Miniature Optical Fiber Spectrometer Extends to VUV

Abstract:

Spectral measurements down to 153 nm can be achieved easily and economically thanks to newly developed back thinned detectors when designed into miniature fiber optics spectrometers. With the adequate vacuum or noble gases purge options in order to eliminate water, oxygen and other gases absorption in the vacuum ultraviolet region.

Introduction:

A variety of materials have spectral signatures in the vacuum ultraviolet (VUV) spectral region, typically described as the region from 30 nm-200 nm [1, 2]. VUV spectroscopy is useful for applications ranging from biomedicine to semiconductor testing. With extensive interest in the VUV ellipsometric field as well as in the research of fundamental physics of atoms and as in the detection of VUV radiation interaction with matter in particle accelerators or synchrotrons. Because the spectral response of standard silicon charge-coupled device (CCD) detectors drops off rapidly at wavelengths as long as 400 nm, and because oxygen and water absorb in the VUV spectral band, maintaining sufficient signal outside a vacuum is not possible. Designing vacuum-compatible spectrometers to address these issues can be difficult and expensive. As a result, most commercially available VUV spectrometers require custom configuration and are too expensive and unwieldy for many common applications.

The Maya2000 Pro with Vacuum UV Option is poised to change that. The spectrometer features a 101.6-mm focal length optical bench with a compact crossed Czerny-Turner design and a back-thinned CCD detector that offers superior UV and VUV performance. To minimize signal attenuation inside the optical path, the spectrometer bench is purged with nitrogen, achieving a robust signal for VUV experiments at wavelengths as low as 153 nm.

Experimental:

To test performance, we started with a Maya2000 Pro configured with a high resolution, UV-enhanced 2400g/mm holographic grating (H7) and a 25 µm slit, providing an optical resolution ~ 0.10 nm (FWHM). The back-thinned detector features a peak quantum efficiency of 75%, with UV quantum efficiencies as high as 50%. A custom magnesium fluoride (MgF2) glass window was placed over the detector for improved transmission over VUV wavelengths. The DH-2000 Deuterium Tungsten Halogen Light Source, which combines the continuous spectrum of deuterium and tungsten halogen light sources in a single optical path, was chosen for this experiment. The combined-spectrum light source produces a powerful, stable output from 215-2000 nm. In addition, deep-UV versions of the light source are available, providing a 190-1700 nm wavelength range.

The test sample for the experiment was a VUV deuterium lamp with a VUV-grade optical window, coupled directly to the spectrometer. We enclosed the source and spectrometer in a glove box and purged the interior of the chamber with standard laboratory-grade nitrogen. The process was sped up by filling a Mylar balloon inside the chamber to evacuate the air. To minimize signal attenuation inside the optical path, the spectrometer bench was purged with nitrogen as well. (See *Figures 1 and 2*.)

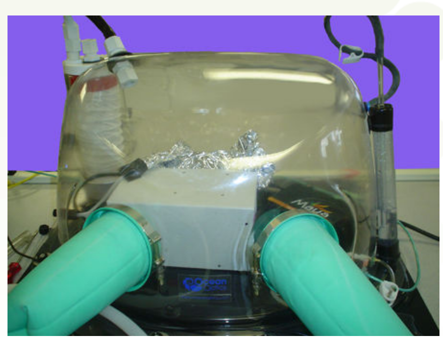

Figure 1. Experimental set up: DH2000 and MAYA2000 Pro inside glove box.

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a.

b.

c.

Figure 2. a. Nitrogen purge of oxygen with Mylar balloon inflated. b. Deflation of m*ylar balloon.* c. *NeoFox oxygen sensor inserted into glove box to verify oxygen levels.*

After air was purged out of the chamber, the Mylar bag was deflated. Nitrogen was pumped constantly pumped into the glove box. Excess gas evacuated the chamber through the partially-filled tube with water on the right side of the chamber.

