26PA7 AN APPROACH TO AN ULTRA RESOLUTION FAULT LOCATOR

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1 INTRODUCTION

The recent development of integrated circuits, the electro and the acousto-optic devices and laser scalpels for high medical skill has been increasing the needs for a high-resolvable fault diagnosis technology. To serve these needs, we have been developing an ultra resolution fault locator named 3D Laser Microvision[1, 2, 3]. This system has a high resolution and can be applied to see through and display these microscopic structures nondestructively using the interferency and permeability of an infrared laser beam.

The principle of the proposed fault locator may be summarized as follows.

The output from a tunable laser diode is split into the frequency unshifted zeroth order beam and 40 MHz shifted first order beam by means of an acousto-optic modulator(AOM). The zeroth order beam is used as a probe beam and the first order beam, as a reference beam. The probe beam is aimed at the object. The reflected probe beam is mixed with the reference beam fed directly from the AOM at the mixer detector. The output from the mixer detector is 40 MHz beat which contains the information about the amplitude and phase of the reflected probe beam. The same measurements are repeated at each step of the wavelength of the laser diode source . The amplitude and phase information of the reflected probe beam is stored in the computer memory bank as a function of the light wavelength from which the computer generates the image of the object by various types of signal processings.

In this report, we show some experimental results by various signal processing methods using the information mentioned above. Furthermore we examine the resolution limit of one of the signal processings, the MUSIC method, by numerical simulation.

2 EXPERIMENTAL RESULTS

Under the same number of sampling points, measurable range or processing time of the methods are compared. The most common method of signal processing is the FFT but its resolution is moderate if the sweep range of the frequency is limited. Under these circumstances, the main theme of this paper is what we should do to overcome the resolution limited by the frequency sweep range.

As signal processing, we applied multiple signal classification(MUSIC)[4] and the neural network processing[5] and compared the results with those by the FFT.

The measurement conditions and performance of the Laser Microvision in this report is shown in Table 1 when FFT is used as a signal processing method.

sweep range of wavelength $1.5\mu m$ to $1.548\mu m$	spatial resolution $24\mu m$
number of wavenumber steps 512	maximum spatial range 12mm

Table 1: The measurement conditions and performance of the Laser Microvision

Figure 1 illustrates the results of the signal processings with an object of an optical fiber measured under the condition mentioned Table 1.

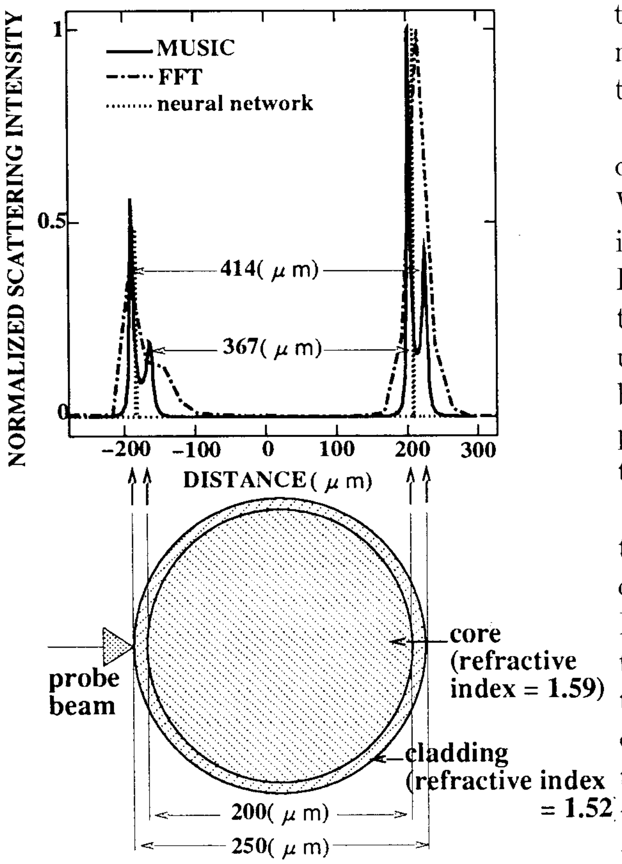

Figure 1. Experimental result

In Fig.1, the horizontal axis and the vertical axis are the estimated position and the normalized scattering intensity, respectively.

