Equivalence in OC and EC between Single- and Multi-wavelength Carbon Analyzers

Judith C. Chow (Judith.Chow@dri.edu)
John G. Watson, Xiaoliang Wang, Dana L. Trimble,
Steven D. Kohl, Benjamin Sumlin, Steven Gronstal,
Sierra Mayorga and L.-W. Antony Chen

Desert Research Institute, Reno, NV

Presented at
the IMPROVE Steering Committee Meeting
Cape Romain NWR, South Carolina

October 15, 2014

Objectives

- Introduce the DRI Model 2015 Thermal/ Optical Carbon Analyzer

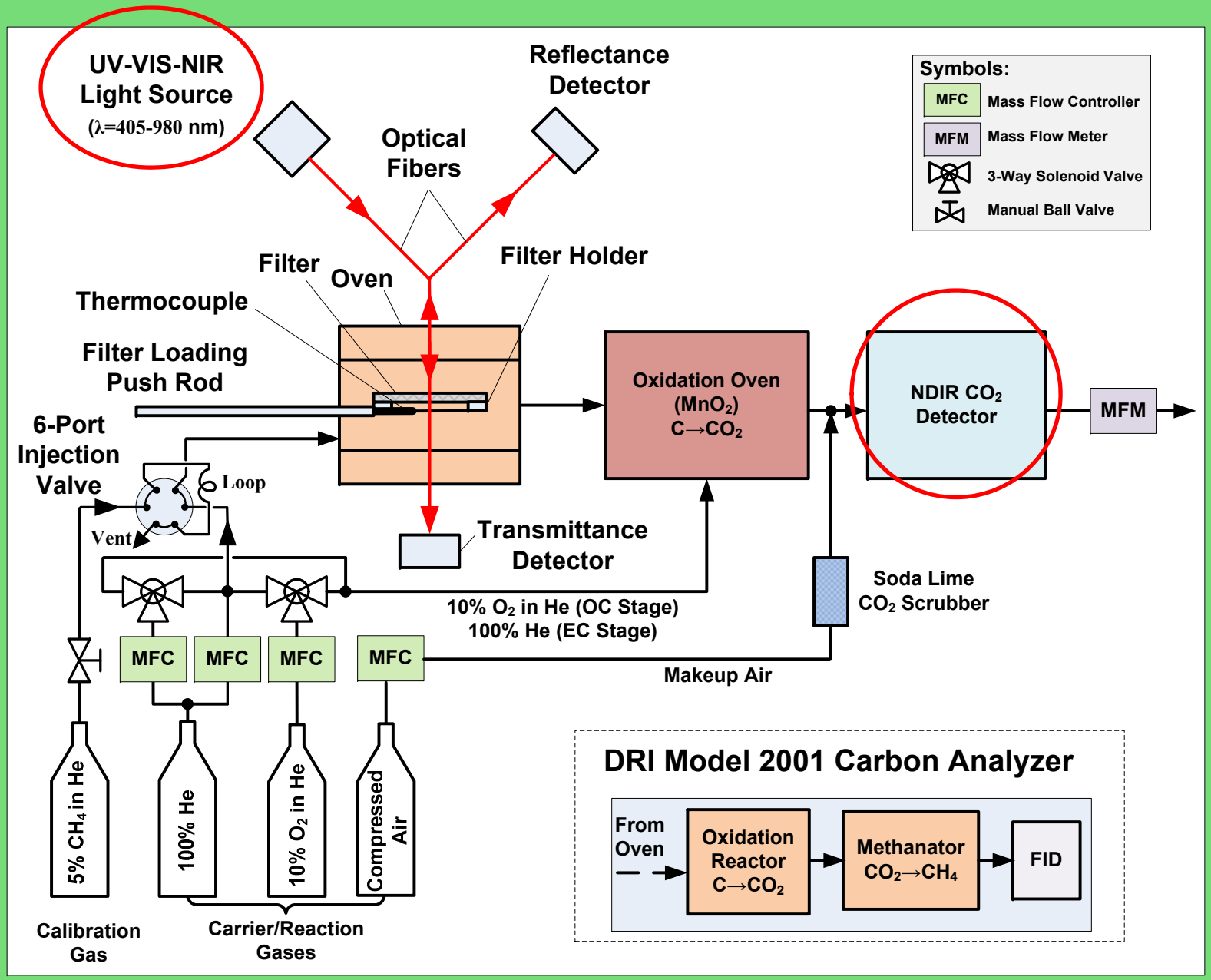
- Demonstrate the equivalence in OC and EC between Models 2001 and 2015

- Discuss follow-up and future plans

Motivations

- Improve efficiency
- Provide more information at lower cost
- Apply multiwavelength R and T to separate brown from black carbon
- Permit flexibility for further enhancements

Model 2015 Thermal/Optical Analyzer



Enhancements in Model 2015

- From single wavelength (λ=633 nm) to 7λ (405–980 nm)
- Replace customized with off-the-shelf parts (e.g., circuit boards)
- Increase stability and reliability (e.g., rotameter→ mass flow controller; and AC→DC heater)
- Provide easier operation and maintenance (e.g., eliminate H_2, and Ni catalyst methanator; provide pull-out drawer for maintenance)
- Reduce cost (e.g., HeNe laser → diode lasers; FID → NDIR, and less hardware) and laboratory footprint (by ~35%)

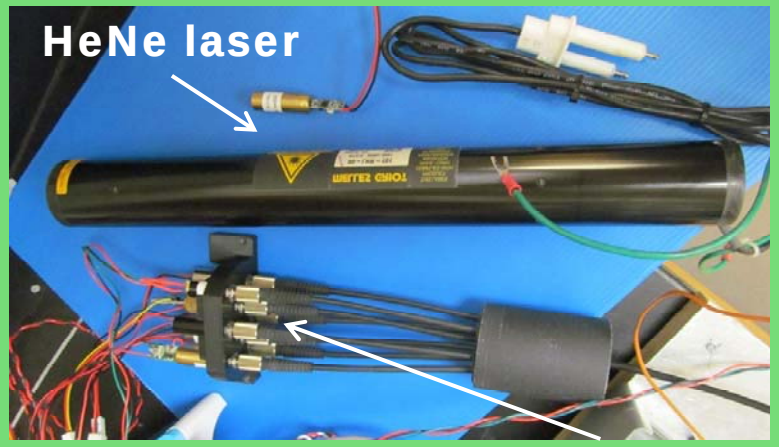
Model 2015 uses the same heating system and light pipes as Model 2001 to retain OC/EC consistency

Component	Model 2001	Model 2015
Light Source	633 nm HeNe laser	405, 445, 532, **635**, 780, 808, and 980 nm diode lasers
Fiber optic	bifurcate fibers (bundle)	8-leg fibers (single)
Sample oven	One arm	Branched side arm
Flow control	Rotameters	Mass flow controllers
Sample oven power supply	110 V AC	DC
Circuit boards	Custom made	Generic/Programmable
Detector	FID (CH_4) detection (requires ultrapure H_2)	NDIR (CO_2) detection (no H_2)
Conversion after thermal evolution	Oxidization (to CO_2) and reduction (to CH_4)	Oxidation (to CO_2)
Data acquisition	Keithley	National Instruments
Software	Visual Basic/C+	LabVIEW

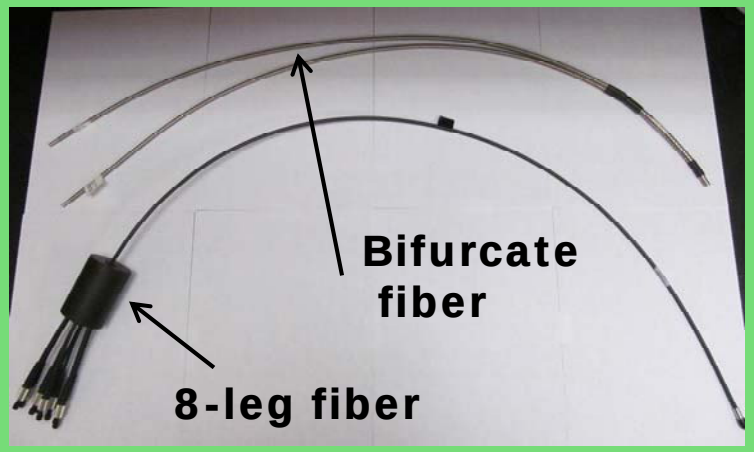
Components Comparison

(Model 2015 components on the bottom of each picture)

Laser



Fiber Optics



Oven

Flow Control

Rotameters

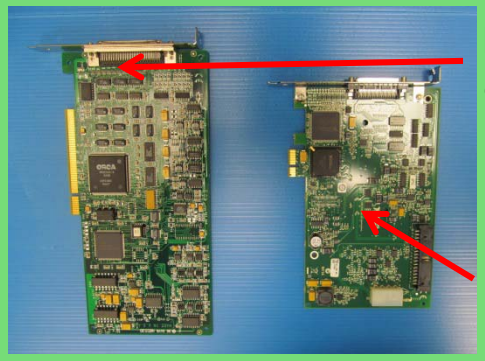
Mass flow controllers

Components Comparison (cont.)

