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Optics Communications 249 (2005) 579–586
OPTICS COMMUNICATIONS
www.elsevier.com/locate/optcom

A monolithically integrated photonic MEMS subsystem for optical network applications

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Received 7 May 2004; received in revised form 21 January 2005; accepted 25 January 2005

Abstract

A single-chip photonic subsystem with a dimension of 3.5 mm × 3 mm × 0.6 mm is developed by integration of a tunable laser with an optical switch using the microelectromechanical systems (MEMS) technology. The potential of the subsystem is also discussed for the niche applications in the reconfigurable optical add/drop multiplexers and the wavelength converters. The subsystem has a tuning speed of <1 ms between different wavelength channels within a range of 13.5 nm by stepwise tuning, and a switching time of <100 μs between different light paths, which are much faster than the conventional mechanical devices. The output power is about 1 mW. In addition to the compact size and fast tuning speed, the MEMS integration also brings in other advantages such as more functionality, high reliability, batch fabrication and low cost. More significantly, the prototype demonstrates the MEMS integration successfully. This is to our knowledge the first realization of a single-chip MEMS subsystem by integrating different functional MEMS components.

PACS: WS 3274
Keywords: Tunable laser; OADM; Optical MEMS; Wavelength converter

1. Introduction

Integration plays a key role in the development of many technologies such as integrated circuits (IC) and planar lightwave circuits. The integration of various components into a subsystem or even a system can significantly improve the functionality, compactness and reliability while reducing the cost. Various devices have already been developed using microelectromechanical systems (MEMS) technology, for instance, optical switches [1], optical crossconnects (OXCs) [2], variable optical

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0030-4018/$ - see front matter
doi:10.1016/j.optcom.2005.01.041

attenuators (VOAs) [3], tunable lasers [4–7], and optical add/drop multiplexers (OADMs) [8]. However, most of them work independently and function only at the component level. Many efforts have been put in the integration of single MEMS components with other components such as optical fibers [1,3], microlenses [9], IC control circuits and planar lightwave circuits [10]. Recently, with an increasing number of MEMS components becoming technologically mature, the integration of MEMS components into subsystems represents the latest trend and has attracted extensive research interests. For example, an optical disk pickup subsystem has been demonstrated by integrating several surface-micromachined components onto single chips [11,12]; various microspectrometers have been prototyped by integration of gratings, micromirrors and photodetectors within a small box [13], and a hybrid tunable laser is formed by the combination of a MEMS actuated mirror and a laser gain chip with other optical components [4,14]. In the optical communications, the components of optical switches and tunable lasers are key enablers for all-optical (or photonic) switching. Thus considerable efforts have been put to apply the MEMS technology to those single components [1,4–7]. Based on the previous works, this paper presents a monolithic photonic subsystem by integrating a MEMS switch component with a MEMS laser component. It provides system-level functions and should have its niche applications in optical networks, for instance, reconfigurable OADMs and tunable wavelength converters, etc.

2. MEMS photonic subsystem and applications

The overview of the MEMS subsystem is shown in the scanning electron micrograph (SEM) in Fig. 1(a). It consists of a tunable laser, a 2×2 optical switch and a microlens. Figs. 1(b) and (c) show the close-ups of the laser and the switch. The optical switch employs a vertical mirror to switch the light paths. Electrostatic comb-drive actuators are used to actuate the curved mirror and the vertical mirror. The microlens is used to couple the laser output to the optical switch. It is designed

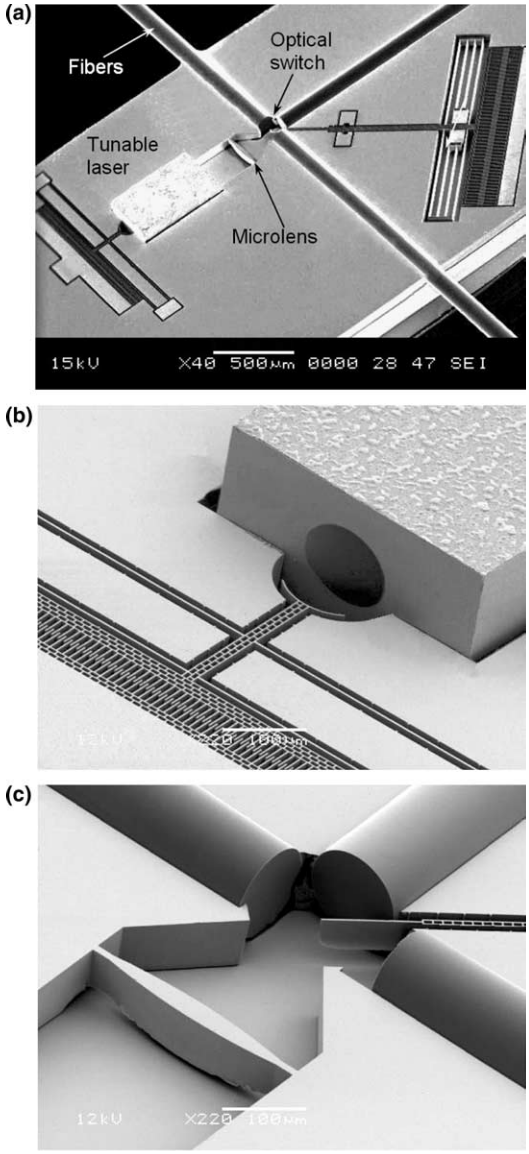

Fig. 1. The on-chip MEMS subsystem: (a) overview; (b) close-up of the tunable laser; (c) close-up of the optical switch.

to have a focus length of 160 μm and a magnification of 1.14. All the MEMS structures are fabricated on a silicon-on-insulator (SOI) wafer by deep reactive ion etching (DRIE) process. The SOI wafer has a device silicon layer (75 μm thick) and a thermal oxide layer (2 μm thick) on a handle silicon wafer. The depth is about 70 μm for the mirrors and actuators, and 75 μm for the fiber