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# Measuring the Cylinder-to-Cylinder EGR Distribution in a Diesel Engine

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# Project Rationale

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- Contemporary Diesel engine designs are using EGR to control  $\text{NO}_x$  emissions
- A cylinder-to-cylinder mal-distribution of EGR may lead to performance and emission problems
  - Non-uniform combustion performance
  - Excessive  $\text{NO}_x$  emissions
  - Excessive PM emissions
- Engine operation transients may aggravate the problem



# Project Objective

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Develop a non-obtrusive, optical diagnostic for measuring the cylinder-to-cylinder EGR distribution in production Diesel engines during both steady operation and engine transients.



# Technical Approach

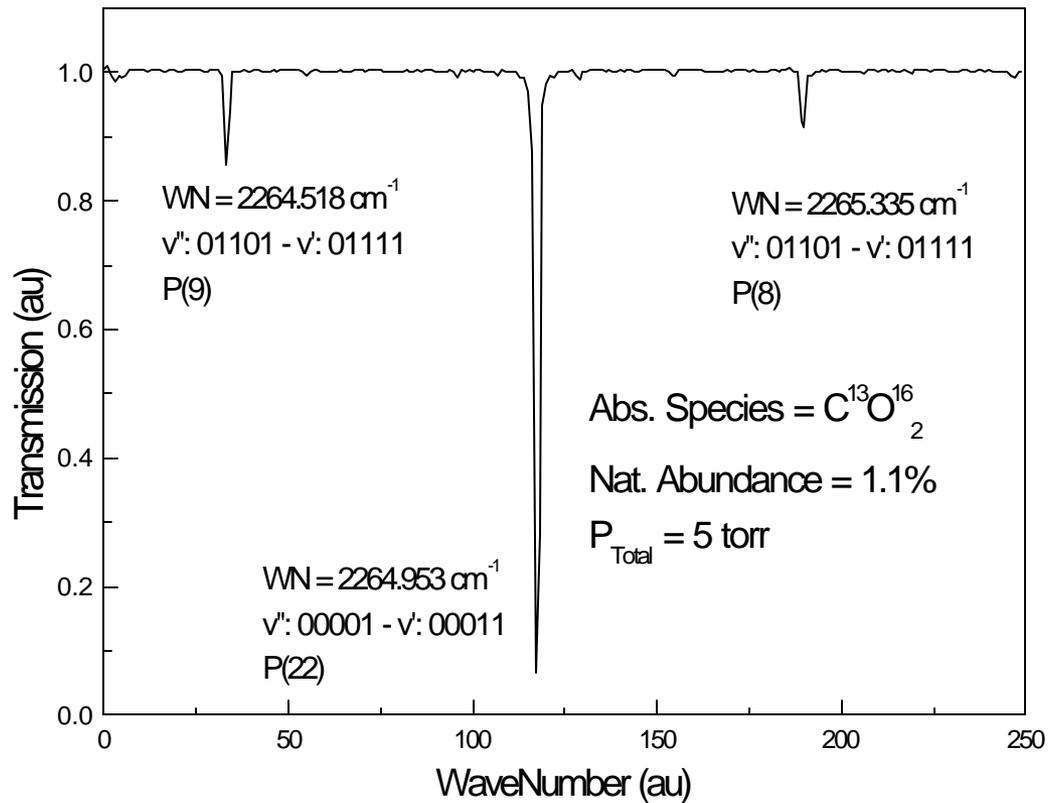
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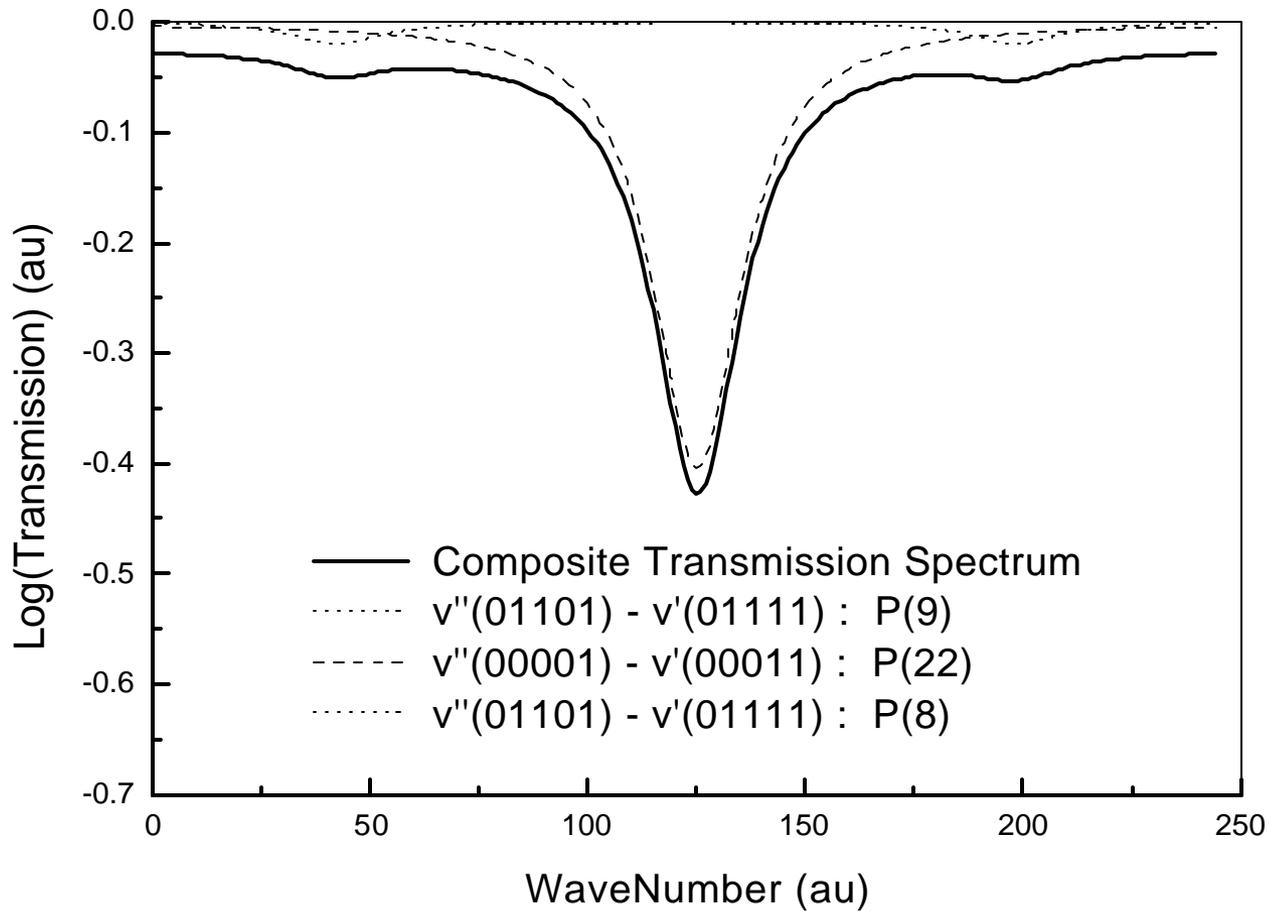
- Develop the diagnostic using a production engine
- Minimize perturbations to the basic engine geometry
- Data acquisition during both steady state and transient operation
- Use IR absorption spectroscopy to measure CO<sub>2</sub> concentration in the intake port of each cylinder
- Acquire the data in a manner that is both crank-angle and cycle-sequence resolved as well as being ensemble-averaged



