Tensile Test Using Photonic Crystal

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Abstract
Photonic crystal fibers are a kind of fiber optics that present a diversity of new and improved features beyond what conventional optical fibers can offer. Due to their unique geometric structure, photonic crystal fibers present special properties and capabilities that lead to an outstanding potential for sensing applications. The objective of this project is to analyze the performance of photonic crystal fiber based strain sensors. PCF, injected PCF with olive oil , and MMF are used to compare between their sensitivity to the stress . It was concluded that the PCF is more sensitive to the stress than the MMF, and the injected PCF with olive oil is more sensitive to the stress than the PCF.
Keywords: photonic crystal, PCF, fiber optics .strain sensor

1. INTRODUCTION

Sensing is a key technology for application areas like entertainment, transport, health and other industrial uses. Many such applications require the concept of remote sensors, where data is acquired from places which are not easily accessible. A basic fiber optic sensing system includes a source of light, optical fiber, a transducer or sensing element and a detector. It depends on the type of sensor, whether intrinsic or extrinsic, that a separate transducer is used in the design or not. A fiber sensor operates by modulating one or more parameters of the system (e.g., wavelength, phase, intensity, polarization etc.) resulting in a change in the characteristics of the received optical signal at the detector. Photonic crystal fibers (PCFs) are fibers with an internal periodic structure made of capillaries, led with air, laid to form a hexagonal lattice. Light can propagate along the fiber in defects of its crystal structure. A defect is realized by removing one or more central capillaries. PCFs are a new class of optical fibers .Combining properties of optical fibers and photonic crystals they possess a series of unique properties impossible to achieve in classical fibers [1]. Classical optical fibers perform very well in telecom and non-telecom applications, but there is a series of fundamental limits related to their structures. The fibers have rigid design rules to full: limited core diameter in the single-mode regime, modal cut wavelength, limited material choice (thermal properties of core glass and cladding glass must be the same).The design of PCFs is very flexible. There are several parameters to manipulate: lattice pitch, air hole shape and diameter, refractive index of the glass, and type of lattice. Freedom of design allows one to obtain *endlessly single mode fibers*, which are single mode in all optical range and a cut-off wavelength does not exist. Moreover there are two guiding mechanisms in PCF: index guiding mechanism (similar to the one in classical optical fibers) and the photonic band gap mechanism [1].

Photonic crystal fibers (PCFs) , which have been first demonstrated in 1991 by Russell and its subsequent theortical demonstration by Briks et. Al. in 1995 , is made of undoped silica with a hexagonal array of air holes running down its length . One hole is missing , the resulting central solid region is the core , while the remaining two dimentional " photonic crystal' , with the array of holes with diameter (d) , is the cladding , the cor's diameter (p) , and the spacing between two adjust holes (A) (or pitch) with definite number of air holes , typicallly expressed by the number of periods (rings) around the core . The fiber is drown from a stack of capillaries (and one central solid rod) in conventional drowind tower , Fig.[1] shows the schematic drowing of the PCF by COMSOL MULTIPHYSICS [ref].

This characteristics, as well as the high refractive index contrast between silica and air , provides a rang of new interesting features . Moreover , a high design flexibility is one of the distinctive properties of PCFs.
In practical, bychanging the geometric characteristics of the air- holes in the fiber cross-section , that is their dimention or position , it is possible to obtain PCFs with diametrically opposite properties .

2. LARGE MODE ARE FIBER

We already have mentioned in our introduction, that certain geometries will support only one mode, no matter the size of the core or the wavelength. These types of fiber are called endlessly single mode crystal fiber, and are fabricated usually with a solid core surrounding by air holes .This properties are very interesting and can have various application, including high power single mode-fiber lasers and amplifiers.. Since PCFs deliver more power compare with conventional fiber, they can lengthen the repeater spacing in telecommunication links. Also since the fiber is made of only silica the fiber has potential application in sensors and interferometers. Losses associated with this type of fiber are usually less than 1 dB/km.

3. STRENTH RANGE IN FIBER

Fiber strengths of generally extend from around 0.1% strain to failure (~50 MPa for silica) to 20% strain to failure (~14 GPa for silica) . Below the lower limit the fiber is so fragile it can not be handled , the upper limit represents the theoretical strength of the material which can not be exceeded . Most techniques can not conveniently access the complete strength range . For such is required . [7]

