High-Energy Laser Diagnostics (HELD) for the Measurement of Diesel Particulate Matter

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Program Manager: Gurpreet Singh

Outline

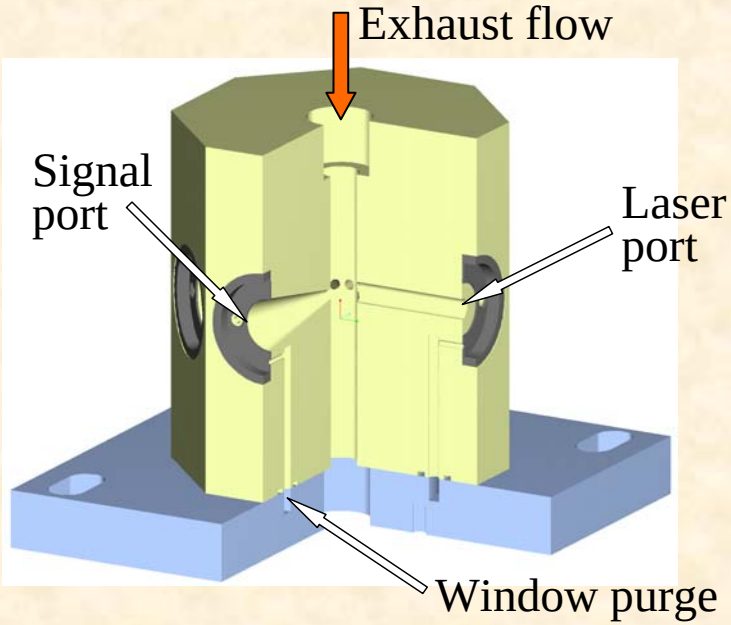
- Need for HELD
- Laser-induced incandescence (LII)
- Laser-induced desorption with elastic laser scattering (LIDELS)
- Laser-induced breakdown spectroscopy (LIBS)
- Current status and future plans

Need for high-energy laser diagnostics (HELD)

- Real-time PM measurement techniques are needed to investigate transients
- Sensitive PM measurement techniques are needed to study cleaner vehicles
- *In situ* PM measurement techniques are needed to characterize engine-out/aftertreatment-in conditions for design optimization and aging models

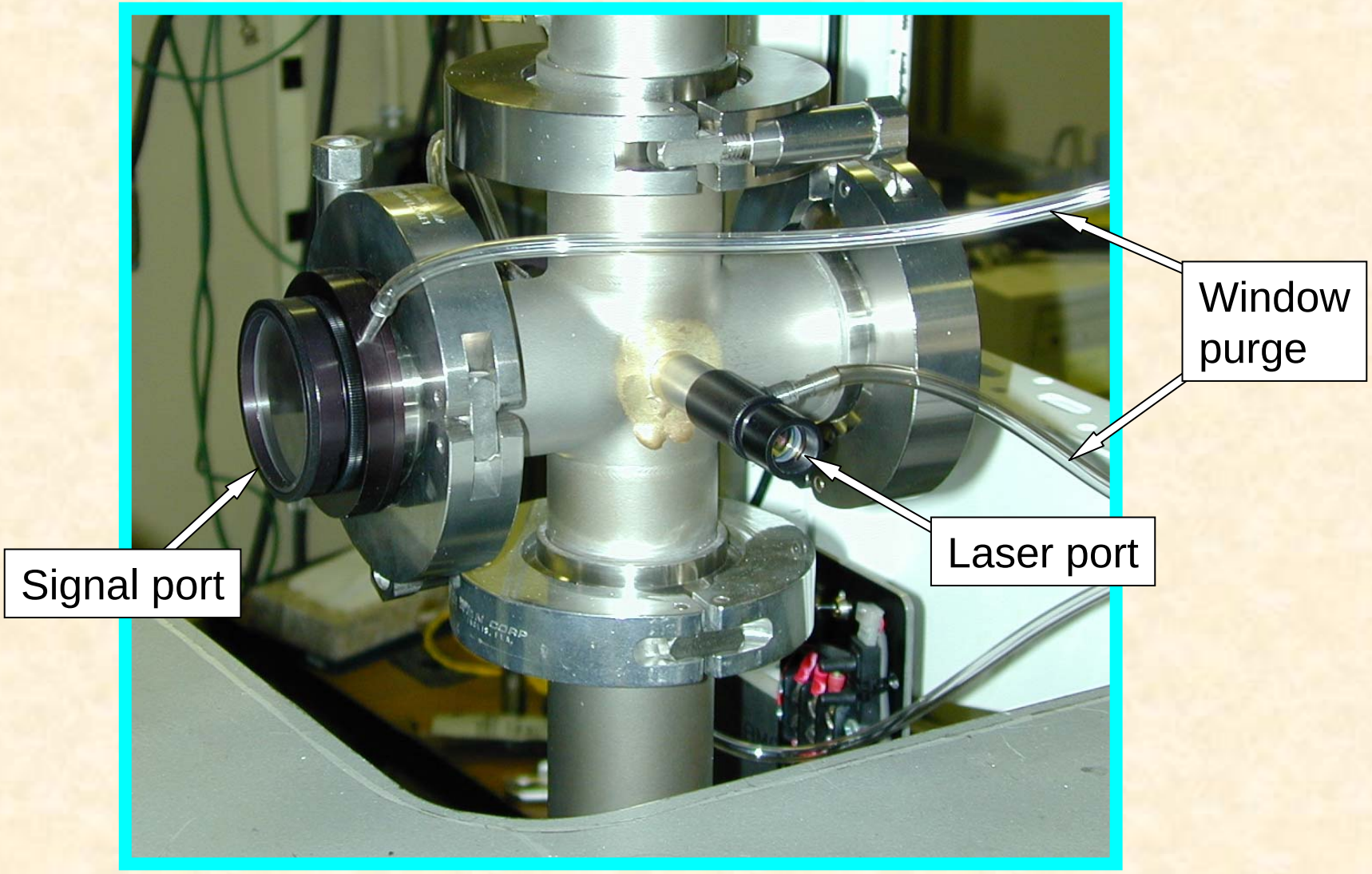
Sandia HELD system (laboratory-on-wheels)