(Model 2015 components on the right of each picture)

AC transformer

DC power supply

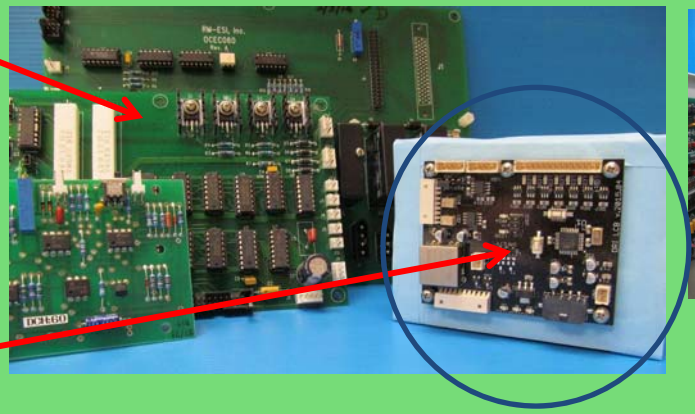


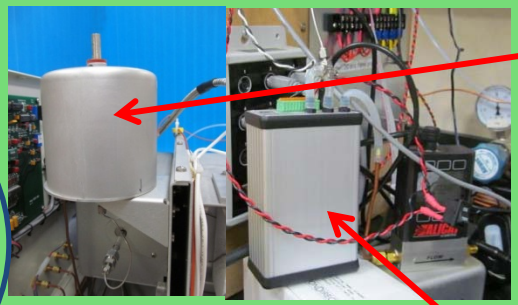
Keithley data acquisition card

National Instruments data acquisition card

Custom circuit boards

Programmable board

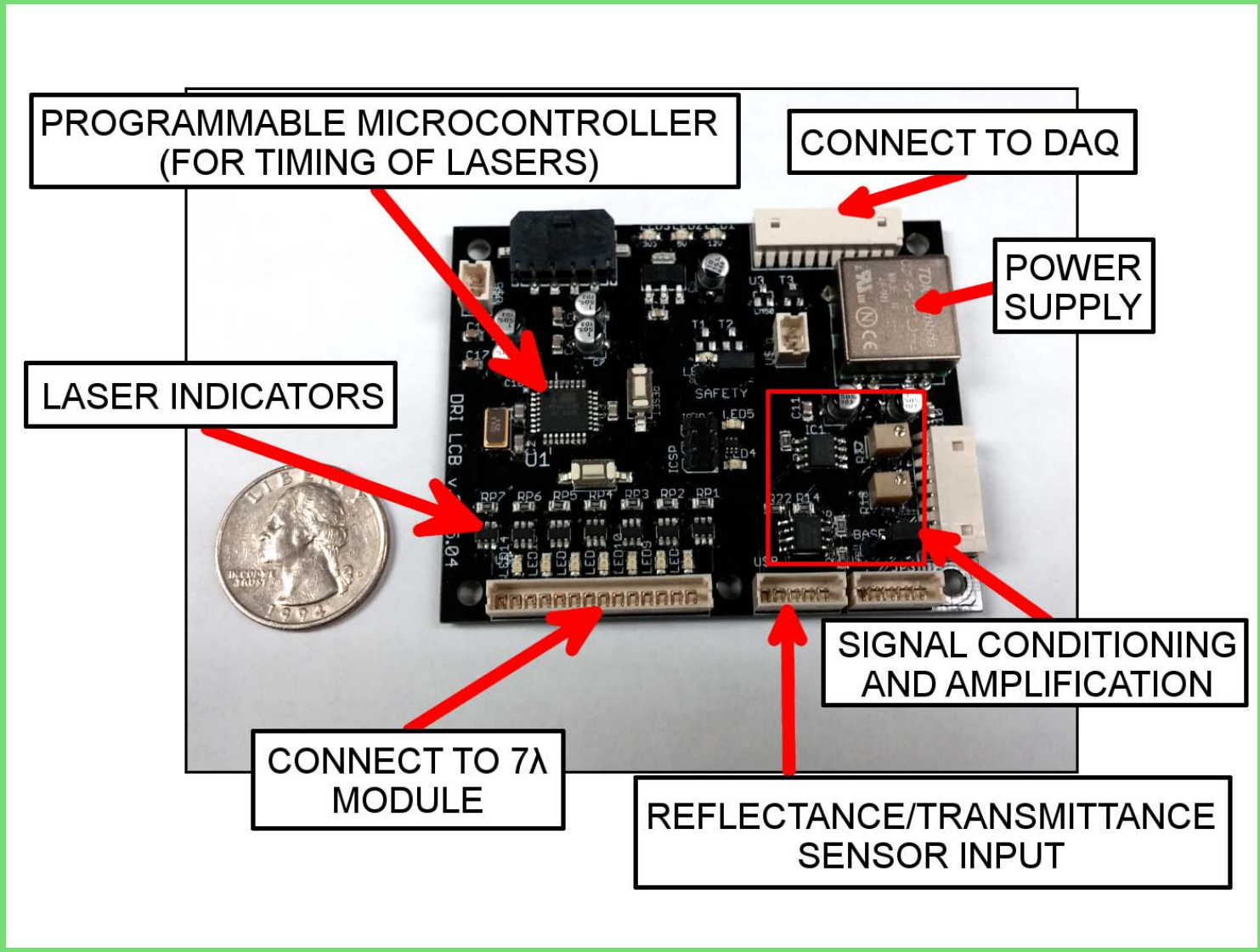




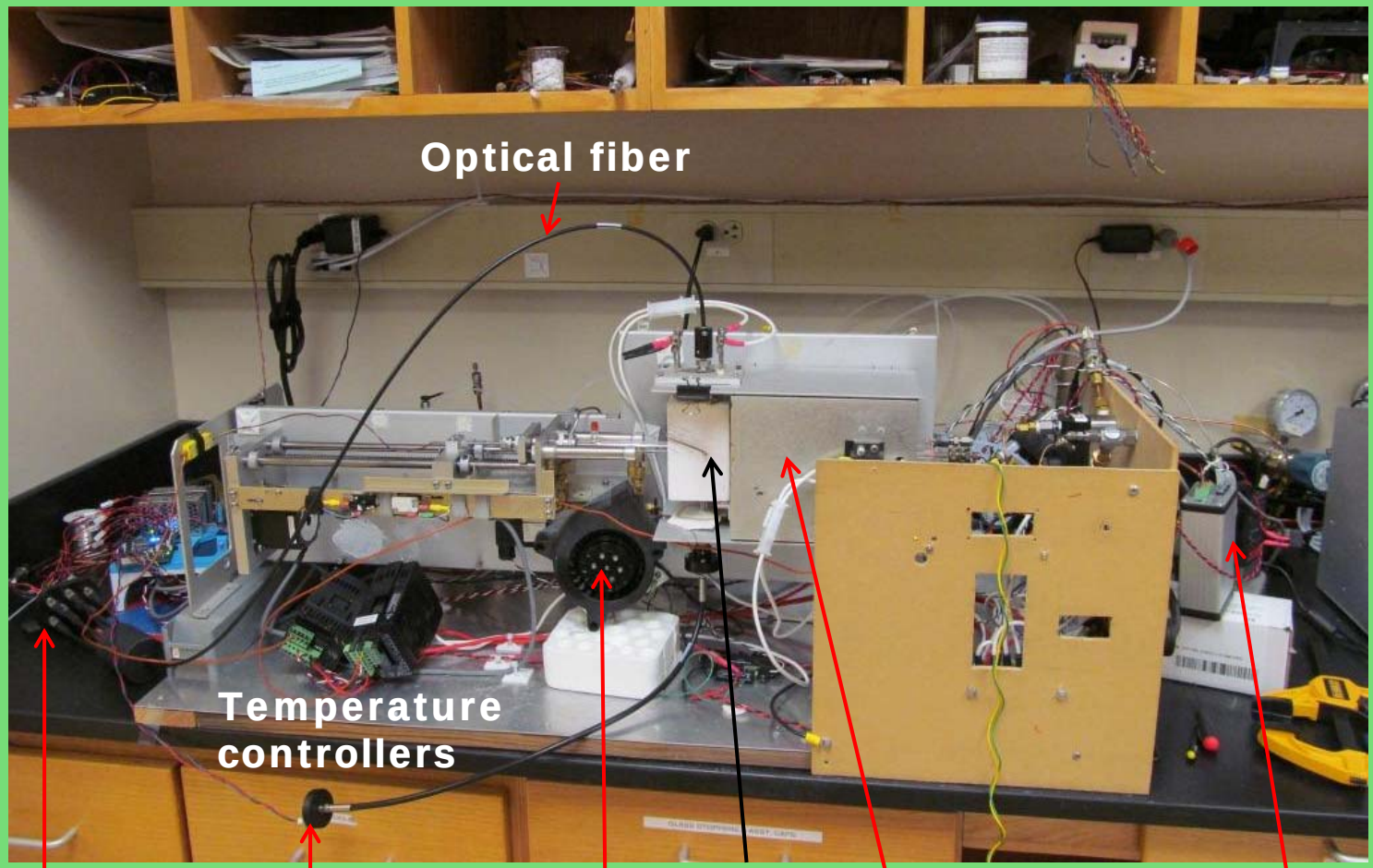
Flame ionization detector (FID)

