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# Comparison of DIC and LDV for practical vibration and modal measurements

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ABSTRACT

We compare laser Doppler vibrometry (LDV) and digital image correlation (DIC) for use in full-field vibration and modal testing. This was done using a simultaneously measured 3D displacement field on a flat 7-in. corner-supported metal plate using pseudorandom excitation via a shaker. We complete a detailed comparison between the techniques and discuss the pros and cons of each. The results show that either technique can be used for quantifying the modal information with the LDV providing better out-of-plane displacement resolution and equivalent in-plane resolution. The strain calculation is considered better in the DIC approach due to the direct tie to the surface displacements. While the LDV does not lose its place as the gold standard for modal testing, DIC has introduced a new and competitive approach that will have significant advantages in certain testing regimes.



## 1. Introduction

To efficiently and effectively evaluate structures and mechanical systems, a significant amount of effort has been expended to develop testing and computational tools. Some of these tools are utilized for the correlation and updating of computational models for structural dynamic predictions. The severe mismatch between the relatively few measured degrees of freedom for the test data compared to those in finite element modeling has been a roadblock to the efficient and effective correlation and updating of these computational models (one example being in the research of mechanical joints). Vibration testing is becoming increasingly complex, especially as the practice is moving towards simultaneous excitation of multiple axes with six degree-of-freedom shakers. Therefore, being able to characterize the stress states from these complex inputs is critical. The vibration testing industry is also increasingly performing tests to failure, and it is important to capture the strains that are leading to these failures. It is also important to capture full-field measurements to be able to capture complex shape information to correlate with uncertain regions of computational models with large degrees of freedom, and characterize the behavior of structures at failure. The need for full-field diagnostics requires the ability to measure the response of a large number of points without significantly modifying the structural response.

Traditional methods for collecting experimental structural dynamics measurements involve using individual sensors, which provide measurements at discrete points by contacting the device under test (accelerometers and strain gages for example). Non-contacting techniques, such as scanning laser Doppler vibrometry (SLDV) have become well established in the modal testing community, while other optical techniques, such as digital image correlation (DIC), are relatively new in

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structural dynamics. Recent studies [1–7] have investigated the possibility of using DIC in vibration applications. All of the studies found the technique to be a viable option to generate full-field data. Helfrick et al. [2] determined that the data collected using DIC provided useful empirical data for correlation with finite element models. Niezrecki et al. [3] showed that it was possible to measure all of the points on the structure simultaneously using DIC, but only one mode at a time.

Recent studies [1,3,8–10] compared the use of SLDV to determine mode shapes and generate data for model correlation with accelerometers and DIC. These studies all found that the main difference between the SLDV and DIC is that the SLDV sequentially measures all of the points on the structure, whereas DIC measures all of the points simultaneously. The sequential measurement of the points, as will be discussed in this paper, requires longer test times to capture all of the data. As with any measurement, they determined that DIC was only viable if the displacements of the modes were above the noise floor, however as shown in this paper – the noise floor of both DIC and SLDV can be in the nanometer range. The studies found that the main drawback to the use of DIC and SLDV was the large amount of data generated. The limiting factor to the efficacy is the computing power and memory available. Ehrhardt et al. [10] discovered that DIC and SLDV techniques were able to collect data to expose inconsistencies in the dynamic behavior of structures and provide insight to modeling and predicting dynamic behavior. In the study by Avitabile et al. [8], there was excellent correlation between the data collected using the various techniques of SLDV, DIC, dynamic photogrammetry and accelerometers. Although the previous studies have shown that SLDV and DIC are both viable solutions in certain circumstances, this paper seeks to understand when to use each technique.

We present in this paper a *direct* and *nearly simultaneous* comparison between Stereo-DIC and 3D-SLDV with the goal of drawing conclusions on how best to use both techniques. A novel aspect of the research is that the comparison involved all 3 directions; both out-of-plane and in plane motion. Previous studies have focused on the out-of-plane motion solely. We show that depending on the experimental goals, one technique will be preferred. To do this we setup a modal test of a square plate to obtain modal frequencies, damping, and mode shapes in both displacement and strain. Both systems acquired the data simultaneously (at least started together as discussed later) with exactly the same shaker inputs. We present a comparison of the state-of-the-art systems (circa 2015) and discuss the pros and cons of each technique.

## 2. Experimental setup

We set up a square, corner-supported plate in the modal laboratory at Sandia National Laboratories as shown in Fig. 1. The sample was a 7 in. (177.8 mm) square aluminum plate, 3/8-in. thick (9.5 mm) supported by ¾-in. (19.05 mm) square posts at the four corners (see Fig. 2) that created a complex displacement and strain field. We supported the thick bottom plate with bungee cords and excited with a shaker stinger (MB-50) applied to the back corner. An accelerometer positioned in line with the shaker stinger provided the drive point response. A Polytec 3D-SLDV system (PSV-500) measured the surface velocity and two Phantom 611 high-speed cameras nearly simultaneously imaged the surface with 50-mm lenses (*f*/8) for later analysis using stereo-DIC.

### 2.1. DIC experimental details

Two Phantom 611 high-speed cameras (16 GB memory option) imaged the plate during the testing. We synchronized the cameras to within the internal clock resolution of 58 MHz using the Fsync output/input on the cameras. The cameras acquired images at 3906.25 Hz with an exposure of 200 μs and a resolution of 800 × 800 pixels. We ran the cameras in 8-bit mode (i.e. 255 counts between the white and black regions of the image) to maximize the number of frames available for the DIC modal analysis in order to allow FFT averaging for better displacement resolution. With a well exposed image there is not a need to

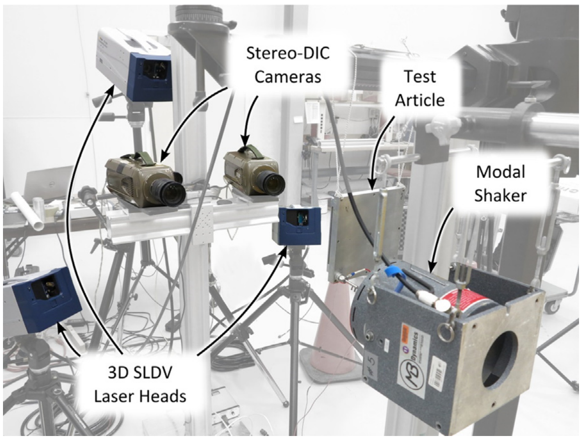


**Fig. 1.** The experimental setup of the scanning LDV and the stereo-DIC system.

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