6 signal ports and active purge
to keep windows clean

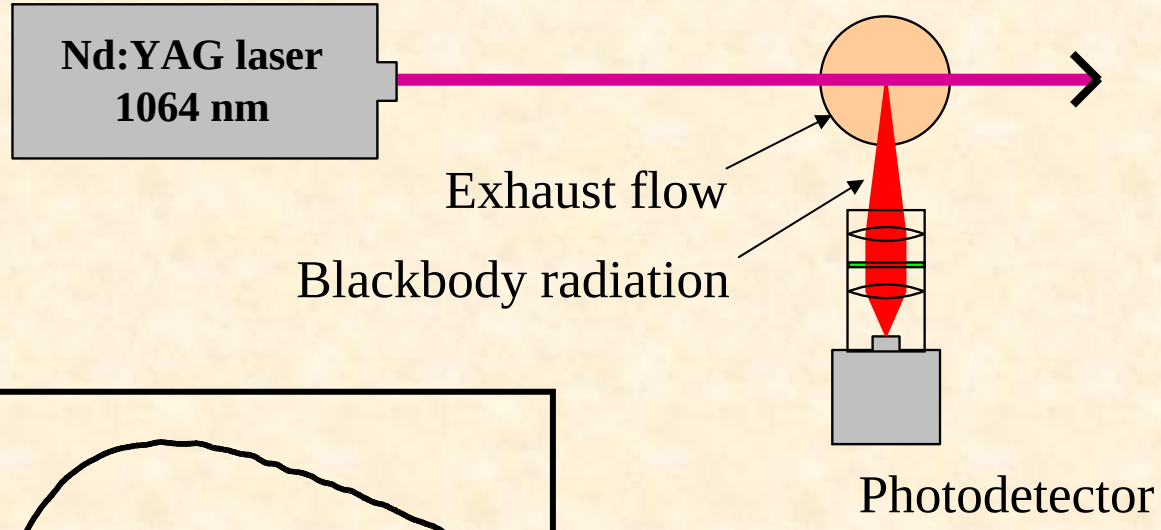


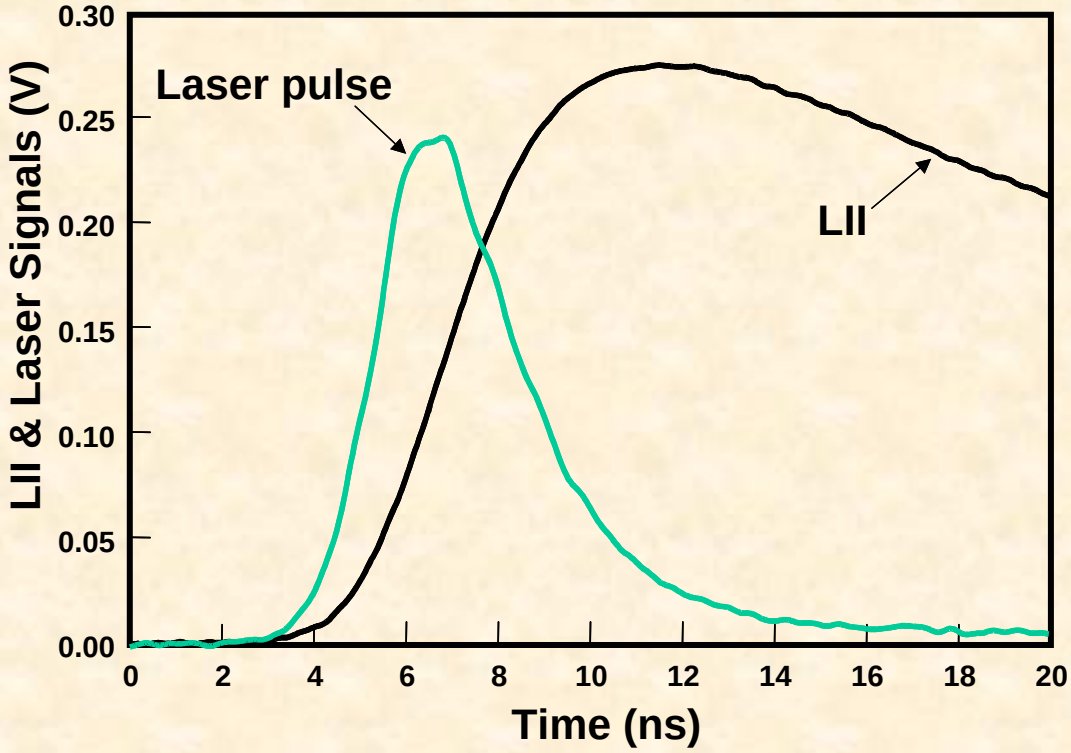
Optical sampling cell

In situ optical cell



Laser-induced incandescence



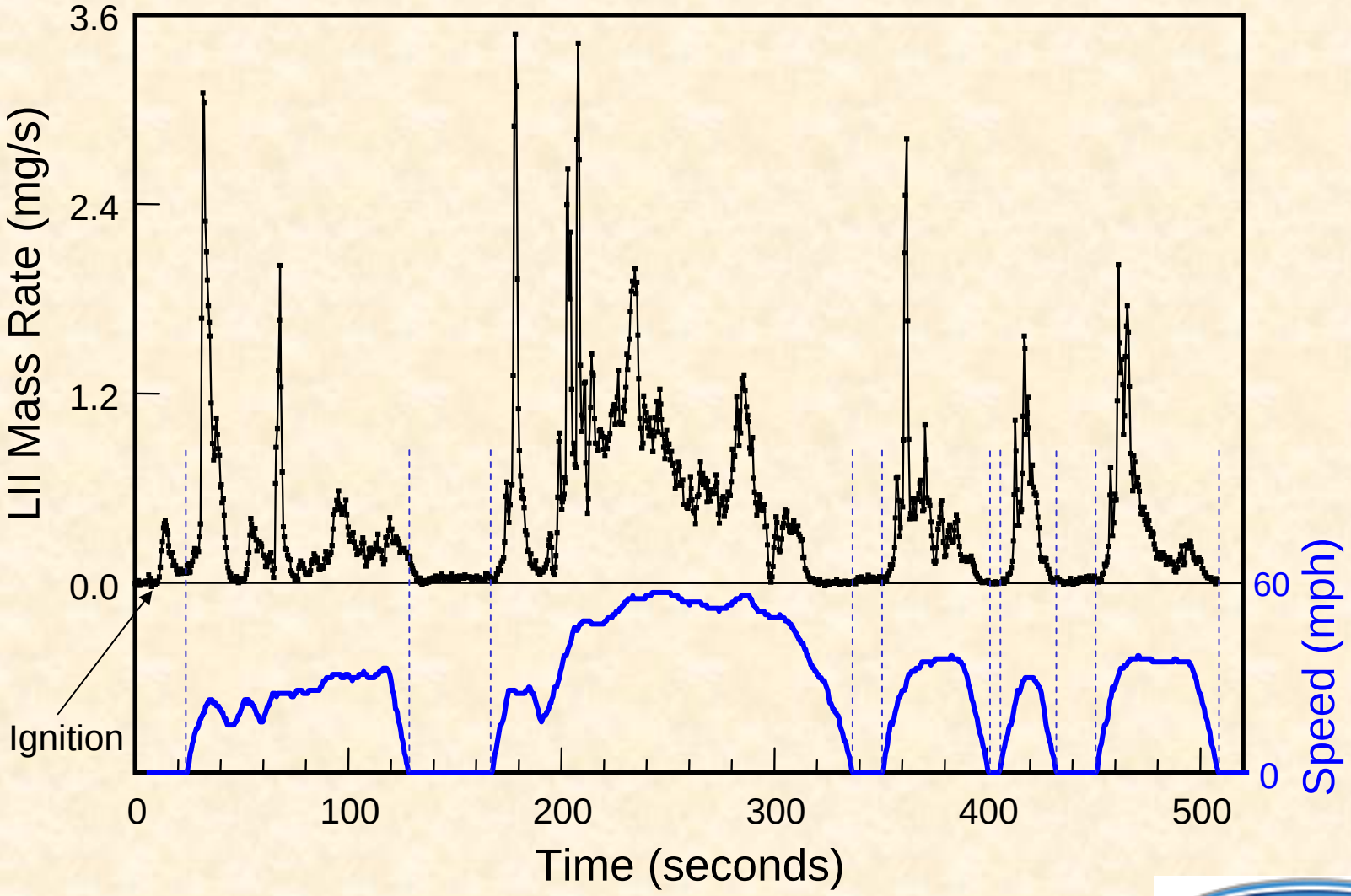


