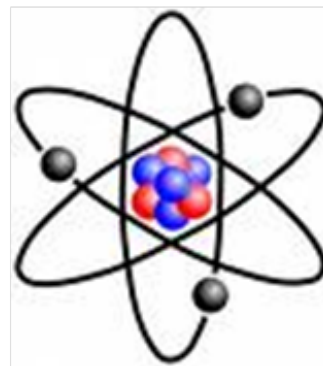# RATS

RESEARCH AND TECHNICAL STUDIES

Research and Technical Studies

Specialty Group Postprints

From the 51st Annual Meeting of the

American Institute for Conservation

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The Research and Technical Studies Specialty Group

of the

American Institute for Conservation

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Research and Technical Studies Specialty Group Presentations

Scientific Characterization of Alternatives to Cyclododecane: A Technical Study of Volatile Binding Media for Temporary Consolidation of Cultural Heritage

Hamada Sadek Kotb*, Elisa Franzoni

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Original Abstract

This paper presents an in-depth technical study exploring alternatives to cyclododecane (CDD), a type of volatile binding media (VBM) previously used widely in conservation as a temporary consolidant but now difficult to source. This study compared CDD to cyclododecanone, cyclododecanol, camphene, menthol, and their mixtures to evaluate their potential use in conservation.

Temporary consolidation is an incredibly important tool in conservation, because museum collections, buildings, and sites are exposed to many types of risk, such as floods, fires, earthquakes, a rapidly changing climate, and damage during military conflicts. Moreover, during archaeological excavation, there is also a risk that objects may be exposed to environmental shock, which can damage the finds dramatically. During all of these situations, cultural heritage can suffer, with a severe risk of losing fragile material forever. Temporary consolidation can help manage these risks; museum collections and site architectural elements can be stabilized via the introduction of a temporary consolidating material that restores the physical integrity of objects to enable emergency treatment, removal, or the securing of an object. VBM, which spontaneously pass from the solid to the gaseous state and do not require additional steps to be removed without leaving residues, are especially useful as temporary consolidants. Cyclododecane (CDD) is the most common temporary consolidant, and it has been used since the 1990s. However, little is known about the interaction between VBM and different substrates, and studies are also lacking on alternative VBM for CDD substitution, especially in terms of exploring sublimation rate, residues, chemical interactions with different substrates, possible mechanical stress due to shrinkage, and morphological observation of the surfaces.

In this study, cyclododecanone, cyclododecanol, camphene, menthol and their mixtures were studied and compared to CDD. The VBM were investigated by differential scanning calorimetry, thermogravimetric analysis, X-ray diffraction, scanning electron microscopy, and with a colorimeter. The VBM that were studied have different melting points and sublimation speeds which may allow conservators to tailor the sublimation time, depending on the purpose of temporary consolidation (long- or short-time).

The experimental tests were carried out on laboratory samples mimicking deteriorated materials including limestone, marble, glass slides, painted murals and ceramic, to understand the physical-chemical behavior of the new subliming compounds. In particular, the following parameters were investigated for the VBM and their mixtures: (1) sublimation rate, which depends on many factors, including microclimatic conditions and porosity of the substrate, and the VBM's crystallization behavior on the specific substrate; (2) interactions between the alternative VBM and substrates, including the chemical composition of the substrate; (3) morphological and chemical chromatic changes in substrate and the formation of micro-cracking on the surface; and (4) presence of residues following sublimation.

Evaluating the Efficacy of Dibarrier Discharge Plasma (DBD) in Decontamination of Bio-Deteriorated Cultural Heritage Objects

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Original Abstract

Cultural heritage objects are subjected to different deterioration agents, some of them microorganisms, that are significantly involved in the deterioration of these objects, in particular organic materials, through different pathways, such as producing acids and enzymes that decompose a wide range of complex polymers into short chains, which provide a nutrient source for growth and colonization of other associated microorganisms.

To avoid using chemical substances that endanger both the object and the conservators, so-called green technologies, such as dibarrier discharge plasma (DBD) were used. The DBD plasma setup was designed within Plasma Lab, Faculty of Engineering, Zagazig University, East of Delta, Egypt.

DBD are generated through ionization gases such as He, under high voltage. This method has many advantages, qualifying it to be a promising sterilization method that produces no hazardous residues, with proven efficacy in the sterilization of surgical instruments. This method does not break down DNA in the treated objects, such as mummies and human remains, contrary to gamma irradiation, and will not impair further investigations and drawing phylogenetic tree.

The efficacy of DBD in the sterilization of deteriorated cultural heritage should depend on different factors. The most important are: the type of gas, its purity, the type of microorganisms as the treated microorganisms varied in their resistance profile to this method, the treatment time, and the distance between the DBD source and the treated object.

The lethal effect of DBD plasma was investigated, and it was concluded that lethal action is attributed to two processes: blocking protein synthesis in the cell membrane of the treated objects; and fragmentation of mycelium of microorganisms into bacilli form.

Finally, it was found that DBD had no effect on pigments (such as vermilion [HgS], Fe_2O_3, $CuCO_3$, C) as FTIR patterns illustrated.

A New Horizon for Atomic Oxygen in Sustainable Heritage Conservation: Green Technology for Contactless Cleaning of Works of Art

Nina M. Olsson*, Anton Nikiforov, Tomas Markevicius

* Corresponding author: Nina Olsson, ninamolsson@gmail.com

Original Abstract

The cultural heritage conservation profession is increasingly aware of climate change, scrutinizes unsustainable approaches, and seeks alternatives to environmentally hazardous and waste-generating methods. Mainstream cleaning methods frequently require mechanical action and physical contact with water or solvents, which can damage many sensitive art materials, and conservators now encounter fragile and untreatable surfaces where soot from smoke or fire, and diverse organic contaminants cannot be removed at all with conventional means. In the context of sustainability, the paper will discuss a radically different green approach to the cleaning of artworks based on extremely short-lived oxygen atoms - atomic oxygen (AO), which could provide a breakthrough solution to safely remove problematic contaminants from a broad range of surfaces in a non-contact manner, without health or environmental concerns or waste, which resonates with the sustainability ethos and the needs of the field today. AO is naturally present in Low Earth Orbit at 96%, but not on the ground, where it is extremely short-lived and self-reactive, and must be produced and used instantaneously. Therefore, its practical application requires a generation system tailored for conservation, which will be discussed in the context of past research, since the AO method was tested by B. Banks at NASA in the 1990s. We will discuss the design and working principle of the AO proof-of-concept system working at atmospheric pressure to achieve O fluencies around $1021m^{-3}$ by flowing gaseous mixture O_2 in He (0.1-10 v.% O_2), using radiofrequency (RF, 13.56 MHz) field, pulsed modulated RF field at the frequency range 2-100 MHz, as well as recent atomic oxygen cleaning experiments at the European Space Agency ESA's LEOX facility. Directed to the artwork's surface, the AO beam ablates carbon-based contaminants by converting them mainly into CO, CO_2, and H_2O vapors. AO is a short-lived active species (a few milliseconds in room conditions) and has the second-highest electronegativity of all reactive elements. Thanks to these qualities, AO interacts readily with a broad range of contaminants, eliminating soiling through ablation at the atomic scale. Since the atomic surface area of contact with the fluid is much more intense than with a volatile species, AO is expected to prove a superior alternative or supplementary means for enhanced safety and efficiency of mainstream methods. The discussion on practical cleaning

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applications will be supported with experimental testing and characterization of AO on 39 samples of archetypal sensitive and porous art materials, such as plaster, alabaster, gouache, acrylic, and oil paint, carried out in the ESA's LEOX facility. Preliminary testing shows that AO technology could fill the critical gap in green cleaning methodology for problematic cultural heritage materials considered untreatable by other means. The paper discusses future research and development plans for AO technology in cultural heritage conservation under Research Foundation Flanders FWO funded PLASMART (2022-2026) project for fundamental science, and the European MOXY project (2022-2026), funded under the Horizon Europe call Green Technologies for Cultural Heritage.

Access and Accessibility: Challenging How We Are Using "Accessibility"

E. Keats Webb[1*], Sally G. Kim[2], Ashley Grady[3]

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[2]Andrew W. Mellon Fellow in Objects Conservation, Smithsonian National Museum of the American Indian
[3]Senior Program Specialist, Access Smithsonian
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Original Abstract

The AIC 2023 Annual Meeting theme of environmental, social, and economic change has sessions touching on "accessibility" of methods, tools, and techniques. Often "accessibility" in conservation and conservation science references tools and techniques that are lower cost, more sustainable, and may not require an expert user. While the cost and complexity are very important considerations for increasing the availability and use of some tools and techniques to conservators and cultural heritage professionals, this presentation aims to challenge our definition of access and accessibility to include people with disabilities and expand our considerations of equity and inclusion as part of our DEAI statements, discussions, and actions. It was previously observed in a 2021 F/AIC Accessibility Survey that 29.0% of conservation-related professionals in our AIC community identify as having disabilities (Teper, Namde, and Kim, 2022). Yet, there is a significant lack of awareness and dialogue on if people with visible and invisible disabilities are given the same level of opportunities to attain the same information and engage in the same activities as people without disabilities (South Carolina Technical College System, 2013).

Using a Disability Justice and Universal Design framework, making a space or activity accessible means providing what is needed in order for everyone to fully participate (Sins Invalid, 2019). Our considerations for space and activities should include our physical spaces, virtual environments, our daily practices, and how we present and publish our work. Accessibility includes wheelchair access, real-time captioning, and ASL interpretation in addition to image descriptions and alt-text for images and videos, teleworking, normalizing sharing access needs, considering timing and breaks (for physical, mental, and emotional well-being and basic needs), and more. Accessibility should not be an afterthought but integrated into our daily practices and budget planning.

This presentation aims to challenge us to extend our definitions of access and accessibility beyond cost, sustainability, and complexity to include people with disabilities and to encourage a social/political/cultural shift in how we are making our work and workplaces more accessible and inclusive. Finally, tips on how to make physical labs, virtual working environments, and disseminated research more accessible for conservators,

scientists, and conservation-related professionals will be shared to demonstrate how Universal Design is applicable and makes research easier for all.

References:

Teper, Jennifer Hain, Namde, Ronel and Kim, Sally G. (May 2022). Accessibility in the F/AIC: Our Membership, Our Strengths, Our Challenges. Poster, 50th Annual American Institute for Conservation Conference, Los Angeles, CA, USA.

Sins Invalid. (2019). Skin, tooth, and bone: The basis of movement is our people (2nd ed.), Berkeley, CA: Sins Invalid.

South Carolina Technical College System. (February 28, 2013). Resolution Agreement: South Carolina Technical College System OCR Compliance Review No. 11-11-6002. Accessed on September 20, 2022 from Resolution Agreement - South Carolina Technical college System (SC) - PDF (ed.gov)

Annotated Slides
Slide 1

On May 18, 2023, Sally G. Kim and E. Keats Webb presented "Access and Accessibility: Challenging how we are using 'Accessibility'" during the Research and Technical Studies (RATS) specialty group session. A QR code is included on the first slide to provide access to the script for this presentation to increase the accessibility of the presentation. (The script linked with the QR code will be the original presentation script which will not align with this edited version for the RATS PostPrints publication.)

The presentation was organized and presented in a way that aimed to model inclusion and accessibility. This includes visual descriptions for any images that were included on slides. We removed third-party material for the publication, so the visual descriptions that were included of the book covers, figures, and images are not included in this version of the presentation. Please consider providing visual descriptions of images and figures that you include in presentations to help increase the inclusion and accessibility of those presentations.

Annotated Slides
Slide 2

This talk was co-authored by E. Keats Webb, Sally G. Kim, and Ashley Grady. Ashley was not able to join us in person in Jacksonville. I (Sally) am an East Asian woman with black bob haircut. Keats is a white woman with long red curly hair.

Annotated Slides
Slide 3

The talk was created in Washington DC, which sits on the ancestral lands of the Anacostans and neighbors the ancestral lands of the Piscataway and Pamunkey peoples.

We would like to acknowledge the Anacostans, Piscataway and Pamunkey communities and pay our respects to their past, present, and future elders.

Annotated Slides
Slide 4

We use "accessibility" a lot – but what do we mean? It may be intended to expand engagement, but still excludes people with disabilities. Also, do we truly mean "accessible" when we use it to describe an imaging technique or an analytical technique?

How can we be more inclusive to make sure that we are taking into consideration people with disabilities when discussing access to these techniques and technologies?

Are there other words that might be more applicable when we are talking about the cost and complexity of a technique?

This presentation aims to challenge us to extend our definitions of access and accessibility beyond cost, sustainability, and complexity to include people with disabilities and to encourage a social, political, and cultural shift in how we are making our work and workplaces more accessible and inclusive.

Annotated Slides
Slide 5

We will start with definitions for "accessibility," "access," and "disability." In all cases, there are varying definitions of these terms, and we have intentionally selected definitions from activists and an artist with disabilities.

What is Accessibility? In Emily Ladau's book *Demystifying Disability: What to Know, What to Say, and How to be an Ally*, Emily describes "Accessibility" as being "about removing barriers to participation, engagement, and understanding so that all people, regardless of ability, can experience the world around us to the fullest extent possible in ways that work for our mind and bodies." [1]

1. Ladau, Emily. *Demystifying Disability: What to Know, What to Say, and How to Be an Ally*. California: Ten Speed Press, 2021, p79.

Annotated Slides
Slide 6

The next term we would like to explore is "Access." Aislinn Thomas, an interdisciplinary artist who identifies as disabled and chronically ill, describes "Access" as being "about welcome, consideration, and care. […] Access that seeks to merely check the boxes or do the right thing is not true access… it does not address the injustices that create and support ableism in the first place."[2]

2. Thomas, Aislinn. "Why Access is Love and There is No Such Thing as "Barrier-Free" by Aislinn Thomas." Akimbo, May 22, 2019, https://akimbo.ca/akimblog/why-access-is-love-and-there-is-no-such-thing-as-barrier-free/.

Annotated Slides
Slide 7

Disability can be defined in many different ways. The Centers for Disease Control (CDC)[3] and the Americans with Disabilities Act (ADA)[4] provide definitions. We wanted to highlight the voice of a disability activist, Alice Wong, and her experience as a Chinese American disabled woman in a "power chair."

Alice edited the book, *Disability Visibility: First-Person Stories from the Twenty-first Century*. Alice defines disability in the Introduction: "Disabled people have always existed, whether the word disability is used or not. To me, disability is not a monolith, nor is it a clear-cut binary of disabled and nondisabled. Disability is mutable and ever-evolving. Disability is both apparent and nonapparent. Disability is pain, struggle, brilliance, abundance, and joy. Disability is sociopolitical, cultural, and biological. Being visible and claiming a disabled identity brings risks as much as it brings pride." [5]

To further define disability, we wanted to share some statistics. Twenty-six percent of adults in the US have disabilities, that's 1 in 4 adults.[6] In the original presentation we shared a couple infographics that speak to the increased impact of disability for Black, Indigenous, and People of Color and LGBT adults.

One of the infographics illustrated the approximate number of adults with disability by ethnicity and race showing that more Indigenous and Black adults have a disability (3 in 10 and 1 in 4, respectively) than white adults (1 in 5) in the US. [7] The other infographic showed that 2 in 5 transgender adults and 1 in 4 LGB adults have disabilities, which is to

underline the research that shows that LGBT people are more likely to have a disability than the general public. [8]

3. CDC: https://www.cdc.gov/ncbddd/disabilityandhealth/disability.html

4. ADA National Network "What is the definition of disability under the ADA?": https://adata.org/faq/what-definition-disability-under-ada

5. Wong, Alice (ed). *Disability Visibility: Twenty-First Century Disabled Voices*. New York: Vintage Books, 2020, p. xxii.

6. *Disability and Health Overview | CDC*. (2020, September 15). Centers for Disease Control and Prevention. https://www.cdc.gov/ncbddd/disabilityandhealth/disability.html

7. *Infographic: Adults with Disabilities: Ethnicity and Race |* CDC. Centers for Disease Control and Prevention, October 25, 2019.

https://www.cdc.gov/ncbddd/disabilityandhealth/materials/infographic-disabilities-ethnicity-race.html

8. *Infographic: LGBT People with Disabilities*. Movement Advancement Project, 2019. https://www.lgbtmap.org/file/LGBT-People-With-Disabilities.pdf

Annotated Slides
Slide 8

The previous slide was focused on statistics within the US which can carry over to the field of conservation. In 2021, the AIC Equity and Inclusion Committee conducted the *AIC Accessibility in Conservation Survey* with the aim of providing baseline data on disabilities and accessibility in our field. The resulting report cover is included on the slide. [9]

There were 558 completed responses with 29% of respondents identifying as having a disability or disabilities, consistent with the statistics for adults in the US. It was noted that, overall, 41% of those who identify as having disabilities reported feeling understood and supported by their colleagues.

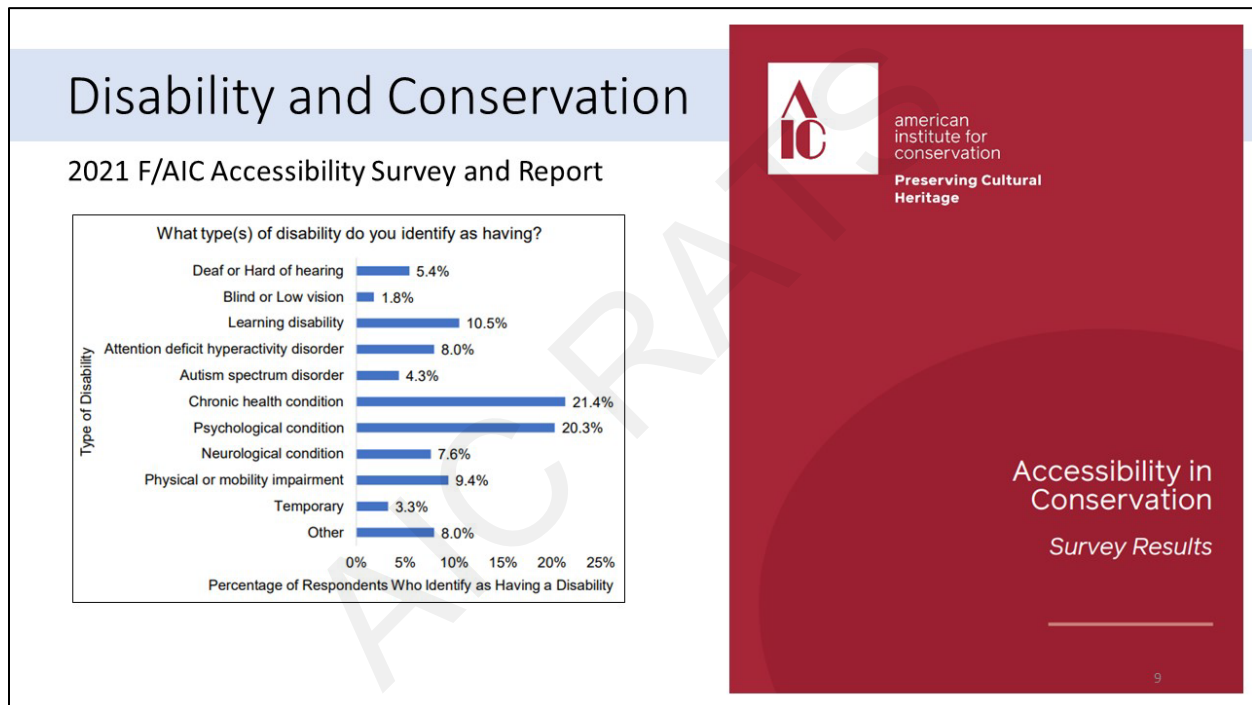9. Report *Accessibility in Conservation Survey Results. American Institute for Conservation*, 2022. https://www.culturalheritage.org/docs/default-source/publications/reports/survey-reports/accessibility-in-conservation-report.pdf.

Annotated Slides
Slide 9

This bar chart from the survey indicates the different types of disabilities that respondents identified as having. It ranges from deaf or hard of hearing, blind or low vision, and physical or mobility impairments to chronic health conditions and psychological and neurological conditions.

The key takeaway from this chart is that the largest percentages for types of disabilities were non-apparent, invisible disabilities, which are "chronic health condition" and "psychological condition."

Annotated Slides
Slide 10
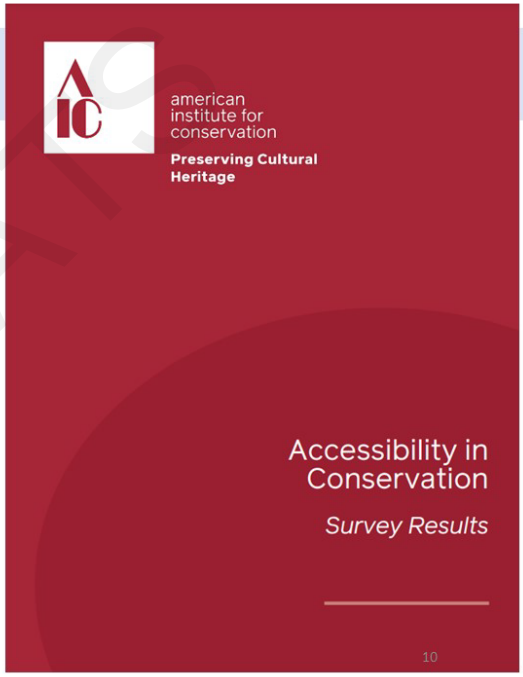
The survey report identified four themes:

- Lack of awareness of existing resources to help create more accessible opportunities and spaces. Many people are not aware of existing resources, including information already provided on the AIC webpages.

