

ACQUITY UPLC® PDA Detector: Introduction and Overview

NOTE: Except where noted, the term “ACQUITY PDA Detector” refers to two detectors:

- ACQUITY UPLC Photodiode Array (PDA) Detector
- ACQUITY UPLC Extended Wavelength (e λ , or eLambda) PDA Detector

The Waters ACQUITY UPLC PDA Detector is an ultraviolet/visible light detector that replaces the ACQUITY 2996 Photodiode Array Detector^a.

The new ACQUITY UPLC PDA detector was primarily developed for drug discovery applications using 0.18 mm x 2.1 mm column IDs, at flows of 10 nL - 2 mL/min.

The new UPLC PDA detector offers improved performance using:

- data rates up to 80 Hz and noise specifications as low as 10 micro AU resulting in sensitivity that provides unequaled trace impurity detection and quantification
- superior linear range up to 2 AU with constant optical bandpass
- a new photodiode array device, operating in the 190-500 nanometer wavelength range (PDA) or 190-800 nanometer wavelength range (e λ PDA)
- a new high brightness lamp contributing to low noise and higher sensitivity
- a filter flag to control the amount of light entering the flow cell, and used to verify calibration
- simultaneous 3D and 2D data collection
- new low dispersion flow cells using light-guiding technology, and
- the Median Baseline Filter algorithm for enhancing baseline stability when using one step linear gradients

For more information:

- ACQUITY UPLC Photodiode Array Getting Started Guide (PN 71500108703)
- ACQUITY UPLC e λ PDA Getting Started Guide (PN 71500160703)

a. To be certain you have the latest version of this procedure, please visit the Waters Support Center at Waters.com.

Overview

Opening the front panel door of the detector reveals the prealigned lamp and lamp connector on the left (Figure 1). The customer installable lamp is a high brightness deuterium lamp chosen for its low noise characteristics and its ability to output nearly twice the brightness of ordinary deuterium lamps. The new high brightness lamp contributes to the high sensitivity of the detector.

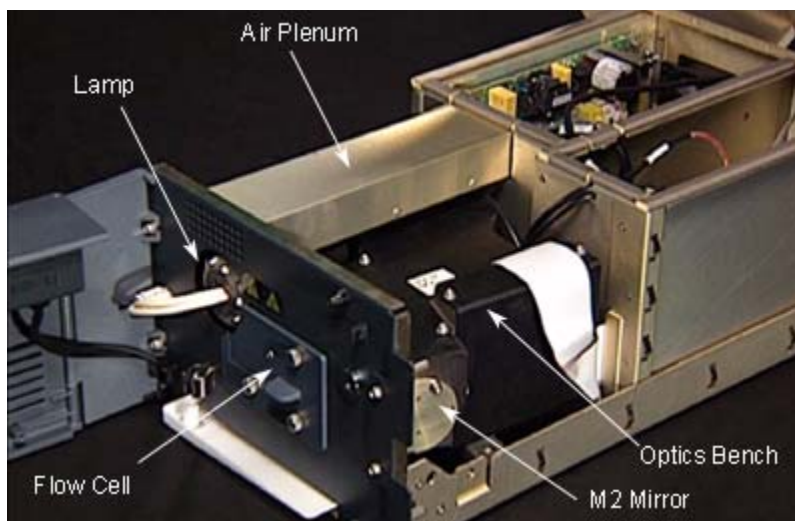


Figure 1 - ACQUITY PDA Components

NOTE: Some of the illustrations show only one type of PDA detector. However, the physical differences between the PDA detector and $e\lambda$ PDA detector are insignificant for this document.

The lamp fits into a lamp housing assembly that provides consistent lamp alignment, while protecting the lamp against damaging stresses from its thermal operating environment (Figure 2).

On the rear of the lamp housing is the thermal snap switch (Figure 2). The thermal snap switch will shut off the lamp if the lamp housing assembly reaches $70\text{ }^{\circ}\text{C} \pm 2.8\text{ }^{\circ}\text{C}$ ($158\text{ }^{\circ}\text{F} \pm 5\text{ }^{\circ}\text{F}$).

NOTE: When removing the lamp, unplug the lamp connector from the front panel and loosen the two captive screws. The lamp in the ACQUITY PDA is replaced the same way as in previous models.

