

DataRay Inc.

Advancing the Technology of Laser Beam Analysis

Simultaneous Intensity Profiling of Multiple Laser Beams Using the BladeCam-XHR Camera

Shaun Pacheco College of Optical Sciences, University of Arizona
Rongguang Liang College of Optical Sciences, University of Arizona
Rocco Dragone Vice President of Engineering, DataRay, Inc.



COLLEGE OF
OPTICAL SCIENCES





Real-Time Profiling of Multiple Laser Beams

There are several applications where the parallel processing of multiple beams can significantly decrease the overall time needed for the process. Intensity profile measurements that can characterize each of those beams can lead to improvements in that application. If each beam had to be characterized individually, the process would be very time consuming, especially for large numbers of beams. This white paper describes how the BladeCam-XHR can be used to simultaneously measure the intensity profile measurements for multiple beams by measuring the diffraction pattern from a diffraction grating and the intensity profile from a 3x3 fiber array focused using a 0.5 NA objective.

Diffraction Gratings

Diffraction gratings are periodic optical components that diffract an incident beam into several outgoing beams. The grating profile determines both the angle of the diffracted beam modes and the efficiency of light sent into each of those modes. Grating fabrication errors or a change in the incident wavelength can significantly change the performance of a diffraction grating. The BladeCam-XHR, Figure 1, can be used to measure the point spread function (PSF) of each mode, the relative efficiency of each mode and the spacing between diffraction modes.



Figure 1 BladeCam-XHR

Using the BladeCam-XHR for Diffraction Grating Evaluation

The profiling mode in the DataRay software can be used to evaluate the performance of a diffraction grating. The experimental set-up to measure the diffraction pattern from a diffraction grating is shown below in Figure 2. A collimated light source is incident on a diffraction grating. The diffraction grating will diffract the incident light into several plane waves at angles determined by the spacing of the grating, the wavelength of light, and the diffraction order mode number. A focusing lens is used to focus each of the diffracted modes onto the BladeCam-XHR.

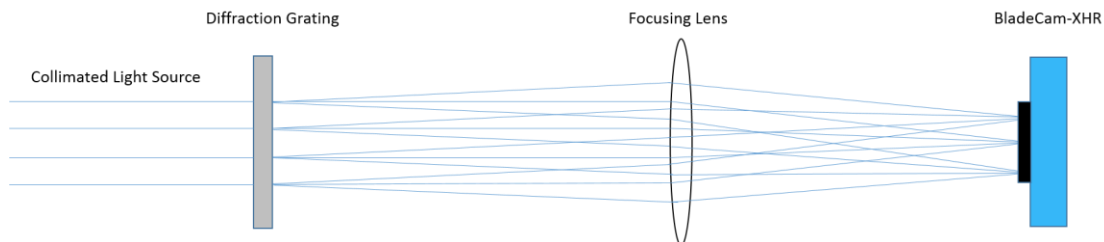
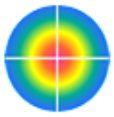


Figure 2 Set-up for Evaluating Performance Diffraction Grating





An important characteristic of a diffraction grating is the efficiency of light sent into each diffraction mode. A slice through the diffraction pattern can be seen in real-time on the profile display by manually placing the cursor on the mode of interest and rotating the crosshairs to align with the diffraction pattern. For this example, collimated light was incident on a custom beam-splitting phase grating with a period of $150 \mu\text{m}$ that splits an incident beam into 9 outgoing beams. The BladeCam-XHR beam profiling camera was placed at the focal plane of a 150 mm lens. The example shown is a beam-splitting phase grating with significant fabrication errors. Note that this beam-splitting grating is designed to have equal energy in 9 modes, however, fabrication errors have significantly degraded the performance. An image of the beam profile captured by the BladeCam-XHR camera is seen in Figure 3.