Measures elemental carbon volume concentration

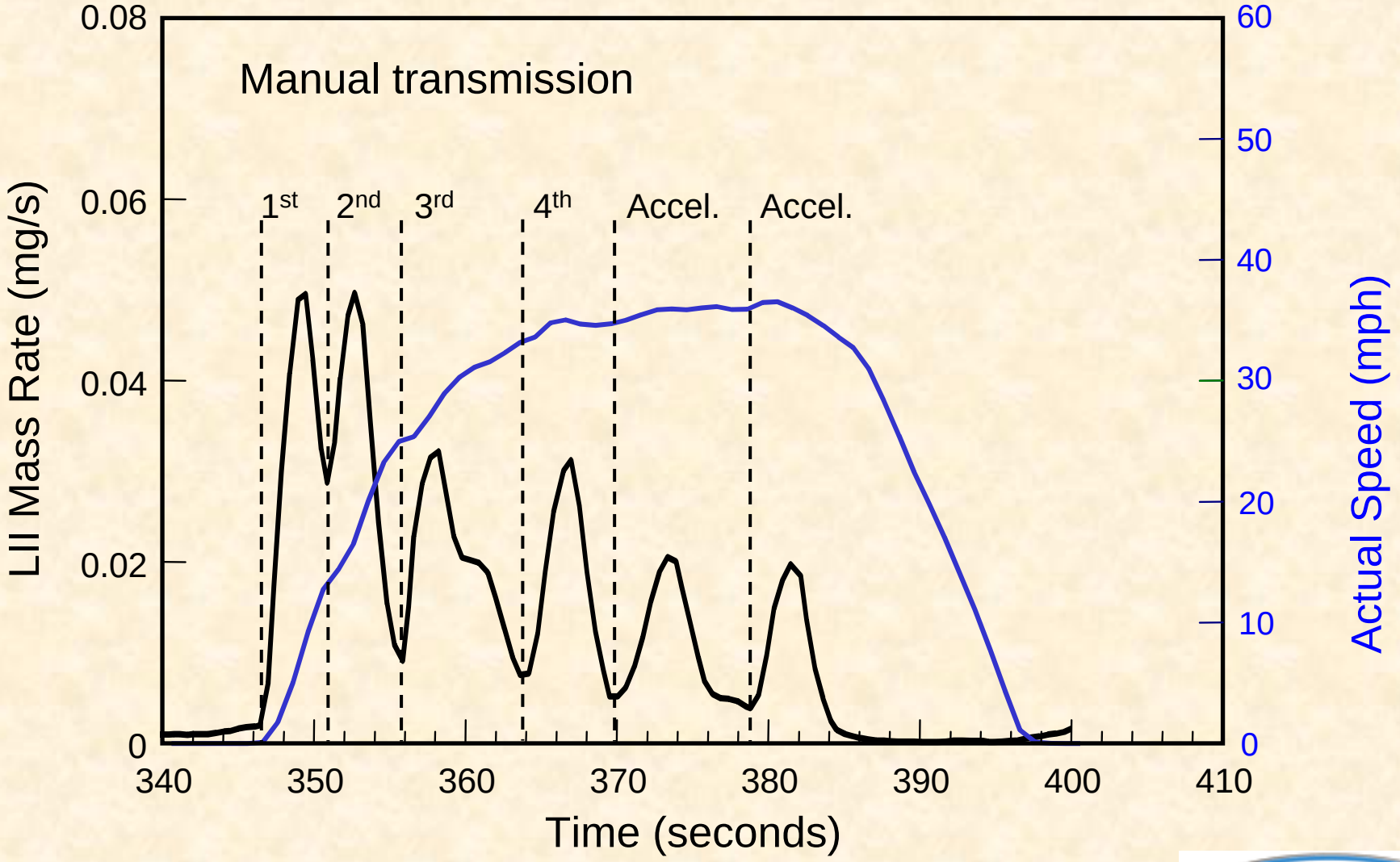
$$f_v \propto \mathrm{LII}_{max}$$

assuming T_{max} of soot is at sublimation temperature

Typical time-resolved LII for light-duty FTP

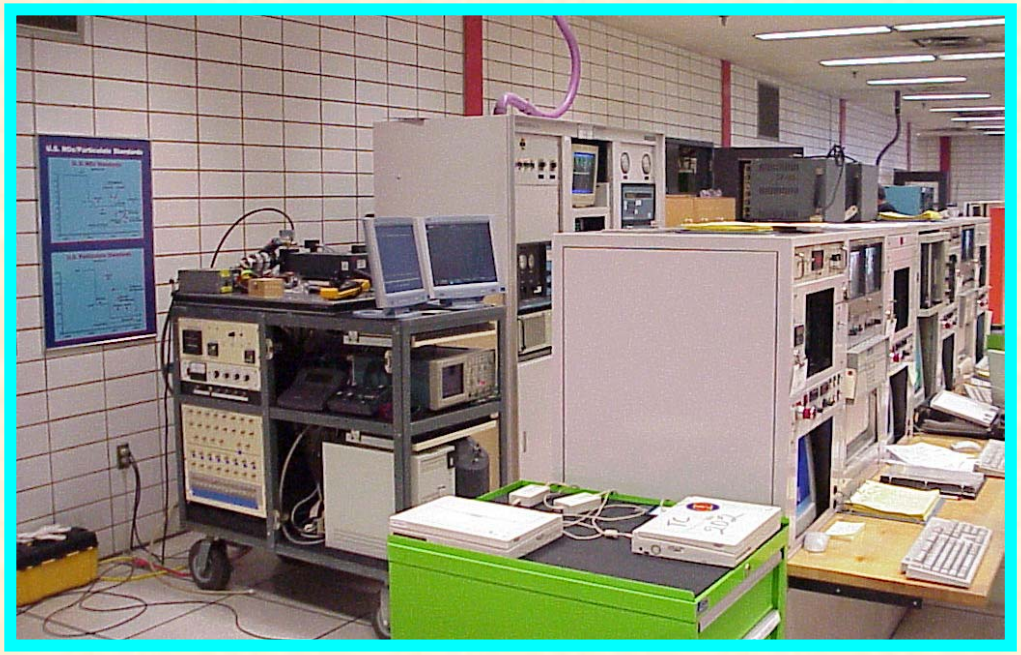


