Opt Quant Electron (2008) 40:1103–1109
DOI 10.1007/s11082-009-9308-z

Mode transitions in distributed-feedback tapered master-oscillator power-amplifier: theory and experiments

Mindaugas Radziunas · Vasile Z. Tronciu · Uwe Bandelow · Mark Lichtner · Martin Spreemann · Hans Wenzel

Received: 26 September 2008 / Accepted: 21 April 2009 / Published online: 20 May 2009

Abstract Theoretical and experimental investigations have been carried out to study the spectral and spatial behavior of monolithically integrated distributed-feedback tapered master-oscillators power-amplifiers emitting around 973 nm. Introduction of self and cross heating effects and the analysis of longitudinal optical modes allows us to explain experimental results. The results show a good qualitative agreement between measured and calculated characteristics.

Keywords Master oscillator · Power amplifier · Taper · Longitudinal mode analysis

PACS 42.55.Px · 42.65.Sf

Mathematics Subject Classification (2000) 35Q60 · 37L15

M. Radziunas (✉) · V. Z. Tronciu · U. Bandelow · M. Lichtner
Weierstraß-Institut für Angewandte Analysis und Stochastik, Mohrenstr. 39, 10117 Berlin, Germany
e-mail: radziuna@wias-berlin.de

V. Z. Tronciu
e-mail: tronciu@wias-berlin.de

U. Bandelow
e-mail: bandelow@wias-berlin.de

M. Lichtner
e-mail: lichtner@wias-berlin.de

M. Spreemann · H. Wenzel
Ferdinand Braun Institut für Höchstfrequenztechnik,
Gustav-Kirchhoff-Str. 4, 12489, Berlin, Germany

M. Spreemann
e-mail: martin.spreemann@fbh-berlin.de

H. Wenzel
e-mail: hans.wenzel@fbh-berlin.de

1 Introduction

During recent years, compact lasers emitting single-frequency, diffraction limited continuous-wave (CW) beams at an optical power of several Watts have received considerable attention regarding several applications, such as frequency conversion, free-space communications, and pumping of fiber lasers and fiber amplifiers. Conventional narrow stripe or broad area semiconductor lasers do not meet these requirements, either due to the limited output power or the poor beam quality and wavelength stability. A device which is capable to maintain a good beam quality and wavelength stability in the Watt range is the monolithically integrated master-oscillator power-amplifier (MOPA), where either a distributed Bragg reflector (DBR) laser O'Brien (1997) or a distributed feedback (DFB) laser Lammert et al. (1999) and a flared (or tapered) gain-region amplifier are combined on a single chip. Recently, a DBR tapered MOPA, which emits a CW power of more than 10 W at 977 nm in a nearly diffraction limited beam and narrow spectral bandwidth of 40 pm, has been demonstrated Wenzel (2007). In this paper we consider a monolithically integrated DFB tapered MOPA emitting around 973 nm. It is schematically shown in Fig. 1 and has been discussed in Spreemann et al. (2009). Different states can be observed in such devices when tuning injection currents in the MO and PA sections. In order to understand the origin of different instabilities and transitions between different states we analyze and simulate a mathematical model based on traveling wave equations which are coupled to a diffusion equation for the excess carrier density and an equation for gain dispersion Balsamo et al. (1996); Egan et al. (1998); Bandelow et al. (2001). In addition, we describe heating effects by a linear nonlocal dependence of the refractive index and the gain peak on the inhomogeneous injection current Spreemann et al. (2009). Our present study is based on former observations and analysis of longitudinal modes Radziunas and Wünsche (2005), their dynamics in narrow waveguide edge-emitting multisection lasers Bauer et al. (2004) and modeling of lasers with an external optical feedback Tager and Petermann (1994). Due to the residual field reflectivity at the PA facet, the MOPA device can be considered as a (DFB) laser with an optical feedback Bauer et al. (2004); Tager and Petermann (1994). The injection currents imply self- and cross-heating affecting the refractive indices of the PA and MO regions and thereby tune the relative optical phases. This phase tuning is responsible for the transitions between modes, observable both in optical experiments and in simulations.

The paper is organized as follows. In Sect. 2 we introduce a short description of the MOPA laser and present its experimental characteristics. Section 3 gives a brief description of the

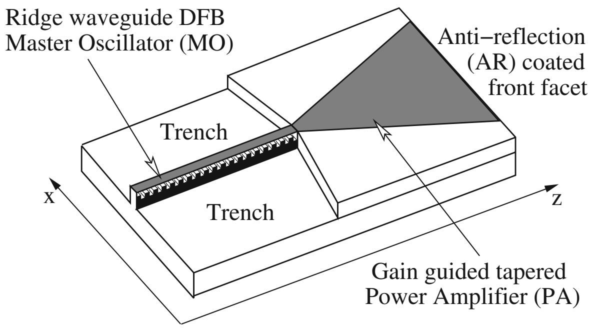

Fig. 1 Schematic view of DFB tapered MOPA