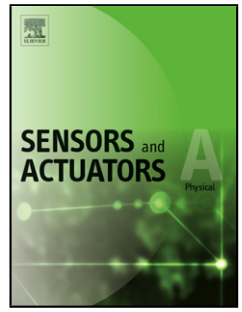
Accepted Manuscript



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PII: S0924-4247(17)31450-4
DOI: https://doi.org/10.1016/j.sna.2017.11.012
Reference: SNA 10441

To appear in: *Sensors and Actuators A*

Received date: 9-8-2017
Revised date: 9-10-2017
Accepted date: 6-11-2017

Compact and sensitive Er^{3+}/Yb^{3+} co-doped YAG single crystal optical fiber thermometry based on up-conversion luminescence

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Highlights

- Er^{3+}/Yb^{3+} co-doped YAG single crystal fiber thermometry based on upconversion emissions is proposed.
- High absolute sensitivity is achieved with the largest value of 0.00486 K^{-1} at 577K.
- The thermal probe is directly connected to YAG single crystal fiber.
- The optical coupling efficiency between the thermal probe and YAG crystal fiber is high and stable.

Abstract

Compact and sensitive Er^{3+}/Yb^{3+} co-doped YAG single crystal optical fiber thermometry based on up-conversion (UC) luminescence is presented. The thermal probe is a YAG single crystal fiber with end Er^{3+}/Yb^{3+} co-doped grown by laser heated pedestal growth method. Excited by a 976nm laser diode, the UC fluorescence intensity ratio (FIR) of the Er^{3+} ions in two emission bands ($^2H_{11/2}$,$^4S_{3/2} \rightarrow ^4I_{15/2}$) was investigated in the temperature range from 298K to 723K. The results indicate that the maximum temperature sensitivity is approximately 0.00486K^{-1} at 577K. Thus, the Er^{3+}/Yb^{3+} co-doped YAG single crystal fiber has potential application in optical thermometry by the FIR technique. Furthermore, the thermal probe has compact structure and high thermal stability, making it a more convenient and effective optical fiber temperature sensor.

Keywords: Optical fiber temperature sensor; Up-conversion luminescence; FIR; YAG single crystal fiber; Er^{3+}/Yb^{3+} co-doped YAG crystal.

1. Introduction

Optical temperature sensors based on fluorescence detection have been widely investigated in optical thermometry [1-5]. The fluorescence lifetime based optical temperature sensor uses the temperature dependence of the fluorescence decay rate from a phosphor material upon removal of the pump source. However, the fluorescence lifetime signal process system is relatively complicated. The fluorescence intensity ratio (FIR) based optical temperature sensor usually utilizes the temperature dependence of fluorescence intensity ratio from two thermally coupled levels (TCL) of rare earth (RE) ions [6]. So, the FIR technique can avoid the fluctuations of the intensity of exciting light source and the connector loss of the fluorescence signal transmission path.

Among various rare earth ions, Er^{3+} has been one of the most effective RE ions for FIR based optical thermometry due to its intense green UC emissions from two thermally coupled levels $^2H_{11/2}$ and $^4S_{3/2}$, under a 976nm laser diode excitation. The Yb^{3+} ions can enhance the UC emission intensity of Er^{3+} doped materials via an energy transfer process due to its large absorption cross section in the near infrared region [7-10]. Thus, various Er^{3+}/Yb^{3+} co-doped host materials have been investigated previously. Moreover, the Er^{3+} /Yb^{3+} co-doped host materials prepared in current literature are mainly glass [11,12], nanomaterials [13-17] or powders [18-21], using various methods such as sol-gel [13], wet chemical process [14], co-precipitation [15], hydrothermal synthesis [16-17], optimized synthesis [18], traditional high-temperature solid state reaction [19-20] and combustion synthesis [21].

YAG crystal is one of the most widely used laser host materials because of its favorable chemical, optical, thermal, and mechanical properties. It is easy to dope YAG crystal with various RE ions, making YAG crystal an excellent fluorescence host material. YAG single crystal fiber combines the favorable properties of the YAG crystal with the structure of optical fiber. YAG single crystal fibers have been grown by laser heated pedestal growth (LHPG) method or micro pulling