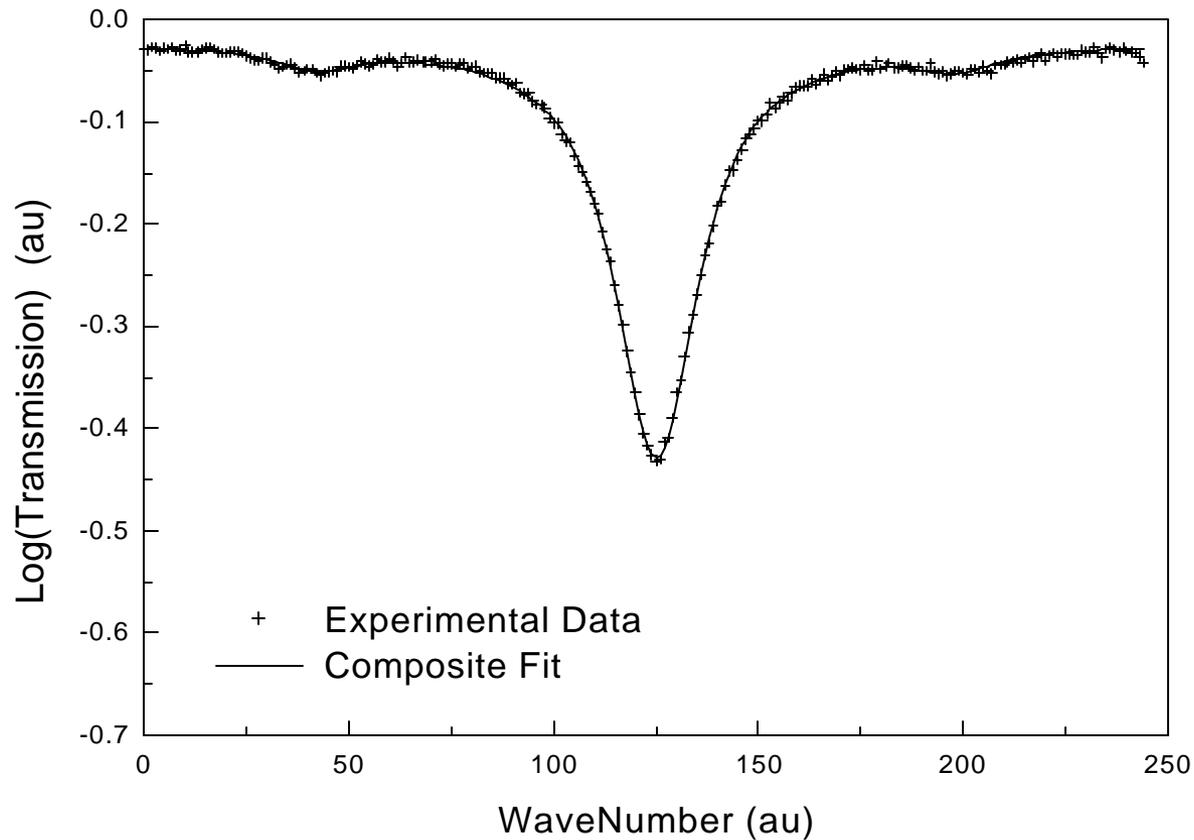
# Reference cell spectrum



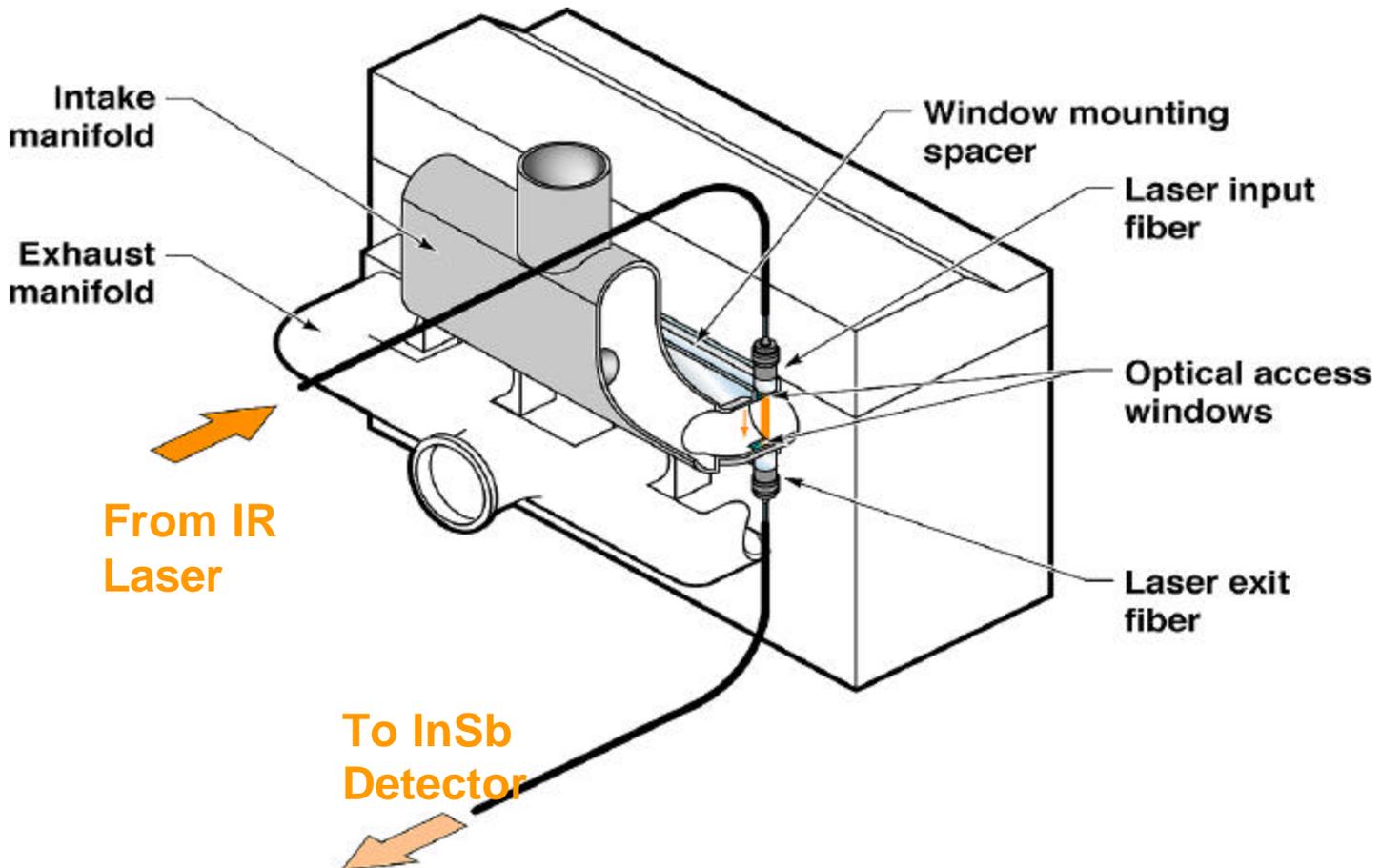
