Dense Fiber Bragg Gratings Array Inscription During Fiber Drawing Process

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Optical fiber sensors, and particularly Fiber Bragg Gratings (FBG) based sensors, are really attractive in a lot of application fields from medicine to structural health monitoring. Most of these applications imply distributed sensing resulting in the need to manufacture Fiber Bragg Grating Arrays (FBGA) [1]. Our inscription process during the drawing fiber process allows us to inscribe a large number of FBG in a short time, making it a cost-effective solution.

We report in the present paper the manufacturing of dense Fiber Bragg Grating Arrays directly during the fiber drawing with a spacing down to 150µm and global regularity of ± 50µm. The grating inscribed are weak, due to the process, but the demand for this kind of dense array of weak Fiber Bragg Grating is growing over the last years for different sensing applications, especially for shape sensing.

Single Pulse Inscription Process

Process

- Since the optical fiber is moving (cf fig. 1), we can only inscribe FBG with one laser pulse
- We are using a ©Coherent Excimer Laser (248nm) with phase mask which pitch is constant (1060nm)
- The trigger signal of the laser pulses is generated by the drawing fiber tower control unit according to the draw speed
  - ➢ Take into account the line speed variations
  - ➢ Fine control on FBG spacing during the whole drawing process

Limits

- Phase mask technic implies that we have a unique wavelength for all FBG defined as:

$$\lambda_B = 2 \times n_{eff} \times \frac{\Lambda_{PM}}{2}$$

Where n_{eff} is the effective index of the guided mode in the fiber, and Λ_{PM} is the phase-mask pitch [2]

- Weak Reflectivity : the maximum reflectivity we can achieve is around 5% for a 10mm long grating

This process is still very interesting:
- ➢ For sensing applications, a few percent of reflection is sufficient
- ➢ The spacing between two laser pulses can be controlled precisely since the laser pulses are controlled by the tower control unit