- Lack of awareness of challenges for colleagues with disabilities. Those who identify as not having disabilities are neither fully aware of the challenges faced by their colleagues nor the number of AIC members who identify as having disabilities.

- Hybrid and virtual events provide opportunities for greater accessibility for members with disabilities. It is possible that some of these practices could be incorporated to make in-person events more accessible for the field.

- People with disabilities need to feel heard and their challenges recognized even if they cannot be fully addressed.

At this point, we have defined some key terms, and we have briefly looked into disability within our field. Now we would like to bring in two disability frameworks to challenge our thinking about access and accessibility and to expand inclusion. These frameworks are Disability Justice and Universal Design.

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Annotated Slides
Slide 11

Patty Berne, a disability rights activist and co-founder of *Sins Invalid*, writes "A disability justice framework understands that:

- All bodies are unique and essential.

- All bodies have strengths and needs that must be met.

- We are powerful, not despite the complexities of our bodies, but because of them.

- All bodies are confined by ability, race, gender, sexuality, class, nation state, religion, and more, and we cannot separate them."[10, 11]

We want to note the difference between the "Disability Rights Movement" and "Disability Justice." The disability rights movement is a civil rights movement that works to secure equal opportunities and rights for people with disabilities, but it has historically focused on the voices and experiences of white people. "Disability Justice" moves beyond by acknowledging and addressing intersectionality. It also considers how ableism affects all justice movements, and how to build mixed ability spaces and cultivate solidarity.[12]

10. *What is Disability Justice?* Sins Invalid. June 16, 2020. https://www.sinsinvalid.org/news-1/2020/6/16/what-is-disability-justice

11. Sins Invalid. *Skin, tooth, and bone: The basis of movement is our people* (2nd ed.). California: Sins Invalid, 2019, https://www.sinsinvalid.org/disability-justice-primer.

12. Mingus, Mia. "Changing the Framework: Disability Justice." Leaving Evidence, February 12, 2011, https://leavingevidence.wordpress.com/2011/02/12/changing-the-framework-disability-justice/.

Annotated Slides
Slide 12

The second framework is "Universal Design" which can also be referenced as "Inclusive Design" or "Design-for-All." Universal Design, as defined by the *Institute for Human Centered Design*, is "…a framework for the design of places, things, information, communication and policy that focuses on the user, on the widest range of people operating in the widest range of situations without special or separate design. Or, more simply: Human-Centered design (of everything) with everyone in mind." [13]

This framework advocates for design with everyone in mind.

13. *What is universal design…inclusive design…design-for-all?* Institute for Human Centered Design. https://ihcd-api.s3.amazonaws.com/s3fs-public/file+downloads/Inclusive+Design+Cheat+Sheet+6+18.pdf
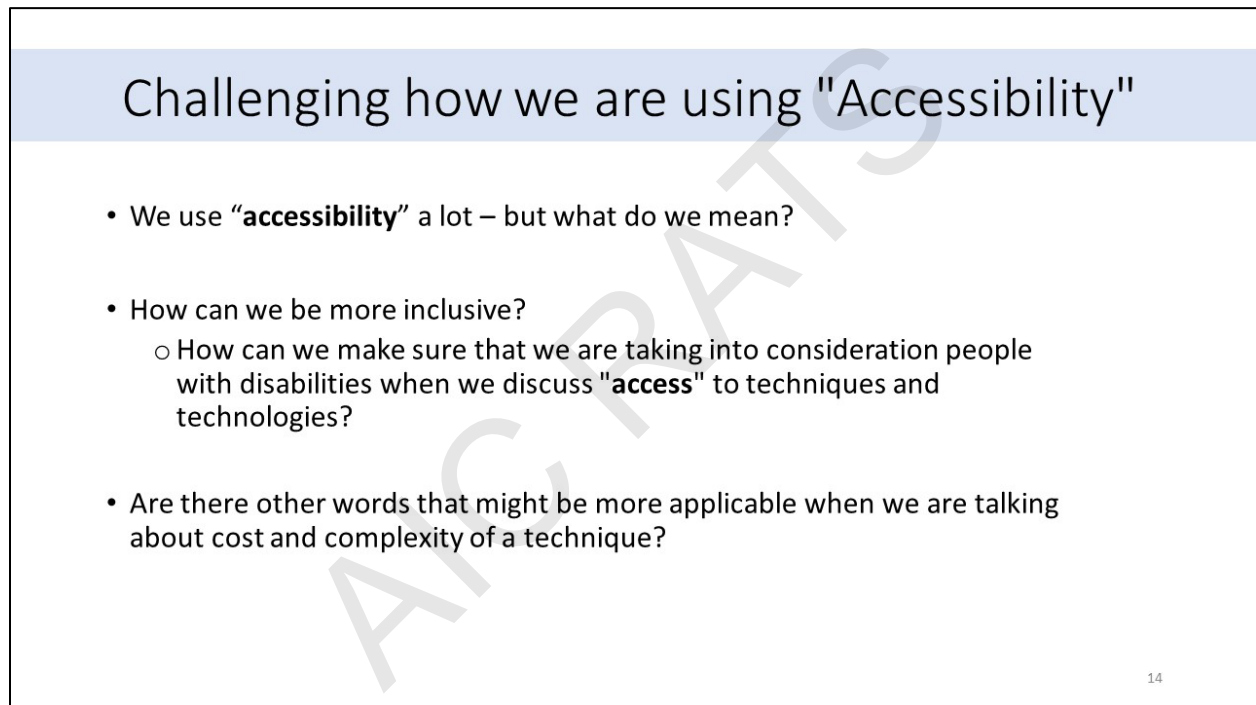
Annotated Slides
Slide 13

Accessibility can be the bare minimum and can be very prescriptive, providing only specific narrow forms of accessibility for a specific need only, whereas "Universal Design" and "Disability Justice" aim to maximize the benefits for everyone with a Design-for-All approach.

Annotated Slides
Slide 14

We would like to return to the initial questions that we asked at the beginning of the presentation.

We use "accessibility" a lot – but what do we mean? It may be intended to expand engagement, but still excludes people with disabilities. Also, do we truly mean "accessible" when we use it to describe an imaging technique or an analytical technique?

How can we be more inclusive to make sure that we are taking into consideration people with disabilities when discussing access to these techniques and technologies?

Are there other words that might be more applicable when we are talking about the cost and complexity of a technique?

We are not saying to no longer use the terms "access" and "accessibility," but we want to challenge you, and ourselves, to extend our definitions of access and accessibility beyond cost, sustainability, and complexity to include people with disabilities. We want to encourage a shift in how we are making our work and workplaces more accessible and inclusive.

The next couple of slides are examples of how to make physical and virtual spaces more accessible. These may provide examples of how you can start to take actions to address the lack of accessibility in physical or virtual environments.

Annotated Slides
Slide 15

There are several products that can be purchased to make the physical space more accessible to people with disabilities. It is not just about space. Some examples include:

- Flexible/adjustable height tables

- Ergonomic chairs

- Visual fire alarms

- Non-slip mats

- Beakers with handles or clamps

- High-contrast, large font signs

- Uncluttered spaces

- Ramps

- Real-time captioning (CART)

- Window masks

Annotated Slides
Slide 16

Example of Accessibility in Virtual Space

- Use of plain, inclusive language

- Sufficient, legible color contrast

- Alt Text for images

- "Coffee Break" rooms for long meetings

- Live open captioning

- Repetition of questions asked both verbally and in written form before answering

- Identify yourself whenever you are speaking in a dialogue

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As for the virtual space, examples include:

- Use of plain, inclusive language

- Sufficient, legible color contrast

- Alt Text for images

- "Coffee Break" rooms for long meetings

- Live open captioning

- Repetition of questions asked both verbally and in written form before answering

- Identify yourself whenever you are speaking in a dialogue

In the presentation, we shared a screenshot of a tweet that provides a great example of an image description. We have pulled the screenshot from this version of the presentation, but the image description can still stand on its own and provide an example of how to write an image description. The image description read, "Shelby Lynch on the cover of Glamour (UK digital). Shelby is a Black woman wearing dark lipstick and a light green sweater with tassels she is in a pink electric wheelchair. The words around her say, 'Fashion is something I can control;' 'The Self-love issue.'" [14]

14. Haller, BA (@Mediadisdat). *Twitter*, January 18, 2023, https://twitter.com/Mediadisdat/status/1615831464339443712?cxt=HHwWgMDQjfyJy-wsAAAA.

Annotated Slides
Slide 17

As we wrap up the presentation, we have three recommendations:

- Add an A to your D&I or DEI work. The "A" represents access and accessibility. We need to be talking about disability and accessibility more, especially whenever we talk about diversity, equity, and inclusion. We encourage you to consider Disability Justice and Universal Design as parts of this work. Think about intersectionality and participation for as many people as possible.

- Explore proactive ways to increase accessibility in physical lab/studio spaces, virtual work environments, and disseminated research. How will you make your work or workplace more accessible?

- Lastly, we challenge each of you to read, watch or listen to stories from the disability communities and by disabled artists and writers. A list of resources will be shared at the end of the presentation. By educating yourself, you can have a more open conversation with your friends and colleagues who may identify as having disabilities.

Please note that what we have provided is not a checklist. Do not see means of access and accessibility as a simple check on your list.

Annotated Slides
Slide 18

We would like to end this presentation with a quote from Steve Ballmer:

"Accessible design is good design – it benefits people who don't have disabilities as well as people who do. Accessibility is all about removing barriers and providing benefits of technology for everyone."

Access and accessibility benefit everyone.

Annotated Slides
Slide 19

Thank you for attending our presentation. On the slide there is a QR code with a list of resources. If you have any questions or would like to contact us, here are our emails.

Sally's Smithsonian email address is no longer active, but her email address at the time of the postprints publication is skim@royalbcmuseum.bc.ca.

Bridging the Gap: Redirecting the Heritage Science Curriculum Towards Accessibility and Globalization

Kyna Biggs[1]*, Alison Murray[2], Aaron Shugar[3], Rebecca Ploeger[4]

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[2] Associate Professor, Conservation Science, Queen's University
[3] Bader Chair in Analytical Imaging, Queen's University
[4] Associate Professor, Conservation Science, SUNY Buffalo State University
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Extended Abstract

Keywords: conservation science, education, online teaching resource, teaching strategies, threshold concepts

Historically, a clear divide between the sciences and humanities has existed, treating the disciplines as separate and with limited overlap. The field of art conservation is, however, uniquely situated within this divide, as conservators must routinely combine knowledge from both scientific and artistic disciplines in their practice. Science is a central part of the conservation training curricula internationally, even if the distribution and focus of pure and applied science courses varies widely. Successful conservators depend on a general body of scientific knowledge and core competencies, and educators have a deep interest in making sure students have a strong science foundation.

While developing an understanding of key scientific principles adds critical aspects to conservation education and practice, it is often noted by conservators that the science curriculum is inaccessible to many entering the field. This perceived disconnect during training can result in a reluctance to incorporate advanced scientific techniques within conservation practice or to collaborate with conservation scientists. As a result, the authors of this paper endeavour to improve the teaching of the science curriculum through various methods.

Defining threshold concepts within the field

A 'threshold concept' is one that, once understood, changes the way that a person thinks about a topic. Understanding threshold concepts is essential for mastering any subject and for adopting a deeper understanding of it. Outlined by Meyer and Land (2003), threshold concepts have five key characteristics:
i.   Troublesome – a place where students get stuck
ii. Transformative – causes a shift in perspective in learning

iii. Irreversible – once the concept is grasped, it cannot be un-grasped
iv. Integrative – brings together separate concepts
v. Bounded – may help to define the boundaries of a particular discipline

Investigating threshold concepts can lead to an improved curriculum, helping to identify why certain topics are challenging, what teaching strategies work well, and what new tools should be developed to tackle teaching challenges.

Defining teaching difficulties

Through interviews and surveys conducted by the authors of this paper, as well as discussions with a global audience during the *Inaugural Conservation Science Education Online (CSEO) Conference* (2022), common themes as to why teaching science can be difficult arose:
i. Science can be unrelatable
   • The way that science is sometimes taught can be disconnected from the conservation practice, making it hard to grasp how theories are actually useful and applicable to treating objects.
ii. Preconceived fear of science
   • In a lot of students' experiences, science has not been taught in an accessible manner in the past, making them apprehensive in science courses.
iii. How much to know
   • Between conservators and educators surveyed, there seemed to be a general confusion of the level of science that students need to know.
iv. Limitations of science
   • Science sometimes cannot give all of the answers, and not fully understanding this can create stumbling blocks for many students.

Conservation Science Education Online (CSEO) Resource

Universal issues raised related to difficulties that come with teaching science illustrated the need for a resource that supports educators and provides them with information to aid in their teaching. In response to this need, the authors of this paper are developing the *Conservation Science Education Online (CSEO) Resource*, an online resource that is based on peer-reviewed contributions from colleagues around the world who participate in science education aimed towards conservation students (**Fig. 1**).

Figure 1. The Conservation Science Education Online (CSEO) Resource.

The resource consists of modules designed by educators who have already taught the topics successfully. A module might be an application, a case study, a collection of infographics, or a problem-based learning method that shows how a certain concept or theory relates to the real-life scenarios a conservator may encounter. Another module could illustrate how a collaborative strategy can make a class or assignment more engaging. Modules are broken down into sections that depend on their specific content (**Table 1**).

Table 1. Content of modules in the Conservation Science Education Online (CSEO) Resource.

Section	Content Description
1. Title Page	Title, purpose, authors, affiliations, intended audience and abstract.
2. Introduction	Concept to be discussed with brief introduction and outline of the topic (e.g., hypothesis that provides the key issue and reason for the unit, the main threshold concept(s) or task being presented, a list of major goals and student learning outcomes).
3. References	Key resources that support the module (e.g., academic papers, theses, images, videos, lab notes, exercises, infographics, data, websites, case studies).
4. Images	Explanatory images, videos, or infographics that can be used to explain key concepts.
5. Lesson plan, teaching method, laboratory, course, project	Details of the plan are needed: procedure, process, case study instrumentation, or outcome that addresses the hypothesis, concept, or key issue in heritage science.
6. Methods for Student Engagement	Discussions, assessments, and challenges (e.g., questions to promote student engagements, sub-topics that are challenging, teaching strategies, class questions).
7. Comments	An area open for comments and suggestions from others in the CSEO community, as well as an assessment of outcomes from implementing the module.

A collaborative, global response to these teaching concerns is needed to develop effective strategies for heritage science curricula to encourage scientific confidence in students, both in short- and long-term learning. Properly linking scientific theory and application to the practice of conservation, giving tangible examples, and encouraging interdisciplinary collaborations will be key to meeting this goal. With contributions from a diverse, global audience, the CSEO resource will provide tools to a community focused on improving the science curricula.

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Increasing Student Engagement in Sustainability Initiatives at the Queen's University Art Conservation Program

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Original Abstract

This poster will give an overview of research into waste disposal and material recycling practices within the Queen's Art Conservation program during 2022 and 2023. The lifecycle of various materials used in the conservation labs at Queen's University, including commonly used solvents, nitrile gloves, and plastics, were assessed with the goal of providing graduate students with resources to make more informed decisions about sustainable material use in the labs. In order to gauge a baseline of student knowledge of material disposal and recycling protocols, a simple survey was sent to current and recently graduated students in the Summer of 2022. The results of this survey were taken in conjunction with an audit of items placed within trash receptacles in laboratory spaces to identify what materials, if any, could have been reused or directed to a recycling stream. It was determined that although students largely believed they were recycling materials to the best of their knowledge during laboratory activities, many materials, including coroplast, mylar, and paper towels, could have been reused or recycled instead of directed to the waste stream. The survey also identified that students desired recycling and waste disposal protocols to be more directly addressed within laboratory modules, and for sustainability as a concept to be better integrated into the general Master of Art Conservation curriculum.

At the time of writing this abstract, further research will take place throughout the fall of 2022 and winter of 2023 to determine the impact of signage placed throughout laboratory spaces to make recycling protocols and initiatives more accessible to students in their everyday lab activities. The effect of these signs in diverting recyclable or reusable materials from the waste stream will be determined through continual waste audits and another student survey to be sent out in winter 2023. This poster directly relates to the theme of this year's AIC conference by introducing a potential avenue for increasing student engagement with sustainable decision making, and gives an insight into ecological sustainability from a graduate student perspective.

The Mysterious Glass Pectoral of the Lady Nfrw Found in Saqqara Necropolis: Theories of Glass in Ancient Egypt -- Is There a Scientific Explanation?

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Original Abstract

This glass Pectoral of the lady Nfrw is preserved at the Egyptian Museum, Cairo EMC, JE 92636, belongs to the collection of the Lady Nfrw – Ramesside period 19th dynasty, discovered among other objects in 1957 at Saqqara Necropolis. The entire pectoral shape of a naos (or shrine) belongs to the lady Nfrw used by ancient Egyptian artisans. This pectoral is in the shape of a naos (or shrine) like a naos, inside a heart amulet is found above a solar barque where the gods Re and Osiris are also visible. On the base – a small part whose edge is chipped – a text is engraved in several lines because of this god's representation and the text's content, which combines the beginning of Chapter 30 B of the Book of the Dead. It is the oldest known example made of glass using the engraving technique. This study aims to analyze the glass heart using Reflectance Transformation Imaging (RTI) and Optical Light Microscopy (OLM) to reveal more information related to the engraving technique and the tools used on the glass surface.

Investigating the Materials and Techniques Used in Traditional Paintings of Rajasthan

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Extended Abstract

Mapping Color in History (MCH) is a digital humanities project led by George P. Bickford Professor of Indian and South Asian Art at Harvard University, and Jinah Kim, focused on gathering historic and scientific data drawn from analyses of pigments in Asian paintings. Of particular interest to this project is the study of South Asian art, including research on the materials and techniques employed by traditional artists to create Indian manuscripts. In order to build on the project's spectral database of Indian pigments, we turned to the workshop of a contemporary miniature painter called Mr. Babulal Marotia, who resides in Jaipur, Rajasthan. Mr. Marotia comes from a long line of traditional artists, including his father with whom he trained, Mr. Natulal Marotia, as well as the late Kripal Singh Shekhawat who garnered the Padma Shri from the Indian government in 1974. As a result of his background and training, Mr. Marotia largely works with traditional materials, including mineral- and plant-based pigments. Thanks to the help and interest of Mr. Marotia, a collection of forty-one pigments were collected by MCH-India project coordinator Ms. Anjali Jain to add to the project's reference material database. The pigments were fully characterized at the Straus Center for Conservation and Technical Studies using Raman spectroscopy, Fourier-transform infrared spectroscopy (FT-IR), X-ray fluorescence spectroscopy (XRF), scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS), excitation-emission matrix (EEM), and powder X-ray diffraction (XRD). The current abstract will highlight a selection of these pigments and detail their names in Hindi, their chemical compositions, and their known processing techniques.

A number of traditional pigments were identified in the collection, including the mercury sulfide *hinglu* (vermillion), the aluminosilicate *khariya* (kaolinite), the arsenic sulfide *harital* (orpiment), the lead oxide *sindoor* (red lead), the carbon-based *kajal* (carbon black), and the copper carbonate *dana farang* (malachite) to name some examples. These mineral pigments have all been previously identified in Indian manuscripts housed in the Harvard Art Museums dating back to the 16th century. **Figure 1a** illustrates one such example, *Krishna*

Sporting with the Cowherds from a Bhagavata Purana series created in the Mathura region of Uttar Pradesh (c. 1540, 1974.125, Harvard Art Museums), alongside spectral data confirming the use of *hinglu*, *khariya* and *harital* in this traditional manuscript. Note that *hinglu* and *harital* were identified using Raman spectroscopy, while the use of *khariya* was confirmed with FT-IR.

Upon analyzing the collection more closely, it was discovered that a few pigments were mislabeled by the artist, showcasing the use of alternative artists' materials found in more recent Indian manuscripts. One example is the blue pigment *neel*, which the artist mistakenly described as being indigo. A combination of SEM-EDS, FT-IR and Raman were used to confirm that the pigment was a mixture of different components, including calcite (likely used as a white pigment), barium sulfate (either used as an extender or white pigment), quartz, and Prussian blue. The use of Prussian blue in Indian manuscripts is, perhaps surprisingly, expected in manuscripts that are dated past the 18th century. **Figure 1b** illustrates an example, *Demons Approaching Rama and Lakshmana at a Fire Ceremony* likely created in Sirohi, Rajasthan (c. 18th-19th century, 1973.164, Harvard Art Museums), alongside spectral data confirming the use of Prussian blue. A second example of a mislabeled pigment was a silvery metallic pigment referred to as *ranga* by the artist, thought to be metallic tin. Analyses using a combination of SEM-EDS and XRD confirmed that the pigment was made of metallic aluminum (with traces of quartz and calcite), a material that had previously been discovered in *Assembly of Warriors, illustration to the Gemini Ashwamedha of the Mahabharata* created in Maharashtra (c. 19th century, 1962.345, Harvard Art Museums) where it is featured as a metallic foil insert, as seen in **Figure 1c**. Although such materials would not be expected in traditional Indian manuscripts dated from the 16th or 17th century, it is possible that in later time periods they were purposely selected by artisans as more economical substitutions compared to indigo and metallic tin.

