Optical improvement for

Even after years of industrial use of lasers, there is still room for new concepts and increased flexibility. The reason why laser technology is used in a wide variety of applications, is not the laser system itself but the ability to tailor optical energy to the demands of the production processes. The full potential of the laser technology is becoming available when combined with optical elements such as polarizers, cameras, lenses and sensors. The use of all these optical tools makes laser technology as a production technology adaptable to almost any situation.

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Serving as an example of the potential of laser technology, a new camera system was developed that co-axially views through a laser scan lens enabling new solar cell designs to be produced more efficiently. And the marking of optical moulds benefits from this new camera option as well. It allows the repair of existing marks on optical moulds. This camera lens system was designed by Sill Optics in close corporation with Molenaar Optics, ECN and Philips Applied Technologies. The new lens enables a scan angle independent view through the scan lens with an integrated illumination of the work piece. Another problem that can be solved by adding optical elements to the laser system, is its inherent change of pulse width and intensity distribution when changing the pulse energy electronically with the power supply of the laser.

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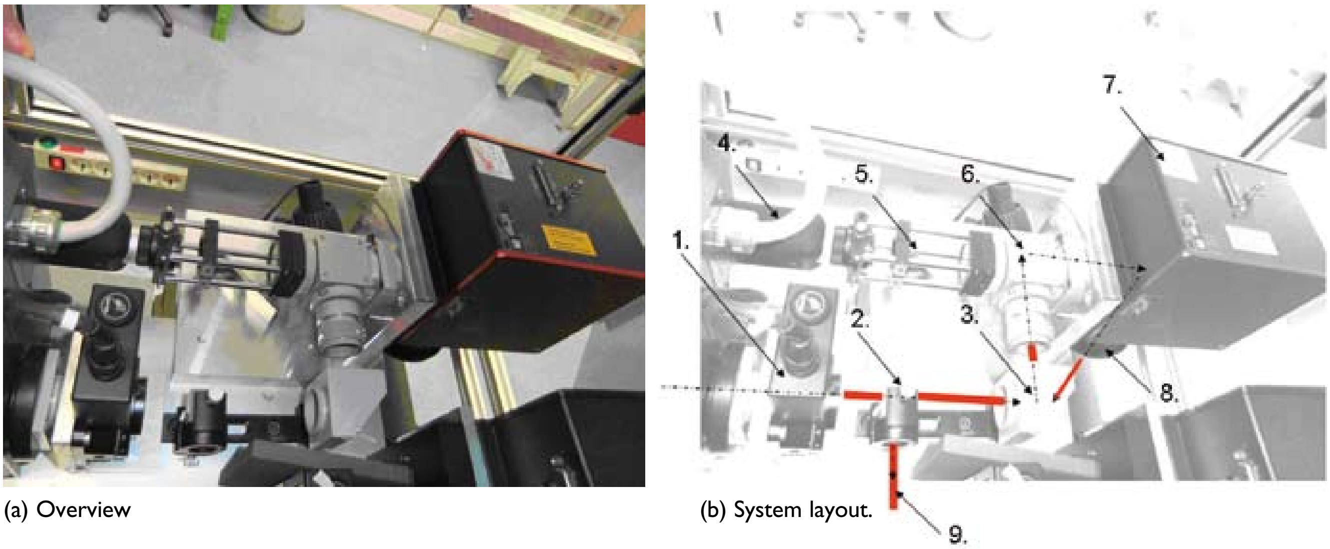
Attenuation

The nature of most laser systems makes the use of attenuation into an efficient production tool. Attenuation is a known solution for many experiments, see Table 1. It allows to change the pulse energy without changing the pulse shape and divergence. A laser is usually most stable at high pulse energies, while selective layer ablation and engraving merely demand moderate pulse energies. Accurate attenuation by computer-controlled polarization variation then provides the necessary reduced pulse energy, while the laser still can be operated at its most stable point. Attenuation can also be used to measure threshold values of laser processes. It is even used as a method to control product quality. A good attenuation system only changes the pulse energy, without any change to the beam quality and pulse duration. Several attenuation methods exist, see Table 1.

