APPLICATION OF LASER LIGHT FOR THE PRODUCTION OF MICRO LENSES

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Introduction

Glass fibres offer a series of advantages compared to electric conductors. But these benefits are opposed by drawbacks: the coupling and uncoupling of light energy, plug connections with high losses and the adaption to opto-sensoric technology make constant further advancements imperative. The fabrication of micro lenses by means of laser light is at present the most promising innovation in the sector of optical production.

Since the 1960's laser technology has been used successfully in various different industries offering a wide range of solutions and applications. The increasing number of applications suggests that the laser market will continue to be booming in future and will achieve several times its present volume.

Picture 1: Connector for eight parallel light guide data- lines.

The success of the laser in material processing is based on its unique physical functions for which there is no equivalent alternatives at present. Despite the achieved successes it has to be pointed out that laser technology for glass and quartz glass processing respectively is still at its infant stage, especially for the production of lenses.
Laser radiation as form of energy qualifies by its high degree of effectiveness to transform materials into other forms of energy or other states of matter. By its easy focussing, high performance density

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and easy manipulation the laser beam is predestined for processing applications. Beside large scale production there are many special applications which are only realisable by means of laser technology, like the production of micro lenses for light guides.

Considering the characteristics of a laser beam on one hand and the characteristics of glass and quartz glass on the other hand, different processing possibilities can be explored. Because of the required laser performance and the homogeneity of the beam, laser wavelengths CO and CO_2 respectively take the limelight.

Glass Processing with Lasers

The use of lasers for processing pure quartz glass into ready to use micro lenses is obvious. As the energy of the laser beam can be focused on minimal space, the quartz glass (SiO_2) is put into another state of matter (vapour phase) within a fraction of a second.
The main aim is to couple the focussed laser beam in such a manner that possibly the entire capacity can be absorbed by the quartz glass surface. Glass and quartz glass absorb almost 90% of the radiation in the IR spectrum. The degree of absorption of glass can be influenced by means of temperature, heat conducting efficiency and heat capacity, so much so that in practise minute divergence is normal.

When the laser beam meets the glass surface, the surface absorption is transformed into heat. With sufficient laser capacity the heat can be used to process quartz glass. The heating process is fast and contact free, within the glass the radiation is transformed into kinetic energy of the grid vibration, in this process the quartz glass is liquefied and vaporised.

The increasing Importance of Micro Lenses

As electronics has reached its physical boundaries the importance of light as a data transmitter increases. Some scientists dream of optical computers, others bet on photonics, a symbioses of electronics and optics.
Optical guides can be spliced without problems or they can be connected by means of single or multiple connectors. Picture 1 shows for example a snap on connector for eight parallel data lines.
The requirements for a fibre optic connection are complex. The most important points on the duty roster are:

- minimal attenuation
- contact free
- not prone to dust
- easily exchangeable
- simple cleaning and servicing

The ultimate aim in the fabrication of an optical connector system is an optimal optical adaption, meaning the transmission of a maximum light energy from a light transmitter (or from an end of a light guide) into another light guide.

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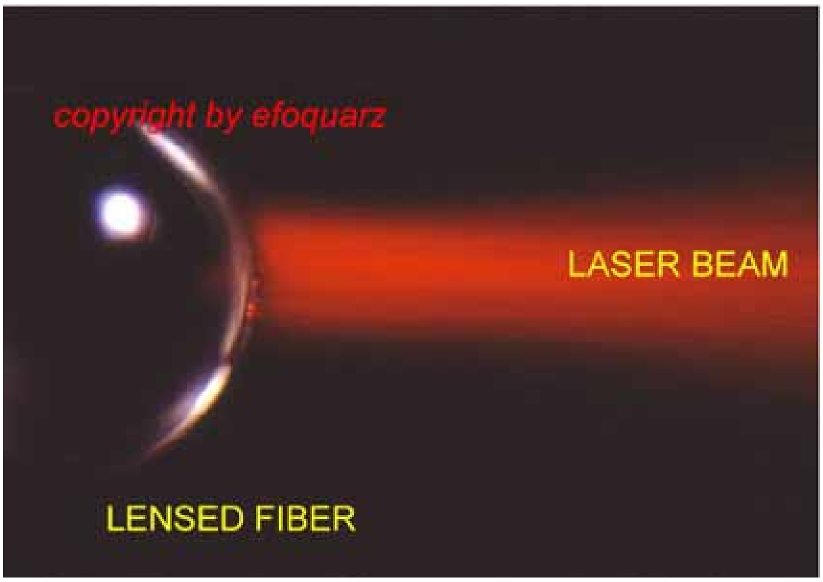