# Spectrum is superposition of 3 lines



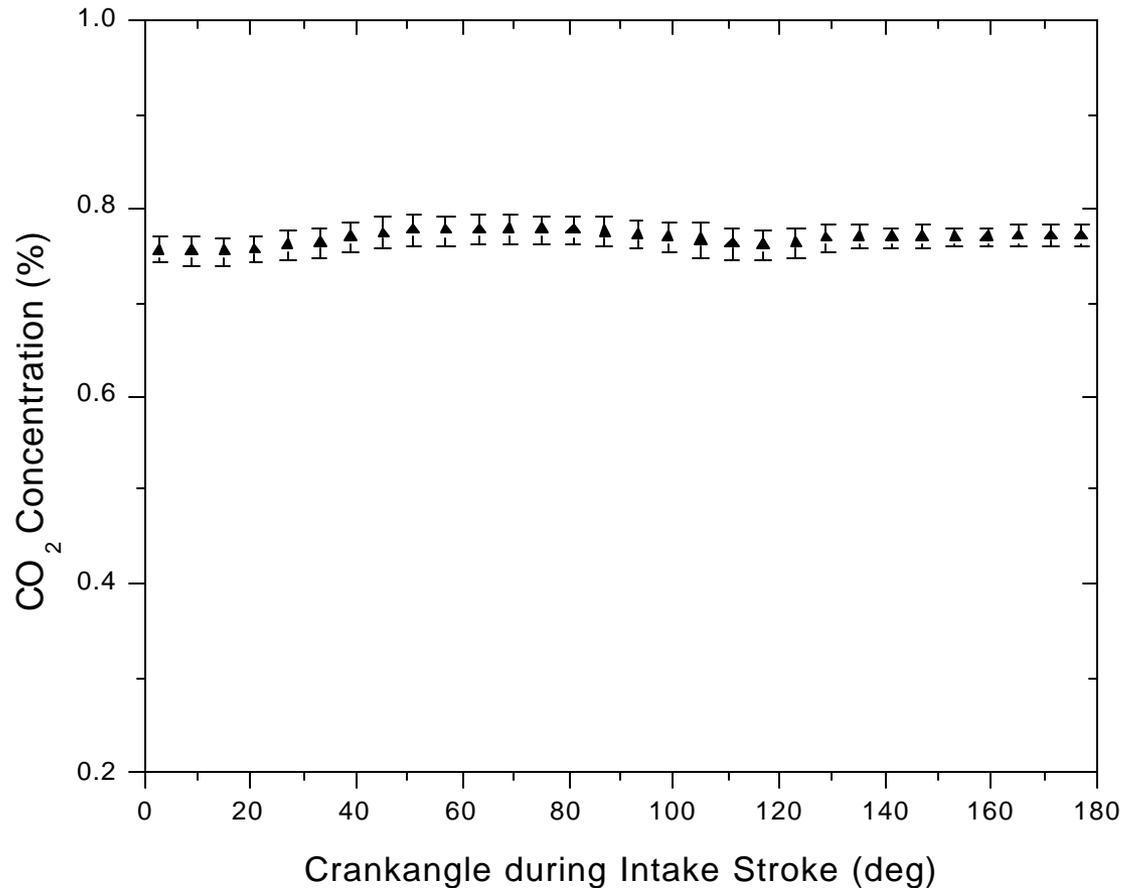
# Fit of experimental spectrum



