



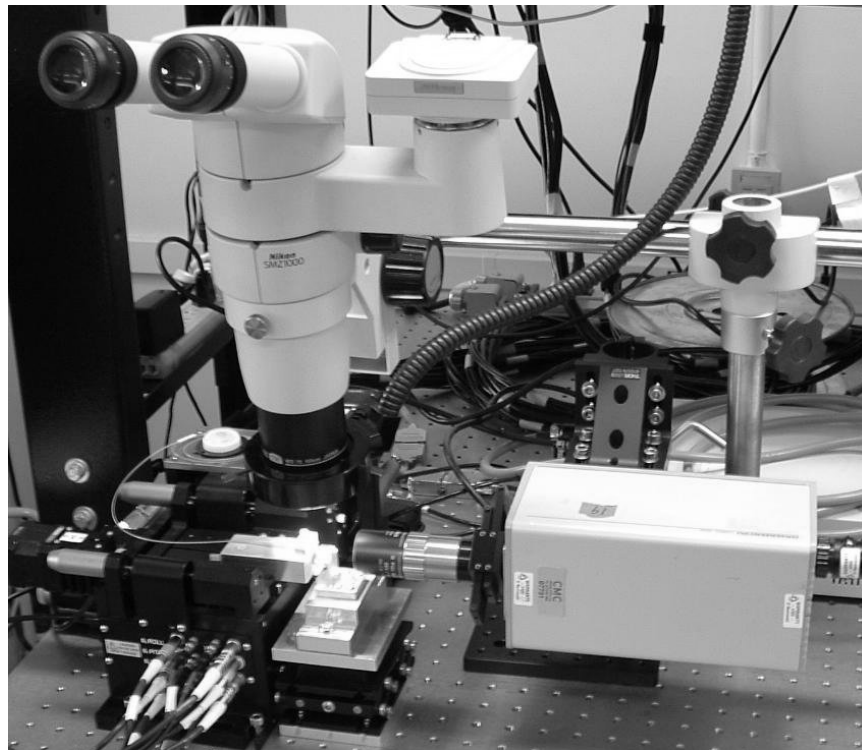
Hamamatsu Laser Beam Profiling System

Setup Guide

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V1.1

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November 5, 2012



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Revision History

Revision	Activity	Date
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1. Introduction

This document describes a method of free-space beam profiling to determine the output beam shape and relative power of optical devices such as lasers, waveguides, or lens systems. Because the beam profile is displayed in 2D or 3D on a computer screen, the operator can avoid exposure to any beam hazards during an experiment. Beam profiling is done in real time and alignment problems can be solved interactively.

The camera, controller, lenses, and beam profiling computer hardware and software described in this document are available from the CMC Microsystems Test Pool.

WARNING: CMC Microsystems assumes no responsibility for the use of this camera system with any laser source. Persons performing laser beam analysis must be aware of and take the safety precautions appropriate for such equipment and they must comply with all regulations specified by their university and department.

2. Equipment

2.1. Hardware

For the example measurement provided here, the test set up consists of a laser source, a waveguide device on a stand, a camera and controller (Hamamatsu's model C2741-03), and imaging system.

The laser source is a distributed feedback (DFB) laser, with an optical connector front end, operating at a wavelength of $\lambda = 1550$ nm (near-infrared) and a power of approximately -11 dBm (approximately $79 \mu\text{W}$). A standard optical fibre patch cord is cleaved at one end. Its connector is inspected, cleaned, and connected to the laser and guides the beam, while the cleaved facet tip rests on a mount or platform of suitable height, edge protruding slightly, where it is fixed into the desired position for scanning. The camera is placed at the most effective distance for beam capture that the operator discovers. The resulting optical output is therefore a function of the type of fibre, and the distance between the camera lens and the cleaved facet. The experimental setup is illustrated schematically in Figure 1.

