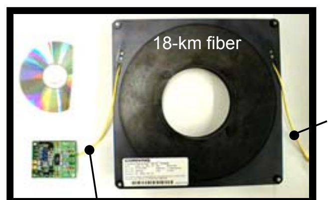
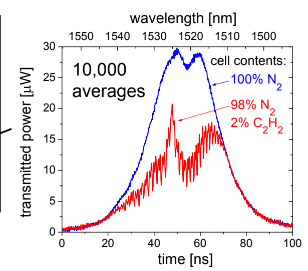
New Sensor Design Based On Frequency Comb Fourier Transform Spectroscopy For Combustion Studies

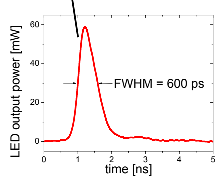
Thilo Kraetschmer, Joachim W. Walewski, and Scott T. Sanders

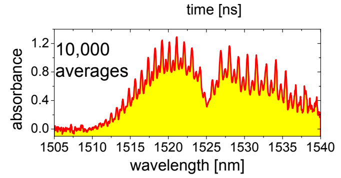
Recent hyperspectral sources developed:

Short, spectrally broad pulse dispersed by long fiber: '**chirp**' *Sanders lab*









drawbacks: 4, 6, 7, 9

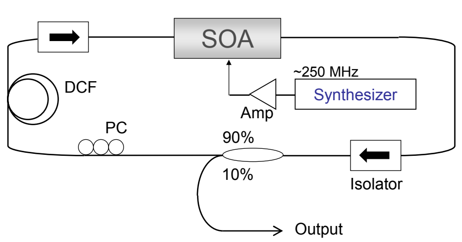
These sources share the following **advantages**:

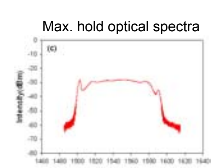
1. Inexpensive, for lasers (<$25k)
2. Wavelength = a consistent f(time)

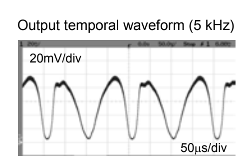
But all suffer from one or more of the following **drawbacks**:

1. Moving parts
2. One scan direction superior to other
3. Unreliable at rapid sweep speeds
4. Wavelength sweeps generally too fast
5. Undesirable polarization effects
6. Unsuitable outside of telcom bands
7. Sweep rates constrained
8. Spectral resolution unstable
9. Spectral resolution = f(wavelength)

Intracavity-dispersion mode-locked laser: '**dispersion locker**' *Yamashita et. al., CLEO 2006*

