

Improving Spectral Quality Using Beam Collimation Control

Benefits of the Agilent Cary 7000 Universal Measurement Spectrophotometer with high f-number apertures for superior data quality and accuracy



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Introduction

In spectroscopy, the quality of spectral data depends greatly on the incident beam that passes through the sample being analyzed. For samples analyzed at large angles of incidence (AOI), such as bandpass and edge filters (e.g., beam splitters), maintaining a high degree of beam collimation is necessary to achieve optimal results. This control is achieved by adjusting the incident beam using apertures within the spectrophotometer that can be customized to meet the specific requirements of the application.

In this work, an **Agilent Cary 7000 UV-Vis-NIR spectrophotometer** that includes the **Agilent Cary Universal Measurement Accessory (UMA)** was used. The degree of beam collimation was investigated using different apertures within the UMA to enhance data quality for the determination of the edge steepness of an optical filter.

Benefits of the UMA

The Cary UMA attaches directly to existing Agilent Cary 4000, 5000, and 6000i spectrophotometers or is a standard feature on the Cary 7000 universal measurement spectrophotometer (UMS). The UMA, which is fully controlled by **Agilent Cary WinUV software**, expands the capabilities of UV-Vis-NIR spectrophotometry for the characterization of solid materials such as thin films, coatings, optics, glass, and solar cells. The flexibility of the UMA enables users to advance their materials analysis for research, development, or QA/QC applications.

Advantages of the accessory include:

- Generation of high-quality data in terms of accuracy and precision.
- Reduced cost-of-analysis by increasing sample throughput of QA/QC verification testing during manufacturing.
- Enhanced end-product quality and lower financial risk of shipping faulty products due to comprehensive data produced from automated, unattended analyses.

The UMA also offers unique measurement capabilities that enable users to automatically measure absolute specular reflectance, transmission, and scattering at a wide range of AOI and different polarizations.

Figure 1 shows the Cary 7000 UMS, which includes the UMA.

