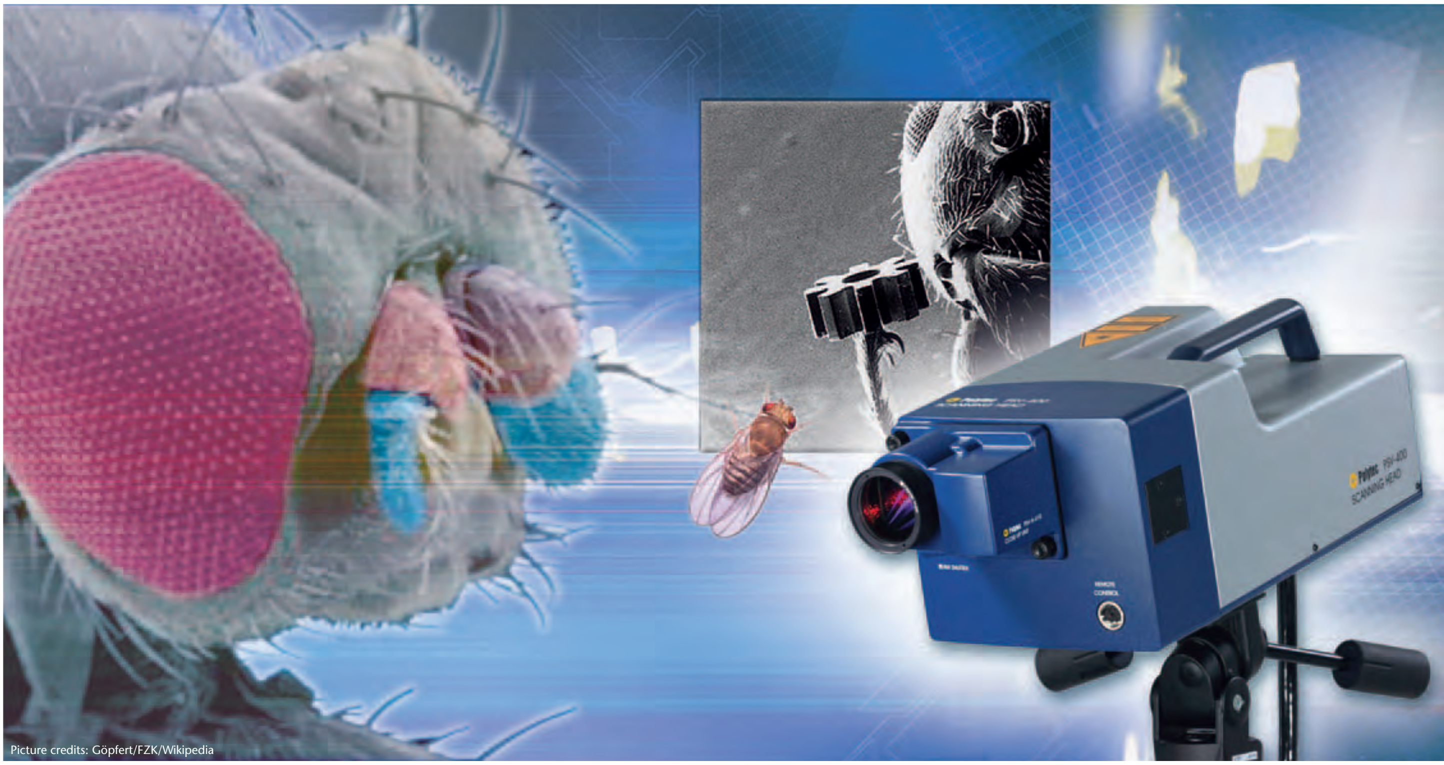
Molecular Motors *on the Fly*



Laser Doppler Vibrometry Brings Insight into the Functioning of Fruit Fly Ears

Ears are complex micromechanical machines that amplify tiny acoustic vibrations and convert them into electrical signals. Which kind of structures and processes are responsible for the signal processing inside the ear? Laser Doppler vibrometry brings insight into the sophisticated mechanisms of hearing.

The Auditory Mechanism

Fruit flies have ears as well. These insects hear with their tiny antennae. The antenna itself forms a sound-receiver, like a human eardrum. Sound-induced vibrations of the antenna are funneled to sensory cells at the antenna's base causing the opening of ion channels that convert vibrations into electrical signals. The general functioning of human ears is similar, yet the ears of fruit flies provide an important experimental advantage: While a human eardrum is buried in the auditory duct, the antenna of the fruit fly sticks out from the body and is freely accessible to mechanical examination.