The result for the FFT or the neural network processing shows only two peaks although there are four discontinuities in the fiber.

On the other hand, we can see four estimated positions of these discontinuities in the case of the MUSIC method.

Other characteristics of these three signal processing methods are as follows.

In case of the FFT the two scattering centers spaced narrower than 24 μm cannot be resolved because the total sweep of the wavelength was only 0.048 μm from 1.500 to 1.548μm. Even though the FFT cannot resolve two scattering centers as two but can tell the location of these centers that may be seen as one, this information of an approximate location is utilized in both the neural network processing and the MUSIC method which can provide much higher resolution than the FFT alone can. Moreover the time for the FFT to estimate the scattering centers is shorter than other processing methods proposed so far in this field. Therefore the FFT is still useful to make a rough estimation of the scattering centers.

For the neural network processing, the resolution limit is higher than that of the FFT. We have studied this neural network processing and derived the resolution limit of 7 μm. However, even in case of specific interval larger than 7 μm, there happens some ill-conditions under which the two scattering centers cannot be resolved. Futhermore the neural network processing is normally the reiterating computation that takes time.

In the case of the MUSIC method, the estimation accuracy is much higher than those of the FFT or the neural network processing. In this method the eigenvalues and eigenvectors of the covariance matrix which consists of the received signal are calculated. So the processing time of the MUSIC method depends on the number of sampling points more drastically than the case of the other methods though the processing time is shorter than that of the neural network processing. On the other hand, we have to have a priori knowledge about the number of the scattering centers.

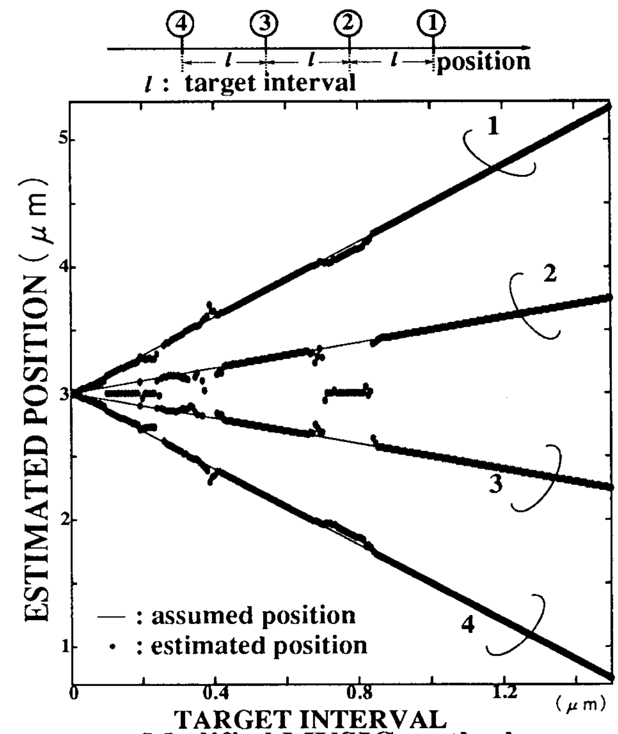

Figure 2. Numerical simulation result

According to the numerical simulation, we can reconstruct the object with high accuracy when the the number of presumable scattering centers is set up as larger one than necessary.

Among these three methods, we pay closer attention to the MUSIC method. To check up the resolution limit, we did the numerical simulation on the condition that there were four scattering centers with equal interval and back scattering coefficients.

Figure 2 is the result of the numerical simulation. The horizontal axis and the vertical axis mean the interval of the true scattering centers and the estimated positions, respectively. From the figure we can conclude that positions of the four scattering centers are determined unambiguously as long as $l \geq 0.8$ μm and we can safely say that the resolution is narrower than 1.0 μm.

3 CONCLUDING REMARKS

We introduced some approaches to realize ultra-resolution in a fault locator and showed their characteristics. Hereafter we will propose the signal processing method with high resolution and short calculating time and then design higher-resolvable fault locator.

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