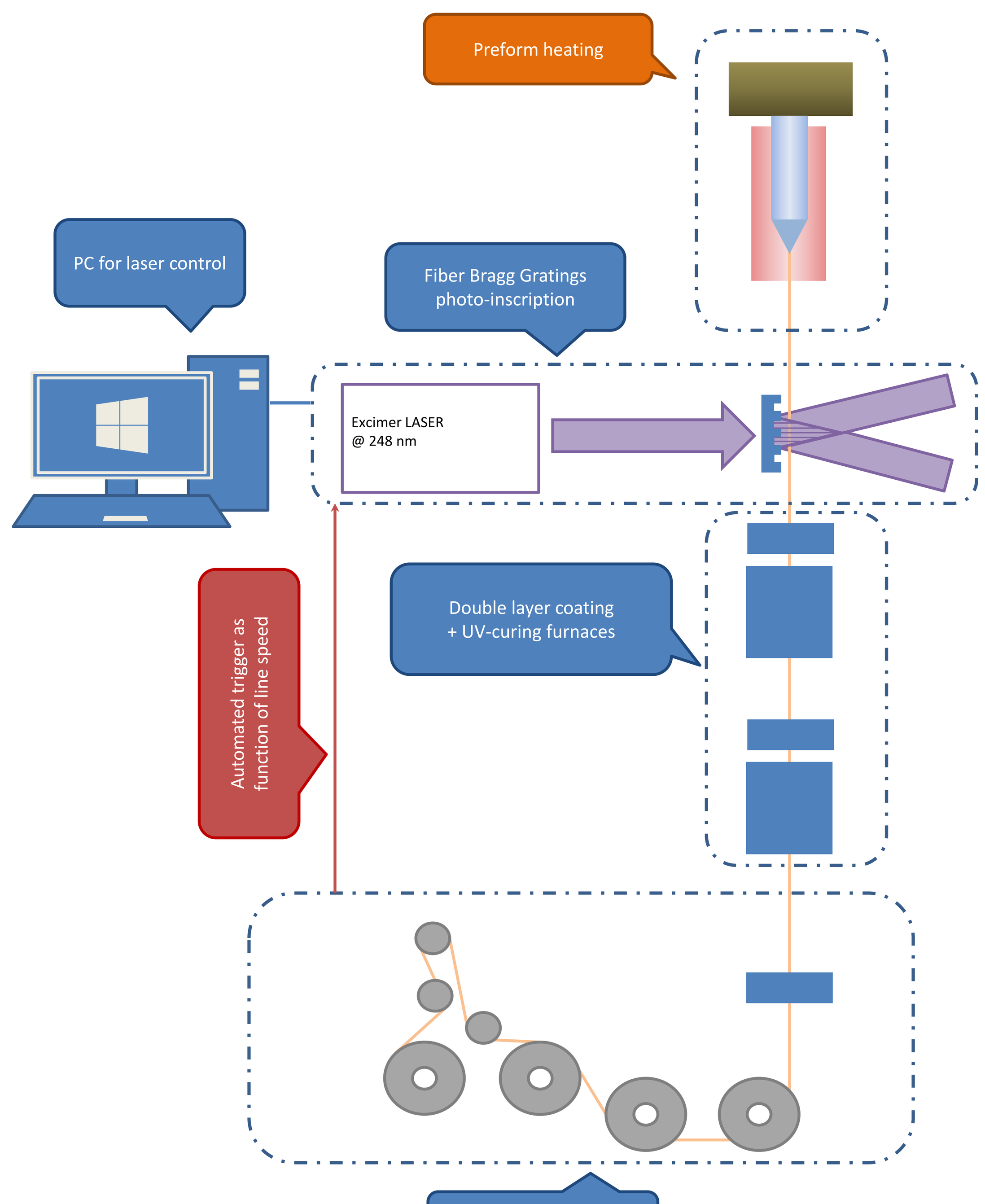

Fig 1 : Fiber Bragg Grating inscription process during the drawing fiber process

Tests and Results

- Objective: to obtain an array composed of 10mm long FBG with a spacing of a few hundred micrometers (for shape-sensing applications for example)
- Our process is well suited for this kind of array:
  - ➢ The spacing between two successive FBGs needs to be precisely controlled [3]
  - ➢ It requires only a very small amount of reflection to work well, less than 1% per grating
- We performed several tests to adjusts settings :
  - ➢ We limited the energy per pulse to 1.5mJ, to ensure weak reflectivity
  - ➢ To improve spacing repeatability the draw speed was set to 20m/min

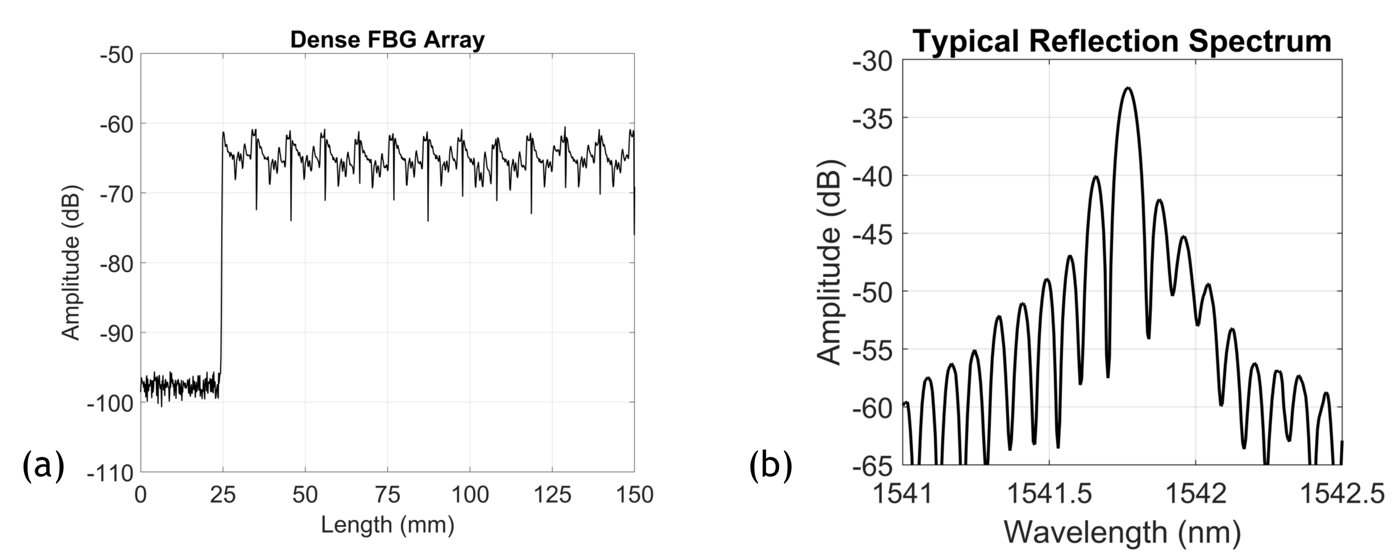

Fig 2 : (a) Temporal response of the FBGA, and (b) spectral response of a single FBG of the array measured using the ©Luna Innovation OBR4600

- We successfully produced a FBG array with a spacing of 150 ± 50µm (cf fig. 2a) and individual reflectivity of around 0.4%
- The gratings individual reflection spectra are quite good with a sidelobe suppression ratio of around 10dB (cf fig. 2b)
- We observe a slight dissymmetry directly linked to the process

Outcome and Perspectives

- FBG arrays with spacing of 1mm, 500µm, and down to 150µm have been achieved
- We also realized FBG arrays with larger spacing (>50cm)
- FBG length can be set from 1mm to 10mm
- Present main limitations:
  - ➢ Single Bragg wavelength, imposed by phase mask technic
  - ➢ Acrylate coating : not suitable for harsh environment (especially high temperature)

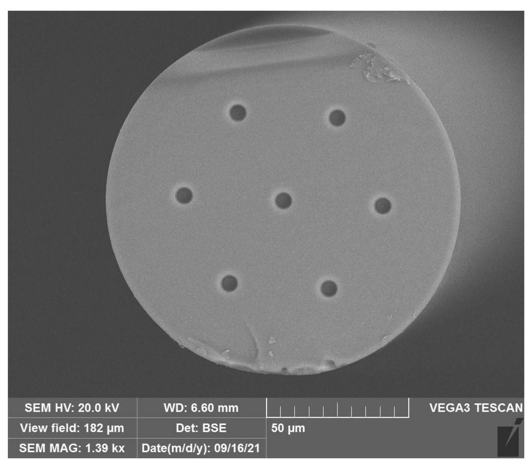

Fig 3 : Scanning Electron Mircroscope image of our 7-core fiber

- We are also working on 125µm 7-core fiber (cf fig. 3) with twisted cores (especially for shape sensing applications [4])
- We manufactured our first FBGA on this kind of fiber with very promising initial results

Aknowledgements

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