Zuverlässigkeitsanalyse einer ortsaufgelösten Intensitätsmessung mittels eines voll-automatisierten x-y-Verschiebetisches

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The presented x-y stage measurement unit has a scan range in x and y direction of 52 mm x 52 mm area with lowest step size in x and y direction of $\Delta x = \Delta y = 0.2$ µm. The whole setup is fully automated and computer controlled. A repeatability tests with 40 different measurements under same conditions result in a low uncertainty of < 0.06 % (1 standard deviation) as maximum deviation.

1 Introduction

Measuring the transversal light distribution of a LED or a laser (and herewith the spot size of a laser beam) can be done with an x-y stage. An x-y stage scans the light distribution in x-direction and in y-direction by sampling, thus generating a huge number of measurement data. It is therefore necessary to control and fully automate the x-y stage measurement. A typical laser beam profile shows Fig. 1.

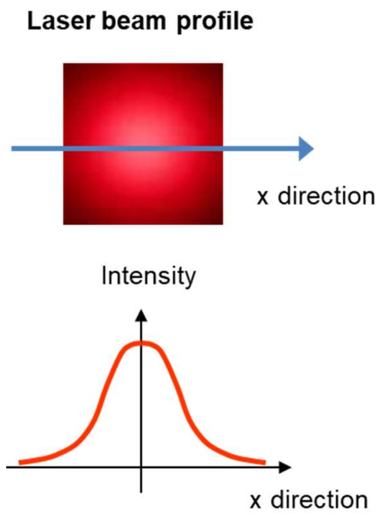

Fig. 1 *Top: Typical laser beam profile in x and y direction. Bottom: cut of the intensity distribution in x direction at the center of the laser spot showing approximately a Gaussian beam profile in x-direction.*

2 Basic measurement principle

An x-y stage measurement unit measures the transversal light distribution of a light source like a laser or LED, see Fig. 2. Thus, the spot size at different positions d of a source is measured. In addition, also the numerical aperture of an optical fiber can be calculated based on spot size measurements at different positions d [1], [2].

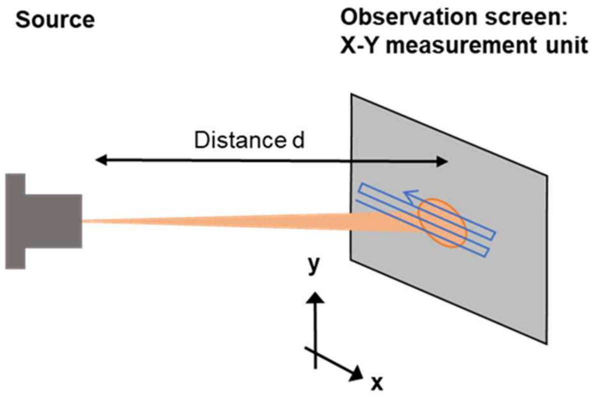

Fig. 2 *. Basic measurement principle of an x-y stage measurement unit: in a distance d the light distribution of a source is scanned in x and y direction.*

3 Current x-y stage measurement unit

The current setup – see **Fehler! Verweisquelle konnte nicht gefunden werden.** - consist of:

- 2 linear stages with stepper motor from PI (Physik Instrumente), mounted at 90° on a heavy aluminum holder to ensure low vibrations and precise repeatable positions
- blackened aluminum holder to suppress stray light
- 2 stepper motors, which are connected to a computer and controlled via the software LabView from National Instruments
- thus fully automated setup
- a 2 inch integrating sphere as a detector. The integrating sphere is calibrated and can detect signals between about 400 nm and 1000 nm wavelength

The whole setup is mounted on an optical granite bench to suppress fluctuations and is located inside a dark room for stray light suppression (controlled via computer from outside).