4. UNIAXIAL TENTION

The uniaxial tension it's in which the ends of the fiber are pulled in a direction coaxial with the fiber . The stat of stress on the fiber is uniform simple tension. Gripping is a major concern to this technique and some commone methods are shown in fig.2.8 The most reliable and widely used technique is to wrap two or three turns of fiber around a capstan (fig.2.8a). The capstans are covered in a compliant rubber layer which smoothes any stress discontinuities and gradually transfers stress from the fiber . The capstan diameter should be large enough so that bending stresses are negligible . Slip necessarily occurs between the capstan and the fiber during loading so that only fiber coated with a reasonably strong polymer can be successfully tested . Typically , approximately 0,5 m of fiber is needed to wrap around both capstans so that short specimens can not be tested with this gripping system. A veriety of techniques can be employed for gripping short specimens (Fig.2.8 b to d) . Rubber faced pneumatic grips can be used with coated fiber (Fig.2.8 b) but strong fiber can only be tested if the coating is strong and if there is sufficient friction to avoid slipping . Alternatively , specimens can be glued to card tabs (Fig. 2.8c) , the tabs can then be held in conventional grips . Finally , the fiber can be glued inside hypodermic needles which protect them from the gropping forces (Fig.2.8 d) . For all these techniques it is important that the load train and fiber be accurately aligned in order to avoid preferential failure in bending where the fiber enters the glue or grips . All the fixtures in Fig.2 are available commercially or are readily constructed . [5]

5. EXPERIMANTAL WORK

The relashion between the hanging weight ranged from 0.5 to 7 killogram (kg) and the shift in laser wavelength of 532 nm that will happen in laser pass through photonic crystal fiber and Multi-Mode Fiber is implemented a fiber optic sensors have emerged as a unique solution in particular cases like potentially explosive environments or those with electrical hazard, Although, conventional optical fiber-based sensors are well established using Optical spectrum analyzer and trestle of hight 50 cm and width 50 cm. The experimantal setup is shown in Figure [3]

The MMF is glued with the hook thread and it is tied to the trestle , and then the laser is shed on it and display the emerging wave from the other end of the fiber using the Optical spectrum analyzer while the weights are attached by the hook thread , and then the laser is shed on MMF and the emerging wave from the other end of the fiber is displyed by using the Optical spectrum analyzer. The PCFis glued with the hook thread and it is tied to the trestle , and then the laser is shed on it and the emerging wave from the other end of the fiber is displayed by using the Optical spectrum analyzer ,the weights are attached by the hook thread , and then the laser is shed on PCF and the emerging wave from the other end of the fiber is displyed using the Optical spectrum analyzer . The PCF is injected with olive oil and then it is glued with the hook thread and it is tied to the trestle , and then the laser is shed on it and the emerging wave from the other end of the fiber is displyed by using the Optical spectrum analyzer .

And finally the weights are attached by the hook thread , and then the laser is shed on PCF and the emerging wave from the other end of the fiber is displayed by using the Optical spectrum analyzer .

6. THE RESULTS and DISCUSSION

Three different types of fiber used in the experimant:
1. **MULTI MODE FIBER,** Table[1]show the results of MMF
2.**PHOTONIC crystal fiber,** Table [2] show the results of PCF
3.**Photonic crystal fiber fill with olive oil** ,Table [3] show the results of PCF with olive oil. Optical properties of air-silica PCFs can be altered by varying the location, shape and size of the air filled holes and can be extended by filling the holes with materials other than air, like liquid crystals. Table 3 show the result of PCF fill with olive oil as liquid crystal.

7. CONCLUSION

From the results that the shift in the wavelength happen whenever the weight is increased . But the shift is not linearly change with the increment of the weight ; the shift sometimes increases with the increment of the weight and and sometimes decreases . The reason is that the adhesive force is not strong enough , it means that the fiber didn't adhere well with the thread , accordingly the tension in the fiber sometimes is strong and other times it becomes weak .Also the intensity of the emerge wave is not constant for all states as well and that because the alignment between the laser and the fiber is not steady , so sometimes the laser light enters the fiber

with good intensity and other times with low intensity .
1-PCF based strain sensors prove better than the conventional FBG-based fiber optic strain sensors due to higher sensitivity to strain.
2- PCF fill with olive oil based strain sensors prove better than the pure PCF
3- Need more stable setup to get more sensitive results.

