Abstract:

Due to the fact that it contains the main absorption bands of most organic molecules, the mid-infrared region of the light spectrum has been the focus of an increasing amount of research in recent years. Indeed, the development of optical devices viable for mid-infrared applications can lead to innovation in scientific fields such as spectroscopy and imaging, as well as in more application-focused environments such as the military and food industry. The development of suitable glasses to produce lenses and optical fibers, and the development of optical elements itself, however, are not a trivial matter, and are the main goals of this thesis.

The first part of the dissertation focuses on the synthesis of new thermally stable heavy metal oxides glasses to produce lenses by the hot-embossing technique. Glasses used to produce mid-infrared lenses by the hot embossing method require both high stability and appropriate thermal properties to comply with the inherent difficulties of this production method such as cracking, crystallization and sticking to the mold. For this reason, SiO_2-PbO-CdO-Ga_2O_3 glass system was developed, and its thermal and optical properties was studied. In a second axis, the purification of tellurite glasses for the production of photonic crystal fibers by the stack and draw was investigated using halides. Indeed, optical fibers made of tellurite glasses also present several problems: they present large absorption bands due to water, reducing their transmission to only 3 µm even in sub-meter long optical fibers, and they generally lack the stability to withstand the multiple thermal processes involved in the production of photonic crystal fibers and more generally to all-solid fibers by the stack and draw method. For this reason, the possibility to extend the transmission of those glasses was investigated, by purifying tellurites via the synthesis of halo-tellurite glasses.

The second part of the dissertation presents the use of chalcogenides glasses for mid-IR applications. Indeed, chalcogenides glasses present a very large transmission from 1 µm to 20 µm, making them particularly appropriate for mid-IR applications. The stack and draw method, usually used for thermally stable soft glasses such as silicates, has shown to be impractical with chalcogenides glasses so far, due to their lack of thermal stability. For the first time, chalcogenides-based nGRIN fibers were developed by the stack and draw method as well as microlenses for applications from 1 µm to 17 µm in collaboration with the University of Rennes 1. For this purpose, 2 different core structures were developed, and fibers with cores from 4.4 µm to 40 µm were developed. In a second time, the possibility to fabricate gradient index chalcogenides lenses directly derived from the fibers produced by the stack and draw technique was investigated. Indeed, traditional means to fabricate gradient index lenses, such as chemical vapor deposition are incompatible with chalcogenides.

The last part of the dissertation tests the validity of nGRIN fibers for the generation of supercontinuum from visible to mid-IR. The versatility offered by the core nanostructuration by the stack and draw method for dispersion management allows the usage of commercially available pump sources, allowing spectral broadening more easily for fibers with a zero-dispersion wavelength (ZDW) in the mid-IR, especially for chalcogenides glasses as mentioned previously. It also allows to design the dispersion profile to obtain all-normal dispersion profile along a wide spectral range. For this purpose, two similar nanostructuration processes with two different glass families were compared, silica-based fibers called MS15B3 previously produced at the Institute of Electronic Materials Technology (ITME), based on commercial fused silica with GeO_2 doped-silicate glasses, and chalcogenide based on Ge-As-Se glass system. Using the appropriate pump sources to each fiber (respectively nanosecond pulses at 1550 nm for the silica and femtosecond pulses at 4 µm for the chalcogenides), supercontinuum generation was attempted.