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Study the effect of different vibration levels on the Laser Speckle Pattern Using the Walsh Transform

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Abstract

The speckle pattern of the laser interference spots of a multimode optical fiber was studied after shedding vibrations of different intensity by means of the Welch Transformation, which has the advantage of having its basic functions square in the shape of different frequencies. The results were compared with Fourier transformation, where the total frequency difference pattern, its total amount, and the time consumed in the calculation were compared, the results were discussed with recommendations.

Keywords: Laser speckle, Model-noise, Discrete Walsh Transform, Fourier Transform, Frequency Domain Analysis.

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دراسة تأثير مستويات الاهتزاز المختلفة على نمط البقع بالليزر باستخدام تحويل والش

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الخلاصة

تم دراسة نمط البقع في بقع التداخل بالليزر للألياف الضوئية متعددة الأنماط بعد التخلص من اهتزازات ذات شدات مختلفة باستخدام تحويل ويلش، والذي يتميز بجعل وظائفه الأساسية مربعة في شكل ترددات مختلفة. تمت مقارنة النتائج مع تحويل فوريه، حيث تمت مقارنة نمط فرق التردد الكلي، ومقداره الإجمالي، والوقت المستغرق في الحساب. تمت مناقشة النتائج مع التوصيات.

الكلمات المفتاحية: بقع الليزر، ضوضاء النموذج، تحويل والش المنفصل، تحويل فوريه، تحليل المجال الترددي.

Introduction:

The low cost and ease of use of optical fibers and lasers in general, make their applications vast at the present time to extend to various fields from wired and wireless communications to their uses in sensing. Despite this diversity of applications, the main application of optical fibers remains data transmission, as the binary system is used to represent data when using a laser in an optical fiber by controlling the intensity of the laser passing through the optical fiber. In order to ensure that there is no expansion or distortion of the signal represented by the laser during its

passage in the optical fiber, single-mode fibers are usually used because they allow one type of signal to pass through it [1].

Away from the applications of optical fibers in communications, the other type of it (i.e., multimode fibers) is used in other applications, although multi-mode optical fibers suffer from the presence of noise, as it allows a large number of modes to pass through it, which causes the expansion and distortion of the passing signal as a result of the random interference of patterns [2], as shown in the figure 1.

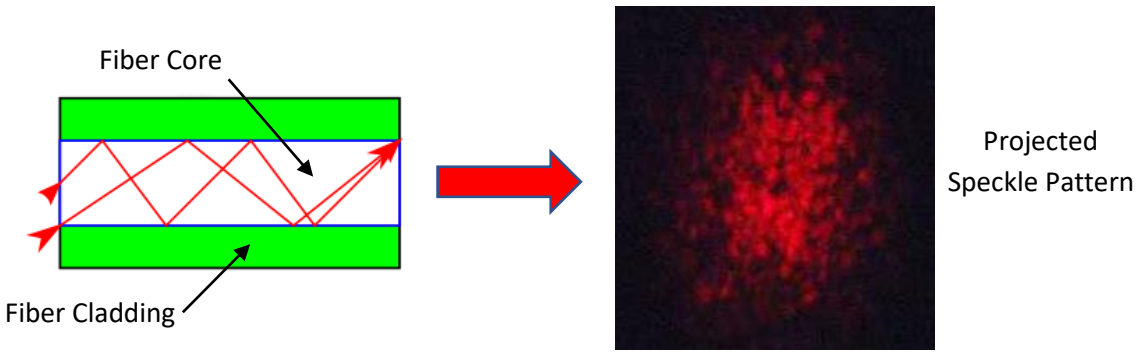


Fig (1). The laser speckle pattern due the interreference between the different modes in the multimode fiber

This distortion is known as pattern noise or speckles [3] [4] [5]. The interference between the different modes in the multimode fiber optics, depends on many factors that cause changing in the fiber dimensions (i.e. length or radius) or its refraction indices, these factors could be heat, strain, joints (connectors or splices) … [6] [7]. This random interference between the different modes passing through the multimode fibers will appear in the received signal as a constant pattern of amplitude modulation unless the factors affecting the fibers change, When the factors affecting the fibers change, this will change the pattern of model noise or speckles [8] [9]. Because of the change of factors affecting the optical fibers, the appropriate domain to study the

change in the speckles pattern is in the frequency domain, and the Fourier transform is usually used to analyze this change [10]. However, the main problem that the researcher encounter when using the Fourier transform is dealing with complex numbers since the frequency domain of the Fourier transform is a complex number, which will require converting the frequency values to real numbers by finding the frequency magnitude [11] [12] [13]. So, when we use the Fourier transform to analyze the change in the speckles pattern, we do not deal with the frequency itself as much as we deal with a modified form of the frequency, which will leave an error percent on the analysis process for the change [14] [15]. The advantage of the Walsh transform lies in the fact that the frequency domain is composed of real numbers, which allows dealing with the change in the speckles pattern without modification [16]. In addition, the basic functions of the Walsh transform are square and not sine, as found in the Fourier transform [17], and as shown in the figure 2.

