Integrated Strain Sensing on Flexible Waveguides with Bragg Gratings Fabricated by Focus Ion Beam

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We have recently proposed a novel waveguide microgripper device which enables the simultaneous manipulation and optical characterization of microstructures [Panepucci08]. These devices will benefit from the ability to measure stress/strain while manipulating sensitive objects such as cells. The integration of mechanical sensors such as Bragg gratings in these structures will allow the existing optical fiber connection to be used for this purpose, maintaining an electrically neutral device for biological applications. Several microgripper devices [ref] have been proposed to carry out assembly and manipulation of nano/micro components; however, they typically require imaging for feedback, or electrically connected strain gauges. The integration of simultaneous optical sensing and manipulation onto a microgripper device enables closing the assembly loop at the microscale level.

Here we report the design of a Bragg grating strain sensor built onto a flexible waveguide. We discuss the design parameters required to achieve an operation range compatible with the manipulation of cells and other microscale objects, including the impact of environmental effects such as temperature and uncertainty in fabrication. Sensitivities suitable for pN forces are predicted for Bragg reflector sensor on single mode waveguide. The operation wavelength was chosen to be in the telecom range of 1550 nm, away from the fluorescence excitation target wavelengths in the visible range of < 700nm. Figures 1 (a) and (b) show the geometry of the device and a simulation of the wavelength shift versus strain on the structure, respectively. The post-process fabrication of Bragg gratings on SU8 waveguides using a focused ion beam method is being investigated and will be reported. Figure 2 shows a SEM of gratings fabricated on SU8 waveguides.

[Panepucci08] R. Panepucci and J. Martinez, "Novel SU-8 optical waveguide microgripper for simultaneous micromanipulation and optical detection," JVST B, 26, 2624, (2008).

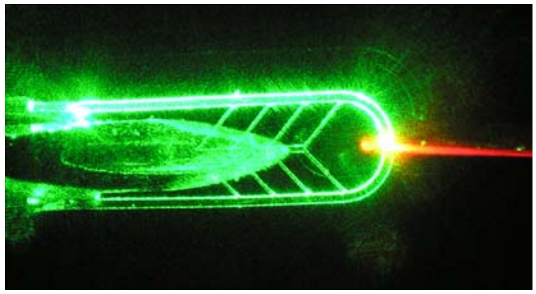

Figure 1 - Optical micrograph of our waveguide microgripper excited by 532 nm coupled through multimode optical fiber. The microgripper is holding a 15 μm thick suspended polymer stripe doped with quantum dots fluorescing.

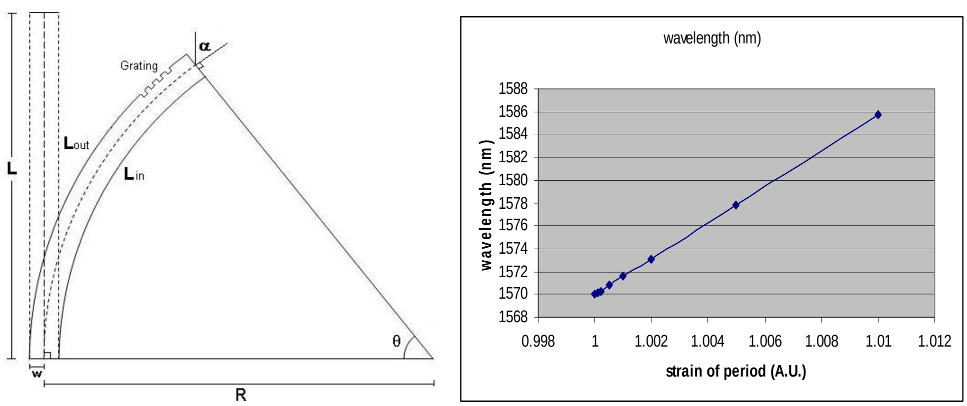

Figure 2 - Numerical analysis of grating waveguide for force sensing.(a) Geometry indicated the shape changes for the grating structure. (b) Calculated spectra shift of fundamental order grating based on period length change.

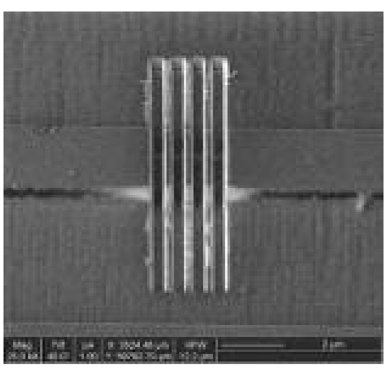

Figure 3 – SEM of a Bragg gratings fabricated in a polymer waveguide by focused ion beam.