Characterization of a New High Resolution Ion Beam Imager to Improve Ion Beam Analysis in Mass Spectrometers

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Introduction:

Ion optics modeling software is often used to design and predict the ion path within a mass spectrometer. However, ion modeling does not take into account all factors within the mass spectrometer, meaning than ion loss within the instrument occurs frequently.

The conventional method for aligning a beam typically consists of scanning the ion beam over a Faraday cup or electron multiplier, integrating the current, and adjusting the settings to produce the highest signal. However, this can be a time consuming process of trial and error with no surety that the optimum tuning has been achieved.

PHOTONIS has introduced a new high resolution ion beam imager that provides static photographs or real-time video analysis, allowing the user to visualize the location of any charged particles at any critical point withinthe receiver of the mass spectrometer. This enables the instrument designer to characterize design the ion beam at several points along the ion path for significantly less ion loss.

Methods:

PHOTONIS has combined two proven technologies into a single unit for efficient ion modeling. A Microchannel Plate (MCP) assembly is paired with a Nocturn CMOS low-light, high resolution camera. The resulting instrument is immune to sudden light damage, yet provides a highly detailed image of an instrument's ion beam. Images can be captured at extremely low light levels and at speeds to 100 frames per second in SXGA resolution (1280x1024 pixels) for high resolution analysis.

The microchannel plate assembly typically mounts to a vacuum flange: the assembly contains two Imaging Quality Advanced Performance™ Long-Life™ Microchannel Plates and a fiberoptic phosphor screen. The phosphor screen is frit sealed into the flange to form a vacuum seal that is tight to a leak rate of 1x10-10 cc/sec of helium. This allows the camera to mount on the outside of the vacuum flange, in atmosphere. The camera views the impact points of charged-particles against the MCP and phosphor screen.

Microchannel plates are available from stock in diameters of 25 mm, 40 mm, and 75 mm with a large number of options to customize the performance to the user's needs. *(See Figures 1 and 2.)*

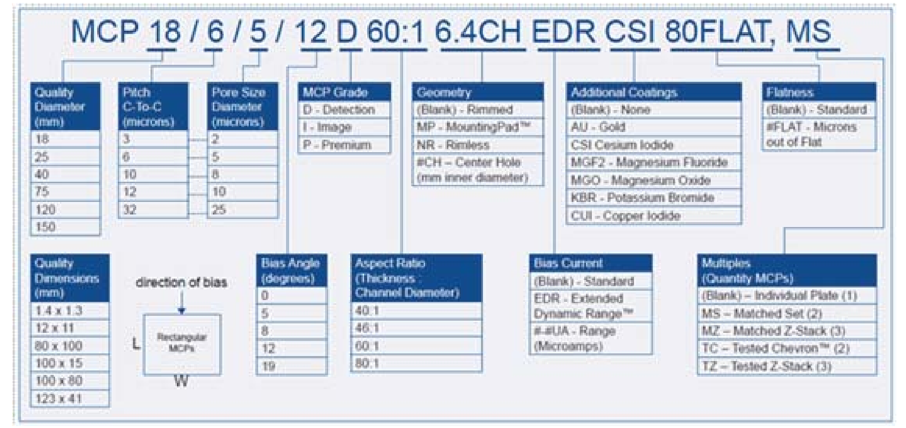

Figure 1: Options for Microchannel Plates

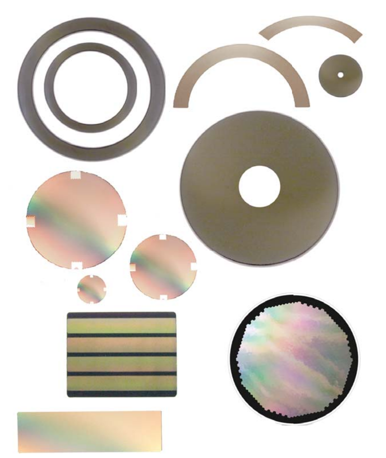

Figure 2: Microchannel Plates

Methods (continued):

The PHOTONIS Nocturn Camera is a 1.3 mega-pixel camera designed for low-noise and excellent low-light performance. Automatic Gain Control (AGC) allows it to change from capturing an image in room lighting to the glow of a single dot on a phosphor screen without operator intervention. *(See Figure 3.)*

Video outputs are available in Camera Link®, NTSC, PAL, USB3 and Ethernet GigE Vision® with sustained frame rates of 30, 50, 60, or 100 frames per second, depending on video mode.

