Bending , Heating and Pressure Effects of He-Ne Laser in Single Mode Fiber

Nizar Salim Shnan **Lubna Abbas Muhammad**
University of Babylon
nizarflifl@yahoo.com

Abstract

In this paper a single mode fiber have been chosen with a refractive index (1.50) to the core, and (1.485) to the cladding, with length of (2 m).

It was exposed this optical fiber to a bending with different diameters, and to a different temperatures as well as pressure due to putting different weights to study dispersion phenomenon which affects on a pulse shape that travels in optical fiber.

Experimental results explain when a bending diameter for an optical fiber increases it will decrease the dispersion and pulse shape will approximate from a Gaussian shape , and the increasing in temperature will increasing the attenuation in the pulse transfer through the optical fiber .

But when increasing pressure, the dispersion will increases and the pulse shape will be distorted.

Key wards: Optical fiber, single mode fiber, dispersion, heating, pressure, and bending.

الخلاصة

في هذا البحث تم استخدام ليف بصري احادي النمط بمعامل انكسار (1.50) للب و(1.485) للغلاف وبطول (2m). تم تعريض هذا الليف البصري الى انحناءات بأقطار مختلفة وايضا درجات حرارة متغيرة, وكذلك ضغط من خلال وضع اوزان مختلفة, ودراسة ظاهرة التشتت التي تؤثر على شكل النبضة المنتقلة داخل الليف البصري, ومن خلال النتائج العملية تبين انه عند زيادة قطر الانحناء لليف البصري يقل التشتت ويقترب شكل النبضة من الشكل الكاوسي. وكذلك عند زيادة درجة الحرارة تحصل زيادة في توهين النبضة المنتقلة خلال الليف البصري , اما عند زيادة الضغط سوف يزداد التشتت ويحصل تشوه في شكل النبضة.

الكلمات المفتاحية: الليف البصري, الليف احادي النمط, التشتت, الحرارة, الضغط, والانحناء.

1. Introduction

An optical fiber is a cylindrical dielectric waveguide made of low-loss materials such as silica glass. It has a central core in which the light is guided, embedded in an outer cladding of slightly lower refractive index . Light rays incident on the core-cladding boundary at angles greater than the critical angle undergo total internal reflection and are guided through the core without refraction[Bahaa *et al.*,1991]. Optical fiber have two types (single mode and multi mode) . Single mode fibers have a core diameter that is larger than the wavelength only by a small factor; typical values range between (7 and 10) µm , In contrast, Single mode and multi mode fibers have cladding of (125) µm [Fedor Mitschke, 2009].

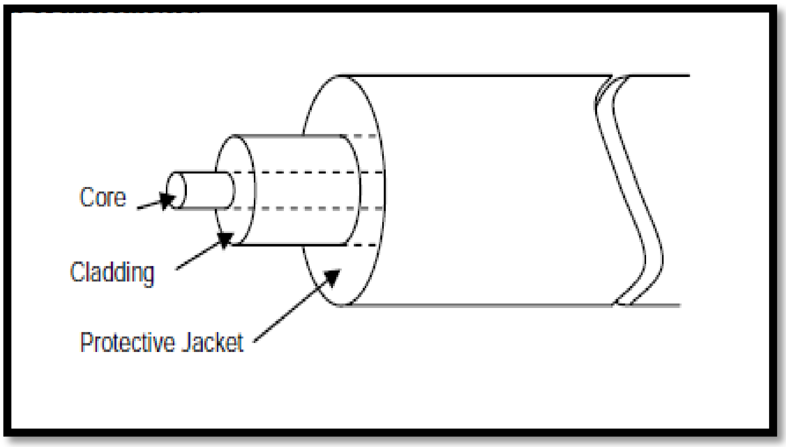

Figure (1): Basic construction of optical fiber[Mohammad,2008]

2. Dispersion in optical fiber

Inside an optical fiber , different light frequencies and different modes need different times to travel from a given location A to another location B. This phenomenon is called dispersion and originating from various different effects. Generally speaking , dispersion leads to pulse broadening in optical transmission which is increasing with distance.

This pulse broadening results in reduction of the possible transmission bandwidth since two pulses must be distinguishable at the end of the fiber [Nizar *et al.*, 2015].

3. Types of dispersion

- **Group-Velocity Dispersion**

Consider a single-mode fiber of length *L*. A specific spectral component at the frequency (ω) would arrive at the output end of the fiber after a time delay **[**William *et al.* , 2012].The frequency dependence of the group velocity leads to pulse broadening simply because different spectral components of the pulse disperse during propagation and do not arrive simultaneously at the fiber output **[Rajiv Ramaswami** *et al.* , **2010]**.

- **Material Dispersion**

Material dispersion is a phenomenon that occurs because light sources put out a signal, which contains a number of different wavelengths. No light source can produce just one frequency (wavelength). It will produce a spectral spread around a central frequency **[**Bailely and Wright,2003].