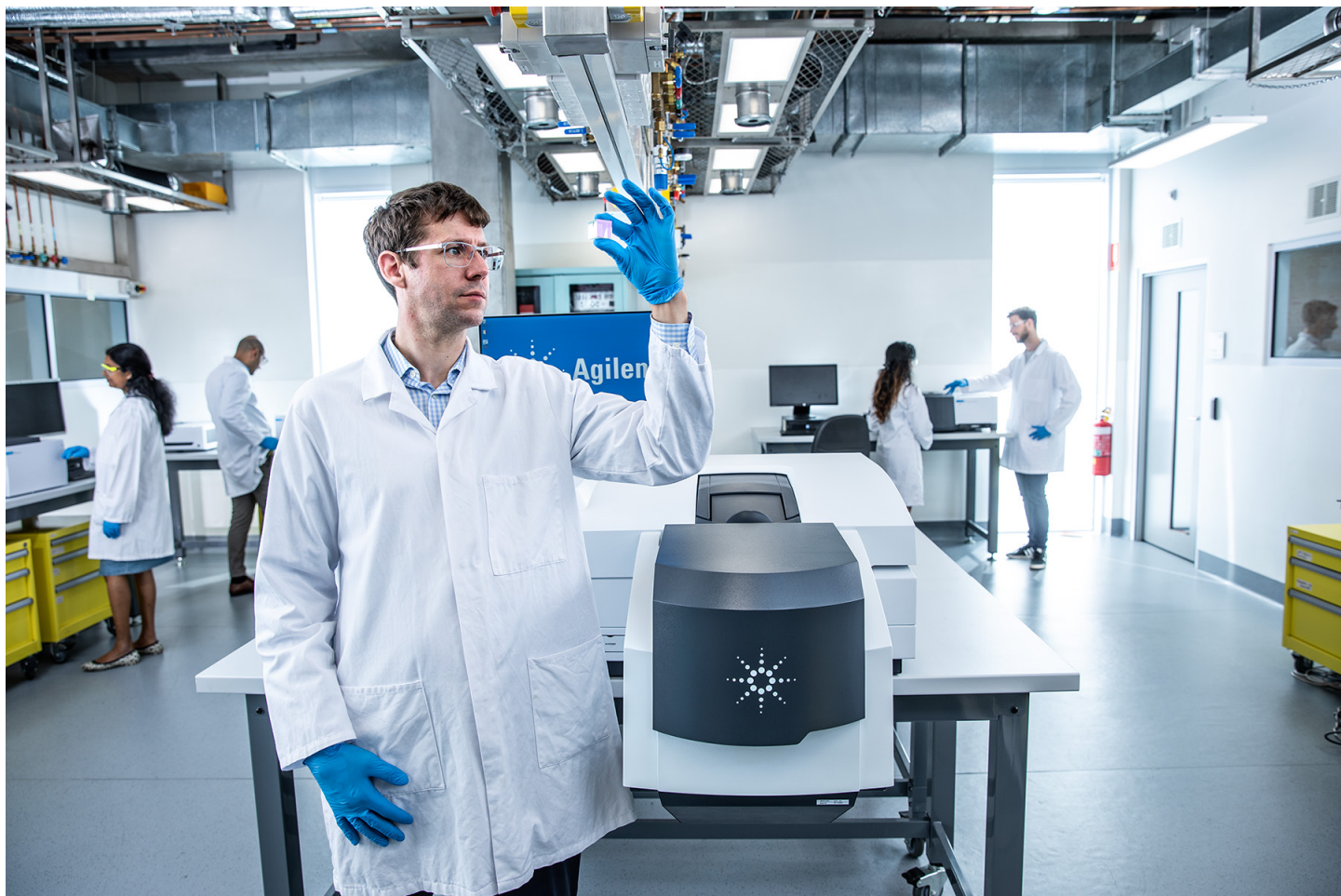


Figure 1. Agilent Cary 7000 universal measurement spectrophotometer (UMS). The system provides complete characterization of distinctive optical samples such as cube beam splitters.

How does the UMA control the degree of collimation?

The UMA has three separate mounting positions for apertures, as shown in Figure 2. Two positions are for a matched pair of apertures that control the degree of collimation in the vertical plane and one position is for a single aperture for control in the horizontal plane. The level of collimation can be set independently in each plane to various degrees using a range of apertures.

The angle quoted for each aperture is the half cone angle, which describes beam convergence or divergence as it hits the sample. The half cone angle is related to the f-number, which represents the light collecting efficiency of an optical component. The f-numbers for the UMA apertures are shown in Table 1.

Table 1. Agilent UMA aperture angles and respective f-numbers.

	Aperture Half Cone Angles					
	0.25°	0.50°	0.75°	1.0°	2.0°	3.0°
Horizontal f-number	f/35	f/18	f/12	f/9	f/4	f/3
Vertical f-number	NA	NA	NA	f/29	f/14	f/10

Apertures with a smaller f-number (e.g., f/3) collect more light due to the increased range of angles incident on the sample. However, this property of low f-number optics can degrade spectral data quality for some applications or sample types that require greater control of the degree of collimation.

