

and length. Modes propagating in the sapphire fiber due to injected SLED light interfere less because the smaller coherence length does not permit the interference to the extent that the LD does. Thus is why the GRIN lens alignment method consistently resulted in EFPI fringes of less than maximum amplitude and length.

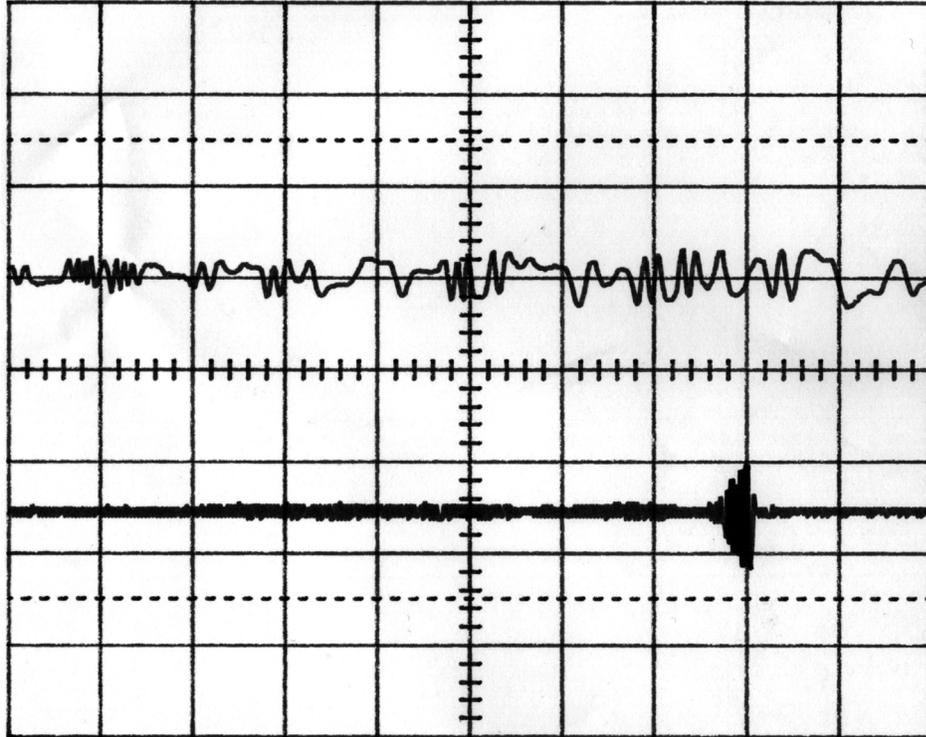


Figure 4.3.14: Sapphire Fiber EFPI Fringes Generated After Detuning the Optimal the Modified WSFMI System Alignment Laterally by 5 Micrometers.

By the same reasoning, the probability that the GRIN lens alignment method will result in no detectable EFPI characteristic fringes is also infinitesimal. Despite not being able to guarantee an optimal EFPI characteristic, the LD is preferable to the SLED for use with the EFPI sensor because the temporal coherence length of the LD, and hence the sensor range (~600 micrometers), is superior to that of the SLED (~160 micrometers). Passing the light through a diffuser prior to injecting the light into the sapphire reference fiber, or subjecting the sapphire reference fiber to constant vibration will mix the modes. When the modes are mixed in this manner, the returned signal is guaranteed to possess a

certain amplitude, although the amplitude will be less than the maximum achievable without mixing the modes. It is not possible to optimize the EFPI fringe characteristic by first optimizing the position of the GRIN lens for white light interferometry, and then adjusting the alignment so that the EFPI characteristic fringes are optimized; any change in the position of the fiber will alter the way the modes interfere in the fiber. Because the EFPI sensor does not have the capability to measure up to 0.25 inches, it will not be considered for this project. However, when this sensing method is used, it is recommended that this alignment method is used. It will always return usable fringes, which could not be achieved previously when the GRIN lens was not used or when the GRIN lens was positioned using less exact methods.

4.4 Discussion

The modified WSFMI has been shown capable of measuring displacements up to 6.4 millimeters at room temperature with the potential to measure larger displacements. Currently, signal attenuation limits the measurement of displacements at 800 degrees Celsius are to under 2 millimeters. The detected interferograms decrease in amplitude as the temperatures of the test environment rise, and the signal quality degrades when the sapphire fiber is subjected to vibrations. It is expected that with improved components and the incorporation of computer control and analysis, this system is capable of measuring displacements exceeding 6.4 millimeters with high accuracy.