Non-dispersive Infrared Detector (NDIR)

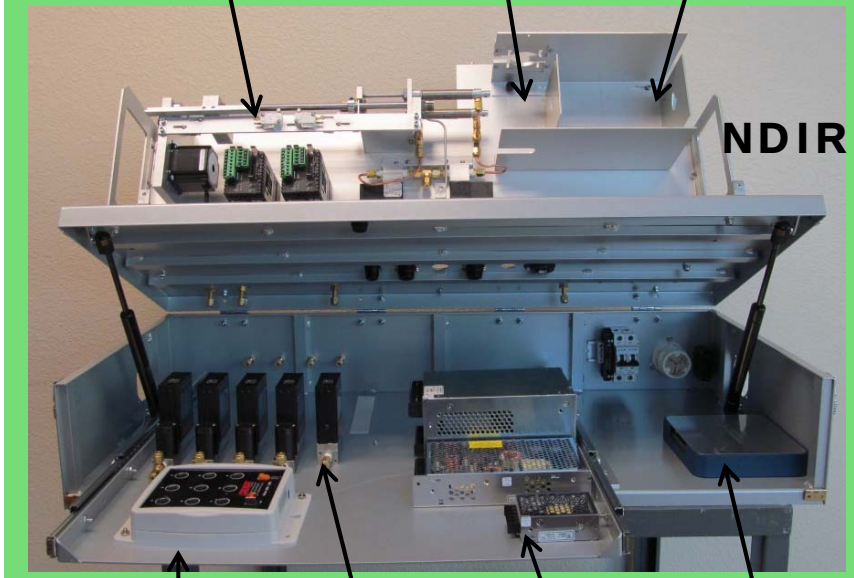
A small microcontroller coordinates the signal creation and detection