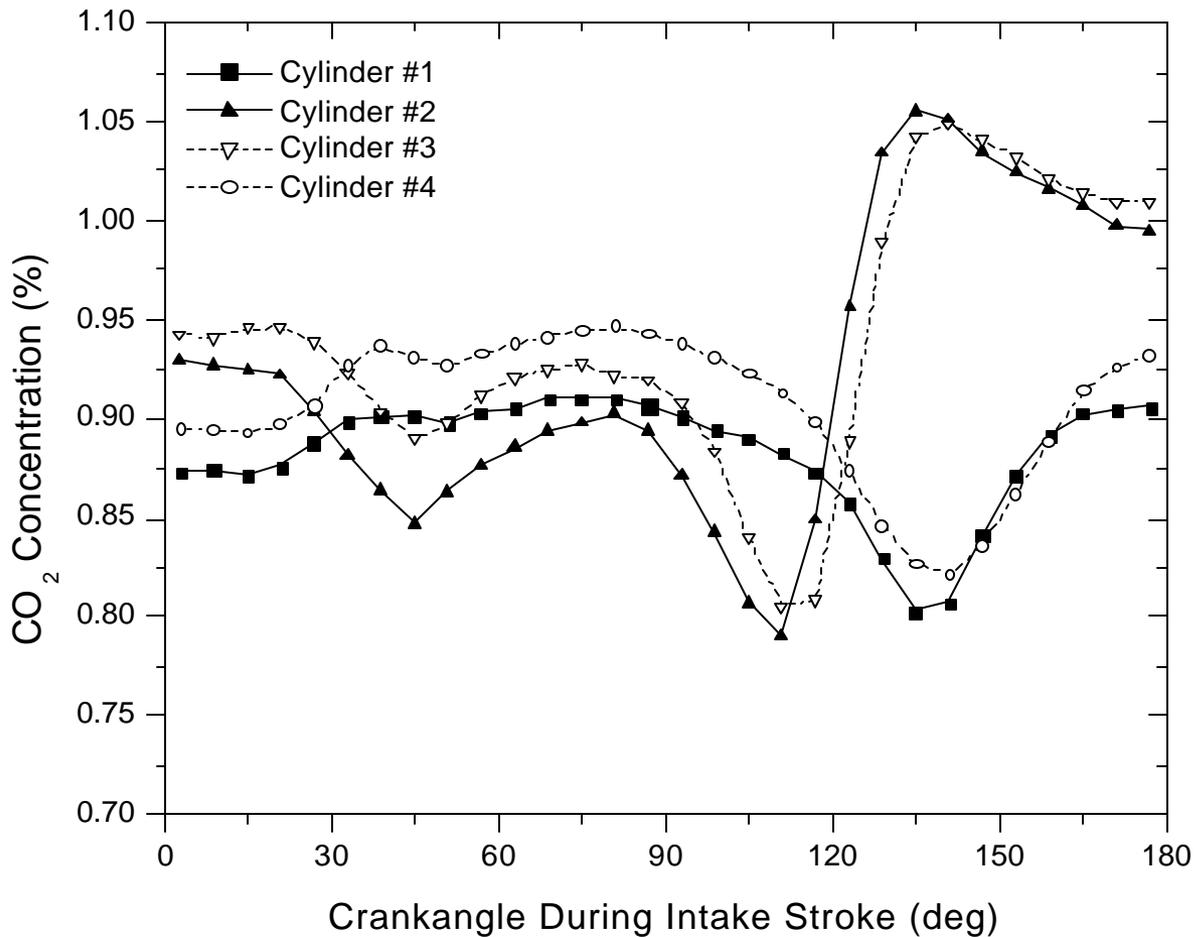
# Optical fibers transmit laser light to windows in the intake system



