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# Comparative analysis of signal processing techniques for multimode polymer fiber interferometers

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## ABSTRACT

This study explores speckle pattern matching methods for deformation sensing using multimode polymer fiber interferometers. The research highlights the benefits of multimode polymer optical fibers, including their flexibility, cost-efficiency, and compatibility with complex structures, making them ideal for strain sensing applications. The primary focus is to evaluate and compare advanced image matching techniques, specifically the sum of squared differences, zero mean normalized cross-correlation, and phase-only correlation. These methods are assessed based on essential metrics such as linearity, precision, and signal-to-noise ratio. Experimental results indicate that phase-only correlation outperforms the other techniques in overall performance, offering combination of high linearity, moderate precision, and strong noise rejection. The normalized cross-correlation also demonstrates competitive results, while the sum of squared differences, despite its strengths in linearity, shows lower precision and weaker resistance to noise. The findings provide a practical framework for selecting suitable signal processing techniques to optimize multimode polymer fiber interferometers for various sensing demands. This work offers novel contributions to the field, highlighting the unique strengths and limitations of each method. These insights are expected to guide the future design and development of advanced fiber-based sensing systems.

**Keywords:** Fiber optic interferometer; multimode interference; speckle pattern matching; image processing techniques

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## INTRODUCTION

Fiber optic sensors, particularly those based on interferometric sensing principles, have received interest as tools for a wide range of applications, including structural health monitoring, biomedical diagnostics, and industrial automation. Their exceptional attributes such as high sensitivity, immunity to electromagnetic interference, lightweight nature, and compact size position them as good candidates for addressing complex sensing challenges in these domains [1], [2], [3], [4], [5]. Among the various types of fiber technologies, multimode polymer optical fibers (POFs) have emerged as a promising sensitive element owing to their inherent flexibility, cost-effectiveness, and ease of integration into intricate structural designs.

A key application of multimode POFs is strain and deformation sensing, where they use multimode interference effects to detect changes in the optical path length induced by external perturbations. In multimode fiber interferometers, the speckle patterns formed by the interference of guided modes exhibit an exceptional sensitivity to external deformations [6], [7], making them a compelling option for advanced sensing applications. However, effectively using these speckle patterns presents a significant challenge, as it requires robust signal processing techniques to extract information regarding the applied deformation.

To address this challenge, researchers have explored a variety of signal processing algorithms to decode and analyze the complex speckle patterns generated within multimode fiber interferometers. Each approach offers a unique set of advantages, encompassing factors such as sensitivity, computational efficiency, resilience to environmental noise, and adaptability to real-world operating conditions. The continued development and optimization of these processing methodologies remain critical to unlocking the full potential of multimode POF-based sensing technologies in diverse application scenarios.

Fiber speckle pattern analysis has emerged as a promising tool for measuring various physical and chemical parameters. In particular, speckle pattern sensing techniques have been applied in numerous domains, including displacement measurement [8], strain sensing [9], force detection [10], temperature monitoring [11], vibration analysis [12], and chemical concentration determination [13]. Practical implementations of these methods have been demonstrated in structural health monitoring [14], biomedical applications [15], and machine learning-based sensing [16].

One of the key challenges in speckle image analysis is extracting accurate and meaningful measurand values from high-dimensional specklegram images. The optical field generated in a multimode fiber interferometer exhibits complex spatial fluctuations influenced by amplitude and phase changes across multiple optical modes. Therefore, simple intensity-based metrics fall short in characterizing the patterns effectively. Overcoming these challenges often involves employing advanced image processing techniques, primarily focused on correlating images captured under reference and disturbed states of the optical fiber. Methods such as normalized correlation coefficients [17], phase-only correlation [18], and statistical intensity analysis [19] have demonstrated the ability to perform precise measurements of deformation and strain with high sensitivity. However, these methods come with limitations that include trade-offs between resolution, computational cost, and dynamic range. To address these issues, researchers have implemented strategies such as frame differencing [20], subdividing specklegram regions [21], or resetting reference images periodically [22].