Samples were analyzed on the prototype Model 2015



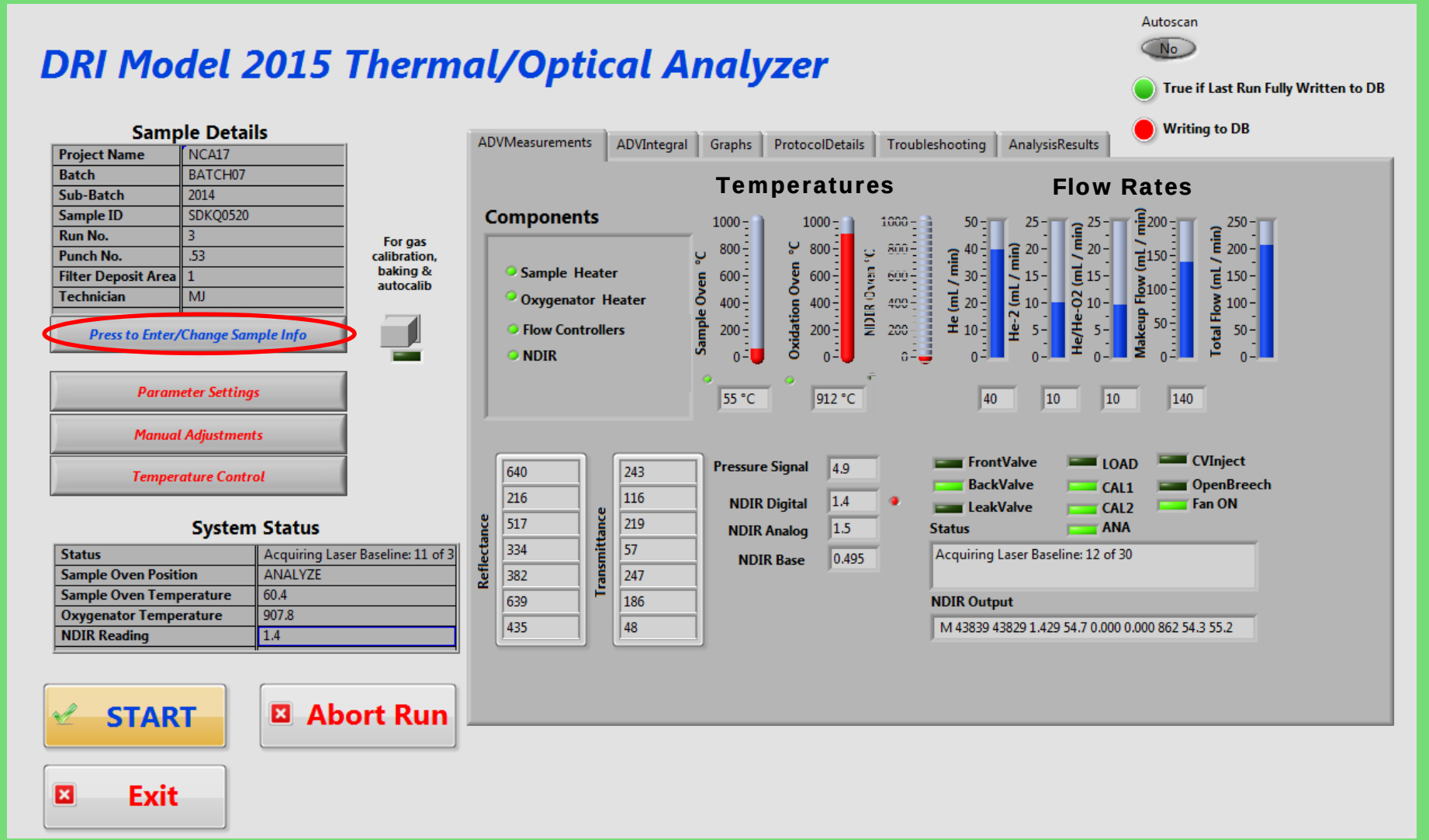
New Model 2015 is under construction



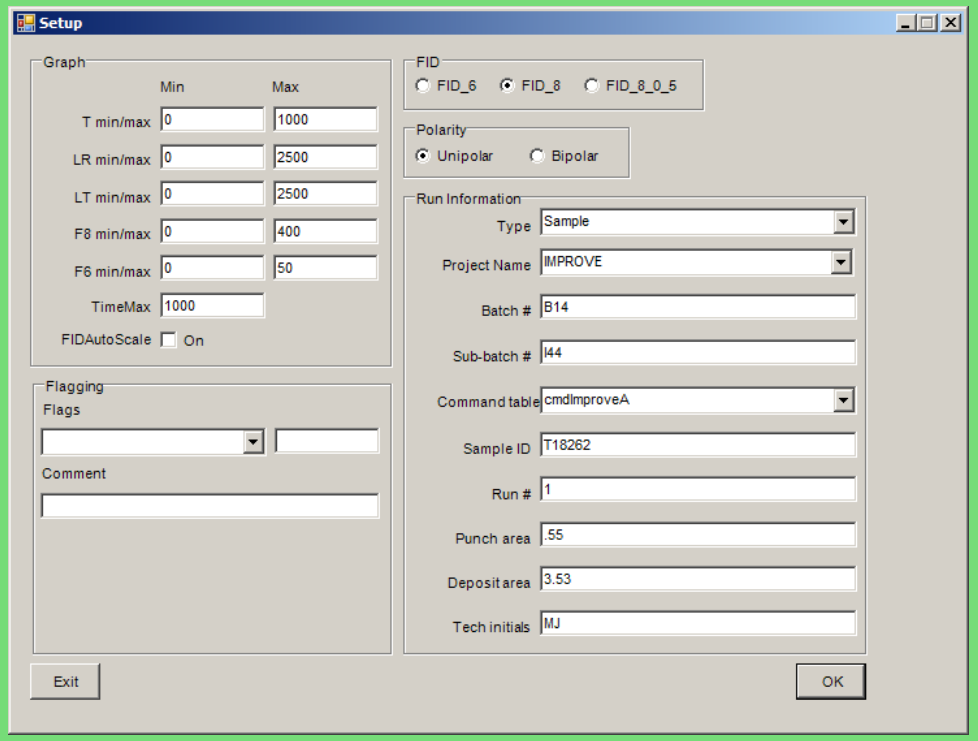
With pull-out drawer for maintenance

Main Operation Screen for Model 2015

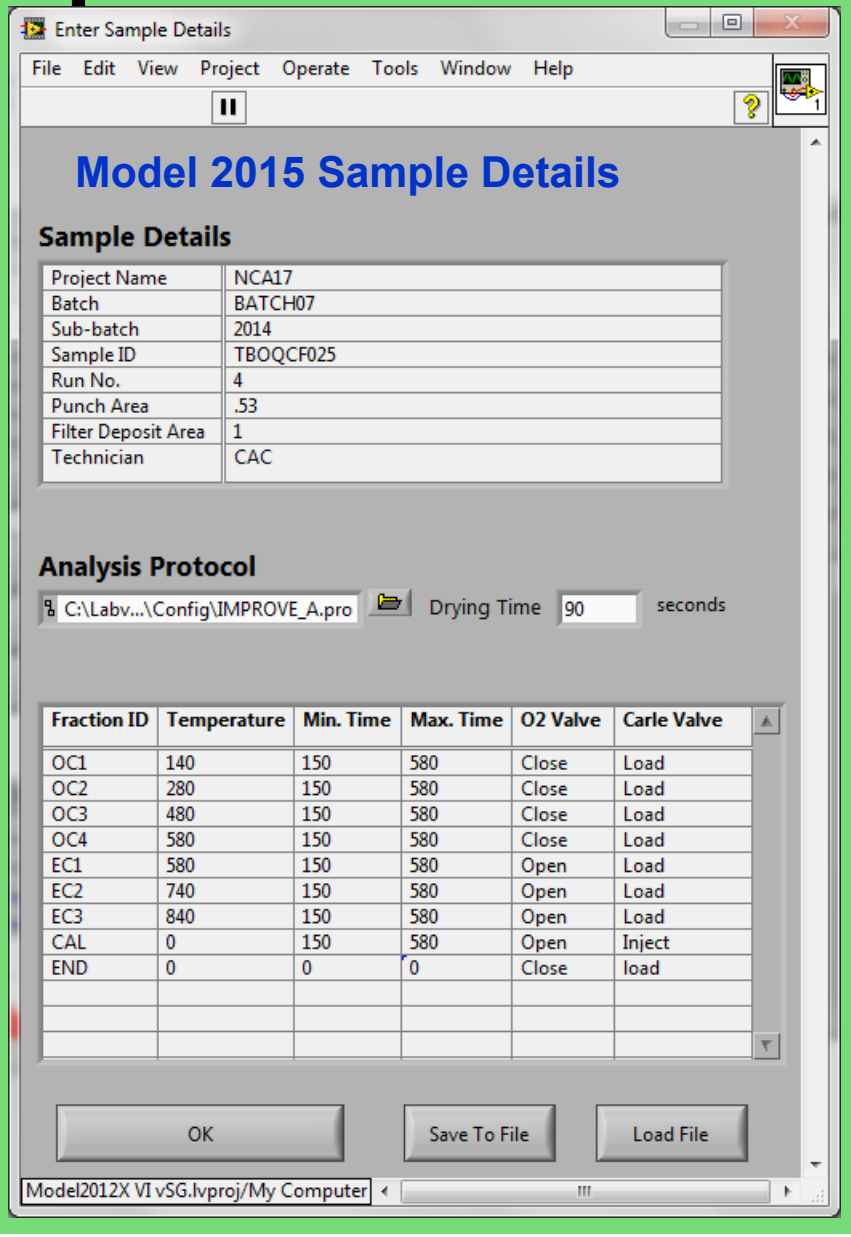
(User-Friendly LabVIEW)