- **Chromatic dispersion**

Chromatic dispersion (CD) is a property of optical fiber (or optical component) that causes different wavelengths of light to propagate at different velocities. Since all light sources consist of a narrow spectrum of light (comprising of many wavelengths), all fiber transmissions are affected by chromatic dispersion to some degree. In addition, any signal modulating a light source results in its spectral broadening and hence exacerbating the chromatic dispersion effect. Since each wavelength of a signal pulse propagates in a fiber at a slightly different velocity, each wavelength arrives at the fiber end at a different time **[**Nizar Salim *et al.* ,2013].

- **Waveguide dispersion**

Waveguide dispersion occurs in single mode fibers (which are of step index construction) where a certain amount of the light travels in the cladding. The dispersion occurs because the light moves faster in the low refractive index cladding than in the higher refractive index core. The degree of waveguide dispersion depends on the proportion of light that travels in the cladding [Bailely and Wright,2003] .

- **Polarization mode dispersion**

Polarization mode dispersion (PMD) is a property of a single-mode fiber or an optical component where pulse spreading is caused by different propagation velocities of the signal's two orthogonal polarizations [Nizar Salim *et al.*,2013].

4. Attenuation in optical fiber

Attenuation is one important characteristic of an optical fiber, since it determines the repeater spacing in a fiber transmission system. The lower the attenuation, the greater will be the required repeater spacing and lower will be the cost of that system.

5. Results and discussion

It was built an optical communication system consist of He-Ne laser and single mode optical fiber with a refractive index (1.50) for core, and (1.485) for cladding, and it was used a CCD camera as an optical detector, and it was exposed an optical fiber to a three phenomena (bending, heating, and pressure) to find out the impact of these conditions on the pulse shape emerging.

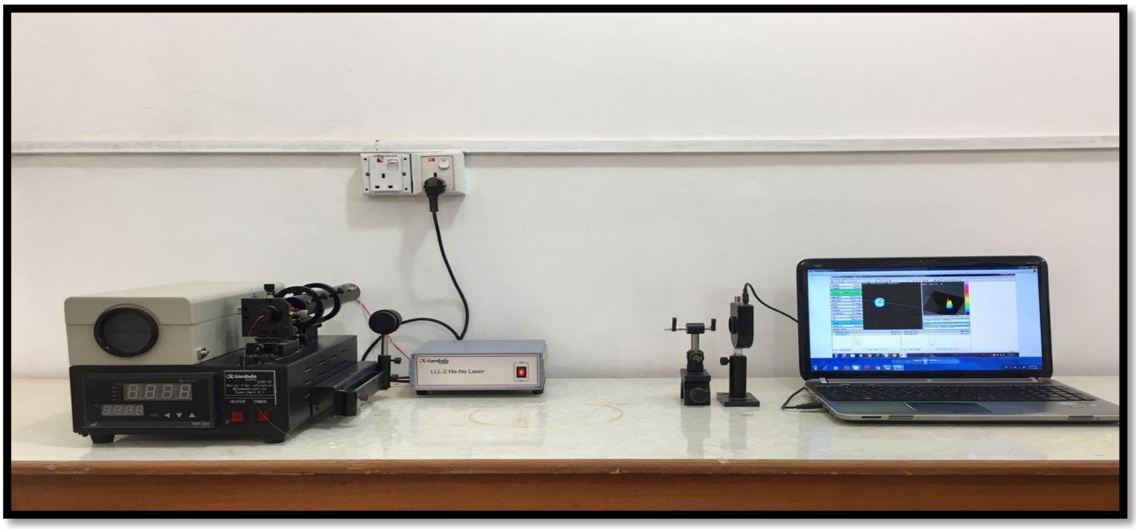

Figure (2) : Optical communication system

- **Without dispersion**

Figure (3) represents Gaussian pulse sent through the single mode fiber has been received without the occurrence of any external effect on the optical fiber.

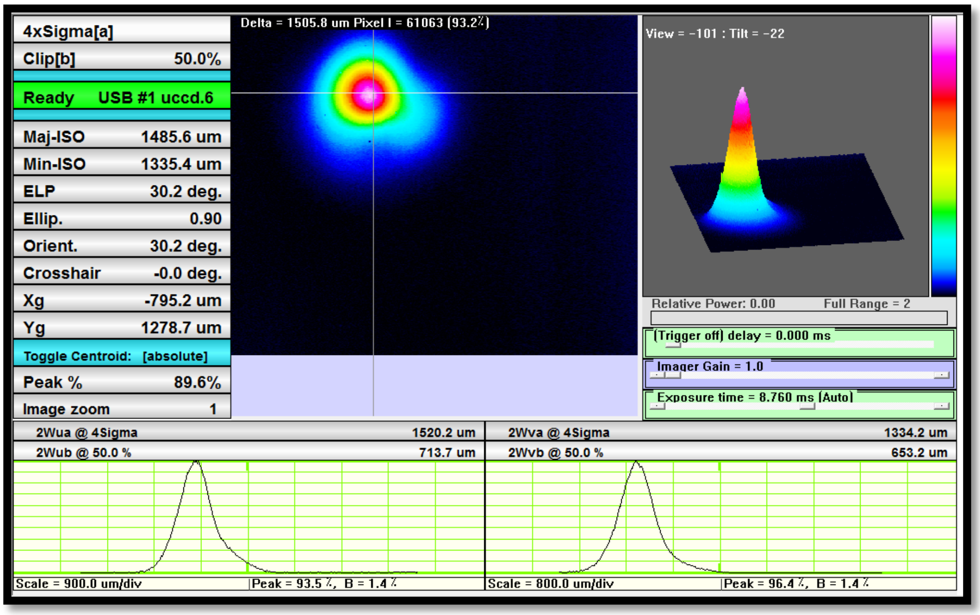

Figure (3) Gaussian pulse without dispersion.