Modern developments in image matching and registration techniques have further expanded the scope of fiber speckle analysis. These approaches aim to compare images of the same scene taken at different times to evaluate perturbations caused by external stimuli such as translation, rotation, or scaling. For instance, the use of functions such as the sum of squared differences (SSD) [23], zero-mean normalized cross-correlation (ZNCC) [24], and phase-only correlation (POC) [25] has gained traction in multimode speckle interferometry. These techniques offer measurable advantages in aligning and evaluating image similarity while ensuring low computational overhead, making them suitable for real-time applications. Additionally, template matching methods and localized peak tracking approaches [26[, [27] have proven effective in situations where high spatial accuracy and resilience against noise are required.

While these methods are highly promising, some still rely on image preprocessing, calibration procedures, or computational adjustments, which may limit their practical use. Therefore, ongoing research continues to refine these techniques, striving to balance sensitivity, precision, and computational efficiency for diverse sensing applications enabled by multimode fiber speckle pattern analysis.

Previous research in the field of interferometric fiber optic sensors has focused primarily on the use of glass fibers as sensitive elements, while polymer optical fibers remain largely unexplored in this context. For instance, in the work [33], statistical features were proposed for the analysis of speckle patterns in glass fibers, which improved sensor sensitivity. However, the potential application of polymer fibers, characterized by greater flexibility and easier integration into complex structures, was not considered. The research [28] presents a comparison of specklegram processing methods, such as SSD and normalized cross-correlation, for sensors based on glass fibers. The authors highlighted the accuracy of correlation-based techniques but noted their limited noise resistance and the need for complex calibration procedures. The study [34] focuses on statistical approaches for multimode fiber vibration sensors, demonstrating that phase correlation methods provide better linearity, yet remain sensitive to external disturbances. Meanwhile, the potential of polymer optical fibers which offer low cost, high flexibility, and ease of installation has been overlooked in these works. Therefore, a systematic investigation of the specific features and advantages of polymer fibers as sensitive elements in interferometric sensors remains a relevant and insufficiently addressed topic.

## RESEARCH OBJECTIVE AND AIMS

The objective of this study is to conduct a comprehensive comparative analysis of signal processing techniques for multimode polymer fiber based interferometers.

To accomplish this, the following specific aims have been established:

1) review and analyze current image correlation and matching algorithms employed for speckle pattern processing in multimode fiber interferometers;

2) experimentally evaluate the performance of SSD, ZNCC, and POC methods applied to polymer fiber based interferometers, with a focus on key metrics such as linearity, precision, and signal-to-noise ratio (SNR). The findings of this study will guide the selection of the most suitable signal processing approach tailored to specific sensor requirements and applications.

## INTERFEROMETRIC SENSORS WITH MULTIMODE FIBERS

Interferometric sensors and transducers using multimode optical fibers operate based on the principle of modal interference, where modes propagating through the fiber at different phase velocities interact to produce a measurable signal. These devices utilize modal interference within a single optical waveguide to measure external


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mechanical perturbations. The output of the interferometer represents a complex optical signal formed by the interference of numerous guided modes, where each mode has its own spatial intensity distribution and phase delay.

When laser light illuminates the end of an optical fiber, it is guided within the core by the principle of total internal reflection. Multimode optical fibers support more modes compared to single-mode fibers, primarily due to their significantly larger core diameters. This characteristic enables multimode fibers to propagate multiple modes simultaneously.

However, these guided modes exhibit different propagation times as they travel through the fiber. Consequently, they interfere with one another when exiting the fiber, a result of their randomly varying phases. This interference leads to a distinctive output phenomenon. Notably, a speckle pattern arises only if the coherence time of the optical source significantly exceeds the time delay differences between any two modes. This condition ensures that optical coherence is maintained across the modes, facilitating the formation of the speckle pattern.

An example of such a speckle pattern is illustrated in Fig. 1a, providing a visual representation of this optical behavior. This phenomenon is especially relevant in understanding the interplay between fiber architecture, light propagation characteristics, and the coherence properties of the light source [22].