Lastly, the collection contained a few examples of pigments that had not been previously identified within Indian manuscripts at the Harvard Art Museums, seen in **Figure 2a**. This included the plant-based pigment *rasot*, that was described by the artist as being obtained from trees. Through EEM, it was identified that the raw pigment was fluorescent under UV light, emitting a green-colored light (~530 nm). This was due to the presence of berberine in the raw material, which was further confirmed with FT-IR analysis. An additional, processed version of this pigment was included in the collection. It was obtained by dissolving the raw pigment in water, and then filtering out the impurities. The processed version of the pigment did not fluoresce under UV and did not contain berberine, likely because this compound would have been removed during the filtering step. The two plant-based pigments will be further analyzed in future studies, in order to gain more information on the source trees. Finally, another pigment that had never been identified in Indian manuscripts within the Harvard Art Museums was the arsenic sulfide *mensil*, which was identified as β-realgar, the high temperature analogue of α-realgar (natural realgar). The Raman spectrum of *mensil* is shown alongside that of natural realgar and pararealgar in **Figure 2b**, confirming that this is a distinct arsenic sulfide phase. It is widely known that natural realgar will alter into pararealgar over prolonged exposures to light. In order to better understand the effects that

roasting the natural pigment might have on its color longevity, future studies will investigate how the light-stability of β-realgar pigments compares to that of natural realgar.

Following the completion of the project, the collection of forty-one pigments and their spectral data will be published and available to access on the MCH website. The pigments will be used as reference materials to aid in the non-invasive identification of pigments in Indian manuscripts using techniques such as reflectance FT-IR and FORS, which will be presented in future work.
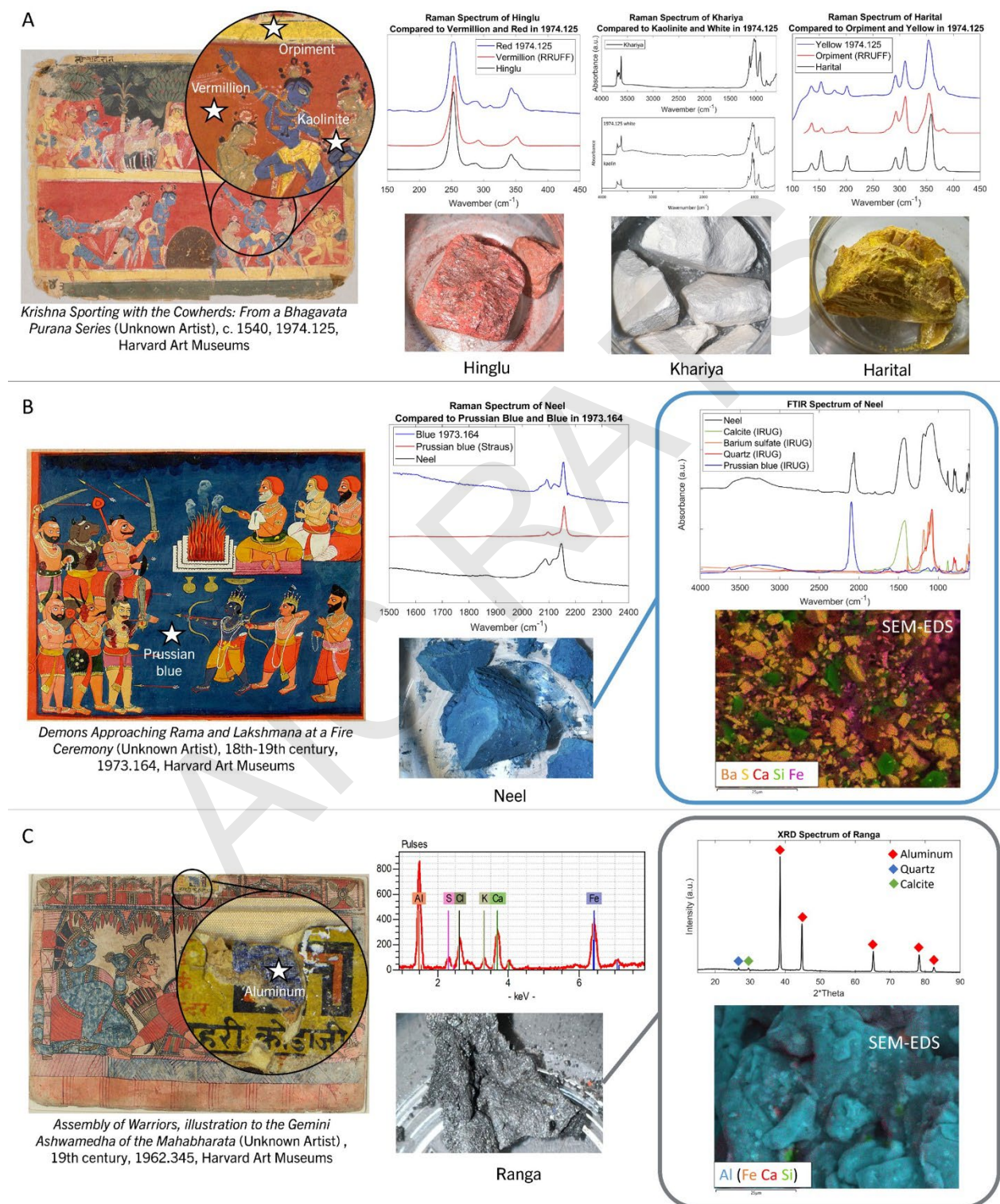
Figure 1. Indian manuscripts from the Harvard Art Museums alongside related pigments from the workshop of Mr. Babulal Marotia. This includes traditional mineral pigments featured in folio (A) 1974.125 (*hinglu*, *khariya* and *harital*), and more modern materials featured in folio (B) 1973.164 (*neel*) and (C) 1962.345 (*ranga*).
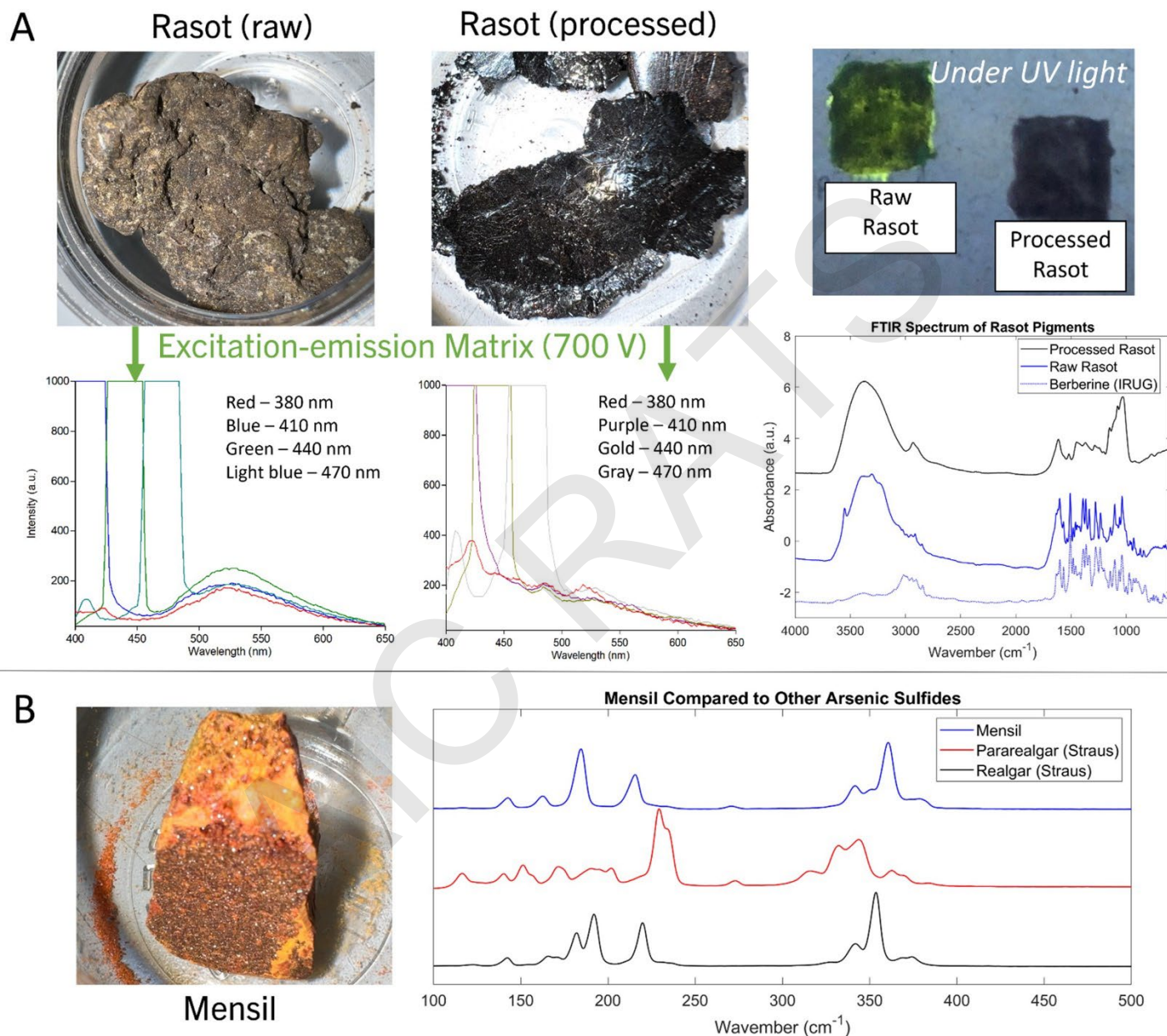
Figure 2. (A) The two *rasot* pigments are shown along with their corresponding EEM spectra, showing that the raw form fluoresces green under UV light, while the processed version does not fluoresce at all. FT-IR spectra of the *rasot* pigments indicates that the raw form contains berberine, while the processed version does not. (B) The Raman spectrum of *mensil* (also known as ß-realgar) is shown alongside other arsenic sulfide phases commonly found in Indian manuscripts.

(Don't) Spare the Horses: A Technical Analysis of Acee Blue Eagle's Tempera Painting, Warriors on Horses

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Original Abstract

Acee Blue Eagle (1907-1959), one of the prolific artists to emerge from Oklahoma, was an internationally celebrated Native American artist in his lifetime. Born Alexander C. McIntosh, Acee Blue Eagle was part of the Muscogee (Creek) Nation and studied painting under Oscar B. Jacobson. Blue Eagle graduated from the University of Oklahoma and became the first Director of the Art Department at Bacone College in 1935. Blue Eagle painted primarily in the flatstyle which employs techniques such as contour lines, bright colors, and minimal background using tempera paint on paper. Blue Eagle's painting, Warriors on Horses, is an example of flatstyle and is in the collection at the Gilcrease Museum in Tulsa, Oklahoma. The painting is part of a larger project funded by the Henry Luce Foundation to catalogue, report, and conserve art in the indigenous painting collection. The poor condition of the tempera painting is an example of the condition commonly found in the vast collection which include works from Woody Crumbo, Fred Beaver, and the Kiowa Five.

Warriors on Horses is in poor condition from previous display and storage, exhibiting photochemical damage of the matboard substrate and paint, cracking of the paint, and media loss. Fourier-transform infrared spectroscopy (FTIR-ATR) analysis and solubility tests revealed that the binder is not soluble in water unless the paint was exposed to environmental factors, especially light. The binder resembles a modern water-based poster paint having a synthetic component, likely a vinyl polymer. X-ray fluorescence (XRF) was completed to ascertain the elemental composition of the pigments which include titanium dioxide/zinc mixtures of white, lead based yellows, iron oxide reds, and calcium found in bone black. Microfading testing (MFT) was performed on the pigments along with the matboard substrate to evaluate the vulnerability of the materials for future exhibition and storage. The analysis of the MFT data collected illustrates the vulnerability of the red paints and the matboard substrate. These findings about the red paint are counterintuitive to the known stability and permanence of iron oxides and provides an example of the complexities of the components that are in the water-based pigments. The investigation into the materials of Blue Eagle's painting revealed the characteristics of his materials, advancing the knowledge of the process that he took in the creation of his art and will

inform the future exhibition, storage, and treatment of his artwork as well as similar artwork found in the collection.

Characterization of Mark Tobey's Paint Materials Using Mass Spectrometry Methods

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Original Abstract

Mark Tobey was a founder of the Northwest School and a 20th c. painter working in the Pacific Northwest, New York and internationally. He worked primarily in aqueous media on paper, utilizing gouache and tempera while experimenting with layering unconventional materials. A painter of calligraphic images inspired by his spirituality, his extensive travel and innovative style established his work in the collections of major museums around the world. Analysis of his painting materials is absent from the literature, and the prevalence of friable and underbound paint layers prompts binder analysis to inform conservation treatment. This study sought to understand the composition of Tobey's paints by utilizing sensitive mass spectrometry methods such as Pyrolysis coupled to Gas Chromatography Mass Spectrometry (Py-GC/MS) and proteomics via Liquid Chromatography Tandem Mass Spectrometry (LC-MS/MS) to identify key components of reference binders and paints as well as microsamples from paintings by Mark Tobey from the collections of the Seattle Art Museum and the Jordan Schnitzer Museum of Art in Eugene, Oregon.

Py-GC/MS utilizing a TMAH methylating agent was modified from a published method and used to characterize a range of traditional and unconventional reference binders, papers, and materials including plant gums, egg, linseed and heat-bodied oils, PVA, resins and waxes as well as commercial tempera paints documented in Mark Tobey's studio. Unique markers for each binder were identified by running references multiple times and the data resulting from these analyses were compiled into custom libraries in AMDIS and searched against when analyzing Tobey paint samples. Egg was identified via Py-GC/MS by detecting indoles and pyrroles and was often found concurrently with linseed oil, detected via the presence of a strong azelaic acid dimethyl ester peak. Analysis of proteinaceous reference binders via enzyme digestion and tandem LC-MS/MS is ongoing and will aid in verifying the presence of egg and other protein binders in Tobey's paints.

The Pecking Order: Using Digital Capture and Multi-Criteria Decision Analysis to Rank Cleaning Techniques for Feathers

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Original Abstract

Though digital images, micrographs, and descriptive notes are typically qualitative in nature, these familiar, affordable, and accessible formats can be used to support highly structured decision-making in treatment. One approach was recently developed by conservators at the American Museum of Natural History using digital capture and multi-criteria decision analysis to assess the impacts of cleaning on feather preservation. This strategy can be applied easily and effectively by others interested in systematically interpreting qualitative data to inform treatment decisions.

After surveying a community of over 100 professionals about their practices for cleaning feathers, the AMNH research team selected 23 techniques for in-depth experimental investigation. In nearly 250 cleaning tests, physical changes resulting from cleaning were recorded using a standardized written template, multi-band digital images taken with a modified DSLR camera, and digital photomicroscopy.

Interpreting the experimental dataset to directly compare cleaning methods required integrating a large volume of qualitative data generated in multiple formats. The research team first developed a comprehensive, controlled vocabulary describing categories of damage with levels of extent, and then used this framework to catalog the results of each cleaning test. Each damage type was further characterized with a visual example, creating a glossary to support shared understanding. The Analytical Hierarchy Process (AHP), a structured technique for analyzing and supporting complex decisions, offered a means to convert this typology into a ranking of techniques based on the relative importance of damages observed in testing.

Through a series of pairwise comparisons, each type of damage was assigned a numerical priority reflecting its importance to the selection of a safe and effective cleaning method. From the priorities, scores were computed for the 23 cleaning methods tested. Ranked by score, one can see which methods carry the greatest risk of damage. From these

rankings, a digital decision-making tool was developed to guide conservators in treating feathered objects.

With a strong data set supporting the analysis, the AHP can be used to systematically merge diverse, categorical, qualitative measures into rational measures of importance to a conservation treatment objective. Although some sophisticated imaging equipment supported this study, the process does not require complex equipment, and provides the conservation community with an accessible approach to characterizing and comparing impacts of alternative treatments.

Pilot study on DRIFT analysis using silicon carbide sandpaper for *in situ* characterization of plastic materials in storage collections

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Extended Abstract

Material characterization of museum objects is critical to understanding the history of technology, evaluating changes in condition, and planning for proper storage. At the Philadelphia Museum of Art (PMA), the Scientific Research Department (SRD) utilizes a complement of analytical techniques for the study of the collection. While in many cases material identification still requires sampling, the SRD has been developing non-invasive analytical protocols, utilizing the Bruker ALPHA II FTIR and its three associated modules.

The three modules include external reflection (ER), attenuated total reflection (ATR), and diffuse reflectance (DRIFT). The ER module is suitable for flat, highly reflective surfaces and is completely non-invasive, whereas the ATR module is used for flexible materials like textiles and soft plastics but can sometimes leave an indentation mark on the surface of the object. The DRIFT module is used for objects that, due to their shape and texture, are not amenable to either ER or ATR analysis; it requires a small sample and, therefore, can be considered micro-invasive.

DRIFT spectroscopy was introduced to the field of analytical chemistry at the end of the 1970's as a rapid and sensitive alternative technique to transmission FTIR[1,2,3]. Initially performed by mixing a sample with potassium bromide, in 1984, Perkin Elmer Limited introduced a rapid sample preparation protocol using only the sample on a piece of silicon carbide sandpaper[4,5]. In the 1990's the Victoria and Albert Museum successfully analyzed cultural heritage materials by DRIFT spectroscopy using a similar method[6].

At the PMA, a pilot study to use DRIFT was carried out for the rapid characterization of plastics that could be performed *in situ* without the sample manipulation typical of transmission FTIR. For DRIFT analysis, a 10 mm disc of 2000 grit Carborundum silicon carbide sandpaper was rubbed against the studied object, sampling 20 micrograms of material. The sample was analyzed directly on the sandpaper disc; the spectra obtained are comparable with transmission and ATR spectra. The *in situ* protocol was developed first on known polymer materials (The ResinKit™, 1997) and then extended to surrogate objects and accessioned artworks at the PMA.
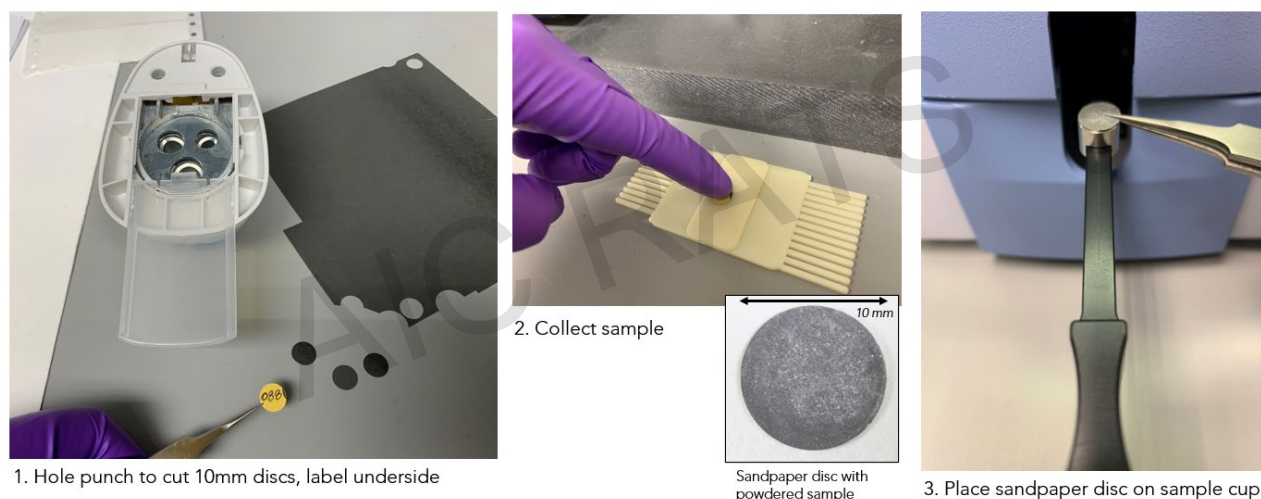
1. Hole punch to cut 10mm discs, label underside

2. Collect sample

Sandpaper disc with powdered sample

3. Place sandpaper disc on sample cup

Figure 1: Sampling methodology using the DRIFT module includes: preparing the 10mm sandpaper discs (1), collecting a sample by rubbing the disc on the object (2), and then placing the sample/sandpaper disc into the DRIFT module for analysis (3).

High-Density Polyethylene (HDPE) was used as a standard for method development due to its relatively uncomplicated chemical formula and typically low additive content. Focusing on the doublets at 1471 and 727 cm^{-1}, due to bending and in-plane deformation of the methylene group, respectively[7,8,9,10], sensitivity and resolution were monitored and compared with the ER spectrum. The background for both modules was a gold mirror, with a resolution of 4 cm^{-1}. **Figure 1** illustrates the steps to prepare the sandpaper discs, sample material, and placement of the disc on the DRIFT module sample cup. Using HDPE, the optimal sampling was achieved by rotating the sandpaper disc 180° clockwise/counterclockwise 3-5x by applying light pressure while still maintaining steady contact between the sample and the sandpaper. It should be noted that this sampling approach abrades the surface; this necessarily limits the application of this technique for some artworks, and when utilized, sampling sites must be chosen judiciously.

This method was repeated to analyze reference samples from the ResinKit™, focusing on four distinct, commonly found polymers: polystyrene, polymethyl methacrylate (PMMA or acrylic), polyamide (nylon), and acrylonitrile butadiene styrene (ABS). Special attention was paid to varying pressure needed to sample the different polymer types. For smooth plastics, a light touch was often needed to successfully sample the material. Too much pressure could cause the sandpaper to grip the surface, preventing rotation and sample collection. Of the materials tested at this stage, polyamide was observed to show the least amount of abrasion due to sampling. Plastics with glossy or transparent surfaces showed the most noticeable abrasion.