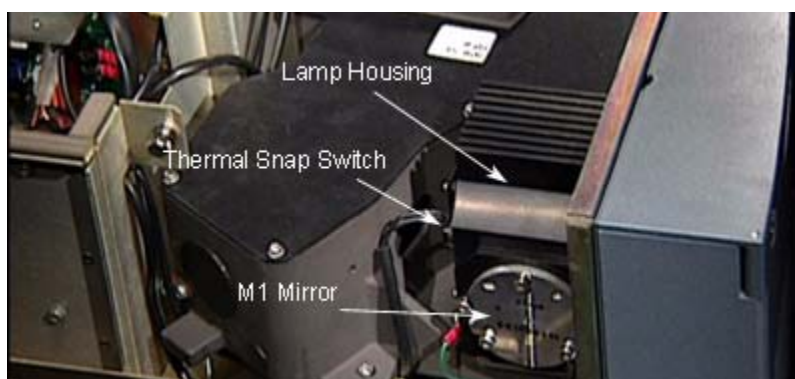


Figure 2 - ACQUITY PDA Lamp Housing Components

To the right of the lamp is the new low dispersion flow cell assembly (Figure 1).

NOTE: Flow cells do not ship with the detector and instead must be ordered as a separate item.

To suit different applications, two flow cells are available.

- An analytical flow cell (with 500 nL volume and 10 mm path length), and
- a high sensitivity flow cell (with 2400 nL volume and 25 mm pathlength)

NOTE: ACQUITY PDA flow cells are replaceable as an assembly only and are not serviceable.

When replacing the flow cell, disconnect the inlet, and if installed the backpressure regulator. Loosen the three captive screws to easily remove the flow cell.

NOTE: For details on replacing the flow cell, refer to the ACQUITY UPLC PDA Getting Started Guide or the Replacing the Flow Cell procedure.

Contributing to the high sensitivity in the ACQUITY UPLC PDA is the light-guiding technology used in all of its flow cells.

Small bore ACQUITY UPLC Columns produce small peaks. To avoid band spreading and maintain concentration, the detector flow cell volume must be correspondingly low. To achieve the required volume reduction with conventional absorbance detector flow cells, the pathlength would need to be reduced, resulting in a loss of sensitivity.

To achieve the desired volume reduction without loss of sensitivity, the light-guiding flow cell uses the same principals as an optical fiber to increase light throughput, and maintain pathlength without increasing the cell volume.

In the light-guiding flow cell, mobile phase and sample compose the liquid core of the flow cell. On the inside wall of the flow cell, Teflon AF, a chemically resistant, glass-like fluorocarbon serves as a cladding material to reflect light (Figure 3).

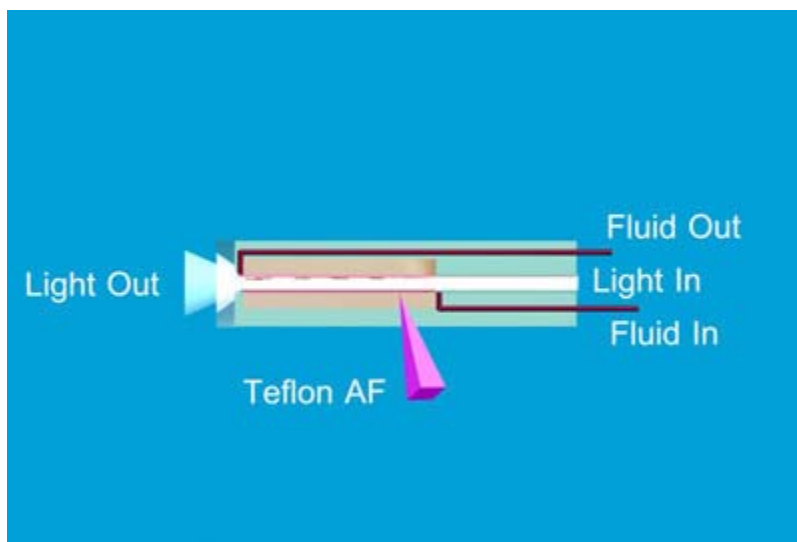


Figure 3 - Light-Guiding Flow Cell Technology

Unlike the flow cell design of the 2996 where the light beam is designed to avoid striking the internal walls of the cell (Figure 4), the cladding with its lower refractive index, allows light that strikes the core-cladding interface to reflect back into the core (Figure 5).

