IMO – LOW LOSS LIGHT GUIDE CONNECTOR TECHNOLOGY

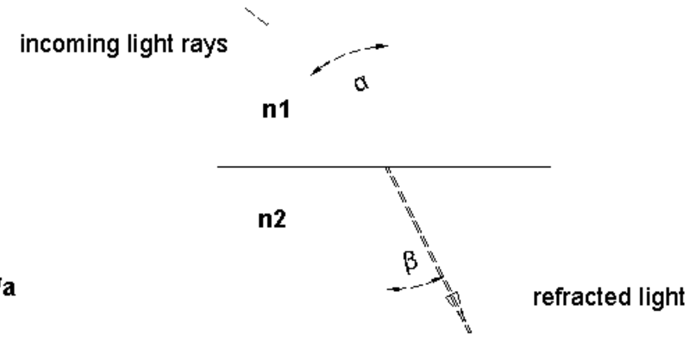
Translation of an article by Lajos Bognar of Efoquarz GmbH Switzerland, published in Technica 5/1992

THE FABRICATION OF HIGHLY INTEGRATED FIBRE OPTIC CONNECTORS

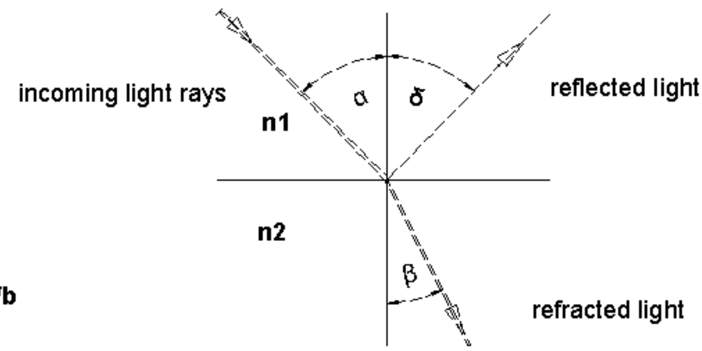
Among the many variants of optical connectors, the new **Integrated Micro Optic** (**IMO**) connectors are expected to be widely used in Local Area Network (LAN) transmission systems. A micro optic integrated at the end of each glass fiber enables almost parallel coupling of light energy.
The IMO-Technology makes the production of optical multipin-fiber optic connectors in low loss quartz glass (SiO_2) a reality.

INTRODUCTION

Reference is made to the basic laws of light guides and optics respectively because these technologies still open a wide range of new application possibilities. Light guide systems cannot be soldered like copper cables to make a connection. But it also applies to the fibre optic technology that there is no transmission of information without transmitter, receiver and connecting elements.



Pict. 1/a



Pict. 1/b

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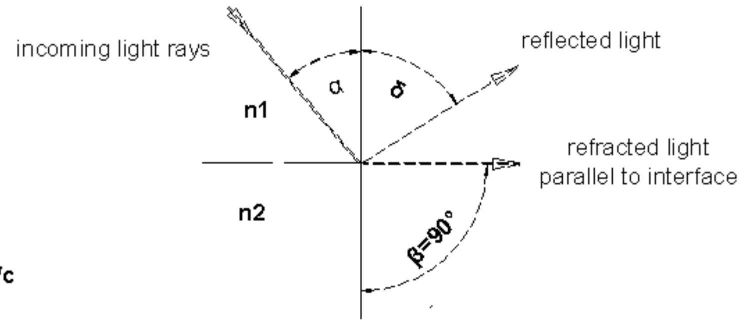
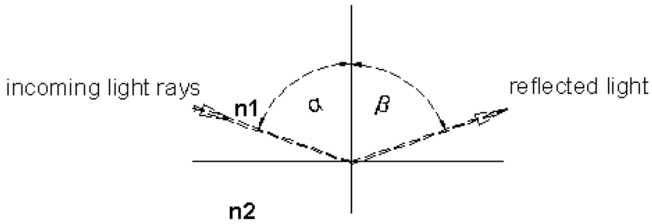