From this point of view, this research compares the study of the change in the speckles pattern in the Fourier domain and the Walsh domain due to external influences represented by projecting a vibrational motion of different intensities on the multimodal fibers.

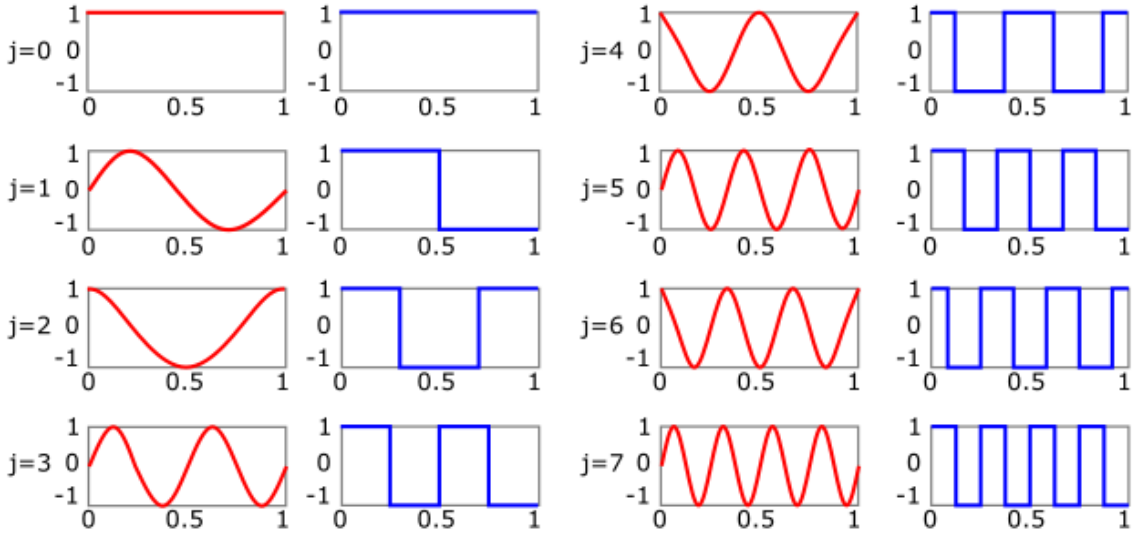


Fig (2). The Fourier (in red) and equivalents Walsh (in blue) transforms Base functions for different harmonics

Methodology

- A laser system model constructed in order to produce and analysis the model noise pattern, which consist of Helium-Neon laser source, lens, multimode fiber optics (Panduit 62.5/125 Type OFNR (UL)), and screen as illustrated in figure 3.

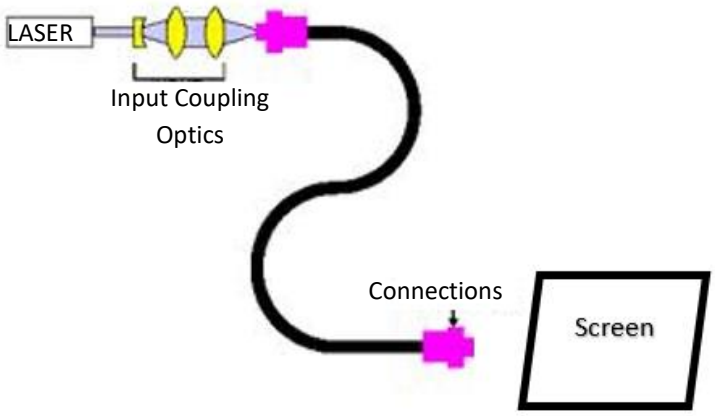


Fig (3). Scheme of the Laser system that used in this research work

- The noise model pattern captured using video camera (Canon, HX1, 30 frame per second) as illustrated in the below figure, after applying different influence factors.

- in this research we used three different vibration frequencies that rating from low, moderate and fast. The second step is analyzing these patterns using Walsh and Fourier transforms.

The whole stapes of the research methodology can be represented in the following follow diagram that represented in figure 4.