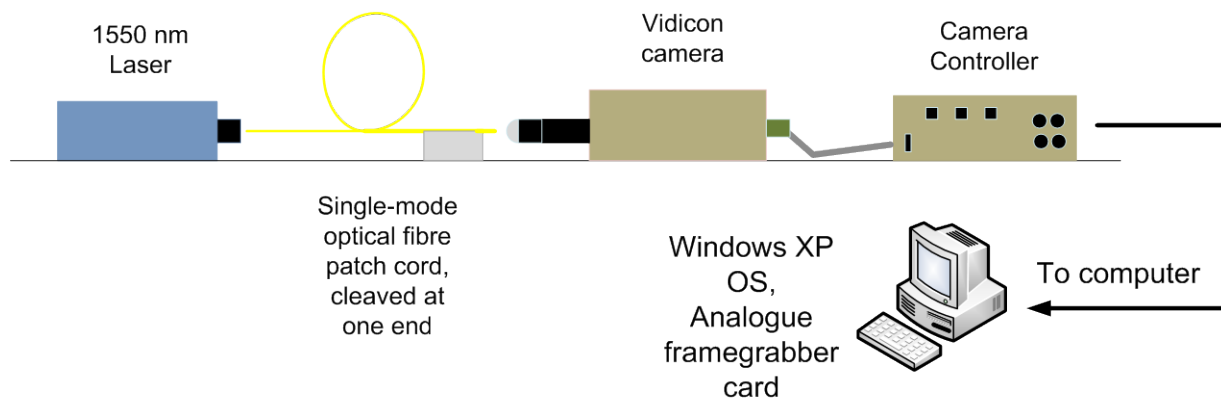


Figure 1: Laser Beam Analyzing Station Setup

The video components are pictured in Figure 2 (from left to right):

- lens kit,
- tubes,
- adapters,
- camera, and
- controller.



Figure 2: Video Components

The Hamamatsu C2741-03 consists of a camera head and a camera controller [1]. The head encases a lead sulphide Vidicon tube with a 1-inch target which is capable of detecting wavelengths between 400 nm and 1800 nm (see Figure 3).

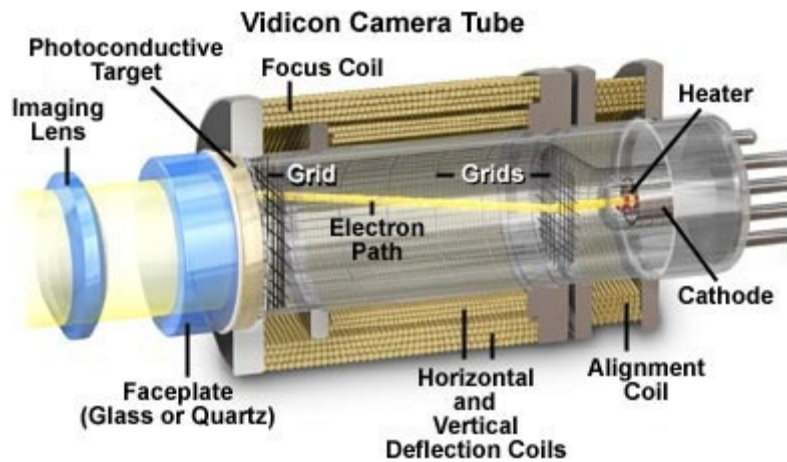


Figure 3: Cutaway View of a Vidicon Camera Tube

A lens is required for magnifying and channeling the laser beam as it reaches the camera. The kit supplied with the C2741-03 camera system allows a variation in magnification from 10 to 60 times. The kit (Newport part no. 5720-C [2]) includes six different magnifications and each has an anti-reflection coating tailored to the wavelength range of 1000 to 1600 nm. Lens type is aspherical, and lens shape is plano-convex (see Figure 4).

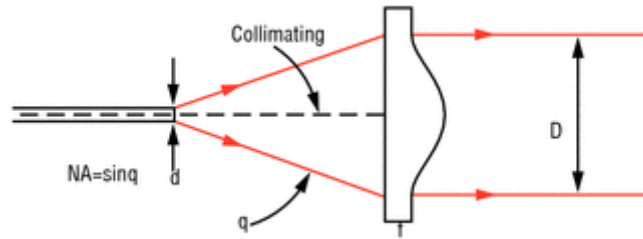


Figure 4: Aspherical Lens Transmission

The camera lens assembly (see Figure 5) consists of six items:

- one C-mount to SM1 thread adapter, fitted to the Vidicon camera head;
- one each of 1- and 2-inch black optical tubes with SM1 threads, male and female;
- one SM1 to RMS thread adapter;
- one RMS lens mount; and
- one 16-times magnification lens, which is the magnification recommended for this application.



