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Precision Motion
And How to Achieve It

NANOSCALE MOTION REQUIRES FASTIDIOUS ATTENTION TO INSTRUMENTATION, OTHER PASSIVE CONTROLS, AND EXPERIMENT DESIGN.

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Achieving precision motion at the micron level is an impressive feat: a carefully choreographed waltz of experiment design, instrumentation, and a keen eye for detail. It stands to reason that processing to nanometer-level precision would simply be a matter of refining a few ideas. However, controlling motion at the nanoscale is a completely different dance.

Consider an experiment in optical microscopy. A researcher may think, justifiably, that their micron-level experiment setup and instrumentation allow for precise control. Simply adding a nanopositioner will allow them to go the last mile in terms of motion control: to take thinner slices of their sample and to locate more minute areas of interest within the sample. But researchers may not realize that complex image-based errors are not the only thing magnified; minor issues at the micron scale can be devastating at the nanometer scale.

Suddenly, things are not as focused as expected or everything seems to be moving. In fact, everything probably has been moving the whole time; the researcher just lacked the technical capability to observe that movement. In this respect, progressing from the micron scale to the nanoscale is like wearing a new pair of glasses.

What Factors Affect Precision Motion at Nanometer Scale?

A common misconception surrounding nanoscale motion is that precision depends solely on instrumentation — specifically, securing equipment with a technical specification of nanometer resolution. But any experiment's metrology loop must also account for thermal expansion, force distortion, misalignments, and other passive factors that affect both instrumentation and the experiment. The instrumentation a researcher chooses is part of passive control, while passive factors include acoustic effects and thermal control of a workspace.

Acoustic effects are composed of any source of vibration, from people slamming lab doors to a boisterous meeting in the room above the lab. Thermal control dictates that researchers maintain optimal temperatures across the lab, down to the immediate area surrounding instrumentation.

Admittedly, it is easy to say, "you need to control your temperature and the acoustics." But a disparity usually exists between the control researchers can exercise over their laboratory and the control they can exert over an entire building. Some researchers may be in a position to dictate terms regarding their environment or workspace but, more often than not, they have been afforded a space and instructed to make a lab of it.

Clearly, researchers always should use the highest-quality instrumentation and data acquisition systems possible (e.g., passive controls). Beyond that, understanding issues to look out for and recognizing their effects at the nanoscale allows experimenters to make the best of their respective situations. Researchers whose utmost universally that they do not want to experiment near heat sources and that the room needs to be as quiet (i.e., vibration-free) as possible. But they may not understand the extent to which actions they perform as part of their workflow produce disruptive heat or vibration.

Embracing a Nano Mindset

For most Mad City Labs customers that have trouble achieving precision motion at the nanoscale, technical support does not comprise giving them new information. It is more about properly contextualizing information they already have, explaining how it affects their nanoscale experiment and how these effects can be mitigated. We attempt to bridge the gap between researchers' stable goals and achieving those goals in a practical sense, acknowledging that many of our customers' experiments exist at the cutting edge of what is technically feasible.

These researchers are experts in their disciplines and their experiments, with a deep understanding of what they are trying to probe. We are experts in the application of instrumentation setups to achieve those research goals. Collaborative, in-depth discussion deconstructing every part of the experiment, from the methodology and equipment to passive factors, often are required to identify issues and collaborate on a solution. Consider the following examples:

Instrumentation — A researcher may be using a motorized microscope stage with a nanopositioner set atop it. The microscope's stage is set to execute a same loop that constantly measures its position and then readjusts accordingly. While that may sound like a great idea, constantly sensing at a microscopic level has a huge impact at the nanoscale, potentially wiping out all the benefits of using a nanopositioner. To ensure nanopositioner effectiveness, the microscope must be assigned a location and noted it with no noise.

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Precision Motion and How to Achieve It

Nanoscale motion requires fastidious attention to instrumentation, passive controls, and experiment design. Most users have experience in motion control within the sphere of the microscale. In this paper we discuss what needs to be considered in the jump to the nanoscale, and how detailed and deliberate choices at the design phase can lead to successful outcomes.

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