Before moving to accessioned objects, surrogate objects of the four polymer types were sourced from museum gift shops or personal collections. The surrogate objects included polystyrene calendar cubes, a Moka pot with polyamide handle, ABS LEGOs®, and an acrylic refrigerator magnet. Utilizing surrogates provided the opportunity to sample from three-dimensional objects and evaluate DRIFT as a viable technique for identifying plastics containing unknown additives. After refining procedures, the sampling methodology was then applied to objects selected from design collections at the PMA. The objects were chosen

specifically because they were non-ideal for analysis with ER and could be sampled discreetly for DRIFT. **Figure 2** represents the analyses of the *"Hot Bertaa" Kettle*, designed by Philippe Starck for Alessi (PMA 1997-185-1). The curvature of the handle was not an ideal geometry for ER analysis and the resultant spectrum is noisy. A discreet sample was taken from the interior of the handle and analyzed by DRIFT; both spectra were identified as polyamide. There is a large inverted peak in the DRIFT spectrum at approximately 800 cm^{-1} known as the *Reststrahlen* effect; this peak is due to the sandpaper matrix (silicon carbide) which has an extremely strong absorption in this area.
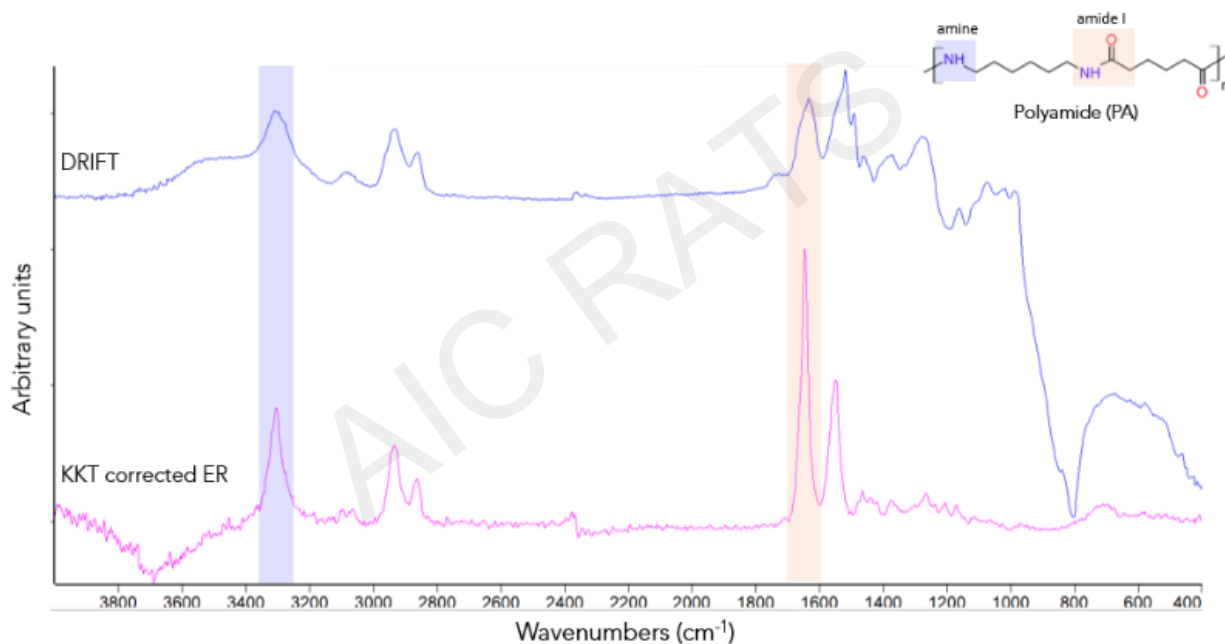
Figure 2: Comparison between the DRIFT and the KKT corrected ER results of an accessioned object at the PMA.

Table 1. Identification summary of the five objects analyzed with ER and DRIFT. Text in red indicates updated identification.

	Material listed in TMS	Identification	ER identified	DRIFT identified
"Hot Bertaa" Kettle, designed by Philippe Starck for Alessi, Designed 1990, PMA 1997-185-1	Aluminum and Acrylonitrile butadiene styrene	Aluminum and polyamide	✓	✓
"Hidden.MGX" Vase, designed by Dan Yeffet for Materialise, Designed 2007, PMA 2007-38-1	Laser-sintered polyamide	polyamide		✓
"Filterjet" Fan, designed by Peter Schlumbohm for Chemex Corporation, Designed 1951, PMA 1983-48-1	Plastic	Acrylonitrile butadiene styrene or styrene acrylonitrile resin	✓	✓
"Poe" Radio, designed by Philippe Starck for Alessi, Designed 2003, PMA 2003-195-2	ABS plastic	Polyester	✓	✓
"Walter Wayle" Clock, designed by Philippe Starck for Alessi, Designed 1989, PMA 2003-195-3	Thermoplastic resin	Polystyrene + other components		✓

DRIFT is a promising technique for the analysis of plastics, but the impact of sampling must be carefully considered. Non-invasive techniques such as ER should always be attempted first. However, for objects with complex geometries such as *"Hidden.MGX" Vase* included in the table above, analysis with ER may not be possible. DRIFT is ideal for these situations. Additionally, DRIFT serves as a corroborative tool, enhancing confidence in material identification by providing complementary data alongside ER results.

Through this pilot study, a better understanding of the strengths and limitations of the various ALPHA modules has been achieved. Eventually the PMA's ALPHA FTIR will be rehoused to a mobile cart, which can be brought into the many storerooms for *in situ* analysis. Unique IR absorption flow charts for each module will be prepared to aid in peak identification of polymers. This will be particularly useful since there are known peak shifts that occur in the DRIFT and ER spectra. With the expanded flow charts, the ALPHA FTIR can be utilized during future surveys of the PMA collection to rapidly characterize plastics *in situ*, providing essential material knowledge to inform conservation strategies.

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Micro-Fading Tester: Optical Considerations, and Operational and Analytical Issues

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Original Abstract

Micro-fade testing (MFT) provides a semi-quantitative method of predicting the fading rate of light-fugitive colored materials due to light exposure (Whitmore, Pan, and Bailey 1999) -- essentially, an Oddy test for museum lighting. However, the equipment is expensive for most conservation laboratory budgets (USD 25-35k), and there is no modern standard open-source software for acquisition and analysis of the results.

In this paper we describe the optical path of the open-source Thomas retroreflective MFT unit (Brown & Thomas, 2021) in detail, and present recent modifications to the design. As before, the instrument can be built from standard Thorlabs optical components in an afternoon, is hardware agnostic in its choice of light source and spectrometer, and costs around USD 8k in parts.

Modifications to the unit include better control of the beam centration, spot size and intensity, and better focusing and target finding to improve the repeatability of measurements. We discuss operational factors which affect the rate at which measurements can be taken (how fast can you take meaningful measurements?), examine the limitations of blue wool as a transfer standard, and describe some current issues in the mathematics behind the analysis of time-series spectral data for MFT.

Annotated Slides
Slide 1

Modifications in the design
and operation of the Thomas
open source retroreflective
micro-fading tester

Optical Considerations, and Operational and Analytical Issues.

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In this talk we consider modifications to the design of a retroflective microfade testing unit designed by Jacob Thomas and built by Jacob and JP Brown in 2020 at the height of the COVID-19 pandemic. We also discuss modifications to the operation of the unit that were developed by JP and Grace Kim with assistance from Jacob.

Annotated Slides
Slide2
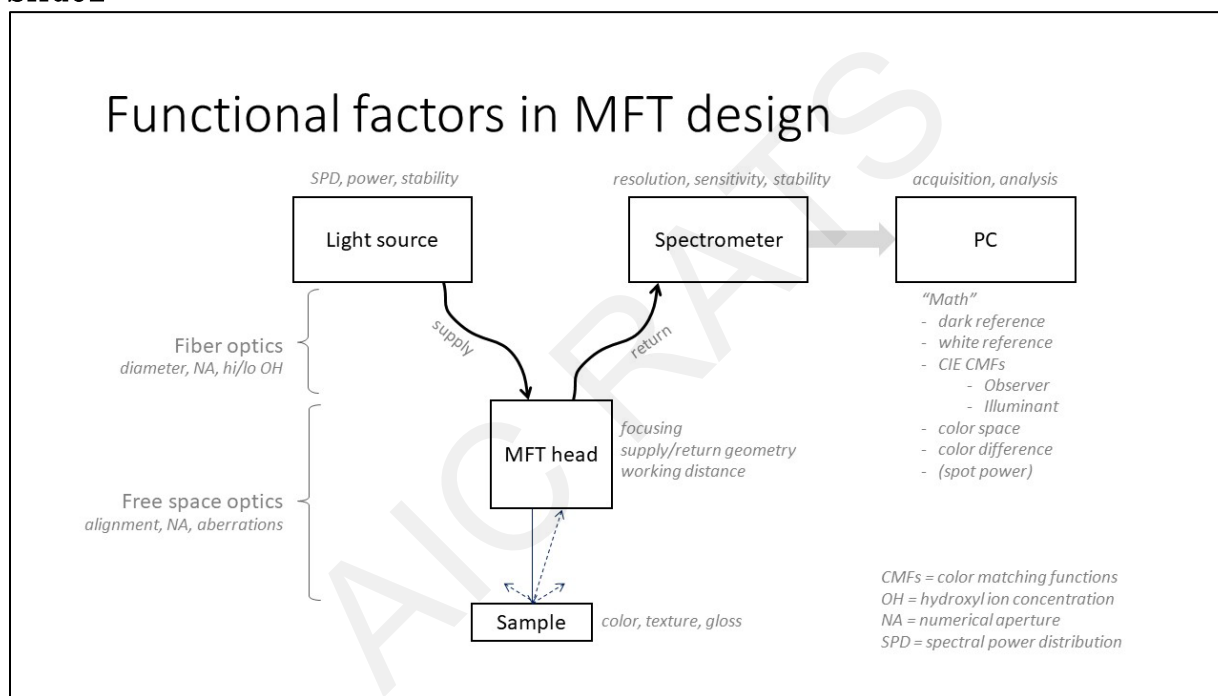
This slide shows a block diagram of a microfade testing unit with the main functional issues tagged onto the various components. We will consider each of the components in the following slides.

Annotated Slides
Slide3
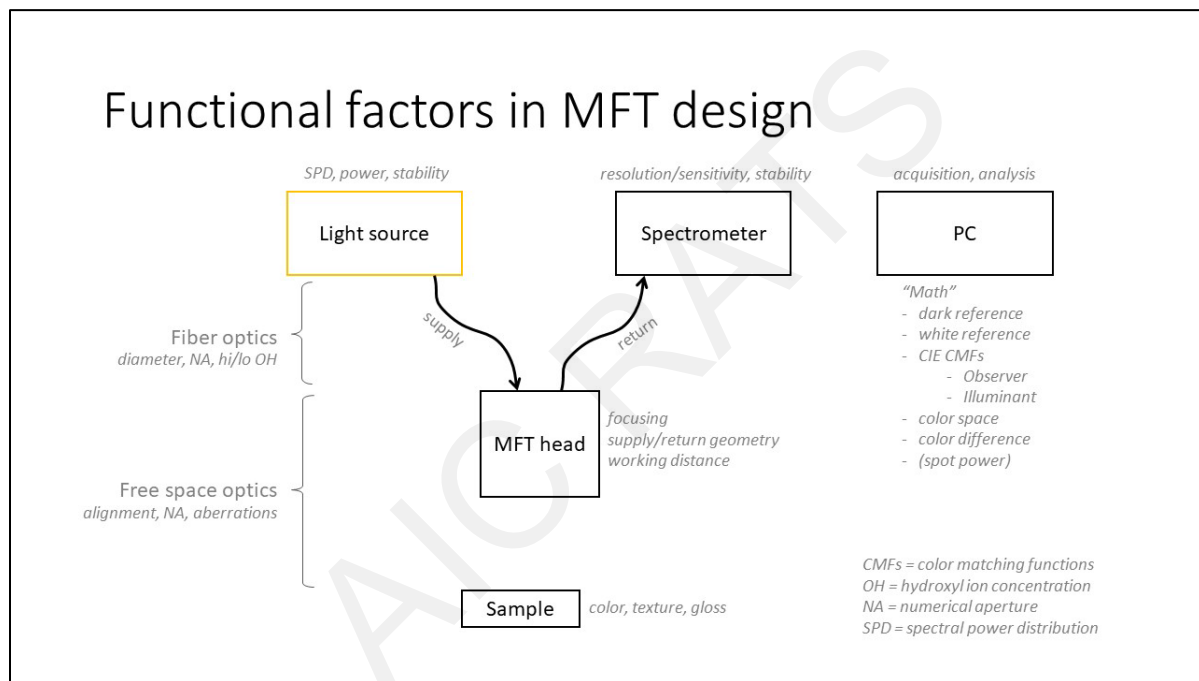
The **light source** (and any associated filters. etc.) is the starting point for the spectral power distribution, and the intensity, of the measurement spot.

Annotated Slides
Slide 4
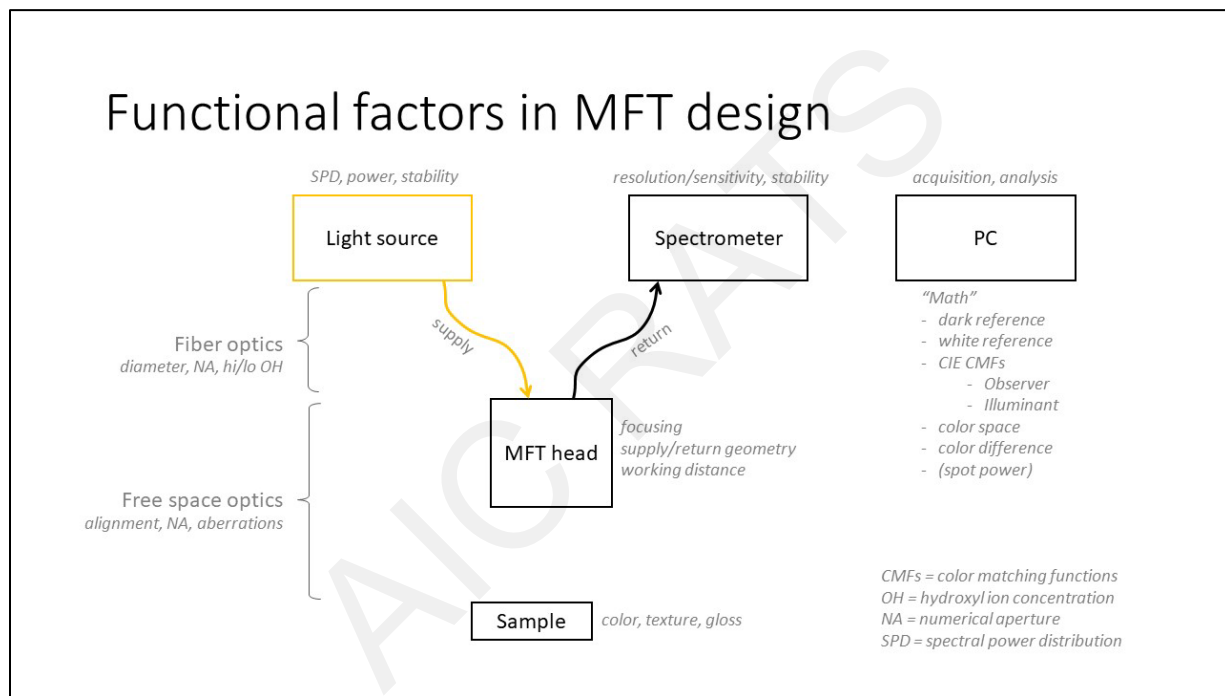
The light source sends light down a fiber optic patch cable – we will refer to it as the **supply fiber** - which is the main starting point for the spot size.

Annotated Slides
Slide 5
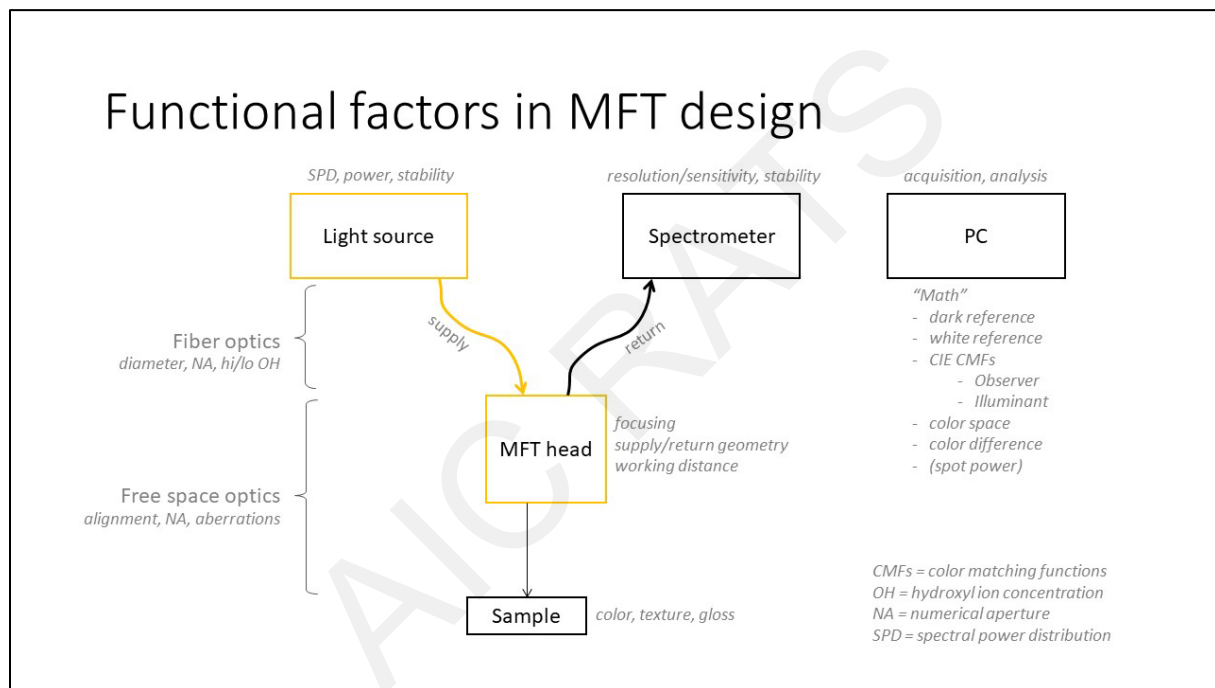
The **MFT head** takes the light from the supply and focuses it on the sample.

Annotated Slides
Slide 6
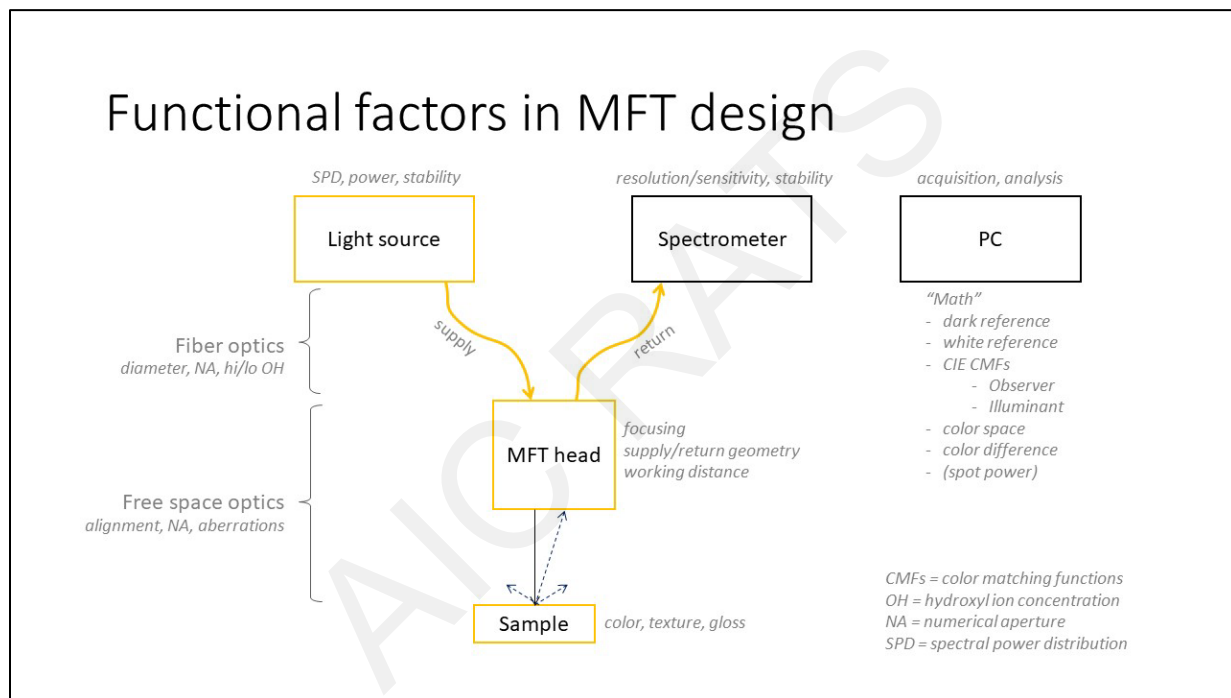
The **sample** absorbs some of the light, and scatters or reflects the rest.

The MFT head picks up *some* of the scattered and reflected light and focuses it onto the exposed tip of the **return fiber** which conducts the light to the spectrometer.