Measurements and Results

Using the PSV-400 Scanning Laser Doppler Vibrometer, the vibrations of the tiny, hardly visible fruit fly antenna can be assessed at defined measurement points. This procedure allows for the systematic study of the vibrational behavior of the sound receiver. (Figure 1 and 2).

The antennal vibrations contain more information than just the mechanical response of the receiver. Because the antenna, the sensory cells, and the ion channels are intimately linked to each other, the vibrations of the antenna also reflect the cellular and molecular processes inside the ear. Just like a stethoscope gives insight into the workings of the heart, the laser vibrometer thus provides access to the hidden, cellular and molecular processes of hearing.

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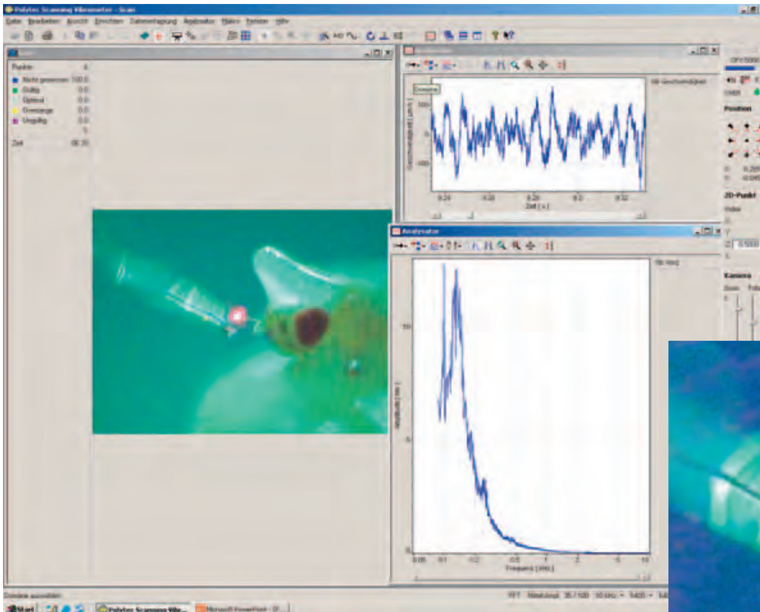

Figure 2: The measurement screen from PSV Software shows the antenna vibration (velocity versus time) in the upper analyzer window; the lower window displays the frequency dependence of the vibration displacement in nanometers

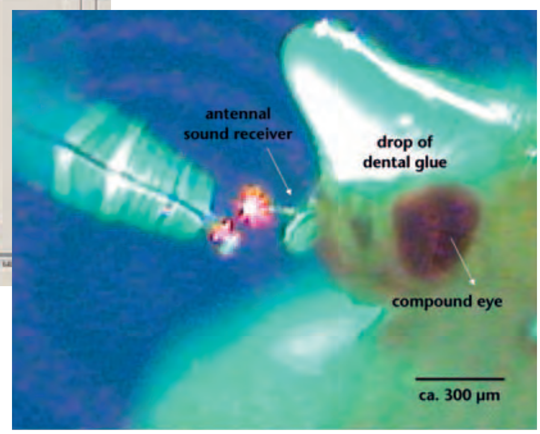

Figure 1: Drosophila head with sound receiver and laser spot focused onto the antenna, as seen by the video camera of the PSV-400 Scanning Vibrometer

Molecular Motors

Recent measurements show that besides ion channels, the sensory cells also house molecular motors that pump mechanical energy into the antennal vibrations providing amplification for weak signals. These motors amplify much like pushing a swing augments its amplitude when the push is in phase with the motion. The energy required for this amplification is very small. Fluctuation analysis based on laser vibrometric measurements shows that the motors lift the Brownian motion of the antenna by an average 20 zepto Joules ($20x10^{-21}$ Joules).
This is twenty times less than the energy of a single green photon!

Conclusion

The PSV-400 Scanning Vibrometer enables non-contact measurements of mechanical vibrations even on delicate biological objects. The vibrational characteristics of the antennal sound receiver of the Drosophila fruit fly could be systematically analyzed. The high sensitivity of the method allows for a deep insight into the cellular and molecular processes behind.

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About the Project

The research project "Active auditory mechanics in insects" is currently underway at the zoological institute of the University in Köln, Germany and is funded by the German Foundation VolkswagenStiftung. Exploiting specific advantages provided by the ears of Drosophila and mosquitoes and combining biophysical, neurobiological, and genetic approaches, the mechanisms that bring about mechanical amplification are investigated on the systemic (auditory performance), cellular (motility of mechanosensory neurons), and molecular (transduction and motor machineries) levels. The highly interdisciplinary project features a unusual combination of biomechanics, acoustics and genetics.

http://www.uni-koeln.de/math-nat-fak/zoologie/tierphysiologie/goepfert