The transverse distribution of speckle patterns is primarily influenced by mode interference and mode coupling within the optical system. Theoretical analysis indicates that the interference of modes is governed by the amplitudes and relative phases of each mode involved. Consequently, under the assumption that the effects of divergence and spatial diffraction of light propagating from the fiber's output end to the digital camera's receiving plane are negligible, the light field E(x, y) and corresponding intensity distribution I(x, y) of the output speckle pattern projected onto the CCD sensing plane (x, y) can be mathematically expressed as following:

$$E(x,y) = \sum_{k} A_k \exp(i\varphi_k)\, \Phi_k(x,y), \quad (1)$$

$$I(x,y) = \sum_{m=1}^{k} \sum_{n=1}^{k} A_m A_n \exp[(i(\varphi_m - (\varphi_n)]\, \Phi_m(x,y) \Phi_n(x,y). \quad (2)$$

Here, $A_k$ and $\phi_k$ denote the amplitude and relative phase, respectively, of the k-th mode. The parameters m and n correspond to the orders of the *m*-th and *n*-th eigenmodes, represented by $\Phi_k$. The intensity of the resulting speckle pattern is significantly influenced by the relative phase deviation, defined as $\Delta\varphi = \varphi_m - \varphi_n$. The distribution of speckle intensity is governed by the phase difference between the modes and the mode coupling dynamics within the system.

Notably, by modulating the length of the optical fiber, one can induce detectable changes in the speckle pattern arising from modifications in phase relationships and coupling dynamics. This pronounced sensitivity to phase variations facilitates highly precise sensing applications. The speckle intensity fluctuations can be quantified to extract detailed information about external perturbations affecting the optical system, making this approach a suitable tool for advanced fiber-optic sensing technologies.

When using multimode optical fibers for sensing applications, the average size of speckles and their overall number play a critical role. Since a speckle pattern is formed as a result of interference between the guided modes within the fiber, the number of individual speckles observed in the registration plane of the speckle pattern can be considered proportional to the number of modes propagating in the fiber.

Consequently, the total number of speckles at the output of a multimode optical fiber can be approximately estimated as [29]:

$$N_s = \left(\frac{d\pi NA}{\lambda}\right)^2, \quad (3)$$

where $d$ is the fiber core diameter, $NA$ is the numerical aperture, and $\lambda$ is the wavelength of the radiation source. For example, in the case of a standard multimode polymer optical fiber with a core diameter of 980 µm, a numerical aperture of $NA$=0.5, and laser radiation with a wavelength of $\lambda$=0.6328 µm, assuming that all modes are excited within the fiber, the number of generated speckles is approximately $N_s$=6.2*10$^6$. Generally, the number of speckles formed at the output of a multimode fiber is primarily determined by the fiber core diameter and the radiation wavelength.

The average diameter of an individual speckle generated by a multimode optical fiber, measured in the registration plane of the speckle structure located at a distance $R$ from the fiber end, can be calculated using the following expression [30]:

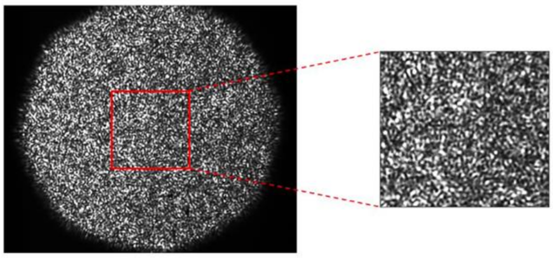
$$S = \frac{1.22\lambda R}{d}. \quad (4)$$

This relation illustrates the dependence of speckle size on the observation distance from the fiber output as well as on the transverse dimensions of the fiber core.

