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Uranium Vaporization Rates**

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The Use of Laser Diodes for Control of Uranium Vaporization Rates

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Abstract

Within the Atomic Vapor Laser Isotope Separation (AVLIS) program we have successfully used the laser absorption spectroscopy technique (LAS) to diagnose process physics performance and control vaporization rate. In the LAS technique, a narrow line-width laser is tuned to an absorption line of the species to be measured. The laser light that is propagated through the sample is measured and, from this data, the density of the species can be calculated. These laser systems have almost exclusively consisted of expensive, cumbersome, and difficult to maintain argon-ion-pumped ring dye lasers. While the wavelength flexibility of dye lasers is very useful in a laboratory environment, these laser systems are not well suited for the industrial process control system under development for an AVLIS plant. Diode-lasers offer lower system costs, reduced man power requirements, reduced space requirements, higher system availability, and improved operator safety. We report the successful deployment and test of a prototype laser diode based uranium vapor rate control system. Diode-laser generated LAS data was used to control the uranium vaporization rate in a hands-off mode for greater than 50 hours. With one minor adjustment the system successfully controlled the vaporization rate for greater than 147 hours. We report excellent agreement with ring dye laser diagnostics and uranium weigh-back measurements.

Introduction

Laser Absorption Spectroscopy (LAS) can revolutionize many industrial processes by permitting highly specific, accurate, and nonintrusive real-time monitoring of species densities. LAS offers significant advantages over conventional spectroscopy. In conventional systems, spectral resolution is limited by the resolution of the dispersive gratings. The spectral resolving power of a LAS system, however, can be as much as five orders of magnitude greater because resolution is limited only by the line-width of the laser source. Sensitivity and signal-to-noise ratio are also increased in a LAS system because of the use of a high-power coherent source and the lack of dispersive gratings. This improvement in sensitivity provides LAS with the ability to detect and measure low concentrations and to take advantage of weak spectral features.

Presently, the majority of LAS systems are based on argon-ion-pumped ring dye laser sources. Ring dye laser systems offer the advantage of tunability over a broad wavelength range, but their cost, size, and difficulty to maintain makes them impractical for most industrial applications. Diode-lasers are emerging as a technology which will, for many applications, replace ring dye lasers and will spark the development of cost effective, reliable, and portable atomic and molecular spectroscopy systems.

In the system described, the sweep signal to scan the wavelength of the diode laser is generated by the computer system and is also used to synchronously trigger the digitizer scan. The wavelength modulated light from the swept diode laser is then sinusoidally amplitude modulated by an acousto-optic modulator. This amplitude modulation facilitates the use of a lock-in amplifier for more sensitive signal detection and greater dynamic range. Although not shown in the block diagram, acousto-optic modulation enables the demultiplexing of signals generated by multiple lasers monitoring other species at the same location. An optical isolator is required before the acousto-optic modulator to prevent optical feedback from entering the laser cavity. A Fabry-Perot interferometer provides a scan width calibration. The laser is centered on the uranium transition initially with a wavemeter and then held on line with a correction signal generated by the computer from the absorption data.

The optical signal is then fiber delivered to the remote vaporization vessel. Sending and receiving units have been designed that bolt directly to the vessel. The design of the sending unit includes the optics and electronics required to split and detect a reference signal before the light is sent through the vapor. This reference is used to detect and effectively cancel out noise generated by intensity fluctuations in the laser or optical delivery system. The absorption signal is detected by the receiving unit which consists of a lens and photo-opamp detector. Cables deliver the electrical signals back to the lock-in amplifier and digitizer. The ratio of the signal to the reference is graphically displayed. The density is calculated using Lambert's law:

$$I = I_0 e^{-n\sigma l}$$

where: I = transmitted light intensity
 I_0 = incident light intensity
 n = density of the sample
 σ = wavelength absorption cross section
 l = path length of the sample

Figure 2a - Typical absorption curve

Figure 2b - Typical Fabry-Perot output
 300 MHz per "tick"

greater than 147 hours with one minor adjustment. Although designed for uranium vapor rate monitoring and control, many applications exist for this diode-laser based real time spectroscopic diagnostic system. Adapting the present system to other processes requires identifying the appropriate absorption transition, changing the software to reflect the new cross section, and substituting a corresponding diode laser head. LLNL, in conjunction with industrial partners, is also investigating other diode laser based LAS systems for commercial applications. These applications are as diverse as a composition control diagnostic for aerospace alloys, a deposition control monitor for micro-structures research and systems for speciating and quantifying the constituents in exhaust emissions.

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