Expanded look at a single (3rd) cycle

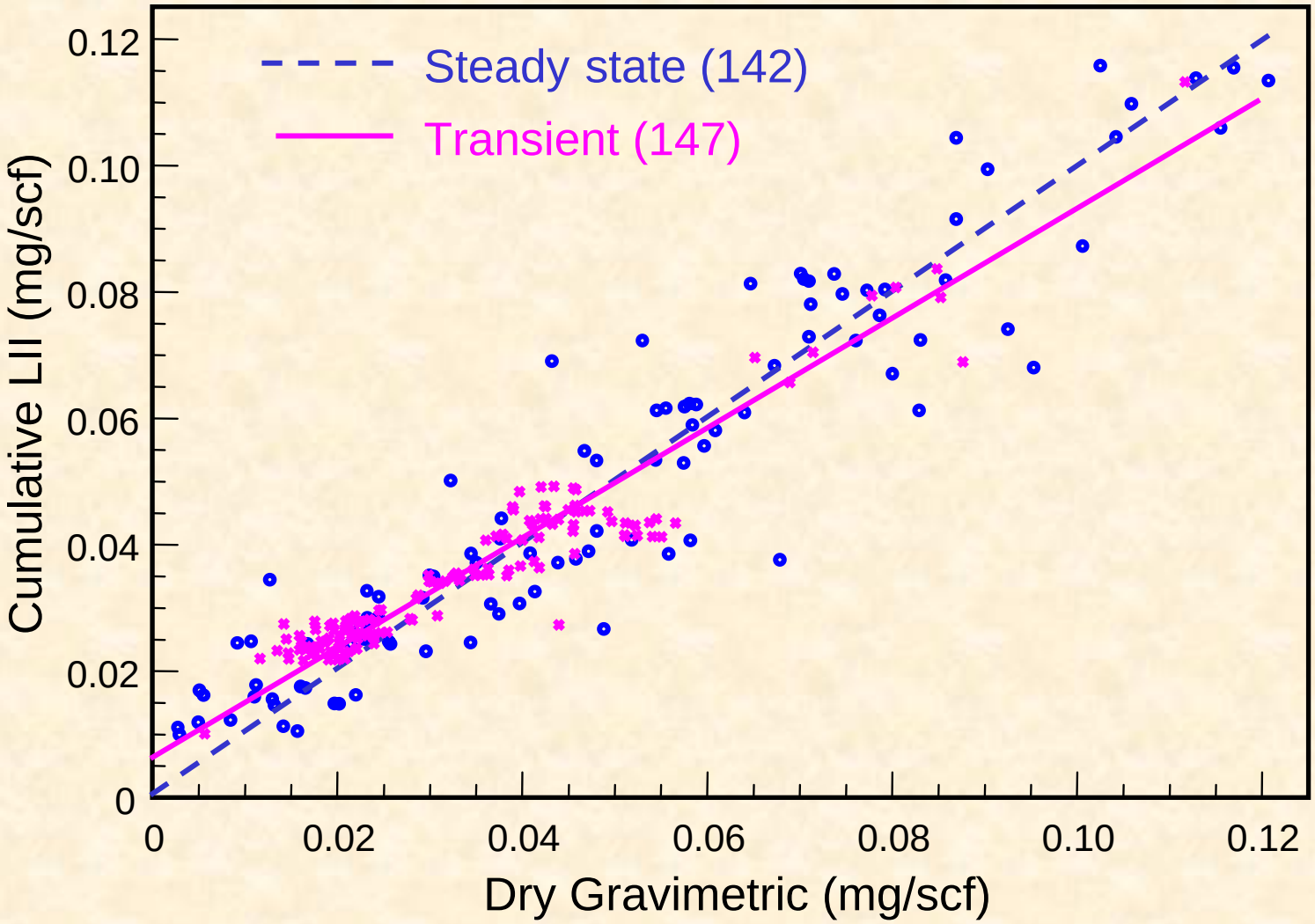


Unattended, 24/7 operation at Cummins

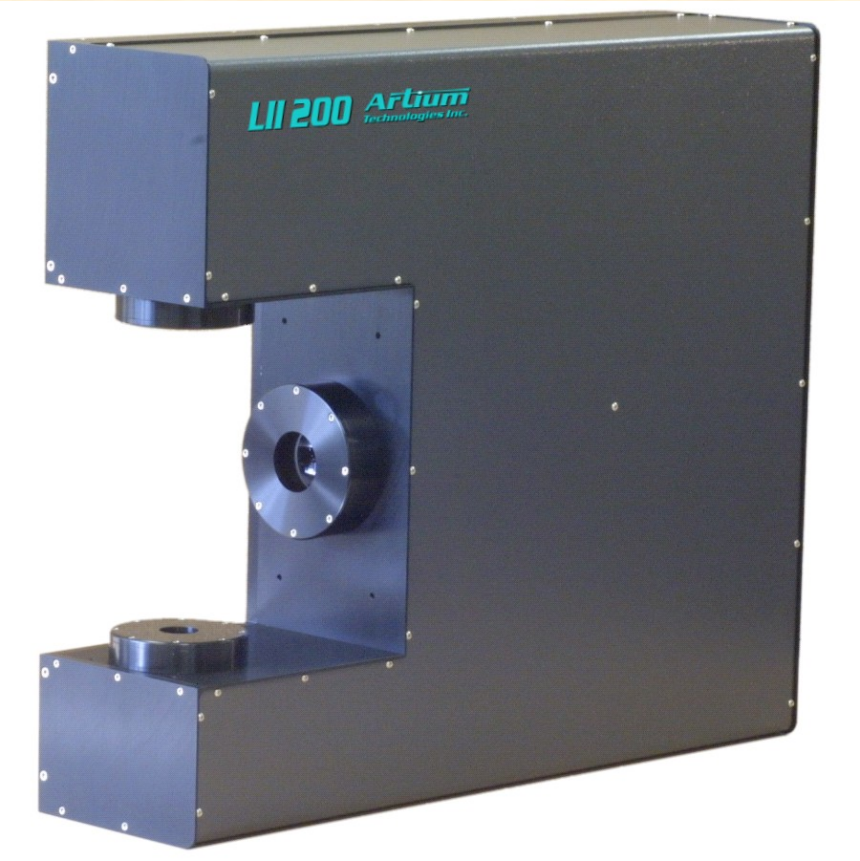
- 7½ weeks of continuous operation
- 1078 individual tests logged
- ~60M laser shots



