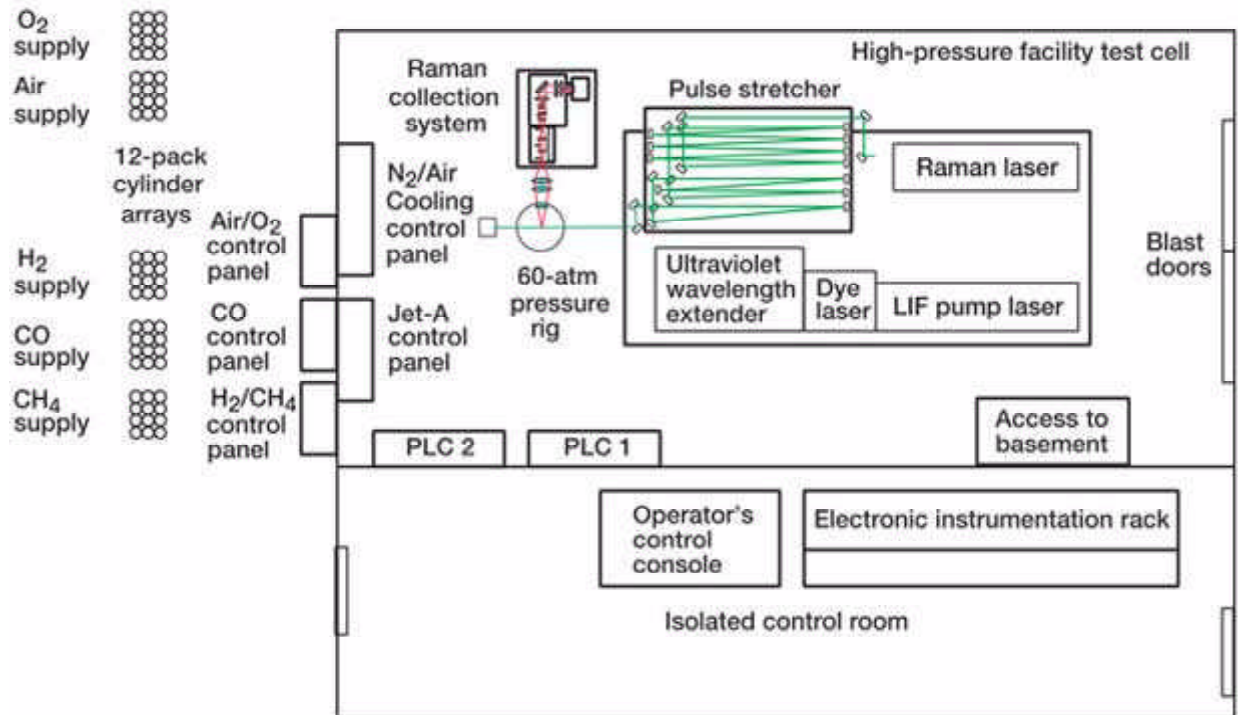


# High-Pressure Gaseous Burner (HPGB) Facility Completed for Quantitative Laser Diagnostics Calibration

A gas-fueled high-pressure combustion facility with optical access, which was developed over the last 2 years, has just been completed. The High Pressure Gaseous Burner (HPGB) rig at the NASA Glenn Research Center can operate at sustained pressures up to 60 atm with a variety of gaseous fuels and liquid jet fuel. The facility is unique as it is the only continuous-flow, hydrogen-capable, 60-atm rig in the world with optical access. It will provide researchers with new insights into flame conditions that simulate the environment inside the ultra-high-pressure-ratio combustion chambers of tomorrow's advanced aircraft engines. The facility provides optical access to the flame zone, enabling the calibration of nonintrusive optical diagnostics to measure chemical species and temperature. The data from the HPGB rig enables the validation of numerical codes that simulate gas turbine combustors, such as the National Combustor Code (NCC). The validation of such numerical codes is often best achieved with nonintrusive optical diagnostic techniques that meet these goals: information-rich (multispecies) and quantitative while providing good spatial and time resolution. Achieving these goals is a challenge for most nonintrusive optical diagnostic techniques.

Raman scattering is a technique that meets these challenges. Raman scattering occurs when intense laser light interacts with molecules to radiate light at a shifted wavelength (known as the Raman shift). This shift in wavelength is unique to each chemical species and provides a "fingerprint" of the different species present. The facility will first be used to gather a comprehensive data base of laser Raman spectra at high pressures. These calibration data will then be used to quantify future laser Raman measurements of chemical species concentration and temperature in this facility and other facilities that use Raman scattering. Raman scattering is perhaps the only technique that can yield simultaneous quantitative concentration measurements of  $N_2$ ,  $O_2$ ,  $CO_2$ ,  $H_2O$ ,  $CO$ ,  $HC$ 's, and  $H_2$ , while also providing a measurement of the temperature in a spatially resolved volume in a single shot in time.



