Optical Fiber Components Obtained by Refraction Index Modulation and Geographical Formulation

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Abstract

The Fiber Bragg Gratings (FBG) and the Long Period Fiber Gratings (LPFG) market is a result of the extraordinary development of the WDM (Wavelength Division Multiplexing) technologies. Various optical fiber components are based on the FBG and on the LPFG and used in WDM networks. They are used for optical data channel insertion and extraction, and they must handle adjacent wavelengths according to the ITU (International Telecommunication Union) standards for WDM. The limitations of FBG and LPFG are presented; in particular, FBG show a possible instability due to temperature and stress changes. The technique of combining electric arcs and geometric deformations to produce LPFG is also discussed. Due to its noticeable flexibility with respect to non-hydrogenated fiber, the electric arc technique presents a great potential for producing more stable fiber gratings by using various fiber materials. Experimental data and pictures of microstructures are presented, including biconic deformations of the modulation index due to tensile stress.

Sommaire

Le marché des réseaux de Bragg sur fibres (FBG) et les réseaux de Bragg à long pas (LPFG) ne cesse de croître suite au développement extraordinaire des technologies de multiplexage en longueur d'onde (WDM). De nombreux composants à fibres optiques utilisés dans les systèmes WDM sont basés sur des FBG et des LPFG. Ils sont employés pour l'insertion et l'extraction de canaux de données optiques et doivent supporter des longueurs d'ondes très rapprochées selon les standards de l'ITU sur les WDM. Les limitations des FBG et des LPFG sont présentées; en particulier, les FBG montrent une instabilité due aux changements de température et de tension. La technique combinant l'arc électrique et les déformations géométriques pour produire les LPFG est également discutée. Dû à sa flexibilité remarquable, la technique d'arc électrique présente un grand potentiel pour être utilisée dans la réalisation de LPFG plus stables en utilisant différents type de fibres. Des données expérimentales et illustrations de microstructures sont présentées, incluant les déformations biconiques de l'index de modulation dûes aux contraintes de tension.

1.0 Introduction

Since their market introduction in 1995, the use of optical Fiber Bragg Gratings in commercial products has grown exponentially, largely in the fields of telecommunications and stress sensors. The demand for broadband is rapidly increasing. This demand for more bandwidth in telecommunication networks has rapidly expanded the search and development of new optical components and devices (especially in Wavelength Division Multiplexers). Optical fiber components are key elements in WDM systems (Figure 1).

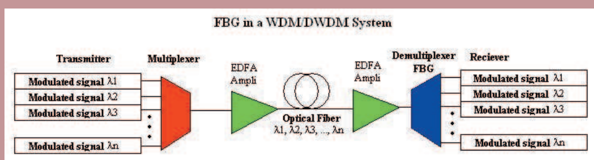

Figure 1. Using FBG in a WDM/DWDM system.

Today, the technology of Fiber Bragg gratings (FBG) and long period fiber gratings (LPFG) has been recognized as one of the most significant enabling technologies for fiber optic communications due to its use in several applications such as gain equalization for Erbium-Doped Fiber Amplifier (EDFA)[4,22], specialized narrowband lasers[19], wavelength division multiplexing (WDM) narrowband and broadband tunable filters[7,20], dispersion compensators for long-distance telecommunication networks[18] and even sensors [8,9,17,23]. The grating period Λ and the grating length (L) are both important factors in building FBG & LPFG.

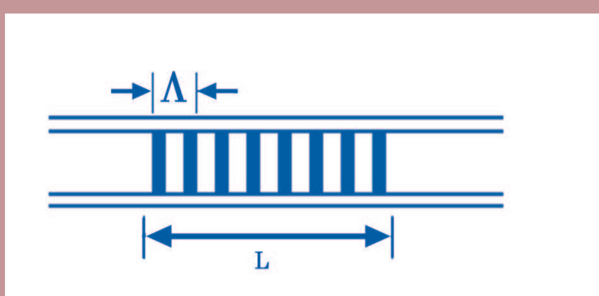

Figure 2: Length and period of FBG and LPFG.

1.1 Fabrication concept

The FBG is a periodic perturbation of the refractive index along the fiber length. Generally, this periodic modification is performed by exposure of the core to an intense optical interference pattern.
UV irradiation through phase masks generates fringe patterns on the fibers therefore producing a periodic index grating which couples the core mode to the dissipating cladding modes [16,18]. Although the UV-based fabrication method is a well-established technology, it has problems. It requires complex and time-consuming processes, including annealing and hydrogen loading for photosensitive fibers (Germanium doped) as well as the need for a large number of photo-masks with various periods.