The use of modern laser systems such as pulsed fiber lasers, makes external attenuation at first sight less important. These systems are using amplifiers to enable the high pulse energies and have much better cooling due to their higher surface-to-diameter ratio. Therefore, for

Table 1. Overview of attenuation methods.

Attenuation method	Specific features
Angle dependent reflection	Thermal effects, separate cooling is required.
Neutral density filters	Good for low intensities, higher intensities tend to damage the filter.
Polarization dependent transmission	No absorption in the optical elements. Used with half-lambda plates and electro-optical polarization rotation. Suitable for high pulse energy.
Surface reflection	Used for beam measurements, a small part is reflected. Polarization dependent.
Acousto-optical deflection	Full attenuation at Bragg angle. Introduces small angle in the system. Used for fast attenuation.



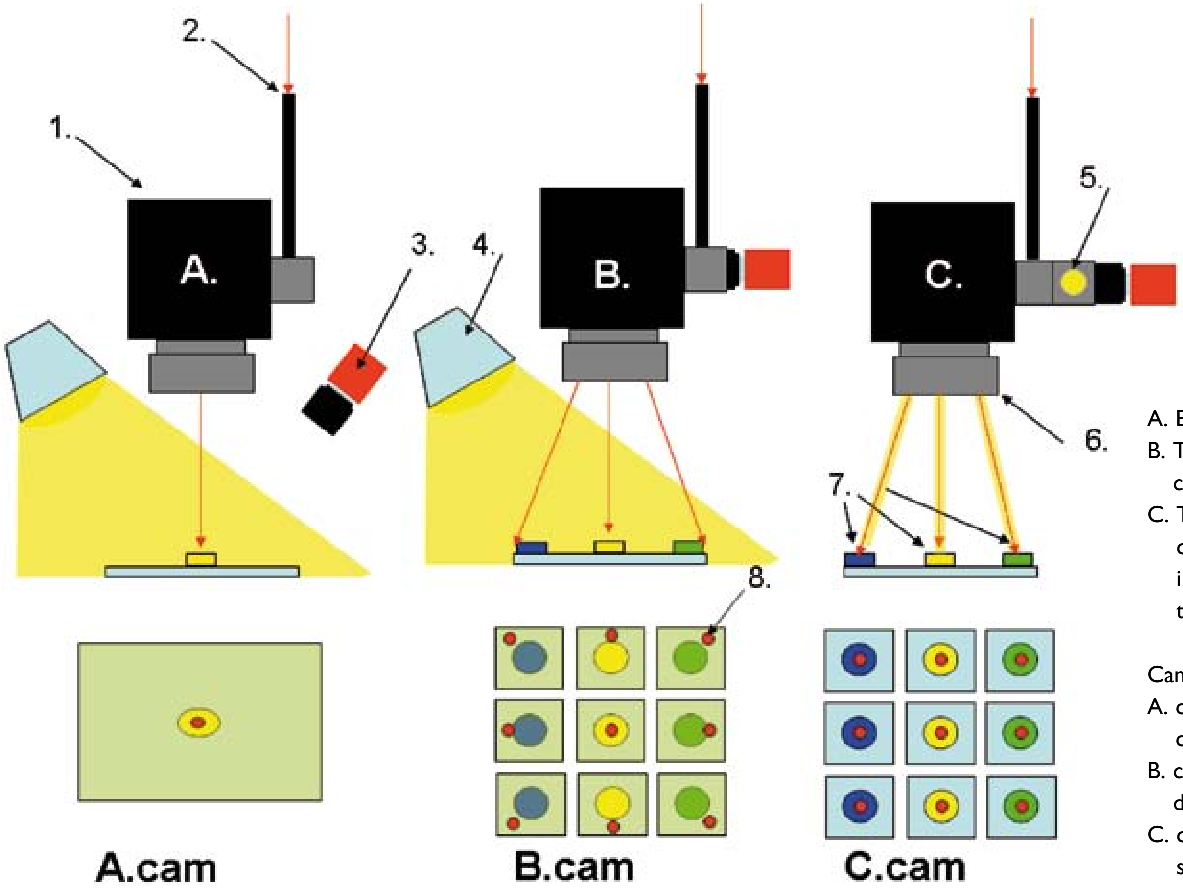
(a) Overview (b) System layout.