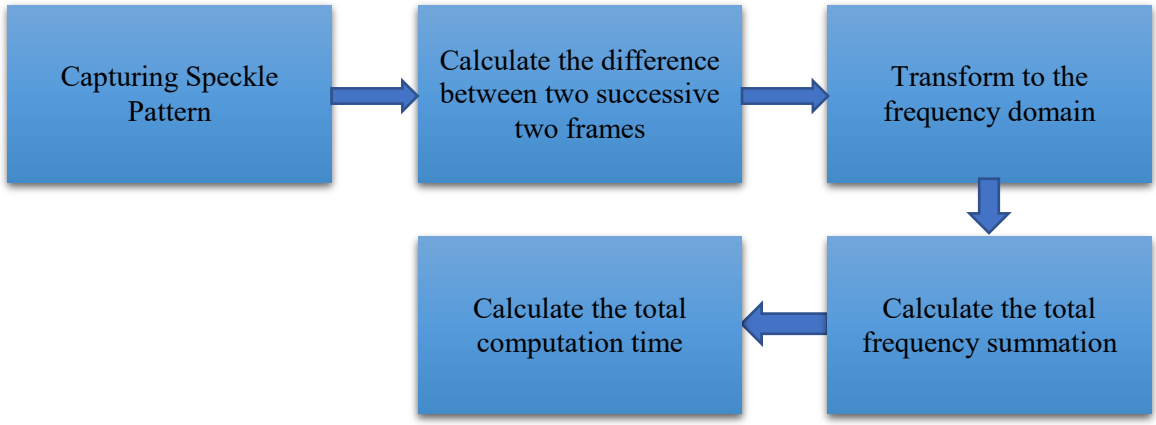


Fig (4). The steps that represent the research methodology

Results and Discussion

To study the changes in the pattern of speckles when applying vibrations of different intensities, see figure 5, Fourier and Walsh transform coefficients were calculated for the total summation of the differences between two successive frames. In addition, we can observe the value of the high frequencies coefficients increases with vibration, which shows the increase and rapid change in the pattern of speckles with vibration for both transforms, see figure 6.

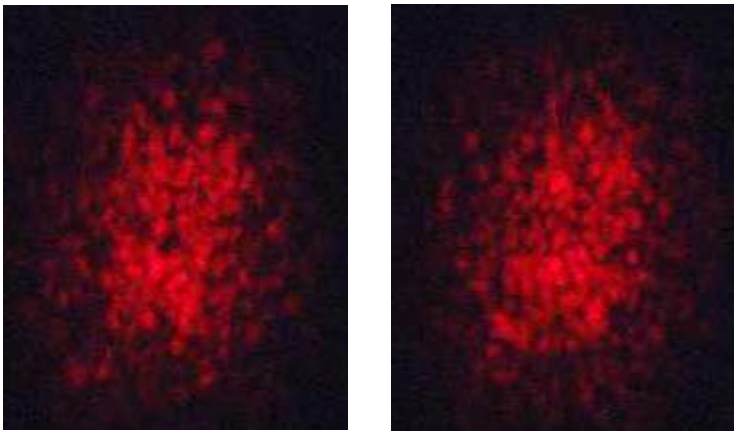


Fig (5). The change in the speckle pattern due to applying the vibration on the fiber