Calibrated-LII/gravimetric correlation



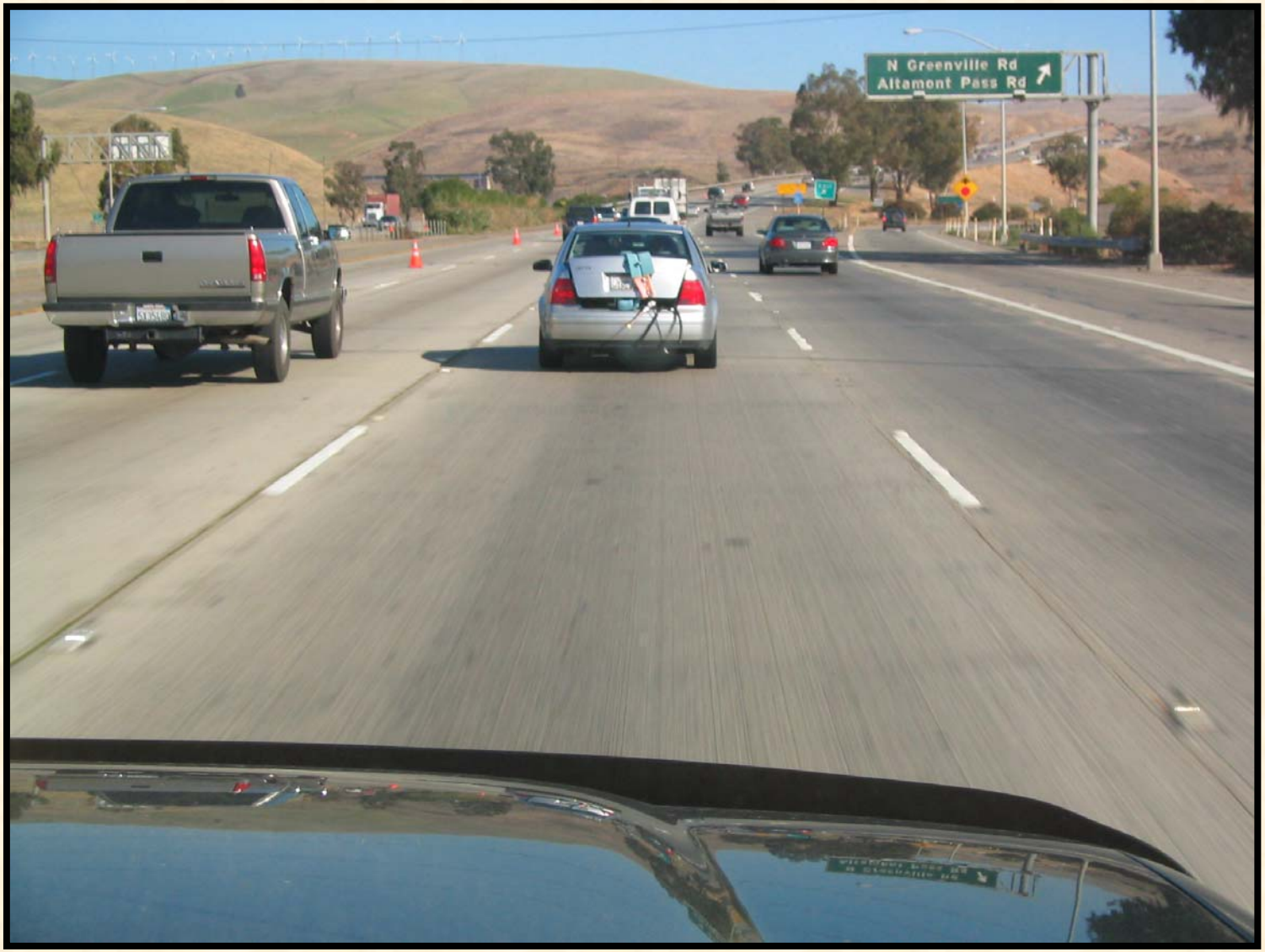
Commercial LII instrument



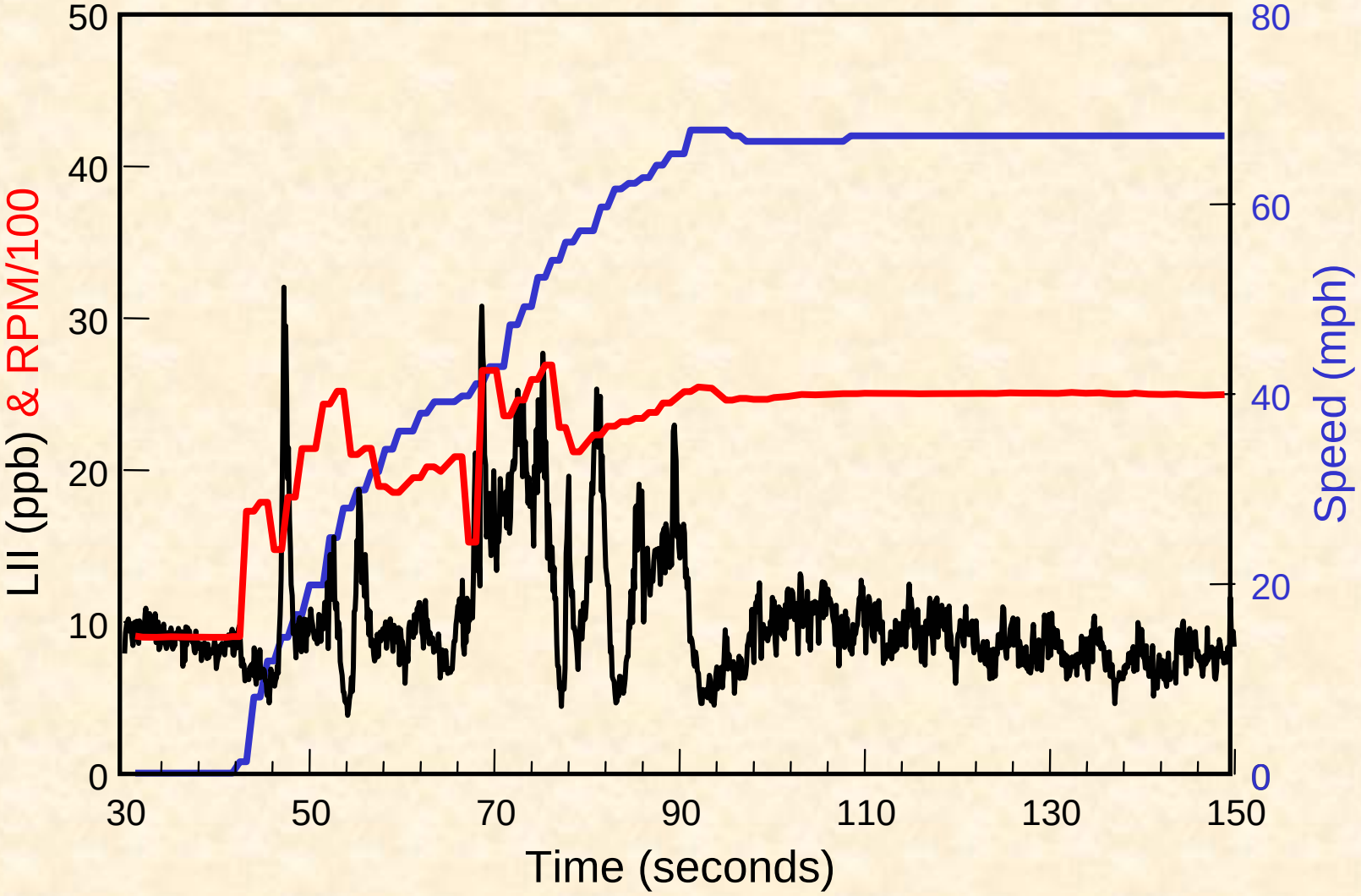
LII 200™ consists of a 50x60x15 cm box that contains the laser, optics, detectors and electronics. All operational functions are controlled by a PC, providing true "turn key" performance for $150k.