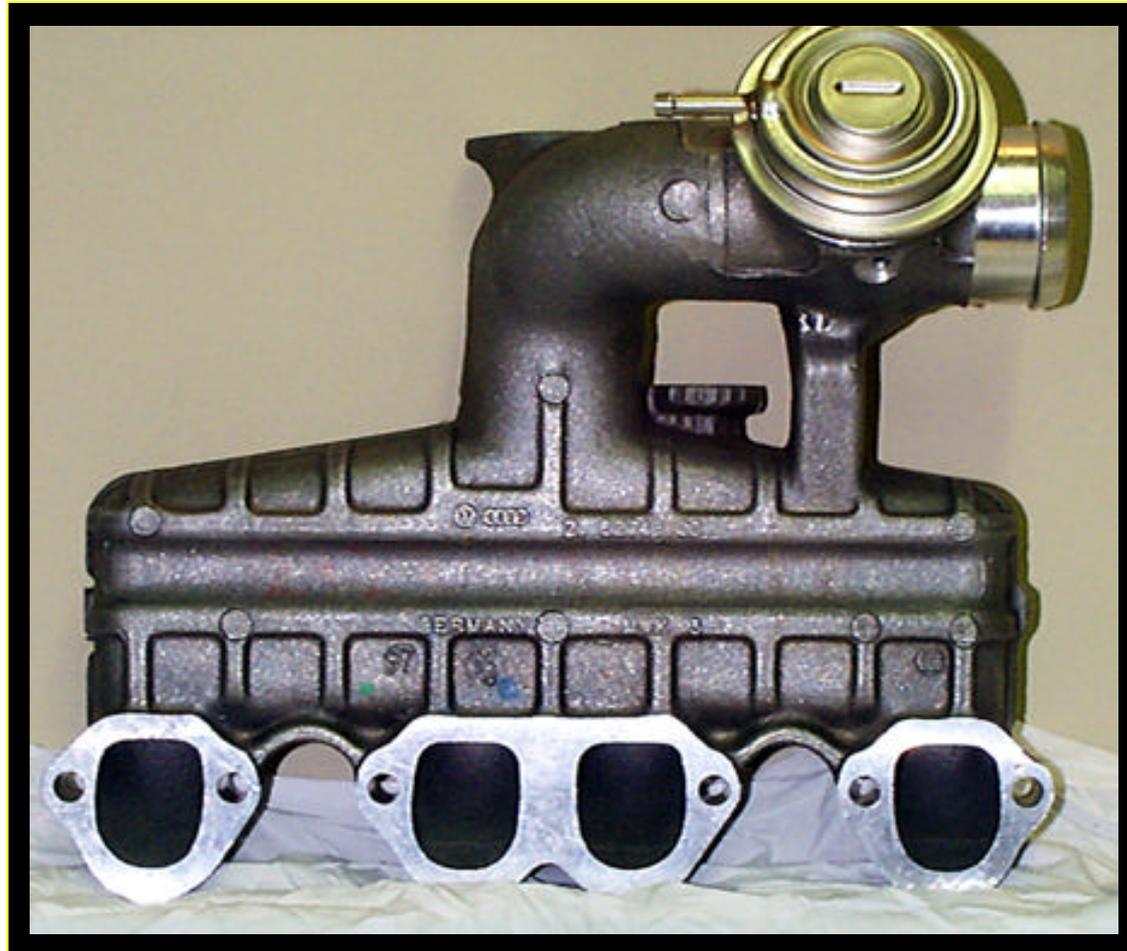
# The CO<sub>2</sub> concentration history during the intake stroke for externally pre-mixed EGR