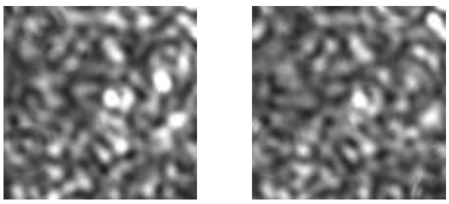
The spatial extent of the speckle pattern generated by the light field emerging from a multimode optical fiber can be determined as follows:

$$D_f = 2NAR. \quad (5)$$

The characteristics of speckle patterns outlined above enable the precise selection of optical component parameters and facilitate the design of measurement system configurations that leverage multimode fibers, tailored to the requirements of specific applications. To ensure the observation of a high-contrast interference speckle pattern at the fiber output, it is essential that the optical path difference between the propagating modes remains within the coherence length of the light source used for mode excitation.



a



b

*Fig. 1.* **Speckle pattern in multimode POF***:*
**a – speckle pattern formed at the output of a 1m long multimode polymer fiber with a core diameter of 980 µm;**
**b – fragments of speckle pattern before and after the application of deformation**
***Source*: compiled by the author**

External mechanical perturbations applied to the optical fiber introduce additional phase shifts between its propagating modes, leading to alterations in the spatial intensity distribution of the speckle pattern (Fig. 1b). By capturing and analyzing these variations, it is possible accurately quantify the magnitude of the external mechanical influence applied on the fiber.

One of the principal advantages of utilizing this type of interferometers lies in its ability to achieve sensitivity levels comparable to those of conventional fiber-optic interferometers, but without necessitating the inclusion of a reference arm. This design innovation not only streamlines the overall architecture of the measurement system but also enhances the sensor's stability in the presence of uncontrolled environmental perturbations, a limitation commonly encountered with traditional interferometric systems. Moreover, the use of multimode optical fibers, characterized by their large numerical aperture, enables these interferometers to efficiently transmit high-power radiation, a key feature that broadens their applicability in demanding measurement environments.

Despite these advantages, the complex spatial structure of the optical signals generated by multimode interferometers demands the development of advanced and efficient methods for signal processing and the interpretation of measurement results. Solving this challenge will further enhance the practicality and accuracy of such systems in real-world applications.

## SPECKLE PATTERN ANALYSIS TECHNIQUES

A simple approach for analyzing speckle patterns involves calculating the normalized average intensity (NI). While the NI metric effectively quantifies overall light attenuation, it falls short in detecting spatial variations in the speckle pattern intensity distribution [30]. Therefore, more advanced methods are necessary to fully characterize the fiber interferometer's performance. For speckle image matching and analysis, both image difference and image correlation features are usually used [28].

The sum of squared differences is one of image matching techniques that based on computing the pixel-by-pixel difference between the reference image $I_0(x, y)$ and the current image $I(x, y)$.

For each pixel $(x, y)$, the difference between the intensities of the two images is squared, and these squared differences are summed across all pixels to obtain a single value, as follows [31]:

$$SSD = \sum_{x=1}^{M}\sum_{y=1}^{N}\left(I(x,y) - I_0(x,y)\right)^2, \quad (6)$$

where $M$ and $N$ are the dimensions of the image. The SSD metric provides a measure of similarity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between the two images, with lower values indicating greater similarity.

Another widely used technique for speckle patterns matching is zero mean normalized cross-correlation (ZNCC). It measures the similarity between two signals while normalizing for variations in intensity and offset.

ZNCC value can be calculated using following equation:

$$ZNCC = \frac{\sum(I_0 - \bar{I}_0)(I - \bar{I})}{[\sum(I_0 - \bar{I}_0)^2 \sum(I - \bar{I})^2]^{1/2}}. \quad (7)$$

Similar to the normalized correlation coefficient algorithm, when the reference speckle pattern image is the same as the measured speckle pattern, the value is equal to 1. When the speckle pattern deviates from the reference image, ZNCC will decrease accordingly.

The phase-only correlation (POC) is a technique used to measure the similarity between the phase components of two images.