8. REFRENCES

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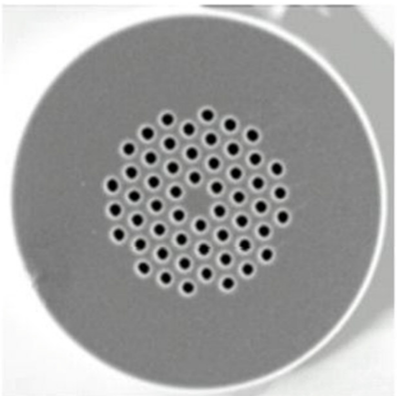

Fig. [1] The schematic drowing of the PCF by COMSOL MULTIPHYSICS

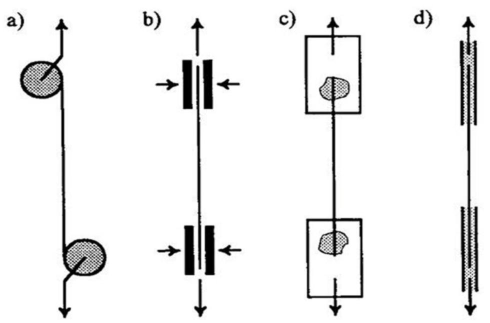

Fig.[2] Common methods of gripping tensile test specimens . [5]

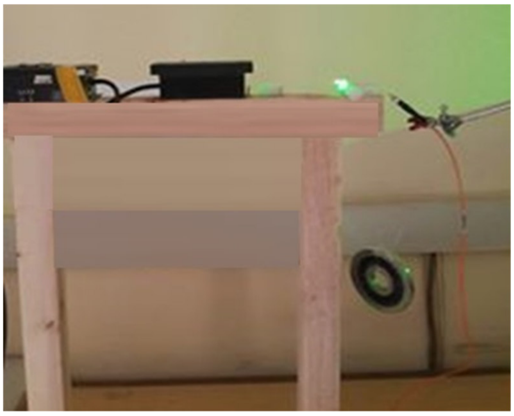

Figure [3] The experimantal setup .