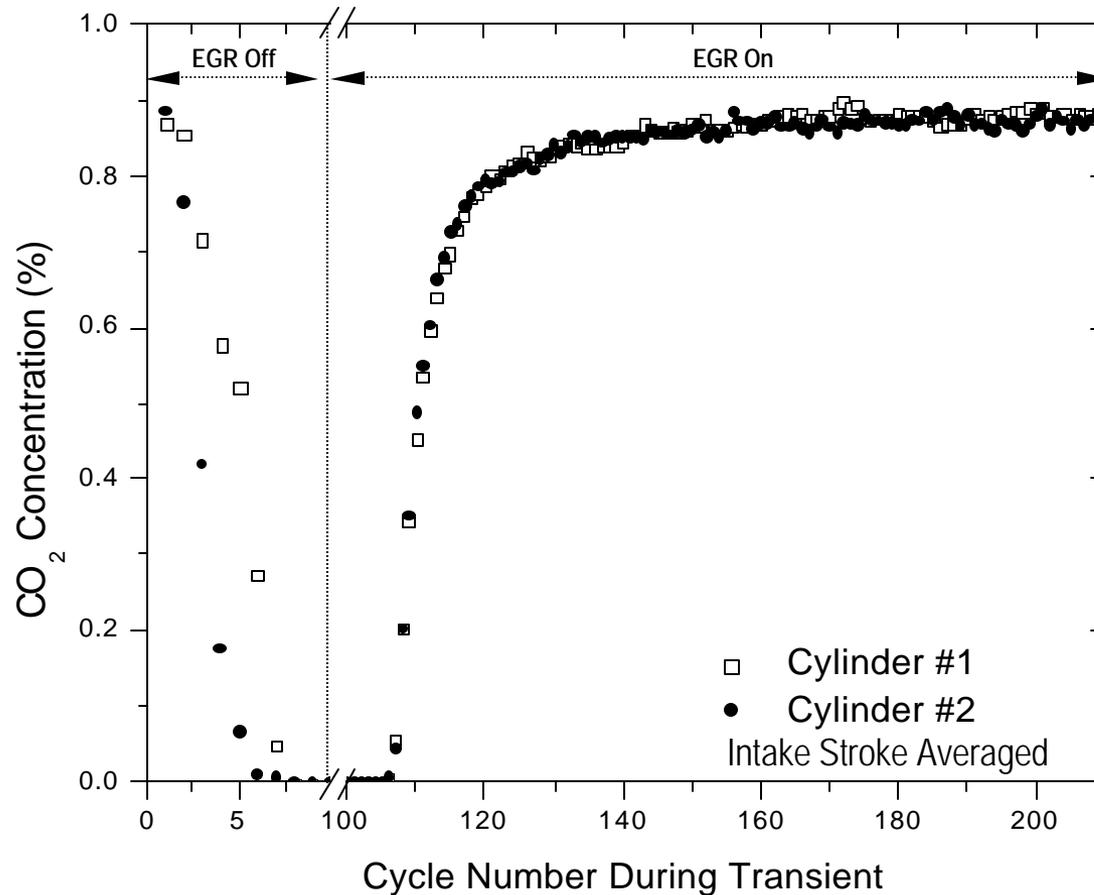
# Cylinder-to-cylinder EGR distribution during the intake stroke for steady engine operation



