Materials Optimization for Optical Fiber Amplifiers and Fiber Lasers

Magnus Engholm
Institutionen för Informationsteknologi och Medier
MITTUNIVERSITETET
2008

AKADEMISK AVHANDLING

För avläggande av teknologie doktorsexamen vid
fakulteten för Naturvetenskap, Teknik och Medier vid
Mittuniversitetet, Campus Sundsvall, som offentligen
kommer att försvaras i sal L111
torsdagen den 22 maj 2008, kl. 13.15

Opponent är Dr. Johannes Kirchhof, Department of Optical Fiber Technologies, Institute of Photonic Technology, Jena, Germany

Title: Materials Optimization for Optical Fiber Amplifiers and Fiber Lasers

Name: Magnus Engholm
Department of Information, Technology and Media
Mid Sweden University, Sundsvall, Sweden.
ISBN: 978-91-85317-93-6, ISSN: 1652-893X, Doctoral thesis nr: 50

Abstract

Optical fibers doped with rare-earth ions such as erbium, ytterbium or thulium are frequently used as fiber amplifiers and fiber lasers. Erbium is a commonly used dopant in optical fibers for amplification of optical signals in e.g. point to point transmission links or metro networks. The Er^{3+} ion has broad absorption and emission bands at the low loss transmission window in silica glass (near 1.5um) and is thus suitable as an active rare-earth ion for use in optical fiber amplifiers and fiber lasers.

The interest for fiber lasers has increased dramatically during the last decade. In particular, there is a large interest for high power fiber lasers for use in different industrial applications. Fiber lasers have a high efficiency and show several advantages compared with conventional lasers in terms of better beam quality, lower cost and a compact design. Materials processing such as cutting, welding and marking are the major application areas today. The ytterbium ion is the active ion of choice because it has a simple energy level structure and high optical conversion efficiency.

There is, nevertheless, still room for improvements of both the erbium and ytterbium doped silica glass matrix for use as fiber amplifiers and fiber lasers. The objective of the work presented in this thesis is to improve the performance of the erbium doped fiber amplifier and fiber laser by optimization of the silica glass material. The applied route is to prepare the glass material by doping with special precursor molecules to increase the separation between the Er^{3+} ions and thereby reduce loss mechanisms related to the Er^{3+} interatomic distance. Two different Er-precursors have been investigated.

Induced optical losses, also known as photodarkening, is a loss mechanism in ytterbium doped high power fiber lasers. It is found that the Yb^{3+} valence state is unstable in the silica glass and a fraction of the Yb-ions can be transferred to Yb^{2+}, depending on the preparation conditions. Furthermore, it is found that this change in valence state ($Yb^{2+} \rightarrow Yb^{3+}$) can also be induced by a so called charge-transfer process. A model based on this valence instability is used to explain the photodarkening phenomenon in ytterbium doped fiber lasers. By using this model different paths to reduce, or even prevent, the extent of photodarkening are presented.