The first difference between a FBG and a LPFG lies in the size of the grating period, which is respectively about 0.1µm and in the range of 200 µm to 700 µm. Another difference concerns the rejection of the optical data signal with Bragg wavelength. In an FBG, at selected wavelength, the optical signal is reflected (shown in red on Fig. 3) while the other signals are allowed to be transmitted.

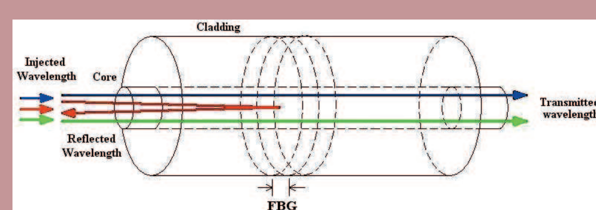

Figure 3: Reflected optical signal in FBG

In an LPFG, for the selected Bragg wavelength, the optical signal exchanges power with the gain mode and is lost (attenuated) while the other signals are allowed to be transmitted.

Another difficulty with UV-induced gratings lies in the photosensitivity of the fibers. This technique requires that fibers contain photosensitive sites, and thus it cannot be applied to those that have no photoreaction

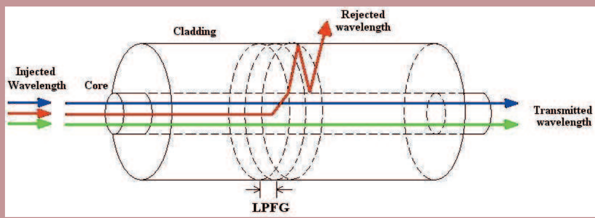

Figure 4. Attenuated optical signal in LPFG.

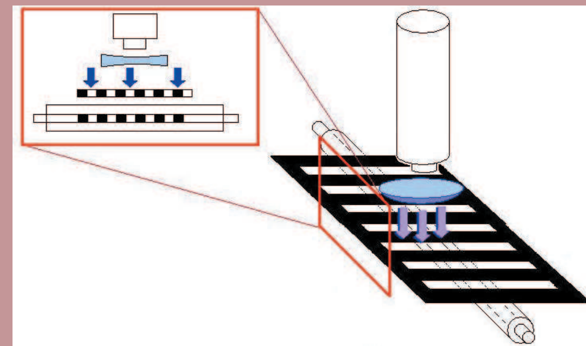

Figure 5. UV used for FBG writing through a phase mask

centers inside 3, 20. But ultimately the UV grating inscription requires expensive and complex laser equipment.

Recently, several photo-insensitive fabrication methods have been reported[1, 2, 3, 5, 6, 11, 12, 21] which overcome some of the technological problems mentioned above while providing comparable results. Some fabrication methods have been demonstrated to be more stable, flexible, and possess additional useful properties.

One of the assets of using the electric arc technique lies in the fact that it is so simple and flexible to use while offering a high thermal stability to the optical component. Studies[13,18] have demonstrated that the gratings implemented by the electric arc technique shows a wavelength shift caused by thermal variation of 0.07nm/100ºC compared to 5 – 15nm/100ºC for UV induced gratings. The temperature sensitivity is related to the refractive index change on the outer cladding of an optical fiber. By using the electric arc technique, temperature insensitive LPFG were produced in this study, thereby eliminating the deterring problem of unstable optical telecommunication components; more specifically building LPFG that is more robust to environmental stress and variations.

The present paper will primarily focus on the electric-arc-based fabrication technique. This technique provides a high thermal stability in the LPFG[7,8,9,18] while using simple and inexpensive fabrication procedure and equipment. To better understand the usefulness of FBG and the LPFG, the limitations of these fiber components and their associated technologies should be investigated. In particular, the instability problem due to environmental changes is worth being investigated. The electric-arc-based technique provides the flexibility to explore new non-conventional grating geometries, which have yet to be introduced. In particular, the technique of combining electric arcs and geometric deformation to produce LPFG will be discussed. For illustration purposes, one of the various microstructures including bi-conic deformation on the modulation index, due to tensile stress, will be presented. The prospects of the fibre gratings and the demands to overcome the present limitations will be presented at the end.

2.0 Limitations with UV radiation technique

In 1978, K. O. Hill et al [10] launched intense Argon-ion laser radiation into a Germanium-doped fiber and observed that after several minutes an increase in the reflected light intensity occurred which grew until almost all the light was reflected by the fiber. This achievement, subsequently called “Hill gratings,” was an outgrowth of research on the non-linear properties of Germanium-doped silica fiber. This discovery later led to the UV inscribed fabrication process, which is performed by using the phase mask to create an interference pattern of UV beams in the core of an optical fiber thereby modifying its refractive index along its axis. In a single mode FBG, these interferences patterns or gratings couple the fundamental mode to a contra-propagating for a resonant wavelength thereby reflecting a specific wavelength when white light is injected into the particular fiber. On the other hand, in a single mode LPFG, the fundamental mode is not coupled with a contra-propagating mode. It’s coupled with several forward-propagating cladding modes for a resonant wavelength. These lasts decays rapidly as they propagate along the fiber therefore they can be used as band rejection filters.