- **Bending**

  Figure (4) This pulse represents a clear case for dispersion of the pulse as a result of the effect of bending and therefore will receive a large increase in deformation and separation pulse, where three peaks appeared, and that means increasing in dispersion.

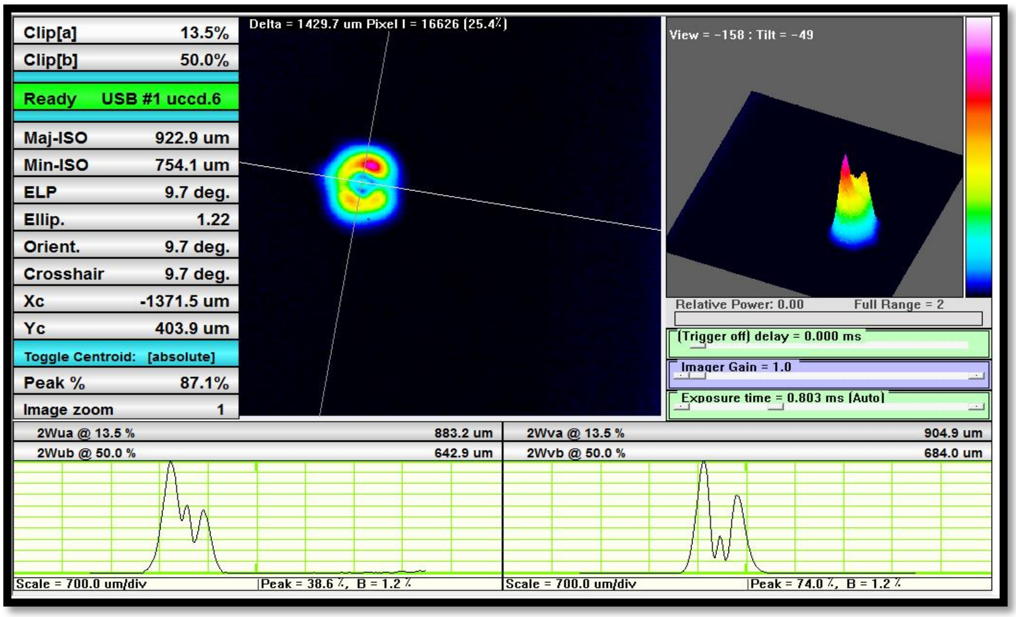

Figure (4): Dispersion effects at diameter (6.5) cm.

Figure (5) explain at the increasing of fiber optic diameter leads to emergence of two peaks and that means the dispersion will decreases.

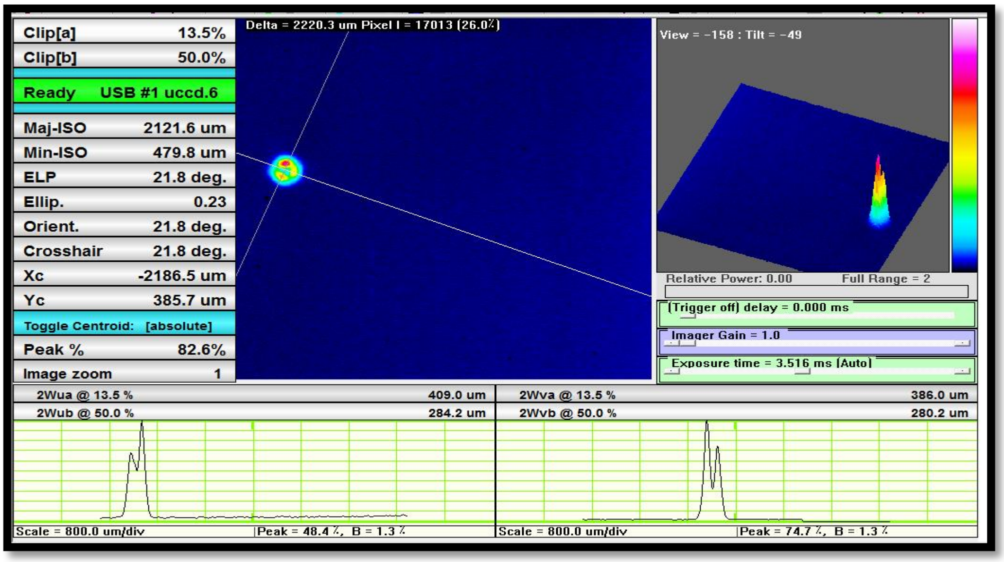

Figure (5): Dispersion effects at diameter (15) cm.