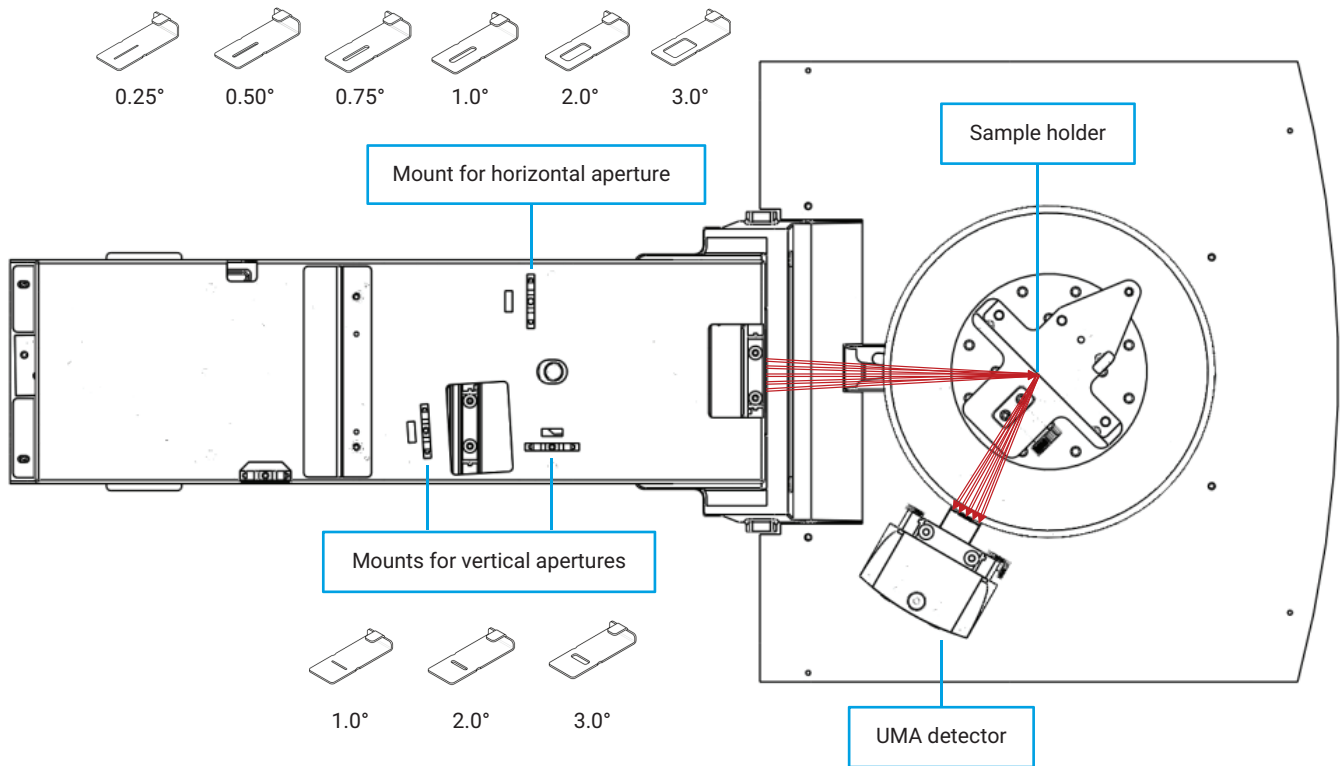


Figure 2. Agilent UMA mounting positions for apertures with various degrees of collimation.

Figure 3 illustrates the variation in degree of collimation depending on the horizontal aperture used in the UMA: 3° (f/3), 2° (f/4), and 1° (f/9).

The vertical cone angle stands perpendicular to the plane of the AOI, thus vertical apertures are employed to adjust the height of the light patch on the sample. Using smaller vertical apertures reduces the patch size, which can be useful for the analysis of small samples.

Setting a horizontal aperture of 0.25° (f/35) provides the highest level of collimation. As this configuration of the UMA is suitable for samples that are sensitive to variations in the AOI, it was investigated for the characterization of an optical filter.