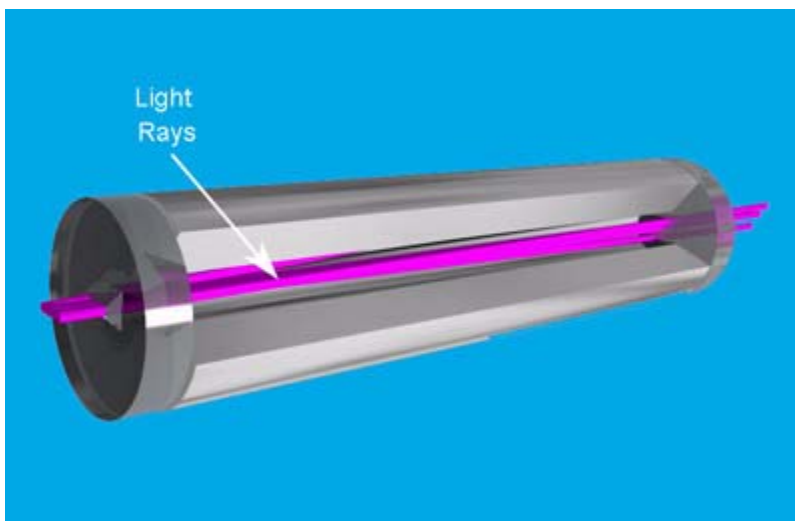


Figure 4 - Taper Slit Flow Cell

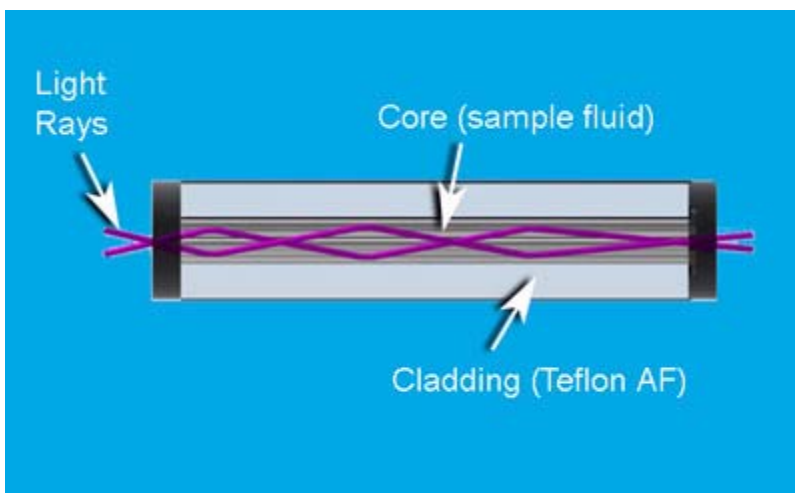


Figure 5 - Light-Guiding Flow Cell Showing Reflected Light Back into the Core

This confines the light to the core for optimum absorption by the sample. Consequently it is important to maintain flow cell cleanliness by following the recommended cleaning procedures found in the ACQUITY UPLC PDA Getting Started Guide.

The amount of light energy that is redirected to the core is influenced by the length of the flow path, its inside diameter, and the light ray angle. Components (charge amp board assembly) external to the flow cell compensate for the variations in refractive index arising from the different mobile phases.

To aid in diagnostics of the optics, and the alignment of the M1 and M2 mirrors, the ACQUITY PDA requires a shunt that emulates light transmission without fluid flow. The shunt is

installed in place of the flow cell, and can transmit approximately the same amount of light. The shunt is available to both engineers and customers.

Removing the top cover of the detector reveals the optics bench, and the air plenum, both located toward the front of the unit (Figure 1).

Heat from the lamp is drawn through the air plenum by the +5 volt DC fan located at the rear of the detector, and expelled out the back.

The newly designed ACQUITY PDA optics bench uses optics components that are very similar to that of the 2996 PDA detector. The most obvious difference is that the main optics components of the ACQUITY PDA are located on the left side, while in the 2996 they are located on the right side. Functional differences include the addition of a filter flag in the ACQUITY PDA to control the amount of light that enters the flow cell.