On-road LII for a 2002 VW Jetta TDI diesel

Getting up to speed

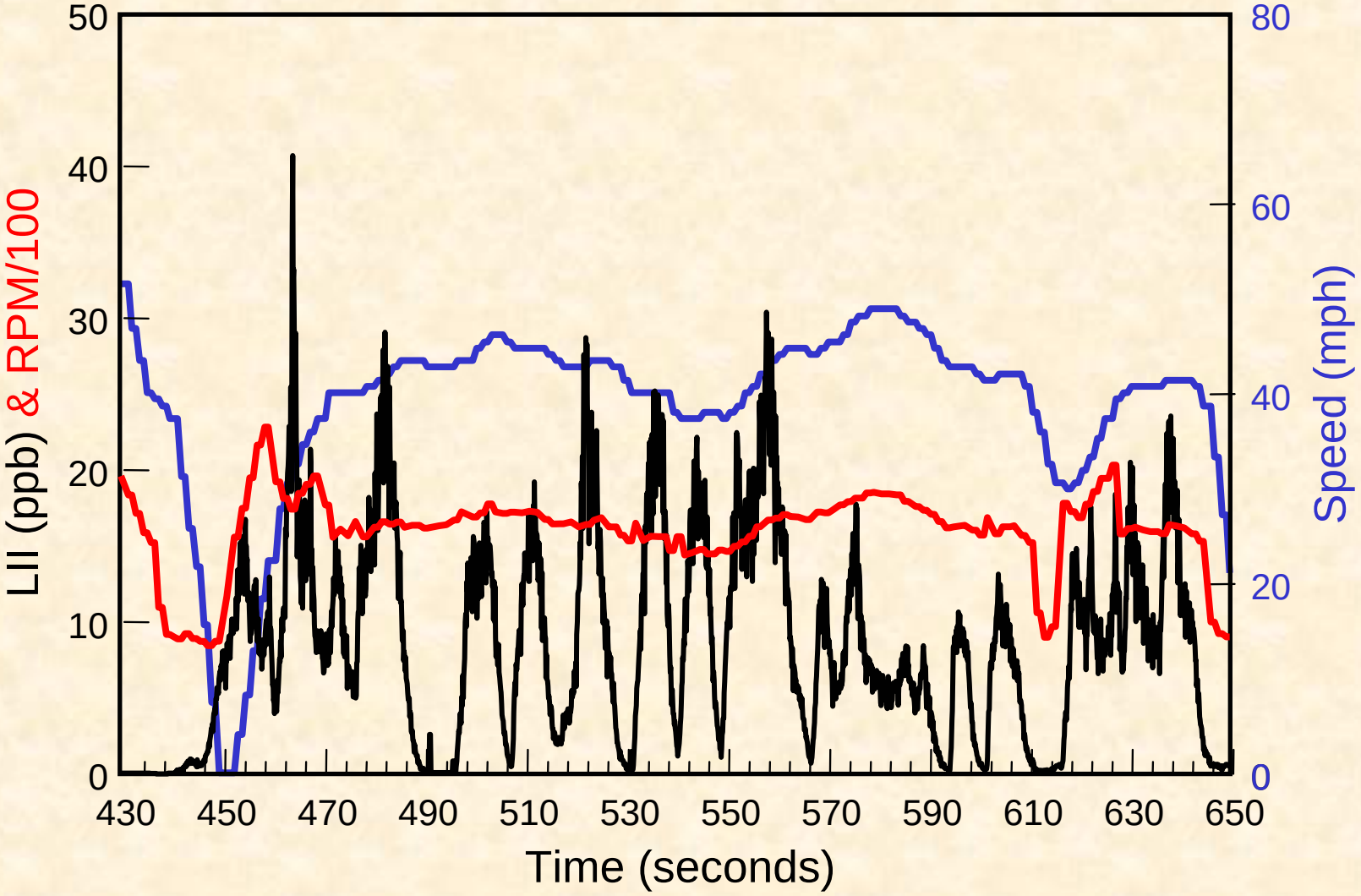


Freeway acceleration to 67 mph



Coasting back down

Winding descent on two-lane road

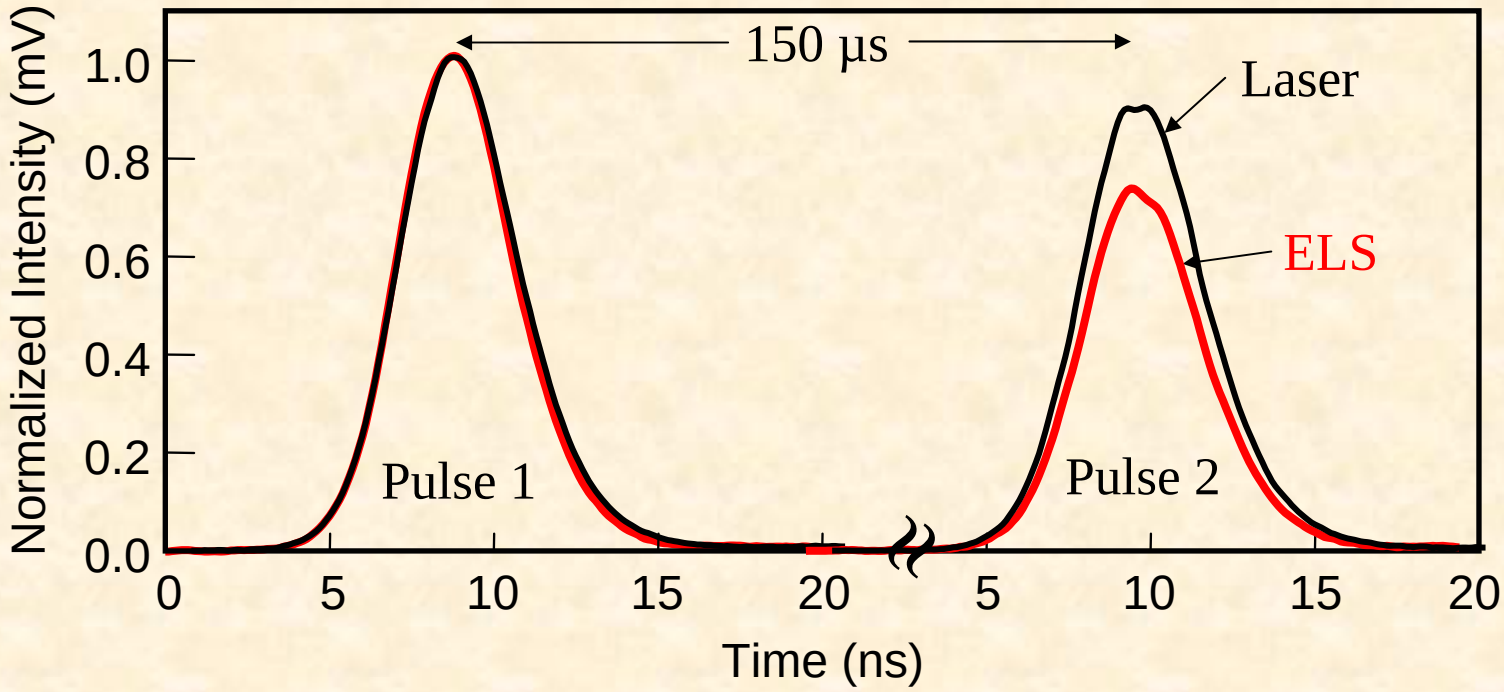


LIDELS with a single laser

Laser-induced desorption (LID) with elastic laser scattering (ELS)

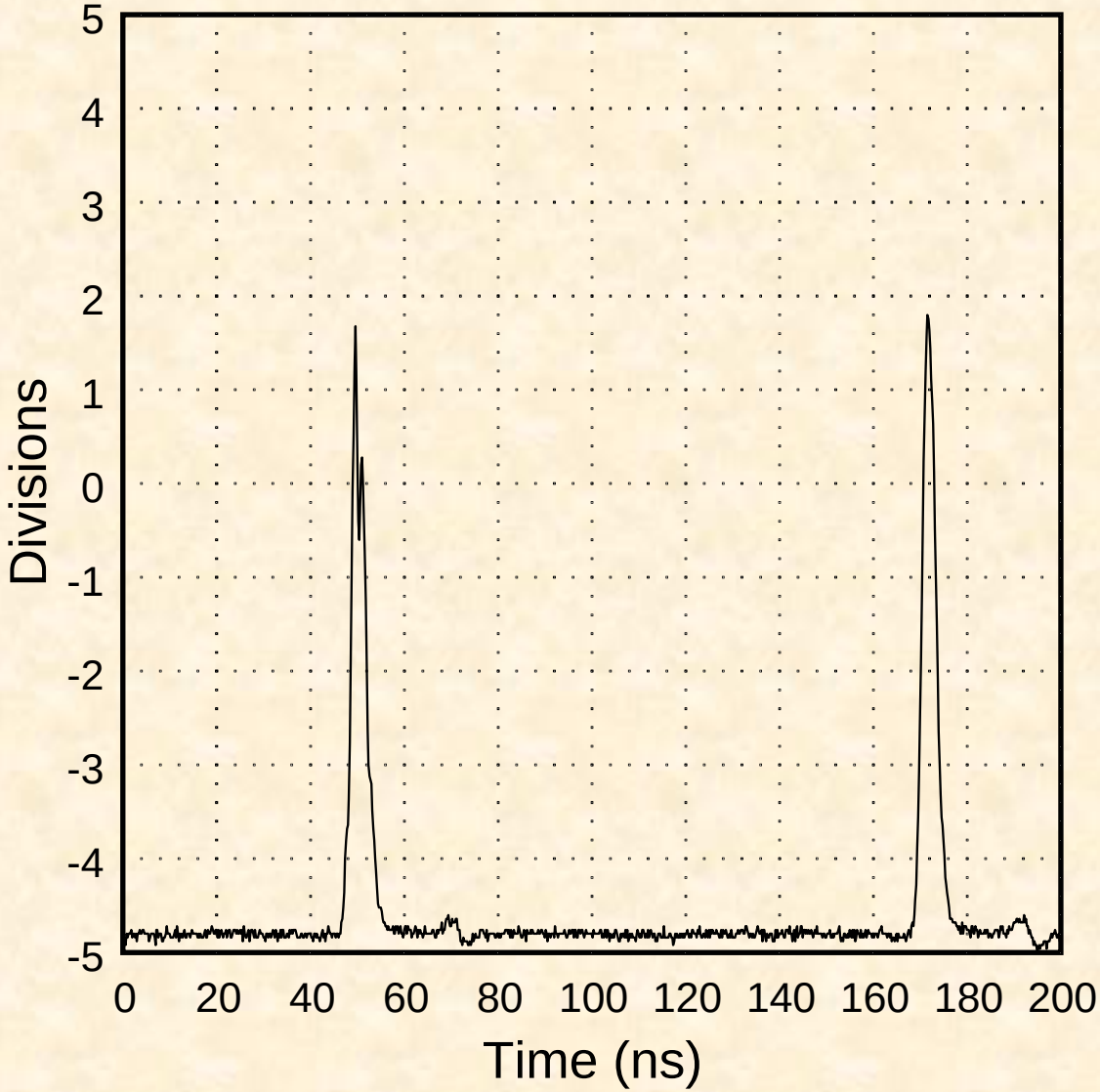
Double-pulse laser, measure ELS

$$\left[\frac{A_{ELS-2}/A_{YAG-2}}{A_{ELS-1}/A_{YAG-1}}\right]^{0.5} = \text{solid volume fraction}$$



