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Novel photosensitive glasses

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Optoelectronics and photonics are technologies of steadily growing importance, because they enable faster, more efficient ways of acquiring, storing, and transmitting information. Optoelectronics is the combination of electronic and optical effects in devices, whereas photonics deals with the development of all-optical components. Both technologies have already had an enormous impact in areas as diverse as telecommunications, manufacturing, retailing, medicine and entertainment. Despite this rapid progress, optoelectronics and photonics have their future ahead of them. The increasing importance of information in our society requires their development, enhancing the progress of the European telecommunication industry.

Fundamental devices in the field of optoelectronics and photonics are glass fibers and waveguides with diverse functions and properties. In the last decade, photosensitivity of glass fibers and waveguides has received much attraction. A high photosensitivity enables the imprinting of special structures into glasses by lasers as a result of refractive index changes. This phenomenon is used to write directly Bragg gratings and waveguides into glasses, which has an enormous impact on the manufacturing, tailoring and efficiency of optical devices.

Photosensitivity of glasses has been discovered first in germanium-doped silica fibers. Much research has been carried out to increase the photosensitivity of these glasses as well as to understand the causes and the mechanism of photosensitivity. Until now, different theories are discussed, but the origin of the refractive index changes has never been fully understood, yet. It has been proposed that densification/expansion and changes in the optical absorption of glass increase the refractive index. Recently, other glass types than silica have gained much attraction as host materials for optical devices. In conjunction with this, the study of the photosensitivity of these glasses and especially the search for dopants increasing the photosensitivity is of great practical importance.

In this project, fluoride phosphate and phosphate glasses have been chosen as base glasses. The photosensitivity of these glasses attractive for devices in telecommunication systems has been only slightly studied. Recently, they received much attention due to their athermal properties, i.e. the decrease of the optical pathlength with temperature. The impact of several dopants and of the melting conditions during the preparation of the glasses on the photosensitivity is of special interest.

Previous examinations of the author have shown that Eu^{2+} dopant is a very promising candidate for increasing the photosensitivity of fluoride phosphate glass. Under normal melting conditions in air, europium ions occur as Eu^{3+} in glass. Using reducing melting conditions, a high amount of Eu^{2+} could be obtained in a fluoride phosphate glass FP10. Before illumination, this FP10/Eu^{2+} glass demonstrates a high absorption at 250 nm due to electronic transitions of Eu^{2+} ions. After 100 pulses illuminaion with an excimer laser at 248 nm, the absorption due to Eu^{2+} is vanished and a very intense absorption at about 200 nm is created (Fig. 1). In general, a high induced UV absorption at 200 nm results in an increase of the refractive index. That means it causes high photosensitivity.

The different raw materials and furnaces available at the host institution of the project compared with previous research of the author have required several attempts to reproduce the preparation of fluoride phosphate glass samples of high optical quality and in different redox states. At last, the fabrication of a Eu^{2+} containing sample has been succeeded.

In order to test the refractive index change induced by laser illumination, we first implemented direct writing of waveguides using a frequency-doubled argon-ion laser at 244 nm (Fig. 2). As expected from the induced absorption, slices having different refractive index compared with the unirradiated regions were imprinted. The waveguides were written through the whole glass sample from the bottom to the top due to the high transparency of the glass sample at the laser wavelength before and after illumination. The waveguiding nature of the slices could be detected by launching light of a fiber coupled laser diode at 633 nm into the waveguides. The polished endfaces of the glass sample were scanned by the fiber connected with the laser diode. The waveguides have been seen as bright strips on the image screen (Fig. 3).

Future work of the project comprises three parts. First, preparation of glass samples with other dopants (Ce^{3+}, Tb^{3+}, Sn^{2+}) will be carried out. Further, other base glasses will be melted. Phosphate and heavy metal oxide glasses are of special interest due to their athermal properties and high refractive indices, respectively. In the next step, direct laser illumination and direct waveguide writing will be implemented. The combination of both methods enables conclusions about the magnitude and the origin of photosensitivity as shown for the FP10/Eu^{2+} sample. For practical applications as well as for measurement of the refractive index change and of the waveguide losses, the fabrication of channel waveguides and optical fibres is necessary. Since this requires much effort on design and manufacture of these devices, it will be carried out only for the most promising base glasses and dopants.

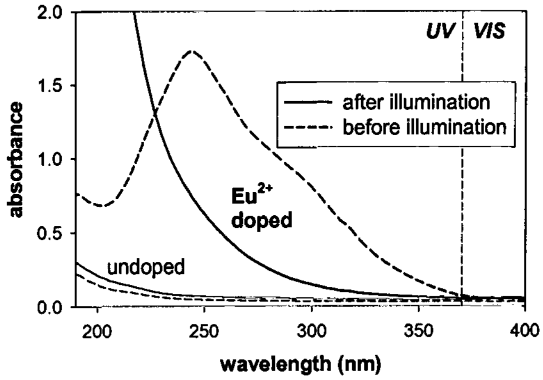

Figure 1: Absorption spectra in the ultraviolet (UV) and visible (VIS) spectral region of FP10 glass samples undoped and Eu^{2+} doped before and after 100 pulses illumination with a KrF laser at 248 nm. The thickness of the samples is 2mm.

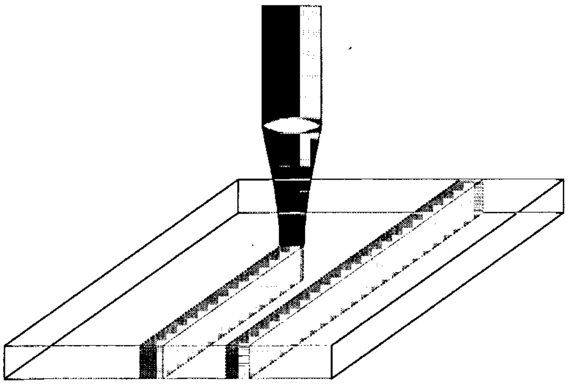

Figure 2: Sketch of experimental set-up for direct waveguide writing.

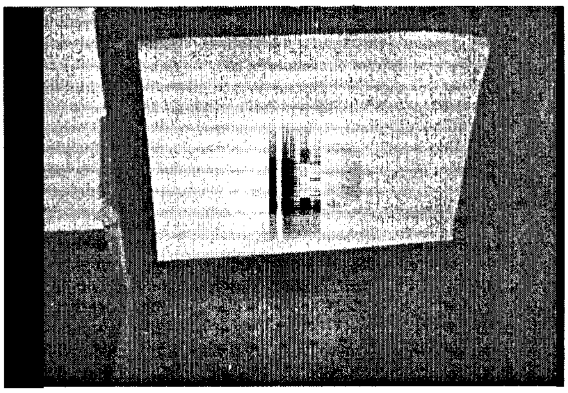

Figure 3: Image of the waveguides imprinted in FP10/Eu^{2+} glass samples.