Annotated Slides
Slide 7
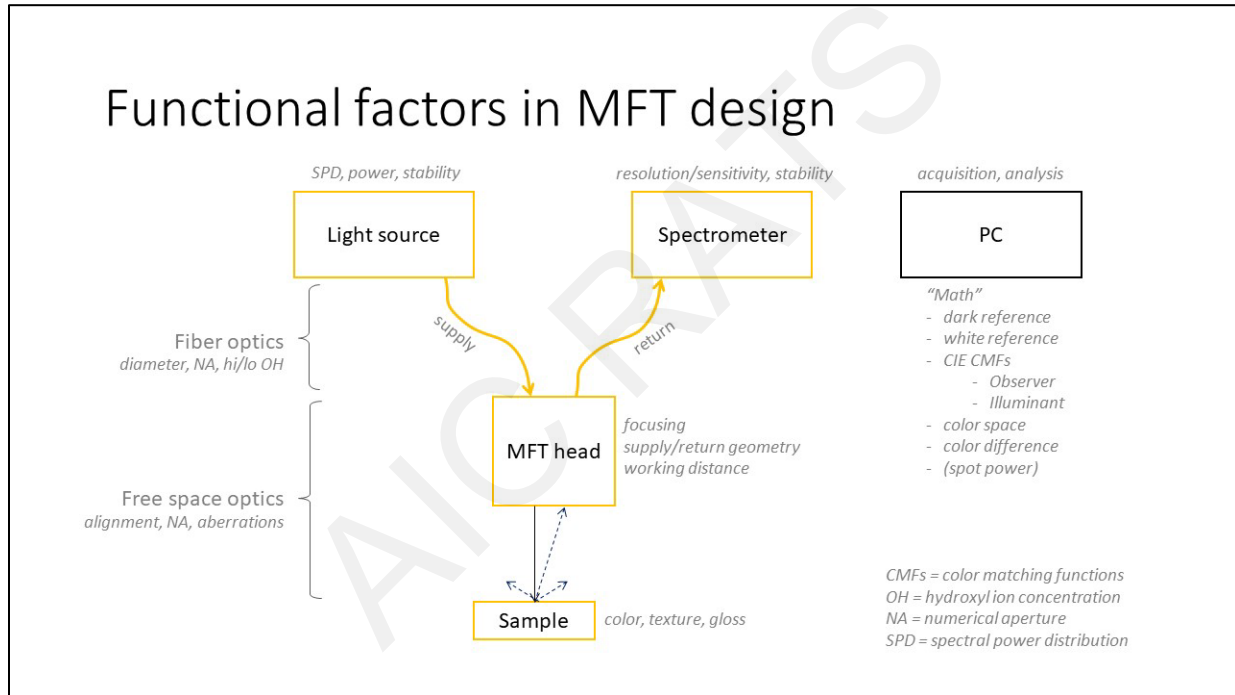
The **spectrometer** does some mirror-and-diffraction-grating magic which projects the light exiting the return fiber onto an array of detectors, and produces a list of light intensities at the different detector positions.

Annotated Slides
Slide 8
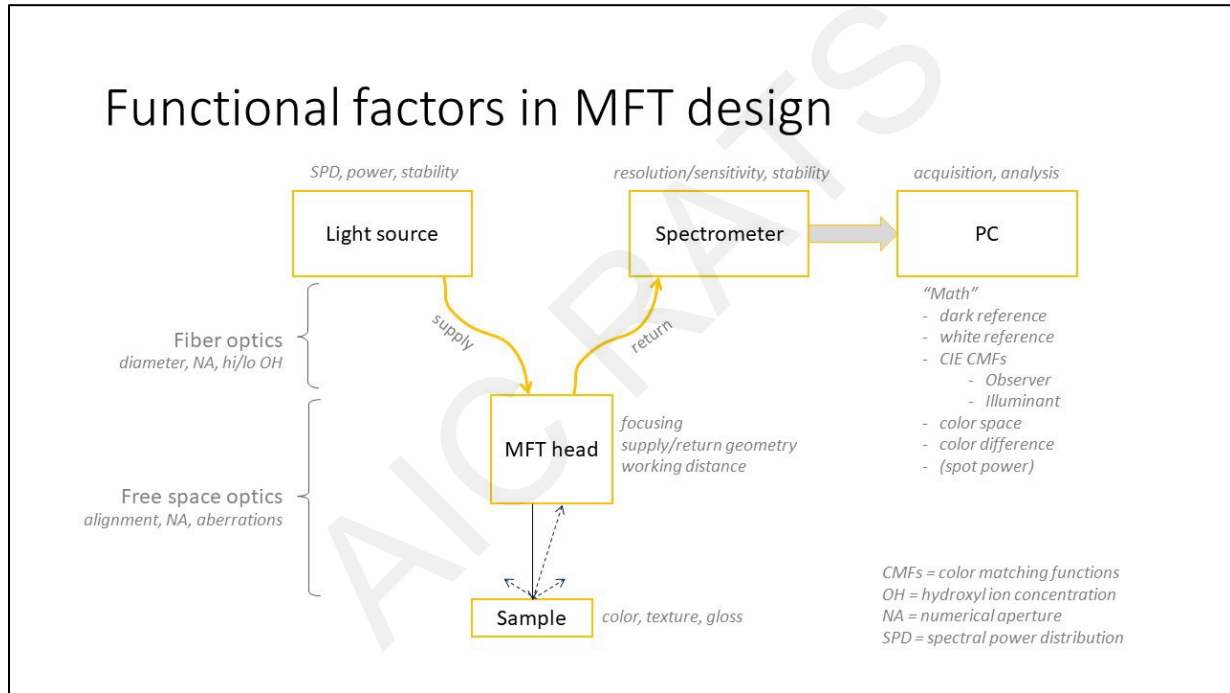
This list of intensities generated by the spectrometer is transferred to software on a **PC** which must already know the *white* and *dark* reference spectra for the spectrometer under the current measurement conditions.

The dark reference spectrum must be taken with the light source on, but the measurement spot defocused.

There are a couple of things to pay attention to on the white reference.

Annotated Slides
Slide 9
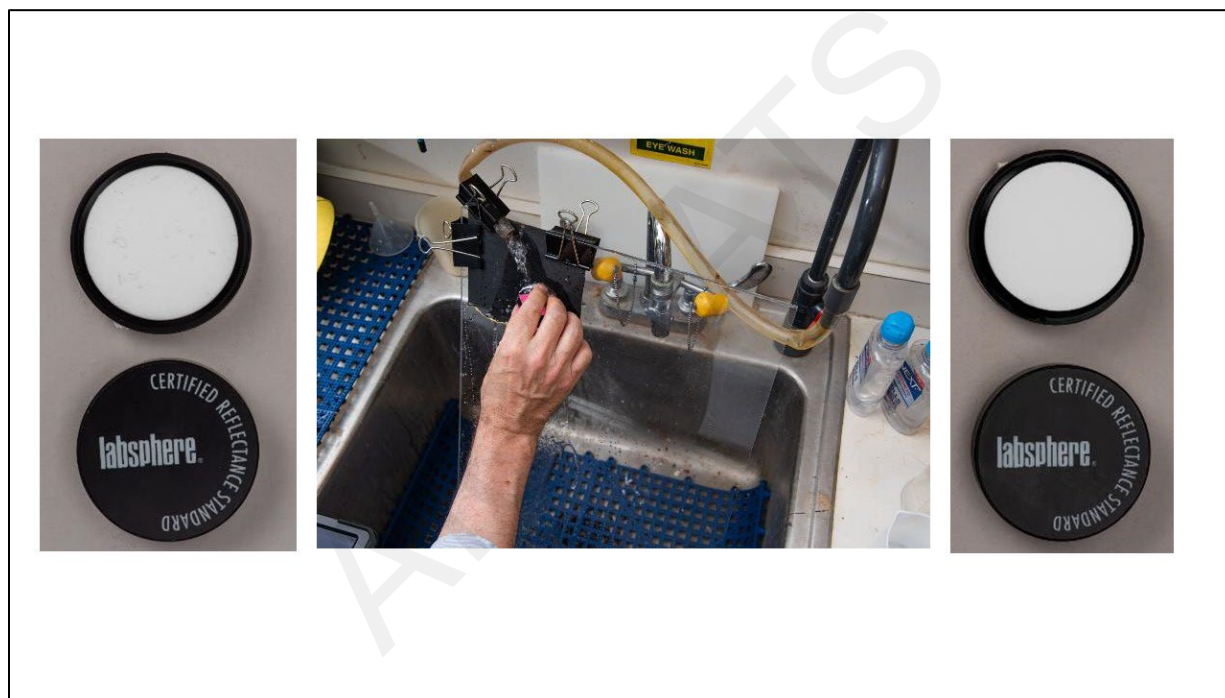
Firstly, it is important that the white reference is clean - no dust, dirt, or fingerprints. A Spectralon target is *expensive*, but you have to think of it as a consumable resource, and it is not doing its best work if it is dirty. If yours looks like the one on the left, a couple of figure-8s over 220 grit wet-and-dry with running DI water will have it spick and span.

Annotated Slides
Slide 10

Second, It is also important that the white reference spectrum is taken with the same angle between the beam and sample as will be used in the actual measurement conditions. Small deviations in angle don't make much difference to spot *size…* or *power*,… but they *do* make a significant difference to the white reference spectrum.

Annotated Slides
Slide 11
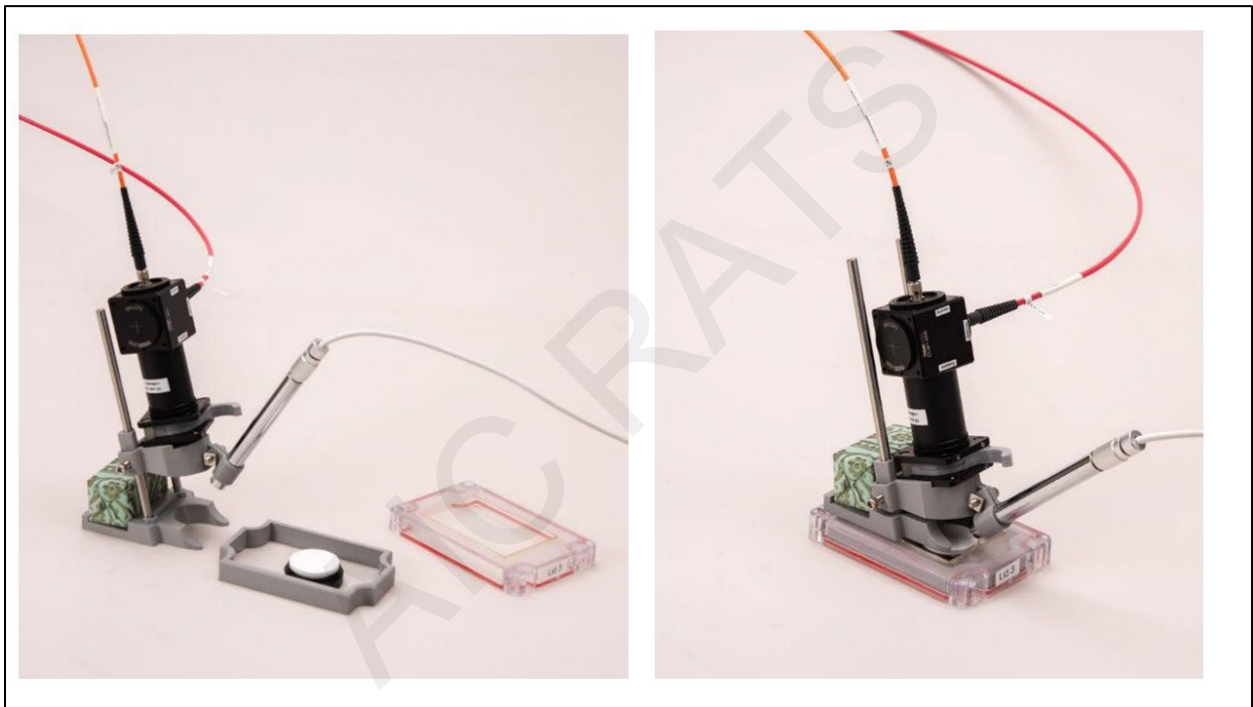
Third, if you're going to be taking measurements through glass, you need to take the white reference and the dark reference through the same thickness and type of glass that you will be using for the measurement.

In addition to the spectral power distribution and scatter, glass makes a difference to the power and size of the spot. The power and size measurements are sensitive to the angles of the supply and return paths. You need to characterize the system with glass in place at the same beam angle as will be used for the actual measurements.

Annotated Slides
Slide 12
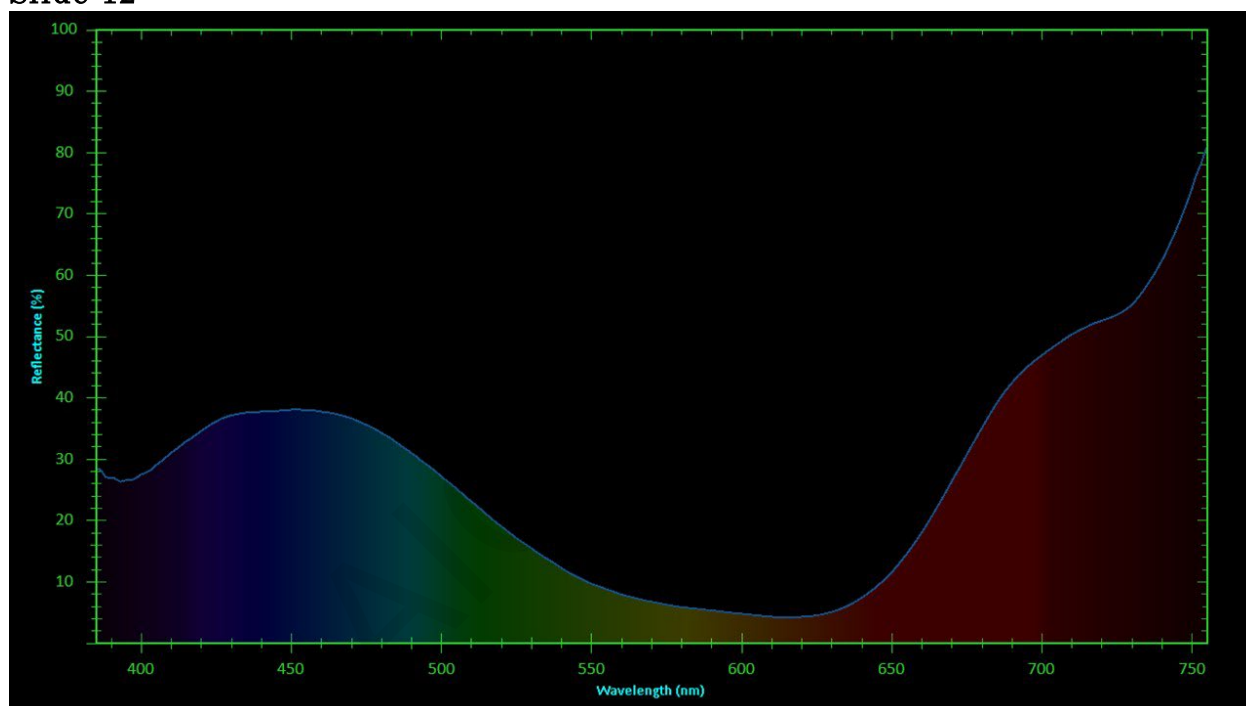
Once the software on the PC is supplied with a correct white reference and dark reference spectra, the software can scale the list of values from the spectrometer to produce a reflectance spectrum.

Annotated Slides
Slide 13
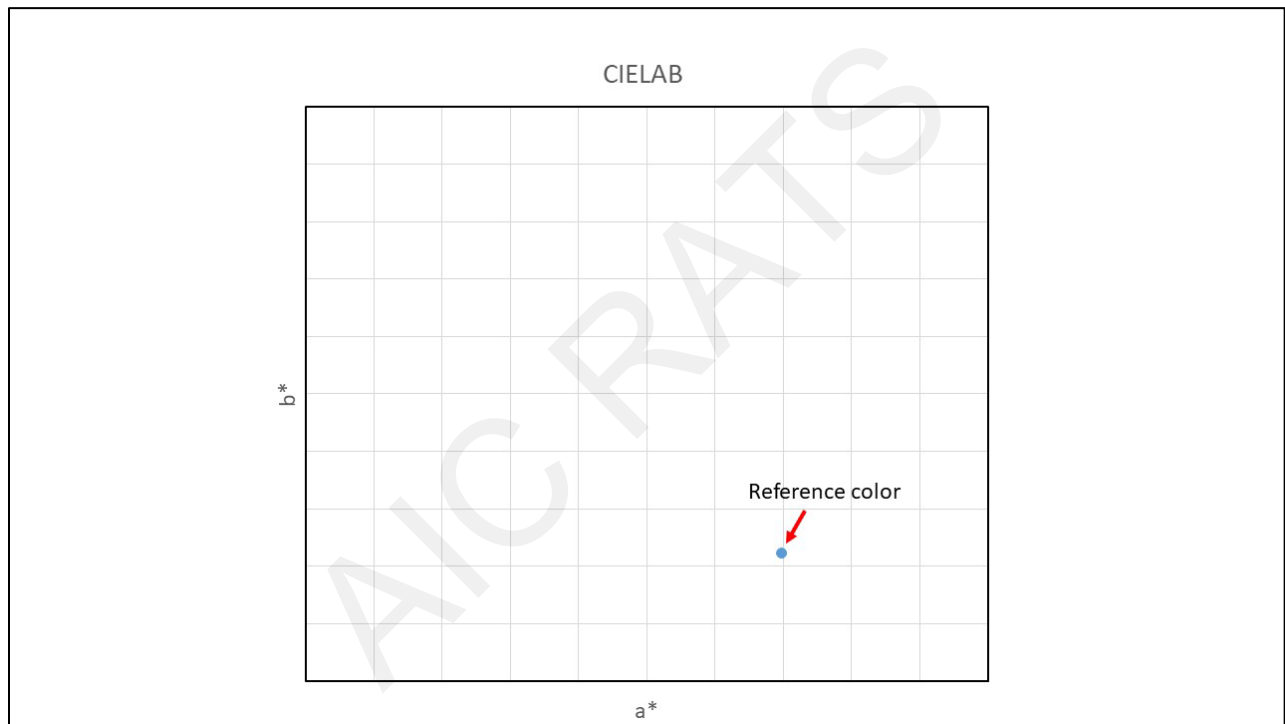
Once we've got a reflectance spectrum we can use the CIE color matching functions for a particular Standard Observer and Standard Illuminant to convert the spectrum into a point in a metric color space such as CIELAB.

