What Was Big As A Jeep, Became Smaller Than A Penny

Tiny Tunable Diode Laser Moisture And Carbon Dioxide Sensors For Pipeline Gas Are The Outcome Of An Exciting Story, And There Is More To Come

by **George Balogh,** CEO, **SpectraSensors, Inc.,** San Dimas, CA

It was a memorable day in January 2003. I had just joined SpectraSensors as CEO and Dr. Randy May — Vice President/Chief Technology Officer and co-founder — used a dramatic visual to put into perspective the development of the tunable diode laser (TDL).

"Imagine a gondola the size of a Jeep weighing about 2,800 pounds. We put a laser spectrometer inside that was cooled by liquid helium, suspended it from a high altitude balloon and launched it into the atmosphere to measure a number of stratospheric gases."

That is how Dr. May described the gondola containing one of the pioneering forerunners of the patented technology we use today for measuring water vapor and CO_2 in natural gas pipelines.

There is something for almost everyone in this story: Mars Lander Mission, WWII bomber, Ozone Hole discovery, Space Station death traps, U-2 spy plane, and Antarctic and North Pole expeditions. But after several meetings with Randy, I came away with a sense of awe and deep respect for American ingenuity and scientific teamwork that laid the foundation at the Caltech-managed NASA/Jet Propulsion Laboratory (JPL) for our company to spin off and commercialize what may be an historic milestone in pipeline safety. We are proud to continue that legacy in the pursuit of R&D innovation and product excellence.

This article is a distillation of main events rather than a strict historical chronology. There have been so many great people involved, from Randy's JPL colleagues to customers who recognized the opportunities and gave us our first break, that I decided to omit names rather than risk offending good friends.

The Early Years

The 1950s and 1960s had witnessed vigorous research activities in laser technologies accompanied by strident patent challenges among leading scientists. In 1964, Bell Labs introduced the first semiconductor lasers but they were very expensive, bulky, and required liquid helium cooling. However, the march toward a technological revolution in many industrial and consumer categories had begun.

In 1985 Dr. May joined JPL in Pasadena, CA and over the next 15 years co-led with Dr. Chris Webster, several major research tasks to develop diode lasers as gas sensors for atmospheric and planetary studies. He also managed a laboratory program to develop spectroscopic analysis techniques, frequency stabilization of lasers, and design of efficient algorithms for the manipulation and interpretation of molecular gas spectra. In the 1980s and '90s, Randy's 10-person group was recognized as the world leader in atmospheric research using high altitude aircraft and balloons.

Shoe Box Size

In 1986, Fujitsu miniaturized and introduced the first near-infrared diode laser that was cooled by liquid nitrogen dewar instead of liquid helium dewar, substantially reducing the overall size. In addition to more compact-sized instruments made possible by use of smaller dewars to hold the liquid cryogen, the availability of lasers operating in the 5-15 micron wavelength region in the mid infrared were ideal for measuring a wide range of atmospheric gases.

Unfortunately, because of high prices, demand was insufficient for Fujitsu to continue manufacturing and the product was dropped a year later. But Fujitsu had pointed the way. Although none of these early instruments measured water vapor, they did measure many other important gases, broadening the overall knowledge base which later benefited the evolving technology of measuring water vapor and CO_2.

During the same period, the Ozone Hole was discovered — an event that in the mid-1990s would drive ground-breaking research in diode laser spectrometers at JPL. Randy's group continued its aircraft and balloon experiments, taking them to Antarctica to conduct atmospheric research of the Ozone Hole followed by similar trips to the North Pole.

A miniaturized, self-contained diode laser system was needed that could provide both day and night-time measurements, but specific project funding was necessary to make it a reality. NASA did just that when it concluded that if the technology used in the balloon experiments was so advanced that laser spectrometers could be installed on airplanes, the Ozone Hole and other important atmospheric research could be more comprehensively studied.

50-Cent Piece Size

Then, in 1993-94, the David Sarnoff Research Center introduced substantially smaller room-temperature lasers offering different wave lengths for gas measurement. Although their lasers cost $7,000 each, Sarnoff had achieved an historic breakthrough.

Randy's group selected six Sarnoff diode lasers as an interim product development step and installed water vapor sensors on a NASA ER2 (Lockheed U-2 high altitude spy plane), a DC-8 jetliner, and a WB57 (a modified Martin bomber), all of which are still flying today and accurately measuring atmospheric water vapor.

NASA followed up with more funding in 1995-96 to develop the next generation of miniaturized diode laser sensors that could be space-qualified. But for the new technology to be effective, it would need real time software and easy-to-use operation, all contained in a small, robust package.

Another Mars mission was announced and Randy's group proposed the inclusion of two on-board diode laser gas measurement systems. Despite the high launch forces and extreme temperatures on Mars, they believed their past successes in harsh environments justified consideration of their systems. NASA agreed and both systems were included on the Mars 1998 Lander payload.

Work continued on water vapor measurement for aircraft and systems shrank in size.

Smaller gas sensing packages became potential life savers, too, because during the same period, Randy's group developed an "advanced life sensor" intended to be worn on the chest of space station astronauts following a CO_2 poisoning event. The sensors would detect and sound an alarm in the presence of life-threatening pockets of CO_2 in crew quarters and research modules.

