Production of Fiber Bragg Gratings in Phase Mask Interferometers

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Abstract

This article describes the production of fiber Bragg gratings using Phase Mask interferometers assembled at the Physics Department, University of Aveiro and Laser Laboratory, CEFET-PR. Those facilities were planned and installed as a consequence of a joint research project established under the auspices of the CAPES/GRICES (formerly ICCTI) international cooperation agreement. Results from the optical characterization of Bragg gratings produced at both centers are reported.

I. INTRODUCTION

Fiber Bragg Gratings are basic in-line fiber devices for several applications in optical communications systems and optical fiber sensors [1]. Those gratings can be produced in optical fibers by means of UV illumination, using a phase mask [2], a phase mask interferometer [3,4] or point-by-point methods [5]. It was already recognized that the development of several devices like, e.g., dense wavelength division multiplexing (DWDM) components, relies on the production of specific gratings, tailored to the proposed application.

The research groups at Aveiro and Curitiba started their cooperation in March 2000. The aim of the joint project is the development of grating based devices both for telecommunications and sensing. After technical analysis and economical planning, it was decided to implement phase mask interferometers to write fiber Bragg gratings, as this method provides better flexibility to write gratings with different profiles, e.g., apodisation or chirp, that are required for the design of grating based DWDM devices. The planed interferometers should work with frequency doubled Argon ion lasers, profiting from the higher efficiency of the corresponding UV wavelengths.

Hydrogen loading units were also planed for both sites, as this would allow the use of standard telecommunication fibers in the recording process of Bragg gratings [1].

The implementation of the interferometers was delayed by several problems, caused both by economical reasons (in Brazil) and accidents during transport (Portugal). As a consequence, they only entered in operation during the second semester of 2003.

A second change was the substitution of the optical source used at CEFET-PR, where a frequency quadrupled Nd:YAG laser was installed.

Both interferometers use the same micro positioning equipment and control units, acquired from Newport, Inc, to move the mirrors that set the recorded Bragg wavelength [2] and to position the fiber in the focal place.

II. THE CEFET-PR INTERFEROMETER

A. Constructive Details

The optical source is a mode-locked, Q-switched Nd:YAG laser (Tempest 20) from New Wave Research, with two frequency doubling crystals in order to obtain UV radiation at 266 nm. The laser can generate light bursts with average energy of 30 mJ, at a repetition rate of 20 Hz. The laser beam, after being spatially conditioned by two diaphragms, enters the phase mask interferometer, assembled in Talbot configuration [4]. The phase mask (Ibsen Photonics) period is 1050.50 nm. The UV-coated Aluminum mirrors are 71 mm appart. This guarantees a small footprint for the interferometer. The diffraction separated beams recombine after being focused by a fused silica cylindrical lens, focal length = 50 mm, used to increase the laser intensity at the focal line, where the fiber is positioned. The useable width of the interference pattern along the fiber core is estimated to be about 2.5 mm (it can be longer when the beam conditioning diaphragms are completely open, but the homogeneity of the interference pattern is reduced due to the beam non uniformity).

B. Performance

Sample gratings (using photo sensitive optical fibers from several suppliers) obtained from this interferometer are shown in Figures 1 and 2. The former grating presents a sharp reflection spectrum with full width at half maximum bandwidth (FWHM) of 0.26 nm. The rejection at the central wavelength is –15 dB, after an exposure time of 15 min.

The second grating presents a larger bandwidth, 0.57 nm, but with a considerably higher rejection, –25 dB. The used exposure time was 30 min. The higher UV light dose in the later exposure accounts for the increased bandwidth.

Although no systematic study was carried up to now in order to give statistical results for the produced gratings, a quick overview on some samples provides preliminary useful

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data. The obtained reproducibility for the Bragg wavelength is around a few hundredths of nanometer. The FWHM lies between 0.25 nm and 1.5 nm and the rejection at the peak wavelength can be chosen up to –25 dB. Table I reproduces the main optical parameters of a few more gratings.

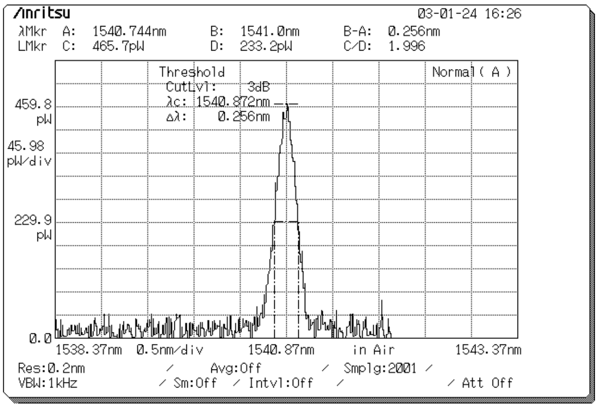

Figure 1 - Narrow bandwidth (0.26 nm) Bragg grating written at CEFET-PR.