Pict.1/c



Pict. 1/d

FUNCTION OF A LIGHT GUIDE

Fibre optics have their own basic terms, the most important ones are:
The *law of refraction*: refraction of light meaning that light changes its direction at the interface of one translucent medium into another. The following applies (see. pict. 1a):

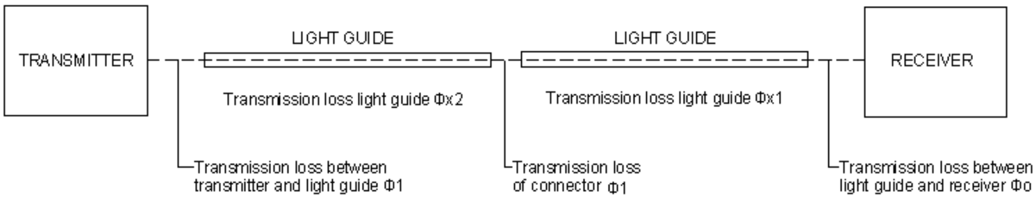
$$\frac{\sin \alpha}{\sin \beta} = \frac{V_1}{V_2} = n$$

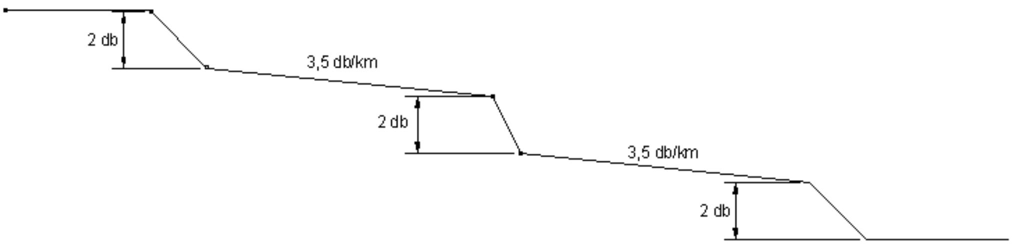
n	=	refractive index
V	=	expansion speed of light in the two different medias
α	=	entry angle
β	=	refraction angle

The refractive index is defined as the relation between the expansion speed in a vacuum to the expansion speed in another medium. A small portion of the light however is not refracted but reflected at the interface to a different medium as per (pict. 1b). The small entry angle α causes the refraction of a big portion of the light (not favourable since a major portion of the light is lost).

In (pict. 1c) the critical entry angle α is shown, resulting in the refraction of the light beam along the interface of the two medias. As per (pict. 1 d) the basic requirement for a total reflection is that the entry angle α has to be bigger than in (pict. 1 c).

The *numeric aperture* (NA) is the main criteria for the connection of light guides and for coupling the light beam with transmitter and receiver units. The numeric aperture indicates the difference of the refractive indices between both medias. The smaller the numeric aperture the bigger is the optical bandwidth of the light guide.





Pict.2: Loss in light guide transmission in dB

Individual light beams (modes) travel different distances along the fibre, causing differences in propagation time. These differences are responsible for the quality and the impulse reaction respectively between transmitter and receiver.

Light guide transmission is aiming to transmit the light energy emitted by the transmitter to the receiver with as little loss as possible as per (pict. 2). Power losses can be analysed and are captured in the following equation.

The available radiation power for the receiver is calculated as follows:

Φ_t = power transmitted (F_t)
Φ_r = power at receiver (available) (F_r)
Φ_m = minimal power requirement for receiver (F_m)
δ_0 = total light loss

$$\Phi_r = \Phi_t - (\delta_l + \delta_{xl} + \delta_l + \delta_0) = \Phi_t - \delta_0$$

For an effective transmission system the available power Φ_{r0} has to be bigger than the minimal power requirement of the receiver Φ_m. The total power loss Φ_{total} of the transmission system is measured in **dB** and is a log. correlation between entry and exit:

$$\Phi_{total} = 10 \log (\Phi_t / \Phi_r)$$

Infrared diodes are used as optical transmitters. The aim is to couple as much light energy as possible into the fibre. For an optimal coupling of the energy transmitted an optical adaptor is required.