Figure (6) represent that when the diameter is (25) cm that means when the diameter of the fiber optic bending increases the pulse width will decrease, which means that the dispersion will decrease.

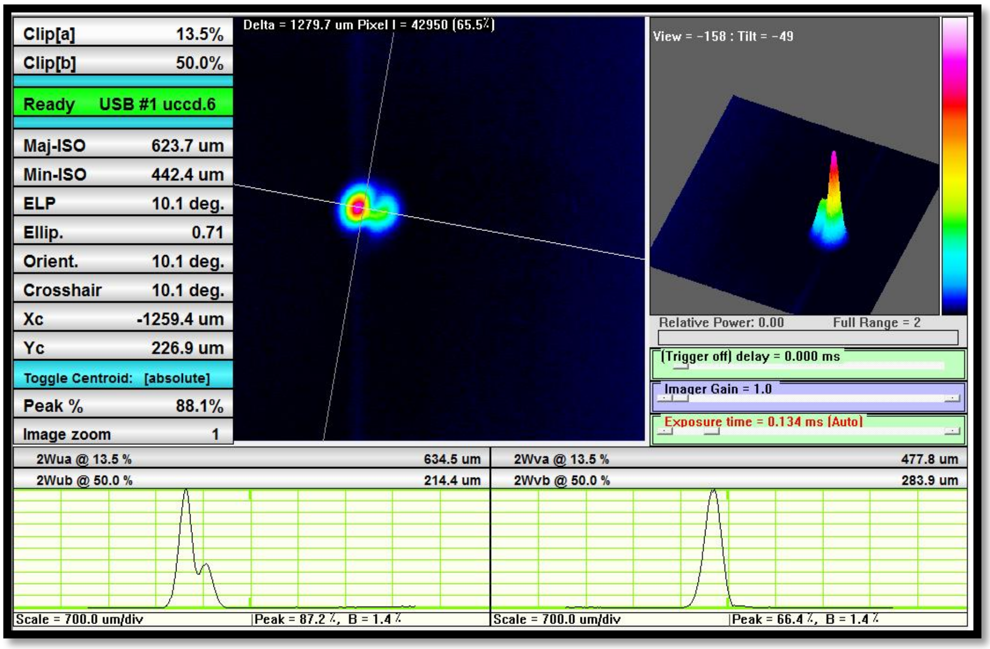

Figure (6): Dispersion effects at diameter (25) cm.

Figure (7) The pulse not exposed too much dispersion as a result the pulse shape approaching to the shape of the Gaussian pulse shape.

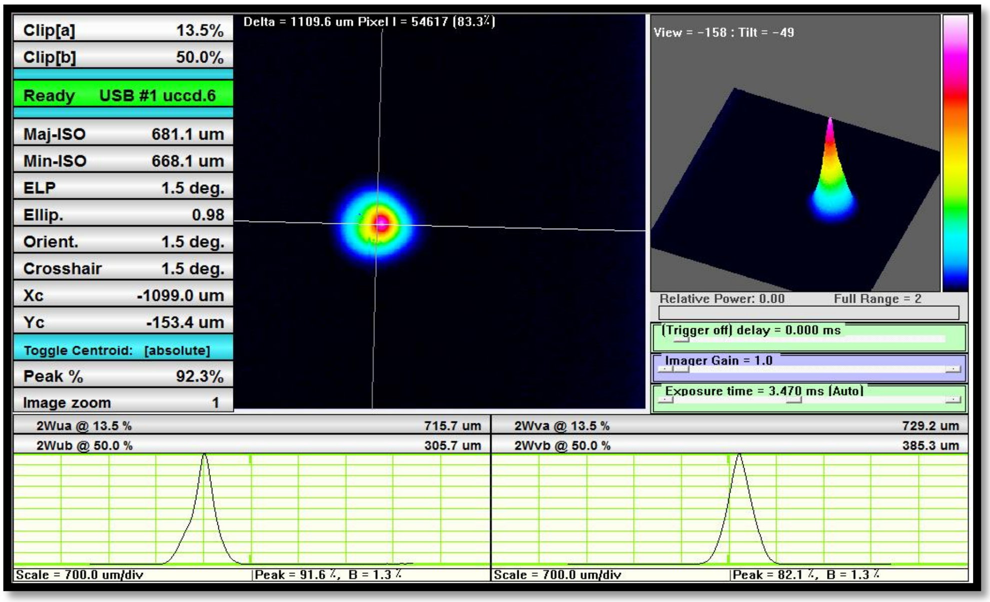

Figure (7): Dispersion effects at diameter (35) cm.

- **Heating**

  Figure (8) Represents the effect of heating on the pulse traveling through the optical fiber .

