The Bending Effect of Single-Mode Optical Fiber at Long Distance from Laser Source on the Spot Laser

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Abstract

The bending effect on coherent light in the single mode optical fiber was studied. In this work single mode optical fiber made from silica and turn over cylinders with different diameters (3, 5 and 10) cm to obtain variable bending diameter of fiber was used. Also, diode laser with wavelength (630-680) nm and max. power (5) mw was used as laser source. The image of spot laser for each turn was captured by digital camera connected with computer and at constant long distance (247) cm from laser source.

From our results, we concluded that the area of spot laser increases with increasing the bending diameter of optical fiber and increase the intensity of spot laser. Increasing the number of turns of optical fiber led to decrease the area of spot laser and decrease the intensity of spot laser. So the fiber with bending diameter (10) cm is the best than the two other fibers. In obtaining region of constant area of spot laser, ie. no. of red point constant.

(1-) Introduction:

An optical fiber is nominally a cylindrical dielectric waveguide that confines and guides light waves along its axis. Basically all fibers used for communication purposes have the same physical structure. The variations in the material and the size of this structure dictate how a light signal is transmitted along different types of fiber[1].

The main advantage of optical fiber is that it can transport more information longer distances in less time that any other communications medium. In addition, it is unaffected by the interference of electromagnetic radiation making it possible to transmit information and data with less noise and less error. There are also many other applications for optical fiber that are simply not possible with metallic conductors. These include industrial applications, subject illumination, and medical applications[2].

There were many researchers study different parameters effected on the single-mode fiber optic. The effect of turn fiber on cylinders with variability number of turns and the radius of cylinder was studied [3]. Thomas P.S.Nejla [4] was studied the bending induced birefringence and its effects on solution propagation in single-mode optic fiber. Kotov et.al [5] studied modulation of the phase difference between polarization modes in single-mode fiber optics. S.Dasgupta [6] improved theoretical model to estimate the minimum fiber length required achieving a certain degree of filtering and showing the effects of both fiber characteristics and launching conditions of the input optical field should be considered to determine the minimum length.

(1-1) The Optical Fibers:

An optical fiber consists of a cylindrical glass core surrounded by a glass cladding. The core has a refractive index (n_1), and the cladding has a refractive index (n_2) as shown in fig. (1). surrounding these two layers is a polymer buffer coating that protects the fiber from mechanical and environmental effects. For telecommunication fibers the core and cladding are made of silica glass (SiO_2)[7].

The refractive index of pure silica varies with wavelength, ranging from 1.45 at 850nm to 1.445 at 1550nm. By adding certain impurities such as germanium or boron to the silica during the fiber manufacturing process, the index can be changed slightly, usually as an increase in the core index. This is done so that the refractive index (n_2) of the cladding is slightly smaller than the index of the core (that is $n_2<n_1$), which is the condition required for light traveling in the core to be totally internally reflected at the boundary with the cladding. The difference in the core and cladding indices also determines how light signals behave as they travel along a fiber [8].

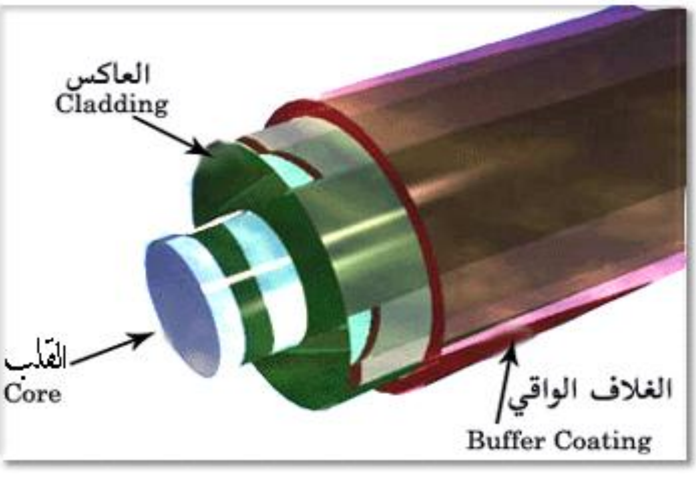


Fig. (1) Optical Fiber Construction [8].