Figure 5: Lens Assembly for Vidicon Camera

Figure 6 shows the lens assembly as it is scanning an optical fibre output.

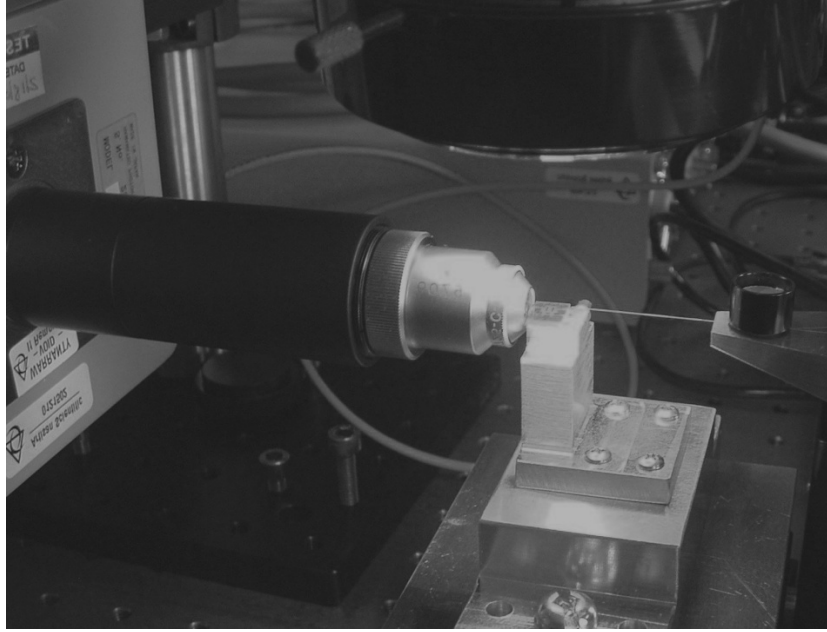


Figure 6: Lens and Tube Assembly in the Experimental Setup

The camera controller is used to manually adjust Vidicon sensitivity, gain, and offset to improve the display result. The camera controller transmits an analogue RS-170 signal over a 75-Ohm BNC cable. The signal can be directly displayed as a black and white image on an NTSC monitor (not supplied).

If requested, CMC Microsystems can include a Spiricon PCI frame grabber card with 12-bit analogue sampling capability, an RS-170 input for use with the Hamamatsu C2741-03, and Spiricon Laser Beam Analyzer (LBA) software [3].

Note: CMC Microsystems does not supply the computer. The card and software combination works under the Windows XP operating system only. When installing it, you must handle the card in compliance with accepted electrostatic discharge (ESD) safe practices.

2.2. Beam Analysis Software

2.2.1. Initial Calibration

The custom software that reads and displays data from the frame grabber card is LBA-PC, version 4.26. The software calculates beam parameters such as width, energy, centroid or peak location, and ellipticity.

