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Optical fiber coupling to a laser diode through chalcogenide microlenses♣♠

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Microspherical lenses (50 ÷ 800 μm in diameter) based on glassy As_2S_3, have been produced by a special flame melting technique. The microlenses have been used for focusing the red – infrared laser light at the end of an optical fiber. Microlens arrays have been produced and applied in coupling optical fibers to a light remitting diode (LED), in order to increase the intensity. A double ball lens coupling scheme has been designed and manufactured.

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Keywords:

1. Introduction

Chalcogenides are materials that contain one or more of the chalcogen elements (S, Se and Te) [1]. Amorphous and glassy chalcogenides can be easily applied in optoelectronics due to their optical properties [2]. They can be used for the production of passive or active optical elements like gratings, lenses, filters, beam couplers or beam combiners, operating in broad spectral region [3]. The advantages of chalcogenides glasses over the conventional optical materials are costs and ease of manufacture.

These materials are able to be introduced in optical integrated circuits, because they fulfill the following requirements: have a wide range of compositions that allows to select materials with appropriate refractive index, can be deposited on different substrates without additional optical losses, the refractive index and the optical losses can be changed by external factors, allow to combine the circuits with radiation sources and have high stability and reliability.

Chalcogenide glasses are characterized by high transparency in IR, high values of the refractive index, in the range 2.3 - 3.2 and low optical losses (<1dB/cm). Therefore, the chalcogenide optical elements can be used for coupling IR light beams.

In the last years it was an increasing interest in fabrication of microlenses and microlens arrays due to their optoelectronic applications. In this way a variety of techniques were developed [4-7]. Microlenses and microlens arrays are used in optical communication and computing, CCD cameras, faxes, imaging systems and IR technology.

2. Experimental

A new technique for producing microlenses (patented) [8] has been developed. This technique allows obtaining spherical and planconvex microlenses from micrometric As_2S_3 chalcogenic powder. The powder is falling vertically into a furnace maintained at 600 °C. This powder is rapidly heated near the melting point and it became spherical under the pressure of the surface tension. Under the furnace is a collecting plate filled with water at room temperature. Inside the water it takes place the cooling and solidification of the spherical microlenses. Using this new technique, we obtained microlenses with the diameter between 50 ÷ 800 μm. One of these lenses is presented in Fig. 1. The refractive index of the lens is 2.43.

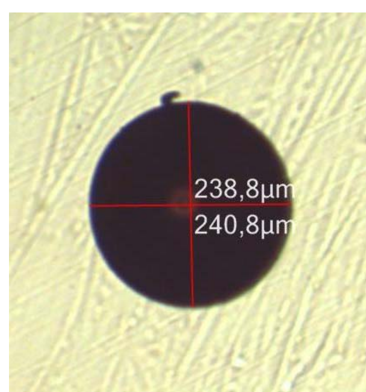

Fig. 1. Single microlens with 240 micrometers diameter

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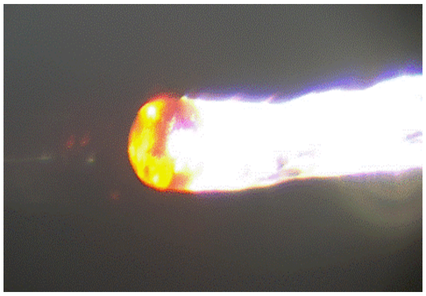

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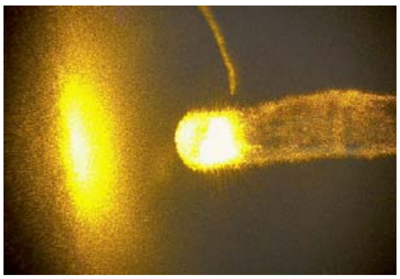


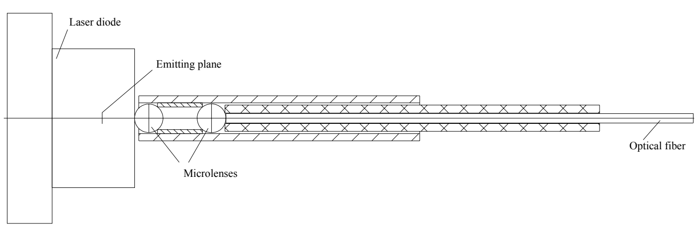
b

Fig.2. Chalcogenide microlens and optical fiber a) Microlens coupled to fiber b) Light focused through microlens

We produced separate microlenses [9 - 11] to be coupled with the fiber ends using an optical glue (type F-65 lens bond with refractive index 1.55 and Tg~100^{o} C). Figure 2a shows the typical combination of fiber and lenslet made of As_2S_3. At the end of the fiber it can be seen the lenslet, in red color. In Fig. 2b it can be seen the focusing of the He-Ne radiation propagated along an IR optical fiber based on silicon oxide. The focal distance and the quality of focusing depend on the type of the lens and on the quality of gluing of the As_2S_3 lenslet on the fiber end. The refraction index of glue permits the transmission of the light without scattering and without high optical losses.