The main factor limiting the bandwidth of the produced gratings is the beam quality. Due to the use of an unstable resonator configuration, the transversal profile of the laser beam is strongly asymmetric. The spatial filtering done by the diaphragms reduces the useable beam width, so that only short gratings can be written at the moment. Such small gratings require higher contrast in the refractive index modulation, but this lead to a situation of strong coupling, causing the large bandwidths [1].

Table I
Characteristics of some gratings obtained at CEFET-PR

Peak wavelength (nm)	FWHM Bandwidth (nm)	Peak rejection (dB)
1539.61	0.68	-20
1539.67	0.57	-25
1539.70	0.52	-18
1540.76	0.25	-20
1540.87	0.26	-15
1546.59	0.31	-16

III. THE AVEIRO INTERFEROMETER

A. Constructive Details

The optical source is an Argon ion laser from Spectra Physics with an intracavity frequency doubler from GWU Lasertechnik based on a BBO crystal. The output power can be up to 300 mW at 244 nm in continuous wave. The laser

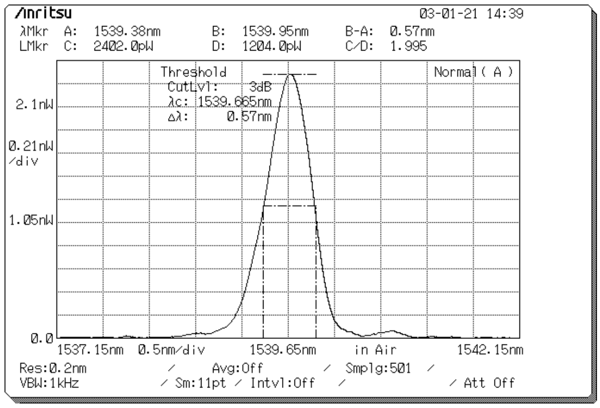

Figure 2 – Grating with higher rejection at the peak wavelength, bandwidth = 0.57 nm.

beam is spatially filtered with two diaphragms, which also control the beam diameter. A maximum diameter of 4.5 mm with a reasonable profile quality can be obtained.

A Talbot interferometer with a UV-grade fused silica phase mask from ADC with a pitch of 1053.9 nm follows the diaphragms. The UV-coated Aluminum mirrors are 105 mm apart. A personal computer can control these, along with the fiber positioning system, with software specially designed for the effect.

B. Performance

Table II, shows the FWHM and the peak rejection ratio of some gratings written with the interferometer.

Table II
Optical data of some gratings written in Aveiro

Peak wavelength (nm)	FWHM Bandwidth (nm)	Peak rejection (dB)
1539.40	0.27	-18
1546.81	0.23	-21
1550.31	0.22	-19
1554.94	0.30	-17.5
1559.40	0.29	-18

Although the maximum rejection ratio was –21 dB, it is expected that, better results can be obtained, with a fused silica cylindrical lens, to increase the laser power at the fiber. The FWHM bandwidth can also be broadened by reducing the beam diameter. Figure 3 shows another grating, written at 1543.81 nm, with a peak rejection ratio of –18.6 dB and a FWHM bandwidth of 0.23 nm.

The gratings also showed good reproducibility due to the auto-calibrating procedure implemented to reduce possible mirror mechanical hysteresis. The stability of the Bragg wavelength, which is an important issue in optical communications, is being studied: after some weeks, the Bragg wavelength of the older gratings, still stays the same.

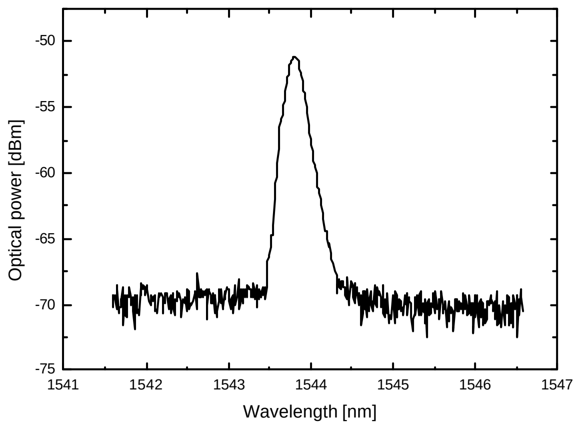

Figure **3** - Fiber Bragg grating written at Aveiro University

The maximum difference between the obtained Bragg wavelengths and the ones calculated with the theoretical model developed in [6] was 0.25 nm. The theoretical resolution of the interferometer is 0.11 nm. The difference might be due to temperature variations or due to a non-complete cancellation of the mirror hysteresis.

IV. CONCLUSION

We reported the characteristics and initial performance of the Phase Mask Interferometers installed at CEFET-PR and University of Aveiro.

The Bragg gratings already written have FWHM bandwidth between 0.25 nm and 1.5 nm, with peak reflectivity varying from –11 dB to –25 dB. The Bragg wavelength can be set by the positioning of the interferometer's mirrors to less than 0.1 nm of the desired wavelength. The produced gratings are useable for applications in optical fiber sensors and also for some devices to be used in WDM optical communication systems.

The improvement of the equipment and training of the personal shall allow the production of gratings with complex refractive index profiles in the near future.

V. REFERENCES

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