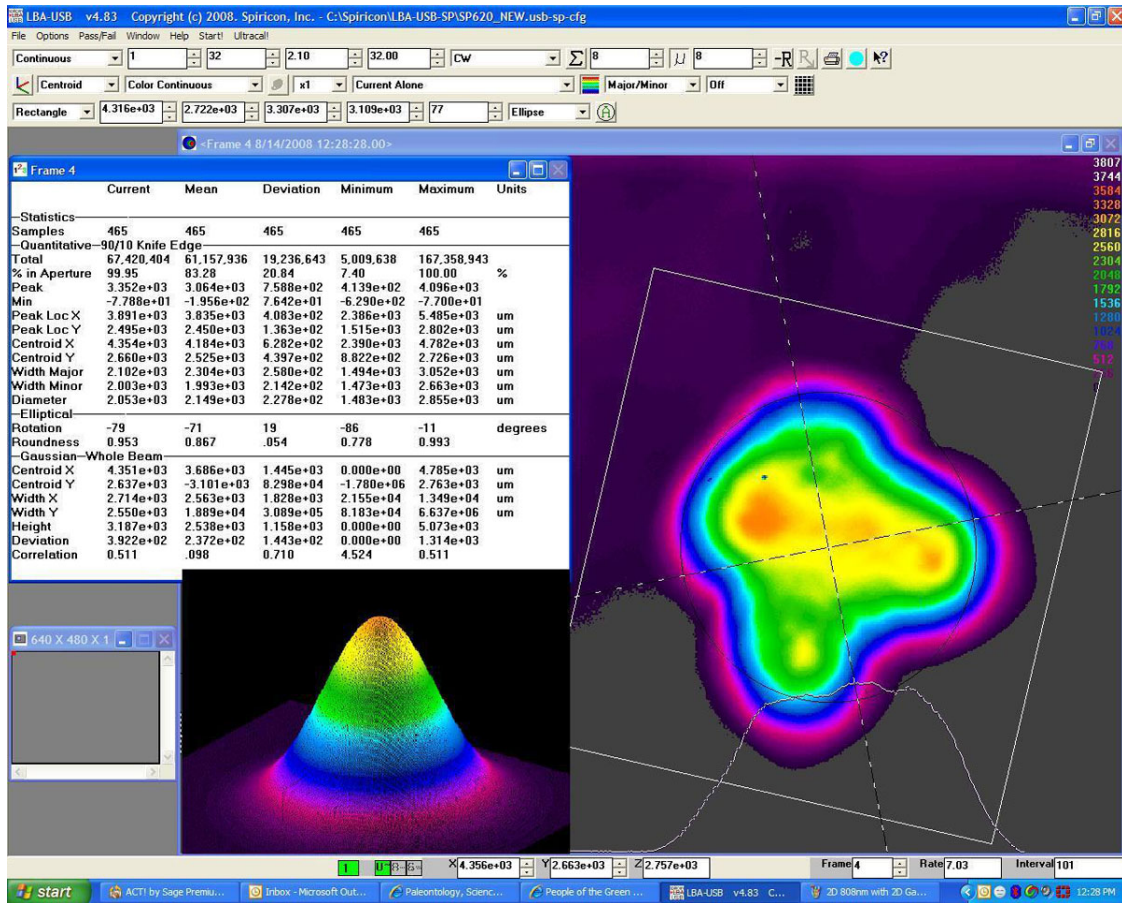


Figure 7: Laser Beam Analyzer (LBA-PC) Main Window

Before taking any measurements, the software must be calibrated to account for ambient laboratory illumination and initial camera conditions. After loading the LBA-PC program onto the PC, proceed as follows.

1. With the laser source off, start the LBA-PC program.
2. On the menu bar in the main window, choose **Options | Camera**.

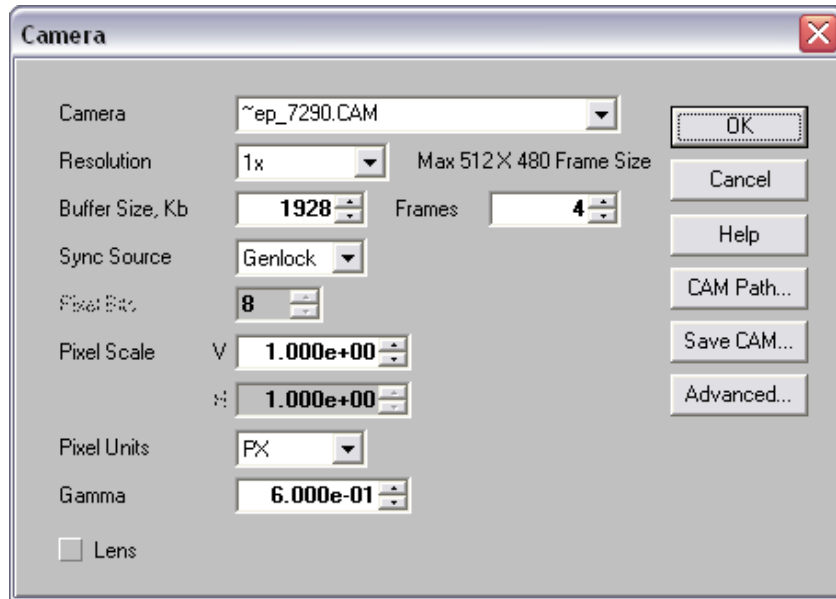


Figure 8: Camera Settings

3. In the **Camera** window (see Figure 8), do the following:
 - a. In the **Camera** dropdown list, choose **~ep_7290.CAM**
 - b. Leave all other settings as the default.
 - c. Click **OK** to close the window.