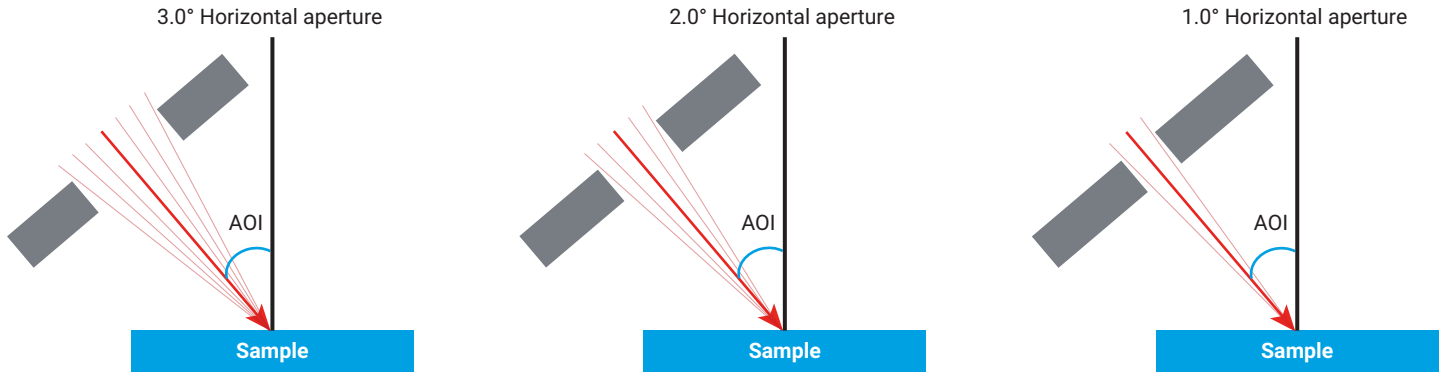


Figure 3. Degree of collimation control based on various horizontal UMA apertures. A nominal 45° AOI spans an angular range from 42° to 48° when using a 3.0° horizontal aperture.

Impact of controlling degree of collimation (using various horizontal apertures) on data quality

To illustrate the effect of beam collimation on spectral quality, the edge steepness of a high-quality beam splitter (supplied by Chroma Technology, Vermont, USA) was evaluated using various horizontal apertures within the UMA. The Cary 7000 was operated in transmission mode.

Edge steepness of optical filters, such as beam splitters, is characterized as the spectral width between two points on the edge pass filter's slope. The smaller a filter's edge steepness, the sharper the transition from transmitting light to blocking it.

To ensure that only the effects of aperture changes could be monitored using the Cary 7000, a constant narrow spectral bandwidth (SBW) of 0.5 nm was maintained throughout the measurements.

As shown in Figure 4, adjusting the horizontal aperture angle from 3 to 0.25° enhanced the steepness of the spectrum (a measure of spectral quality) between 780 and 800 nm, facilitating accurate qualification of the beam splitter. The graph confirms that optimal data were acquired using a horizontal aperture of 0.25°.