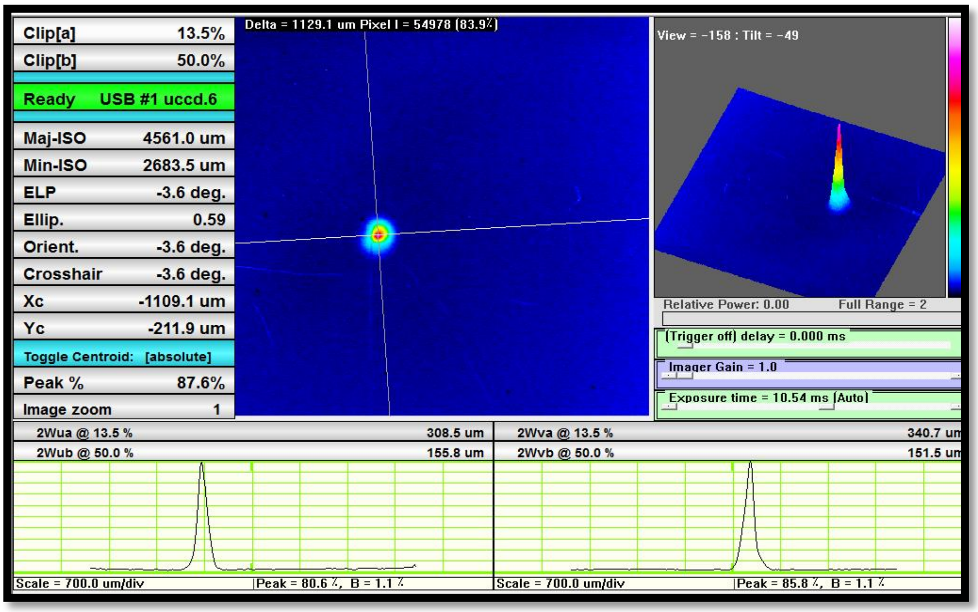

Figure (8):Attenuation effect at (30^{o} C)

Figure (9) Explain a gradual increase in temperature, relative decreasing in spot which leads to increased attenuation .

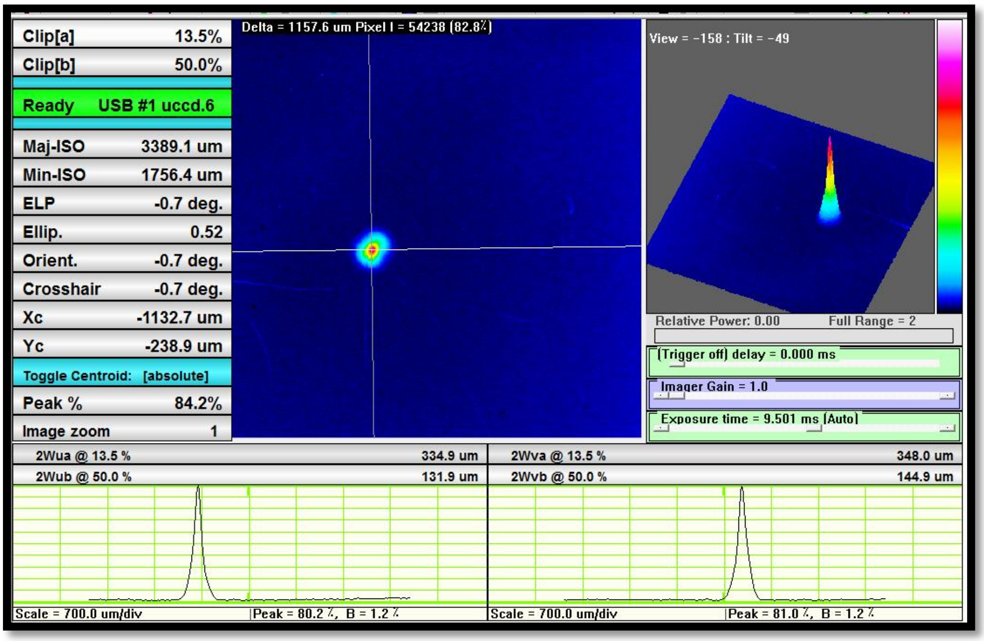

Figure (9): Attenuation effect at (40^{o} C)

Figure (10) Represent an increases in temperature will be increases in attenuation and reduction in spot , because the temperature increase of the internal energy of the particles and increased movement of impurities leading to obstruction of the signal transmission within the optical fiber.