SAE 2002-01-1685

Time-resolved LIDELS with 2 lasers

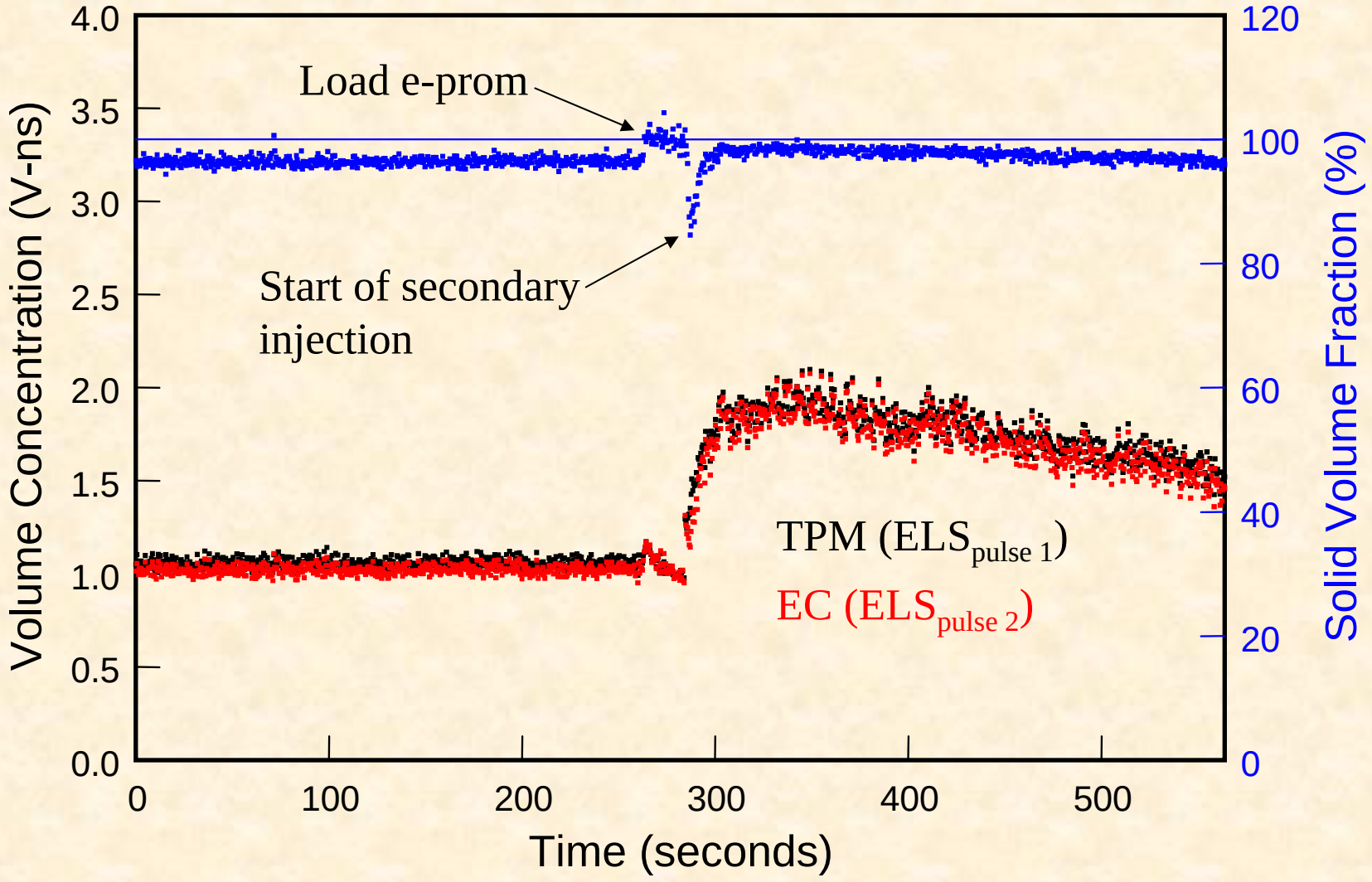


~120 ns delay

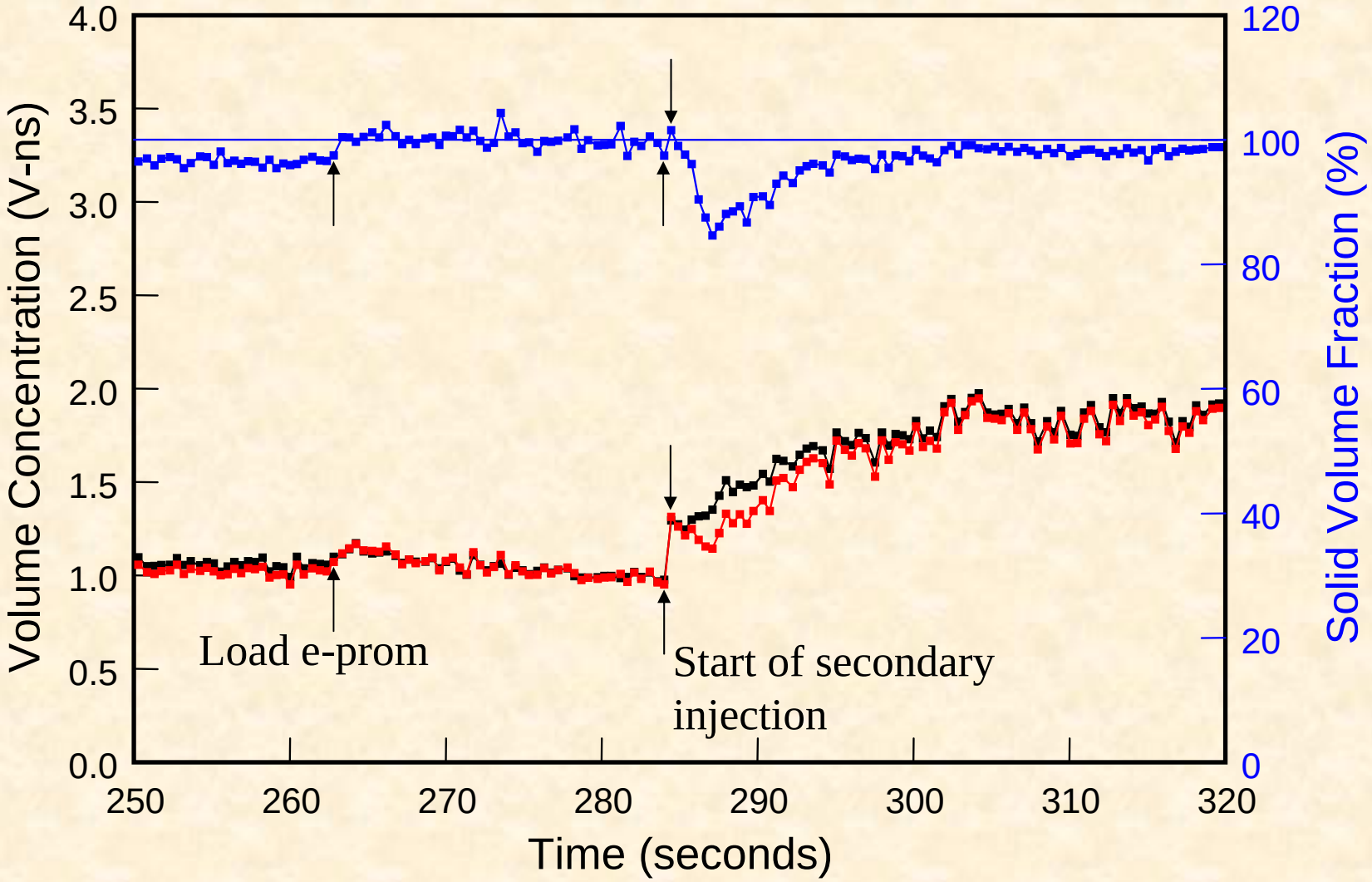
5 GS/s = 1000 pts

~3Hz throughput rate
(GPIB limited)