The UV fabrication process is still the most common and readily used fabrication method in the industry [14]. However, it’s relatively complex and time-consuming as mentioned before. FBG and LPFG produced by this method are also plagued by adverse environmental instabilities. These instabilities are caused by strain, bending and thermal sensitivity, doping concentrations, photosensitive degradation, polarization dependence, photo-induced birefringence and etc… Due to these weaknesses, FBG and LPFG based optical components have reached certain limitation especially in high-speed telecommunication applications. There is a definite technological requirement to overcome such limitation in order to further develop and improve the utilization of the FBG and LPFG based components in high-speed, all optical network applications.

The instability due to sensitivity to temperature and stress is neither specific to fiber grating nor associated to the fabrication technique; the drawback is rather linked to the fiber material in which the gratings are recorded. In order to surmount and overcome this obstacle, new methods of fabricating fiber gratings have been reported. These fabrication processes offer many advantages and introduce the prospects of using different material composites to produce more stable fiber components.

The use of electric arc is powerful and rentable fabrication technique. This method provides a simple, flexible and low cost means of producing LPFG with good overall performance. Moreover, LPFG can be written on any type of optical fiber with this method while providing a high thermal and mechanical stable optical component. The electric arc technique will also provide the flexibility to explore new non-conventional formations. In the following section, we’ll take a closer look at how this fabrication process works and the experimental results it produced.

3.0 Experimental Setup

There exist many diverse fiber grating fabrication methods. Each method has a different effect and analysis on the fiber grating knowledge that is essential to the total development of this evolving technology. The electric arc technique provides a very simple yet robust solution to some of the future LPFG development simply because it will allow researchers to explore new various geometric structures on different types and generations of optical fibers like the photonic crystal fibers. One of the greatest advantages of using the electric arc technique resides in the fact that it is so simple and flexible to use yet still providing a high thermal stability to the optical component it helps fabricate. Studies [13,18] have demonstrated that the electric arc technique only has a thermal variation of 0.07nm/100ºC as compared to 5 – 15nm/100ºC on UV induced gratings. The temperature sensitivity has been related to the refractive index change on the outer cladding of an optical fiber. Using the electric arc technique, temperature insensitive LPFG were produced in this study, thereby eliminating the deterring problem of unstable optical telecommunication components; more specifically building LPFG that is more resistant and robust to environmental stress and variations.

Writing LPFG using the electrical arc technique consists of placing an uncoated optical fiber between the electrodes (Fig. 6) of either a splicing machine or an arc generator to induce a refractive index change.

An electric arc, with an approximate diameter of 150um, is generated from the splicing machine creating a grating on the optical fiber. The fiber is then moved periodically to create a series of electrically induced gratings. White light is injected into one end of the optical fiber through a system of focalizing lenses while both end of the fiber are fixed to motorized translation stages that are co-controlled by a central computer. This will provide the option of either displacing the translation stages in unison or to explore the effects of applying micro-tensile stress on an optical fiber to create tapering. The other end of the optical fiber is connected to a spectral analyzer, where the spectral signal will be saved and analyzed. Once the splicing machine cover is closed an internal camera is used to visualize the micro-displacement of the optical fiber while the fabrication process is activated.

Not only are the translation stages connected to the central computer, but the spectral analyzer and the electric splicing machine are as well. The central computer system will oversee all the control and manipulation of the physical hardware of the entire experiment. The objective of having the experiment completely software driven is an attempt to completely isolate the experimental setup to prevent and/or minimize random human error, which can corrupt or affect the experimental data.

A spectral analyzer is used to analyze the component output optical power. This optical signal is characterized while the gratings are inscribed on the optical fiber.

The electric arcs serve to create periodic perturbations along the fiber by modifying the refractive index profile or the geometry of the fiber. These perturbations give rise to the LPFG coupling effect. In this case, the fundamental mode yields a part of its power to the various modes that are being propagated in the fiber (core and cladding modes). The coupling is carried out differently according to the wavelength, and the interaction between modes is characterized by an important attenuation of the output optical power for one wavelength.