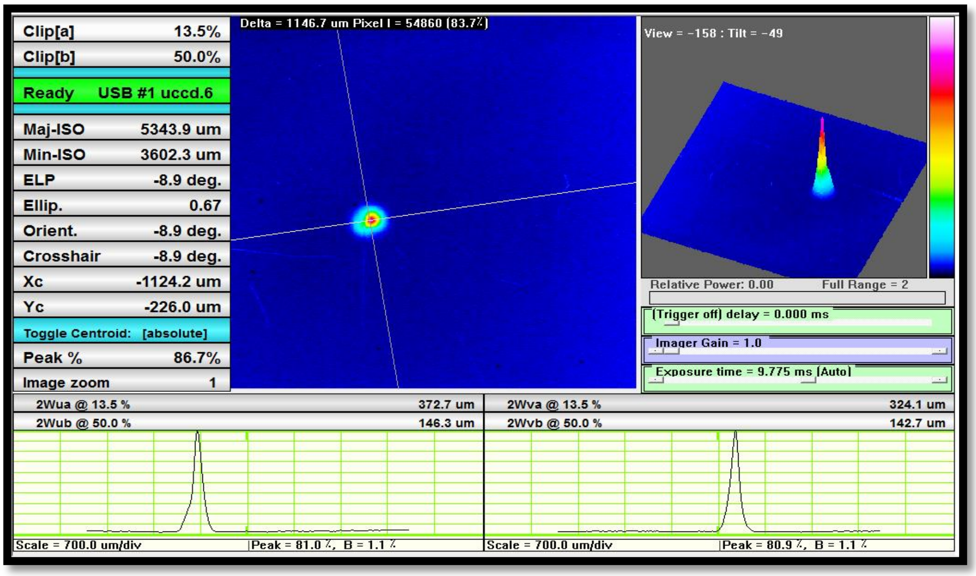

Figure (10): Attenuation effect at (50^{o} C)

Figure (11) Explain the reduction in spot results from attenuation .

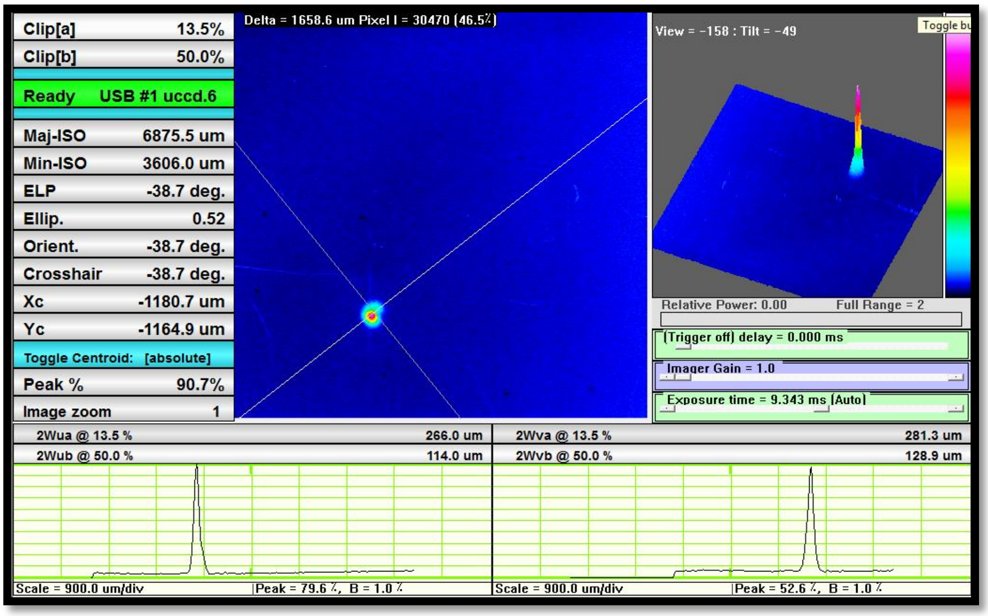

Figure (11): Attenuation effect at (60^o C)

Figure (12) At high temperature the attenuation will be increasing, and the spot will be very narrow.

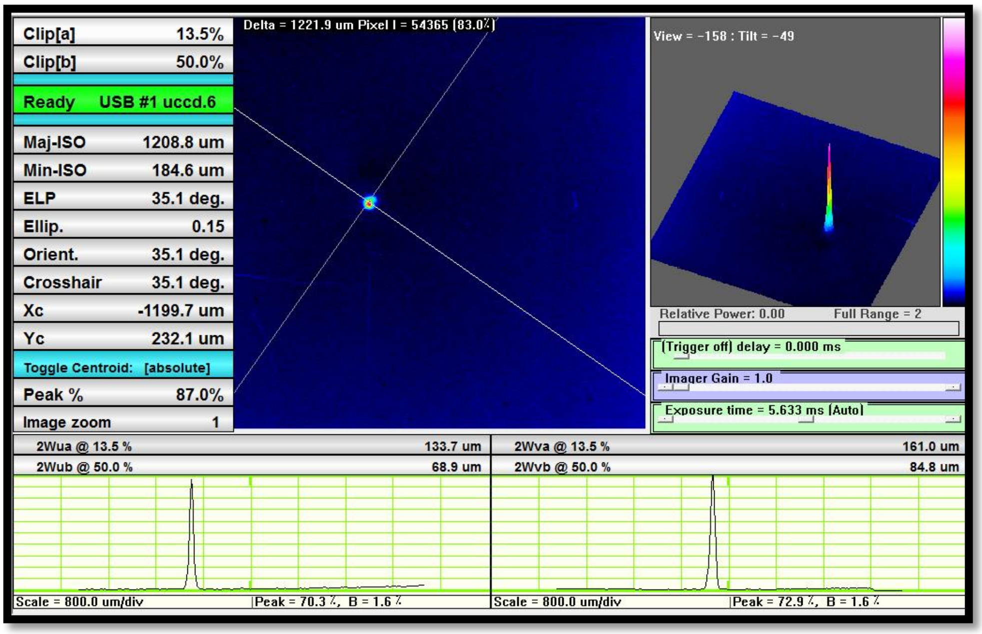

Figure (12): Attenuation effect at (70^o C)

- **Pressure**

In figure (13) note in this case when putting certain amount of weights on the single mode fiber, the pulse width will increase.