Model 2015 includes more details in "sample info" input screen

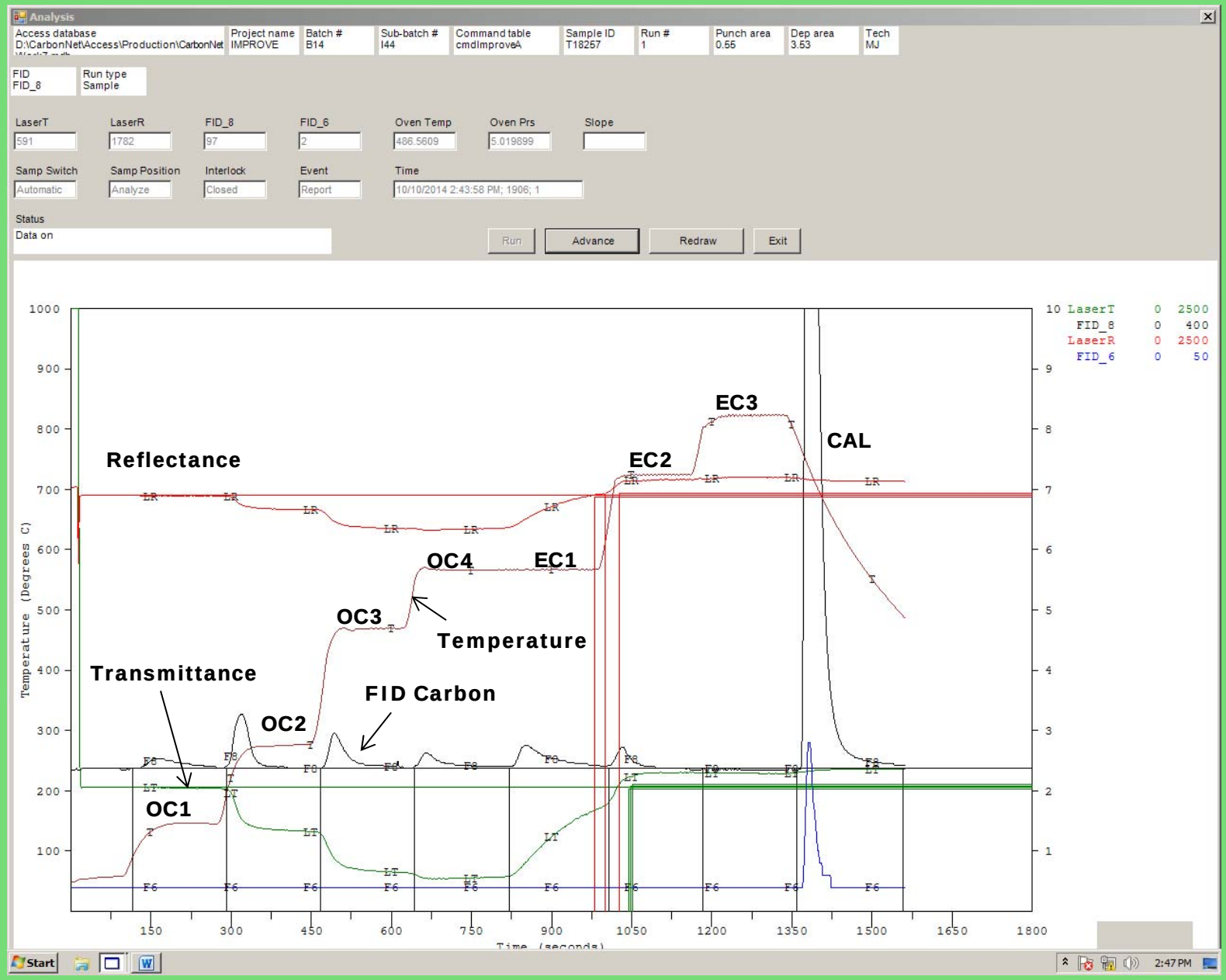


Model 2001

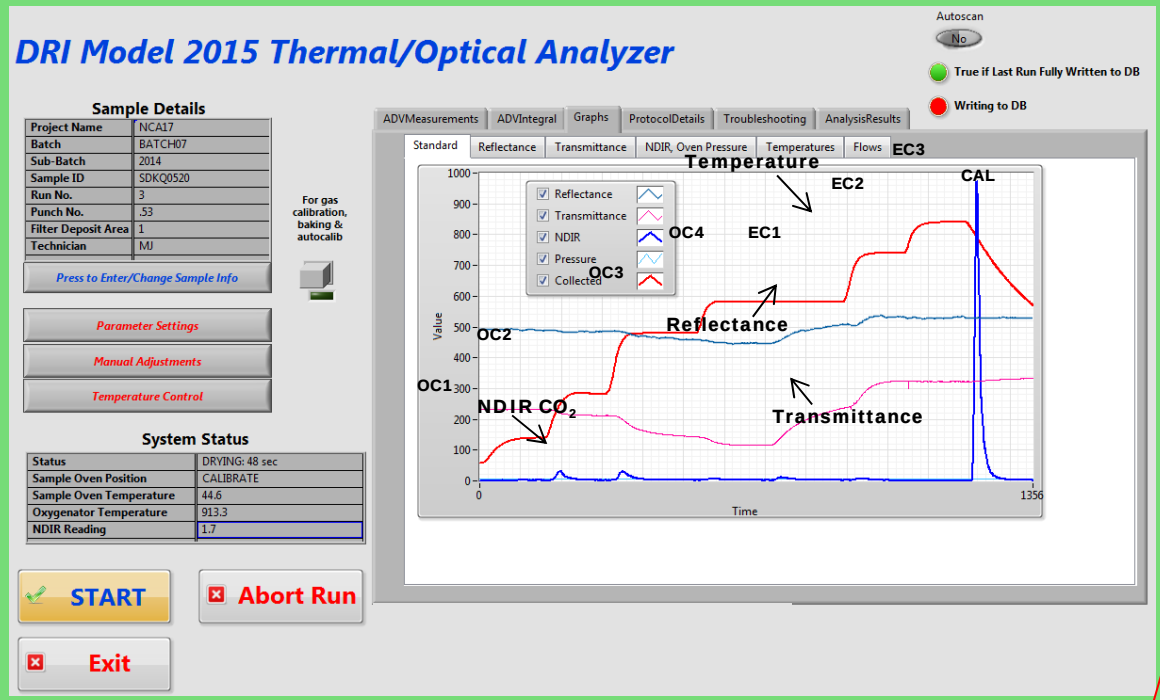


Model 2015

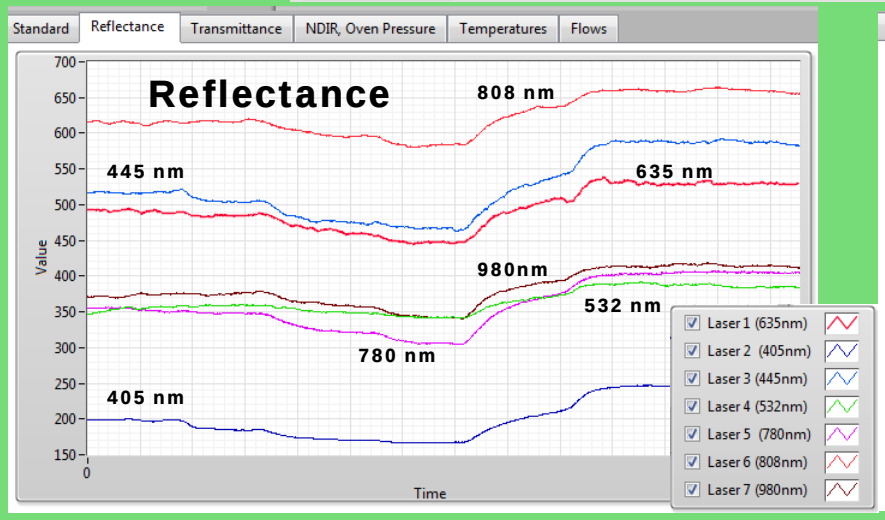
Model 2001 Thermogram Display

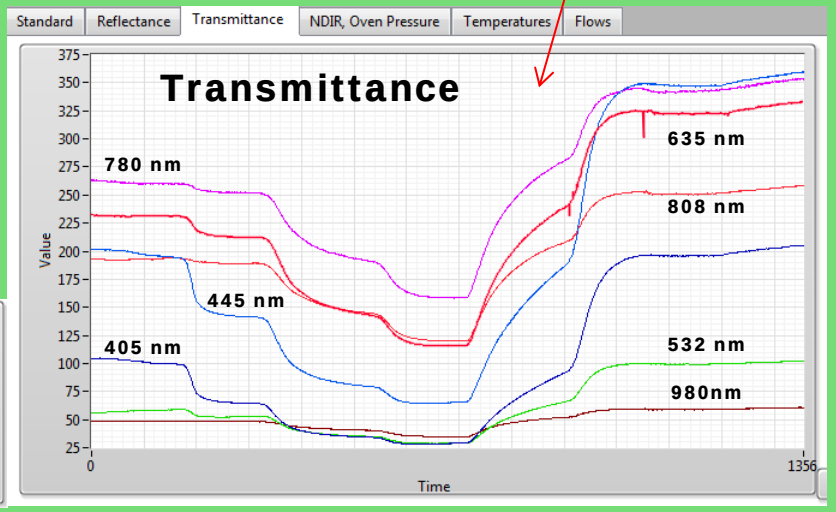


Displays for Model 2015 show 635 nm reflectance and transmittance (Similar to Model 2001)



Optical signals with 7λ



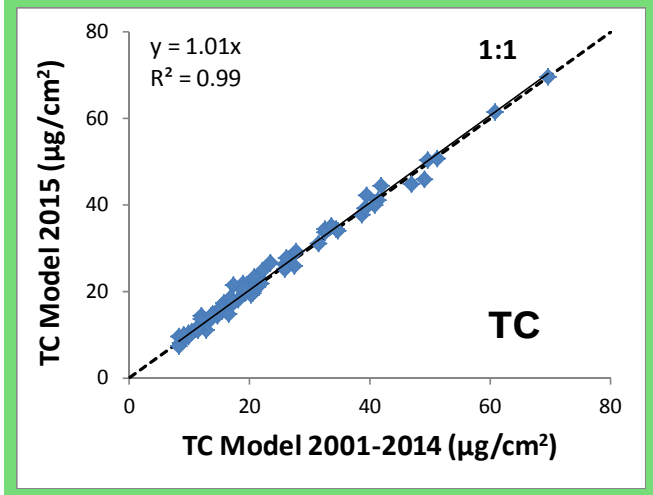


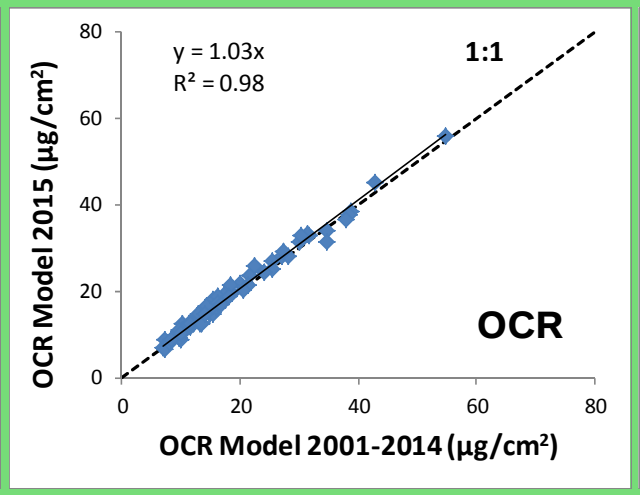
IMPROVE and urban Fresno samples* were analyzed for equivalence testing