Typical diode laser package for sensing moisture or CO_2 in natural gas. Spectroscopy using tunable diode lasers (TDL) was developed at Caltech's Jet Propulsion Laboratory in the late 1970s. In 1999, SpectraSensors perfected and applied its proprietary TDL spectroscopy to industrial process and environmental monitoring applications.

Smaller Than A Penny

Typical SpectraSensors diode laser package for sensing water vapor or CO_2 in natural gas pipelines.

As the late '90s approached, laser-based spectrometers became even smaller and supporting software smarter. Thanks to the widespread use of diode lasers in telecommunications, CD players and bar code scanners, the cost of diode lasers plummeted, making it possible to offer affordably priced industrial process control systems. In 1998, with Caltech's and JPL's blessing, an Internet Web site announced the formation of SpectraSensors, Inc. co-founded by Randy May. Caltech became, and remains today, one of SpectraSensors' founding shareholders.

Increased Focus On Pipeline Safety

Several serious accidents in recent years prompted governmental regulatory agencies and others to seek the use of more advanced and reliable safety devices to protect the integrity of pipelines. As industry members know only too well, if natural gas is too wet, Btu content decreases as the danger of corrosion increases. Further, water vapor can combine with CO_2 to produce carbonic acid along with ice plugs in winter.

Some in the industry believed that laser-based sensors installed at critical pipeline sites could address the safety issues and possibly reduce maintenance costs because of the inherent stability of extractive, non-contact laser sensing. SpectraSensors built several prototypes and in the summer of 1999 demonstrated their accuracy and virtually calibration-free reliability. The first units were sold to El Paso Gas in the fall of 1999, followed by sales to Enron and BPM-Williams. U.S. patents were subsequently granted for tunable laser wave length and measurement method of sensing water vapor in natural gas.

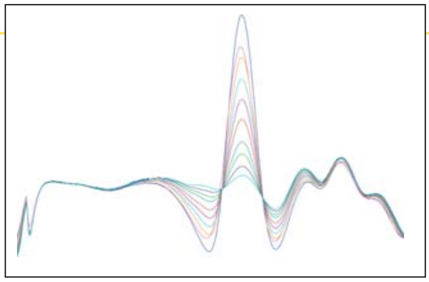
In April 2003 an additional round of funding from investment bankers was achieved and the company moved its headquarters and manufacturing to its current location in San Dimas, CA.

New Technologies, New Markets

As for the future, SpectraSensors will shortly introduce several new water vapor/CO_2 gas analyzers for the natural gas pipeline industry and next year will enter two exciting new fields.

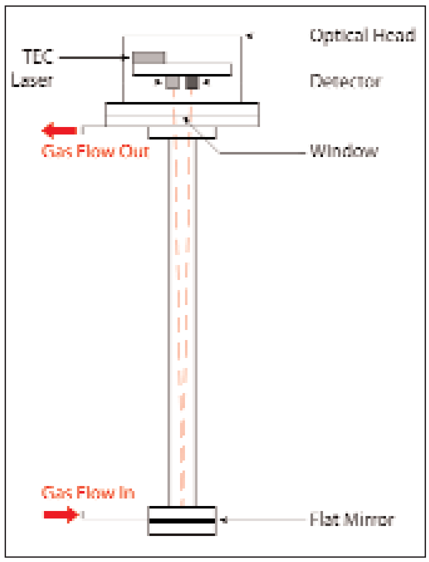
The company recently reached an exclusive worldwide agreement with a major university to develop and market an arsenic sensor based in part on its patented technology. Of special interest is helping third world nations as well as our own, to address this terrible carcinogen which pollutes many of our wells and public drinking water supplies.

Second, working with the National Weather Service, FAA, and Aircraft Communications Addressing and Reporting System, SpectraSensors will ship its new WVSS-II (Water Vapor Sensing System-II) to United Parcel Service. UPS Boeing 757 aircraft will measure water vapor at various altitudes while en route, contribute to real time weather forecasting models and help their aircraft maintain uninterrupted delivery schedules by avoiding dangerous upper level weather conditions. For more information www.spectrasensors.com. ***P&GJ***



Water absorption spectra in natural gas. The graph shows several moisture spectra in natural gas. The higher the concentration of moisture or CO_2, the more absorption of light, and the stronger the corresponding absorption signal. Since the calculation is a direct, fundamental measurement, the amount of moisture or CO_2 present can be measured quickly and accurately. There are no wet-up or dry-down delays like those associated with surface-based capacitance sensors.

Author: George Balogh *joined SpectraSensors in November 2002 as CEO. Balogh was Senior Vice President and founder of the Passive Telecom Group at Spectra-Physics. He has 23 years of management experience in optical components and instrumentation industries. He is a past president of the Lasers and Electro-Optics Manufacturers Association (LEOMA). Balogh holds a B.S. degree in industrial engineering from California Polytechnic State University and an MBA from Golden Gate University.*



Schematic of laser sample cell. SS Series analyzers use robust, tunable diode lasers that emit near-infrared light at wavelengths absorbed by moisture or CO_2 in natural gas. As IR light passes through the gas sample, energy is absorbed, reducing the amount of light arriving at the solid state detector.