Figure 3: Nocturn Cameras

Camera	Specifications
Sensor Resolution	1280 × 1024 Pixels
Sensor Pixel Pitch	9.7 µm × 9.7 µm
Sensor Well Capacity	> 25000 e-
Sensor Dynamic Range	> 60 dB
Sensor Read Noise	< 4e- median at 60 Hz
Sensor Quantum Efficiency	> 60% at 600 nm
Frame Rate	50, 60, or 100 Hz with full field resolution (user selectable)
Sensor Image Lag	< 0.1%
Sensor Shutter Mode	Rolling
Features	
Imaging Startup Time	< 5 sec
Image Correction	Bad pixel replacement and 2 points non-uniformity correction (NUC)
Gain Control	Automaticgain and exposure control or manual
Windowing	Full field of view down to 1/2 vertical resolution
OSD	Full on-screen display capability with text, standard geometrical shapes and graphics
Digital Zoom	Up to 8X (0.001 increment resolution)
Contrast Enhancement	Contrast stretching, equalization and adaptive equalization
Snapshots	On-board capture of *.JPG or *.PGM (8/10b)
Housing	
Lens Mount	CS-mount
Dimensions (excluding connectors) (Width × Height × Depth)	34.1 mm × 36.6 mm × 37.4 mm
Weight	< 85 g
Input/Output	
Digital Video Output	10/8 bit CameraLink® Compatible
Analog Video Output	NTSC/PAL (user selectable)
Communications	Serial via CameraLink® Compatible or USB
Synchronization	Frame start trigger (2 to 12 V) Analog output strobe reference (2 to 12 V)
Environmental and Power	
Operating Temperature	-40° C to +60° C
Storage Temperature	-50° C to +80° C
Input Voltage	USB powered or external +5 to +15 VDC
Power (Typical)	60/50 Hz mode, <1.8 W; 100 Hz mode: < 2.25 W

Figure 4: Full specifications of Nocturn Camera (XL Model)

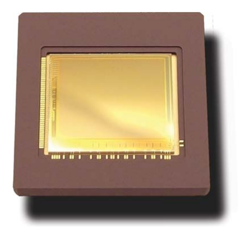

Figure 5: Lynx CMOS Low-Light Sensor for Nocturn camera.

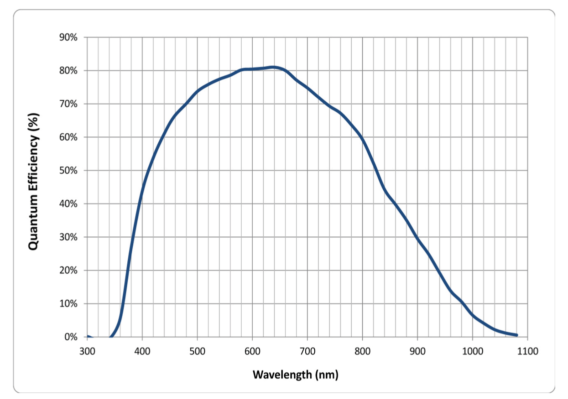

Figure 6: Quantum Efficiency Curve of Lynx CMOS Sensor within the Nocturn Camera, showing greater than 80% at peak.

Results:

A typical reflectron time-of-flight mass spectrometer consists of a pulsed ion source, ion mirror, and ion detector. *(See Figure 7.)*

For this experiment, the ion detector was removed and substituted with the high resolution ion beam imager, here a 25 mm MCP that closely matches the ion detector's entrance, mounted on a 5-inch vacuum flange. (See Figure 8.) Prior work by Laprade and Prunier in 2004[1], demonstrates the usefulness of this technique with a mass spectrometer to identify areas of improvement for alignment and focus within the instrument.

Results (continued):

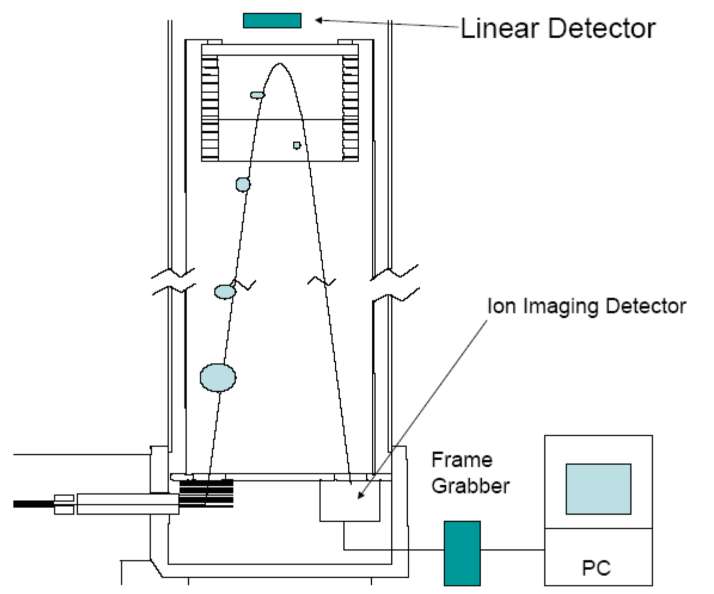

Figure 7: Simplified Reflectron Instrument geometry showing the Ion Beam Imaging Profiler.