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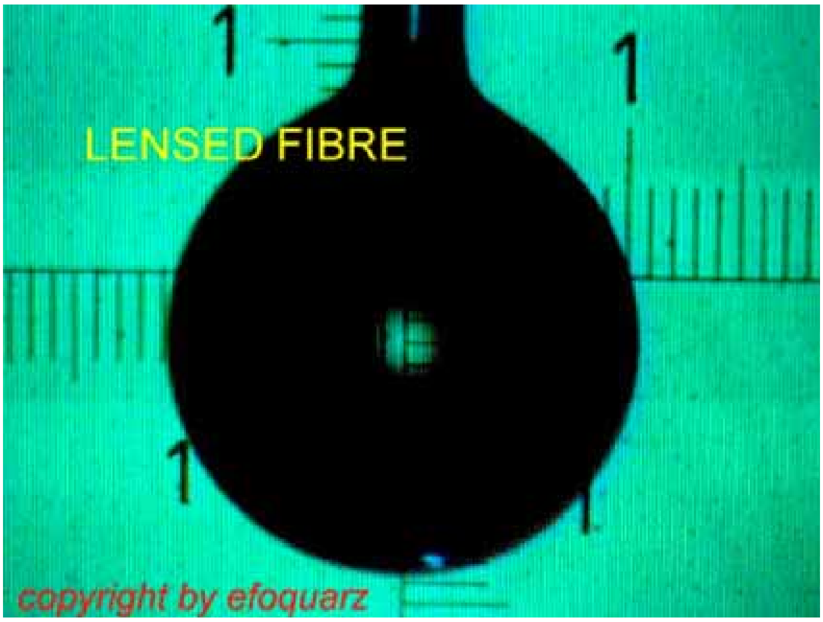
INTEGRATED OPTICAL MICRO STRUCTURES

s in micro electronics integrated optical micro structures and passive integrated optical components are developed on common substrates.

It is a characteristic of integrated optics with light guides, that it is possible to dote materials such as SiO_2 in form of micro lenses onto the fibre using the fibre end surface (diameter of 125 µm (pict. 3) as a basis substrate. For applications in fibre optics there are a few SiO_2 modifications (β - quartz) known.

During the lambda-transformation (2nd order) process controlled additive application can be achieved within a specific pressure and temperature range. Under hydrothermal conditions spheric and / or parabolic optical systems can be created.

Pict. 3 shows a fibre with an integrated optic. This optic has a diameter of 125 µm and it focuses the light beam onto the focal point with the focal length depending on the optic. The centre beam within the fibre reaches the focal point without bending, whereas the reflected light beams are bent according to the entry angle towards the focal point.



Pict. 3: End of graded fibre with a diameter of 125 µm. Fibre and lens are integrated.

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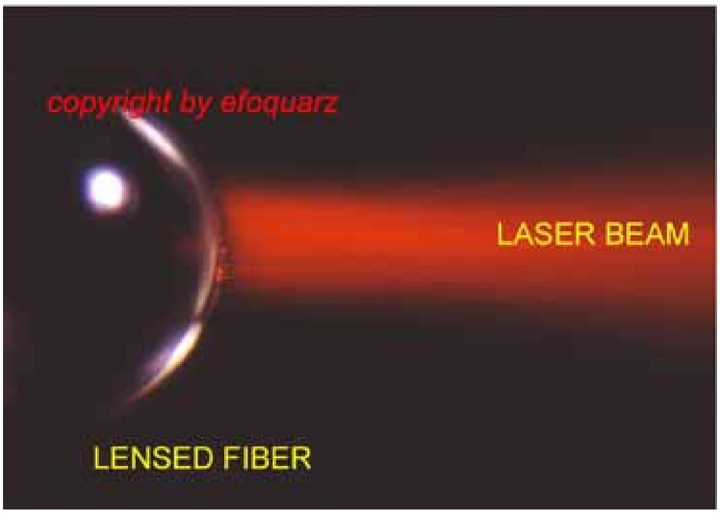
Pict. 4) shows the a distribution of intensity which is reflecting these correlations. For this photo an Integrated Micro Optic (IMO) was used on both ends. The light was coupled from a laser source and the parallel beam was made visible with smoke under a microscope.



