# Laser Doppler Vibrometer Investigation on Head-Disk Contact Detection

## at the University of California, Berkeley

## Application Note

Yung-Kan Chen[1] and David B. Bogy[1], Fellow, IEEE

[1]Department of Mechanical Engineering, University of California, Berkeley, California 94720, USA

**The accurate spacing control between the flying head and disk is the key to maintaining a reliable head-disk interface that targets toward an areal density of 1Tb/in2 and beyond. Recently the head-disk spacing during read-write process has reached a value around 2 nm. By understanding the spacing control is based on a reasonable definition of contact, Computer Mechanics Laboratory (CML) have performed a study on the slider behavior approaching proximity to the lubricated disk surface. A Polytec laser Doppler vibromter together with an in-situ optical surface analyzer spin-stand were used to investigate the contact phenomenon from both slider dynamics and lubricant modulations. With the inspections from the modulated lubricated surface and the measured slider vibrations from multiple locations of the slider body, it is concluded that the head-disk detection depends on different vibration modes and lubricant behavior subjected to high air bearing pressures.**

# Introduction

In the evolution of hard disk drive (HDD) technology, the continual increase in areal density **[1]** has introduced several new technologies such as thermal fly-height control (TFC) **[2]**, shingled magnetic recording (SMR) **[3]**, and heat assisted magnetic recording (HAMR) **[4]** to achieve the massive storage needs in the near future.

It is recognized that regardless of which method being implemented in HDDs, the control of mechanical spacing between the flying head (slider) and the top surface of spinning disk below is the key to maintaining a reliable head-disk interface (HDI). The HDI consists of the flying head, the air gap and the disk. The disks are either made of aluminum or glass substrate, and on top of the substrate are multiple layers of thin films. In addition to the magnetic layers that store bits, a layer (~2-3 nm) of diamond-like carbon overcoat and a topmost lubricant layer (~1 nm) are deposited to improve resistance to corrosion and head-disk collision.

The control of mechanical spacing mainly relies on the TFC technology, which is achieved by an embedded resistive element near the read-write portion of the head and locally protrudes towards disk surface upon heater power supplied. However, the TFC spacing control can only determine the relative fly-height change, and therefore the determination of the absolute mechanical spacing requires a properly defined contact surface. The definition of contact varies by the sensors chosen. Inheriting in the magnetic head, the magnetic read-back signal can be used as a sensitive spacing measure according to Wallace's spacing law and contact-induced magnetic noise. Nonetheless, the accessibility of magnetic signals are often limited to specific head/media matches and are thus less flexible for component-level studies. In component-level testing, acoustic emission (AE) sensors are commonly used for its sensitivity to contact-induced stress waves. The frictional heating effect is also found as an indicator of head-disk contacts, which is captured by placing a temperature-sensitive resistive element, the contact sensor, on the read-write portion of the head.

The aforementioned contact-induced signals are all scalars, and scalars cannot explicitly provide the information of a contact-induced motion. Slider motion plays the essential role in determining its flying attitude, and moreover the contact-induced slider vibration may result in signals that excite the AE sensor, magnetic read-back signal and contact sensors. In this regard, laser Doppler vibrometer provides a direct measure on the velocity signal at specified locations that can be used to retrieve a slider's motion when it approaches contact proximity **[5-6]**.

# Experiment

Experiments were performed on a customized spin-stand capable of in-situ measurements of lubricant modulations and slider dynamics. An optical surface analyzer (OSA)was used to monitor lubricant surfaces, an acoustic emission sensor (AE) was used to detect contact induced elastic stress waves, and laser Doppler vibrometers (LDV) were used to capture the slider dynamics. All dynamic signals were acquired at 5MS/s sampling rate simultaneously.

For this study, we used a model OFV-534 Compact Sensor head with integrated camera. This sensor head features coupling to microscope lens for high spatial resolution and fine positioning of the laser on the head on the gimbal assembly (HGA). The 5X microscope lens used provided a spot size of 6 µm in diameter, as shown in Fig. **1**, This setup also used OFV-5000 Electronics with a VD-06 digital velocity decoder with velocity resolution down to 0.02 µm/s. This setup allows the highest resolution capability required for measurement of contact induced response of the head.

