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Thesis Report
Xavier Forestier – Optimization of glass properties devoted to multi-thermal processes: Toward mid-infrared photonic components

Summary of Thesis

Xavier Forestier's thesis describes a series of experimental studies on the synthetis and characterization of the properties of different types of glasses. Applications including the fabrication of optical fibers for the generation of broadband supercontinuum light are also explored. The development of novel types of glasses has been an intensive field of research for the past two decades, and especially for the mid-infrared redgion of the electromagnetic spectrum that corresponds to the molecular finger region. With the progress in fabrication techniques, there is currently an intense international activity in optimizing the development of glasses for the mid-infrared and tailoring their characteristics to ensure mechanical, thermal, and optical stability. This. in turn, can enable the fabrication of optical fibers to guide and can confine light over extended distances for enhanced light-matter interactions. The work of Xavier Forestier belongs to this framework.

The thesis examines in detail the synthesis of two different types of glasses, based on heavy metal oxides and chalcogenide elements, respectively. The first type of glass is applied to the manufacturing of optical components such as lenses while the second type is used to draw optical fibers with high nonlinearity. Application to the generation of broadband mid-infrared supercontinuum is also demonstrated using the developed fiber. More generally, the types of materials, approaches, and fabrication techniques demonstrated provide interesting avenues for the development of glasses with tailored characteristics.

The thesis itself consists of an introduction, conclusion and 5 chapters. Chapter 1 introduces the basic physics and chemistry properties of glass, as well as their structural characteristics. Different types of glasses are also described along with their classification into different families. A sub-section is also fully devoted to the description of optical fibers with the guidance mechanism, optical properties, and nonlinear propagation regimes. Chapter 2 briefly describes the different measurement techniques (calorimetry, microscopy, and interferometry) employed to characterize the thermal (expansion, density) and optical properties (refractive index and dispersion) of the synthesized glasses. Chapter 3 on the other hand reports on the synthesis of heavy metal oxides glass for the mid-infrared spectral region. The synthesis is based on the combination of multiple elements including Silica, Lead, Cadmium, and Gallium Oxides. Extensive characterization of the glass thermal and optical properties is reported. The fabrication of lenses made of this glass is briefly addressed along with quality measurements. The second part of the Chapter reports another type of heavy metal oxide glass based on low-water content Tellurite to extend the transmission further into the mid-infrared. Although not successful, fiber drawing attempts are also mentioned, which could provide further directions for the development of Tellurite fibers with nanostructured core. Chapter 4 deals with the development of graded-index fibers and micro-lenses made of chalcogenide glass. The synthesis process and fabrication approach for the fiber are described in detail along with the achieved characteristics. In line with previously developed fibers made of heavy metal oxide glasses, these results shows that the stack and draw method combined with appropriate combination of glasses of the same family but with slightly different indices is a particularly efficient

way for customizing the refractive index profile of a fiber. The end of the Chapter further reports the fabrication of micro-lenses but their quality lack of quantification. Chapter 5 focuses on the generation of a broadband supercontinuum in the fabricated graded-index Chalcogenide fiber described in Chapter 4 with impressive results including a broad spectrum and good beam quality. Supercontinuum generation in a graded-index silica fiber fabricated using the same stack and draw method are also discussed in the Chapter but perhaps with less impressive characteristics. Finally, a conclusion and outlook section provide a summary of the achieved results.

Clarity and Structure of Presentation

Mr Forestier's thesis is generally well structured and easy to follow. Necessary concepts are introduced, and the bibliography provides pertinent references to the original literature. The thesis has involved the study of different experimental glass platforms, and the fabrication steps, characterization setup, and properties of each synthesized glass/fiber are clearly presented. The experimental results are either discussed in terms of behavior expected on physical grounds and/or compared with numerical modeling. Mr Forestier demonstrates both understanding of the underlying chemistry, as well as a detailed hands-on knowledge of the many experimental issues that need to be mastered. My only mild criticism with the current presentation is that the introductory part of the thesis mostly repeats the information already contained in the published manuscript and in fact is some cases the text is merely a (partial) reformulation of the manuscript with several of the figures identical to that of the published papers. Also, many of the figures are directly taken from other sources which are not provided, and their quality is sometimes poor. The thesis lacks some context and in particular reference to the state of the art is not always given. The conclusion(s) lacks discussion on directions for future research. From the reader viewpoint who might not be so knowledgeable about the topic, it would have perhaps been more valuable to give a broader overview of the field and elaborate on the implications of the findings both from a chemical, physical and application perspective. There are some inconsistencies between the length and structure of the different chapters. Of course, I perfectly understand that this partially reflects the author's own contribution to the work presented in the thesis. On a side note, I would also recommend proof-reading the language which could benefit from some (minor) improvements.

General Evaluation of the Results Obtained

The results obtained by Mr Forestier in this work are of international quality and represent an extensive body of original studies in a competitive and technologically important field of research. The work has been published in 3 international peer-reviewed journals in the Material Science and Optics fields, including Journal of Non-Crystalline Solids, Applied Nanoscience, and Advanced Photonics Research. There are also other manuscripts that to which Xavier Forestier contributed but which are not part of the thesis. Mr Forestier has had a major contribution to all the manuscripts published (he is the first authors in two of them and second author in another), and, in particular, from the experimental perspective where he has fabricated the glasses and fibers and performed a significant fraction of the experimental measurements and characterization.

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Importance and Impact

The importance of this work lies in the range of material processing, nano-structural design, fiber fabrication, optical properties tailoring and control, and experimental non-linear optics. Although building on the extensive current activity in this field, each of the different glass systems studied by Mr Forestier presents some specific originality in design or achieved characteristics. This leads to the demonstrated fabrication of novel types of glasses which have the potential to lead to important steps forward, and in particular for the fabrication of mid-infrared optical fibers or components. The results obtained are scientifically interesting and likely to stimulate others to take the ideas developed in the thesis even further.

Conclusions and Recommendation

I believe that the work presented in this thesis is sufficient for a PhD and recommend that that Xavier Forestier can proceed to the oral defense.

Sincerely,

Goëry Genty
Tampere University
Professor in Ultrafast Photonics