Characterization of Ultrasonic Transducers using MV-H Series Laser Vibration Sensor

OmniSensing Photonics LLC

2020/12

Content

1. Scope

Developed by OmniSensing Photonics (OSP), the MV-H series laser vibration sensor can measure sub-micron vibration signals up to 3.5MHz frequency range mainly due to its 5MSPS high-speed sampling rate and nanometer scale resolution. This type laser vibration sensor is suitable for ultrasonic transducer testing/calibration as it can record real time displacement on the transducer surface. In this document, it summarizes the testing results of several vibration tests carried out on 6 different types of ultrasonic transducer using OSP's MV-H laser vibration sensor.

2. Test Summary

2.1 Test 1: 20KHz Transducer

Fig. 1 shows the testing setup that is used to perform the vibration test on a 20KHz ultrasonic transducer. The MV-H laser vibration sensor is placed about 15cm away from the sample. In this test, the vibrations at both the center and edge of the transducer were measured.

Fig. 1: Testing setup for 20KHz transducer

Table 1 summarized the 10 times test results at the center of a 20KHz transducer with better than 1μm repeatability.

Table 1a:

ID	Sample Working Frequency	Testing position	Tested Frequency (Hz)	Tested Amplitude (um)
1	20Khz	Center	19841.8	27.546
2	20Khz	Center	19842.1	27.560
3	20Khz	Center	19842.0	27.499
4	20Khz	Center	19841.8	27.443
5	20Khz	Center	19841.7	27.506

6	20Khz	Center	19841.5	27.753
7	20Khz	Center	19841.3	27.556
8	20Khz	Center	19841.1	27.571
9	20Khz	Center	19841.0	27.509
10	20Khz	Center	19840.9	27.463

Similarly, the table 1b shows the results of 10 times test at the edge of the same 20KHz transducer with better than 1μm repeatability.

Table 1b:

ID	**Sample Working Frequency**	**Testing position**	**Tested Frequency (Hz)**	**Tested Amplitude (um)**
1	20Khz	Right edge	19840.8	25.911
2	20Khz	Right edge	19840.8	25.953
3	20Khz	Right edge	19840.6	25.631
4	20Khz	Right edge	19840.2	25.649
5	20Khz	Right edge	19840.1	25.846
6	20Khz	Right edge	19840.0	26.034
7	20Khz	Right edge	19839.8	25.744
8	20Khz	Right edge	19839.8	25.818
9	20Khz	Right edge	19839.7	25.875
10	20Khz	Right edge	19839.6	25.808

Fig. 2 shows the typical vibration signals in time domain and its spectrums for both tests.

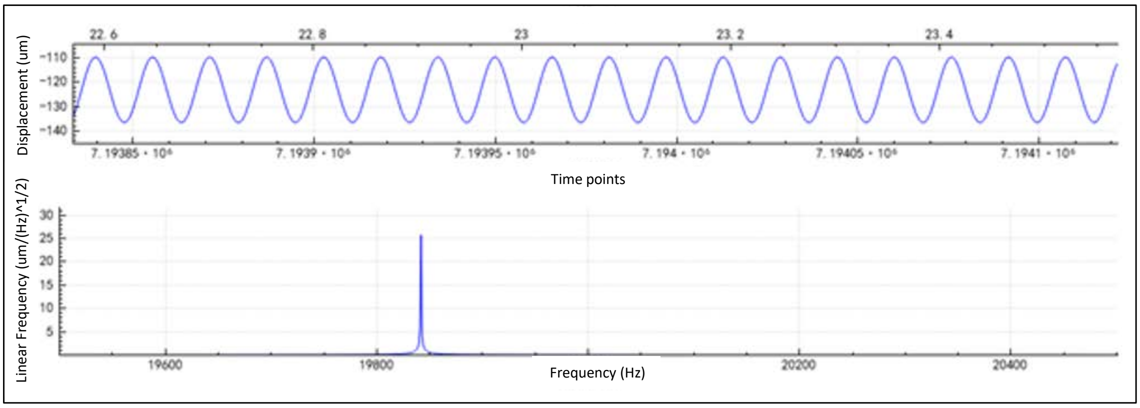

Fig. 2: Typical vibration waveform & spectrum of a 20KHz transducer

2.2 Test 2：15kHz power transducer

Fig. 3 shows the testing setup that is used to perform the vibration test on a 15KHz ultrasonic transducer. The MV-H laser vibration sensor is placed about 15cm away from the sample. In this test, the vibrations at both the center and edge of the transducer were measured.

