Using a Structured LED Linear Light Instead of a Laser Line Generator for High Measurement Tasks

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Abstract. *Measurement tasks are often solved by using the triangulation principle for getting the structure and the surface of the object under test. For this purpose a laser line or even a laser multi line generator is used normally. Though the laser generator is limited having regard to its power, high costs and especially if there are speckles on the object under test.*
Other structured linear light sources are possible to use, if the linear light has got a define width, brightness and sharpness. Due to theirs fast development the LED seems to be a feasibility.
For this several researches were done at the department quality assurance in Ilmenau for getting the three dimensional coordinates of the ground of a groove by using a structured LED linear light. This is done in a first step by extensive computer-aided simulations and the solutions are given here.

Keywords: Linear Light, Structured LED Light, Detection of 3D Surfaces, Triangulation

1. The Triangulation principle for 3D measuring

Triangulation is a method for distance and surface measurements, using mostly a laser as the light source [1]. If the send out beam is a point only the distance can be measured. But if the beam is structured to a more complex geometric shape, like a line at least, also surfaces can be measured.

In a typical case, the laser beam illuminates the object under test in the distance of which from the laser device is going to be measured. Diffuse or specular reflections from that point are monitored with a detector which is mounted in a known distance from the laser beam. This is done in such a way that the laser source, the object and the detector form a triangle. At the detector, normally a CCD camera, the position of the linear light on the chip and its composition reveals the direction of the incoming light, i.e., the angle between the laser beam and the returning light, from which the distance and the surface of the object can be calculated [1].

Laser lines are primarily characterized by their length and their working distance, with other parameters becoming relevant depending on the measuring task. The measurement resolution is given by the line width, which can be limited by speckle. A sufficient depth of focus has to be taken into account when measuring objects of variable height [2].

This is exactly the measuring task for getting the ground of a groove, i.e. of a spectacle frame like in Fig.1. The transparent plastic frame on the left side of Fig.1 has got speckles and hence the width can not be detected clearly. Beside high reflective metal also transparent objects under test causes a lot of speckles, due to the fact that the laser beam is not only reflected at the surface furthermore also on different particles in the transparent plastics like dust, bubbles or flaws.

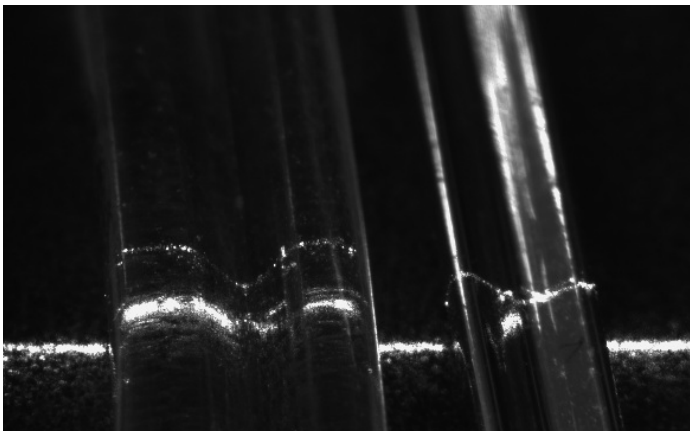

Fig. 1. A plastic and a metal frame with its groove, illuminated with a laser line generator (from left to right).

2. Advantages of structured LED light sources compared to laser line generators

The main disadvantage of laser line generator is the incidence of speckle. Because of the coherence of the laser light there can be interference pattern on the surface of the objet under test. This has got a huge influence on sharpness of the contour and homogeneity of the linear line. The speckle pattern depends on the surface and material under test. An exact measuring is not possible especial by high reflective metal and polish surfaces.

On the other hand laser diodes are very expensive compared to a LED. There is not only an unbalance at the acquisition cost for both systems, also protection measures have to be demanded often during operation. Even the power dissipation and thus the heating are higher for laser than for LED light sources, see also table 1. For this reason a laser based 3D object recognition system is inappropriate for several measuring tasks.

There again an enormous offer of different LEDs is on the market. The diversity of power, spectral color, structural shape and so on allows a solution to nearly all measuring tasks. In some cases this is possible only by changing the source of light, the LED. So the main advantages of LED light sources are the huge range of spectral colors and the ten times higher illumination power.

Table 1. Typical Properties of LEDs and Laser diodes [3].

property	LED	Laser diode
Wave length	NIR, red, yellow, green, blue, UV, white	NIR, red, blue, UV
Power (typical)	500mW	visible: 50mW
Spatial coherence	highly multi-mode	single transversal modus (speckle)
Time coherence	incoherent ($\Delta\lambda > 10$ nm)	coherent ($\Delta\lambda < 0{,}1$ nm) (speckle)
Dimming	linear	not linear, Laser Threshold
Modulation	MHz	GHz

But the illumination is shared in all directions, like in Fig. 2 on the left side. So high power LED for measuring tasks need an attachment optic (Fig. 2 on the right side) for building a powerful point light source.

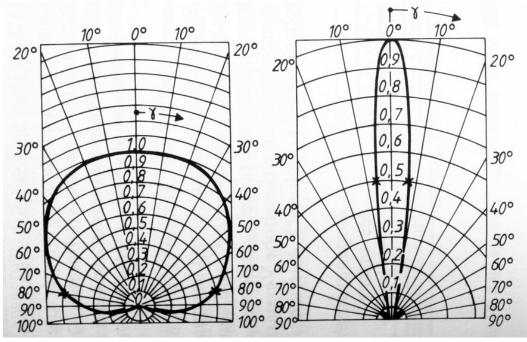

Fig. 2. Light emission of a LED without and with attachment optic [3].