Given $F(\omega_x, \omega_x)$ and $F_0(\omega_x, \omega_x)$ as the Fourier transforms [32], [35] of the images $I(x, y)$ and $I_0(x, y)$, respectively, the POC is computed as:

$$POC = IFFT\left[\frac{F(\omega_x, \omega_y)\, F_0^*(\omega_x, \omega_y)}{\left|F(\omega_x, \omega_y)\, F_0^*(\omega_x, \omega_y)\right|}\right], \quad (8)$$

where $IFFT$ denotes the inverse fast Fourier transform, and $F_0^*(\omega_x, \omega_x)$ is the complex conjugate of $F_0(\omega_x, \omega_x)$. This method evaluates the similarity of the phase information between two speckle fields, allowing precise detection of changes in the fiber's state. If the images are similar, the POC returns a surface with a sharp, single peak at the center, indicating zero phase difference. As the images become less correlated, this peak decreases and spreads out. For simplicity, instead of analyzing the entire surface, the POC result can be reduced to its maximum peak value, which can be referred to as the POC value. This peak amplitude serves as an efficient indicator of the degree of correlation between the two speckle images.

In conclusion, each of the presented speckle pattern matching methods offers distinct advantages and disadvantages depending on the specific performance criteria. The choice of method for implementing a fiber interferometric sensor should be guided by the system's required characteristics, such as precision, sensitivity, or computational efficiency. By carefully considering these factors, the most suitable method can be selected to optimize the sensor's performance for the intended application.

## EXPERIMENTAL PROCEDURE AND RESULTS

The schematic of experimental setup depicted in Fig. 2 was utilized to analyze and compare different image matching techniques for multimode fiber interferometer. This setup allowed for a detailed evaluation of the interferometer's performance under deformation, providing insights into the effectiveness of each method in detecting changes of the sensitive fiber status.

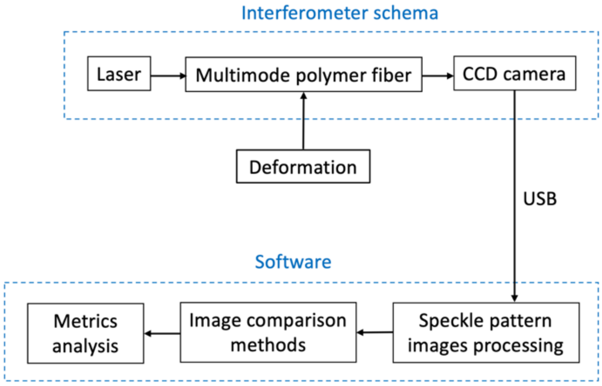


*Fig. 2.* **Schematic of experimental setup**
***Source*: compiled by the author**

The light from a laser source is directly coupled into a 1 m section of standard polymer step-index fiber, featuring a 980/1000 μm core/cladding. The fiber was mounted at both ends using holders to provide tension and fixation. Axial deformation of the sensitive section of the fiber was induced by a micrometer translation stage, which applied small displacements along the fiber axis, causing elongations of the sensing fiber (Fig. 3). To capture the resulting speckle intensity patterns, a CCD camera was used. Initially, the camera records a reference speckle pattern corresponding to the fiber's undeformed state. Any subsequent deformation due to external forces alters the spatial distribution of the speckles. Using custom-developed software implemented in Python programming language, three different matching techniques were applied to compare speckle patterns before and after deformation. Importantly, when tension is applied and then released, the speckle pattern returns to its original state, demonstrating the reproducibility of the measurement.

To evaluate the performance of each image comparison technique in fiber speckle images processing, the optical fiber was displaced incrementally from 0 to 200 μm, with step sizes of

$\Delta d$ = 10 μm. At each displacement level, the setup was held steady for the acquisition of speckle image frames, allowing the speckle pattern to stabilize before further displacement. This approach ensured that any variations in the speckle patterns were consistent and attributable to the applied deformation, providing reliable data for comparison across different image matching techniques.