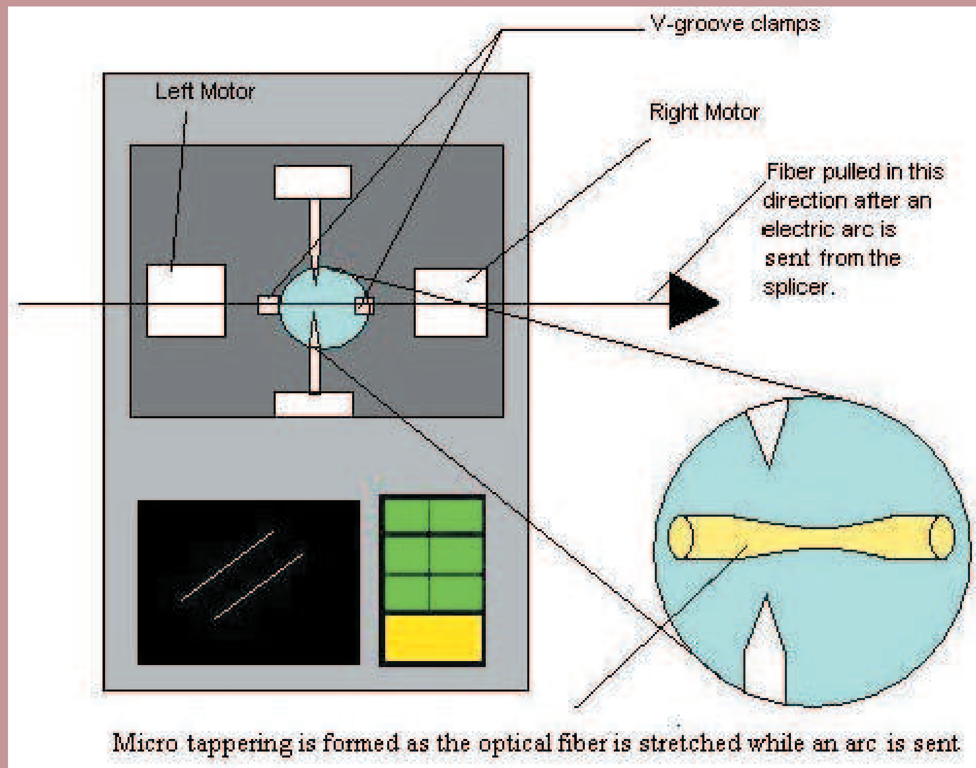

Figure 6. Refractive index changing using electric arc.

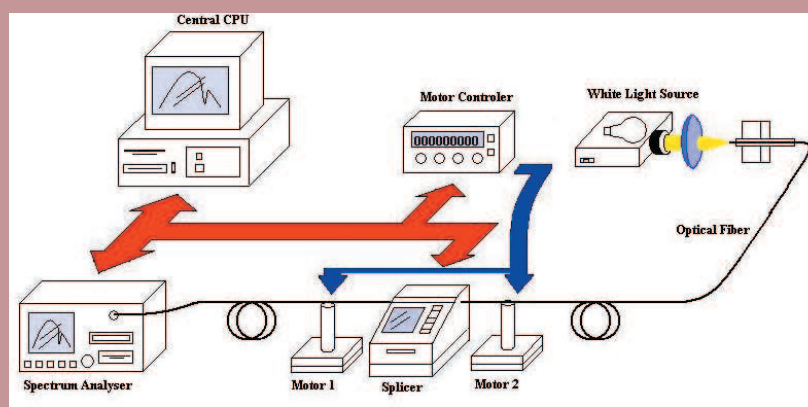

Figure 7. Experimental setup

4.0 Experimental results

LPFG are fabricated with grating period that varies from 200-700nm while FBG have periods lower than 1um. Since the width of an electric arc is approximately 400um, it's logical that the technique is more suitable to LPFG. Given that the electric arc technique provides the ability to use many different types of optical fiber, an adaptable and accommodating setup is necessary to unsure that flexibility is not lost on encumbering experimental support hardware. In another word, the flexibility of the technique has made it an ideal tool in exploring and analyzing optical components and new geometric formation generated by fiber tapering. In figure Fig. 8 and for a 500µm LPFG period size, we have used a 1mA of the electrical-arc intensity without fiber elongation. After a several exposures to the electrical arc, the transmission spectrums show the output optical power attenuations for different durations of the arc.

We note that the electric arc discharge can be used for writing and implementing the Long Period Fiber Bragg Gratings. The fiber doesn't need to be a Germanium doped one. These techniques will also provide the flexibility to explore new non-conventional formations which have yet to be introduced. For the simulation we can use the coupled modes equations [2] to find out the fundamental mode output power at the output of the LPFG. The optical fiber can be considered as an ideal fiber with refractive index variations and core radius perturbations with considering a core modes and cladding modes propagation. After the fabrication process, the LPFG sensitivity to the temperature variations can be analyzed using the heating module mounted on the splicing machine.