Pict. 4 Laser beam leaving the integrated Micro optic. Lens diameter 125µm.

SYMMETRICA LIGHT DISTRIBUTION

Above and beyond the centre beam of the optical axis the intensity is reducing. The light distribution is symmetric, a phenomenon with a simple explanation. Not all light beams are bent towards the focal point. Partial beams from the fibre which are bent (by multiple reflection) with an angle α_0 to the centre beam create side maxima. These side maxima make up only a small fraction of the intensity of the main maximum.

To define the focal point a light source (i.e. a GaAs-Infrared Diode) is installed in a distance emitting mono-chromatic light in a radiation angle of α_0. A single light beam is observed, applying the optical laws mentioned. The refraction law describes how this light beam is refracted but it does not describe where the light beam does not enter the spherical lens surface anymore but is reflected on the surface (total reflection).

CALCULATION OF THE OPTICAL SYSTEM

Crucial for the calculation as in (pict. 5) at point P_0 is the angle δ_1 between the perpendicular in point P_0 and the beam.
This entry angle δ_1 is calculated as follows:

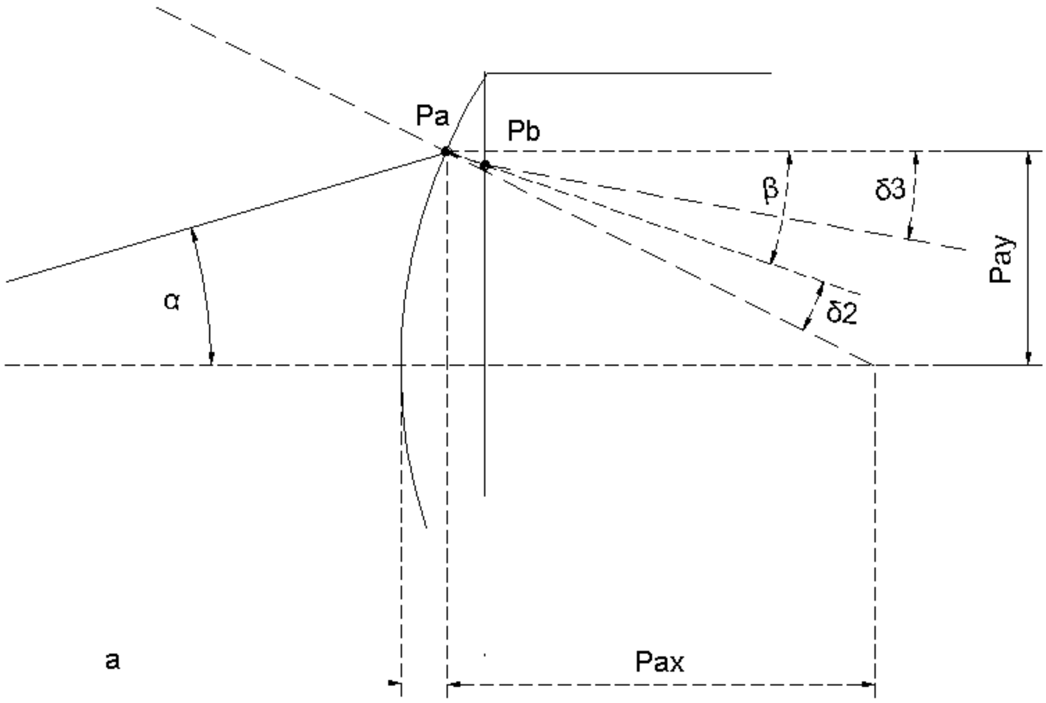
$$\delta_1 = \alpha_0 + \arctan (P_{ay} / P_{ax})$$

