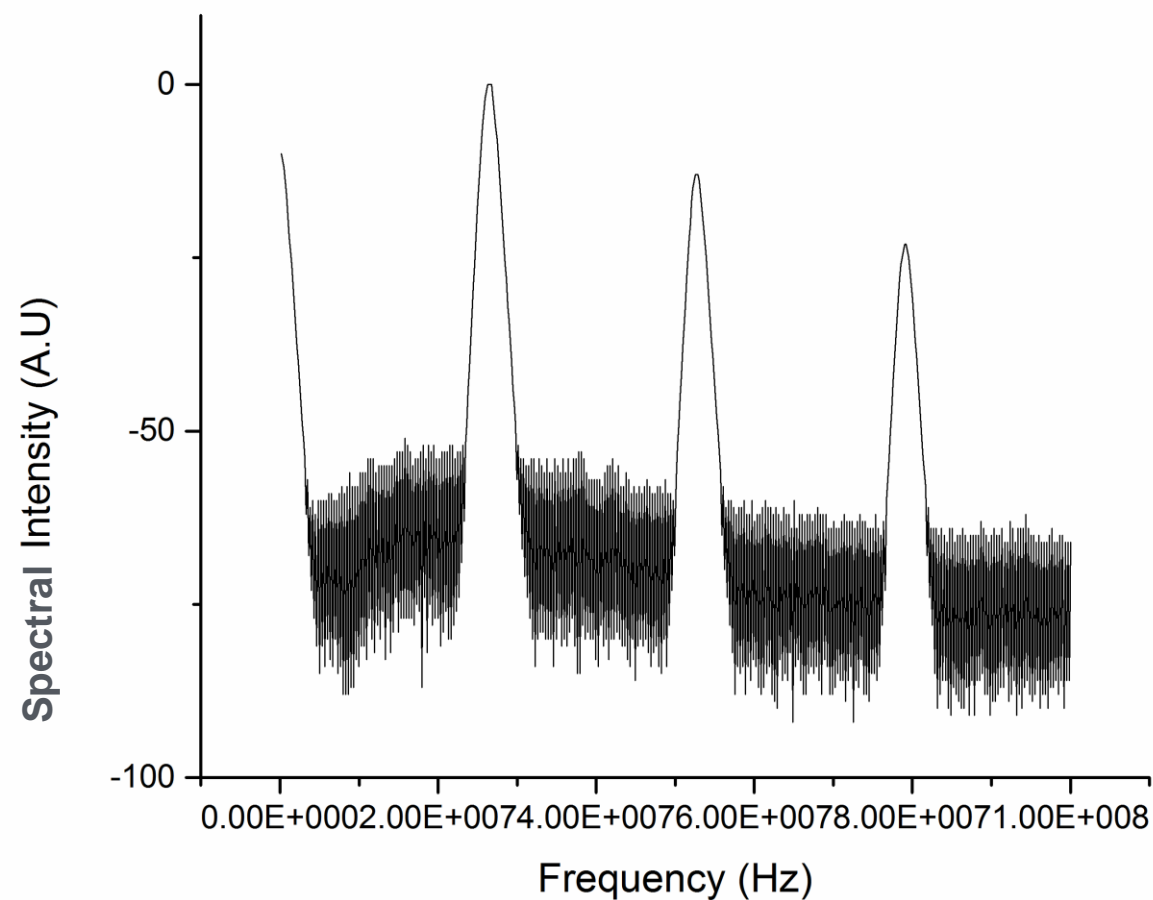




# Spectrum: No UHNA-7



# Spectrum: with UHNA-7



Length of Tm/Ho fiber: 1.24m

Length of UHNA-7: 2.889m

Length of SMF: 3.628m

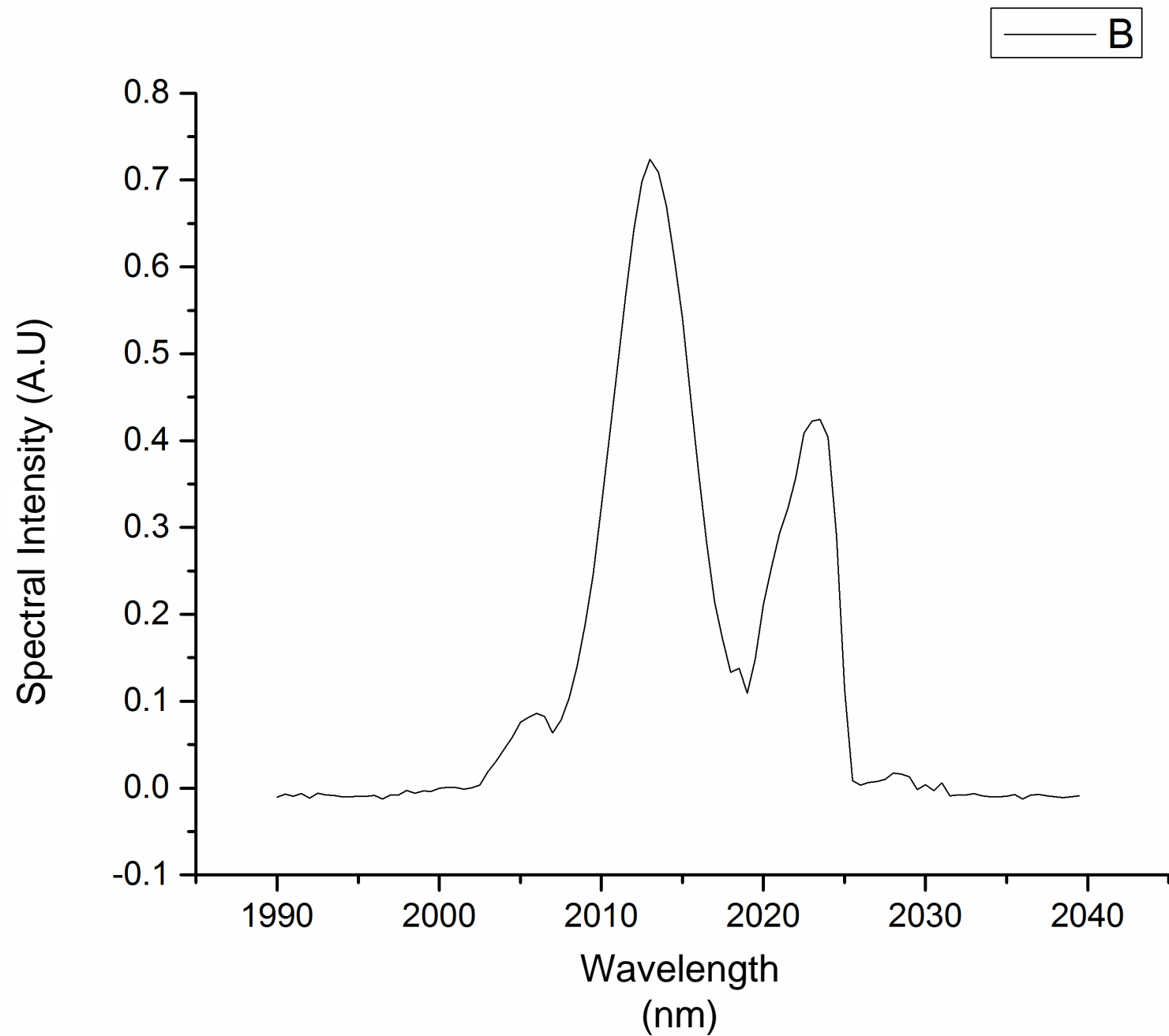
**TOTAL cavity length:**  
**L=7.757m**

Total cavity length from  
repetition rate:

$$\nu = \frac{c}{n} = \frac{L}{T}$$

**L=7.85m**

# Single Peak



# What's Next?

- Temporal pulse measurements
- Cut back UHNA-7 and see how the pulse changes

# Acknowledgements

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# References

- [1] R. Kadel and B. R. Washburn, “All-fiber passively mode-locked thulium/holmium laser with two center wavelengths,” *Applied Optics*, vol. 51, no. 27, pp. 6465-6470, Sept. 2012.
- [2] R. Kadel and B. R. Washburn, “Stretched-pulse and solitonic operation of an all-fiber thulium/holmium-doped fiber laser,” *Applied Optics*, vol. 51, no. 4, pp. 746-750, Feb. 2015.