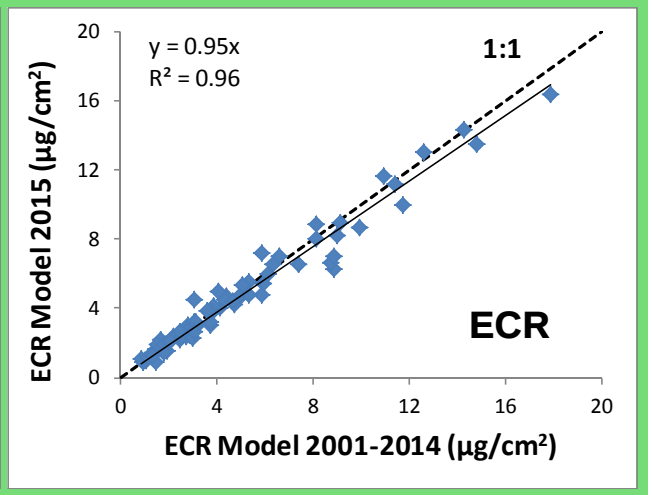
- 73 IMPROVE-X Modules (2010-2014)
- 71 IMPROVE (2010-2013)
- 67 Fresno Supersite Samples (2003-2006)

*n=211

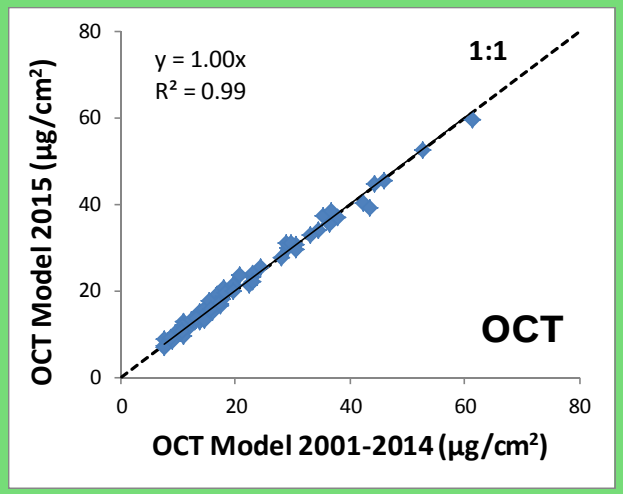
Good equivalence is found for Fresno samples analyzed by Model 2001 and Model 2015

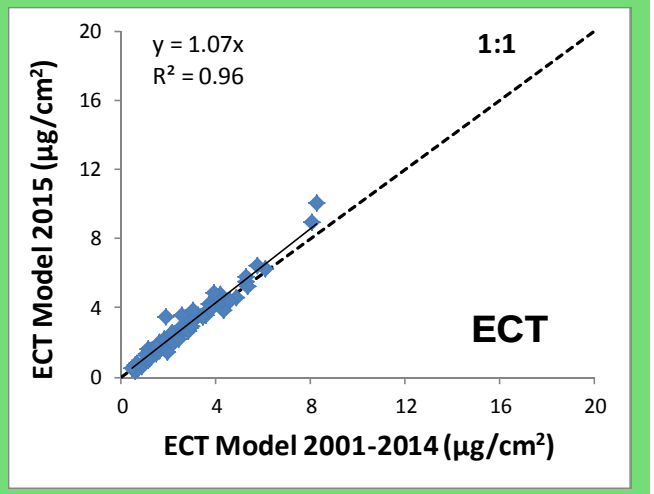




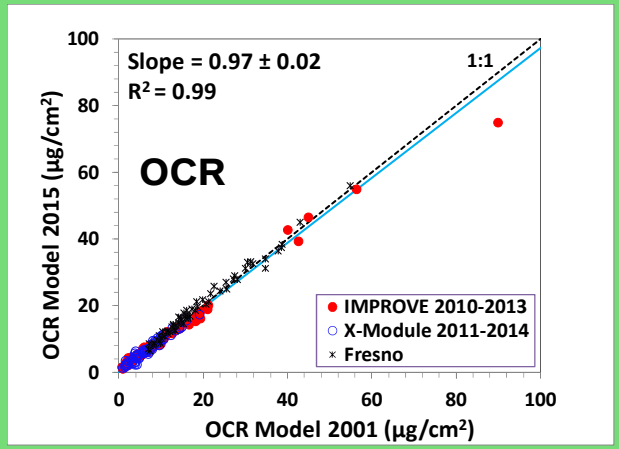


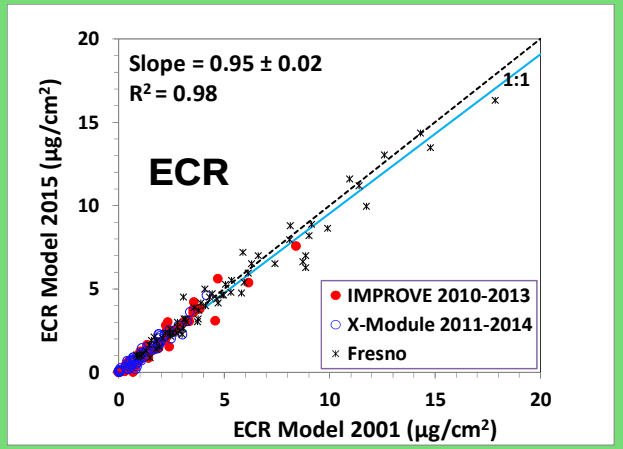
N=67

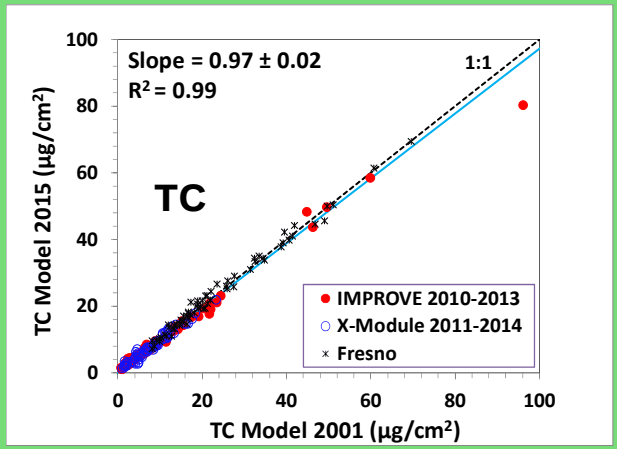


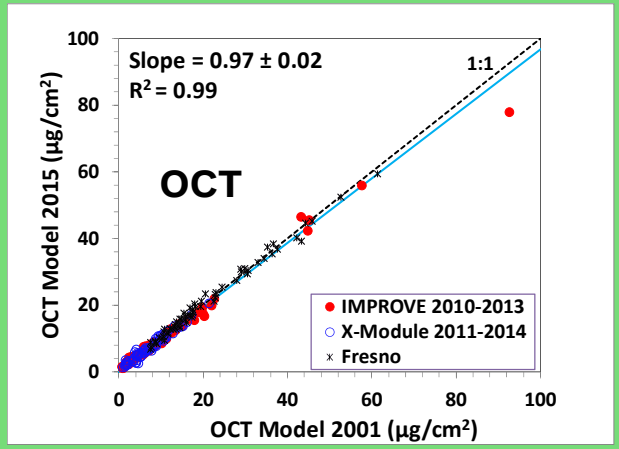


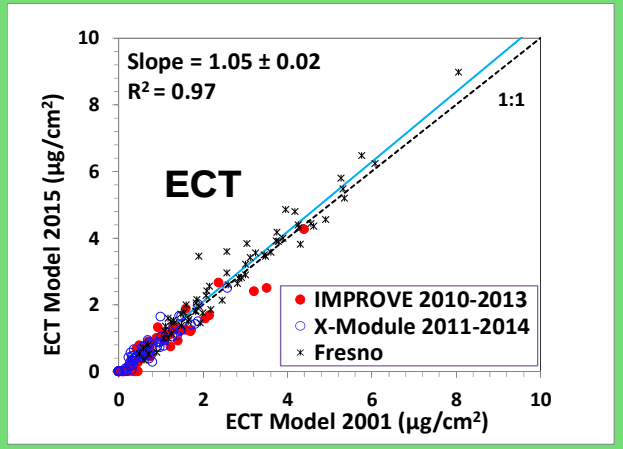
For a wide variety of samples, TC, OC, and EC compare well between model 2015 (635 nm) and Model 2001 (633 nm)