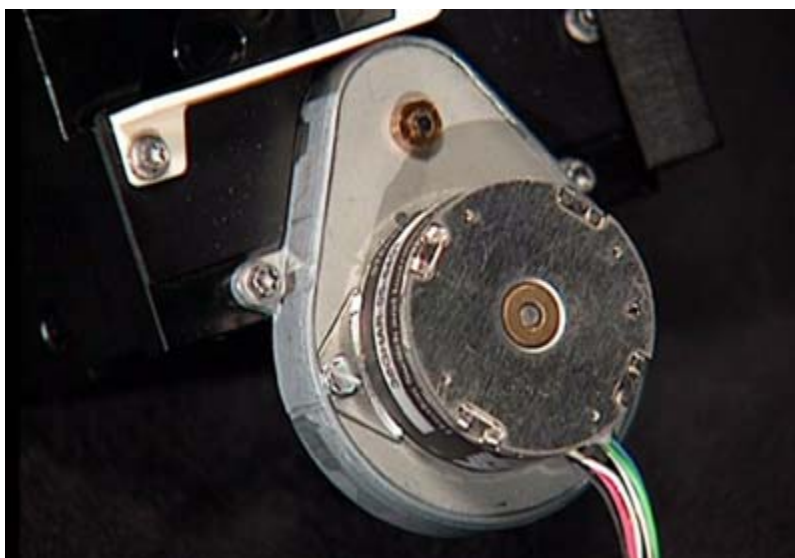


Figure 6 - Filter flag Assembly

At the front left side of the optics bench is the lamp housing assembly (Figure 2). The lamp housing assembly consists of the:

- high brightness deuterium lamp in the front,
- M1 mirror to the left
- beamsplitter and mask (internally),
- thermal snap switch, and
- filter flag located on the bottom of the lamp housing

The filter flag controls the amount of light entering the flow cell using four different settings:

- the closed position for preventing light from entering the cell and used for calculating signal counts (i.e. dark current);
- the open position for allowing light to enter the flow cell, and used when performing chromatography,
- the Erbium position which positions the Erbium filter into the light beam for wavelength verification checks, and
- the UV blocking position that positions the UV blocking filter into the light beam to minimize light with wavelengths shorter than 210 nm. Low wavelength UV light may act as a catalyst for oxidation which can be detected by mass spectrometers.

On the bottom of the optics bench is the aperture slit. Once the optics bench is removed, the aperture slit can be replaced by removing two T-10 Torx screws.

The front of the optics bench houses the light-guiding flow cell and to the far right, the M2 mirror (Figure 1).

Seated beneath the optics cover is the non-serviceable grating.

Located on the right side of the optics bench and housed under a metal cover is the charge amplifier board/PDA assembly (Figure 7). The charge amp board interfaces the photodiode array assembly to the personality card and provides signal conditioning and A/D conversion services. The photodiode array (PDA) mounts directly to the back of the charge amp board. Both the charge amp board and PDA are only available separately and not available as a complete assembly.

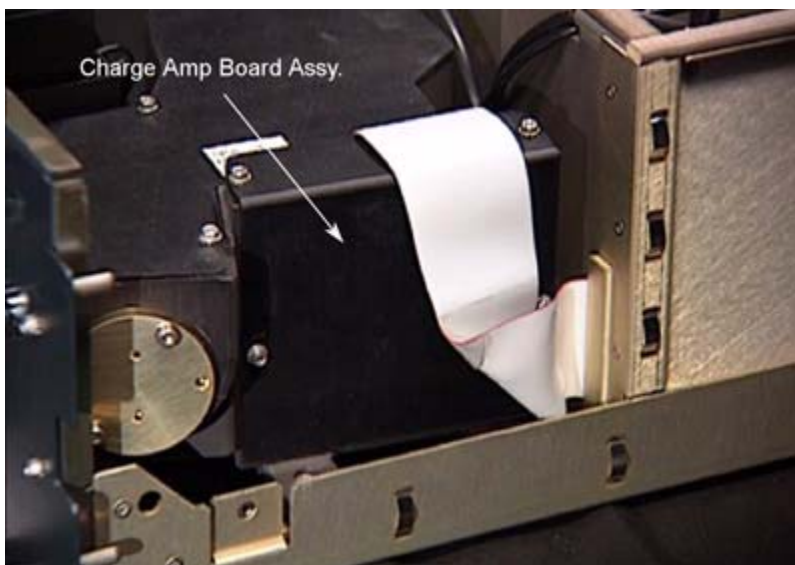


Figure 7 - Location of Charge Amp Board Assembly

As in the 2996, the ACQUITY PDA is a beam deflection design. Light emitted from the high brightness lamp is focused by the M1 mirror through the beam splitter and then into the flow cell (Figure 8).

NOTE: *Unlike earlier photodiode array detectors, there is no reference diode and the light beam is not actually split.*

Most of the light then passes through the filter flag and into the flow cell.