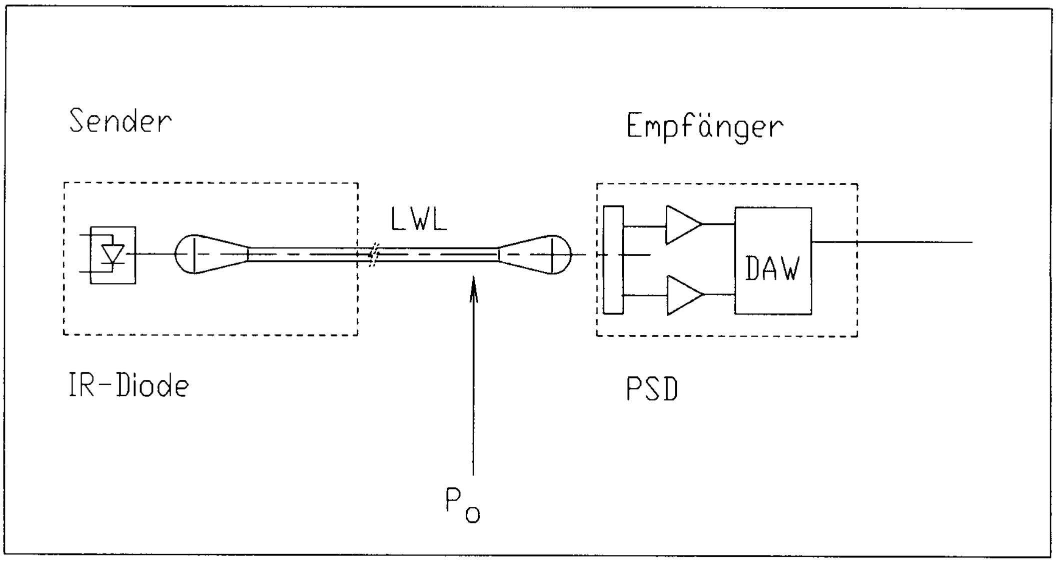
Picture 2: Integrated Micro Optic. It is clearly visible that the laser beam (680nm) exits the ball lens quasi parallel with a cross section of just 300μm.

The First Development Objective

The first stage of the objective has been achieved by expanding the ends of a light guide and then melting a ball lens. Picture 2 shows that the laser beam exits the ball lens virtually parallel. The coherent length of the beam in monomode fibres measures up to 100 mm, compared with just a few mm in multi-mode fibres. To eliminate the disadvantage of the multi-mode fibres, meaning to maintain the coherence of the exiting beam up to a distance of 100 mm or more, a micro lens with an outer cross-section of 0,8mm and a length of 1,7 mm is needed.

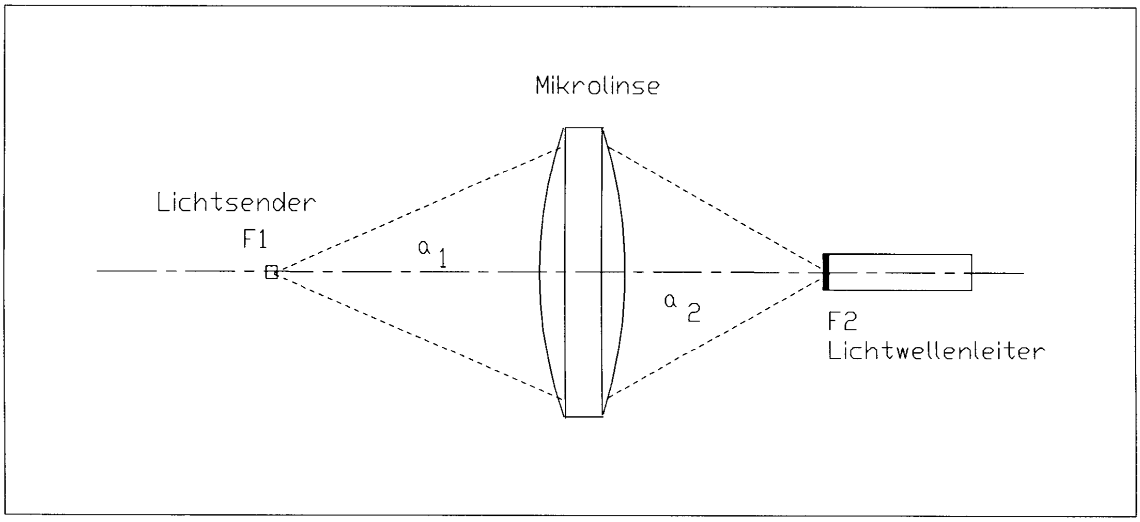
Integrated Micro Optic for Sensor Applications

The quartz glass light guide (in the distance range of 20-100 mm) at both ends with integrated micro optic (IMO) can be used in numerous sensor applications, such as distance measuring, vibration, aerodynamics, inclination, flexibility, lengthening which are registered with linear Position Detectors (PSD). With PSD Elements uni and bi-dimensional position divergence can be easily detected. Digital or analog processing of the PSD signals is possible. When a IR-Diode (Picture 3) is operated with changing signals, the PSD signal can be intensified without drift. The data can then be digitalised with a 16 Bit (max. 24 Bit) AD-changer for instance. The results are distance resolutions in the nm range.