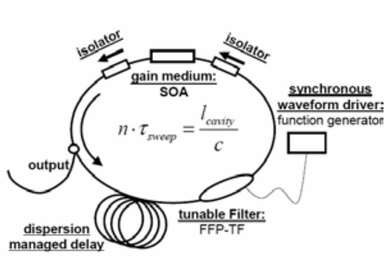


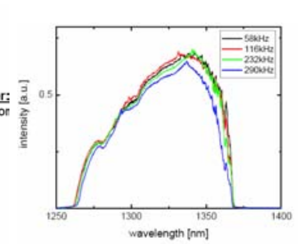


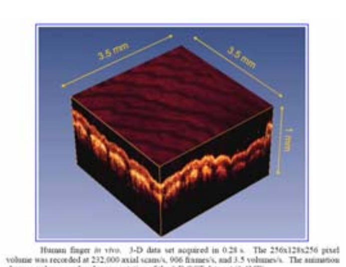


drawbacks: 2, 3, 7, 9

Fourier domain mode locked '**scan amplifier**' *Huber et. al., CLEO 2006*



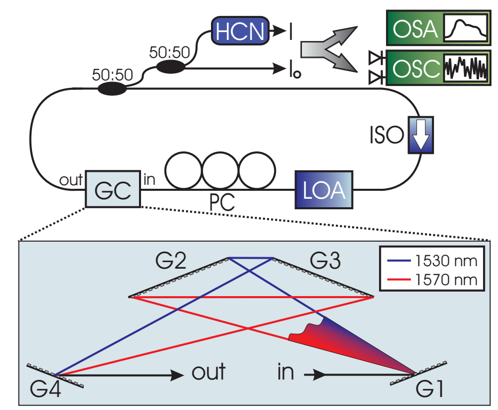




drawbacks: 1, 2, 5, 6, 7, 8

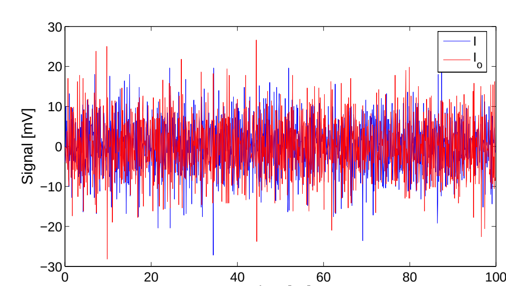
Instead of wavelength sweeps, here we use a Fourier approach (CW c-FTS): all colors always on, each modulated at a unique frequency. In principle, drawbacks 1-9 are eliminated.

Setup, Ring Cavity with Grating Compressor

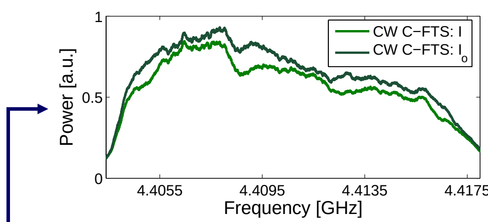


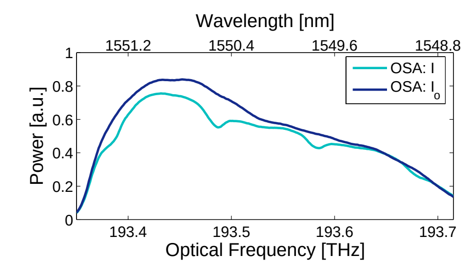
Picture of Setup

Time Trace I and Io of CW c-FTS



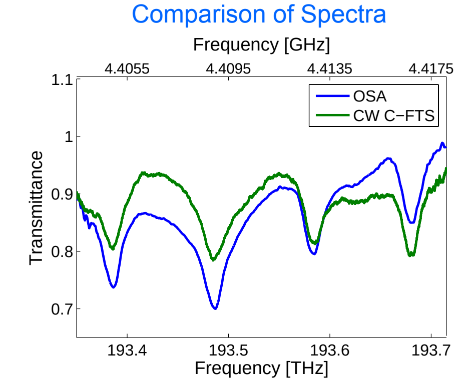
Fourier Transform of Time Traces…





… agrees with Spectrometer Data

Comparison of Spectra

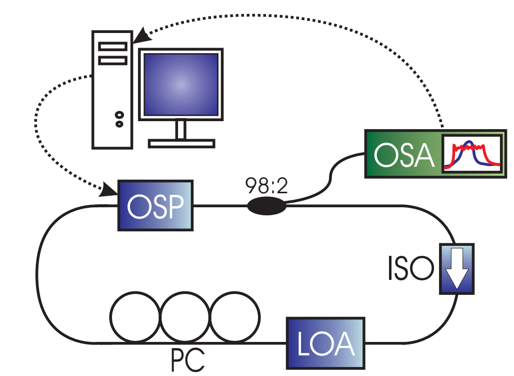


- CW c-FTS spectrum recorded in 1 ms.
- Required data acquisition bandwidth: 15 MHz
- With improved laser stability, expect total acquisition times limited only by Fourier principles
- With broader spectral coverage ~ 50 nm, the source is suitable to many sensing and imaging applications

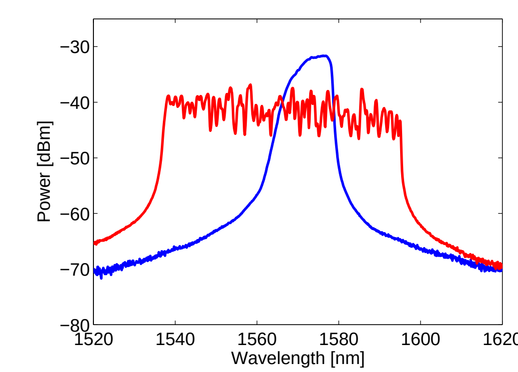
Challenge: Semiconductor gain media like our linear optical amplifier (LOA) tend to cover only ~ 5 nm

Solution: Control intracavity programmable spectral filter to broaden spectral coverage:

Setup, Ring Cavity with Optical Programmable Profiler, Closed Loop Control



Results



Next steps:

- Try version based on fiber Raman amplification rather than LOA gain medium. Raman ring should offer improved comb stability.
- Perform more simulations to forecast performance limits of CW c-FTS.

University of Wisconsin Engine Research Center