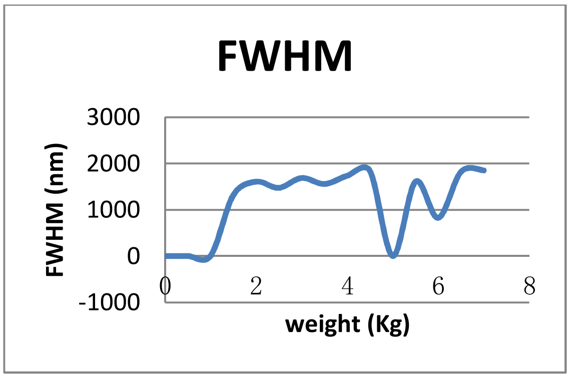

Fig.[4] FWHM vis weight in MMF

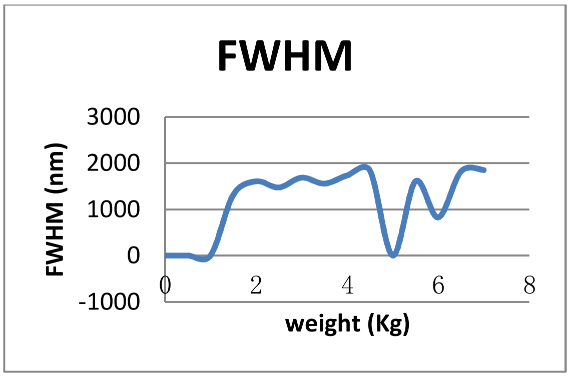

Fig.[5] FWHM vis weight in PCF

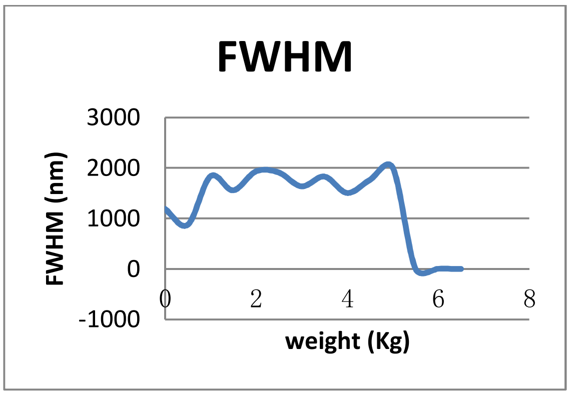

Fig.[6] FWHM vis weight in PCF fill with Olive oil

Weight Kg	Wavelength nm	Level intensity	3.0db width	FWHM nm	Position nm	Offset(nm	ΔLevel intensity
0	531.694487	0.3111158	1996.19	2007.344	-275.21894	-126.35526	0.309765
0.5	532.195648	1.000	2.74744	2.751877	-274.54356	262.42919	0.998543
1	531.805063	0.9375473	2.08150	2.088675	-274.8281	234.2347	0.936247
1.5	531.454797	0.4663935	1409.84	1414.270	4.184382	-69.130086	0.465179
2	531.889638	0.3511856	2.61765	2.623656	-26.753586	-292.550708	0.350086
2.5	531.919686	0.5577425	2.4564	2.461340	-274.77561	273.75236	0556387
3	531.926961	0.8018248	2.46143	2.470126	-274.657005	-320.707573	0.800196
3.5	531.55484	0.0940691	1629.02	1634.121	-75.019633	246.393074	0.092396
4	531.559895	0.0286391	1864.71	1869.894	-169.237262	-402.569075	0.027283
4.5	531.597805	0.0270759	1756.24	1759.871	-250.444079	-77.719108	0.025957
5	531.548216	0.0484082	1771.958	1775.859907	-323.325487	-374.897246	0.047028
5.5	531.668514	0.0375713	1828.42	1832.212	-387.503170	128.378355	0.036421
6	531.8445766	0.0731432	2.21579	2.219308	-64.139936	-188.266569	0.071849
6.5	531.7876021	0.0582807	2.250551	2.254896	140.439292	-135.806008	0.057127
7	531.5882552	0.0887243	1619.74	1623.641	-448.85436	50.451838	0.087675

Table [1] By using Multi Mod Fiber (MMF)

Weight(Kg)	Wavelength (nm)	Level (Intensity)	3.0db width(nm)	FWHM(nm)	Δ Position(nm)	Offset(nm)	Δ Level(Intensity)
0	531.376173	0.0244833	2.068071	2.071889	-274.369066	-462.296079	0.023199
0.5	531.890883	0.1306142	2.579116	2.5883322	-156.940397	-389.224344	0.128963
1	532.055803	0.0589944	2.928243	2.936659	-259.284904	-330.754321	0.057652
1.5	531.450588	0.0201721	1299.05183	1314.8797	-67.211510	-129.323341	0.018368
2	531.603410	0.0382015	1605.04873	1607.87101	-348.757658	-117.816705	0.036924
2.5	531.580029	0.0488469	1471.344359	1443.69622	-386.377359	200.076452	0.047487
3	531.599118	0.0542415	1681.938209	1686.7805	-41.213693	33.410194	0.052830
3.5	531.569527	0.0414854	1555.344731	1557.83496	-368.536724	-250.823836	0.040174
4	531.537782	0.0365704	1721.380696	1734.05398	7.406156	336.337446	0.035259
4.5	531.456315	0.0522129	1835.072212	1838.08816	-293.757185	-263.274068	0.050765
5	531.871437	0.0186611	2.597257	2.600384	331.498538	-373.850978	0.017311
5.5	531.439509	0.0166240	1604.280787	1607.62876	-3.619579	-116.113443	0.015254
6	531.395805	0.0117414	823.701836	826.247305	-1.84386	-492.499895	0.010607
6.5	531.609944	0.0257439	1819.638506	1822.51668	-82.653842	-47.973478	0.024580
7	531.528306	0.0422129	1842.620045	1851.20002	-99.544671	-460.798733	0.041046

Table[2] By using Photonic Crystal Fiber of (PCF)

Weight(Kg)	Wavelength(nm)	Level(Intensity)	3.0db width(nm)	FWHM(nm)	Δ Position(nm)	Offset(nm)	ΔLevel (Intensity)
0	531.4923606	0.2990311	1187.813982	1187.813982	302.292911	-460.819568	0.297555
0.5	531.2839981	0.0147730	869.906716	872.507587	110.878402	260.231023	0.013664
1	531.6789482	0.0434160	1832.325093	1835.037194	-273.600046	-488.2534848	0.042063
1.5	531.5625273	0.0295629	1552.222528	1556.041010	-3.427551	168.837255	0.028257
2	531.7175002	0.0291609	1930.746607	1933.237366	181.583728	-464.097303	0.027575
2.5	531.8046318	0.0311661	1905.887417	1909.512997	-195.171807	-492.807155	0.029765
3	531.6648889	0.0340795	1628.256358	1634.594411	-405.110442	-236.795646	0.032825
3.5	531.7327627	0.1039403	1819.624938	1829.339817	19.146606	209.494888	0.102756
4	531.6578241	0.2059920	1501.331203	1504.56854	-143.839935	-351.059352	0.204568
4.5	531.7072577	0.3723986	1750.457525	1761.971533	191.565119	174.449973	0.3705057
5	531.7514573	0.0356018	1961.432673	2004.971206	269.992718	-238.882528	0.034063
5.5	531.8427786	0.0665297	2.177855	2.181453	161.073645	-214.386087	0.065072
6	531.9136428	0.0397012	2.410507	2.413468	-120.284430	40.912198	0.038334
6.5	531.7653645	0.0618450	2.052651	2.05921	-97.194166	166.843147	0.060720
7	531.7096168	0.0689871	1960.305817	1966.173373	330.943937	-246.811326	0.067647

Table[3] By using PCF fill with Olive Oil