(1-2)Optical Fiber Modes:

When the fiber diameter is on the order of (8 to 10) μm , which is only a few times the value of wavelength , then only the one single fundamental ray that travels straight along the axis is allowed to propagate in a fiber . Such a fiber is referred to as single-mode fiber.

Fiber with larger core diameter (e.g. greater than or equal to 50 μm) support many propagating rays or modes and are known as multimode fibers [9]. Also the variations in the material composition of the core and the cladding give rise to the two basic fiber types. In the first case, the refractive index of the core is uniform throughout and undergoes an abrupt change (or stop) at the cladding boundary. This is called a step-index fiber. In the second case, the core refractive index varies as a function of the radial distance from the center of the fiber. This defines a graded-index fiber [10].

In our Study, we use single-mode optical fiber. There is important parameter for this fiber is cutoff wavelength. This is designated by (λ_{cutoff}) and specifies the smallest wavelength for which all fiber modes except the fundamental mode are cutoff ; that is, the fiber transmits light in single mode only for those wavelengths that are greater than (λ_{cutoff}) . The fiber can support more than one mode if the wavelength of the light is less than the cutoff, $\lambda_{cut\ off}$ can be calculated from [8, 11]:

$$\ldots\ldots\ldots (1)\ \lambda_{cutoff} = \frac{2\pi a}{2.405}\left(n_1^2 - n_2^2\right)^{1/2}$$

Where **a** is the radius of the fiber core, n_1 is the core index, and n_2 is the cladding index.

(1-3)Optical Fiber Attenuation:

Light traveling in a fiber losses power over distance, mainly because of absorption and scattering mechanisms in the fiber. The fiber loss is referred to as signal attenuation or simply attenuation. Attenuation is an important property of an optical fiber because, together with signal distortion mechanisms, it determines the maximum transmission distance possible between a transmitter and a receiver (or an amplifier) before the signal power needs to be boosted to an appropriate level above the signal noise for high – fidelity reception. The degree of the attenuation depends on the wavelength of the light and on the fiber material [12].

Fig.(2) shows a typical attenuation versus wavelength curve for a silica fiber. There are three transmission windows due to absorption: the first window ranges from (800 to 900) nm; the second window is centered at (1310) nm; and the third window ranges from (1480 to 1600) nm In addition to the intrinsic absorption and scattering loss mechanisms in fiber, light power can be lost as a result of fiber bending. Fibers can be subjected to two types of bends:

1- Macroscopic bends that have radii which are large compared with the fiber diameter.

2- Random microscopic bends of the fiber axis that can arise when fibers are incorporated into cables [8, 13].

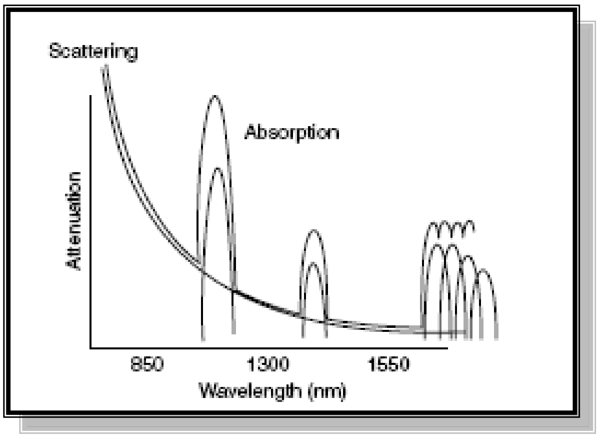


Fig. (2) Attenuation of Fiber [8]

(2-)Experimental work:

In this work, we use the optical system shown in fig. (3). This system contain of diode laser with wavelength (630-680) nm and maximum power 5 mw, and single-mode optical fiber made of silica.