LIDELS during secondary-injection enable

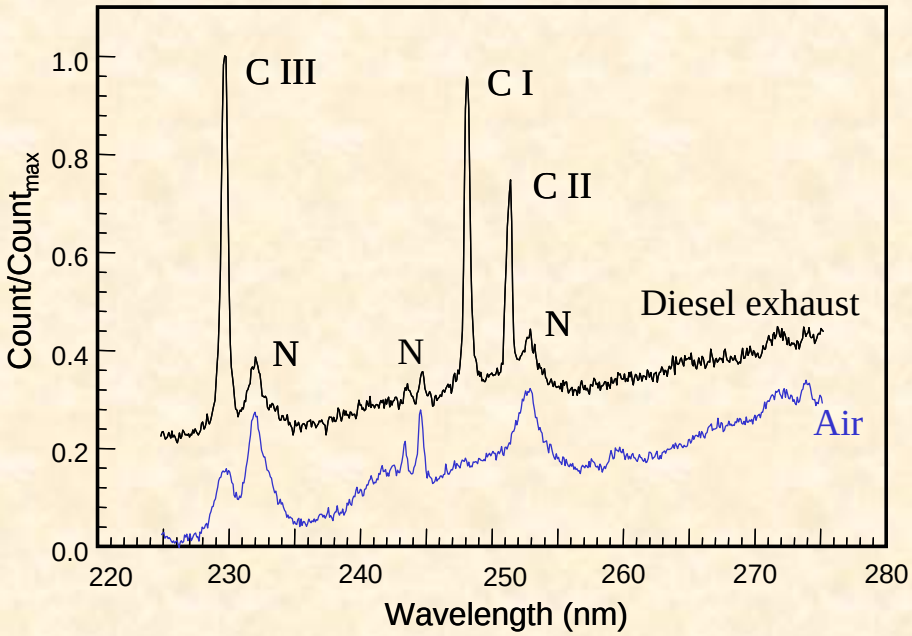


LIDELS during secondary-injection enable



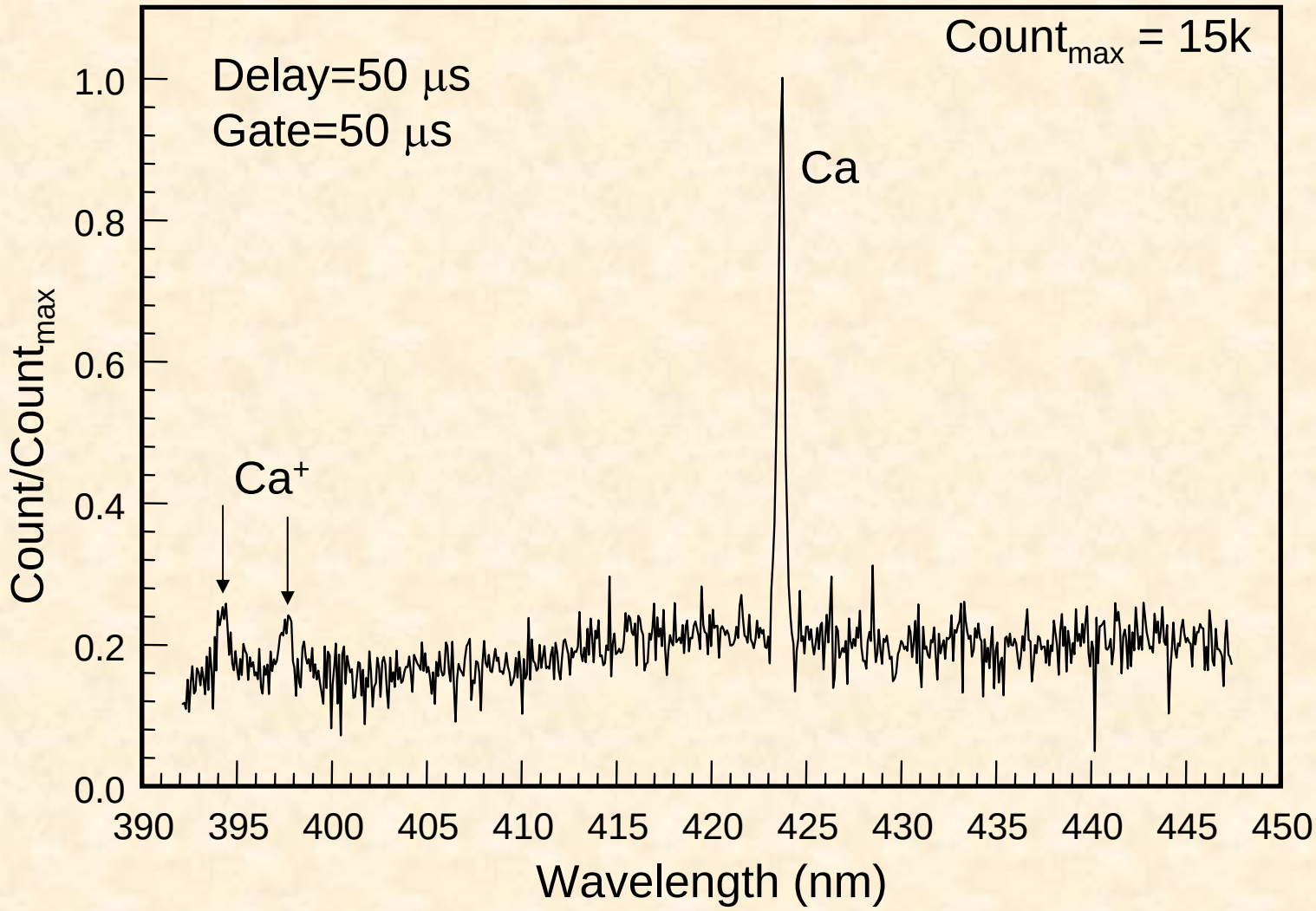
Laser-induced breakdown spectroscopy (LIBS)

- Focused laser beam creates a plasma that emits light characteristic of neutral and ionized atoms
- Spectrometer output is imaged onto an intensified CCD camera

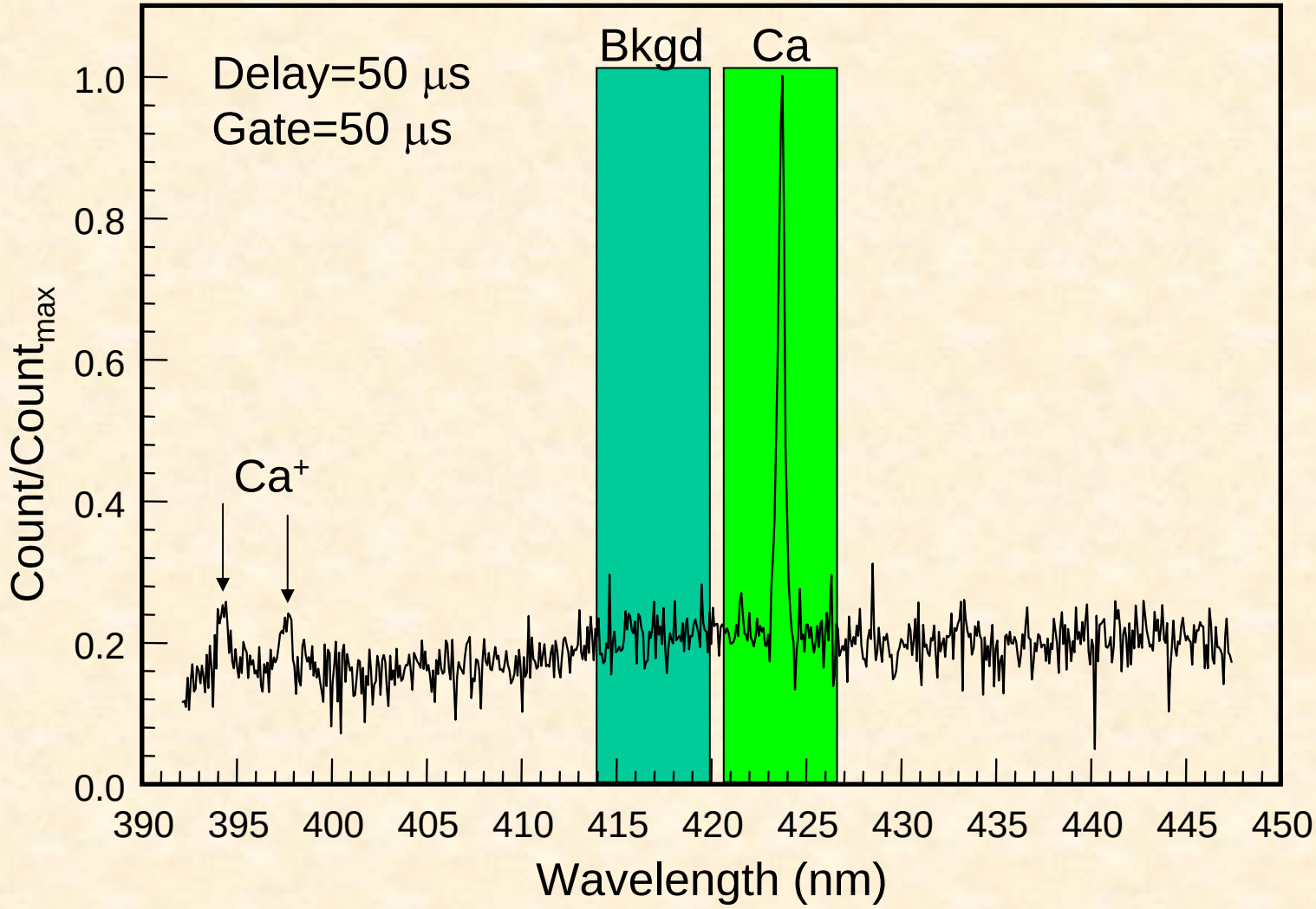


- Line position provides species identification
- Line intensity provides species concentration

LIBS of Ca from ash in diesel exhaust



Real-time LIBS via bandpass filters



Current status of HELD

- Commercial LII instruments are in use.
- LIDELS needs further validation and is more costly than LII, but there is strong industry interest.
- LIBS has yet to “spark” much interest.

Future plans for HELD

- Time-resolved LIBS of Ca
- ELS/LII for measurement of size
- ELS using Rayleigh-Debye-Gans polydisperse fractal aggregate theory (RDG/PFA) for aggregate morphology.