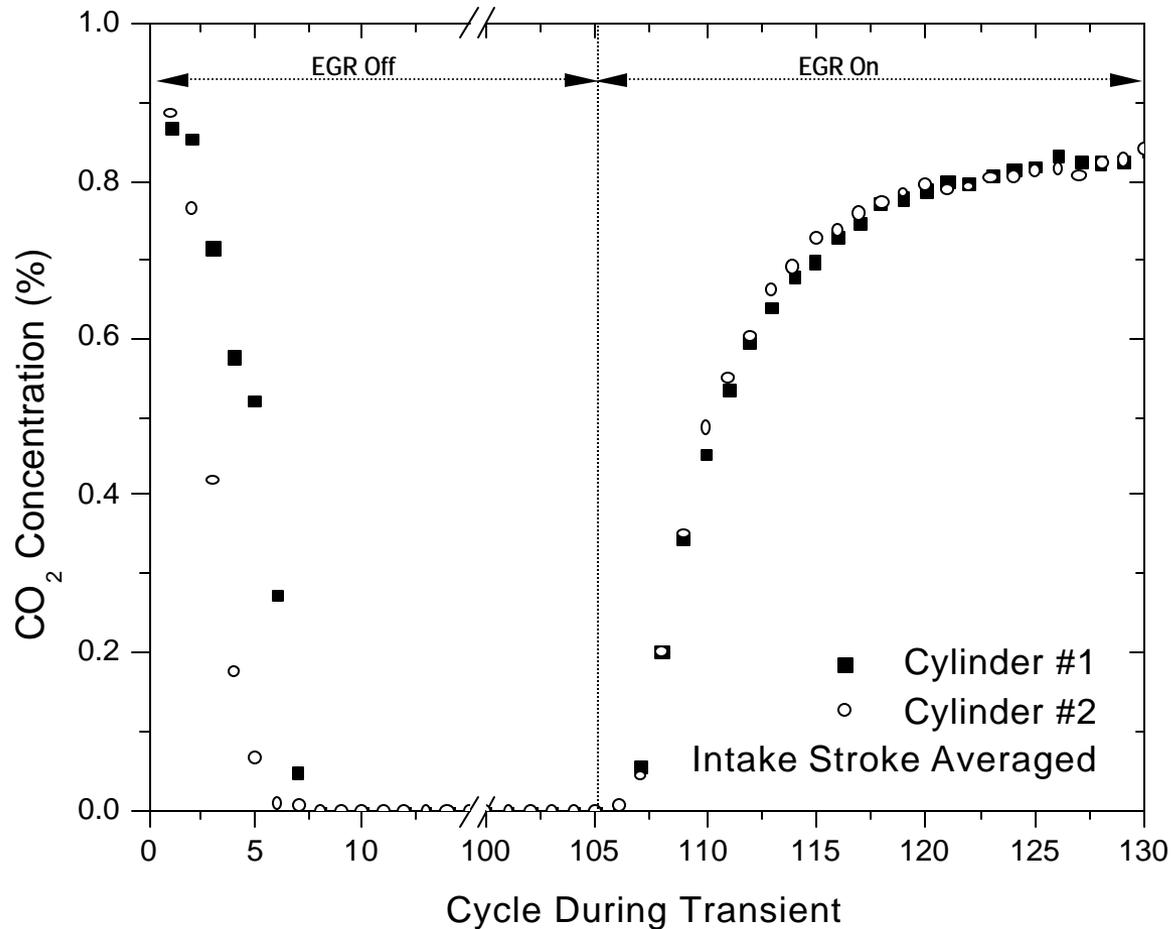
The intake manifold of the Volkswagen TDI engine has a symmetrical design



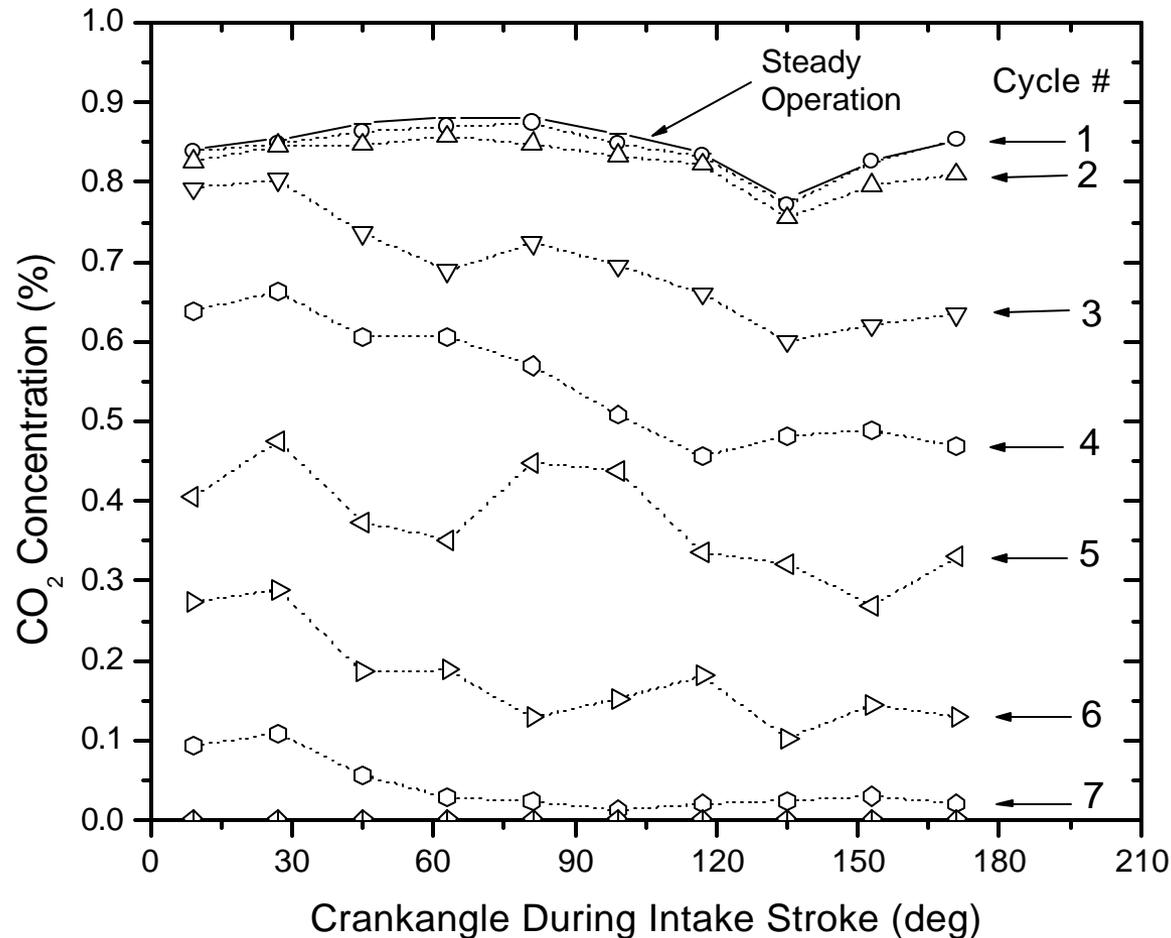
# Cylinder-to-cylinder distribution of EGR during 'EGR-OFF' and '-ON' transients