A Neofox oxygen sensor was also inserted to monitor oxygen levels inside the glove box to monitor oxygen levels. *(See Figure 3.)*

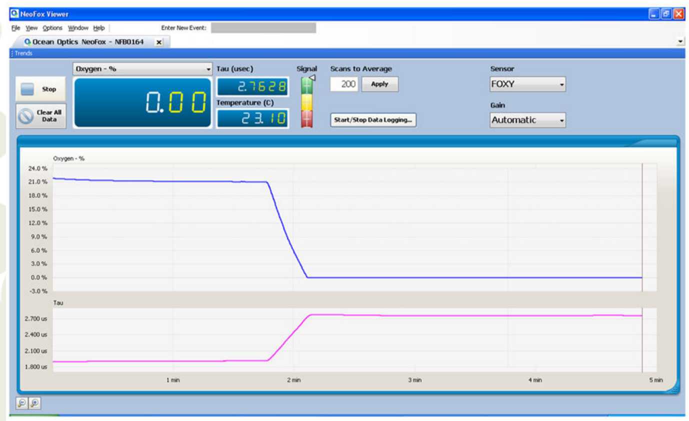

Figure 3. Neofox Viewer software screen shot showing the drop in oxygen levels during purge.

Results:

The system operated with a spectral resolution of 0.1 nm and a signal-to-noise ratio of 450:1. Integration time for the measurement was 100 ms. The normalized purged (without oxygen) and un-purged (with oxygen) spectra can be viewed in *Figure 4*. The un-purged spectra shows the emission peaks of oxygen. The resultant emission spectrum shows sharply defined spectral peaks in absorbance with emission starting at wavelengths as low as 182.85 nm. Also shown is the comparison of normalized purged (no oxygen) versus un-purged (with oxygen) data demonstrating the Schumann-Runge Bands (absorption bands for oxygen) between 176 and 192.6 nm.

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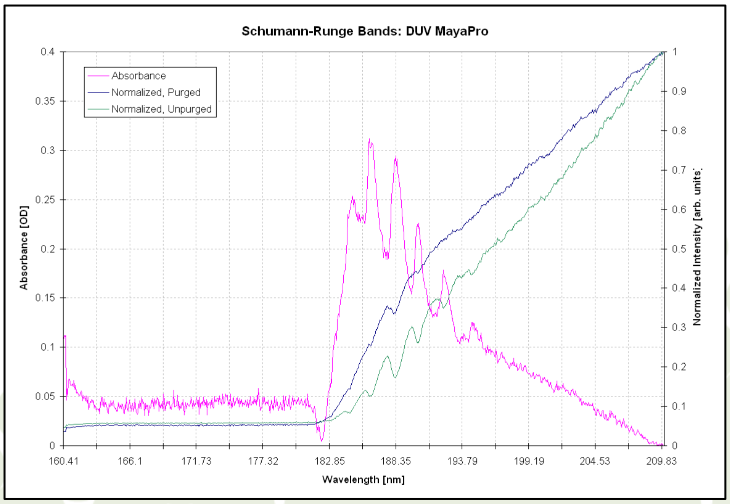

Figure 4. Emission spectrum of a VUV deuterium lamp shows clearly defined peaks, and normalized purged versus unpurged data demonstrates the Schumann-Runge Bands.

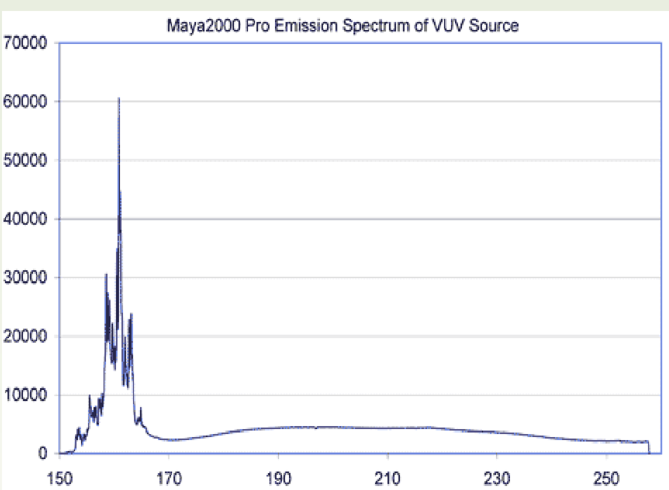

Figure 5. Spectra of a VUV emission source shows clearly defined peaks in a different experiment, with good signal-to-noise performance and 0.1 nm (FWHM) optical resolution.

Conclusions:

Although the Maya2000 Pro with Extra-Deep UV Option was used to get down to 182.85 nm, this experiment was limited by light source which did not allow us to go below that wavelength. Depending on the equipment used, it can be used for VUV experiments at wavelengths as low as 153 nm. See *Figure 5*.

The results demonstrate that the innovative and cost effective design of the Maya2000 Pro can be easily used for VUV applications.

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