For coupling a laser diode with a optical fiber we developed and manufactured a device using two spherical microlenses. The coupling scheme of a laser diode with an optical fiber using two microlenses is shown in Figure 3a. The laser diode used was a Roithner RLT7605MG – 760 nm lasing wavelength, index guided single transverse mode. The distance between the two lenses is set in such mode to get the required transverse magnification of 0.91 mm. The two ball-lenses were carefully selected from our production to have the same diameter (0.76 mm). The ball-lenses were glued using an optical bond glue. The first lenslet was glued on a metallic spacer (Figure 3b), the second one on the end of the optical fiber, who is also encapsulated in a metallic tube (Figure 3c) and finally making up the assembly (Figure 3d). The alignment of the optical components is very important in collecting the laser beam optical power into the receiving fiber and was achieved by using calibrated steel tubes and by positioning the glued assemblies under microscope.

We built an array of chalcogenic microlenses. Figure 4a represents an array of spherical chalcogenide microlenses which can be applied on the front face of a LED. We applied such an array on the surface of a diode (Figure 4b) for light extraction improvement. The array can also be used as a laser homogenizer, but the lenses must have exact the same dimensions and they should be arranged such that the empty space between them be minimum.



a

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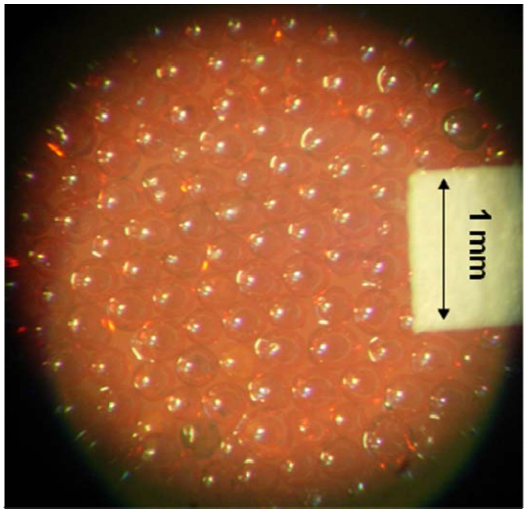
Fig. 3. a) The coupling scheme of a laser diode with an optical fiber b) First microlens glued on the metallic spacer c) Second microlens glued on one end of the optical fiber d) Double ball lens coupling device.



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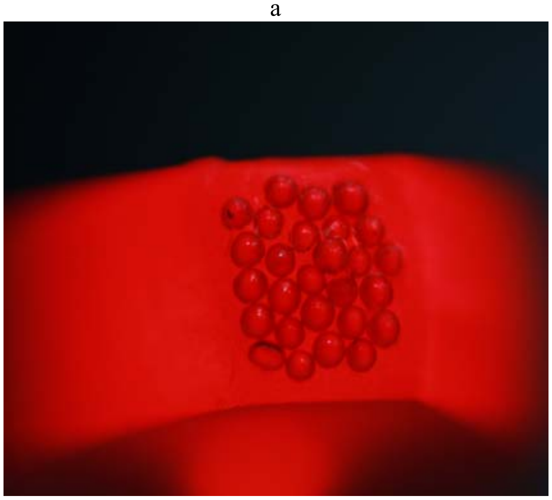

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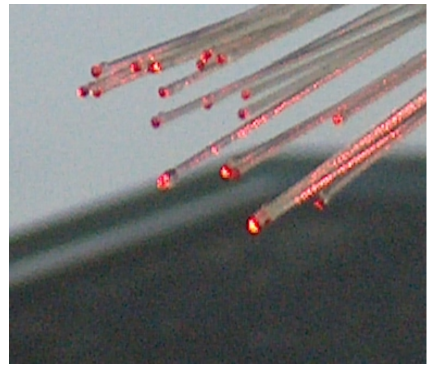
Fig. 4. a) Microlens array b) Microlens array applied on the surface a LED.



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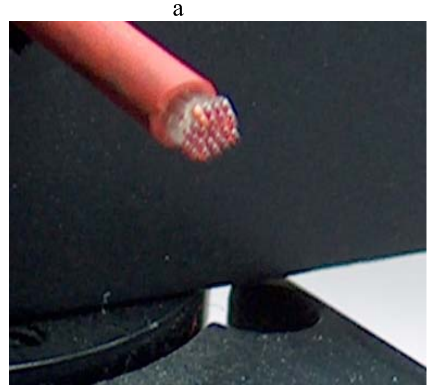

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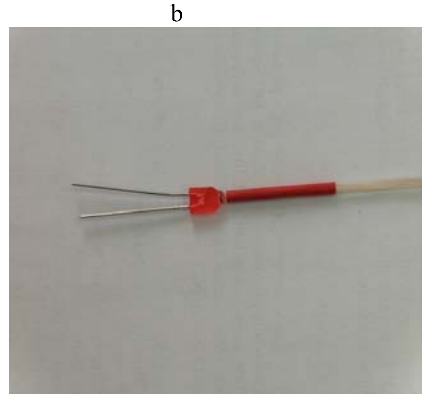


