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## WHITE PAPERS & APPLICATION NOTES



### Understand Noise At The Sub-nanometer Scale

Astronomers around the world were awestruck in September 2015 when they got word that the Laser Interferometer Gravitational-Wave Observatory (LIGO) had picked up a sound from the distant universe. That sound was the noise of two black holes smashing into one another more than a billion light-years from Earth, and LIGO detected it by measuring the minuscule movement of a mirror as a gravity wave from the collision passed by.

Most everyday users of nanopositioners don't need to detect distant astronomical events, but they still must have devices sensitive enough for whatever task they are performing. Such users may perform more demanding work intentionally or by accident using beams with high accuracy. They might be interested in looking at single cells under a microscope or using scanning probe microscopy to characterize the surface roughness of a microchip. And to know whether their system is up to their particular task, they need to understand the inherent noise of their positioners.

Every positioner has some level of uncertainty in its position, some slight amount of movement that contributes noise to a measurement. The question is whether that uncertainty also known as position noise is tolerable for a given device and a given application. Most manufacturers of nanopositioning systems specify their noise, but for a customer to make an informed decision, they must have some understanding of what that noise specification means.

**What's The Source?**  
The people performing high-precision nanopositioning tasks generally understand that vibrational noise coming from external sources can cause errors in their applications.

Usually they'll place their equipment on air tables that isolate it from common environmental vibrations, and often they'll add an enclosure to block out noise caused by air currents or ambient sound. There can also be electrical noise from the electronics of the control system, caused by poor design or using the wrong type of power supply.

But even when all of these noise sources have been taken into account, the nanopositioner itself has some inherent noise that cannot be completely eliminated. That noise may be random motion of the device, or it may be driven by the resonant frequency of the nanopositioner. It must be understood so the user is sure he's getting accurate measurements.

A high-resolution nanopositioner usually has a range of motion of between 5 and 500 micrometers. It typically consists of a flexure-guided stage that is moved by piezoelectric actuators, along with a position sensor that provides a feedback signal to the control electronics. Each of these components produces some noise, and the inherent noise of the nanopositioning system is the sum of all these sources. Even if the job of the nanopositioner is to hold something still rather than move it over a certain range, it won't be absolutely still. The question becomes, is it still enough for what one is trying to measure?

Whatever resolution a particular application needs, the inherent noise of the nanopositioner has to be lower or it will swamp any signal. For instance, if you're trying to measure a surface feature that's 500 picometers high but the noise of the nanopositioner is on the order of 300 picometers, the measurement won't be reliable.

### Understand Noise at the Sub-nanometer Level

Every positioner has some level of uncertainty in its position, some slight amount of movement that contributes noise to a measurement. The question is whether that uncertainty — also known as position noise — is tolerable for a given device and a given application. Most manufacturers of nanopositioning systems specify their noise, but for a customer to make an informed decision, they must have some understanding of what that noise specification means. That cannot be expressed in a single value, but should be shown as a spectrum that plots noise over frequency and separates the noise from different axes. Armed with such information, users can be sure they're getting a low noise, high-precision system that meets their needs.

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