We use cylinders with different diameters (3,5 and 10) cm to turn the fiber over them to obtain different bending diameter of fiber .The detector in system represents by digital camera type (web camera) to capture image for each spot laser, this camera connected with computer . This system places in dark room to avoid any external effects.

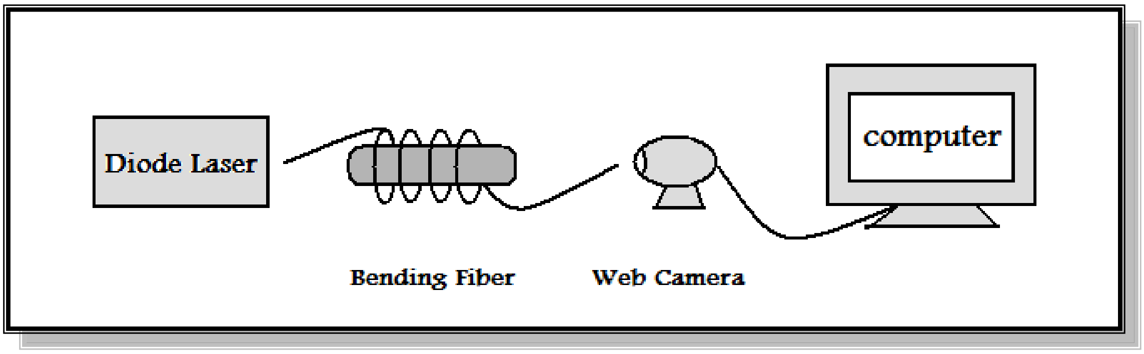


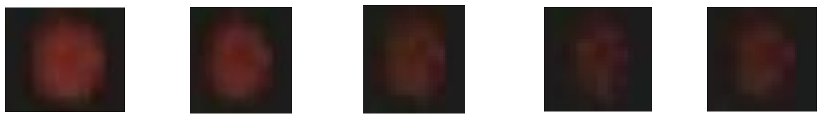
Fig. (3) The Optical System.

(3-)Results and Discussions:

The image of spot laser that captured by digital camera of three bending diameter (3, 5 and 10) cm of single-mode optical fiber shown in figs. (4, 5 and 6) respectively. We can be shown that the intensity of spot laser increased with increasing bending diameter of fiber and decreased with increasing number of turns.

Fig. (7) Shows the relation between number of turns and No. of red point or area of spot laser for bending diameter 3 cm. At first turn, No. of red point was 160 and decreased with increasing number of turns. At four turn, it becomes 80 and decreased sharply to zero at seven turn. This will be identifying with the image of spot laser as shown in fig. (4), whereas the intensity of image decreased with increasing number of turns until disappeared at seven turn.

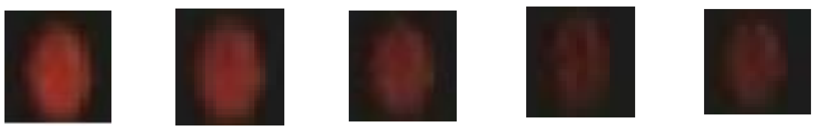
Increasing bending diameter to 5 cm (fig.(8)), led to increase the area of spot laser to become 190 at first turn. Increasing number of turns led to decrease the area of spot laser to be 105 at for turn and lowering to zero at ten turn with sharp decreasing. This was similarity to the behavior of image of spot laser shown in fig.(5). At large bending diameter 10 cm (fig.(9)) , the area of spot laser reach 200 that is larger than in the two other fibers . Also, increasing number of turns led to decrease the area of spot laser gradually, at third and four turns become approximately 160. Also, at five and six turns, the area of spot laser was constant 140. This give us region of constant area of spot laser, i.e. No. of red point constant. So that, this fiber with 10 cm bending diameter was the best than the two other fibers.