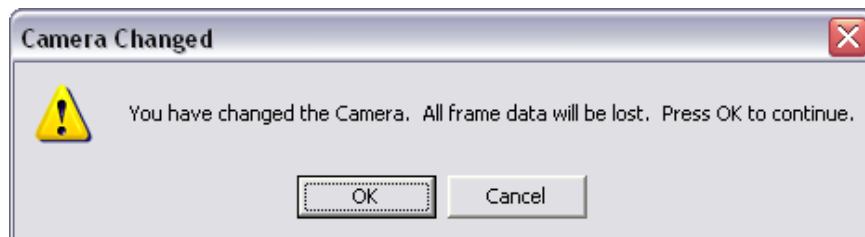


Figure 9: Warning Message after Changing the Camera

4. In response to the warning message that the camera has been changed (see Figure 9), click **OK** to continue.
5. On the menu bar in the main window, click **Ultracal!** to calibrate the camera for the actual laboratory conditions.

Note: The software will capture some images and calculate the background noise, in order to cancel it out as much as possible. When the calibration is complete, you may use the system for beam analysis.

6. To collect data, click **Start!** on the menu bar to begin capturing images.

2.2.2. Configuration (Gain, Offset and Sensitivity)

To produce accurate measurements, it is important to choose the correct values for gain, offset and sensitivity.

While the camera settings in the software are simple, choosing the correct settings on the camera controller is somewhat trickier. A large dynamic range, from no visible signal to an oversaturated state, is possible. Hence, choosing a too high initial power at the laser source can damage the tube inside the camera. It is also advisable to keep hands or metal tools away from the magnetic fields generated around the camera, so as not to perturb its operation.

Examples of oversaturated and undersaturated conditions are illustrated in the following figures, Figure 10 to Figure 15. Output intensity is correlated to color, from blue (lowest) to red (highest). However, when the beam intensity exceeds a certain threshold, the resulting pattern turns white, indicating that the detector's safe operating range has been passed.

WARNING: Oversaturation of the camera detector can severely damage the Vidicon tube. If this condition is observed, turn off the source or remove the camera to a safe location.