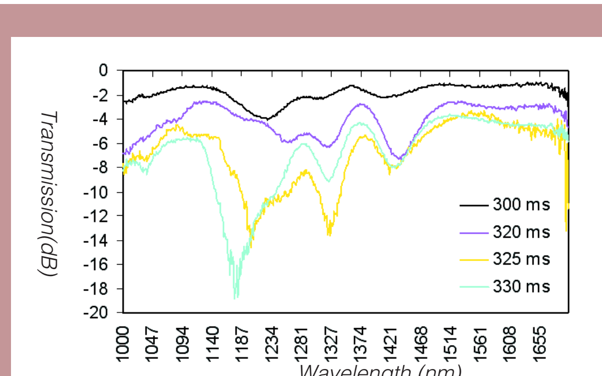

Figure 8. Transmission spectrums for 500µm LPFGs.

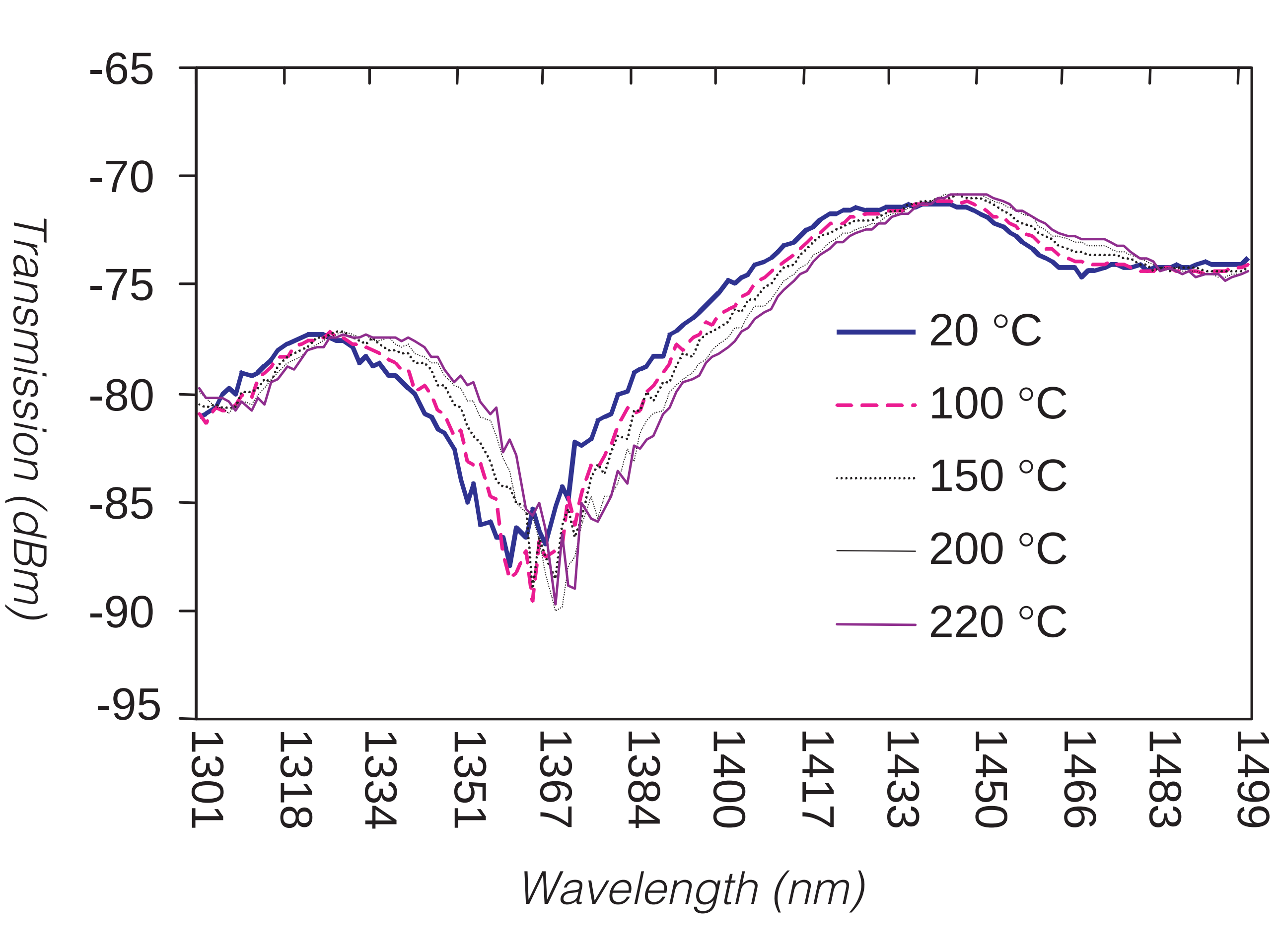

Figure 9. Figure spectrum senstivity to the temperature.