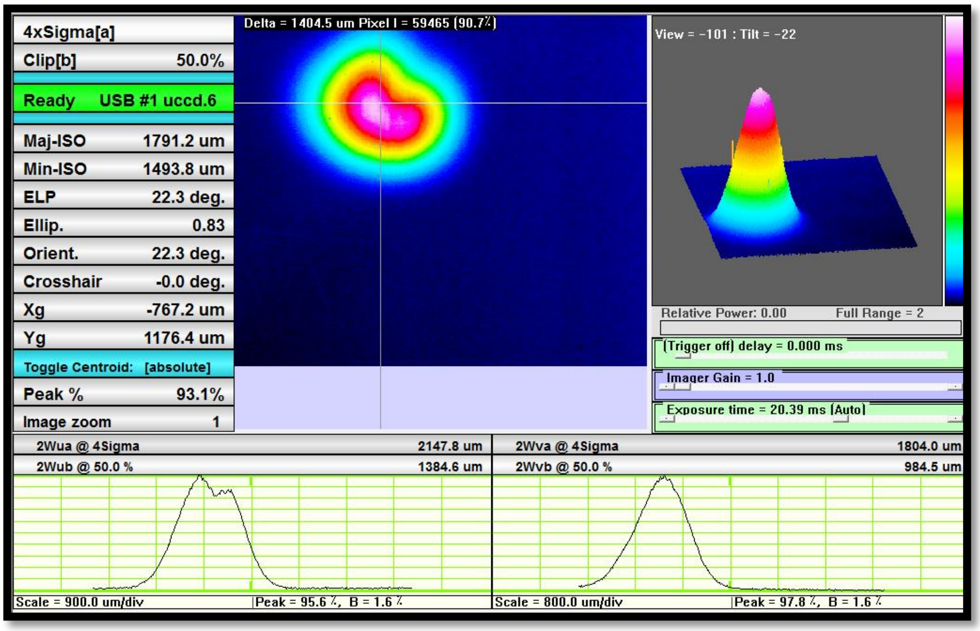

Figure (13): Dispersion effects at weight (1.5) kg .

Figure (14) in this case when increasing the amount of weights hanging over single mode fiber gets more increase in pulse width.

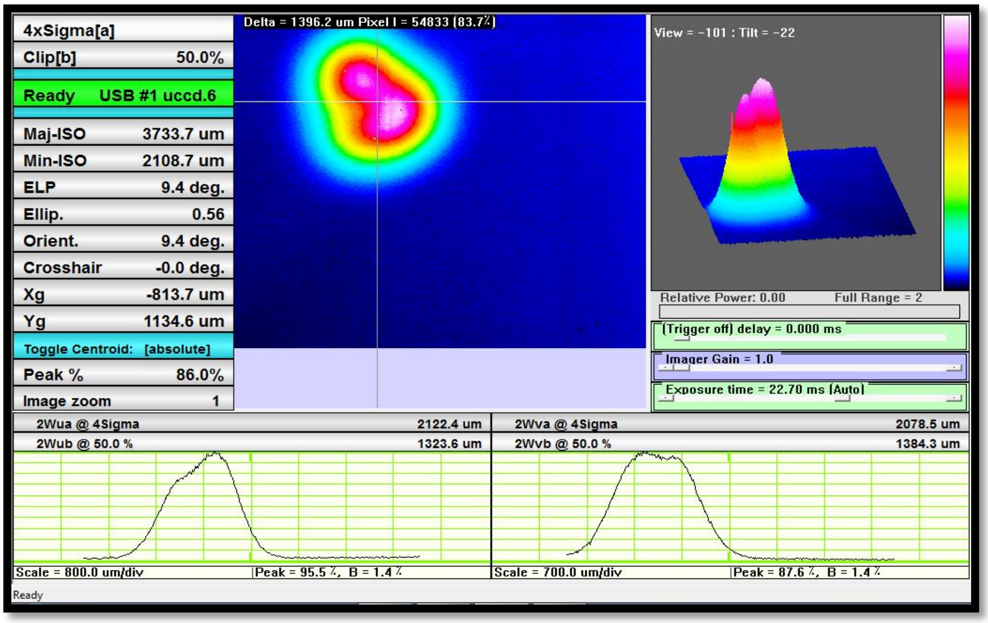

Figure (14): Dispersion effects at weight (4) kg.

Figure (15) this case shows increase the weight on the optical fiber will get deformation in pulse extra.

