In-Plane MEMS Tunable Gires-Tournois Interferometers

Raphael St-Gelais, Thomas Kerrien, Alexandre Poulin and Yves-Alain Peter
École Polytechnique de Montréal, Department of Engineering Physics
P.O. Box 6079, Station Centre-Ville, Montréal (QC), H3C 3A7, CANADA
E-mail : {raphael.st-gelais, yves-alain.peter}@polymlt.ca

Abstract: We present MEMS tunable Gires-Tournois interferometers (GTIs) based on deeply etched Bragg reflectors. The broad reflection bandwidth (~100 nm) of the Bragg reflectors allows operation over almost the whole C and L bands with a single cavity, while the in-plane configuration allows the design of a wide range of cavity length (i.e. free spectral range). Applications such as fast tunable dispersion compensation in optical fiber networks are expected.

OCIS codes: (130.2035) Dispersion compensation devices; (230.1480) Bragg Reflectors

1. Introduction

Deeply etched Bragg reflectors attracted a lot of attention in the past few years, especially for the development of in-plane Fabry-Perot filters and sensors. Using the expertise developed for these systems [1], we present what is, to our knowledge, the first Gires-Tournois interferometers (GTIs) based on deeply etched Bragg reflectors.

GTIs are formed by a first low reflectivity mirror and a second high reflectivity mirror. The latter ensures a nearly wavelength independent 100% reflectivity, while the former induces wavelength dependant group delay (dispersion). These properties make the GTIs attractive for dispersion compensation in telecommunication networks [2-4], and for use as dispersive mirror in multifunction Michelson interferometers [5].

2. Fabrication and principle of operation

A fabricated GTI is presented in Fig. 1 (a). The Bragg mirrors, the MEMS actuator and the cleave trench are first defined (UV contact lithography) and etched (DRIE, see [1]) through the 11 μm device layer of a SOI wafer. The waveguide is then fabricated in a second step using the same technique.

The 5.5 silicon-air periods (1.5 μm layer thickness) of the high reflectivity Bragg mirror ensures a nearly 100% reflectivity on a wide spectrum. The low reflectivity mirror can either be made of 1 silicon-air period (Fig. 1 a) or simply of a silicon-air interface (Fig. 1 b). The waveguide limits diffraction losses. Its transverse dimension (11 μm width) is matched to the beam diameter of conventional single mode fiber in order to minimize butt-coupling losses. The high reflectivity mirror and the mobile parts of the actuator are released by wet etching (HF). Applying a voltage to the actuator changes the effective length of the cavity and tunes the resonance wavelength.

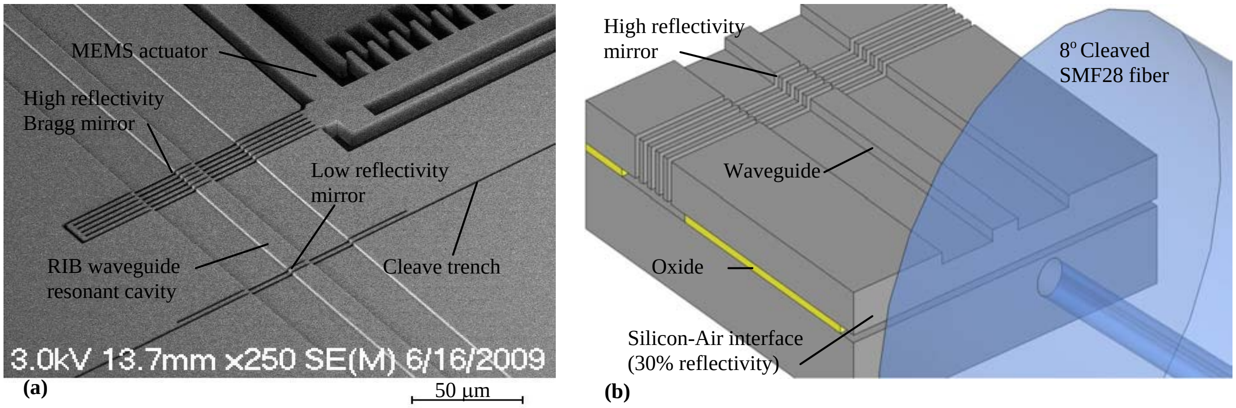

Fig. 1. (a) SEM photograph of a fabricated MEMS tunable Gires-Tournois interferometer (GTI). (b) Schematic of the MEMS GTI after structural release and cleaving. The silicon-air interface is used as the low reflectivity (30%) mirror. The single mode optical fiber is cleaved with an angle of 8° to avoid interference from the glass-air interface.

