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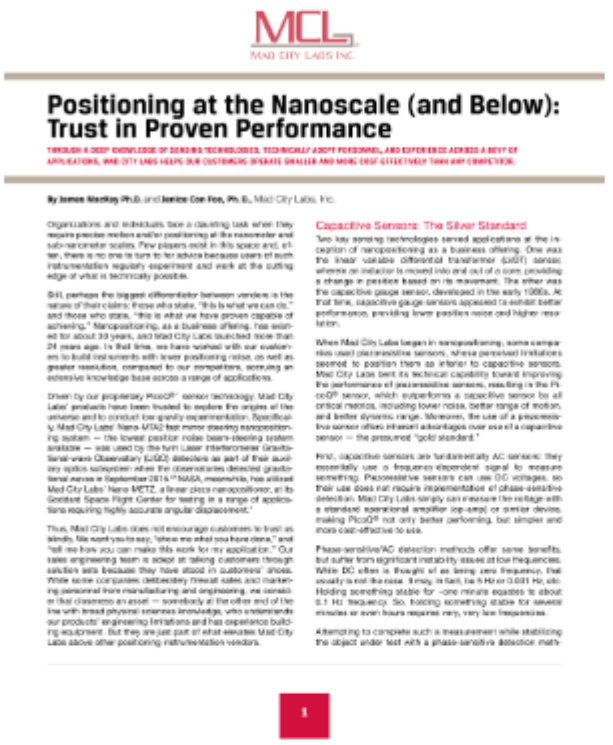
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Positioning at the Nanoscale (and Below): Trust in Proven Performance

THROUGH A DEEP KNOWLEDGE OF SENSING TECHNOLOGIES, TECHNICALLY ADEPT PERSONNEL, AND EXPERIENCE ACROSS A DEVT OF APPLICATIONS, MAD CITY LABS HELPS OUR CUSTOMERS OPERATE SMALLER AND MORE COST-EFFECTIVELY THAN ANY COMPETITOR.

By James Mackay Ph.D. and Janice Coe-Fee, Ph. D., Mad City Labs, Inc.

Organizations and individuals face a daunting task when they require precise motion and/or positioning at the nanometer and sub-nanometer scales. Few players exist in this space and, of late, there is no one to turn to for advice because users of such instrumentation regularly experiment and work at the cutting edge of what is technically possible.

Still, perhaps the biggest differentiator between vendors is the nature of their claims: those who state, "this is what we can do," and those who state, "this is what we have proven capable of achieving." Nanopositioning, as a business offering, has existed for about 30 years, and Mad City Labs launched more than 24 years ago. In that time, we have worked with our customers to build instruments with lower positioning noise, as well as greater resolution, compared to our competitors, providing an extensive knowledge base across a range of applications.

Driven by our proprietary PicoQ® sensor technology, Mad City Labs' products have been trusted to explore the origins of the universe and to conduct low-gravity experimentation. Specifically, Mad City Labs' Nano-MTA2 fast mirror steering nanopositioning system — the lowest position noise beam-steering system available — was used by the twin Laser Interferometer Gravitational-wave Observatory (LIGO) detectors as part of their auxiliary optics subsystem where the observatories detected gravitational waves in September 2015.[1] NASA, meanwhile, has utilized Mad City Labs' Nano-MET2, a linear piezo nanopositioner, at its Goddard Space Flight Center for testing in a range of applications requiring highly accurate angular displacement.[2]

Thus, Mad City Labs does not encourage customers to trust us blindly. We want you to say, "show me what you have done," and "tell me how you can make this work for my application." Our sales engineering team is adept at talking customers through solutions sets because they have stood in customers' shoes. While some companies deliberately forecast sales and marketing personnel from manufacturing and engineering, we consider that classroom an asset — somebody at the other end of the line with broad physical sciences knowledge, who understands our products' engineering limitations and has experience building equipment. But they are just part of what elevates Mad City Labs above other positioning instrumentation vendors.

Capacitive Sensors: The Silver Standard

Two key sensing technologies served applications at the inception of nanopositioning as a business offering. One was the linear variable differential transformer (LVDT) sensor, wherein an inductor is moved into and out of a core, providing a change in position based on its movement. The other was the capacitive gauge sensor, developed in the early 1960s. At that time, capacitive gauge sensors appeared to exhibit better performance, providing lower position noise and higher resolution.

When Mad City Labs began in nanopositioning, some companies used piezoresistive sensors, whose perceived limitations seemed to position them as inferior to capacitive sensors. Mad City Labs bent its technical capability toward improving the performance of piezoresistive sensors, resulting in the PicoQ® sensor, which outperforms a capacitive sensor for all critical metrics, including lower noise, better range of motion, and better dynamic range. Moreover, the use of a piezoresistive sensor offers inherent advantages over use of a capacitive sensor — the presumed "gold standard."

First, capacitive sensors are fundamentally AC sensors: they essentially use a frequency-dependent signal to measure something. Piezoresistive sensors can use DC voltages, so their use does not require implementation of phase-sensitive detection. Mad City Labs simply can measure the voltage with a standard operational amplifier (op-amp) or similar device, making PicoQ® not only better performing, but simpler and more cost-effective to use.

Phase-sensitive/AC detection methods offer some benefits, but suffer from significant instability issues at low frequencies. While DC often is thought of as being zero frequency, that usually is not the case. It may, in fact, be 1 Hz or 0.001 Hz, etc. Holding something stable for ~one minute equates to about 0.1 Hz frequency. So, holding something stable for several minutes or even hours requires very, very low frequencies.

Attempting to complete such a measurement while stabilizing the object under test with a phase-sensitive detection meth-

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Through a deep knowledge of sensing technologies, technically adept personnel, and experience across applications as diverse as astronomy to live cell imaging, Mad City Labs helps our customers develop cost-effective and high-performance solutions. This white paper describes how our high-performance sensors can help customers achieve high-precision motion control. Combined with our knowledgeable technical team, we help our scientific customers develop unique instrumentation solutions.

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