The contact detection was based on a chosen threshold of AE RMS value. For each HGA, the LDV signals were measured from the down-track direction (DTD), the leading edge center (LEC) and the trailing edge center (TEC) respectively. The AE and LDV signals were captured at AE-defined head-disk contact and post-analyzed by digital filters and numerical integration.

# Results and Discussion

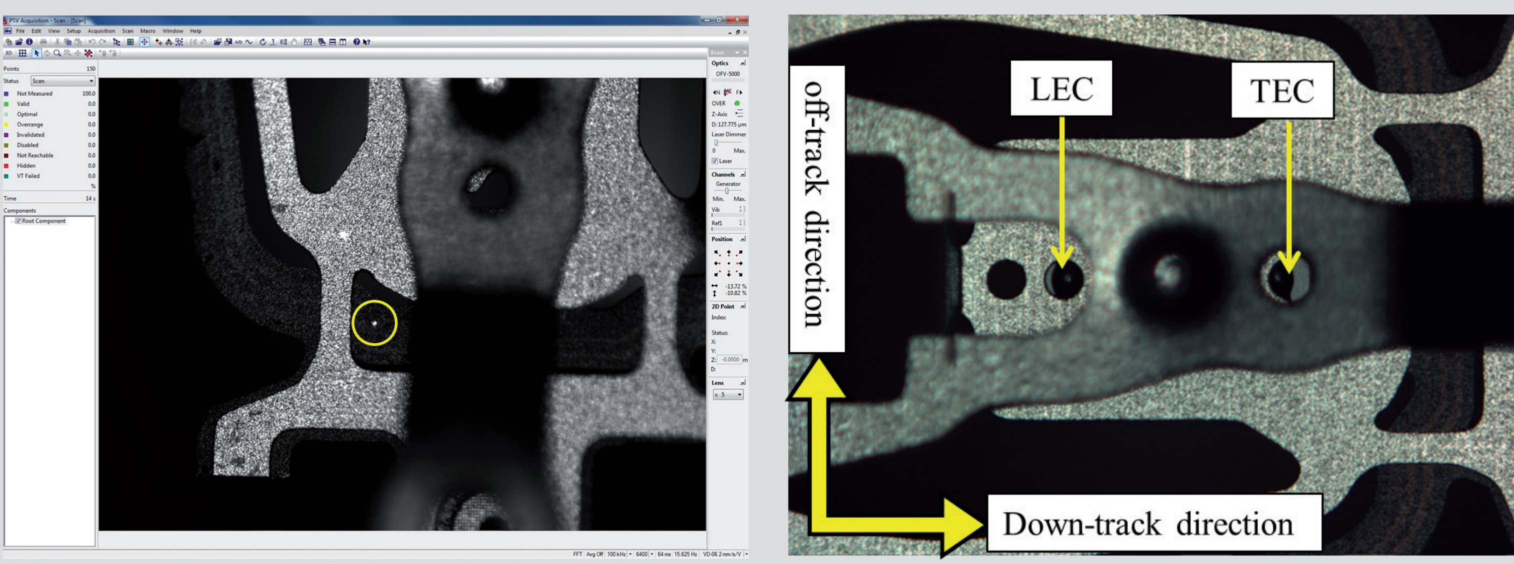
### A. General head-disk contact behavior

A representative AE-defined head-disk contact detection scheme is shown in Fig. **2**. The heater power was gradually increased until a sudden rise in the AE RMS value, and the corresponding power value is called the touchdown power (TDP). The sudden rise in AE RMS signal indicates a transition of a slider from a stable flying state to contacts with disks.

However, the slider dynamics at contact cannot be identified merely from the increase in AE RMS. As shown in Fig. **3**, the time domain signal signals at TDP further shows that the AE RMS comes from sporadic AE pulses, and these pulses correspond to very light velocity modulations measured by LDV, which can be correlated to lubricant surface topography by the OSA in part. It is surmised that the perturbed lubricant surface forming moguls that acts as asperities exciting slider vibrations. Although the velocity modulations are very small, they provide useful information when being filtered and numerically integrated into displacement modulations.