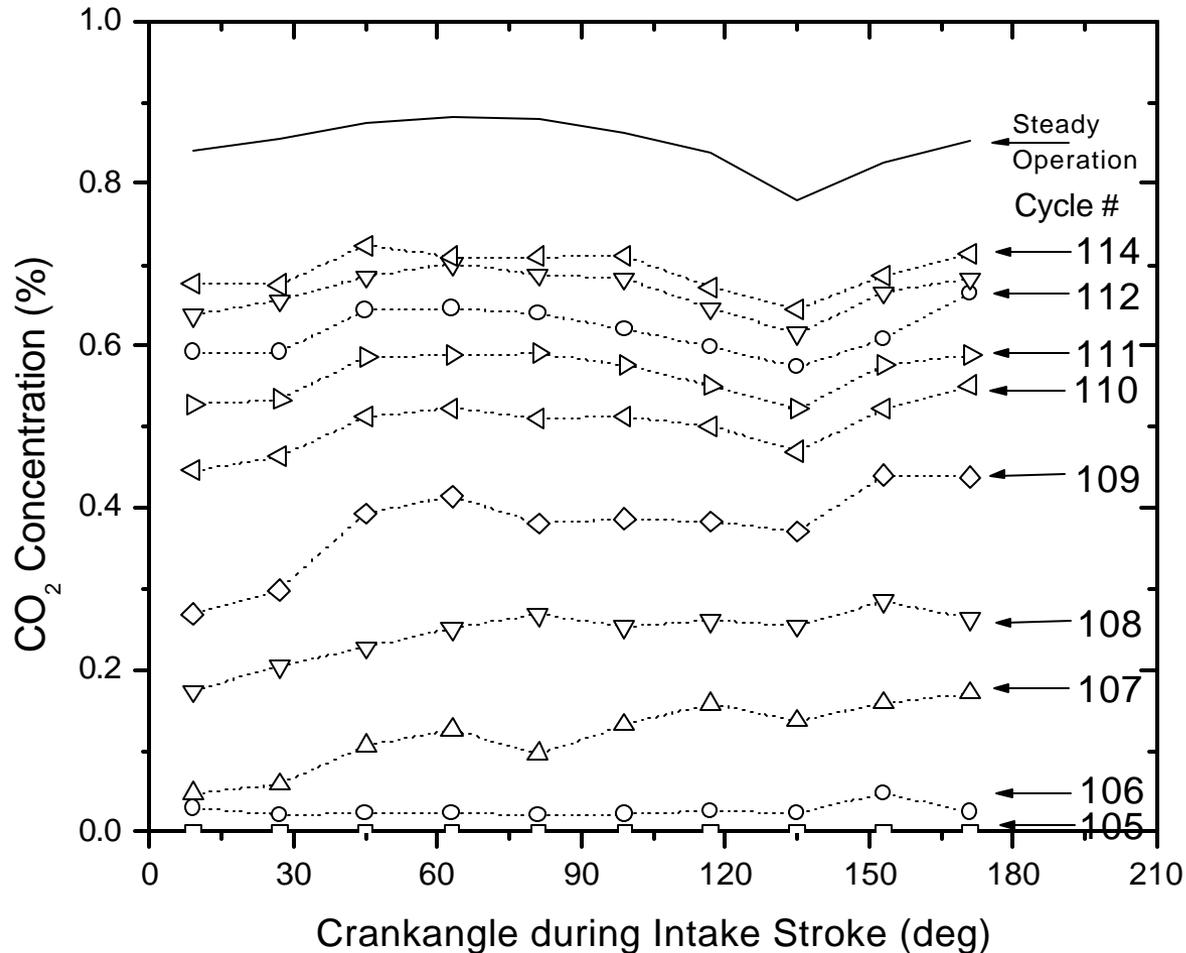
# Cylinder-to-cylinder distribution of EGR during 'EGR-OFF' and '-ON' transients



# Crankangle-resolved EGR concentration during an 'EGR-OFF' transient



# Crankangle-resolved EGR concentration during an 'EGR-ON' transient



# Project Status

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- A non-intrusive diagnostic that measures the cylinder-to cylinder EGR distribution in the intake charge has been demonstrated
  - Steady operation
  - Transient operation
- Issues related to system portability are complete
- We've approached industry regarding cooperative interaction
- We're prepared to work out the details for performing 'off site' measurements on either development or production engines