*HPGB facility. This rig, along with the laser Raman scattering diagnostic equipment and control electronics that include the programmable logic controller (PLC), is located in the main test cell. The gaseous flow control system for the fuel and oxidizer are housed in gas cabinets located outside of the test cell. The facility is remotely operated from the adjacent control room. Below a chamber pressure of 30 atm, the rig is air-cooled by dilution provided from facility compressors. At higher chamber pressures, the rig uses cooling air supplied by two compressed air trailers located outside of the building. The combustion gases (fuel and oxidizer) are provided by 12-pack cylinder arrays located outside of the test cell. LIF, laser-induced fluorescence.*

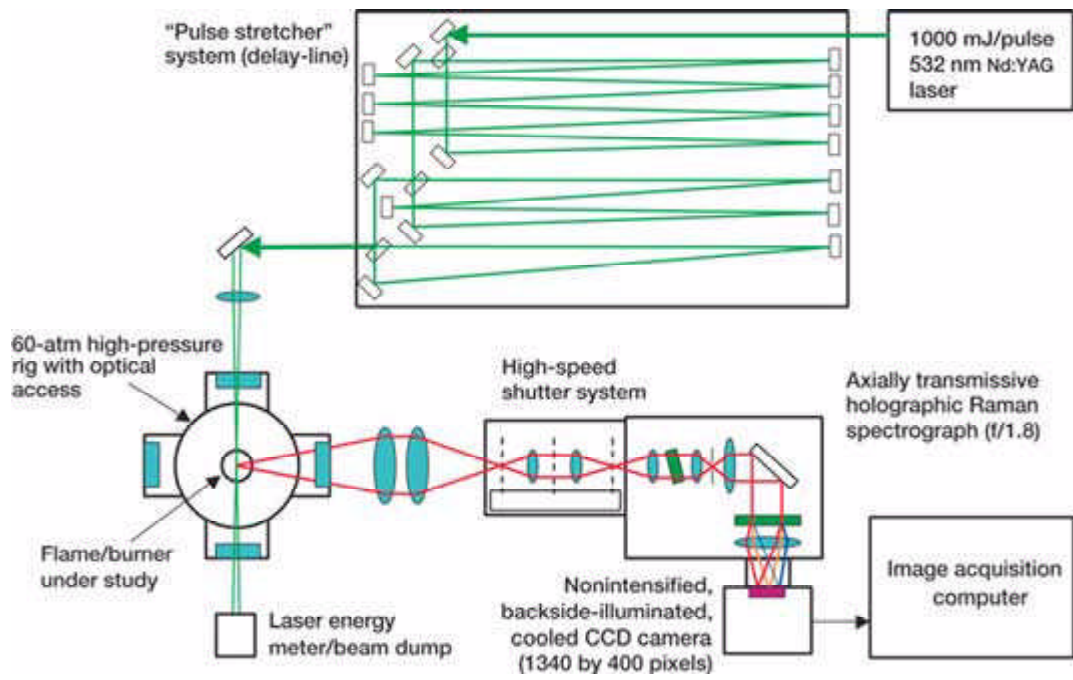
The preceding figure shows a schematic of the facility layout. A unique micropremixed hydrogen-air burner, shown in the photograph, is mounted inside the rig. The burner design avoids the problems of flashback and meltdown normally associated with high-pressure premixed hydrogen-air operation. The burner face is constructed of high-temperature alloy and is coated with a thermal barrier coating made of a flame-sprayed zirconia ceramic (not shown). An alternate design, which utilizes a staggered array of fuel-oxidizer jets that rapidly mix outside of the burner face to provide a nonpremixed mode of operation for the burner, has also been developed. The burner is designed to generate high-temperature combustion products over a wide range of fuel and air flow rates. The facility is operated with a computer-controlled system developed with the help of engineers from Glenn's Facilities and Test Engineering Division and Engineering Design and Analysis Division.



*Micropremixed, self-cooled burner used to generate hot combustion products inside the high-pressure rig. The burner consists of an array of 49 premixed fuel-oxidizer jets that combine to form a larger homogeneous combustion zone.*

The burner and the Raman diagnostic system was designed by Dr. Nguyen of Glenn's Combustion Branch and built in-house. In the process of building the Raman diagnostic system, a novel high-speed (8.5- $\mu$ sec) electromechanical shutter was developed by Dr. Nguyen to improve the Raman signal-to-noise ratio (SNR) by 1000 times over conventional leaf shutter systems. A patent for this shutter design is currently being pursued. The Raman-scattering diagnostic system is shown schematically in the figure on the next page. The state-of-the-art design of the Raman collection system permits the detection of weak Raman signals with a 40-fold improvement in sensitivity and a 1000-fold increase in dynamic range over conventional Raman scattering systems. Recently, Dr. Jun Kojima, a National Research Council Postdoctoral Research Associate (a recent graduate of Kobe University, Japan), has been assisting Dr. Nguyen with many of the experimental aspects of this facility.

Milestones achieved for this year include completion of the gaseous burner system, obtaining a safety permit for hydrogen operation in the test cell, completion of the laser Raman scattering system, demonstration of the laser pulse-stretcher, demonstration of the shutter system, cold-flow testing (rig shakedown) to verify proper operation, and a successful first light-off with a hydrogen-air mixture at 10-atm rig pressure. The facility is now operational and in the process of beginning Raman data collection in high-pressure flames.



*Raman diagnostic system. The Raman excitation is provided by a pulsed Nd:YAG laser that generates a green (532 nm), high-energy (1 J), and very brief (8.4 nsec) full-width, half-maximum (FWHM) pulse of light (at 10 Hz), which is then temporally "stretched" to a 75-nsec FWHM pulse using an optical delay line "pulse-stretcher" to reduce the peak intensity. The high pulse energy is necessary to provide a high signal-to-noise ratio for the weak Raman effect. The temporally stretched laser pulse is a requirement, as the intensity of the focused and unstretched laser pulse would immediately destroy the 45-mm-thick fused silica windows used on the rig and cause an optical breakdown at the focal point. The stretched laser pulse is then focused into the flame zone inside the rig where Raman-scattered light is collected at a right angle with a high-speed lens and directed into the shutter system. The high-speed shutter rejects the continuous background light through temporal gating and transmits the Raman-scattered light into the entrance slit of a high-speed (f/1.8) spectrograph fitted with a special backside-illuminated unintensified charge-coupled device (CCD) camera. The spectra, in the form of digital images from the computer-controlled CCD camera, are then stored on a computer for analysis.*

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