1. Rotating half-lambda plate, 2. Polarizing beamsplitter cube, 3. 45° mirror, 4. Camera, 5. Projection optic camera, 6. Infrared 45° mirror, 7. Scanner, 8. Flat-field focusing optics, 9. Laser beam to beam dump. Dashed and red lines: optical path of the UV laser through the system.

Figure 1. UV attenuation system using polarization with camera setup.

nanosecond systems the pulse shape is less dependent on the pulse energy. However, the use of external attenuation is quite helpful in determining the intensity threshold of processes. This does not mean that attenuation is only limited to the design phase. The new picosecond fiber lasers all use internal attenuation to ensure efficient and stable running of the laser under industrial conditions. The attenuator used, see Figure 1, comprises of an accurate computer-controlled steppermotor-rotated quartz halfwave retardation plate from OptoSigma (Figure 2) to rotate the polarization direction of the laser beam. This controls the power output of a high-power laser polarizing cube beamsplitter before it enters the flat-field scanner system.

Figure 2. OptoSigma motorized rotation stage.



A. External camera.
B. Through-the-lens without compensation.
C. Through-the-lens with compensation and illumination through the lens.

Camera views:
A. cam: schematic picture of camera, small distortion.
B. cam: laser spot (red dot) deviates from centre.
C. cam: no deviation of laser spot from camera centre.

1. Scanner, 2. Laser in, 3. Camera, 4. Illumination, 5. LED coaxial (inline) illumination, 6. Scan lens, 7. Objects, 8 Laser spot in camera view.

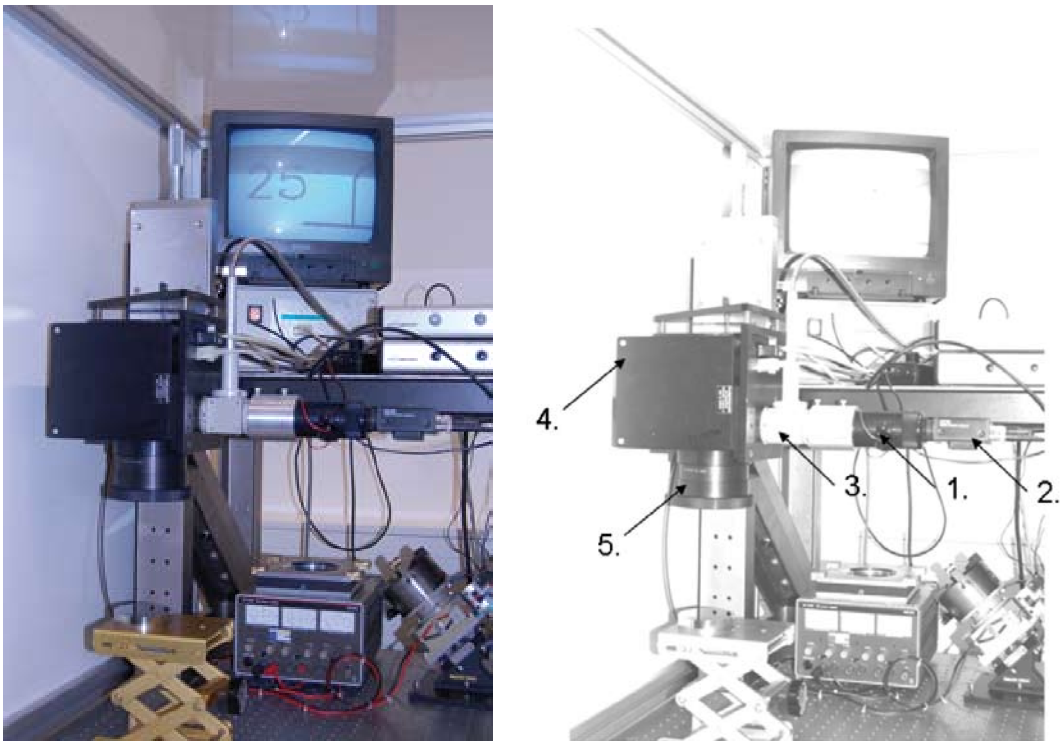
Figure 3. Three different camera and scanner combinations.