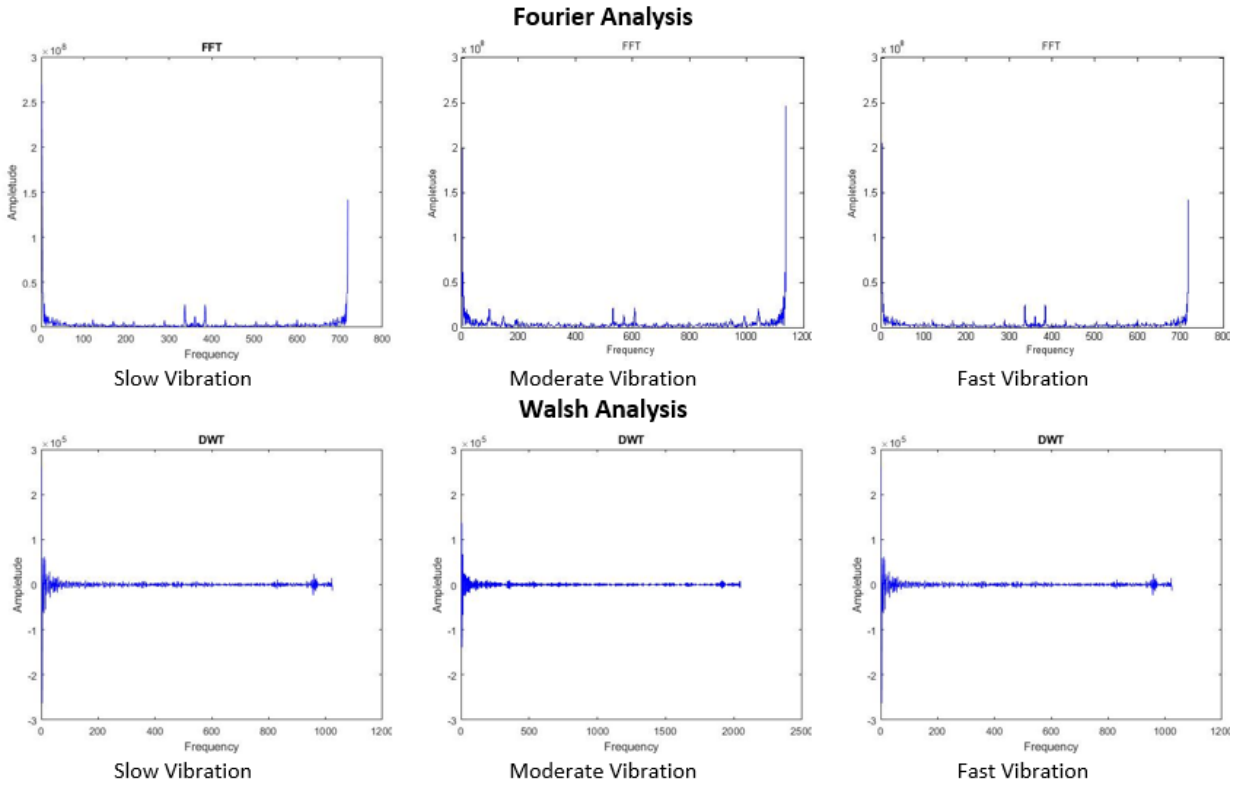


Fig (6). The Fourier (magnitude) and Walsh coefficients of the speckle pattern differences

For the same transform, the frequencies pattern is almost the same, the difference between them, in Fourier transform suffer from

complex to magnitude conversing, therefore, it does not represent the alteration in the model-noise pattern precisely, while for Walsh transform, the frequency behavior belongs to the changing in the model-nose pattern.

The effect of the increase in the vibration intensity can be noticed in the total summation of the transform's coefficients, which represent the strength of the chances in the speckles pattern, as illustrated in figure 7.



Fig (7). The accumulated coefficients for Fourier and Walsh

The computation time to analyze the speckles pattern is calculated for both transforms, as illustrated in figure 8, which we can notice that there is forward relation between the vibration intensity that applied on the fiber with the computation time. besides that, it is obvious that Walsh needs in general more time comparing to use the Fourier transform.

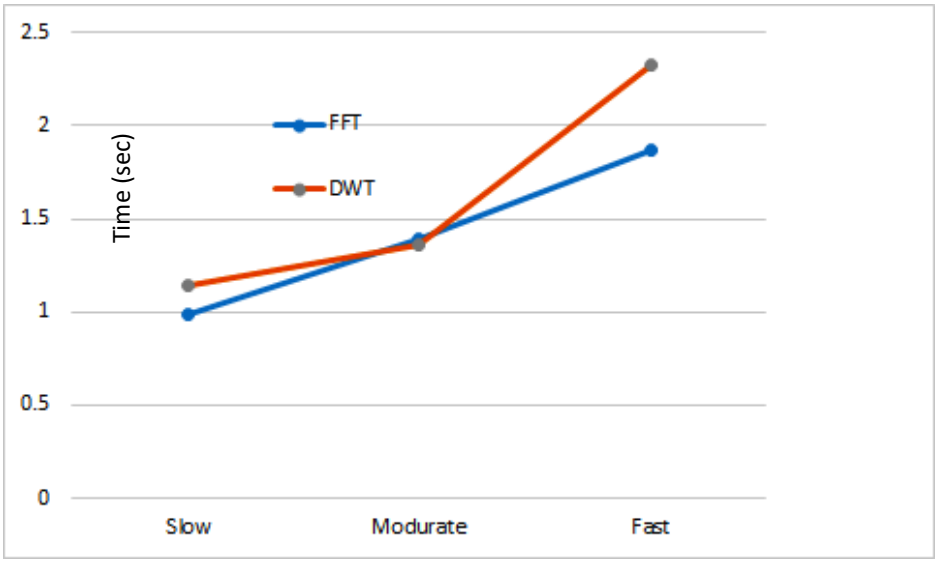


Fig (8). The computation time for applying Fourier and Walsh transform

Conclusions

The results of using Walsh transform to analyze the changes in the speckles pattern due to applying different vibration on the fiber is concise with result that obtain from the use of Fourier transform, in spite of the great differences between the base function of the two transforms, but it is interesting to mention that the Walsh transform is more accurate in describing the changes in the speckle pattern more than Fourier transform since it coefficients does not suffer any kind of alteration as it in Fourier transform, therefore, we recommend to use Walsh transform to analyze the changes in the speckles pattern.

The accumulated effect of the coefficients of the transforms increases with the intensity of the vibration. the total computational time for both transforms increase with the vibration intensity but for Walsh transform it need in general little more time compared to the Fourier transform. According to the calculated computational time for both transform, using the Walsh transform dose not differ a lot comparing to the Fourier transform.

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