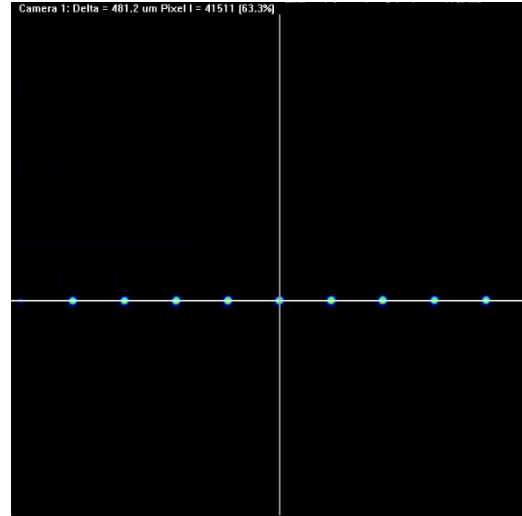


Figure 3 Diffraction Profile of Beam-splitting Phase Grating

Note that the following specifications should be set in the software in order to ensure the most accurate PSF measurement:

Capture Resolution: Under the **Setup** drop-down menu, choose the **Capture Setup** dialog menu. The capture resolution should be set to **FULL = 3.20 x 3.20 microns**, instead of **FAST = 6.40 x 6.40 microns**. This will ensure that the maximum spatial resolution is used to sample the PSF of each diffraction mode.

Imager Gain & Exposure Time: These should be adjusted so the ADC Peak percentage is approximately 80%. This ensures the signal to noise ratio is high enough without saturating the signal.

Filter: The default profile smoothing filter (0.2%) applies a smoothing function which changes the shape of the PSF. In order to best measure the true PSF, **No Filtering** should be selected in the pull-down **Filter** menu.

Area Filter: The area filter averages the pixel values over a specified area. The area pixel should be set to 1 (Default), so no smoothing is applied to the acquired image. Note that this filter can be applied in post-processing in another application.

The measuring tool in the profile display can be used to measure the distances between each order of the diffraction pattern in real time. To get a more accurate reading in real time, the profile display can be zoomed in. Both measurements can be seen in Figure 4. If the focal length of the system can vary, this measurement can be used to monitor the distance between successive modes in the diffraction pattern in real-time in order to meet a specific distance constraint.

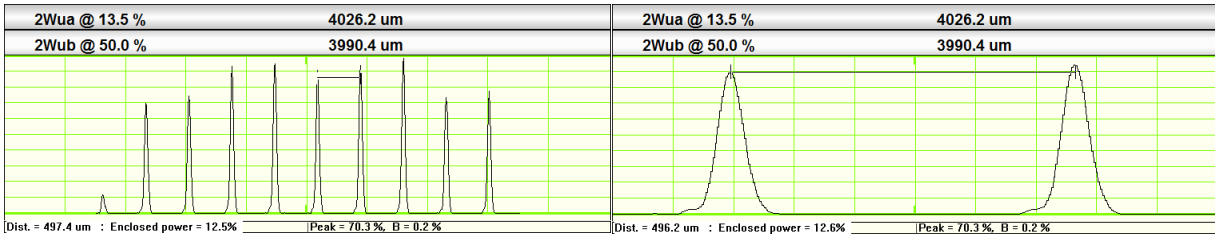
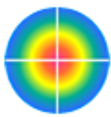


Figure 4 Horizontal Profile of Diffraction Pattern: Full Pattern (left) and Zoomed-In (right)

By using the vertical profile, the beam width of modes of the diffraction pattern can be measured, as seen in Figure 5. This measurement can be used to find the plane of best focus by minimizing the beam width of the mode of the diffraction pattern. For this example, the beam of interest has a FWHM of 37.9 μ m.

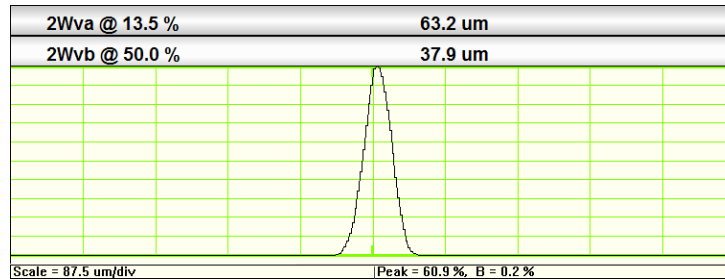


Figure 5 Vertical profile of the diffracted beam

Measuring an Array of Focused Spots from a Fiber Array Using the Data Ray Microscope Attachment

In addition to measuring the profile of multiple beams in a linear array, the BladeCam-XHR profiler can be used to measure the relative energies in multiple beams in a 2D pattern. An example where the relative energies of an array of beams needs to be known is during array confocal fluorescence microscopy, where multiple points on the sample are excited and imaged simultaneously. Ideally, all excitation point should have equal energies.