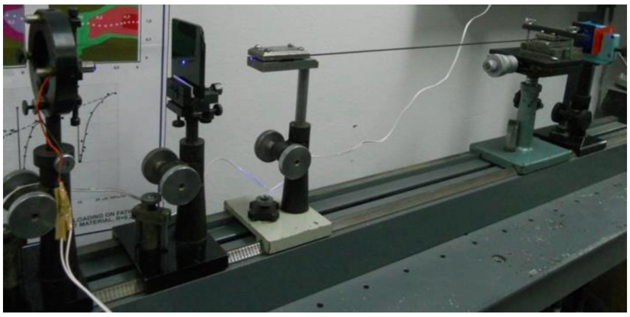

*Fig. 3.* **Photograph of the experimental setup**
***Source*: compiled by the author**

After establishing the reference speckle image $I_0$, the speckle pattern for the n-th frame $I_n$ was used to calculate the relevant performance metrics. The experimental data are then fitted with linear functions to determine key parameters such as the linearity, precision, and signal-to-noise ratio associated with each signal processing method.

Linearity was evaluated using the coefficient of determination ($R^2$), which characterizes the degree to which the sensor response conforms to a linear model:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - f_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}, \quad (9)$$

where $y_i$ are the measured values, $f_i$ are the fitted values from the linear regression, and $\bar{y}$ is the mean of the measured values.

Precision describes how consistently a sensor produces the same result when the same effect is applied repeatedly. It is defined as:

$$P = \frac{e_p}{y_a}, \quad (10)$$

where $e_p$ is the root-mean-square value of the sensor's output fluctuations under constant conditions, and $y_a$ is the average measured value for a fixed applied force. Lower values indicate higher precision (less variability).

Finally, the SNR was computed as the ratio of the mean signal to its standard deviation:

$$SNR = \frac{\mu}{\sigma}. \quad (11)$$

where μ is the mean and σ is the standard deviation of the sensor response. *SNR* indicates method's robustness against noise, with higher *SNR* values denoting superior noise immunity.

These metrics collectively provide a comprehensive framework for comparing the effectiveness of the investigated image matching techniques in fiber-optic interferometric sensing applications.

The static responses of fiber interferometer evaluated for each method are illustrated in Fig. 4, where each data point corresponds to the average of 3 measurements.

The curves above illustrate the interferometer's response under static conditions for each investigated image matching technique, highlighting the distinct behavior and sensitivity of each method in detecting speckle pattern changes induced by deformation. Linearity is a critical parameter that indicates how well the interferometer's output correlates with the applied deformation. Among the methods, POC demonstrates the highest linearity ($R^2$ = 0.948), closely followed by ZNCC ($R^2$ = 0.904), making these techniques highly suitable for applications requiring a strong linear response. SSD also performs well with $R^2$ = 0.838, while NI exhibits a much lower linearity ($R^2$ = 0.164), suggesting that it is not as effective in providing an accurate linear response so this method is not counted in further analysis. The performance analysis of the multimode polymer fiber interferometer demonstrates significant differences in terms of linearity, precision, and SNR, as shown in Table 1.

Precision metric measures the consistency of the output signal. For precision metric, ZNCC (0.256) and POC (0.373) provide a more balanced trade-off between precision and sensitivity while SSD shows the least precision. SNR is a key factor in assessing the robustness of a method against noise. ZNCC and POC exhibit moderate SNR values of 3.90 and 2.68, respectively, which indicates balance between noise rejection and signal detection. SSD has the lowest SNR (2.27), indicating higher susceptibility to noise, which could negatively impact the interferometer's overall accuracy.

From the results, POC emerges as the most effective method, offering the balance of high linearity, moderate precision, and acceptable SNR, making it better for fiber interferometric sensors that require accurate and consistent response to applied deformations. ZNCC also shows strong results, particularly in terms of linearity, but its precision could be improved. SSD technique, despite its reasonably good linearity, suffers from lower precision and poor noise rejection.