Annotated Slides
Slide 14
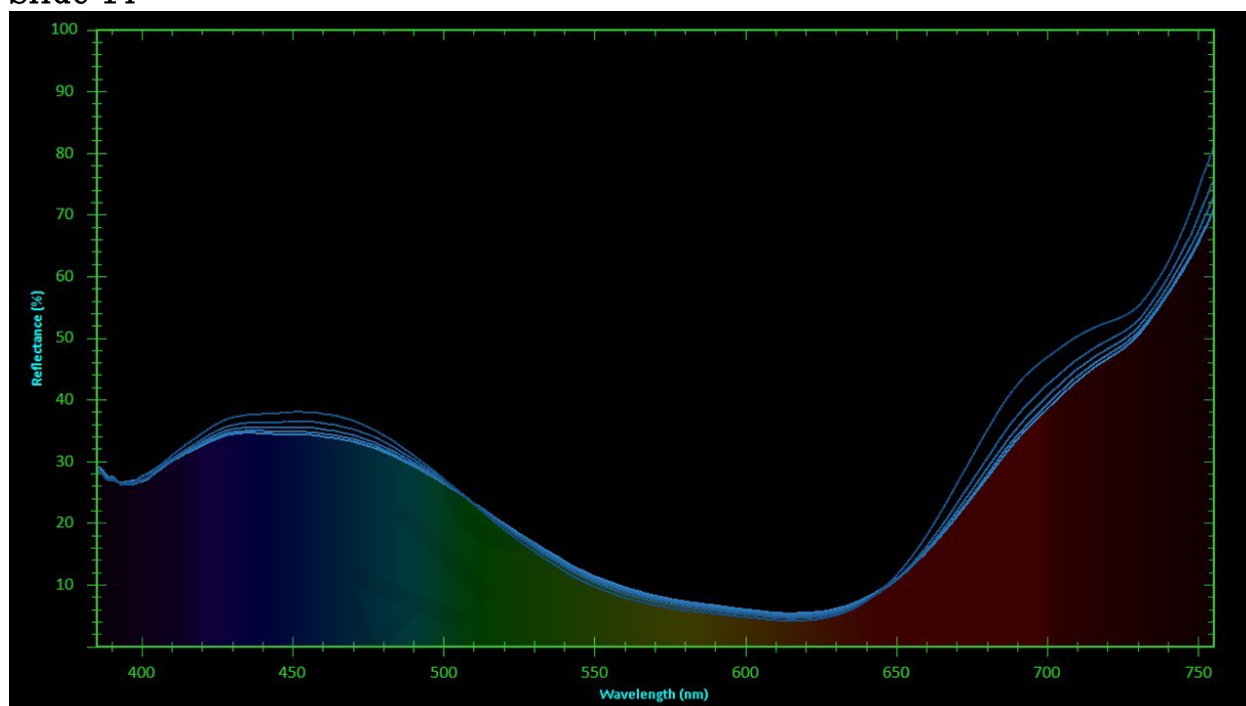
And we can go on taking spectra…

Annotated Slides
Slide 15
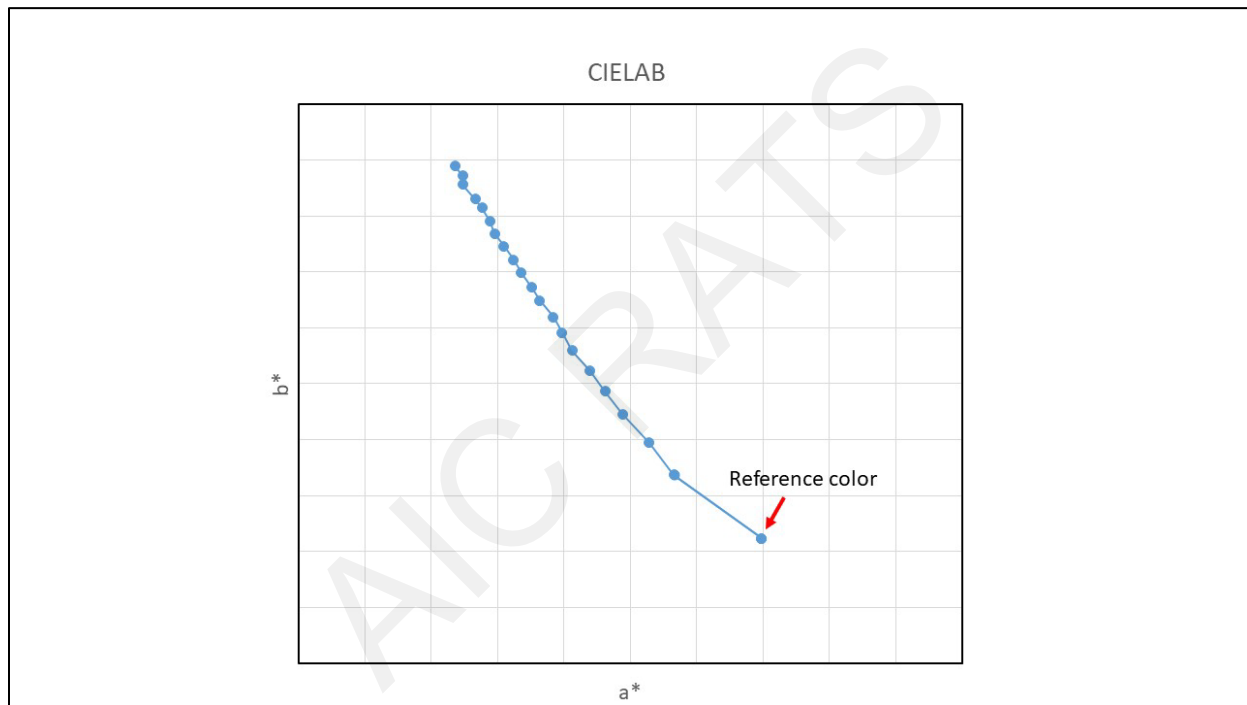
… calculating the color points over time, …

Annotated Slides
Slide 16
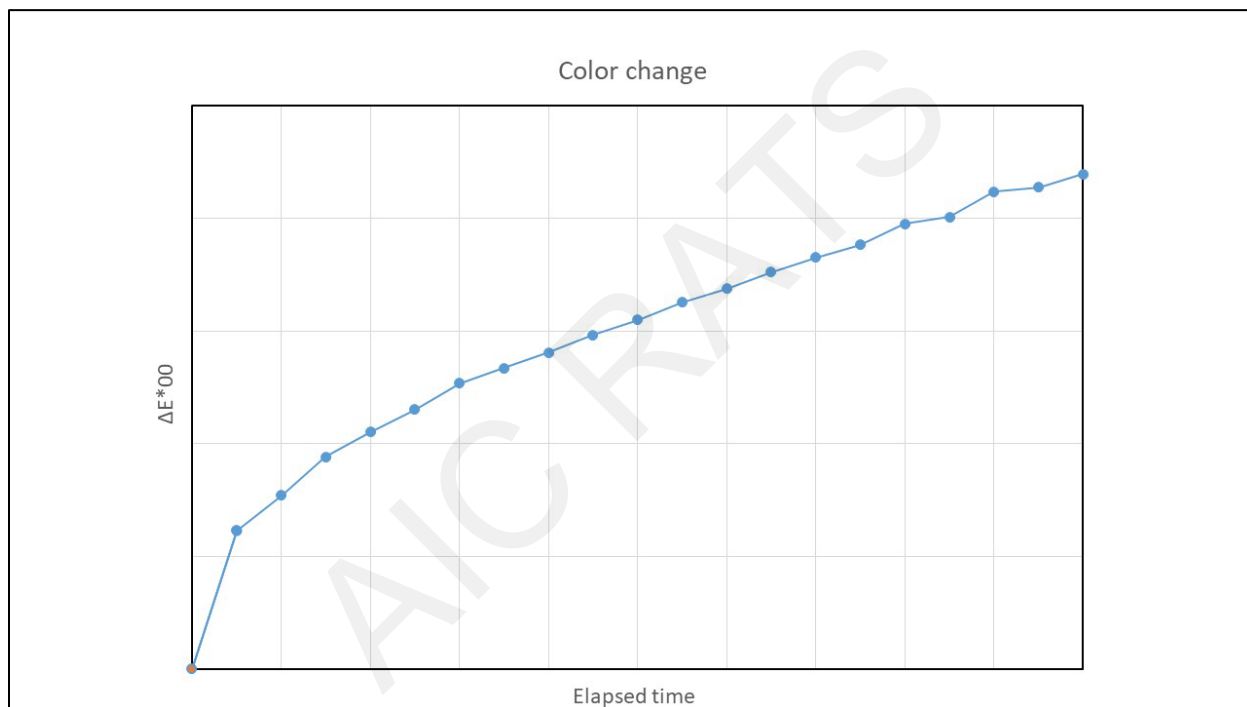
… and calculating their difference from the reference color, until we think we've got enough data to make a decent guess at how much color change the sample will show under gallery display conditions.

Annotated Slides
Slide 17
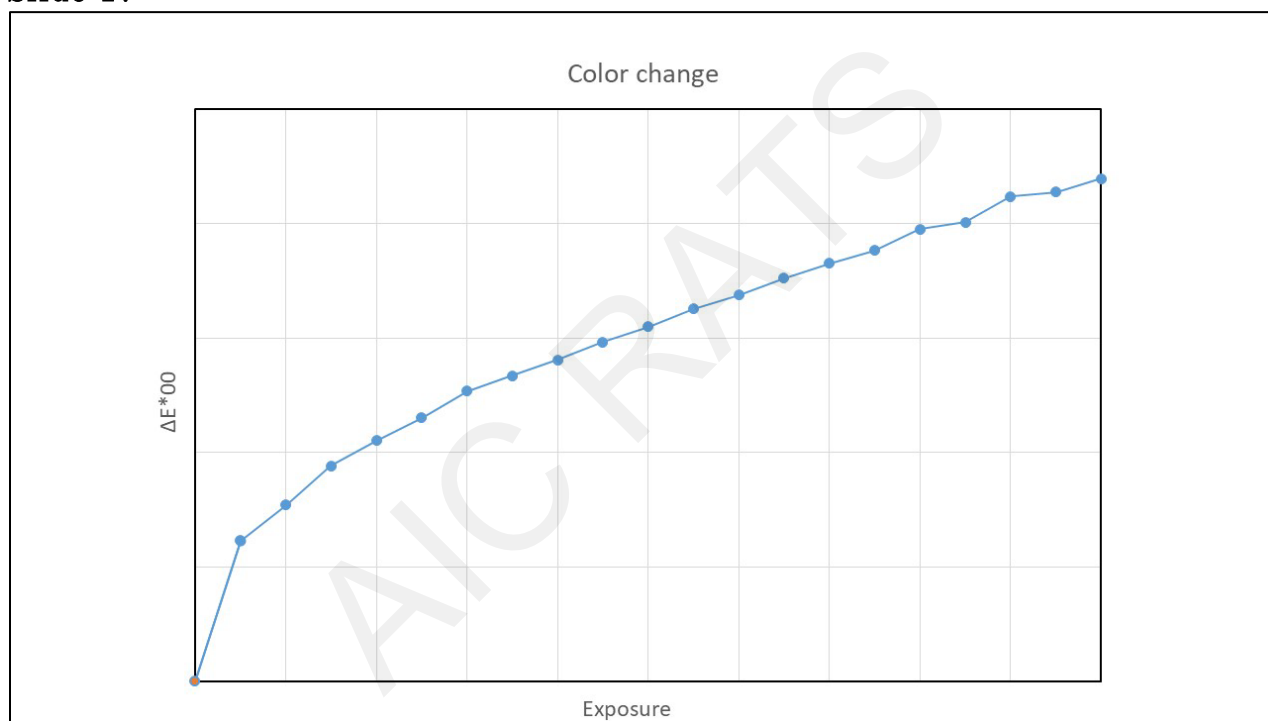
If we *also* know something about the spot size, and the intensity and spectrum of light beam incident on the measurement spot, we can turn the time series into an exposure series, which potentially allows us to sanity-check our results,

Annotated Slides
Slide 18
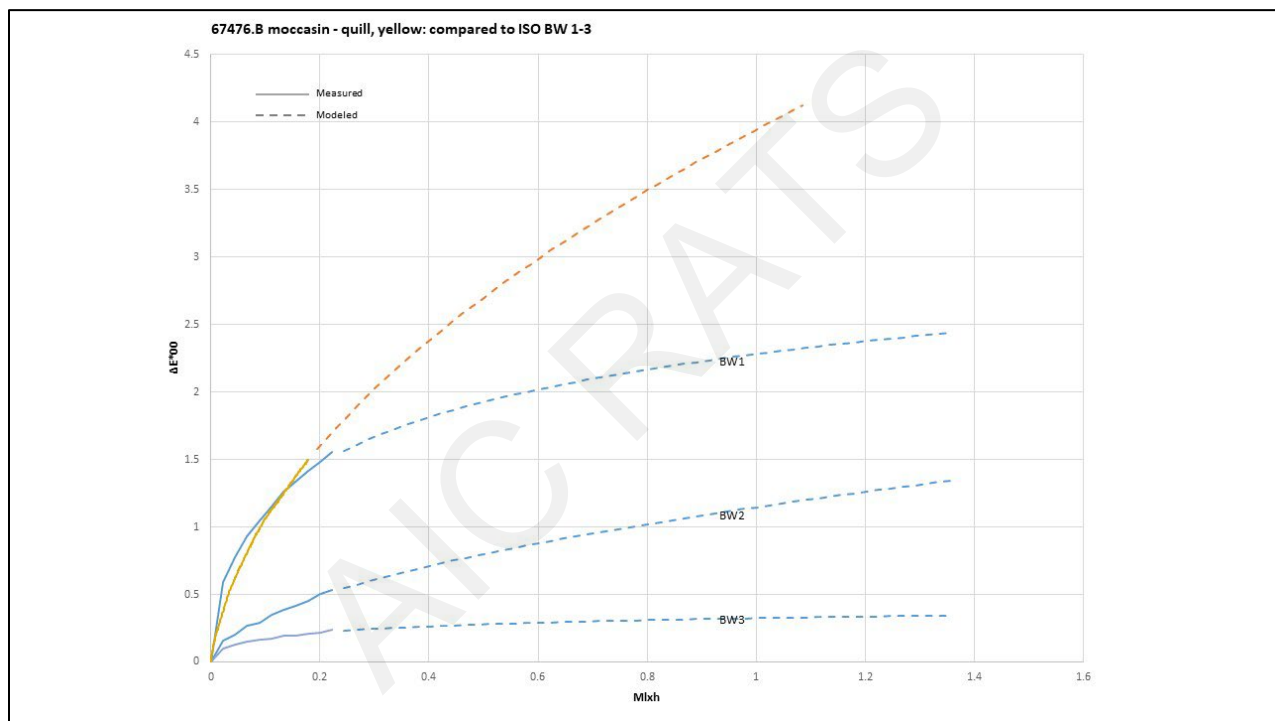
And do projections into the future.

Annotated Slides
Slide 19

67476.B moccasin - quill, yellow

Predicted color change (ΔE*00) by display interval and light level. (Values with a '?' are modeled)

Light level (lux)

Interval	35	50	65	80	100	125	150	175	200	225	250	300	500
1 week	0.08	0.10	0.12	0.14	0.16	0.18	0.21	0.23	0.25	0.28	0.30	0.34	0.48
2 weeks	0.14	0.17	0.20	0.23	0.27	0.31	0.35	0.39	0.42	0.46	0.49	0.55	0.76
1 month	0.26	0.31	0.37	0.41	0.47	0.54	0.60	0.66	0.72	0.77	0.82	0.92	1.24
2 months	0.43	0.52	0.59	0.66	0.75	0.85	0.95	1.03	1.11	1.19	1.27	1.40	1.87 ?
3 months	0.57	0.68	0.78	0.86	0.97	1.10	1.22	1.32	1.42	1.52 ?	1.61 ?	1.78 ?	2.36 ?
4 months	0.69	0.82	0.93	1.04	1.16	1.31	1.45	1.57 ?	1.69 ?	1.80 ?	1.90 ?	2.10 ?	2.77 ?
6 months	0.90	1.06	1.20	1.33	1.49	1.67 ?	1.83 ?	1.99 ?	2.13 ?	2.27 ?	2.40 ?	2.64 ?	3.46 ?
9 months	1.16	1.35	1.53 ?	1.69 ?	1.88 ?	2.11 ?	2.31 ?	2.50 ?	2.68 ?	2.84 ?	3.00 ?	3.30 ?	4.30 ?
1 year	1.38	1.60 ?	1.81 ?	1.99 ?	2.22 ?	2.48 ?	2.71 ?	2.93 ?	3.14 ?	3.33 ?	3.52 ?	3.86 ?	5.02 ?
1.5 years	1.75 ?	2.03 ?	2.28 ?	2.51 ?	2.78 ?	3.10 ?	3.39 ?	3.66 ?	3.91 ?	4.15 ?	4.38 ?	4.80 ?	6.22 ?
2 years	2.06 ?	2.39 ?	2.68 ?	2.94 ?	3.26 ?	3.63 ?	3.96 ?	4.27 ?	4.57 ?	4.84 ?	5.10 ?	5.59 ?	7.23 ?
3.5 years	2.83 ?	3.26 ?	3.64 ?	3.99 ?	4.42 ?	4.90 ?	5.35 ?	5.76 ?	6.14 ?	6.51 ?	6.85 ?	7.50 ?	9.67 ?
5 years	3.44 ?	3.95 ?	4.41 ?	4.83 ?	5.34 ?	5.92 ?	6.45 ?	6.95 ?	7.41 ?	7.84 ?	8.25 ?	9.03 ?	11.63 ?
7.5 years	4.28 ?	4.91 ?	5.47 ?	5.99 ?	6.61 ?	7.33 ?	7.98 ?	8.58 ?	9.14 ?	9.68 ?	10.18 ?	11.13 ?	14.31 ?
10 years	4.99 ?	5.72 ?	6.37 ?	6.96 ?	7.69 ?	8.51 ?	9.26 ?	9.96 ?	10.61 ?	11.23 ?	11.81 ?	12.90 ?	16.58 ?
15 years	6.18 ?	7.08 ?	7.88 ?	8.60 ?	9.49 ?	10.50 ?	11.42 ?	12.27 ?	13.07 ?	13.82 ?	14.54 ?	15.88 ?	20.38 ?
20 years	7.19 ?	8.22 ?	9.15 ?	9.99 ?	11.01 ?	12.17 ?	13.23 ?	14.22 ?	15.14 ?	16.01 ?	16.84 ?	18.39 ?	23.59 ?

values marked with '?' are modeled

- $0 < \Delta E*00 < 1$ - observer does not notice the difference,
- $1 < \Delta E*00 < 2$ - only experienced observer can notice the difference
- $2 < \Delta E*00 < 3.5$ - unexperienced observer also notices the difference,
- $3.5 < \Delta E*00 < 5$ - clear difference in colour is noticed,
- $5 < \Delta E*00$ - observer notices two different colours.

If we're really daring, we can use the reciprocity principle to do things like producing a heat map of predicted color change under actual gallery lighting conditions.

Annotated Slides
Slide 20
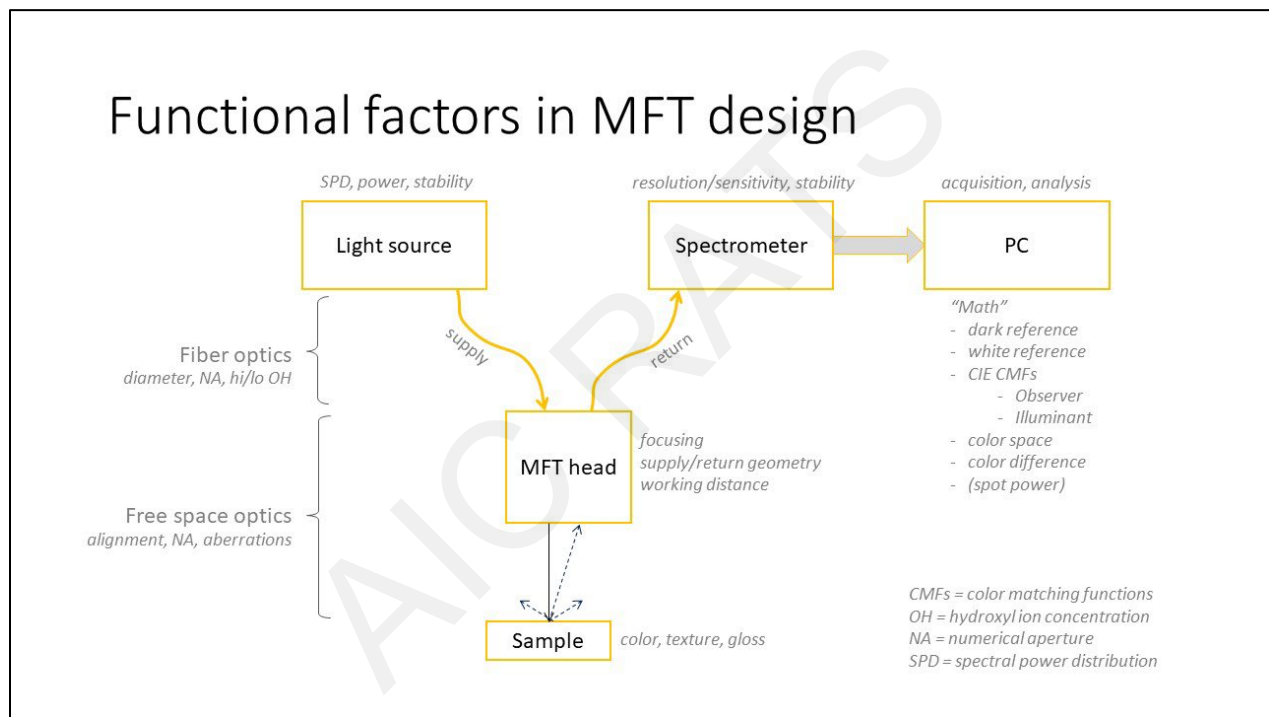
The point is that all the operational features we've tagged on this diagram are consequential for the results that you get.

In this presentation we're going to talk about the issues that we experienced with the version of the Thomas MFT unit that we built at the Field Museum in 2020.

This was not a *great* time to be building a scientific instrument - we had to make some sub-optimal part substitutions due to supply chain issues.

Annotated Slides
Slide 21
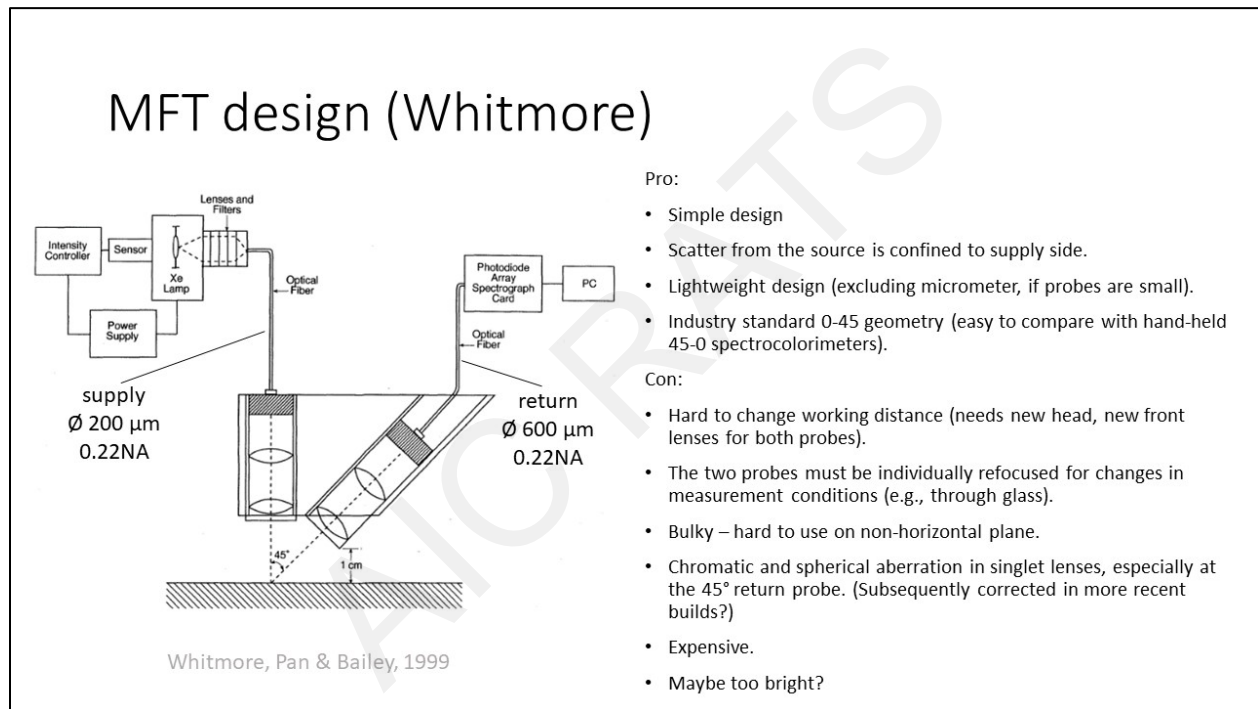
Here is a brief nod to the classic Whitmore design – the origin of MFT. Supply is at the surface normal. Return is at 45°. This setup is widely used, but it is expensive, fragile, and kind of a beast if you want to look at 3D social history items (which, as an Objects conservator at the Field Museum, JP mostly does).