In the ACQUITY PDA light passes onto an optical fiber that forms at the flow cell. Light then travels into the “AF tube” of the flow cell where it interacts with the sample stream. Any absorbance of light by the sample reduces the light intensity that exits the fused silica window of the flow cell.

Light is then focused by the M2 mirror and mirror mask, and directed through a 100 μm slit that determines wavelength resolution and intensity of light. It then passes light onto the fixed grating, where it is dispersed into bands of wavelengths that are focused onto the 512 photodiodes arranged linearly on the photodiode array (Figure 8). An order filter mounted on the PDA assembly reduces second order diffraction of UV light at visible wavelengths (greater than 340 nm).

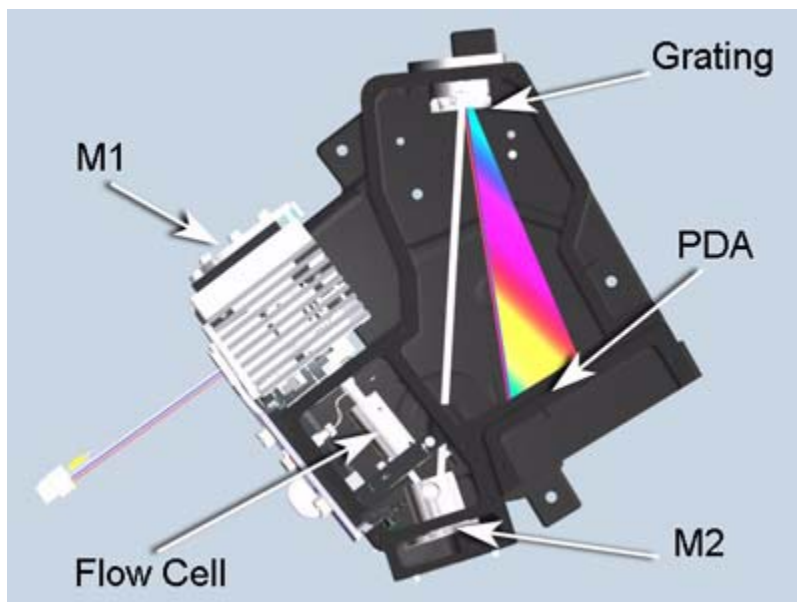


Figure 8 - ACQUITY PDA Light Path

To the rear of the detector are two electronic compartments (Figure 9). At the far right is the Personality Card, which defines the functionality of the detector. Mounted on the Personality Card is the CPU 2000 PCB, which is a common design with other Waters detectors. Together they receive inputs from, and provide control to, all of the subassemblies in the ACQUITY PDA detector.

In the left rear compartment is the DC Power Supply that supplies the +5, +24, and ± 15 voltages necessary to operate the detector. The lamp power supply board is responsible for supplying the necessary voltage to fire the lamp.

NOTE: *With the exception of the battery on the CPU 2000 PCB, none of the boards contain any serviceable parts.*

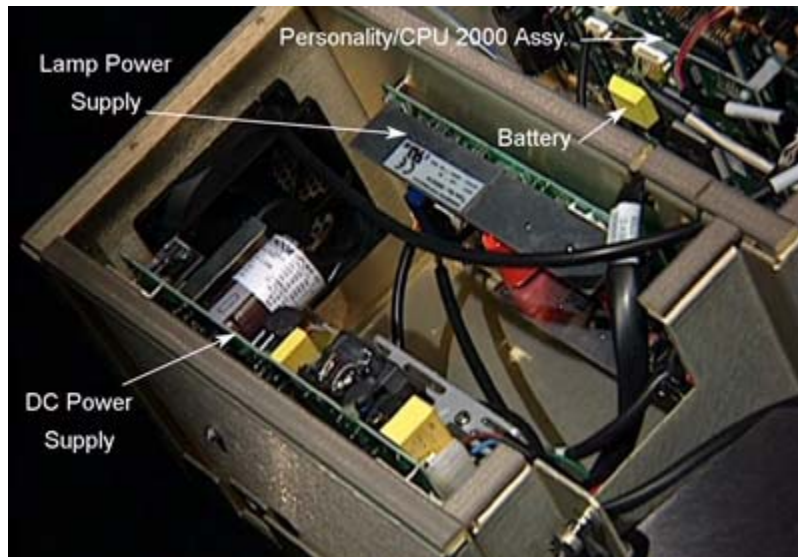


Figure 9 - Electronic Compartment