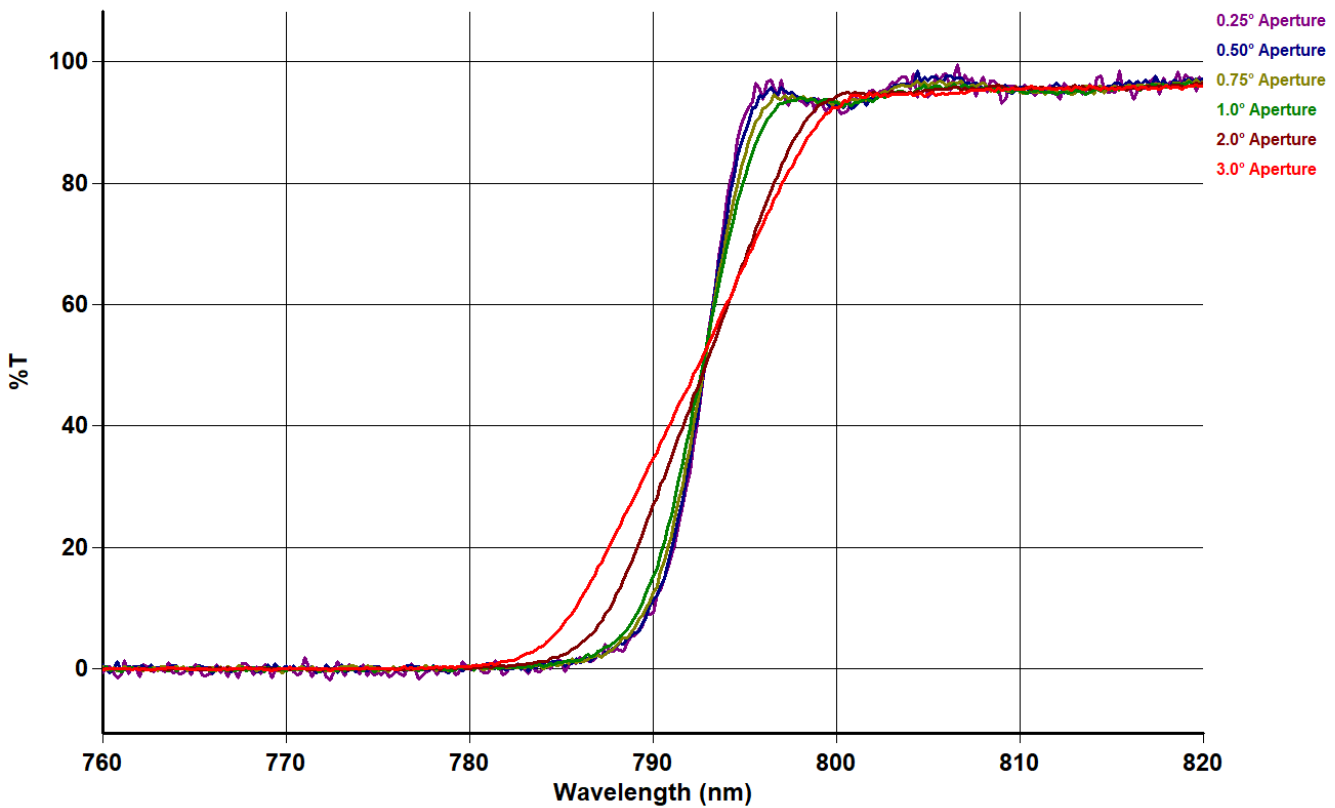


Figure 4. Beam splitter edge steepness measured using the Agilent Cary 7000 UMS with UMA at various degrees of beam collimation (0.25 to 3.0°) in the horizontal plane.

Conclusion

Characterizing the edge steepness of optical filters is an important measurement for manufacturers and users of these types of devices. The steeper the edge, the better the quality of the filter, so careful determination of edge steepness is required to differentiate between high and low quality filters. Accurate measurements depend on the half cone angle of the apertures used in spectrophotometers to control the degree of collimation.

This study has shown that the degree of collimation on the Agilent Cary 7000 Universal Measurement Spectrophotometer (UMS) that includes the Agilent Cary Universal Measurement Accessory (UMA) can be controlled precisely using different horizontal apertures ranging from 0.25 to 3°.

Exploring the use of higher f-number optics in the incident beam of the UMA can lead to improved sensitivity and accuracy in various spectroscopic applications. This performance was demonstrated by the investigation of the edge steepness of a beam splitter. The best data were acquired by the Cary UMA with collimation control using a 0.25° (f/35) horizontal aperture.

The UMA with optimized and controlled beam collimation enables the complete characterization of optical samples, ensuring optimal performance of final components.

Acknowledgment

We would like to thank **Chroma Technology** for providing the sample and for their collaboration throughout this project.

Further information

- Cary 7000 Universal Measurement Spectrophotometer (UMS)
- Cary Universal Measurement Accessory (UMA)
- Cary WinUV Software for UV-Vis-NIR Applications
- UV-Vis and UV-Vis-NIR Instrument Selection Guide
- UV-Vis-NIR Solid Sample Measurement Accessories Guide

www.agilent.com/chem/cary7000ums

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