Annotated Slides
Slide 22
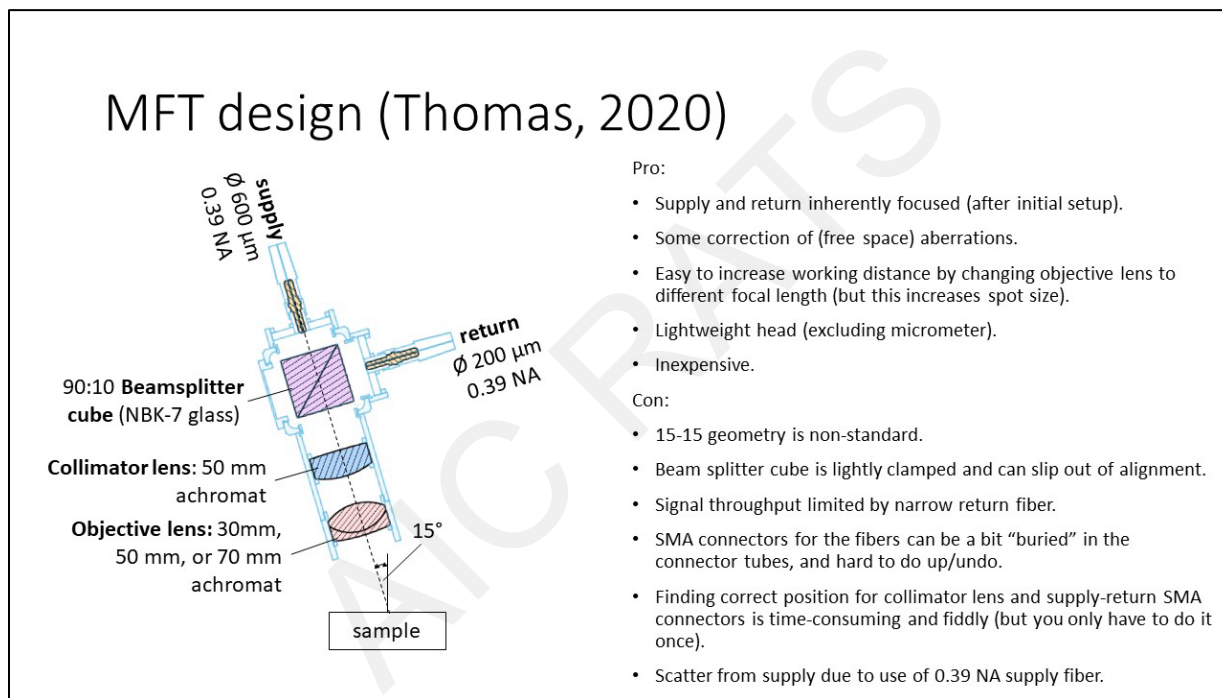
Here is a diagram of the MFT design that Jacob Thomas and JP Brown built at the Field Museum in 2020.

It is compact and inexpensive. The build is fiddly, but it takes an afternoon and you only have to do it once. The supply and return are then inherently co-focused and stay that way unless the beamsplitter cube gets bumped. It is easy to change spot size and working distance by changing the objective lens.

The main problem after we built it was that the 200 micron diameter return fiber was not really getting enough light to the spectrometer, and so noise was going up when we were measuring darker colors.

So what can we do about this?

Annotated Slides
Slide 23
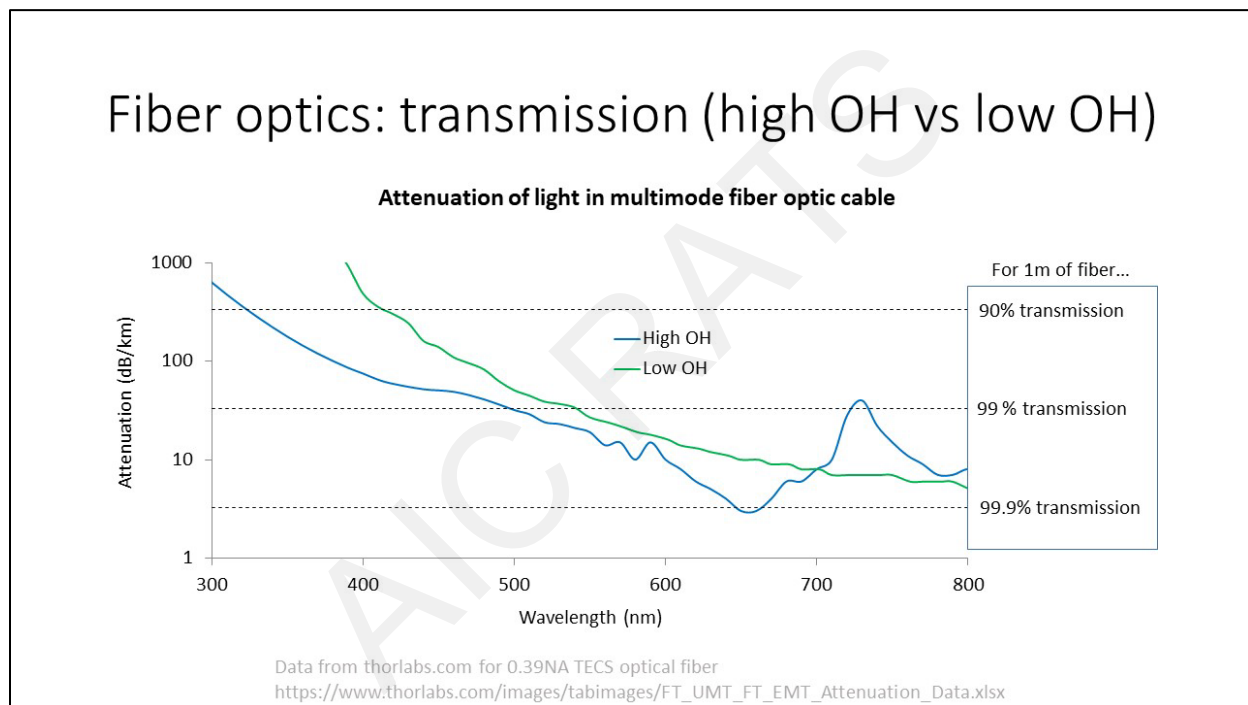
The first thing that you can vary is the **composition** of the glass in the fiber, but that doesn't make too much difference to *amount* of visible light that the fiber carries (although, as you can see from the example above, the glass composition has an effect on the spectral power distribution of the light).
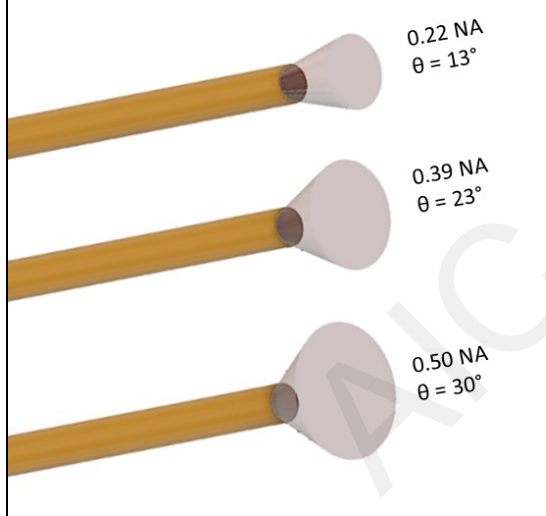
Annotated Slides
Slide 24
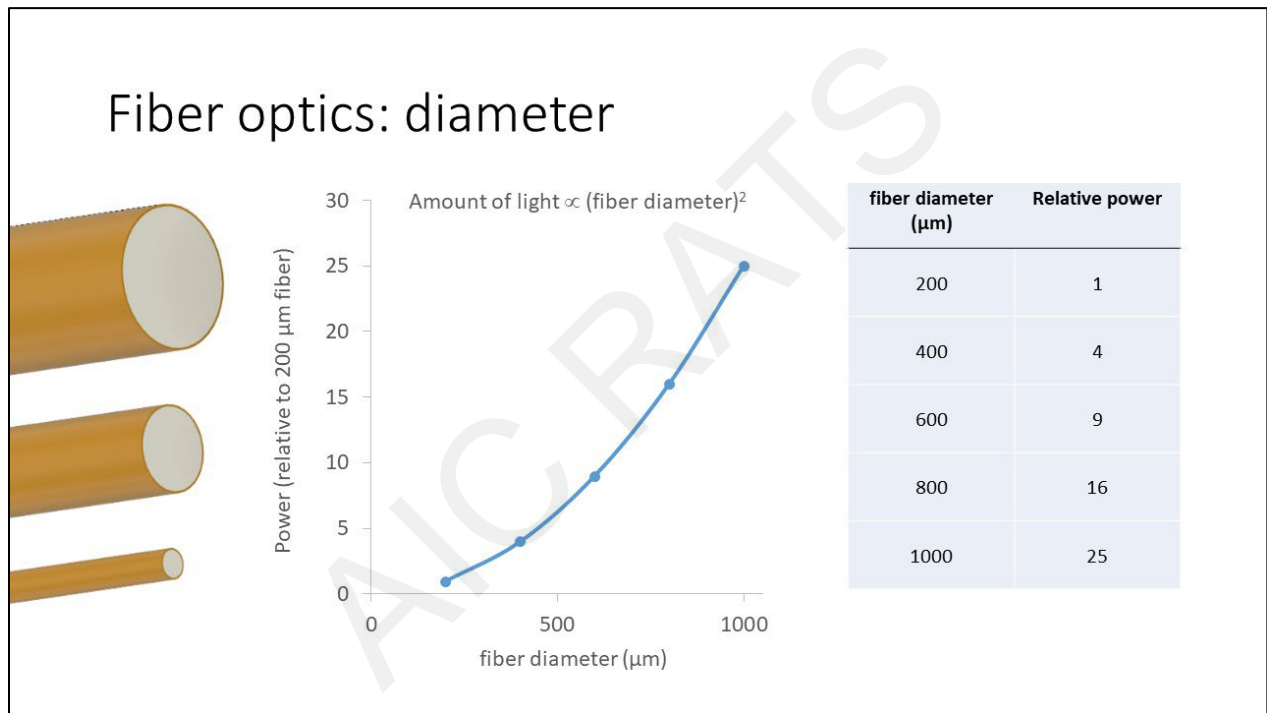
The second thing you can vary is the **diameter** of the fiber. The diameter of the fiber *is* important – the amount of light goes up as the square of the diameter, and so small variations in diameter are significant. For the *supply* fiber, increasing the diameter is something that we would want to do cautiously since it will also increase the spot size. However, there is no such constraint for the *return* fiber.

Annotated Slides
Slide 25

Finally, there's the **numerical aperture** (which we're going to abbreviate as *NA* in most of the figures and text).

Numerical aperture is a measure of the size of the cone of light that is received or emitted by an optical element. The amount of light that is transmitted goes up as the square of the NA…

So we have two useful variables – diameter and numerical aperture. To get a quick fix on how these variables are helpful, we can measure power at different parts of the MFT system.

Annotated Slides
Slide 26

Our work on power profiling started using the thermoelectric unit on the left – this was a supply chain thing – it was all we could get in the Summer 2020, and we kept using it because it was quite expensive.

Thermoelectric units have great spectral measurement range and broadband response, but we had a lot of issues with getting this unit to measure power repeatably at low mW levels. In particular, we had issues with continual slow zero drift, and changes in value from small changes in ambient temperature. This is *not* to say that thermoelectric sensors are useless, just that this one didn't work for us in our particular application.

The silicon photodiode sensor on the right is what we use now. It is not sensitive in the UV but we only have a tiny signal in the UV.

The main issue with silicon photodiodes is that the response curve is wavelength dependent, so before taking measurements you have to choose a response wavelength that is sensible for the spectral power distribution of your light source. However, silicon photodiodes settle quickly, the zero on this unit seems solid, and it is not affected by normal ambient changes in temperature. We also like that It is easier to integrate into a 30 mm cage system than the thermoelectric unit.

Annotated Slides
Slide 27

If you are doing repeated power profiling, it is helpful to have a cheap and cheerful optical breadboard to take away the problems of keeping everything correctly spaced and aligned. Indeed, this is arguably the best $200 we spent during the project. The power measurements in the following figures are taken using this breadboard.

Annotated Slides
Slide 28
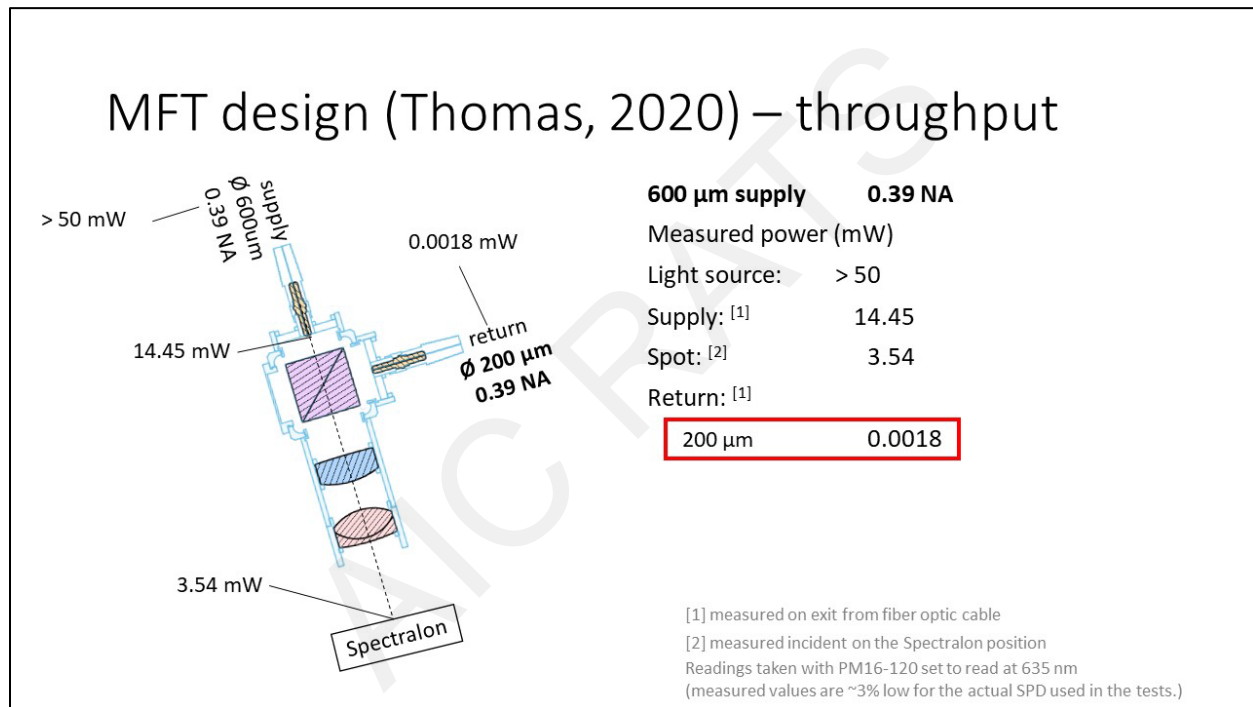
Here is the original setup with the 600 um diameter 0.39 NA supply fiber, 200 micron 0.39 NA return fiber.

We get around **14.5 mW** emitted from the supply fiber into the top of the head.

The power incident at the measurement spot is about a quarter of this – around *3.5* mW

And at the end of the return fiber for the *spectrometer* we're getting about **1.8** *micro*watts - three orders of magnitude lower that the spot power.

The return power is very low both because of Lambertian scattering at the sample, and because it is difficult to couple a free space light beam into a fiber optic cable with high efficiency.

Note that the amount of light that actually gets to the *detector in the spectrometer* will be significantly lower than the already tiny number exiting the return fiber - the circular beam exiting the tip of the return fiber reaches the spectrometer detector through a narrow rectangular slit which has a very low numerical aperture.

Annotated Slides
Slide 29
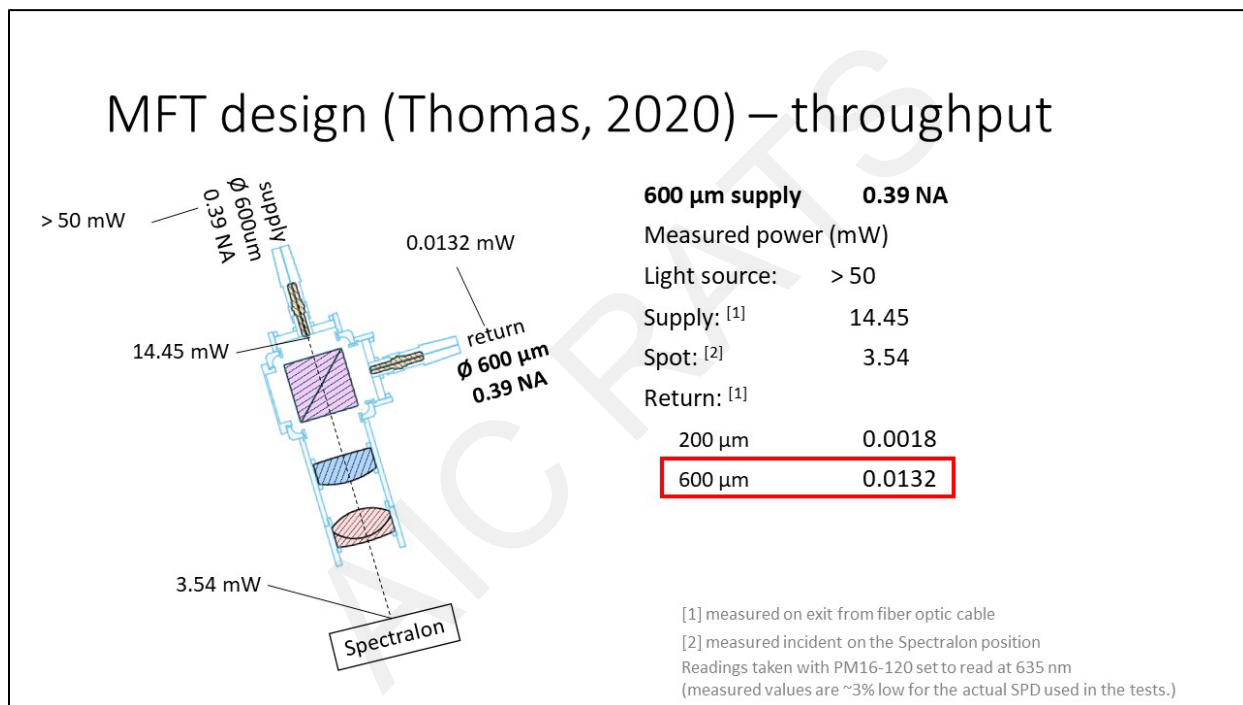
Changing to a 600 μm return fiber increases the supply to the spectrometer an order of magnitude. Theory predicts that the ratio improvement should be about 9x, measurement shows about 7x.

Signal to noise ratio goes as square root of intensity, so we have improved the snr by a factor of nearly 3.

Annotated Slides
Slide 30
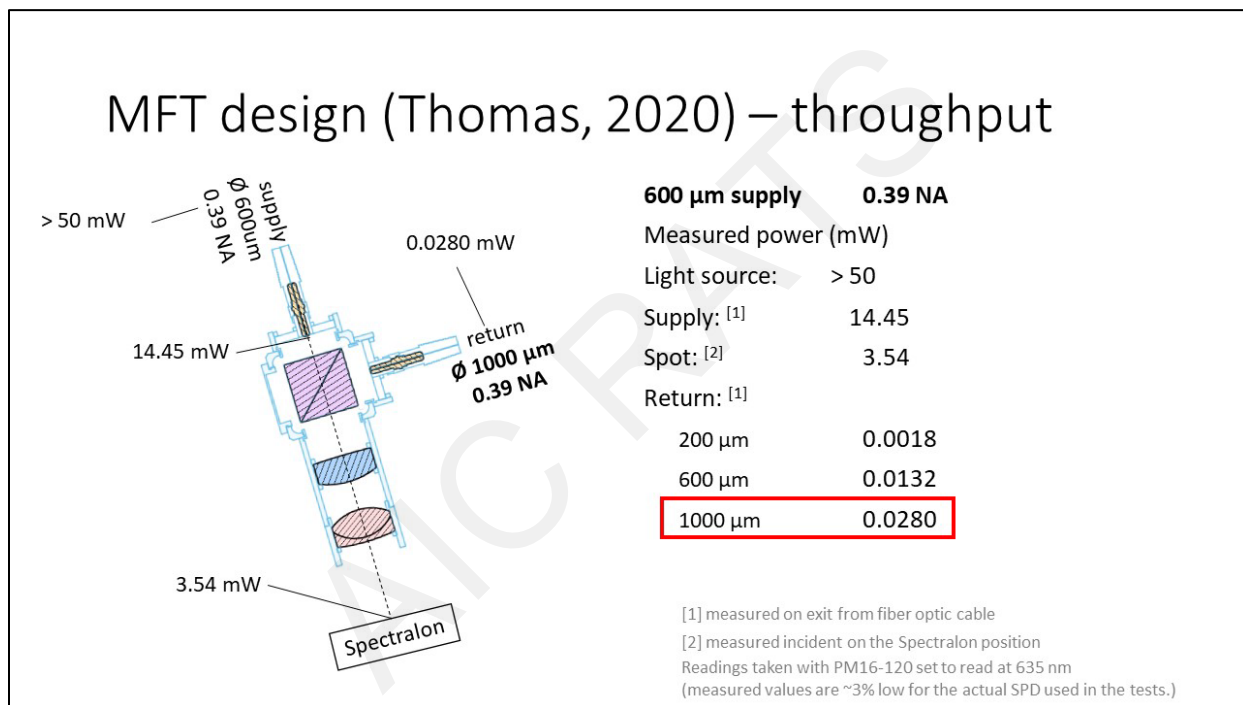
Theory predicts a further threefold improvement if we go from 600 micron to 1000 micron diameter. But we only get around a 2-fold improvement – maybe the 1000 um fiber is a little under-filled and/or the entrance tip for the return fiber is not optimally positioned? In any case, we have a factor of 4 improvement in s.n.r over the original 200 um fiber.