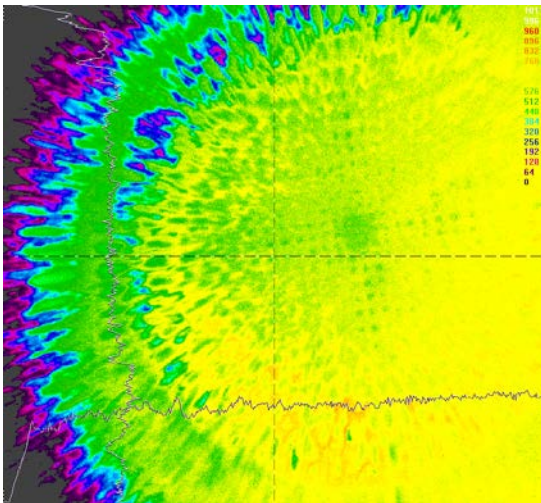


Figure 10: Oversaturated (high sensitivity) Pattern with Low Gain

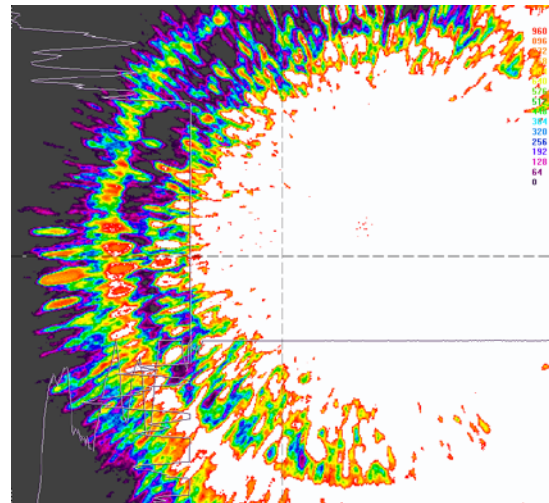


Figure 11: Oversaturated (high sensitivity) Pattern with Too High Gain

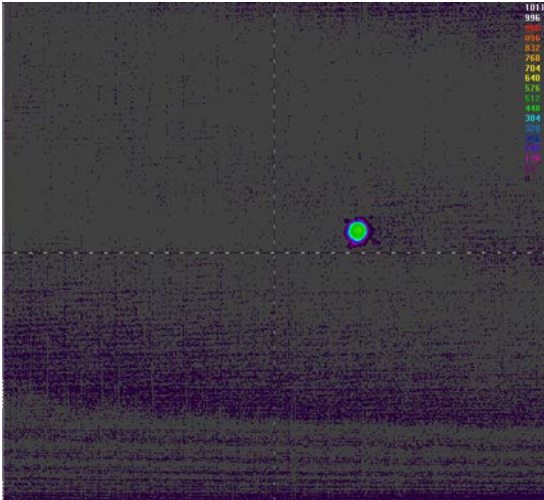


Figure 12: Undersaturated (low sensitivity) Pattern with Low Gain

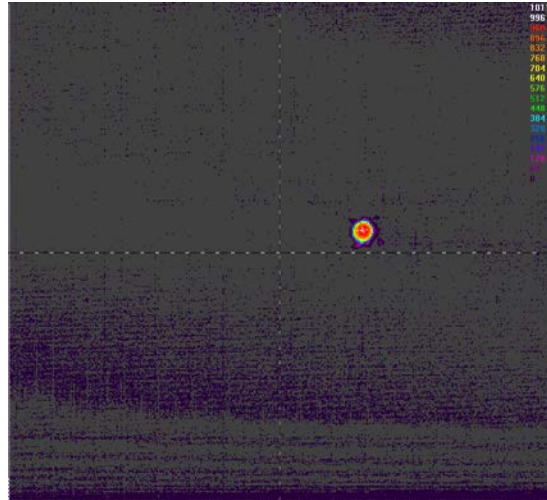


Figure 13: Undersaturated (low sensitivity) Pattern with High Gain

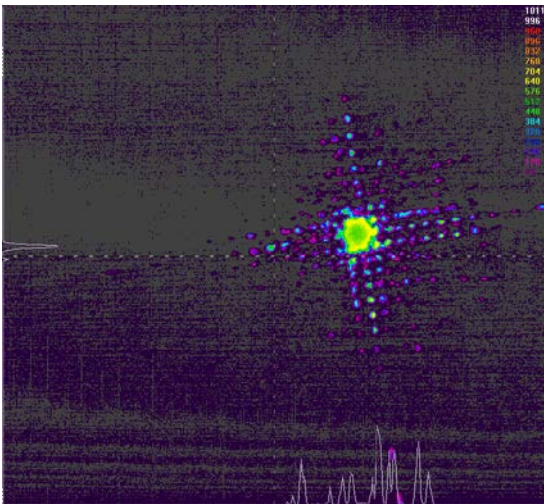


Figure 14: Medium Sensitivity Pattern in Focus with Low Gain

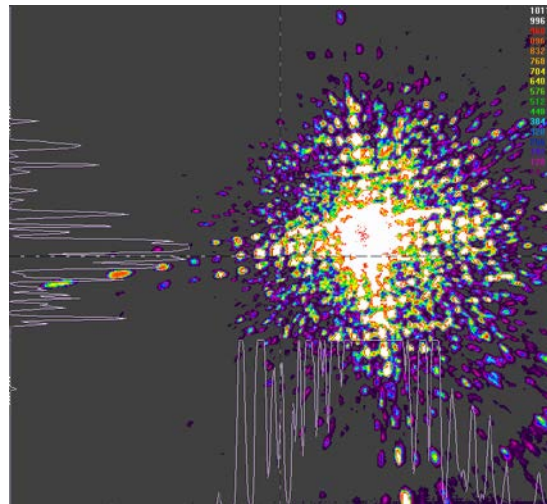


Figure 15: Medium Sensitivity Pattern in Focus with High Gain

3. Experimental Results

3.1. Different Optical Waveguide Results

To help users, and for comparison, four different waveguides were selected and their beam profiles recorded. In order to do that, the image of just the fibre tip is recorded for different types of tips. Four possible sources were chosen so that a coarse differentiation was made in terms of light guidance in the fibre. Single- and multi-mode fibers were compared (see Table 1). Plain cleaved fibre tips are simple and cost-effective means of input for both types of fibers.

Additionally, for multi-mode fibers, two commercial versions were compared: a tapered tip and a gradient index (GRIN) lens fibre tip.

