Evaluating Reflectivity Test Station for UV Measurements

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This note discusses the capabilities of DSG's existing reflectivity test station equipment for measuring light in the deep-UV spectrum (~200 nm wavelength). Also discussed are results from proof-of-concept tests performed with existing test station equipment and proposals for a fully UV-capable test station.

Jefferson Lab will be constructing ring-imaging Cherenkov (RICH) detectors for the EIC and SoLID projects. Each detector has arrays of mirrors that focus Cherenkov light to the detector's electronics array. The mirrors must comply with manufacturing specifications, particularly for their reflectivity. To check that the mirrors meet the required reflectivity specifications in the deep UV wavelength spectrum (~200 nm), they will be tested in the Detector Support Group's reflectivity test station. However, to be able to do so, the individual test station components must be tested to determine if they can be used at the deep UV wavelengths. If a component is not suitable for deep UV reflectivity measurements, adequate replacements must be found.

The current reflectivity test station uses two Thorlabs compact charged couple device (CCD) spectrometers (CCSs) to measure the power of light before and after reflection from a mirror. Out of the box, the CCSs are specified to be able to measure wavelengths from 200–1000 nm. To verify this specification, a simple proof-of-concept test was performed, using the test station's Thorlabs SLS201L quartz-tungsten halogen (QTH) lamp.

The light source, the QTH lamp, was connected to one CCS using only the reference leg of a Thorlabs fiber-optic reflection probe RP26, Fig. 1, since the reference leg is a direct connection through the fiber-optic cable bundle between the QTH lamp and the CCS and the main concern is the capability of the CCS to measure deep UV light.

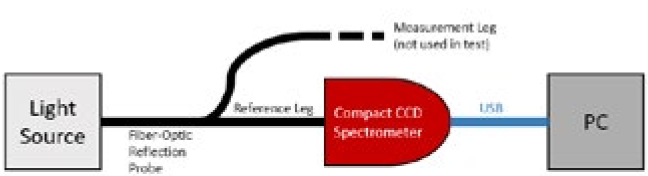

FIG. 1. Diagram of setup used to test CCS capabilities at measuring light in the deep UV spectrum.

The Thorlabs Optical Spectrum Analysis software shipped with CCSs was used to take a snapshot of the light intensity from ~200–300 nm with a 40-ms CCS exposure time, Fig. 2. The relatively flat wavelength vs. intensity curve shown in Fig. 2, and the fact that the QTH lamp is only specified to output stabilized light down to 360-nm wavelengths, indicate that the QTH source is not a suitable light source for deep UV wavelength measurements.

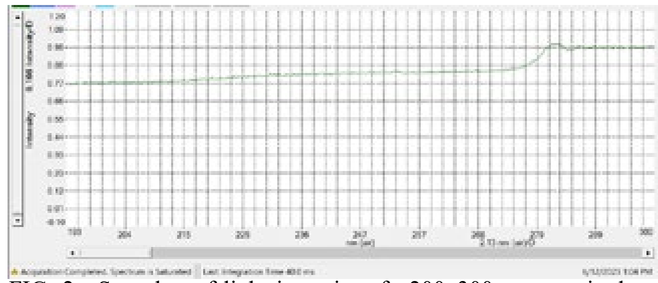

FIG. 2. Snapshot of light intensity of ~200–300 nm acquired using a CCS and Thorlabs' Optical Spectrum Analysis software. Light source was a QTH lamp. CCS exposure time for the acquisition was 40 ms.

With this finding, a second test was performed, replaceing the QTH lamp with a 30-W deuterium lamp, to see how the CCS would operate with a source specifically rated for UV light. The Optical Spectrum Analysis software was used, but exposure time was increased to 900 ms.

Fig. 3 is a snapshot of the light intensity measurement from ~200 nm–300 nm. With the deuterium lamp, a well-defined spectral curve is present in the CCS measurement, indicating that the lamp does out put light in the desired deep UV spectrum. However, the much longer 900-ms exposure time is an indicator that either the lamp might not be powerful enough for consistent UV measurements or that the fiber-optic cable is improperly coupled to the light source. To account for both of these possibilities, a more powerful UV light source with appropriate fiber coupling optics should be procured.

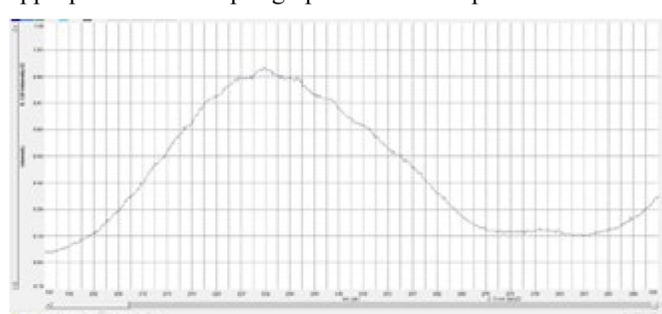

FIG. 3. Snapshot of light intensity of ~200–300 nm acquired using a CCS and Thorlabs' Optical Spectrum Analysis software. Light source was a 30-W deuterium lamp. CCS exposure time for the acquisition was 900 ms.

A candidate for the UV light source is the Newport model 66080-30DU-Q15 deuterium source. This lamp's output is specified as 160 nm–500 nm and can be adapted with a condenser and focusing optics to output light through an optical fiber.

In addition to a new UV light source, a fiber optic cable bundle that is resistant to UV damage should be procured. The RP26 has a minimum recommended wavelength of 250 nm and the probe's documentations warns that UV exposure will permanently damage the probe's fiber core, reducing the UV light transmission to ~30% in approximately three hours. Thorlabs suggested fabrication of a custom reflectivity probe with UV-resistant optical fibers. However, Thorlabs also gave a disclaimer stating that the custom fiber's UV transmission will drop to ~75% after approximately three hours; therefore any optical fiber used with UV wavelengths should be considered a consumable with a limited lifespan.

Three courses of action are recommended.

Procure a custom reflectivity probe with the understanding that its UV transmissibility drops in approximately three hours. The main benefit is that the test station procedure for UV spectrum measurements and visible spectrum measurements will be identical.

Design an assembly that only uses in-stock Thorlabs optical fibers that could be ordered and received within two weeks. However, the alignment procedure required for the assembly may be challenging.

Do not use optical fibers, but transmit the beam through empty space. However, manual alignment of the test station will be time consuming and the entire test station will have to be enclosed in a low-oxygen environment, since oxygen will absorb low-wavelength light. An enclosure purged with nitrogen would have to be used.

In summary, for future RICH detectors, the reflectivity of the detectors' mirror arrays for deep UV light must be tested to ensure the mirrors meet required specifications. The Detector Support Group has a visible light spectrum reflectivity test station and its compact CCD spectrometers can be used for light with wavelengths down to ~200 nm.

However, it is strongly recommended to procure a more powerful UV lamp for the tests. Additionally, inconstancies in results induced by damage to any optical fiber caused by UV light over time should be mitigated. To mitigate damage, a custom reflectivity probe could be used, with the understanding that its optical fibers will become more opaque over time, requiring the entire probe assembly to be replaced, a probe assembly could be designed that uses standard optical fibers that can be replaced if damaged, or forgo using optical fibers and transmit the test beam through empty space in a low-oxygen environment. With these considerations, UV reflectivity measurements can be performed for the EIC RICH mirrors to confirm that the mirrors meet reflectivity specifications.