Fig. 3: Testing setup for 15KHz transducer

Table 2a summarized the 10 times test results at the center of a 15KHz transducer with better than 1μm repeatability.

Table 2a:

ID	Sample Working Frequency	Testing position	Tested Frequency (Hz)	Tested Amplitude (um)
1	15Khz	Center	15030.1	43.424
2	15Khz	Center	15029.7	44.617
3	15Khz	Center	15029.6	43.451
4	15Khz	Center	15029.6	43.742
5	15Khz	Center	15029.5	43.450
6	15Khz	Center	15029.4	43.629
7	15Khz	Center	15029.3	43.333
8	15Khz	Center	15029.3	43.439
9	15Khz	Center	15029.2	43.628
10	15Khz	Center	15029.0	43.377

Table 2b summarized the 10 times test results at the center of a 15KHz transducer with better than 1μm repeatability.

Table 2b

ID	Sample Working Frequency	Testing position	Tested Frequency (Hz)	Tested Amplitude (um)
1	15Khz	Right edge	15029.0	38.002
2	15Khz	Right edge	15028.8	38.621
3	15Khz	Right edge	15028.6	37.797
4	15Khz	Right edge	15028.6	36.001
5	15Khz	Right edge	15028.5	36.280
6	15Khz	Right edge	15028.4	36.241
7	15Khz	Right edge	15028.2	35.920
8	15Khz	Right edge	15028.1	35.904
9	15Khz	Right edge	15028.1	36.006
10	15Khz	Right edge	15027.9	35.810

Fig. 4 shows the typical vibration signals in time domain and its spectrums for both tests.

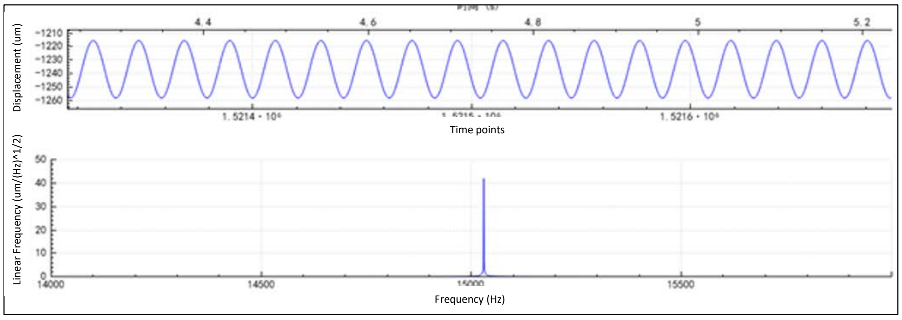

Fig. 4: Typical vibration waveform and spectrum of a 15KHz transducer

2.3 Test 3： 500KHz high power transducer

Fig. 5 shows the testing setup that is used to perform the vibration test on a 500KHz high power ultrasonic transducer. The MV-H laser vibration sensor is placed about 15cm away from the sample. In this test, 4 testing points were selected, along from the center to the edge of the transducer (see Fig. 5). For each testing point, 3 groups of tests were performed, 15 seconds long for each test, 30 seconds in between.