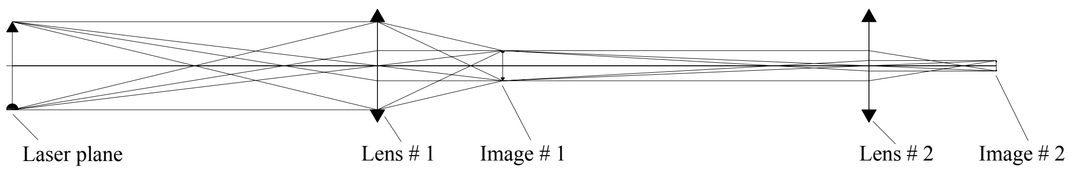
c

Fig. 5. a) Fibers before setting-up in bunch b) Optical fiber bunch c) Optical fiber bunch coupled to a diode

In order to split the signal from source to a number of receivers we developed a device consisting of a laser diode and a bunch of optical fibers with microlenses glued on one end. In Fig. 6c is shown a system for the distribution of the signal from a diode towards a bunch of optical fibers, which can be connected afterwards. First the optical fibers were cut (45 cm length) and polished using a special polishing kit. We used 25 silicon oxide multimode optical fibers, with the 62,5 µm diameter of the core, 125 µm diameter of the cladding and 250 µm diametr of the jacket. Then, the microlenses are glued each one of them on a fiber (Figure 6a) and the obtained matrix (Fig. 6b) is glued on the diode (Figure 6c).

3. Results

Based on the Fig. 6a optical scheme a device with two As_2S_3 chalcogenide microlenses was developed. The entrance pupil was divided by a mesh, as it can be seen in Fig. 6b. The results of the ray trace measurements show that the largest part of the rays concentrates in the image point after the first lens (Fig. 7c) and improves after the second one (Fig. 7d).



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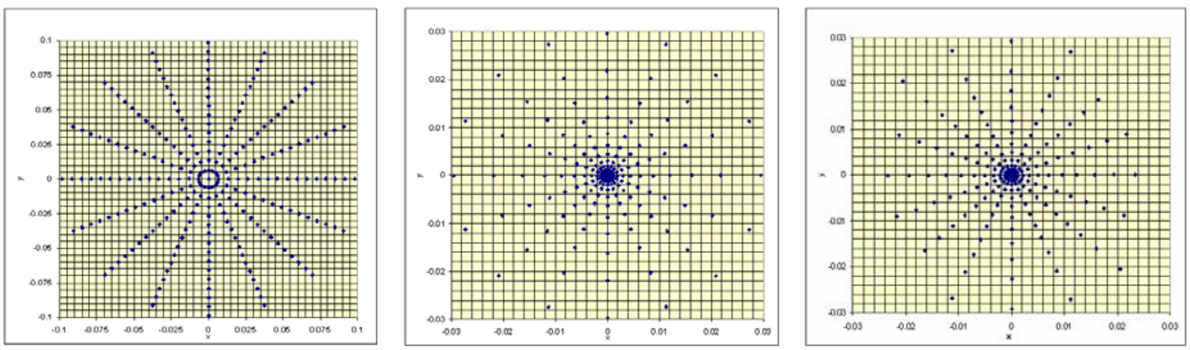

b c d

Fig. 6. a) Optical scheme of a laser diode coupling to a fiber using two chalcogenide microlenses b) Pupil mesh c) Image after first lens d) Image after second lens

Concerning the light extraction improvement of the microlenses array applied on the light emitting diode, we found that Y-K Eee and al. [12] obtained increase the extraction efficiency of light more than 200%. They used InGaN quantum wells light emitting diodes and an array of SiO_2/polystyrene microspheres for a wavelength of 480 nm. Figure 7 is taken [12] and shows the improvement.

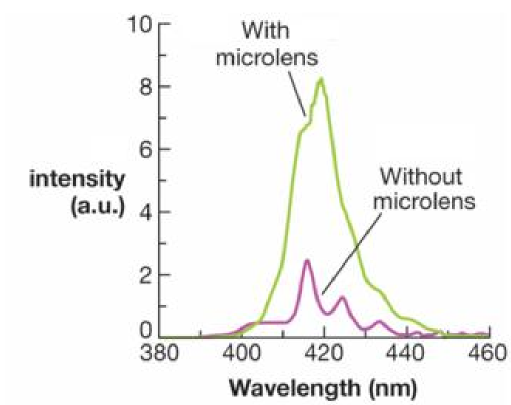

Fig. 7. Intensity of the light after applying a microlens array on the LED (see ref. [12])

4. Conclusions

Good quality chalcogenide lenslets with diameter situated in the range 50 ÷ 800 μm, produced by a new method, find applications in optoelectronics. They are promising for coupling the light sources to optical fibers in the red-infrared range of the electromagnetic spectrum. The optoelectronic coupling systems developed in this work can be applied in optical circuits and in devices used in the laser field, optical measurements, in medicine and in various types of sensors.

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