Tuning Mechanism for a MEMS External Cavity Laser

R.R.A.Syms, A.Lohmann

Dept. of Electrical and Electronic Engineering, Imperial College,
Exhibition Road, London, SW7 2BT, UK (email r.syms@ic.ac.uk)

Miniature external cavity lasers have been demonstrated using a semiconductor optical amplifier (SOA), collimator and piezoelectrically actuated blazed grating in the Littrow configuration [1]. For mode-hop free tuning, the grating should rotate about a remote pivot [2]. A suitable method of rotation has been demonstrated using an electrostatic MEMS actuator carrying an external mirror, for an external cavity laser in the alternative Littmann configuration [3]. Here we demonstrate integration of the optical element, elastic suspension and drive for a MEMS external cavity laser in silicon. The design is based on a Littrow cavity, using a conventional HR/AR coated SOA, collimated by a ball lens and coupled to a lensed fibre (Figure 1a). The MEMS part is formed by deep reactive ion etching and undercut of bonded silicon-on-insulator material. The movable components consist of a blazed grating, suspension and electrostatic drives (Figure 1b).

A simple cantilever cannot provide the deflection needed to mimic rotation about the pivot. Here we have used a novel compound flexure, consisting of a cantilever (which carries the grating) connected to a portal frame (attached to the substrate at the pivot) (Figure 1b). If the dimensions L_1 and L_2 are suitable, the tip deflection of the cantilever under a point load F_2 corresponds to the required rotation. In addition, application of a point load F_1 to the portal allows independent translation of the grating for axial tuning. Using simple bending theory, the linear and angular end displacements d and a_2 are $d = d_1 + d_2 = F_2 \{1/k_{1L} + 1/k_{2L}\}$ and $a_2 = F_2 \{1/k_{2A}\}$, where k_{1L} is the linear stiffness of the portal, and k_{2L} and k_{2A} are the linear and angular stiffnesses of the cantilever, given by $k_{1L} = 24EI_1/L_1^3$, $k_{2L} = 3EI_2/L_2^3$ and $k_{2A} = 2EI_2/L_2^2$. I_1 and I_2 are the second moments of the portal and cantilever flexures, and E is Young's modulus. To mimic rotation about a fixed centre we require $d = a_2 \{L_1 + L_2\}$. This can be satisfied by careful choice of the ratio $r = L_1/L_2$. When $I_1 = I_2$, r is the solution of the cubic equation $r^3 - 12r - 4 = 0$, namely $r = 3.62$. The design has been verified using ANSYS (Figure 2).

We have fabricated suitable MEMS components in 100 micron thick bonded silicon layers (Figure 3a). The resolution of the process is limited and only 12th order gratings can currently be fabricated reliably (Figure 3b). These gratings have approximately -6 dB reflectivity and 20 nm half power bandwidth at 1550 nm wavelength, using a 300 micron diameter ball lens. Laser operation with a threshold of 15 mA has been demonstrated using an Optospeed LASH-1550 TAP SOA in a 3 mm long cavity (Figure 4a). Over 1 mW singlemode power can be coupled into a 9 micron diameter lensed fibre, with a maximum sidemode suppression of almost 30 dB. Wide-range tuning has been demonstrated (Figure 4b). The design is a 3 DOF system, with three dominant resonances. The lowest order resonance is at roughly 200 Hz with a Q-factor of 5.

Acknowledgement: The Authors are grateful to EPSRC and Marconi Communications for financial support and to ADI Belfast and STS Ltd. for deep etching.

1. Mellis J., Al-Chalabi S.A. et al. "Miniature packaged external-cavity semiconductor laser with 50 GHz continuous electrical tuning range" *Elect. Lett.* **24**, 988-989 (1988)
2. Favre F., Le Guen D. "82 nm of continuous tunability for an external cavity semiconductor laser" *Elect. Lett.* **27**, 183-184 (1991)
3. Berger J.D. et al. "Widely tunable external cavity diode laser based on a MEMS electrostatic rotary actuator" presented at OFC 2001, Anaheim, CA, Mar. 17-22, Paper Tuj2 (2001)

Figure 1. a) Layout of MEMS external cavity laser; b) principle of tuning mechanism.

Figure 2. a) ANSYS model of mechanism; b) verification of tuning mechanism.

Figure 3. Device fabricated in 100 micron BSOI: a) overall layout and b) grating

Figure 4. a) Light-current characteristic and b) tuning characteristic of laser.