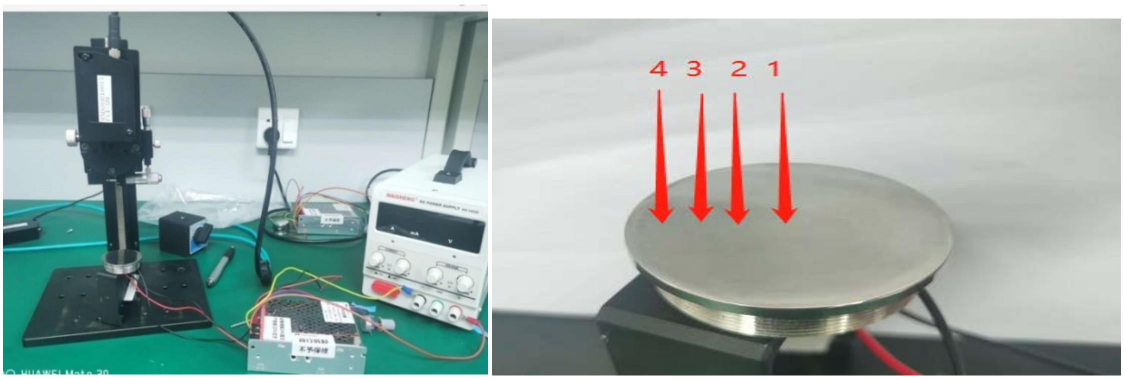

Fig. 5: Testing setup for 500KHz high power transducer

Table 3 summarizes the testing results at each location. It's obvious that it needs higher testing resolution when testing high frequency (>100KHz) transducer. It turns out the MV-H can precisely measure the vibration, reaching nm scale resolution.

Table 3

Testing Location	1		2		3		4	
Testing Times	Freq. (Hz)	Amp. (um)	Freq. (Hz)	Amp. (um)	Freq. (Hz)	Amp. (um)	Freq. (Hz)	Amp. (um)
1	506546	0.156	506566	0.064	506567	0.053	506571	0.014
2	506582	0.168	506473	0.079	506372	0.055	506117	0.014
3	506547	0.182	506488	0.077	506523	0.066	506178	0.016

Fig. 6 shows the typical vibration signals in time domain and its spectrums for all tests.

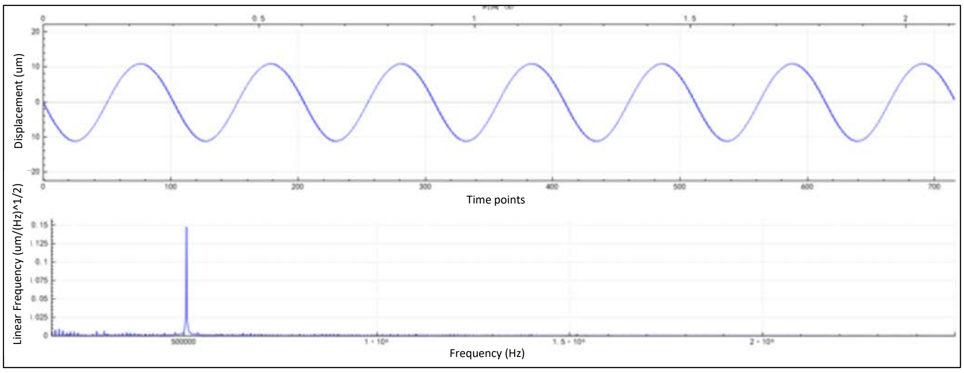

Fig. 6

2.4 Test 4： 1MHz Power Transducer

Fig. 7 shows the testing setup that is used to perform the vibration test on a 1MHz high power ultrasonic transducer. The MV-H laser vibration sensor is placed about 15cm away from the sample. In this test, 4 testing points were selected, along from the center to the edge of the transducer (see Fig. 7). For each testing point, 3 groups of test were performed, 15 seconds long for each test, 30 seconds in between.