As shown in Fig. 9, electric arc based fabrication techniques provide a thermal stability of the LPFG components. On this figure an important rejection of the optical signal around the wavelength 1367 nm. The vertical axis represents the attenuation in dBm (relative to 1mw power). We note that an attenuation of 3 dB represents 50% of rejection. The LPFG was exposed to different temperatures between 0°C and 220 °C. We observe that the wavelength spectrum shift to greater wavelengths. The sensitivity can be calculated after determination of the wavelength shift as function as the variation of the temperature. For the case shown before, the average wavelength shift is 11 nm (± 1nm) between 1300 nm et 1450 nm for a temperature variation of 200°C. The sensitivity will be around 0.055 nm/ °C (± 0.005nm/ °C). The figure below shows that the sensitivity seems to be linear as function of the temperature variations.

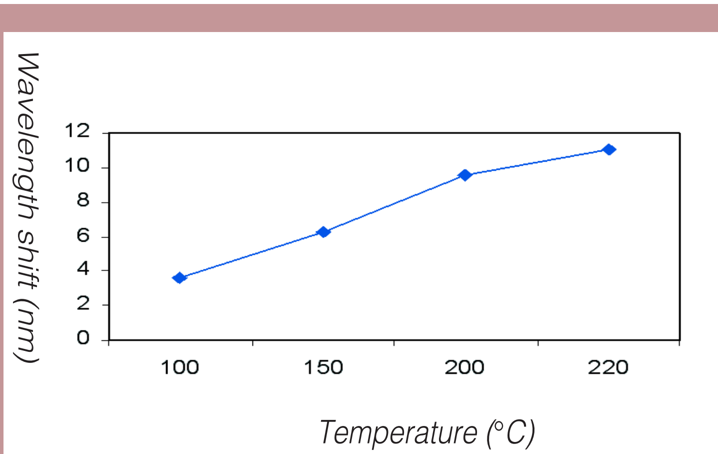

Figure 10. LPFG sensitivity to the temperature.

The electric arc technique provides a very simple yet robust solution to some of the future LPFG development simply because it will allow researchers to explore new various geometric structures on different types and generations of optical fibers like the photonic crystal fibers.

On the computer-controlled translation stage, the fiber can move with a precision under a micrometer. If the optical fiber is elongated under exposition, micro deformations can be produced on the fiber. The LPFG fabrication is accomplished by one or the both processes; by exposition to the arc discharge, and by elongating the fiber using the micro-displacement stage. These two methods create a permanent change of the refractive index of the fiber or/and modulate the effective index along the optical fiber. For micro-deformations we can use also a CO_2 laser beam [2]. If the fiber core radius after deformation becomes smaller than the cut-off frequency radius, the core mode becomes a cladding one. At the output optical power is subjected to wavelength oscillations and rejections. Hence, in an LPFG device, optical power is exchanged between core and cladding modes. Periodic

expositions of the optical fiber to the electrical arc produce a permanent and periodic modification of refractive indexes.
The elongation distance is the most important parameter in the fabrication processes. As shown on the figure below we can produce an LPFG only with a few elongations if we use the right elongation distance. The transmission powers are measured for 200µm, 300µm and 400µm elongation sizes. The exposition duration is about 350ms; the period size is 500µm.The effect of tension on grating formation was also studied in [19]; by increasing the tension and keeping the arc parameters constant, it is possible to get higher isolation loss with less discharges although insertion loss increases. So with these results, we can say that the axial tension during the LPFG fabrication is favorable to the writing process. Also, it's important to say that different tensions during the writing process produce different resonance wavelengths [19].

