



# Optical properties of ytterbium doped oxyfluoride glass-ceramics - Concentration and temperature dependence studies for optical refrigeration applications

Jyothis Thomas<sup>a,\*</sup>, Lauro J.Q. Maia<sup>b,c</sup>, Kummara Venkata Krishnaiah<sup>a,d,e</sup>, Yannick Ledemi<sup>d</sup>, Jean-Sebastien Boisvert<sup>a</sup>, Antsar Hlil<sup>a,d</sup>, Denis Seletskiy<sup>a</sup>, Younès Messaddeq<sup>d</sup>, Raman Kashyap<sup>a,b</sup>

<sup>a</sup> Department of Engineering Physics, École Polytechnique de Montréal, P.O. Box 6079, Station Centre-ville, Montréal, QC, H3C 3A7, Canada

<sup>b</sup> Department of Electrical Engineering, École Polytechnique de Montréal, P.O. Box 6079, Station Centre-ville, Montréal, QC, H3C 3A7, Canada

<sup>c</sup> Instituto de Física, Universidade Federal de Goiás, Av. Esperança 1533, Campus Samambaia, Goiânia, GO, 74690-900, Brazil

<sup>d</sup> Centre d'Optique, Photonique et Laser, 2375 Rue de la Terrasse, Université Laval, Québec, QC, G1V 0A6, Canada

<sup>e</sup> Department of Physics, Rajeev Gandhi Memorial College of Engineering and Technology, Nandyal, 518501, India

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## ABSTRACT

Oxyfluoride glass-ceramics (GCs) doped with lanthanides have recently attracted much attention as a novel optoelectronic material candidate for optical refrigeration. In this study, the optical properties of highly transparent (~90% in the near infrared region) ytterbium doped germanate and aluminosilicate oxyfluoride glass ceramics with different rare earth ion concentrations varying from 0.5 to 3.0 mol % synthesized by the conventional melt quenching technique have been investigated to determine and compare their potential for optical refrigeration applications. The photoluminescence (PL) emission spectra at different temperatures (25 °C–200 °C) were measured using different excitation wavelengths varying from 920 nm to 1030 nm in order to understand the behaviour of Stokes and anti-Stokes emission in all the glass-ceramics. The influence of ytterbium content is studied and found to substantially affect the PL emission and quantum yield and thus affect the cooling/heating characteristics. The highest intensity of anti-Stokes emission from the GC samples was observed in the composition containing 1.5 mol % or 2.0 mol % of Yb<sup>3+</sup>. Experiments monitoring the sample temperature at varying excitation wavelength between 1020 and 1030 nm demonstrates that the 1.5 mol % or 2.0 mol % Yb<sup>3+</sup> concentrations are the most suitable for laser cooling applications.

## 1. Introduction

Optical cooling based on anti-Stokes emission has been attracted a great deal of interest during the past few years focusing on several applications such as sensors and satellite instrumentations which require mechanical vibrations-free operation, no moving parts and high reliability [1,2]. Ever since the first experimental demonstration of solid-state laser cooling in 1995 by Epstein et al. [3], a series of experiments on different types of materials include crystals, semiconductors, optical fibers and glasses have been proposed and demonstrated as potential candidates for optical refrigeration [4–12]. Among them, lanthanide (Ln<sup>3+</sup>) doped oxyfluoride glass-ceramics have received great attention recently since they are mouldable and are easier to

manufacture into complex structures such as optical fibres, using standard techniques in the glass industry [13–15]. The size of the crystal and crystallinity can be easily manipulated with controlled heat treatment [13,16–18].

Concomitant with these properties, one of the significant advantages of glass ceramics is the presence of low phonon energy nanocrystals, which is essential for optical cooling. The nanocrystals in the GCs can enhance or provide completely new properties than those of the parent glass. Further the multi-phonon decay and non-radiative transition probabilities become very small in these materials since Ln<sup>3+</sup> ions are incorporated in the nanocrystals [19]. In addition, the presence of Ytterbium (Yb<sup>3+</sup>) provides the advantage of a low quantum defect, weak concentration quenching effect and no excited state absorption, making

\* Corresponding author.

E-mail address: [jyothis.thomas@polymtl.ca](mailto:jyothis.thomas@polymtl.ca) (J. Thomas).

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