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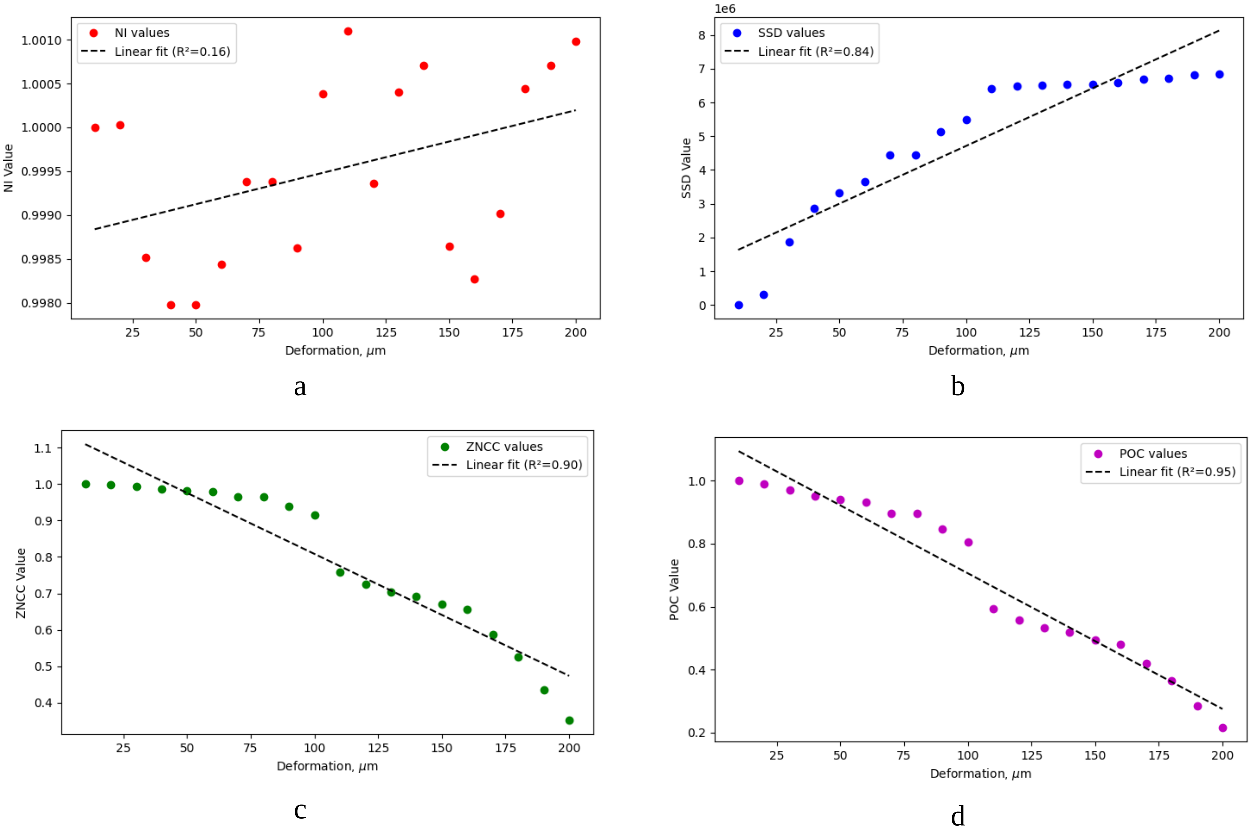


*Fig. 4.* **Static calibration curves of the multimode fiber speckle interferometer for different image processing techniques: a – NI; b – SSD; c – ZNCC; d – POC**

***Source*: compiled by the author**

*Table 1.* **Comparison between different image matching techniques**

| Method | Linearity | Precision | SNR |
|---|---|---|---|
| SSD | 0.838496 | 0.441080 | 2.267165 |
| ZNCC | 0.904068 | 0.256435 | 3.899623 |
| POC | 0.948073 | 0.373408 | 2.678033 |