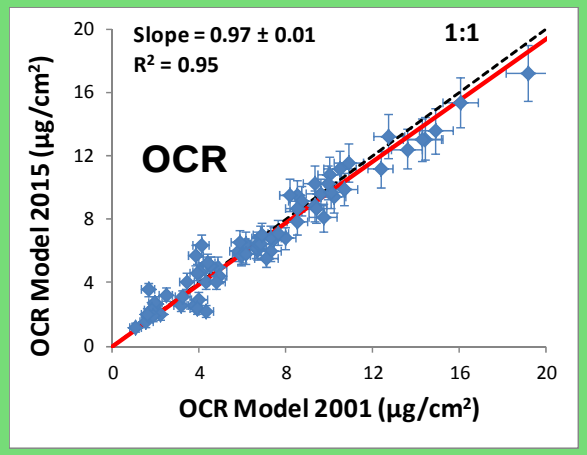


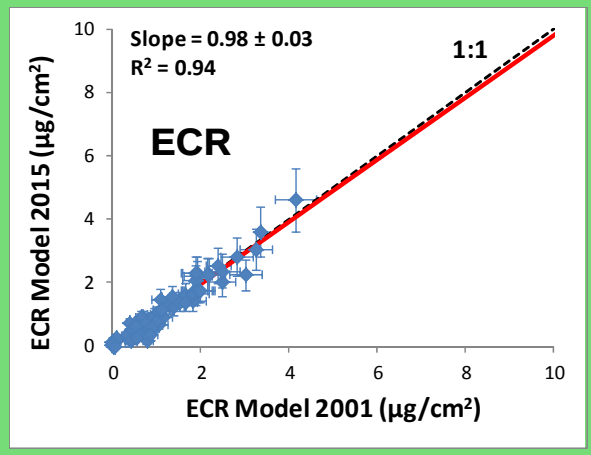


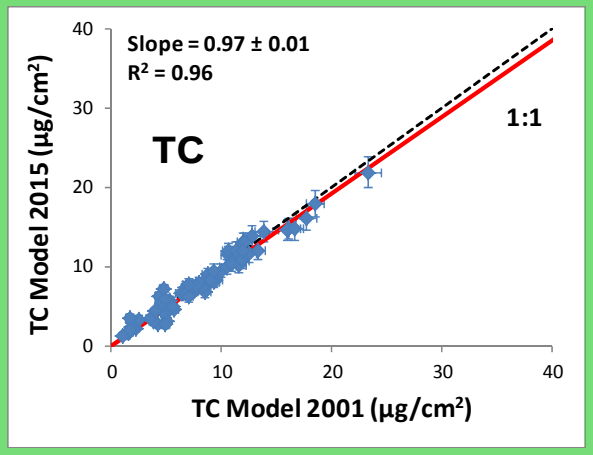


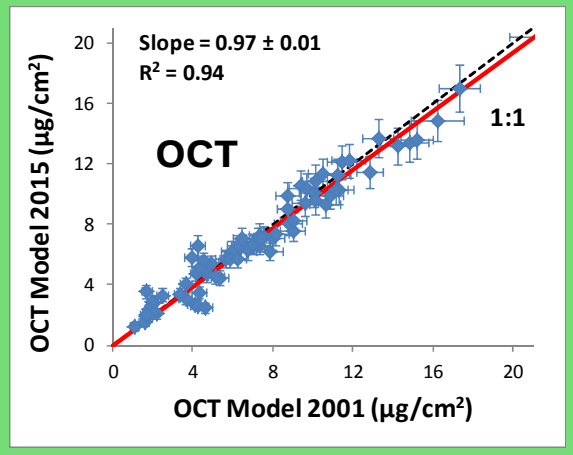
N=211 (IMPROVE 2010-2013, X-Module 2011-2014, and Fresno)

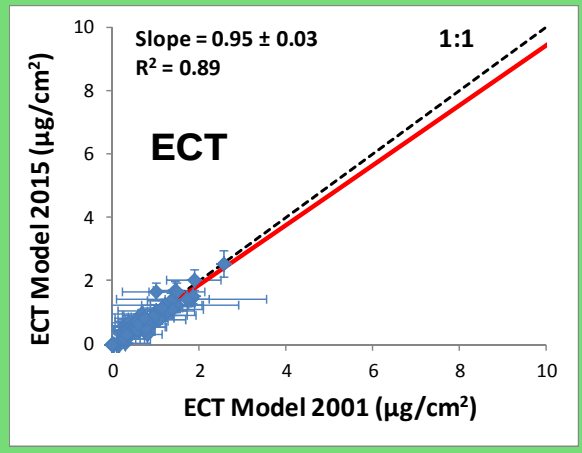
For IMPROVE samples, TC, OC, and EC are comparable for 2015 (635 nm) and Model 2001 (633 nm)





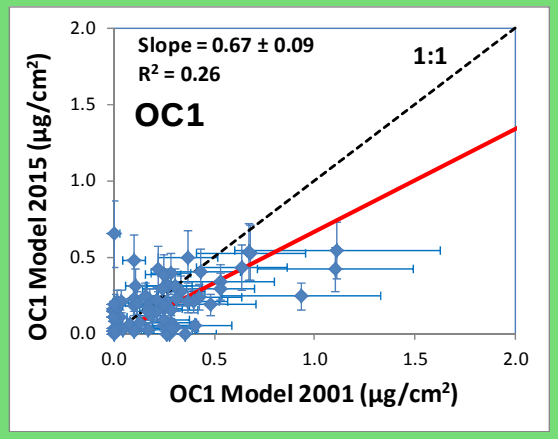


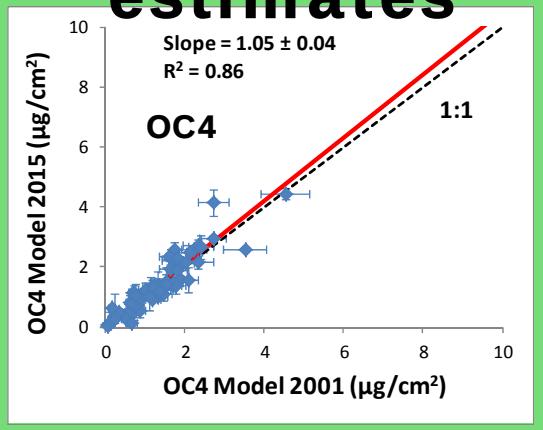


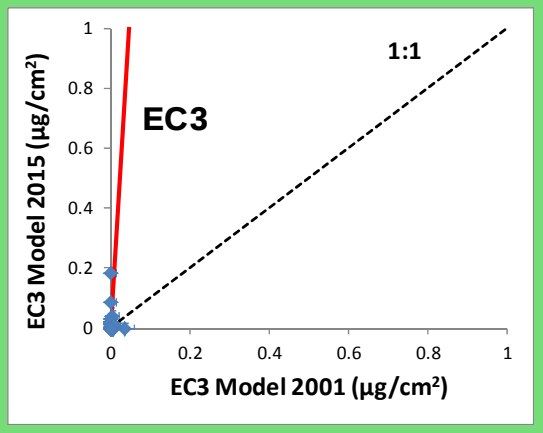


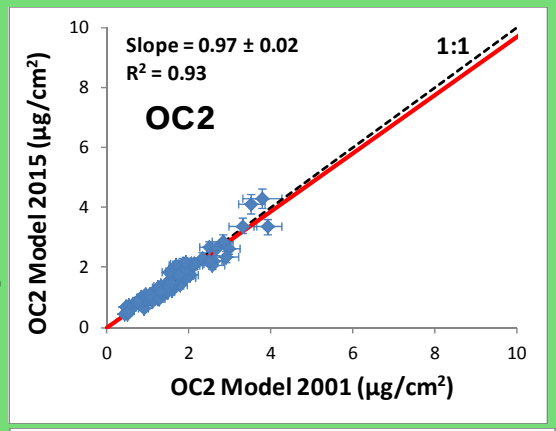
N=73 (IMPROVE X-Module 2011-2014)