Table 1: Waveguide Type

Waveguide Type	Input Method
Single-mode (8- μm core)	Plain cleaved tip Tapered tip GRIN lens tip
Multi-mode (62.5- μm core)	Plain cleaved tip

Starting with a plain cleaved multi-mode (MM) fibre tip, an asymmetric pattern of unequal energy distribution is observed (see Figure 16).

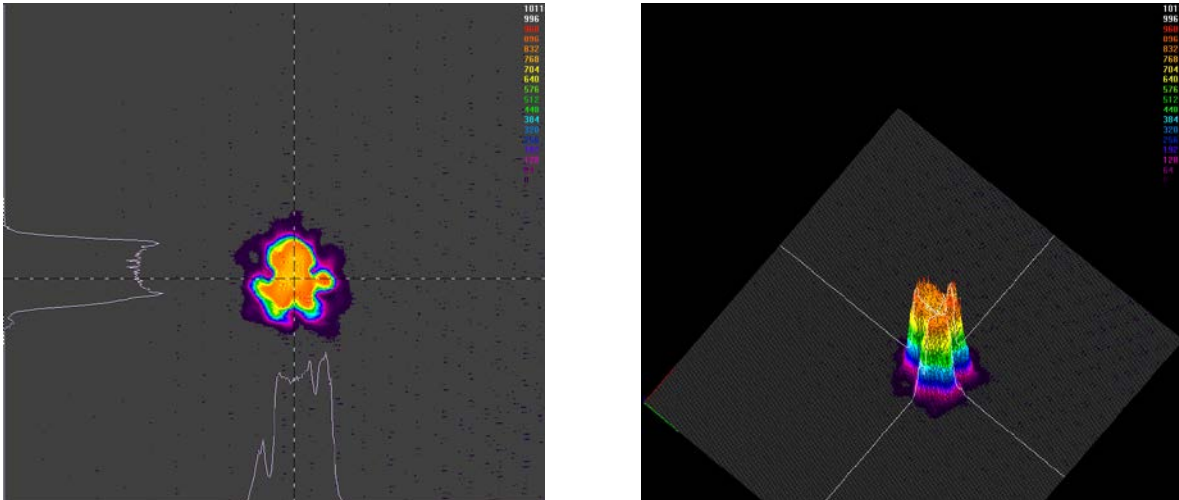


Figure 16: 2D and 3D Beam Profile Pattern of a Flat-cleaved Multi-mode Optical Fibre

The plain cleaved single-mode (SM) fibre produces an evenly shaped Gaussian beam (see Figure 17).