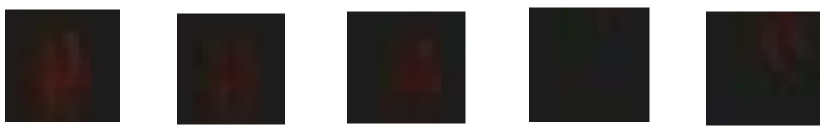
1turn 2turn 3turn 4turn 5turn

10turn 9turn 8turn 7turn 6turn

The spot laser for ten turns and bending diameter (3) cm Fig.(4)

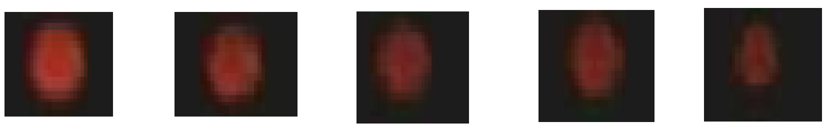


1turn 2turn 3turn 4turn 5turn



10turn 9turn 8turn 7turn 6turn

The spot laser for ten turns and bending diameter (5) cm Fig.(5)



5turn 4turn 3turn turn ٢1turn

7turn 6turn

The spot laser for seven turns and bending diameter (10) cm Fig.(6)

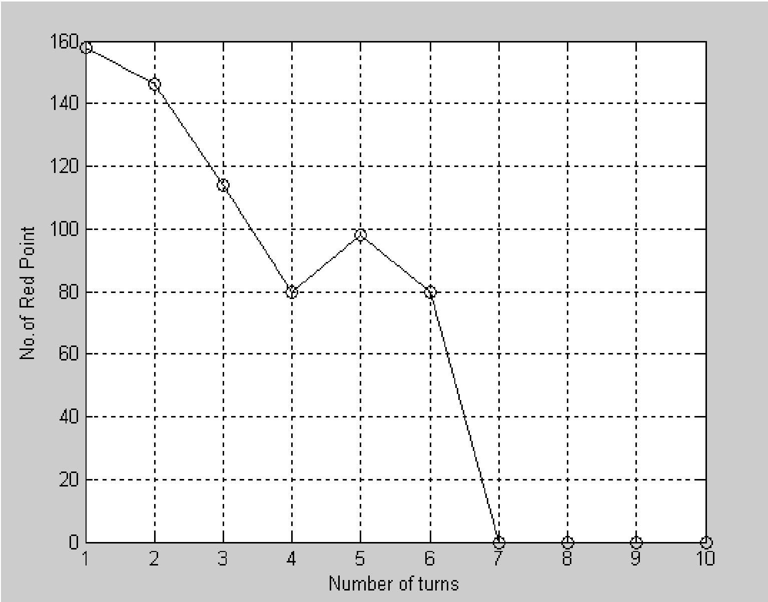


Fig.(7) The relation between area of spot laser (No. of red point) and number of turns for bending diameter (3)cm.

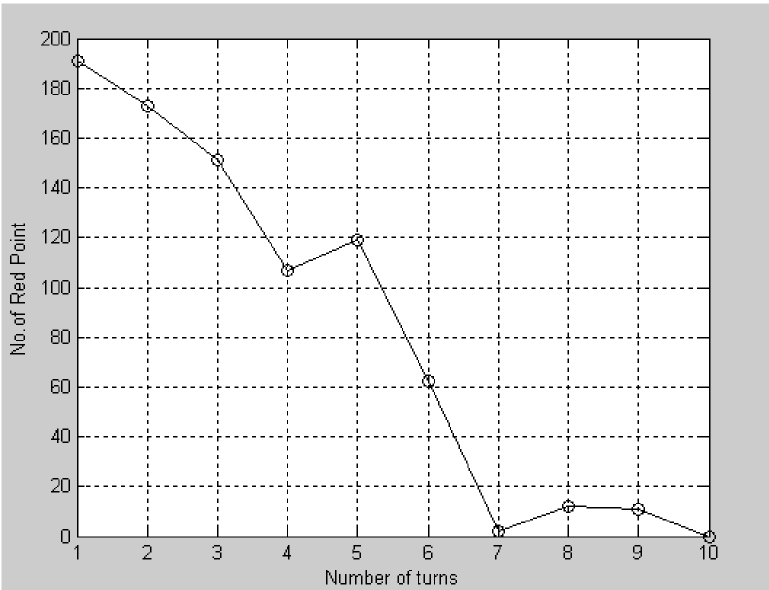


Fig.(8) The relation between area of spot laser (No. of red point) and number of turns for bending diameter (5)cm.