3. Results and discussion

The reflectivity and group delay spectrum of two different GTIs are presented in Fig. 2. The measurements are performed by the phase shift technique (Agilent 86038B). The simulations are based on the method described in [6]. Scattering losses upon reflection on the Bragg reflectors are taken into account by including a 30 nm thick absorbing layer at each silicon-air interface [7]. Propagation losses in the waveguide (~5 dB/cm) are also considered by including a complex part to the refractive index of silicon. Simulations of group delay were also performed but are not included to lighten the presentation (the curves superposed almost perfectly to the measurements).

As can be seen in Fig. 2 (a), the usable bandwidth of the Bragg reflectors extends over almost the whole C and L bands because of the high refractive index contrast between silicon and air. This is an important advantage compared to fiber Bragg grating based GTIs [3, 4]. Also, Fig. 2. demonstrates that the in-plane configuration allows the cavity length (and hence the free spectral range) to be designed very easily to a wide range of values, which is an advantage compared to the out of plane MEMS configuration [2].

The wavelength dependent reflection losses are due to scattering, which is enhanced at resonance, and are almost fully explained by the model. These losses should be minimized by further improving the fabrication process but are already close to the ones of other MEMS GTI [2]. Wavelength independent losses are most likely caused by imperfect alignment and mode dimension mismatch between the optical fiber and the waveguide.

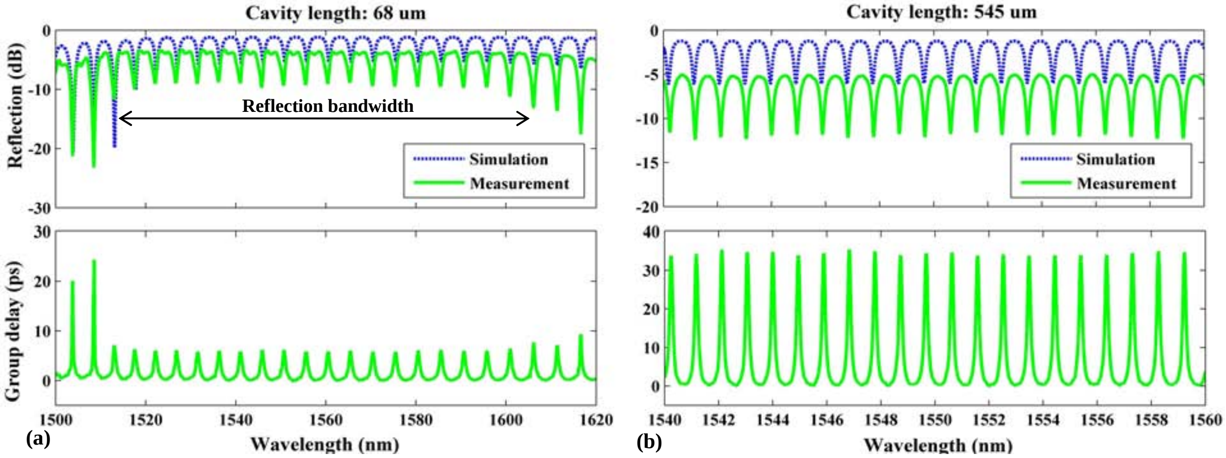

Fig. 2. Measurement (plain lines) and simulation (dashed lines) of the reflectivity and group delay spectrum of two GTIs. The low reflectivity mirror consists of the silicon-air interface at the entrance of the system, as in Fig. 1 b. (a) Cavity length of 68 μm for a free spectral range of ~5 nm. (b) Cavity length of 545 μm for a free spectral range of ~1 nm.

Figure 3. presents the group delay spectrum, for the same device as in Fig. 2. (a), for three different voltages applied to the MEMS actuator. As expected, changes in the effective cavity length induce displacements of the group delay peaks. This should be useful for tunable dispersion compensation at much higher speed (~ kHz) than the one achieved with systems based on thermally tuned fiber Bragg gratings (~ Hz).

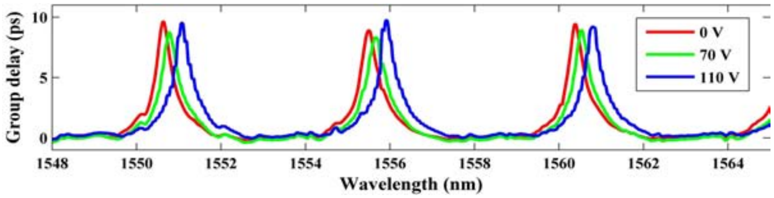

Fig. 3. Measured group delay of the Gires-Tournois of Fig. 2 (a) for three different voltages applied to the MEMS actuator.

4. Conclusion

We presented what is, to our knowledge, the first MEMS tunable Gires-Tournois interferometer based on deeply etched Bragg reflectors. The reflection bandwidth extends over almost the whole C and L bands and the in-plane configuration allows large cavity length (i.e. free spectral range) design flexibility. The device should therefore be useful for applications such as fast tunable dispersion compensation in optical communication networks.

5. References

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