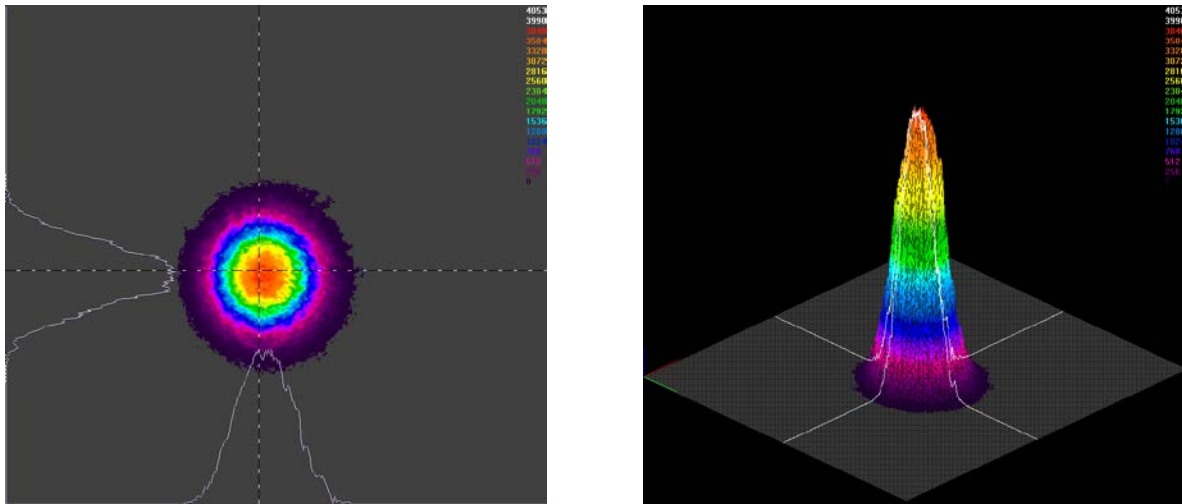


Figure 17: 2D and 3D Energy Pattern of a Cleaved Single-Mode Optical Fibre

Figure 18 shows a pattern of a gradient index fibre lens with an asymmetric energy distribution of the beam because the GRIN lens may not have been properly aligned to the camera lens. The pattern of a tapered fibre (see Figure 19) is evenly distributed, similar to the plain cleaved SM fibre with a flat energy distribution in the center of the core.

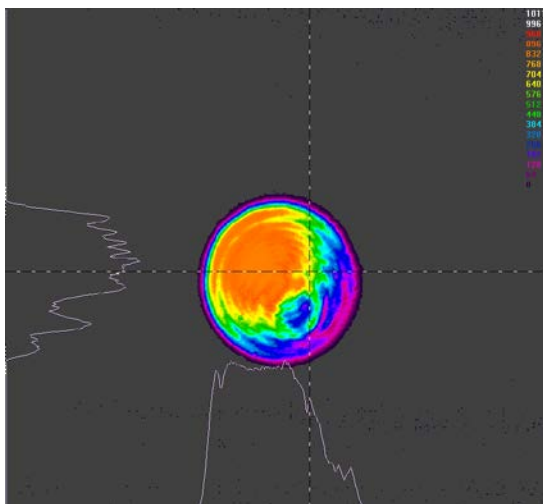


Figure 18: Pattern of a Graded Index GRIN Fibre-pigtailed Lens

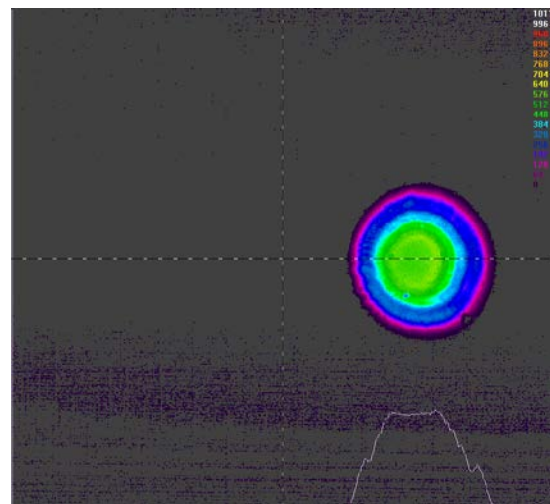


Figure 19: Pattern of a Conical Lensed Fibre

Changing the position of the optical fibre on the axis of optical path transmission produces a proportional variation of the intensity distribution on the path axis, as would be expected.

3.2. Factors influencing Measurement Accuracy

In experiments involving free-space optical propagation, external influences can distort or degrade measurements:

- Background illumination (for example, daylight and light bulbs), particularly in the measurement range of interest, or a change in background lighting during data capture,
- Dirt on the lenses or transmission through dust and particles in the air, scattering or blocking beams,
- For the cleaved facet of an optical fibre, the quality of the surface affects the resulting beam geometry, and
- In the particular case of a Vidicon camera, interference from nearby electrical fields affects its coils and thereby results in a very noisy signal. For accurate results, do not bring metal objects or hands near the camera while taking images.

The images presented in this document were taken with care to minimize such factors, and may be used as references for similar measurements.

4. References

4.1. Product Related

- [1] C2741-03 Infrared Vidicon Camera datasheet. [Online] Available at: www.hamamatsu.com.
- [2] Aspheric Lens Kit, Model 5720-C. [Online]. Available at: www.newport.com.
- [3] Imaging System software LBA-PC. [Online]. Available at: www.ophiropt.com.

4.2. Beam Analysis Related

These papers are not cited in this guide, but may be of use to researchers seeking to reproduce the results depicted here.

- [4] A. Asadpour et al., “Fiber Output Beam Shape Study Using Imaging Technique”, Journal of Applied Sciences 10 (4), January 2010, pp. 312-318.
- [5] Kowalevitz Jr. and Bucholtz, “Beam Divergence from an SMF-28 Optical Fiber”, document NRL/MR/5650--06-8996, October 6, 2006.