Through-the-Lens Camera System

The repeatability accuracy of optical galvo scanners is very high, 3.5 μm for a 160 mm scan lens. But the absolute position accuracy is not as good. Thermal drift often causes problems when high absolute accuracies are needed (for example, Intelliscan: 0.6 mrad/8 hours * 160 mm = 96 μm). Some systems can calibrate the mirrors internally to ensure a better performance of the scanner. Another, novel scanner design uses less energy and subsequently generates less heat for improving the absolute accuracy. But, these systems are not the answer for measurement of production line variations of part dimensions or errors in positioning systems. In such cases a camera system is the solution.

Cameras are often placed alongside the scanner and communicate with the software of the scanner system. A camera that can look through a complex scan lens is more accurate but only in the centre of the field (see Figure 3). To overcome this position limitation, a calibration can be used to compensate for the errors the scanner lens introduces. This so-called compensation table solution is used in baseline solar cell production at ECN for edge isolation and via drilling. However, it is very time consuming and the complete scan field has to be illuminated. Because the compensation is position dependent, the actual angular position of the mirrors is needed to calculate the real compensation.

Philips, Molenaar Optics, Sill Optics and ECN worked together to enable a more generic solution with a system that eliminates the need for the position feedback and solves another problem, the illumination; see Figure 4. A dual-wavelength scan lens from Sill Optics was used to simultaneously enable vision in the green and a laser process in the near infrared. The lens was originally designed for simultaneous infrared and green laser processing, so it has the same focal length and F-theta condition for both wavelengths. Adding a camera and a telecentric objective lens with coaxial illumination (a green LED) completes the system.



(a) Overview.

(b) System layout.

1. Camera optic and illumination source, 2. Camera, 3. Infrared 45° mirror and incoupling of the fiber laser beam, 4. Scanner, 5. Telecentric lens

Figure 4. Position-independent through-the-lens camera system with illumination.

Going through the objective lens, the green LED illuminates the camera field only, not the surroundings. A polarizing beamsplitter transmits the reflected light with the image of the processed part to the camera while keeping the illumination source away from it. This system has no need for a compensation table. If an automatic camera system is used, the measurement of the camera can be directly fed to the scanner card. This makes fast calibration possible. The system can even measure parts and can act actively when combined with an intelligent camera. The same system can also be used for the green processing wavelength with infrared illumination. The integrated illumination is more efficient because only a small area of the product is illuminated. For some materials like polymers and biomaterials, a full illumination can change the product temperatures through absorption. This could cause melting and deformation of the product.

Conclusion

The cooperation between Molenaar Optics, Sill, Philips Applied Technologies and ECN made it possible to define the needs for a new through-the-lens optical system. This lens system enables a higher absolute accuracy while using scanners and compensates for the thermal scanner drift and displacement of the part during production. The position-independent compensation enables a larger working area. The old system was limited to the centre of the lens. But this optical system can even be used, with an intelligent camera, to find the part and calculate the compensation directly. This reduces the need for accurate positioning.

The other system discussed, computer-controlled optical attenuation, is a good example of simplification. It makes laser operation easier by adding a direct power knob. The user does not have to think about all the other parameters of the laser, while normally changing the pulse energy would automatically lead to a change somewhere else in the laser beam.

Information

www.ecn.nl
www.apptech.philips.com
www.molenaar-optics.nl
www.silloptics.de