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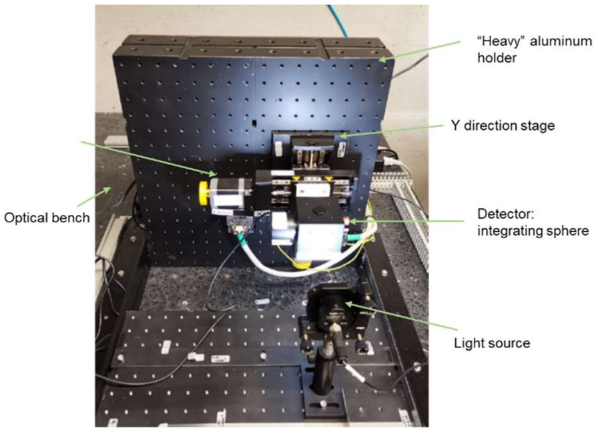

***Fig. 3** . The current x-y stage measurement unit in front view (outside the dark room). The 2 linear stages mounted at 90° to each other mounted on a "heavy" aluminum holder are shown. An integrating sphere is currently used as a detector.*

Specifications:

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Specification	**Value**
Max. scan area in x-direction	52.0 mm
Max. scan area in y-direction	52.0 mm
Lowest step size Δx in x-direction	0.2 µm
Lowest step size Δy in y-direction	0.2 µm
Unidirectional repeatability	0.5 µm
Aperture of integrating sphere	Ø 1.0 mm
Detector wavelength	400 nm … 1000nm
Delay time (between 2 measured data)	Adjustable – 10 s
Automation	Fully

***Tab. 1** Specifications of the current x-y stage measurement unit*

As soon as the detector reaches a new position, the setup acquires the new measurement data at that position after a freely selectable "waiting time" (called delay time). This suppresses possible fluctuations due to the movement.

4 Repeatability test results of the current set-up

After manufacturing and mounting all components, we developed the control software under LabView. With the software the whole setup is fully automated since a large number of data points are generated and stored for later evaluation. All components and the software, were tested and verified. A test measurement result shows Fig. 4 for a green LED and a coarse resolution to handle the measurement data.

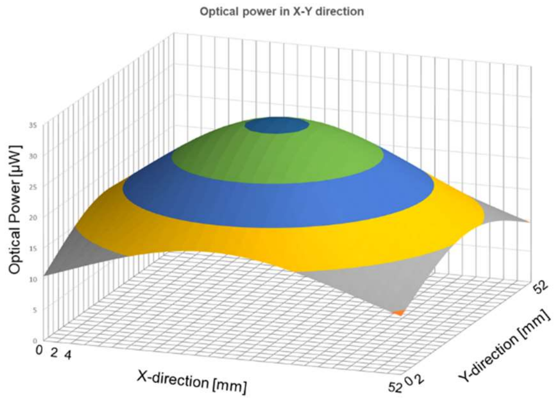

***Fig. 4** . Example of a possible measurement result for a 555 nm LED in d = 100 mm distance scanning the whole 52 mm x 52 mm area sampled with Δx = Δy = 2.0 mm. The low distance ensures a good signal-to-noise ratio.*

A repeatability test was done with N = 40 repeated measurements to estimate the performance of the whole setup. A red LED array at 630 nm center wavelength (optical intensity: 4mW/cm²), mounted at a distance d = 100 mm was the source. The whole 52 mm x 52 mm area is sampled with Δx = Δy = 1.0 mm. The measurement of the 40 passes took more than 24 hours. The average value $(\overline{x_i}, \overline{y_i}) = \frac{1}{40}\sum_{i=1}^{40}(x_i, y_i)$ at each position (x_i, y_i) is calculated as well as the standard deviation $s_i = \sqrt{\frac{1}{40-1}\sum_{i=1}^{40}[\,(x_i, y_i) - (\overline{x_i}, \overline{y_i})]^2}$ [3], where i is one out of 2809 individual positions. Afterwards the worst case, which is the largest value of the standard deviation, is calculated as a measure of the accuracy, see **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Worst case result	**Value**
1 standard deviation (max. value)	$1 \cdot s_{max} = 0.065\ \%$
2 standard deviations (max. value)	$2 \cdot s_{max} = 0.130\ \%$

***Tab. 2** Accuracy results*

5 Result

A low uncertainty of < 0.06 % (1 standard deviation) as maximum value was obtained with this fully automated measurement unit. This shows the high precision reached with this set-up.

References

[1] Eugen Hecht, *Optik*, (2. Auflage, Oldenbourg Verlag, München 1999)

[2] Dietrich Marcuse, *Principles of Optical Fiber Measurements*, (Academic Press, New York 1981)

[3] Reinhard Lerch, *Elektrische Messtechnik*, (Springer Verlag, Wiesbaden 2005)

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