An array of excitation beams can be created by using a fiber array where the light exits in an $N \times N$ array. A collimating lens and an infinity corrected microscope objective focus the light from the fiber array onto a microscopy sample. Note that spacing between beams may be smaller than a pixel on the BladeCam-XHR camera, and the working distance of the microscope may be too small to allow an image of the focused array of beam to be captured using the BladeCam-XHR. Therefore, the microscope attachment for the Data Ray cameras can be used to view the microscopic array of excitation beams. A diagram of the system used for this example can be seen in Figure 6.

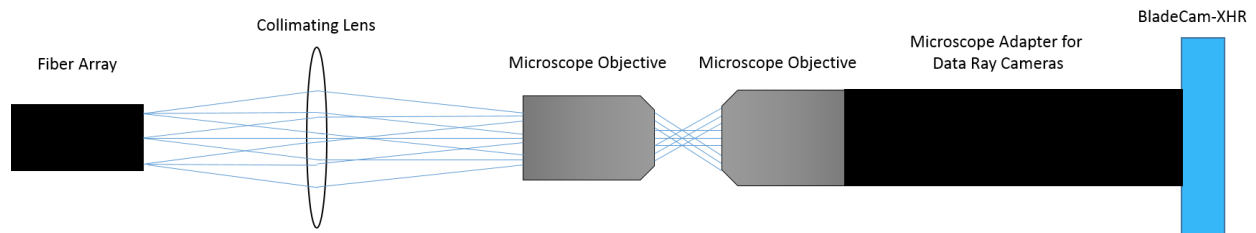


Figure 6 Setup for Evaluating Performance of Focused 2D Fiber Array





A pattern of beams is created by a 3x3 fiber array with 500 μ m spacing between fibers. The light from each fiber is collimated using a 30 mm lens and focused using a 0.5 NA objective. The pattern is imaged onto the BladeCam-XHR beam profiler sensor using the DataRay microscope attachment and a 10x objective. Note that the size of the PSF after focusing through an NA = 0.5 infinity corrected objective is too small to be properly resolved on the BladeCam-XHR, so the microscope attachment is necessary to properly sample the PSF. The image of the focused array of beams is seen in Figure 7. Each beam in the array is simultaneously captured. Post-processing can analyze each of the 9 beams individually. The sampling of the sensor is fine enough to resolve significant deviations from a diffracted limited beam.



Figure 7 Focused 2D Array of Beams Using Microscope Attachment

In order to get the relative energies of each beam, the image from the DataRay software is exported as a 16-bit TIFF and imported into MATLAB. In MATLAB the centers of each beam are identified and the pixels are summed in a box around the center of each beam to measure the energy of each beam. Each beam is shown in Figure 8 with the relative energies of each beam above each subplot.

Conclusion

In conclusion, the BladeCam-XHR can be used in applications that require profiling of multiple beams simultaneously. It can be used to measure the PSF and efficiency of the diffracted orders for a diffraction grating, while also measuring the spacing between the diffracted orders. Additionally, the microscope attachment can be used in conjunction with the BladeCam-XHR in order to simultaneously profile multiple beams at the microscopic level.

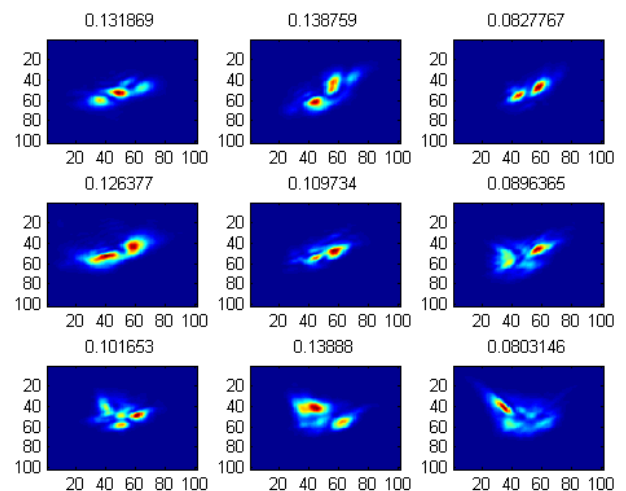


Figure 8 Relative Efficiencies of Each Beam