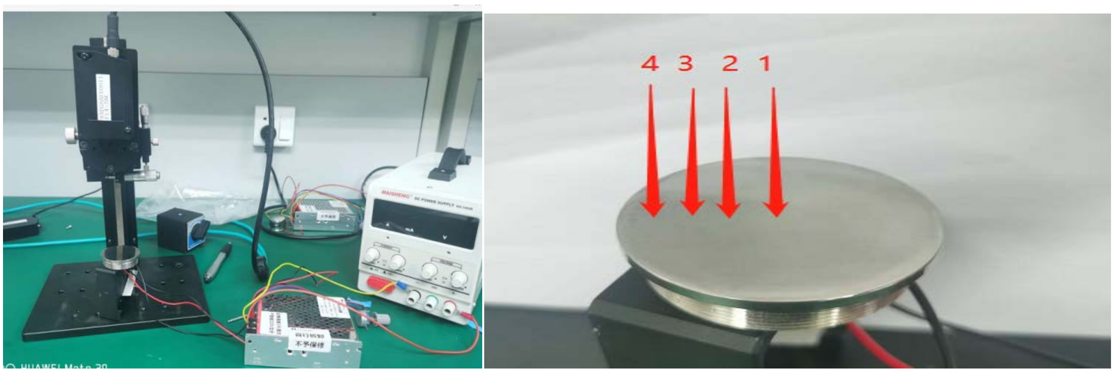

Fig. 7

Table 4 summarizes the testing results at each location.

Table 4

Testing Location	1	2	3	4

Testing Times	Freq. (Hz)	Amp. (um)	Freq. (Hz)	Amp. (um)	Freq. (Hz)	Amp. (um)	Freq. (Hz)	Amp. (um)
1	1014311	0.112	1015220	0.065	1013640	0.022	1013599	0.014
2	1014175	0.122	1013931	0.077	1013843	0.02	1013449	0.014
3	1014790	0.11	1013797	0.073	1013609	0.022	1013005	0.015

2.5 Test 5：3MHz Power Transducer

Fig. 8 shows the testing setup that is used to perform the vibration test on a 3MHz high power ultrasonic transducer. The MV-H laser vibration sensor is placed about 15cm away from the sample. In this test, 4 testing points were selected, along from the center to the edge of the transducer (see Fig. 8). For each testing point, 3 groups of test were performed, 15 seconds long for each test, 30 seconds in between.

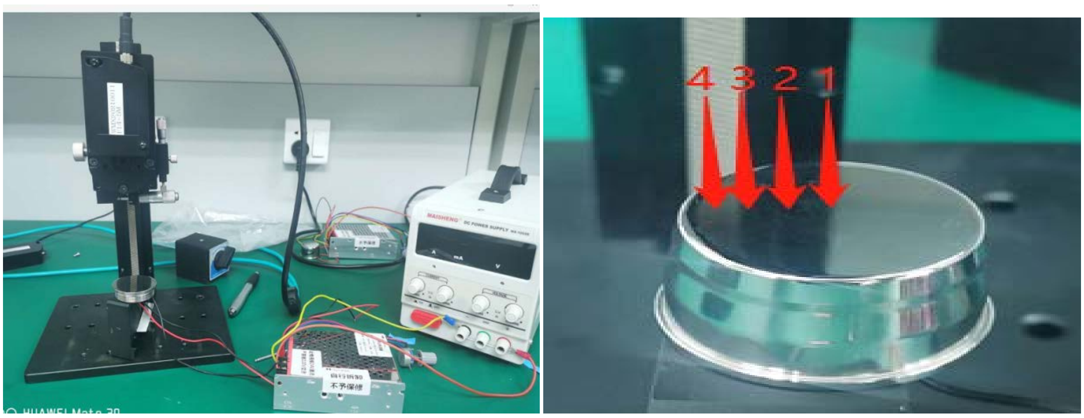

Fig. 8

Table 5

Testing Location	1	2	3	4

Testing Times	Freq. (Hz)	Amp. (um)	Freq. (Hz)	Amp. (um)	Freq. (Hz)	Amp. (um)	Freq. (Hz)	Amp. (um)
1	3115866	0.017	3115740	0.007	3116178	0.007	3115684	0.004
2	3115647	0.013	3115930	0.008	3115597	0.008	3115745	0.009
3	3115115	0.019	3116110	0.007	3115666	0.009	3116084	0.005

Fig. 9 shows the typical vibration signals in time domain and its spectrums for all tests.