### B. Location-sensitive LDV measurements

The LDV spectra are shown in Fig. **4**. Frequencies of interests are the in the range of 50 kHz to 350 kHz. Both the DTD and LEC vibrations are much more responsive than TEC at TDP (TEC spectrum not shown due to its reduced response). The approximate maximum peak-peak displacement modulation is 1 nm, 0.6 nm and 0.15 nm for DTD, LEC and TEC respectively. The LEC spectrum possesses prominent peaks from 86 kHz to 140 kHz. These modes found from LEC are identified to be related the slider’s 1st pitch modes. By comparison, the DTD spectrum shows strong 75 kHz, 86 kHz and 117 kHz peaks. The 86 kHz and 117 kHz are then conjectured to be DTD and LEC shared modes, whereas the 75 kHz mode is unique in the DTD. This observation suggests that at TDP, the head-disk contact starts with stronger vibration at the LEC and DTD, but not at the TEC, which is closer to the contact area. Conventionally it is the vibration at TEC concerns the HDI reliability, but in terms of touchdown detection, TEC modulation may not be the most sensitive indicator when slider arrives at contact proximity.




**1**

*Representative HGA with the laser spot (circled in yellow) focused at flexture (Top), and with labeled measurement locations (Bottom).*

# Conclusion

By taking LDV measurement among different locations on the slider body, we conclude that at head-disk contact, a better detection choice may be chosen elsewhere except the TEC. Although DTD and LEC modulations are found to be much larger than that of TEC, the amount of modulation is very small. It is through the digital decoder VD-06 and the in-line imaging interferometer OFV-534 can we detect such subtle vibration differences over a tiny slider body. The low-noise LDV measurement system is required for future HDI studies and spacing control.

