Is A DIY Microscope For You?

By Jenice Con Foo, Mad City Labs, Inc.

Any professional's work is affected by their tools: hockey players seek a specific curve or flex in their sticks, mechanics know when a socket wrench is preferable to a box-end wrench, and microscopists demand exactitude from their instrumentation.

In the case of the latter, turnkey microscope solutions — engineered to excel in specific applications — perform established techniques extremely well. Fitment issues arise when you repurpose a technique to do something a little different, or you wish to explore a new area of research that requires an innovative microscopy technique.

This article helps readers determine whether a do-it-yourself (DIY) microscope is the appropriate solution for their application. It then details how to procure an instrument that meets both current and future application needs while remaining cost effective.

Why a DIY Microscope?

Perhaps your current microscope is adequate, but you don't have as much control over its tools as you would like; you're left with the feeling that you could have done a task better, or that it would be simpler to complete in a different way. Or, in a more clear-cut scenario, you're trying to accomplish something not well-suited to equipment that's generally commercially offered.

This scenario may affect individual researchers, as well as research groups, in both academic and commercial settings. Such researchers may not be convinced that the application is a major part of their research infrastructure, so they're seeking a cost-effective method.

Consider, too, that standard instruments aren't necessarily designed for alterations; it's ill-advised to take a functional microscope that, at one point, you paid a lot of money for, and literally start cutting holes in its side.

Your specific application will dictate where on the spectrum of DIY microscope solutions your needs fall: whether the work demands a full component build-up or (relatively) simple modifications to existing instruments.

First, think about both your current application and what you plan to do with the instrument in the future: what are you trying to accomplish? For example, you may currently be exploring microscopy techniques requiring single molecule microscopes, but you're planning — maybe two or three years in the future — to do some studies using atomic force microscopes.

This awareness is vital because it informs manufacturer design considerations relevant to a DIY instrument's flexibility; this versatility is at the heart of cost effectiveness.

In this same vein, a DIY customer both takes risks with their time and guards against setbacks. Perhaps the technique initially envisioned doesn't work out for them, or they change direction and need this instrument to be repurposed for something else. A well-designed DIY microscope creates a clear path to that course of action.

Getting Started

An analysis of builders' needs and skillsets lays the groundwork for a DIY solution's success. Critical to this introspective step is clear-eyed acknowledgement of what the builders do not know — areas where they'll have to expand their team or seek third-party expertise.

Most DIYers understand thoroughly their application and its goals — for example, how the microscopy technique will be used and its limitations. This information is used to create a checklist: "I can do that part, but I've got no idea about this part." Then, evaluate: "which things on the checklist can we absolutely do? Which things can we learn to do? Which things will require somebody else's insight?"

The manufacturer is trying to glean from this analysis how well the builder understands what they want to achieve — not just from a research objective, but in terms of the technique's mechanics and its intricacies. Indeed, understanding how to create an instrumentation environment that allows a technique to succeed is very different from implementing the technique.

Builders might consider elements including how to focus light on specific areas of interest, for instance. They may want to ensure that they don't see distortions along the way, or they wish to angle light at their sample from a particular angle. A partner like Mad City Labs connects the dots between the builder's concept of the application and an understanding of how to enable that technique when building it from scratch.

Identifying "Hidden" Parameters

Exploring new instrumentation is exciting, but don't overlook the exercise's pitfalls in your enthusiasm. If you're not used to measuring at the nanometer scale, several parameters exist that you may not have previously considered. These elements can represent the difference between success and failure at the nano scale.

Temperature — If you've never measured at the nano scale before, you may not think about how traffic through your lab matters. Nearly all metals are sensitive to temperature change on some level, and a shift in temperature of even 1°C can affect measurement.

Stability — Most microscope users place their instruments on air tables to remove vibrations. However, somebody new to observation and experimentation at this scale may not realize an air table is necessary to remove vibrations and keep samples in the field of view.

Long-term maintenance — One of the biggest differences between a DIY microscope and a commercial instrument is the service agreement usually offered with the latter. Many turnkey customers purchase this option, ensuring that a field technician will be available for routine maintenance and repairs. But with a DIY microscope, on a fundamental level, you're constructing a random assemblage of parts, and long-term maintenance becomes the user's responsibility.