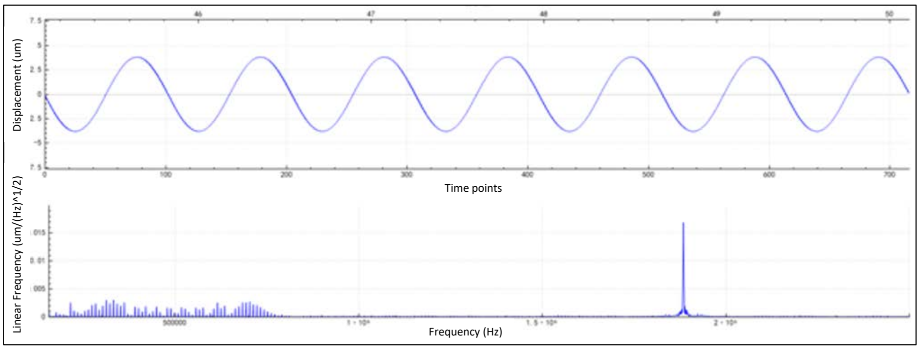

Fig. 9

2.6 Test 6：100kHz Pulsed Transducer

Fig. 10 shows the testing setup that is used to perform the vibration test on a 100KHz pulsed ultrasonic transducer. The MV-H laser vibration sensor is placed about 15cm away from the sample. Since the MV-H sensor can record the real time displacement of the transducer, thus the real time spectrum can be calculated and displayed as well.

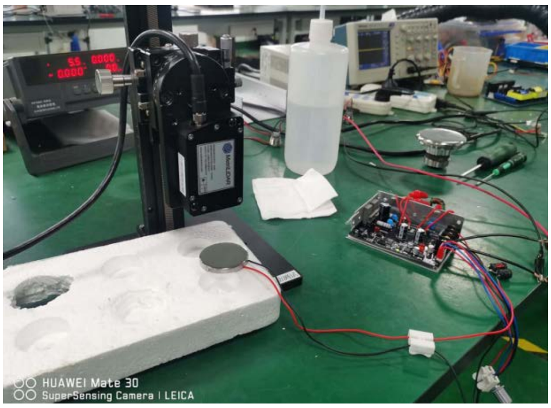

Fig. 10

Fig. 11 shows the typical real time results.

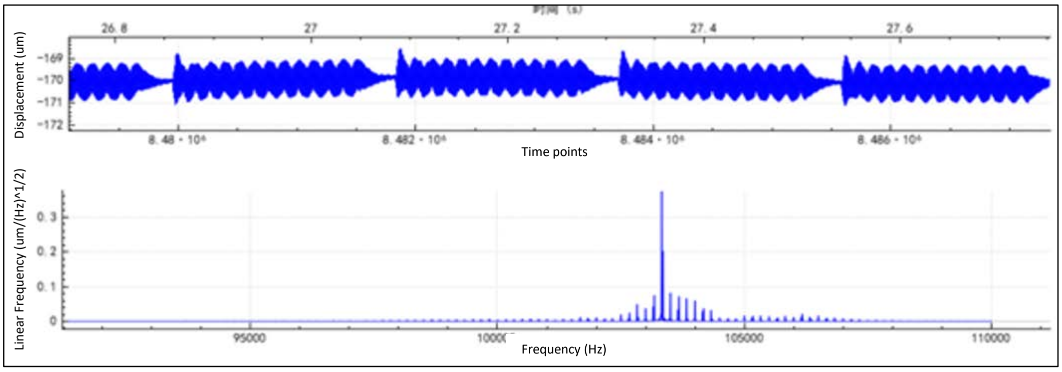

Fig. 11

3. Testing Results Comparison and Analysis

3.1 Testing Results Analysis

As stated above, the MV-H laser vibration sensor could record the real time displacement information of the ultrasonic transducer under test due to its 5MSps high speed sampling rate and ~nm scale testing resolution. Thus the user could collect the full information about the transducer, not just its maximum vibration amplitude, but also its real time movement trace in time domain and its associated spectrum contents in frequency domain. It can also be found out whether there is any distortion on the surface of the transducer, or its in-time response under different testing condition.