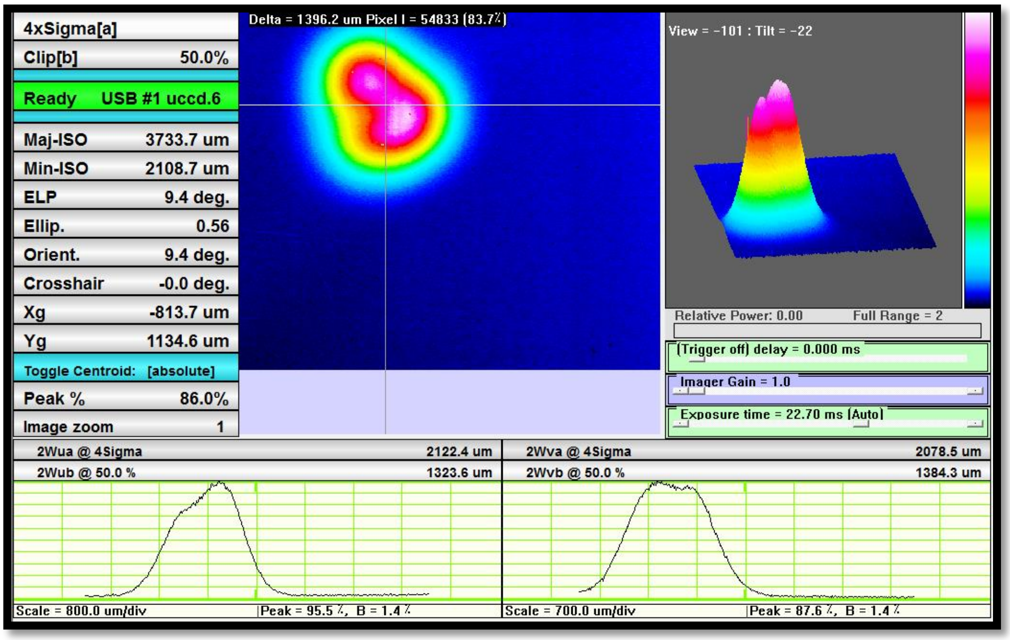

Figure (15): Dispersion effects at weight (4.5) kg.

Figure (16) represents a clear case of pulse dispersion effect as a result of pressure off the optical fiber and thus will get a large increase in deformation and separation pulse.

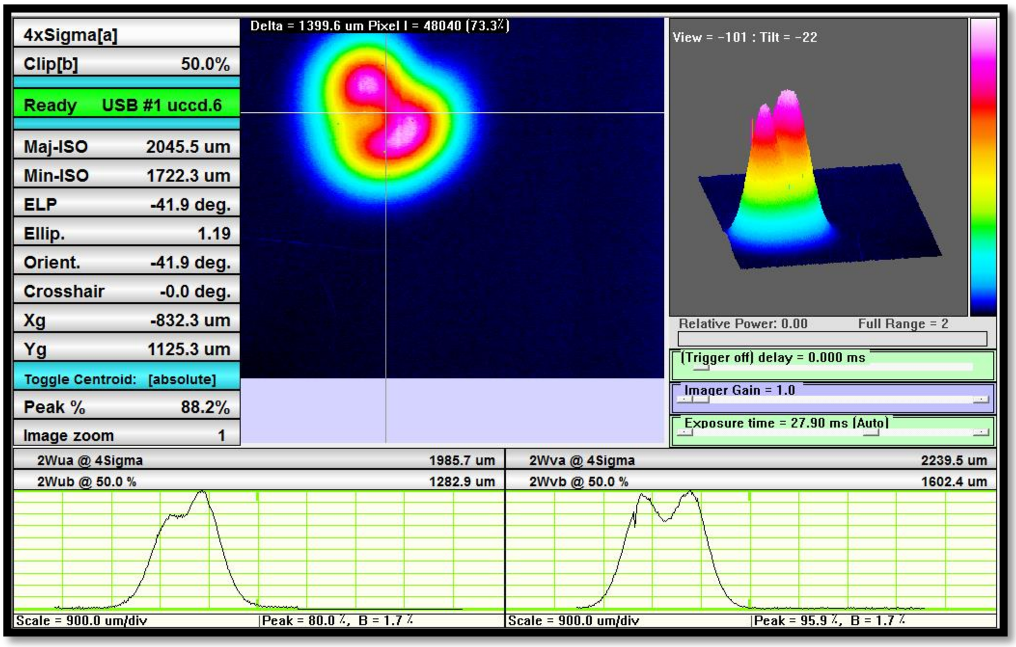

Figure (16): Dispersion effects at weight (5.75) kg.

6. Conclusions

1- Fiber bending has a big affect on output pulse shape .The increasing in the fiber bending diameter, that will decrease the dispersion.

2-When the bending diameter equal to (15) cm , the pulse shape will be separated in two pulse .That's mean the deformation on the fiber core cause the deformation on the pulse shape.

3-The temperature effect on single mode fiber causes attenuation in pulse traveling through optical fiber.

4-When temperature equal to (70^oC) , the pulse will be very narrow . That's mean the deformation on the fiber core cause the deformation on the pulse shape.

5-The pressure on single mode fiber causes broadening of pulse width , increasing of pressure on single mode fiber causes increasing of pulse width.

6-When the weight on single mode fiber equal to (5.57) kg , the pulse shape will be separated in two pulse . That's mean the deformation on the fiber core cause the deformation on the pulse shape.

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