Picture 3: An interesting application for Integrated Micro Optic are sensors, consisting of a IR-transmitter and position detectors (PSD)

The basic structure of such a sensor - consisting of transmitter and receiver unit - is shown in Picture 3. The transmitter unit contains a IR-Diode and the light guide with IMO-ends. The receiver consists of a PSD unit for analog distance recording. A single photo element with two light sensitive cells and corresponding signal analysis is sufficient for digital evaluation. Should the free end of the light guide change its position towards the PSD due to minimal forces (P_o) the light point onto the PSD changes, which leads to a changing signal.



Picture 4: Shows one of the most common applications, a light transmitter sending light via a micro collimator lens into a light guide.

The Second Development Objective

The main objective of the development is to maintain the exiting beam coherent over a longer distance (>100 mm) and to enable optical adaption during coupling (Picture 2). To achieve this a collimator lens is required. For production reasons it is advisable to consider whether a single

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collimator lens already offers a workable solution. For simplicity a borderline case is taken as a base and losses and absorption (n=1) are neglected. Applying a geometrical optic results in the following equation:

$$dF_1 \cdot \alpha_1 = dF_2 \cdot \alpha_2$$

dF_1 = surface of the light transmitter
dF_2 = light guide surface
α_1 = entry angle
α_2 = exit angle

For a focussing lens it is assumed that $\alpha_1 = \alpha_2$, therefore α is inserted as angle and $F_1 = F_2$, F is defined as standard surface area.

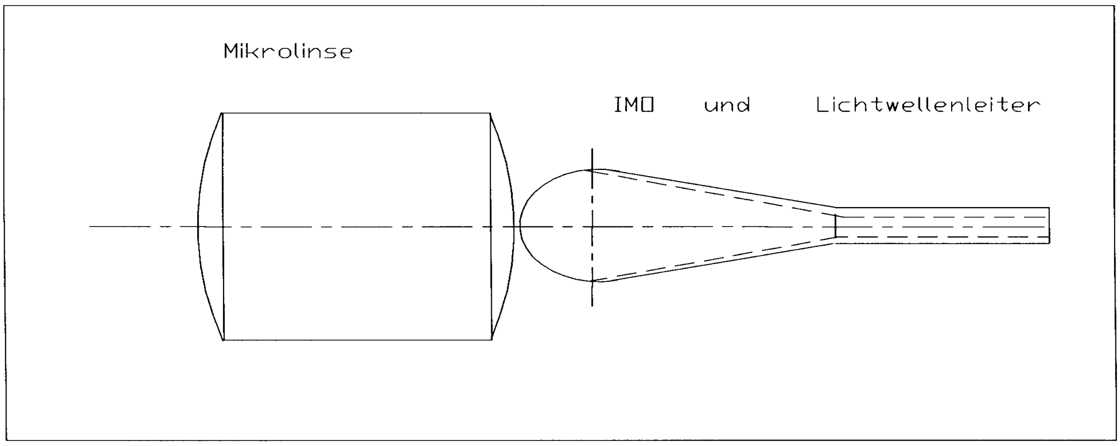
The product of the surface of the light transmitter and the angle is:

$$F \cdot \alpha = S$$

S = System constant.

In fibre optics S is determined by the aperture and the opening angle of the light guides. Everything that reduces S determines the effectiveness and no lens, no matter how sophisticated, can increase the effectiveness.

The adaption or focussing lens should have an S-value which equals a maximum, same as S_{max}. Higher S values are permissible as more light energy is induced, which however by the geometrical expansion cannot penetrate completely.



Picture 5: An optimal fibre optic adaption consists of an adaption lens (fabricated by laser) and an integrated micro lens which is melted onto the end of the light guide.

This means for a light guide connector that part of the light energy is lost or reflected within the light guide. The effects can disturb the frequency range. An optimal fibre optic adaption (Picture 5) consists of an adaption optic produced with laser and of an integrated micro lens which is melted onto the end of the light guide. The micro lens optimises the optical adaption in two aspects. Firstly at the entry point coupling of the energy with 6 - 8 times higher effectiveness is possible. Secondly at the exit coupling point a coherent beam guidance in ranges above 100 mm is possible.

These conclusions are based on normal quartz glass stick collimators with an external cross section of 0,8 mm and a step index casing profile.

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Good Laser Processing Control Brings Optimal Results

The application principle of laser sublimation can be seen in Picture 6. A focussing device (mirror system) within the beam guide head focuses the laser beam onto the working material (SiO_2 quartz glass). At typical performance levels of 10^8 W/cm^2 the quartz is melted and vaporised in the focal point. The protective gas emitted by a jet protects the optical head against pollution. As the excessive quartz glass is vaporised this process is called laser sublimation.

The wavelengths are fixed by the laser active medium. This is very important because the absorption of quartz glass increases when the wavelength is reduced (CO = 5 nm /CO_2 = 10,6 nm), the focussing performance also increases. Of crucial importance for the focussing performance of a laser beam are the Mode TEM_{00}, the intensity distribution, beam cross section and divergence.

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