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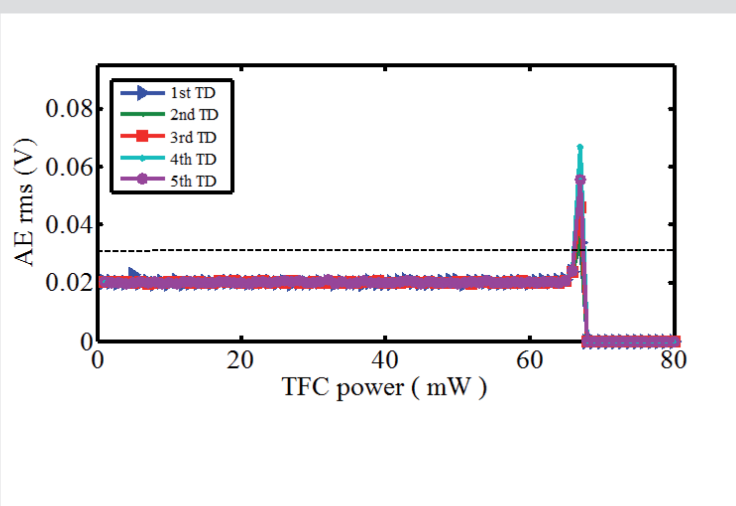
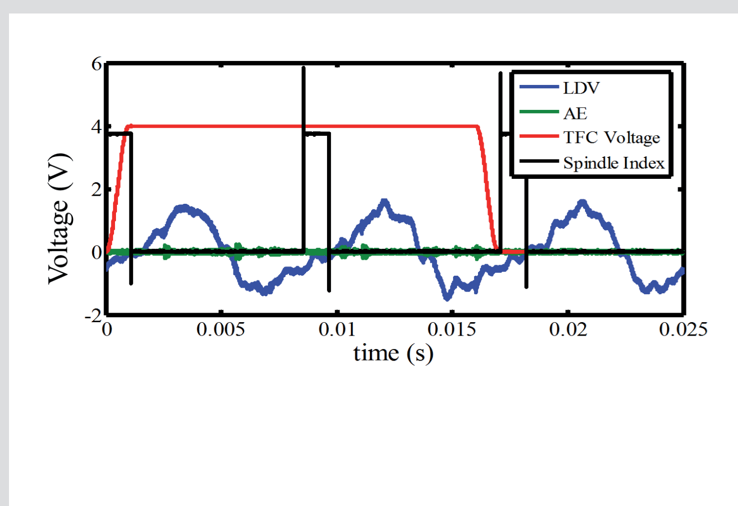
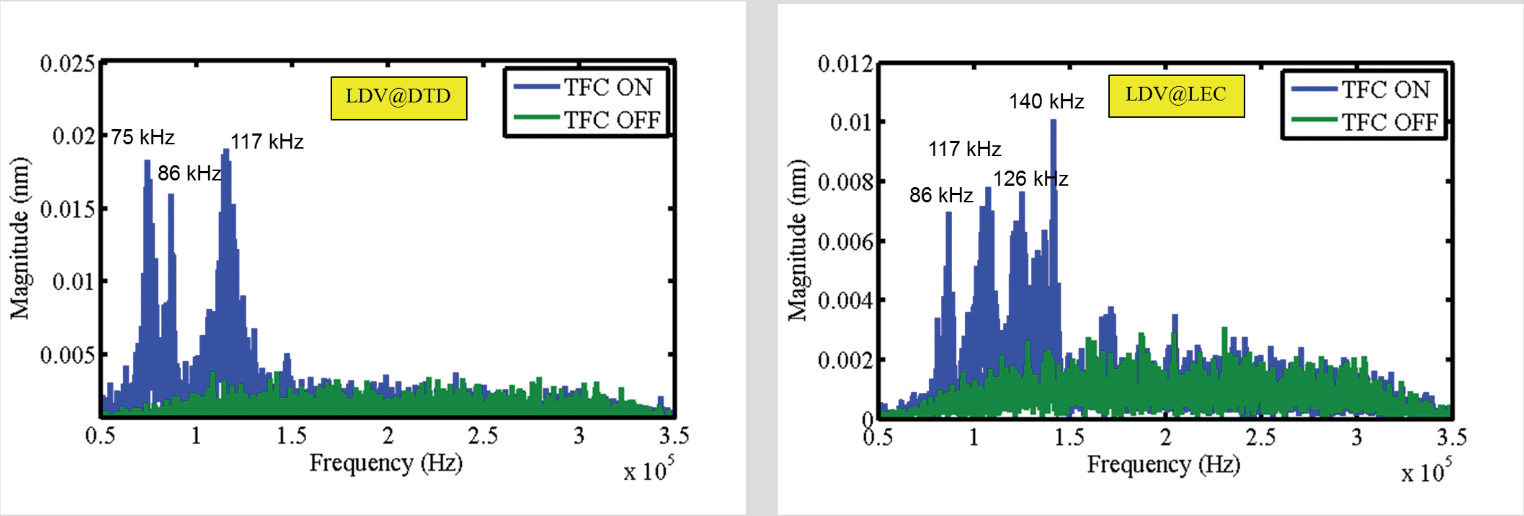



