Application note:

Laser beam characterization using a SHSLab wave-front sensor

1 Introduction

For laser beam characterization, the conventional camera-based method described in ISO 11146 requires several measurements at different locations along the beam path. When using a wave-front sensor, a single measurement is sufficient to characterize a laser beam with moderate or good beam quality. In this application note, the characterization of a diode laser using Optocraft's wave-front sensor SHSLab is described.

2 Experimental

A diode laser with a wavelength of 635nm coupled to a single mode fiber is collimated by lens 1 (small focal length) and then focused by lens 2 (large focal length).

Figure 1: Experimental Setup

For comparison, we first use a standard industrial camera with a pixel size of 3.75µm to characterize the beam according to ISO 11146, taking several images of the beam cross section at different positions along the beam. Then we use SHSLab of the type *AR-S-130* and measure the wave-front at position z_m = 144mm in the divergent part of the beam.

3 Beam parameter calculation

The SHSLab measurement provides us with the intensity and phase distribution at the measurement position z_m. This enables us to determine the wave-front curvature radius R, the 1/e²-diameter of the beam $d(z_m)$ and the beam propagation factor M². M² is calculated from the second spatial/angular moments σ_i, σ_α, $\sigma_{i\alpha}$ of the measured intensity distribution/wave-front: $M^2 = \frac{4\pi}{\lambda}\sqrt{\sigma_i{}^2\sigma_\alpha{}^2 - \sigma_{i\alpha}{}^2\sigma_{i\alpha}{}^2}$ (λ denotes the laser wavelength). Using this information, we then calculate the position of the beam waist z_0, the beam waist diameter d_{bw} and the Rayleigh length z_R:

$$z_0 = \frac{R}{1+\left(\frac{4\lambda R}{\pi d(z_m)^2} M^2\right)^2} \qquad z_R = z_0 \frac{4\lambda R}{\pi d(z_m)^2} M^2 \qquad d_{bw} = \frac{d(z_m)}{\sqrt{1+\left(\frac{\pi d(z_m)^2}{4\lambda R M^2}\right)^2}}$$

4 Results

4.1 Comparison of wave-front- and camera-based measurement

Figure 2 shows an example of the measured intensity distribution and wave-front used to calculate the beam parameters. From the wave-front-/camera-based measurements we obtain the values 1.14/1.10 for M², 0.056mm/0.053mm for d_{bw} and 3.57mm/3.52mm for z_R, respectively. Note that these results are influenced by the noise present in the camera images and by the parameters used for the wave-front reconstruction.

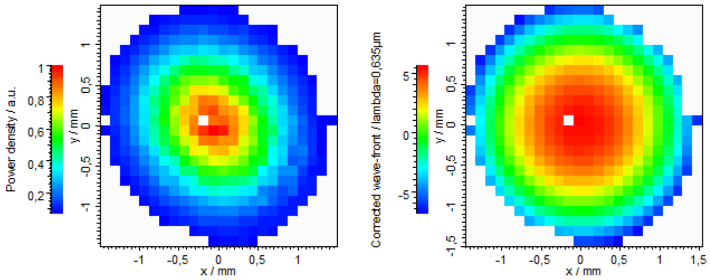

Figure 2: Intensity distribution and wave-front measured with SHSLab in the divergent part of the beam.

4.2 Stability of the beam parameter measurement

In order to analyze the stability of the wave-front measurement, we took continuous measurements with a frame rate of 3Hz for period of 30 minutes. The resulting mean values and standard deviations (rms) of the respective beam parameters are shown below. For all parameters, the fluctuations are reasonably small.

	R	$d(z_m)$	M²	d_{bw}	z_0	z_R
mean	144.07	1.87	1.14	0.057	143.18	3.57
rms	0.044	0.007	0.013	0.00075	0.061	0.059

Table 1: All values in mm (except M²)

4.3 Beam diameter calculation

From the wave-front measurement taken at position z_m = 144mm we calculate the beam diameter $d(z)$ at the positions z where the single camera images for the beam characterization according to ISO 11146 were taken, using the equation

$$d(z) = d_{bw}\sqrt{1+\left(\frac{z}{z_R}\right)^2}$$

The result gives a very good congruence of both methods, see plot in figure 3. The maximum deviation between the diameter determined from the camera images and the diameter calculated from the wave-front measurement was 0.107mm, the mean deviation was 0.034mm.

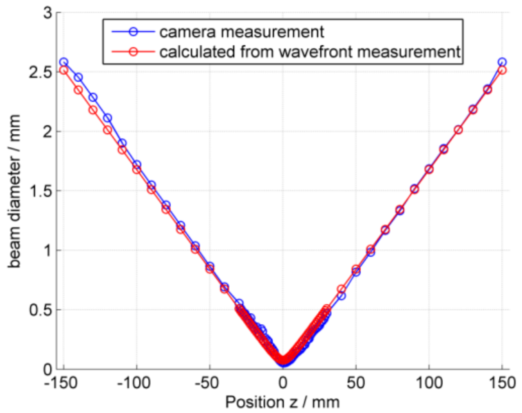

Figure 3: Comparison of the beam diameter measured with the camera and calculated from the wave-front measurement.