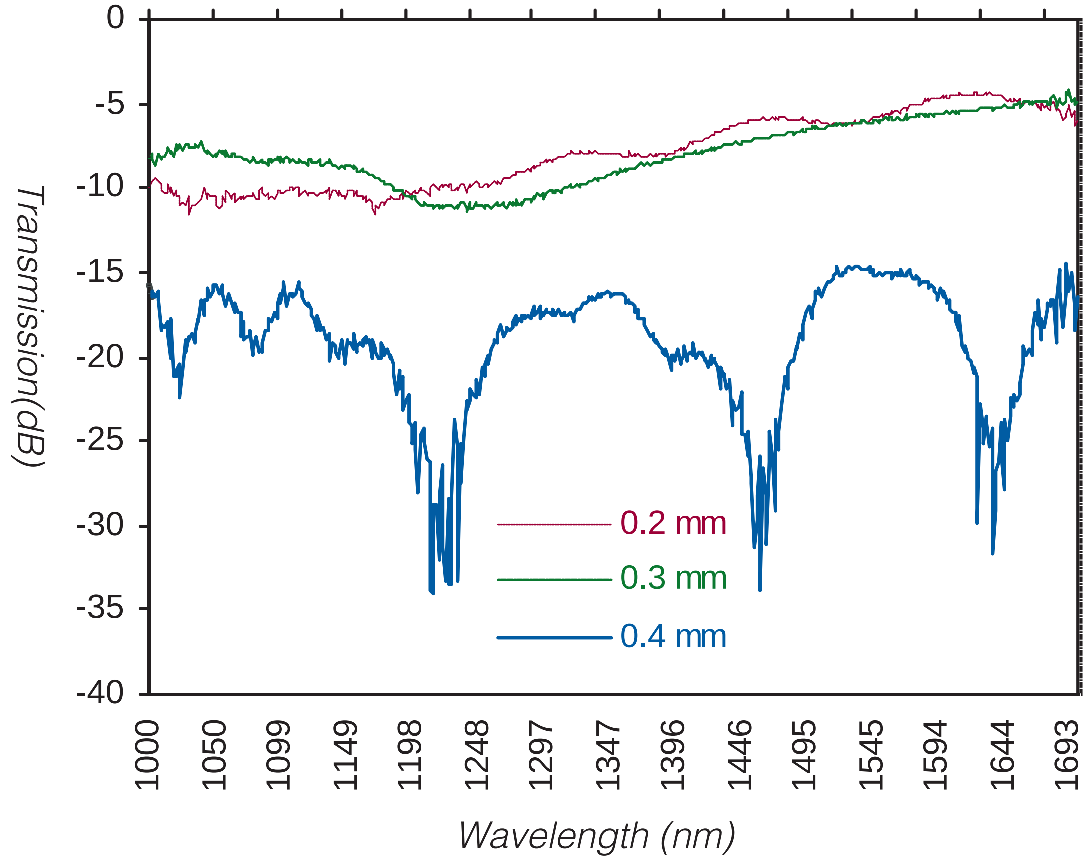

Figure 11. LPFG with different elongation sizes.

Experimental results have been obtained by combining the effects of electric arc and geometric deformation. The objective was to improve the quality and the efficiency of producing LPFG using electric arc by manipulating other favorable external parameters. In our experiment we generated a series of electrically tapered grating in effort to analyze the combined effects on a LPFG. The result shows greater wavelength isolation was obtain as a result of combining the two effects. Even though an initial insertion loss was observed, the final result of the LPFG demonstrated a pronounced wavelength isolation with less inscriptions.

In general, using the electric arc technique has produced comparable and useable wavelength isolation as compared to the conventional UV technique. Cutoff wavelengths with more than 25 db have been produced within the ranges of 1250 nm and 1600 nm. Depending on the type of fiber the gratings has been inscribed on; peak loss position obtained have varied. It demonstrates that the potential to create better optical component resides in the exploration and the research of new types and generation of optical fiber. Therefore by using the electric arc technique it will provide the necessary tool to possibly continue advancing this technology.

5.0 Prospect

The advantage of this technique resides in the simplicity, flexibility and adaptability to study new generations of optical fibers. By using the unique characteristics of these fibers, we can explore and extract properties that will contribute and aide the progression of the development of useful optical component. One of the fibers that we are presently working on includes photonic crystal fibers. The effects of applying an electric arc across a holey fiber will be examined along with the use of other external parameter to create a useable optical component.

Another advantage the electric arc technique provides is the ability to build a self-sustaining optical component-fabricating machine. Instead of simply buying an electric splicing machine, manufacturers can easily build a machine that not only splice optical fibers together but produces custom LPFG as well. This allows producing customized optical components suiting the user's needs.

6.0 Conclusion

With the increase of the number of its applications and its fabrication, we can easily note that the long period fiber gratings are a booming technology. In addition to reducing the costs and the increase in the fabrication rate, every new fabrication method provides new types of LPFGs with new characteristics. Thus, LPFGs that are fabricated with a change of the fiber's macroscopic structure (using CO^2 laser or an electric arc) have a high thermal stability. Moreover, these new characteristics propose new application fields like high temperature applications for electric arc induced LPFGs.

The high economic potential to construct a tool that will enable us to better understand the potentials and the possibilities of this enabling technology is definitely worth investigating. This technique is not only simple to use but will provide a suitable developments on new fibre material which may radically solve the instability problem.

7.0 Acknowledgement

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8.0 References

[1] M. Akiyama, K. Nishide, K. Shima, A. Wada, R. Yanauchi, "A novel long- period fiber grating using periodically released residual stress of pure-silica core fiber," Proc. Optical Fiber Communication Conf., pp.276-277, 1998.

[2] Y. Bouslimani, H. Hamam, O. Latry and M. Ketata, "CO^2 laser beam based technique for producing optical fiber components", SPIE Vol. 5260, p154-162, 2003.

[3] T. Enomoto, M. Shigehara, S. Ishikawa, T. Danzuka, H. Kanamori, "Long-period fiber grating in a pure-silica-core fiber written by residual stress relaxation", OFC Technical Digest, pp.277-278, 1998.