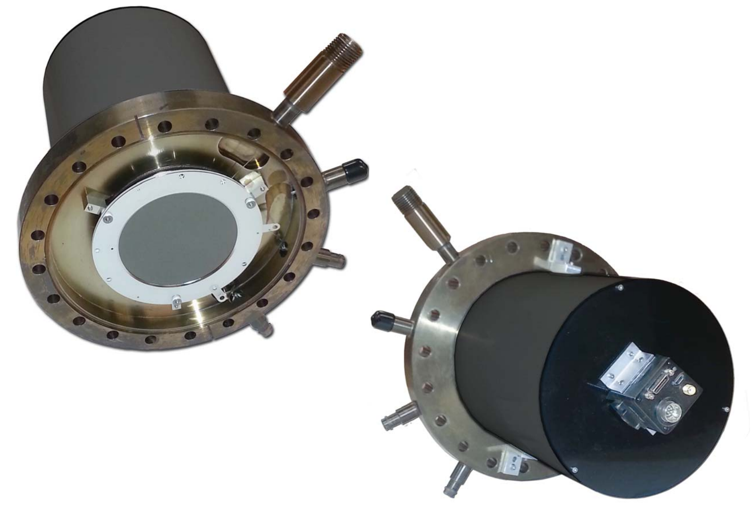

Figure 8: The left image shows the front of the ion beam instrument with MCP and flange. The right image shows the rear of the instrument with the Nocturn XL camera attached to the housing for direct digital video output.

Perturbations to the ion beam were manually created to show the versatility of the imaging system. The camera quickly shows alignment and focusing problems with the ion beam. *(See Figure 9.)*

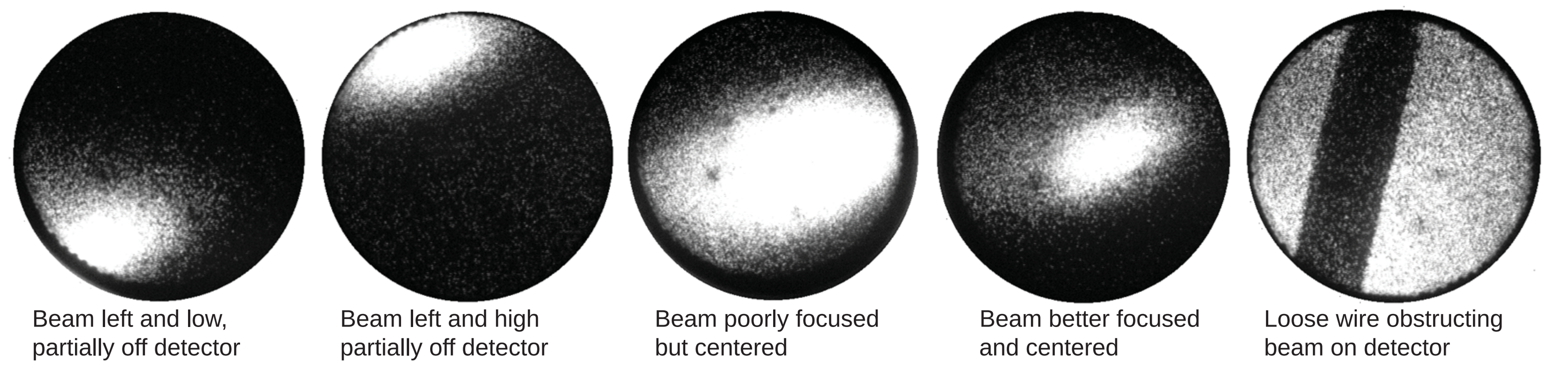

Figure 9: Still images of poor alignment, poor focus, or obstructions impeding optimal beam transport.

Conclusion:

The ion beam profiler provides significant insight beyond traditional ion optics modeling software. It can clearly show alignment with the detector, whether a beam is focused, and other characteristics that may interfere with an efficient ion analysis. The characterization of the ion beam can then be optimized for a more efficient transport based on the imaging from this instrument.

The ability to see the beam image in a real-time video is a powerful tool for optimizing instrument performance.

1. Laprade and Prunier (2004), *Ion Beam Profiling Using a Novel Electronic Imaging Detector,* Poster #1700-2400, Burle Industries. Presented at the Pittsburgh Conference for Analytical Chemistry and Applied Spectroscopy.