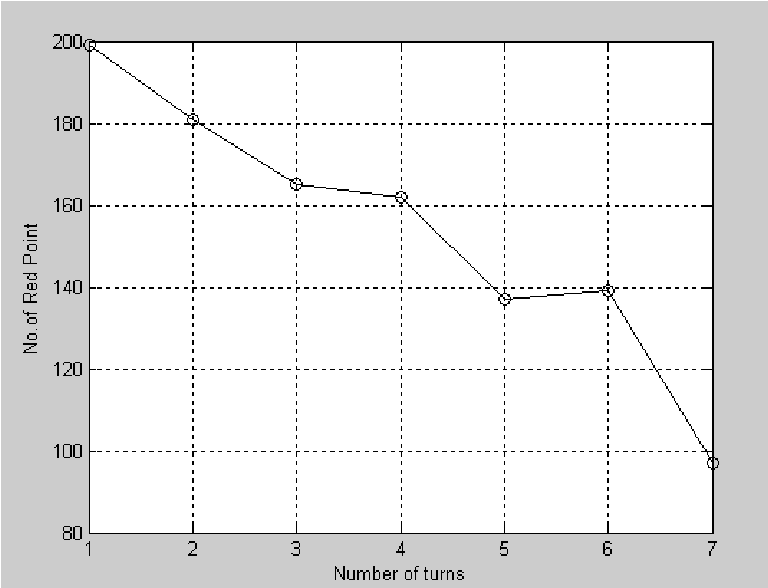


Fig.(9) The relation between area of spot laser (No. of red point) and number of turns for bending diameter (10)cm.

(4-)Conclusions:

For our results, we concluded:-

1- Increasing the bending diameter of single-mode optical fiber led to increase the intensity of image of spot laser and area of spot laser.
2- Increasing number of turns led to decrease the intensity of image of spot laser and area of spot laser (No. of red point in spot laser).
3- The best diameter of single-mode optical fiber was (10) cm to obtain region of constant area of spot laser (No. of red point constant).

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تاثير الانحناء لليف البصري الاحادي النمط عند المسافة الطويلة من المصدر الليزري على البقعة الليزرية

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الخلاصــة

تمت دراسة تأثير الانحناء على الضوء المتشاكه داخل الليف البصري الاحادي النمط ، واستخدم في هذا البحث ليف بصري احادي النمط مصنوع من السليكا لف حول اسطوانات مختلفة الاقطار (10,5,3) سم للحصول على اقطار انحناء متغيرة لليف البصري . استخدم كذلك ليزر شبه موصل بطول موجي (680-630) نانومتر واقصى قدرة (٥) ملي واط . وتم التقاط صورة للبقعة الليزرية لكل لفة بواسطة كاميرا رقمية مربوطة بحاسوب وعلى مسافة طويلة ثابتة (247) سم عن المصدر الليزري .

من خلال النتائج التي حصلنا عليها استنتجنا بان مساحة البقعة الليزرية تزداد مع زيادة قطر الانحناء لليف البصري وزيادة الشدة للبقعة الليزرية . ان زيادة عدد اللفات لليف البصري تؤدي الى انخفاض مساحة البقعة الليزرية وهبوط الشدة للبقعة الليزرية ، ووجدنا بان الليف البصري الاحادي النمط ذو القطر (10) سم يكون الافضل في الحصول على منطقة ذات مساحة ثابتة تقريباً أي عدد النقاط الحمراء في البقعة الليزرية يكون ثابت تقريباً .