[4] O. Frazão, G. Rego, M. Lima, A. Teixeira, F. M. Araújo, P. André, J. F. da Rocha, H. M. Salgado "EDFA Gain Flattening Using Long-Period Fibre Gratings Based on the Electric Arc Technique", London Communications Symposium 2001, http://www.ee.ucl.ac.uk/lcs/prog01/LCS041.pdf

[5] M. Fujimaki & Y. Ohki, "Fabrication of long-period optical fiber gratings by use of ion implantation," Optics Letters., v. 25, pp. 88-89, 2000.

[6] David C. Gerstenberger, "Method and apparatus for fiber Bragg grating production," United States Patent Application, 20030048523, www.utc.fr/~farges/recherche/recherche.htm, March 13, 2003.

[7] Y. G. Han, W. T. Han, U. C. Paek, Y. Chung, "Tunable Bandpass Filter with novel Core Mode Blocker Fabricated by Local Heat Exposure", Kwangju Institute of Science & Technology, 2002, http://fdlab.kjist.ac.kr/mis/publications/data/2002/256.pdf

[8] G. Humbert, A. Malki, "Temperature characterization of long-period fiber gratings fabricated with electric arc discharge", Proc. SPIE Vol. 4579, pp. 176-183, 10/2001.

[9] G. Humbert, A. Malki, "Characterizations at very high temperature of electric arc-induced long-period fiber," Opt. Commun. 208, pg.329-335, 2002.

[10] K.O. Hill, D.-C. Johnson, B.-S. Kawasaki: "Photosensitivity in optical fiber waveguides: application to reflection filter fabrication" in Applied Physics Letters / Vol. 32, p. 647-649 / 1978

[11] I. K. Hwang, S. H. Yun, and B. Y. Kim, "Long-period fiber gratings based on periodic microbends," Optics Letters., vol.24, pp.1263-1265, 1999.

[12] G. Kakarantzas, T. E. Dimmick, T. A. Birks, R. Le Roux, P. St. J. Russell, "Miniature all-fiber devices based on CO2 laser microstructuring of tapered fibers", Optics Letters, Vol. 26, No. 15, August 1, 2001.

[13] N. Godbout, X. Daxhelet, A. Maurier, and S. Lacroix, "Long Period Fiber Grating by Electric Discharge", ECOC'98, pg 397-398, September 1998.

[14] G. Meltz, W. W. Morey, and W. H. Glenn: "Formation of Bragg gratings in optical fibers by a transverse holographic method" in Opt. letters / Vol. 14, No. 15 / 1989.

[15] R. M. Mead, "Method and apparatus for fiber Bragg grating production," United States Patent Application, 20030007730, www.utc.fr/~farges/recherche/recherche.htm, January 9, 2003.

[16] N. Fisher, "Fiber Bragg grating fabrication method," United States Patent Application, 20030002795, www.utc.fr/~farges/recherche/recherche.htm, January 2, 2003.

[17] Y. J. Rao, J. D. Jones, H. Naruse, R. I. Chen, "Novel mechanical fiber optic sensors based on long-period fiber gratings written by high-frequency CO2 laser pulses", Proc. SPIE Vol. 4920, pp 43-53, 9/2002.

[18] G. Rego, O. Okhotnikov, E. Dianov, V. Sulimov, "High-temperature stability of long-period fiber gratings produced using an electric arc," Journal of Lightwave Technology, pp. 1574-1579, Vol.19, Issue 10, Oct. 2001.

[19] G. Rego, M. Melo, J. L. Santos, H. M. Salgado "Optical Filters for Fibre Lasers and Amplifiers", Portugal, 2002.

[20] M. Vengsarkar, P. J. Lemaire, J. B. Judkins, V. Bhatia, T. Erdogan, and J. E. Sipe, "Long-period fiber gratings as band-rejection filters," J. Lightwave Technol., vol. 14, pp. 58–65, Jan. 1996.

[21] M. L. von Bibra, A. Roberts, J. Canning, "Fabrication of long-period fiber gratings by use of focused ion-beam irradiation," Optics Letters, Vol. 26, Issue 11, pp. 765-767, June 2001.

[22] Y. P. Wang, Y. J. Rao, Z. L. Ran, T. Zhu, A. Z. Hu, "Novel tunable gain equalizer based on a long-period fiber grating written by high-frequency CO^2 laser pulses", Proc. SPIE Vol. 4906, pp. 180-184, 8/2002.

[23] H. Younggeun, K. Chang-Seok, P. Un-Chul, C. Youngjoo, "Performance Enhancement of Long Period Fiber Gratings for Strain and Temperature Sensing", IEICE Trans Electron., vol. E83-C, No.3 March 2000.

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