The Table 6 compares the results of a series of vibration test performed on the center of a transducer, using several types of sensor including MV-H. It shows that the MV-H has similar performance as the image measuring instrument, but big difference comparing to the results using the triangulation sensor. Secondly, the MV-H has the best repeatability.

Table 6

Sensor type	Triangulation sensor		Image Measuring Instrument		OSP MV-H	
Sample Type	20kHz (30%)	15kHz (40%)	20kHz (30%)	15kHz (40%)	20kHz (30%)	15kHz (40%)
1	37.1	50	23.5	35.9	27.546	43.424
2	37.7	49.6	24.4	35.4	27.560	44.617
3	37.5	51.7	24.2	35.1	27.499	43.451
4	34.8	50.5	24.1	35.9	27.443	43.742
5	34.9	47.9	22.1	36.3	27.506	43.450
6	37	50.2	23.4	36.6	27.753	43.629
7	37.6	51.4	23.9	32.8	27.556	43.333
8	39.4	50.8	23.7	34.7	27.571	43.439
9	40.2	49.9	23.2	35	27.509	43.628
10	40.4	50.7	23.9	33.8	27.463	43.377
mean	37.66	50.27	23.64	35.15	27.541	43.609
std	1.93	1.06	0.66	1.16	0.09	0.38

3.2 Technical Benchmarks with Triangulation Method.

Currently, the sensors based on the triangulation method are more frequently used for low-frequency (<100KHz) ultrasonic transducer's vibration amplitude measurement through a statistical approach.

Fig. 12 shows the operational principle for the triangulation sensor, where the received light from the DUT is re-focused and re-imaged on the linear CCD pixel array; the location of this re-focused light beam on the pixel array represents the DUT's displacement. Due the speed limitation of the CCD pixel array, the triangulation sensor cannot precisely record the real time displacement of the transducer vibrating surface, but rather its statistical positions. Thus the calculated vibration amplitude using the triangulation sensor is strongly influenced by low-frequency vibrations, testing laser beam size and measurement angles etc.

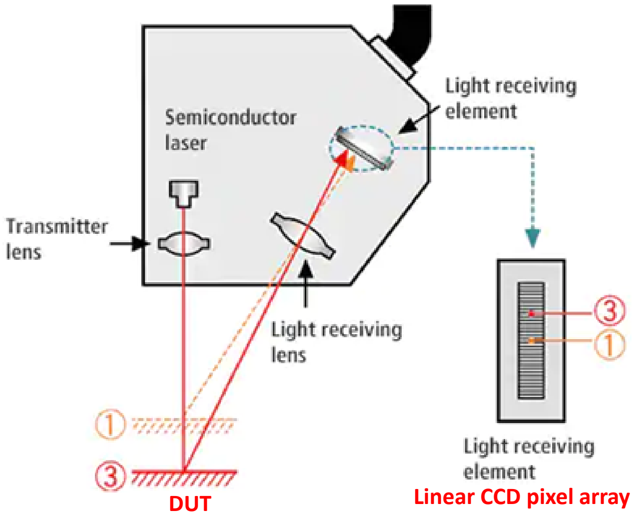

Fig. 12

In contrast, OPS's MV-H can record every details of the transducer's vibration movement in real time, and extract the correct information from the effective frequency range, suitable for transducers working at ~10s KHz to ~MHz. Clearly, OSP's MV-H is superior to any triangulation sensor in term the ultrasonic transducer measurement.