The data presented in Section 4.3 indicate that the modified WSFMI, which employs a sapphire fiber sensing head, is capable of returning usable data at elevated temperatures. However, this presently requires dedicated operator interaction with the system. Requiring the operator to have this level of involvement with the system violates the stated goal of developing a sensor that may be operated by personnel who are only generally familiar with the system and with the field of fiber optics. The sensitivity of the system to misalignment resulting from changes in the operating environment is largely responsible for the high-maintenance nature of this system. The present level of involvement demanded by the system also limits the rate of data acquisition to the speed

with which the operator is able to perform the system alignment and collect and analyze the data.

The gap separation in the sensing head must always be kept greater than some minimum value to enable the collection of accurate displacement data. If the separation is too small, the fundamental fringe group associated with the sensing fiber endface overlaps with the fringe groups associated with the reference fiber endface. The resultant noise that is impressed on the fundamental fringe group associated with the sensing fiber endface distorts the envelope of the fringe group and complicates the detection of the zero order fringe. The data presented in Section 4.3 indicate that, for best results, the gap separation should not fall below 900 microns. Because the system has been shown capable of detecting the location of the sensing fiber endface for displacements in excess of 6.4 millimeters, it is not anticipated that this minimum gap separation will compromise the operation of the sensor for larger displacements.

While the position of the sensing fiber endface can be detected for gap separations greater than 6.4 millimeters, it is not advisable to operate the system with a mirror assembly that continually scans the length of the gap separation. With computer control of the system, acquisition of the detected signal, and analysis of the data, the length of time required for the mirror to complete a half cycle of motion is expected to limit the number of data points that can be acquired. The time required to acquire the data will be reduced if the position of the reference fiber endface is found once at the beginning of the test, or only intermittently during the length of the test. By doing this, the motion of the mirror can be limited to interrogating the immediate vicinity of the sensing fiber endface.

It is a characteristic of the modified WSFMI system that the fundamental fringe groups associated with the two fiber endfaces cannot be optimized at the same time. The system may be aligned to favor one, the other, or achieve a state of compromise. As is apparent from the figures included in Section 4.3, the system may also be aligned such that the fundamental fringe group associated with either the sensing or the reference fiber has the

higher signal to noise ratio. This ability appears to be independent of the gap separation in the sensing head. Referencing the successful tests conducted with the silica singlemode and multimode fibers, which did not exhibit these optimization characteristics, the cause in the case of the sapphire fiber sensing head is thought likely to lie with either the poor optical quality of the sapphire fiber or with the non-ideal alignment of the reference and sensing endfaces in the sensing head. The proposed measurement technique of registering the position of the reference fiber endface periodically, but concentrating efforts on tracking the position of the sensing fiber endface more exclusively will eliminate this problem of optimization; only one fundamental fringe group will be of interest at a given time.

The performance of this system suffers from a low signal to noise ratio. This is especially apparent from the data taken while the system measures displacement at high temperatures. The use of components that are less lossy and better aligned will help alleviate this problem to some extent, but the use of a more powerful source would likely have a large positive impact. Compact fiber-based amplified stimulated emission sources are an option, as is the combination of the outputs of more than one semiconductor source to create one source beam.

The detection of the zero-order fringe in the fundamental fringe groups is not straightforward. Examination of the fundamental fringe groups generated in this work indicate that there are a number of fringes generated in each fundamental fringe group that may be interpreted as the zero-order fringe. This is partly due to the coherence length of the source and partly due to the noise modulating the signal. As the coherence length of the source is reduced, the number of fringes contained in the fundamental fringe group will decrease. With the number of fringes currently generated by the system, it is necessary to compute a fringe envelope and use the construct of the envelope to determine the fringe of greatest amplitude. With a reduction of the coherence length of the source, it may be possible to track the zero-order fringe without the aid of an envelope function. The accuracy of the system will also improve with the increase of the

signal to noise ratio of the detected signal. The modulation of the signal by the noise obscures the shape of the fringe envelope and the location of the zero-order fringe. The minimum acceptable signal to noise ratio for any of the fundamental fringe groups is dependent on the accuracy with which the position of the zero order fringe must be determined. This work suggests that any signal to noise ratio less than 10 decibels is unacceptable.

This work clearly illustrates the potential of the modified WSFMI system for accurately measuring displacements at elevated temperatures. With more work devoted to refining the system, and the replacement of components identified as being sub-optimal, this sensor has the potential of being a useful device for measuring displacements at elevated temperatures.