

MEMS Diffraction Grating Technology

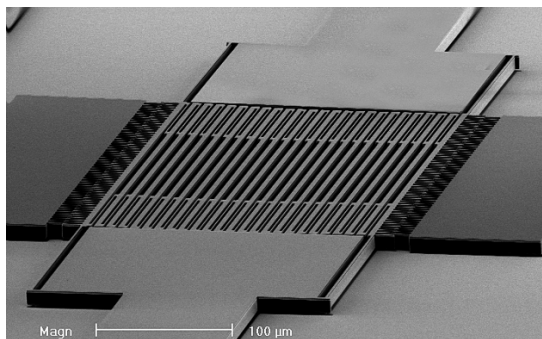
Main theme:
Photonics applications



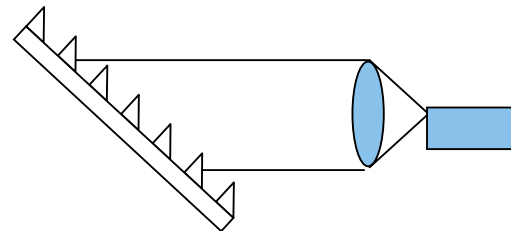
INTRODUCTION

The ability to micromachine silicon has led to the development of micro-machines known collectively as Micro-Electro-Mechanical Systems (MEMS). The MEMS market is rapidly growing with the most important devices being accelerometers, e.g., in airbags and in inertial navigation systems for aircraft, and pressure sensors. In optical systems, Micro-Opto-Electro-Mechanical Systems (MOEMS) are mainly found in the form of single mirrors for scanners and bar code readers and in mirror arrays as telecom switching elements or more importantly as the Digital Light Processor™ of Texas Instruments that is now found in most upmarket projector systems.

A second type of MOEMS technology has emerged over the last few years: MEMS diffraction gratings. Here the MEMS device controls light through diffraction. Generally such a device consists of an array of parallel beams where the diffraction properties depend on the shape, spacing and position of the beams. The difference between a MEMS grating and standard grating is that the diffracting elements (beams) can be actuated either individually or as a group in the former case. This means that all the properties of the diffraction grating – wavelength dependence, angular dependence and efficiency, can be tuned at will, leading to a highly versatile technology.



Overview of a fabricated deformable MEMS grating. The grating dimensions are on the order of $200\ \mu\text{m} \times 200\ \mu\text{m}$. The grating period is $9\ \mu\text{m}$ and its duty-cycle 50%.



An external cavity laser tuned with a MEMS grating. The light from a laser (right) is collimated by a lens and directed onto the tunable grating (left). Unlike a normal ECL there are no external mechanics to tune (rotate) the grating.

MEMS diffraction gratings can be divided into two families: accordion or stretch gratings, and piano or sampled gratings. In an *accordion grating*, the whole grating can be stretched perpendicular to the beams (in the plane of the grating). This changes the periodicity of the grating and hence the wavelength diffracted at a particular angle or the angle diffracted for a given wavelength. Accordion gratings are ideal as the tuning element in an external cavity laser. In a *piano grating*, the individual beams can be moved up and down in a direction normal to the grating, like the keys of a piano. A piano grating can be operated as sampled gratings or as greyscale pixel elements. The latter is exploited commercially by Silicon Light Machines, Sony, Polychromix and Lightconnect.

While the principles are simple the implementation is not easy as certain parts of the grating need to be rigid and optically flat (e.g. the diffracting beams) while others need to be flexible (e.g., springs) In addition the structure needs to be floating so it can be actuated, yet remain attached to the substrate, so electrical connections can be made. The goals of the project are to take the concepts of accordion and piano gratings and make working devices in Silicon and to apply them in devices such as external cavity lasers and spectrometers.

RESEARCH OBJECTIVES AND RESULTS

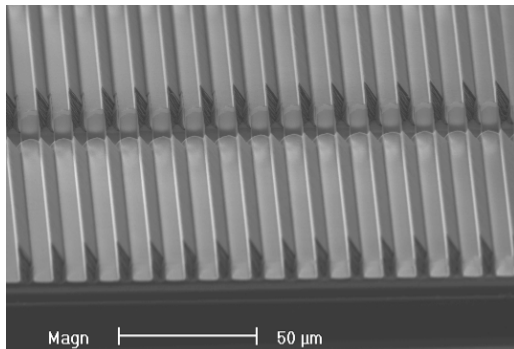
Objectives-

The two families of diffraction gratings are targeted in this project. The development of Accordion gratings started in the second half of phase I of the NCCR. The goal in the second phase is to improve the efficiency of these gratings by making blazed MEMS gratings. Increase the size and tuning range of the grating to make them more useful.

The development of the piano or parallel moving beam (PMB) grating starts in this project. We hope to demonstrate such technology on top of a CMOS platform.

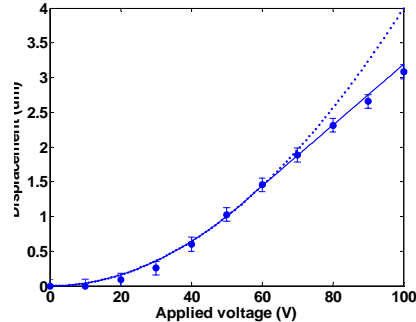
results to date

We have moved through several generations of accordion gratings. The first was fabricated in a 1 micron thick sheet of Silicon. The rigidity was not sufficient to prevent bowing. In the second generation, the device is 10 μm thick made from a Silicon on Insulator (SOI) wafer in a single mask process. This prevents deformation of the free-standing grating. In the third generation, we moved to blazed gratings.



Top view of a blazed grating test structure with period 12 μm .

A blazed grating can have a much higher diffraction efficiency than a square-profile. This is particularly important in external cavity lasers where the amount of light reflected back from the grating need to be high.



Measured (dots) and simulated (solid line) displacement in μm versus applied voltage for a 9 μm period grating.

Mechanical and optical experimental results show good agreement with simulation.

For the piano gratings, the design and conception phase are over and first manufacturing tests are underway.

APPLICATION PERSPECTIVES

For each class we are developing unique technological platform. The first is an in-plane stretchable MEMS grating, operated as a tunable filter. The second is what we have called the Parallel Moving Beam (PMB) technology; in this case, the grating is operated as a sampled grating.

The goal of this project is to demonstrate both technologies and to use them as tunable element in External Cavity Quantum Cascade Laser. In addition, we will develop a high resolution, wide bandwidth and low power micro-spectrometer based on, and exploiting the advantages of PMDG technology.

The exploitation channels of this work on the short term is the manufacture of various MEMS gratings for external partners. A start-up based on this technology is also an option.

Contact:
 Dr Ross Stanley (CSEM Neuchâtel)