***Source*: compiled by the author**

The primary sources of noise in multimode fiber interferometric sensors include optical noise from laser intensity fluctuations and wavelength instability, thermal and mechanical noise, and electronic noise from CCD camera. The spectral characteristics of these noise components vary: optical and electronic noises typically exhibit a white spectrum and are well described by Gaussian distributions, while thermal noise often manifests as low-frequency drift. Each image matching technique processes noise differently. In particular, NI is highly susceptible to both amplitude and background fluctuations, SSD partially suppresses noise through spatial integration but remains sensitive to local variations, ZNCC mitigates additive and background noise via normalization, POC demonstrates better resilience by focusing on phase information and disregarding amplitude fluctuations. These distinctions are reflected in the experimental SNR values, where ZNCC and POC outperform SSD, confirming their superior robustness against noise. For each of the presented speckle image processing methods, the measurement error can also be determined by statistically analyzing the fluctuations of the corresponding metric under conditions with no external perturbation.

## CONCLUSIONS

This study has achieved a comprehensive comparative analysis of signal processing techniques for multimode polymer fiber interferometers, directly addressing the stated objectives. First, a review and analysis of image correlation and matching algorithms for speckle pattern processing was conducted, highlighting the theoretical foundations and practical considerations of each approach. Second, the experimental evaluation of


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SSD, ZNCC, and POC methods on polymer fiber based interferometers provided quantitative insights into their performance with respect to linearity, precision, and signal-to-noise ratio. The results demonstrate that the POC method offers superior linearity and balanced precision and SNR, making it the most robust choice for deformation sensing applications. ZNCC also exhibits high linearity and noise immunity, while SSD, despite reasonable linearity, is less effective due to lower precision and SNR. These findings not only inform the selection of optimal signal processing strategies for polymer fiber interferometric sensors but also establish a foundation for further research into advanced sensing methodologies and the development of fiber-optic sensor systems. Future efforts will concentrate on leveraging these methodologies to design enhanced multimode fiber interferometric sensors with improved performance characteristics, including optimized detection sensitivity, robustness, and dynamic range. Special emphasis will be placed on exploring the capabilities of the POC technique, particularly its unique ability to refine sensitivity and resilience while uncovering additional properties that could expand its applicability to diverse fields. Furthermore, research should prioritize hybrid approaches that integrate the strengths of multiple signals processing methods, enabling the development of more versatile and high-performing sensors and transducers capable of addressing a wider array of applications.

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# Порівняльний аналіз методів обробки сигналів для інтерферометрів на багатомодових полімерних волокнах

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## АНОТАЦІЯ

В статті розглядаються методи аналізу спекл-зображень для вимірювання деформацій з використання інтерферометрів на основі багатомодових полімерних волокон. Обгрунтовано та підкреслено актуальність використання багатомодових полімерних оптичних волокон при вимірюванні деформаційних напружень, враховуючи їхню гнучкість, економічну ефективність та придатність для інтеграції у композитні структури. Основна мета дослідження полягає в оцінці та порівнянні ефективності сучасних методів обробки зображень, включаючи метод суми квадратів різниць, нормалізованого коефіцієнта кореляції та фазової кореляції, на основі ключових метрик, таких як лінійність, точність та співвідношення сигнал-шум. Експериментальний аналіз показує, що метод фазової кореляції демонструє найкращі результати, забезпечуючи високу лінійність, помірну точність і стійкість до шуму; метод розрахунку нормалізованого коефіцієнта кореляції також показує задовільні результати. Метод суми квадратів різниць, хоча і забезпечує прийнятну лінійність, характеризується нижчою точністю та меншою стійкістю до шумів. Отримані результати пропонують практичний підхід до вибору відповідних методів обробки сигналів, що дозволяє оптимізувати роботу інтерферометрів на основі багатомодових полімерних волокон для різноманітних сенсорних застосувань. Дане дослідження наводить систематичне порівняння методів та підкреслює їх переваги, що слугує орієнтиром для майбутнього проєктування і розробки волоконно-оптичних сенсорних систем.

**Ключові слова:** волоконно-оптичний інтерферометр; міжмодова інтерференція; порівняння спекл-зображень; методи обробки зображень

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