As the transition from an optically thinner to a more dense material is given, the light beam is refracted towards the perpendicular

$$\delta_2 = \arcsin [(n_{air} / n_{quartz}) \sin \delta_1]$$

To find point P_b , where the refracted light beam meets the fibre core surface, first the absolute angle between beam and optical axis has to be calculated

$$\beta_1 = \delta_2 - \arctan (P_{ay} / P_{ax})$$



Pict. 5: Beams at IMO ends

Analog to the above the exit angles δ_3 in point P_b can be calculated. From this point, symmetrical observations made should enable work progress.

This is a start towards the calculation of optical systems. It is shown in the previous calculations that the beams obviously do not intersect in one focal point but they have different focal lengths.

This is manifested in the finding that only parabolically curved optical systems enable error free focussing of light beams. In small optical systems the spheric lens shape is not easily fabricated as compared to the parabolic lens shape. In practise they only cause very minute reproduction errors.

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This would solve the problem - apart from a minor detail, being: in a light guide with graded fibre the refractive dispersion is parabolic and therefore the beam is diverted as per (pict.5), therefore there is no reflection at the interface. The gradient of the refractive index is responsible for no-loss and no-dispersion of the light expansion.

IMO-CONNECTOR AND TRANSMISSION PROGRAMME

The Integrated Micro Optic was developed by *Efoquarz*. The optic at the end of the fibre is hermetically adjusted and glued into a metal pin. Any number of IMO-connections can be built into snap on connectors.

IMO-ends with a confectioned light guide gain a key role, they account for the lowest energy loss in data transmission between the active transmitter and the receiver. The IMO ends are not in physical contact at the point of transition.

IMO-PROGRAMME: (Pict. 6)

- Connectors (Light guides 50/125 µm fibre with integrated micro optic)
- Connection unit (Connector to connector)
- Transmission unit (Plug with GaAs IR-Diode incl. solder pins or SMD respectively)
- Receiver unit (Plug with PIN-Diode incl solder pins or SMD respectively)

AREAS OF APPLICATION:

For laser application gradient fibres have the following advantages:

- Laser beam transition with consistent coherent characteristics;
- Stable distribution of intensity at entry and exit point, even when changes occur, i.e. bending of the fibre;
- Optimal focussing possibility;
- No modem dispersion.

This means that IMO-light guides can ideally be used in connection with a semi-conductor laser. Increasingly gradient fibres play a key role for optical data transmission systems. LAN data networks normally work simultaneously in order to obtain a high density of data to be transmitted.

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THE FUTURE – PARALLEL PROCESSING

The connector enables data transmission between efficient processor units in systems with distributed memory. By parallel processing with IMO and light guides, data-processing gains an efficient tool to attempt new solutions for complex problems in the fields of mathematics, physics, chemistry and medicine.

In the areas of automation and industrial robots the number of information channels between machines and control units is increasing, so are the sensoric needs. More complex controls of tools require accurate data transmission.

The main advantages of IMO-connectors are:

- accurate data-transmission even under electromagnetic disturbances;
- potential differentiation between transmitter and receiver devices;
- high transmission capacity;
- minimal light guide cross section;
- minimal weight and
- minimal space requirement
- high mechanical and optical stability
- user friendly installation.

Pict. 6: IMO components: connector, connection unit, transmitter and receiver

Confectioned light guides with IMO, ready to use with connectors at both ends are supplied in standard design. As an option they can be supplied with a connector unit as extension plug or with LED (transmitter) and PIN (receiver) units respectively.

IMO as multi pins are suitable for parallel data transmission between static (Si) hard disks and processors even as memory card connectors.

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