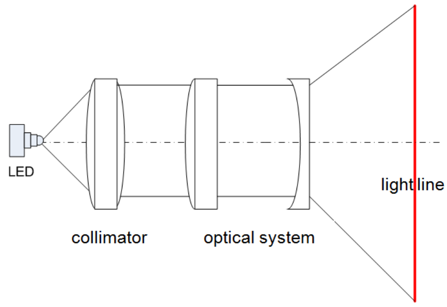

Fig. 3. Basic set up to generate a light line.

3. Creation of a structured linear light

One premise a point light source is already mentioned. The other is: beams have to be parallel and bundled before they can be modelled by optical systems with apertures, splits and lenses. Also the scattered radiation has to be reduced with apertures. In the field of technical optic the elementary way to build a collimator is a biconvex lens [3].

There are different basic set ups to generate a light line, see also Fig 3:

- projection of a split
- beam moulding with a cylindrical lens
- beam moulding with a parabolic reflector
- a combination of them

The plurality of assembling out of the set ups depends a measuring task with a clear special aim. The object under test is the groove of a spectacle frame, which depends the following list of specification (see Table 2) to measure it.

Table 2. Criteria for groove measuring and realised criteria

Criterion	Specification	realised criteria
light source	LED white coloured	LED Vishay (TLCR5100-white)
width	≤ 500 µm	336 µm
length	10 mm	9,4 mm
depth of focus	≥ 5 mm	6 mm
illuminance	0,1 lm/mm²	0,03 lm/mm²
low cost	< 350 €	145 €
working distance	< 50 mm	40 mm

With these parameters different solutions were simulated with the optical program ZEMAX. The best results were simulated (see also Table 2) for the measuring task by the following assembling:

An optical system build out of a split and a cylindrical lens for generation the linear light, like in Fig. 4 and 5.

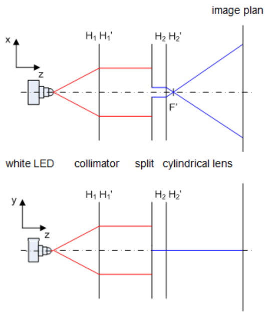

Fig. 4. Beam rum with split and cylindrical lens.

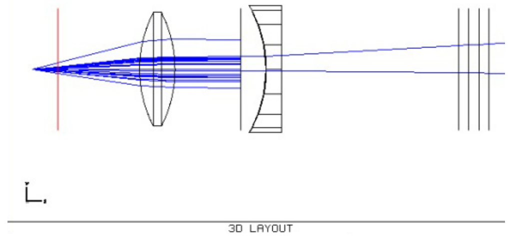

Fig. 5. ZEMAX 3D Layout.

The split has got a width of 300 μm and a length of 12 mm and projects the linear light on the image plane. Its width is constant over the whole depth of focus, like in Fig 6. The cylindrical lens is used to the beam expansion (see Fig. 7) and due to this the illuminace is reduced to larger working distance, like in Fig. 8. An example of the Simulation is given in Fig. 9.

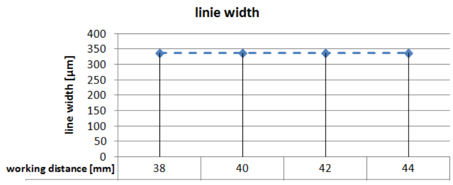

Fig. 6. Line width.

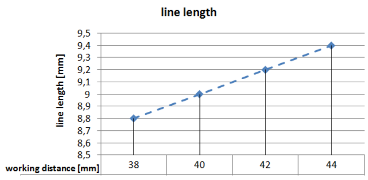

Fig. 7. Line length.

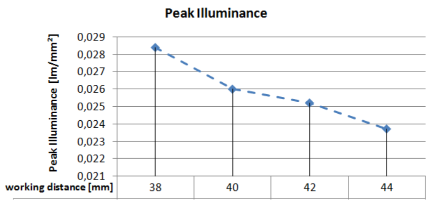

Fig. 8. Peak illuminance.

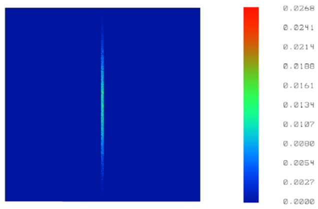

Fig. 9. False Color DV – line width 336μm.

4. Results

This study shows, that it is theoretical possible to use a structured LED linear light instead of a Laser line generator for high measurement tasks, here brought out of detecting the ground of the frame groove. The best results are achieved with an optical system out of a split and a cylindrical lens.

Acknowledgements

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References

[1] Dorsch R. G. et al. Laser triangulation: fundamental uncertainty in distance measurement, Appl. Opt. 33 (7), 1306 (1994).

[2] Schäfter + Kirchhoff GmbH http://www.sukhamburg.de/download/laser_lg_e.pdf (13.02.2011).

[3] Kienast S. Untersuchung, Auslegung und praktische Erprobung eines LED-Multilinienlichts – Strukturierte Beleuchtung zur 3D-Objektvermessung, Ilmenau, diploma thesis, 2009.