How can this be problematic? Recently, an individual reached out to MCL to inquire about installations for third-party products. A now-departed colleague in their research group had built a DIY microscope, and the team needed to move this microscope to a new lab within the same university but had no idea how it had been put together. Thus, the researchers have a working instrument they're terrified to damage, but they have to move it and are unsure whether they can properly reassemble the instrument. That's a long-term maintenance issue.

If you're going to build a DIY microscope, you must be willing to document your process, creating a maintenance log for future reference. The instrument manufacturer and the laser manufacturer can tell you how their parts should work, but not how the parts should fit together.

In many cases, graduate and post-doctorate students build the microscope, and their principal concerns are assembling the instrument properly and drawing data from it. They become an integral part of that technique and instrument's knowledge base but, unfortunately, the knowledge base leaves every two to three years. DIYers must consider as part of the task, "what's my process for documenting and retaining this knowledge base?"

Control systems and analysis — It's the least exciting part to think about: how do I control all this instrumentation? Are you planning to use existing software, write new software yourself, assemble existing bits and pieces, or purchase third-party software?

More importantly, when you acquire data, how do you plan to analyze it?

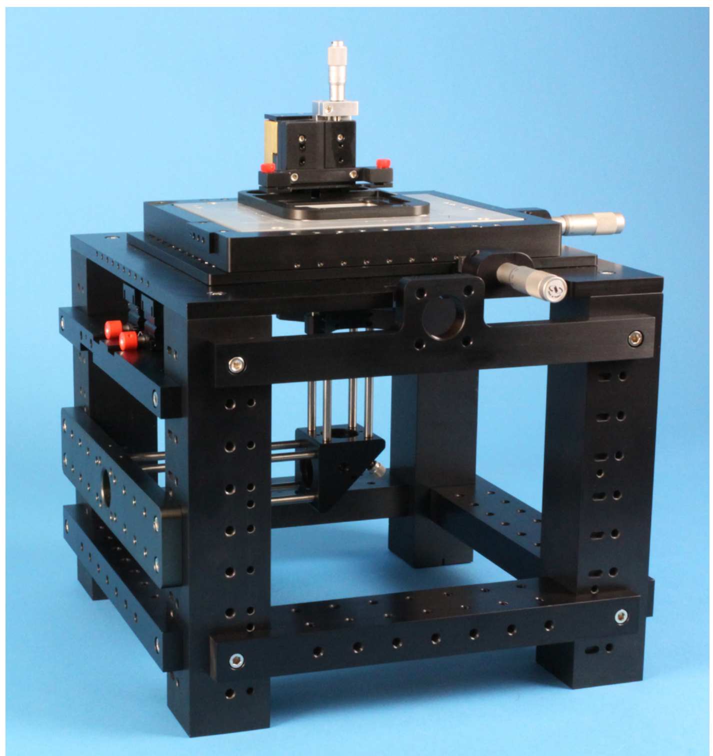
One of these problems is easy to resolve. Most times, with hardware control, the component parts are known, so you know which third-party software, freeware, and languages are supported for each component part. The result may be clunky at first, but it's usually operable if all the parts you intend to buy are supported under the same software umbrella.

The greater challenge with new techniques, or variations to existing techniques, lies in puzzling out analysis software. To wit, you've got these great new images, and you need to apply some sort of mathematical algorithm to make sense of them.

Sometimes, the researcher or team knows somebody doing similar work, and they can acquire adequate analysis software from that other research group. But if you have to write everything from scratch, this analysis (e.g., super resolution microscopy and single molecule microscopy) is mathematically complex. Not only do you need to know how to code, but you also need to know what your research may require of the instrument in the future.

Because DIY microscopes are more attractive to people conducting/creating complex techniques or never-before-seen techniques, commercial analysis software may not exist for your application. Ultimately, the builder must address how they will deal with this hurdle. The easy part is building the microscope; the hard part is drawing useful data from it.

Time investment — Customers approaching a DIY microscope from a cost-effectiveness point of view can focus so much on the fact that it's not going to cost as much as a turnkey solution that they fail to adequately consider how much time the build will consume.