**2**
*Representative of AE-defined head-disk contact with dashed line indicating a chosen threshold.*

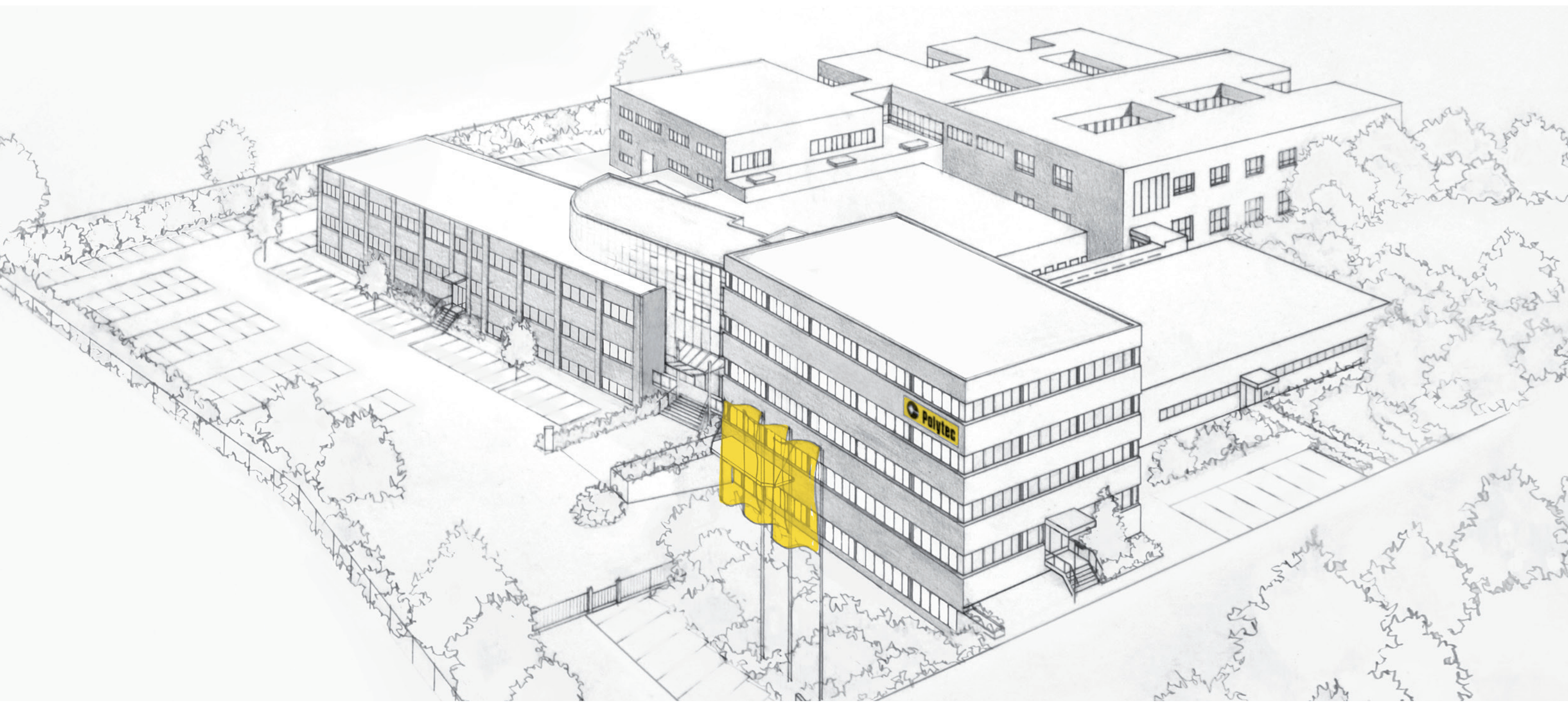



**3**
*Representative measured raw signals.*




**4**

*Frequency spectrum at DTD and LEC.*



**Polytec GmbH (Germany)**
Polytec-Platz 1-7
76337 Waldbronn
Tel. +49 7243 604-0
info@polytec.de

**Polytec GmbH (Germany)**
**Vertriebs- und Beratungsbüro**
Schwarzschildstraße 1
12489 Berlin
Tel. +49 30 6392-5140

**Polytec, Inc. (USA)**
North American Headquarters
16400 Bake Parkway
Suites 150 & 200
Irvine, CA 92618
Tel. +1 949 943-3033
info@polytec.com

**Central Office**
1046 Baker Road
Dexter, MI 48130
Tel. +1 734 253-9428

**East Coast Office**
25 South Street, Suite A
Hopkinton, MA 01748
Tel. +1 508 417-1040

**Polytec Ltd. (Great Britain)**
Lambda House
Batford Mill
Harpenden, Herts AL5 5BZ
Tel. +44 1582 711670
info@polytec-ltd.co.uk

**Polytec France S.A.S.**
Bâtiment Orion – 1er étage
39, rue Louveau
92320 Châtillon
Tel. +33 1 496569-00
info@polytec.fr

**Polytec Japan**
Arena Tower, 13th floor
3-1-9, Shinyokohama
Kohoku-ku, Yokohama-shi
Kanagawa 222-0033
Tel. +81 45 478-6980
info@polytec.co.jp

**Polytec South-East Asia Pte Ltd**
Blk 4010 Ang Mo Kio Ave 10
#06-06 TechPlace 1
Singapore 569626
Tel. +65 64510886
info@polytec-sea.com

**Polytec China Ltd.**
Room 1026, Hanwei Plaza,
No. 7 Guanghua Road
Chaoyang District,
100004 Beijing
Tel. +86 10 65682591
info-cn@polytec.com

**www.polytec.com**