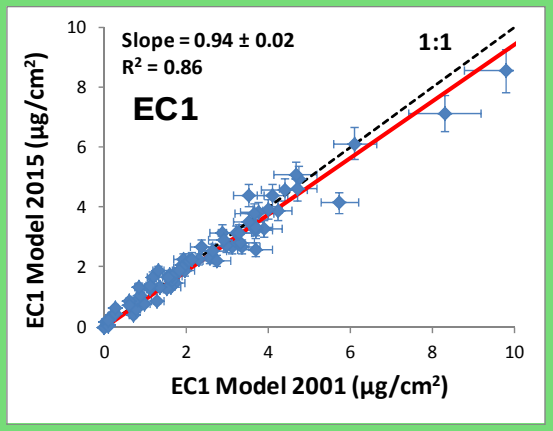
Most carbon fractions are within uncertainty estimates

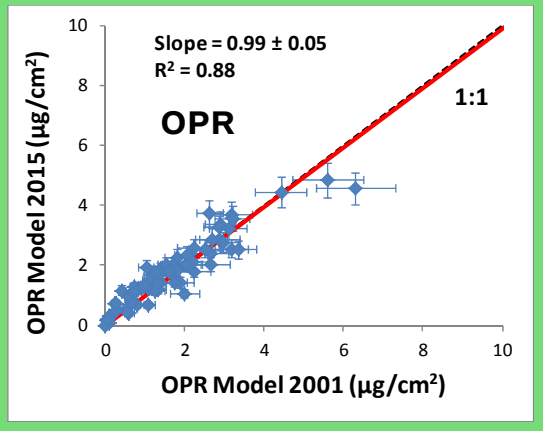


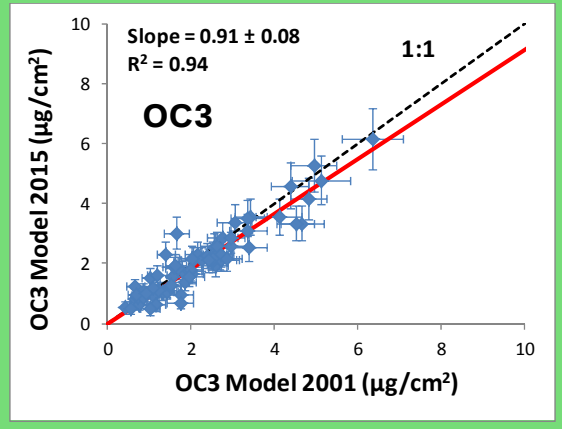


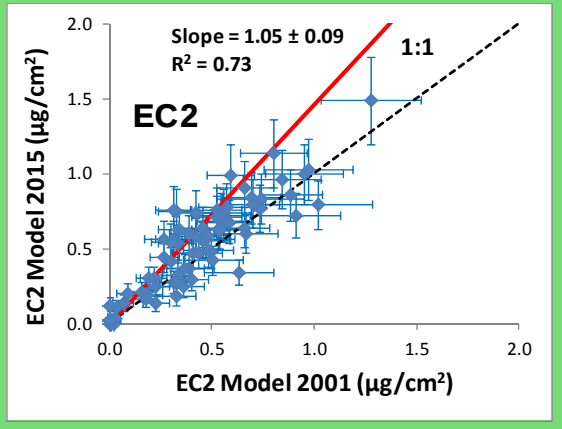


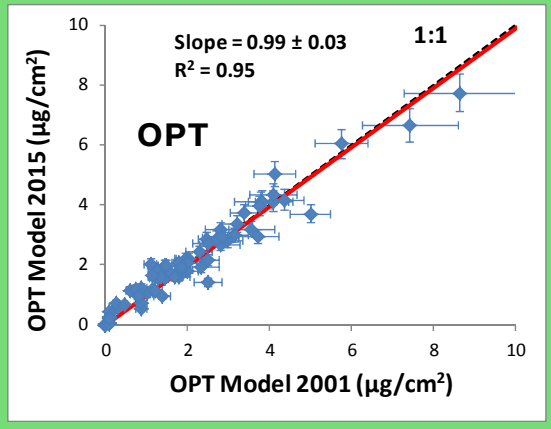












y - Model 2015

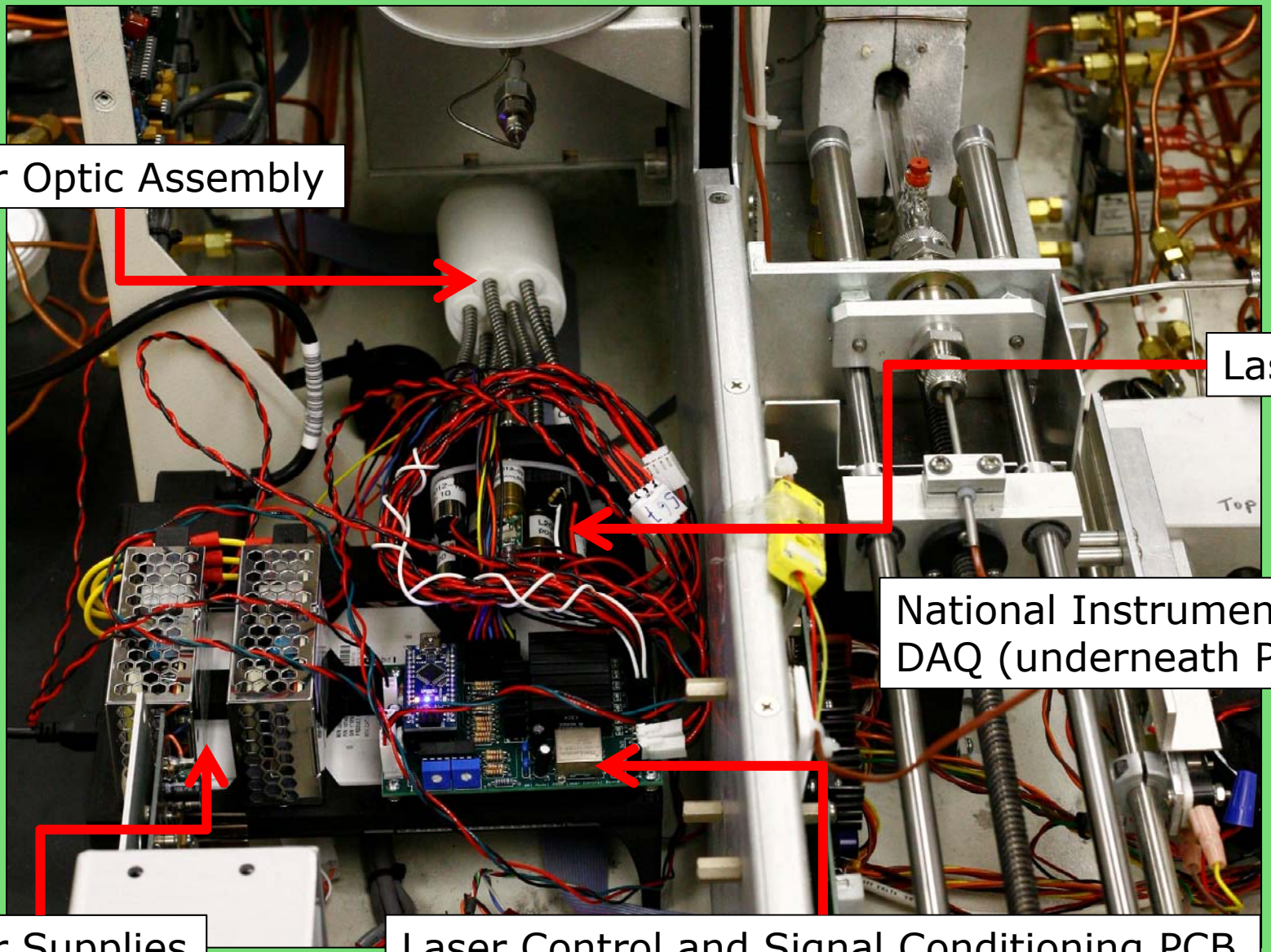
x - Model 2001

N=73 (IMPROVE X-Modules)

Summary

- Consistency in OC and EC is found between Models 2015 and 2001 Carbon Analyzers
- Model 2015 has enhanced features with modernized components and provides additional optical characteristics

Existing Model 2001 analyzers can be retrofitted with seven-wavelength laser (Model 2001-7λ)



Follow-up and Future Plans

- Start replicates on a growing fraction of samples with Model 2015 and Model 2001-7λ retrofits
- Compare precisions for different units
- Prepare publication documenting equivalence
- Begin 7λ data reporting for 2015 IMPROVE samples