Mad City Labs RM21® MicroMirror TIRF Microscope is a single molecule microscope designed to interface with a variety of optical and imaging components. This style of microscope is appealing to microscope builders looking for a happy medium between full component level builds and turnkey optical microscopes.

Consider that a commercial microscope has set parameters, and the manufacturer can outline its product's exact capabilities. If you want to conduct total internal reflection microscopy, you order a microscope designed for that. You don't have to know that the excitation line has to come in at this angle, and it has to have a way of exiting; such "engine details" already are worked out in turnkey instrumentation.

For a DIY microscope builder, the process is, "tell us what you need the instrument to do, and we'll tell you how it needs to be designed." Researchers not used to calculating field of view and adjusting lenses now are being asked to become part of that process. Thus, you may not be giving up as many dollars, but weigh that against the value of your time when determining exactly how you define a cost-effective solution.

How Mad City Labs Approaches DIY Microscopes

One of the first questions Mad City Labs asks DIY microscope builders is, "does the application require nano scale precision?"

While this metric may not be applicable to all DIYers, it's true of anyone looking at single molecule microscopes, and the majority of Mad City Labs customers. A nanopositioner is an expensive, precision instrument comprising a significant part of the overall system cost. Since nanoscale motion control is our core competency, a Mad City Labs DIY build necessarily focuses on achieving this goal. If it is unnecessary to your research, other more appropriate solutions may exist.

Once that question has been answered, a broader discussion of the microscope takes place. For example, how many excitation laser lines are you planning to use? (Some researchers like to study systems using different probes, probes that respond to different light wavelengths.) Do you think that, in the future, you're going to use as many as three or four colors to inspect the system you're looking at? (Mad City Labs instruments excel in building out beyond a single color, to multiple colors of laser light.)

Customers might ask us to enable a technique they can't get anywhere else, but the clincher for them on our DIY product tends to be that ability to add other functionality, ensuring instrument flexibility. The up-front time investment becomes an investment in their own research and instrumentation future.

Further, a DIY customer is reliant on trusting relationships with vendors. For instance, if you need a laser, and the laser salesperson can't or won't discuss certain specs, that's bad news, because he or she is your first point of contact if something goes wrong. We embrace presale back-and-forth questioning as a collaboration, or at least the foundation for a trusting business relationship.

So it follows that customers must be candid about what they're trying to achieve because once you've got a functional system, your relationship with vendors doesn't really end. At some point, you'll probably need to go back to them and say, "this doesn't seem to be working quite the way I expected," or "I want to do this a little differently; can I do it with your instrument?"

Conclusion

Among microscope users, there always will be pioneers – women and men developing new techniques and thinking through the fundamental problem of what is needed to enable that technique. They might not want to be icebreakers, but that's what they've become, because they're the first to try a given new approach.

However, part of a pioneer's responsibility when working with a manufacturer to create custom instrumentation is to document the build, the analysis, and the challenges encountered and overcome each step of the way — mapping a clear path for those who follow to understand, and build upon, their achievements. Even at the nano scale, we stand on the shoulders of giants to accomplish greatness.

Mad City Labs, with its DIY single molecule microscopes, connects the dots between inception and achievement. We have the experience and expertise to enable these techniques, be it through interfacing with existing instrumentation or guidance in building a new DIY microscope. Finally, our collaborative process ensures that the knowledge and processes behind the build can be retained for future use or modification.

About The Author

Jenice Con Foo is a member of the technical sales and marketing team at Mad City Labs. She obtained a Ph.D. in physics from La Trobe University (Australia), followed by positions at the Synchrotron Radiation Center and the University of Wisconsin-Madison. Her research background is in experimental condensed matter physics and ultra-high vacuum instrumentation.

About Mad City Labs

Mad City Labs designs and manufactures a complete product line of high precision piezo nanopositioners, micropositioners, atomic force microscopes, and single molecule microscopes. We provide innovative instrument solutions from the micro- to pico-scale for leading industrial partners and academic researchers. Visit www.madcitylabs.com or email mclgen@madcitylabs.com for more information.

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