Our first modification, then, was to go to a wider diameter return fiber.

Annotated Slides
Slide 31
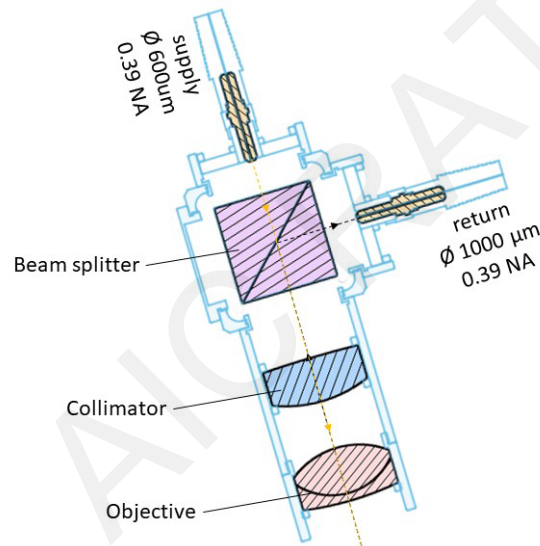
Turning our attention to the optics in the head., the Thomas retroreflective design has a **beamsplitter**, which is an inch thick cube of NBK-7 glass. The beamsplitter has important consequences for the placement of the **collimator lens** - the collimator needs to be in the right position to provide parallel light for the **objective lens** which focuses the spot.

We'll take a step back in the next few slides, and review basic optical *ray* analysis for these components, starting with the objective lens, and working back to the beamsplitter cube.

Annotated Slides
Slide 32

The **objective lens** at the front of the head brings a collimated beam of light to a point at the focal distance f from its principal plane. This focused beam provides the measurement spot.
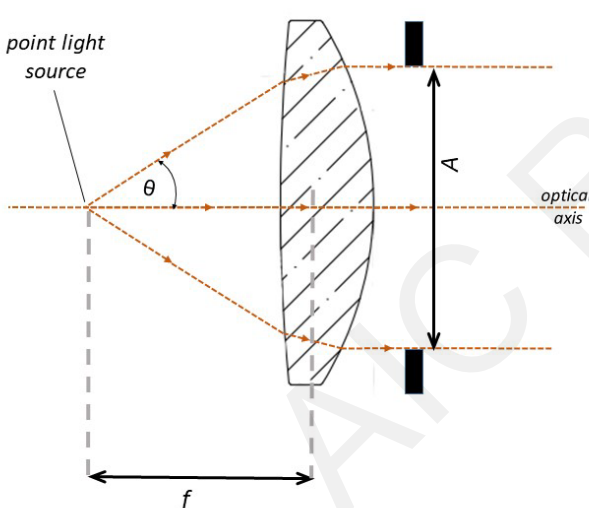
Manufacturers specify f (the focal length) and A (the *clear* aperture). We can do simple math with the manufacturer's numbers to estimate the effective *numerical* aperture of a particular lens, and hence how it will couple to other optical components.

We get the *collimated* light beam by flipping the geometry of the this setup, and putting a *light source* at f.

Annotated Slides
Slide 33

The **collimator lens** in the Thomas MFT has a focal length of 50 mm and the clear aperture is around 23 mm (lens diameter is 1 inch, but the lens's optical properties are not maintained across the full diameter). The resulting numerical aperture is around 0.23.

Annotated Slides
Slide 34

If we pair up a collimator with an objective lens, we can project an image of the tip of the supply fiber onto the sample.

Using this arrangement we can change the magnification (and hence the size) of the projected spot by using an objective lens with a *different focal length* from the collimator. This is a major strength of the Thomas design. However, for this magnification change to work properly we need the light between two lenses to be collimated, which means we need the collimator lens at the correct distance from the tip of the supply fiber.

What is the right distance between the tip of the supply fiber and the principal plane of the collimator lens?

**Annotated Slides**
Slide 35
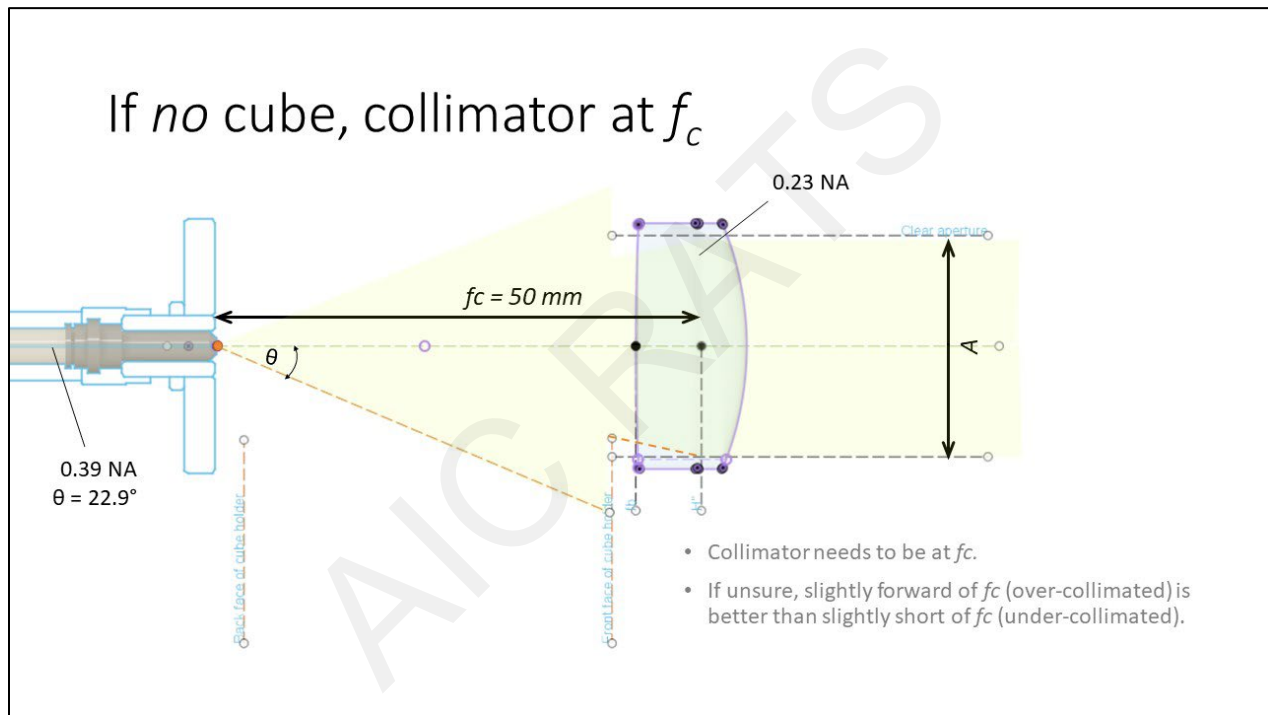
If there was no beamsplitter cube, we would want the principal plane of the collimator lens one focal distance (f) from the tip of the supply fiber.

As we saw earlier, the 50 mm focal length collimator lens in the Thomas unit (one inch diameter, 23 mm clear aperture) has a numerical aperture of around 0.23, and this value of NA is a problem, because the light from our 0.39 NA fiber has spread pretty wide by the time it reaches our collimator. (In fact, we are losing or scattering about two-thirds of the light from a fiber with such a high numerical aperture.)

Annotated Slides
Slide 36
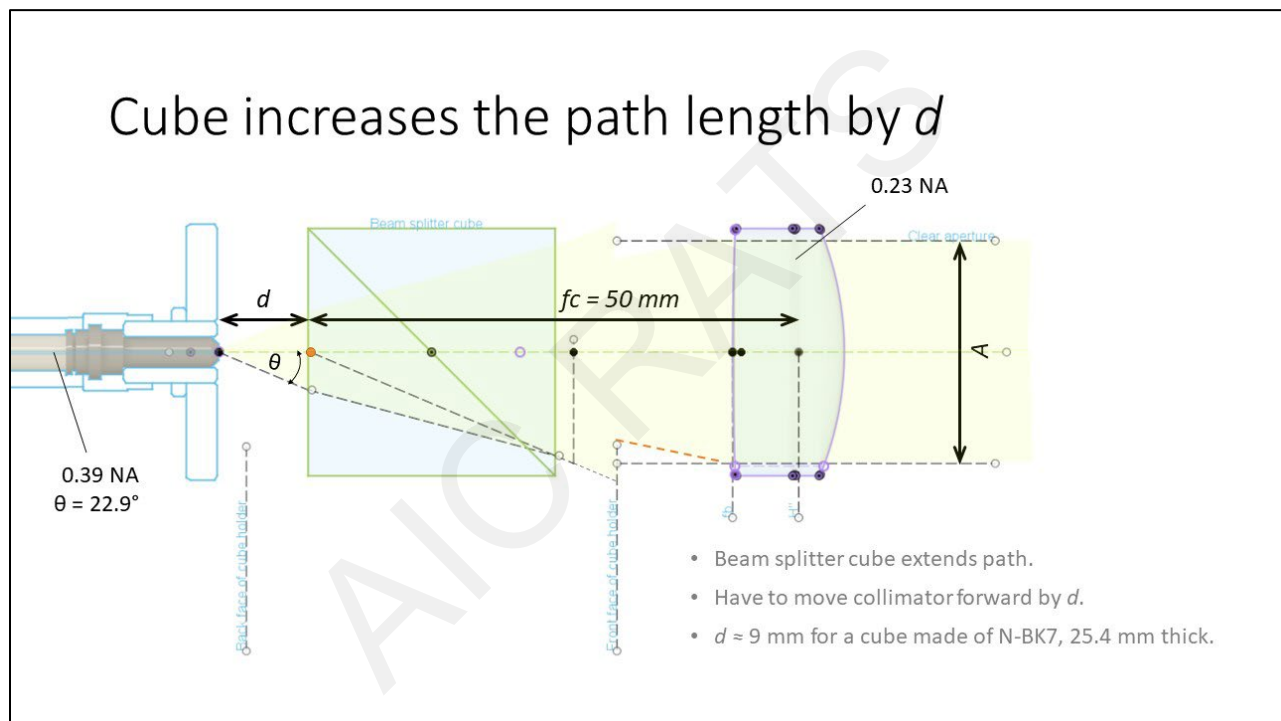
Inserting the beamsplitter cube into the light path *narrows* the cone of light emitted from the supply fiber, and it *also* increases the path length, which means we have to move the lens away from the tip of the supply fiber by an amount we'll call *d*.

For our 1 inch thick cube of NBK-7 glass, *d* is around 9 mm.

Annotated Slides
Slide 37
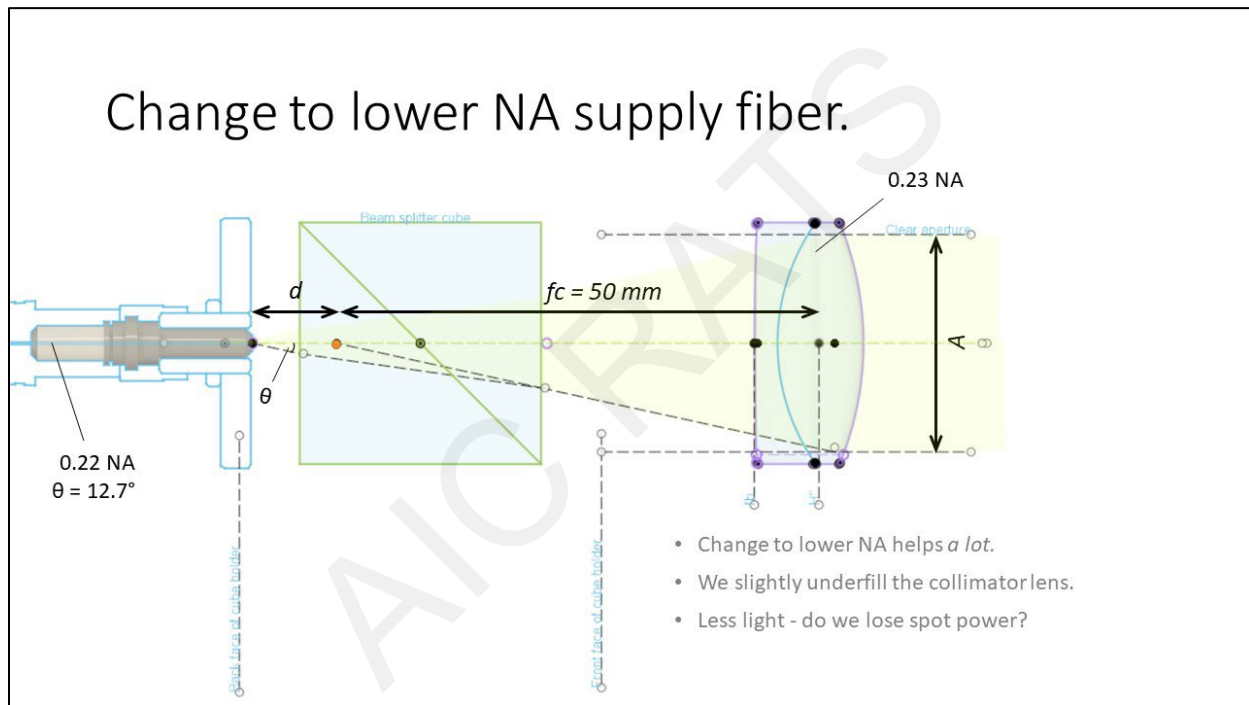
The position of the beamsplitter cube in the cube holder is invariant, so the best thing to do here is to push the supply tip as far forward as we can, and change the fiber for one with a numerical aperture that more closely matches the collimator lens.

Changing to a 0.22 NA supply fiber means we're under-filling the lens a little, which is good for optical performance.

Making this change also means that we're supplying a lot less light to the head, so how does this affect spot power and signal to detector?

Annotated Slides
Slide 38
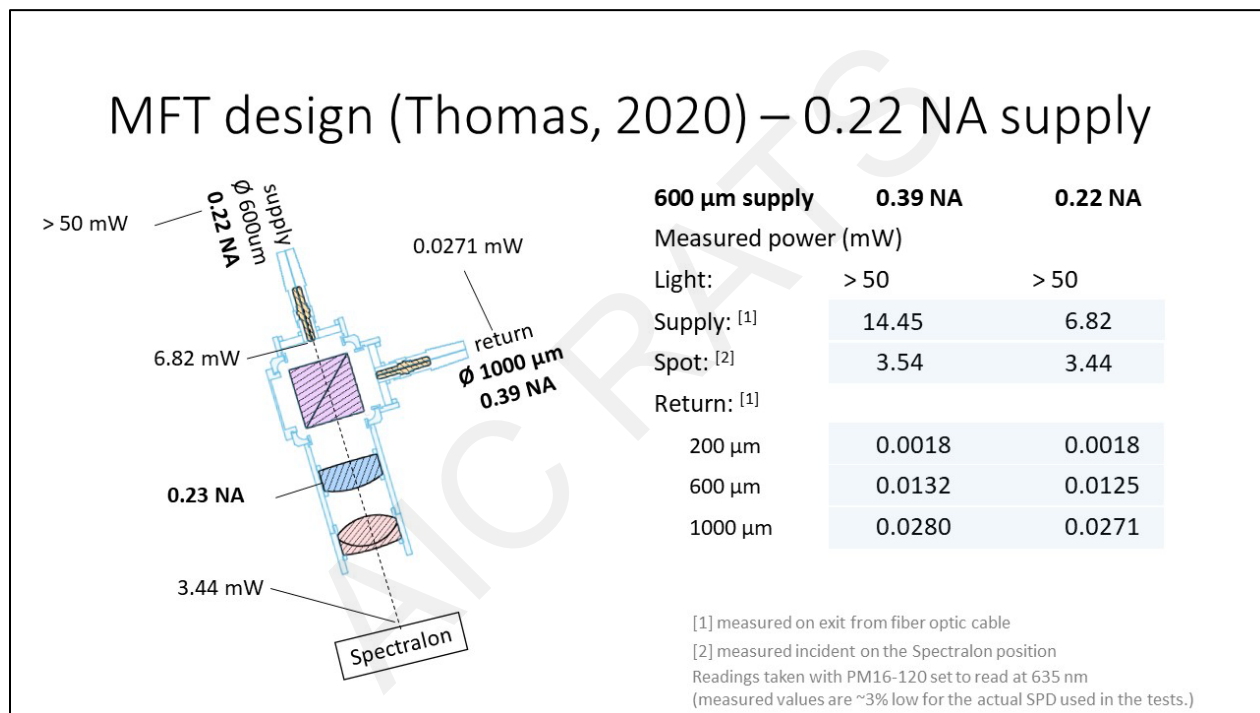
Looking at results from the optical bench, changing to an 0.22 NA supply fiber means that the power exiting the supply fiber is significantly reduced (as we'd expect).

However, both the power measured incident on the sample, and the power exiting the return fiber, are down less than 5%. Changing to the lower NA supply fiber makes very little difference to the power values that we care about – the extra light that was emitted from the tip of the 0.39 NA fiber is mostly lost to scatter.

**Annotated Slides**
Slide 39
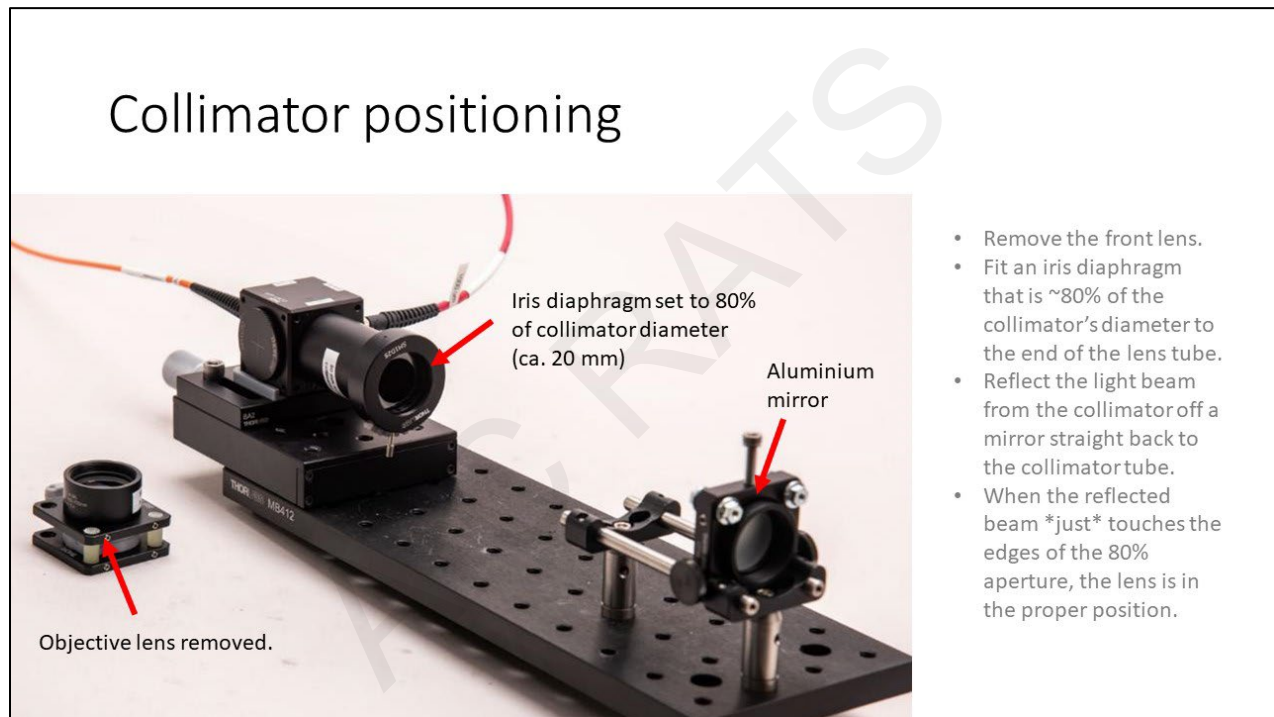
While we were looking at this, we wondered how you verify that the collimator lens is in the right position?

Moving the collimator forward until the spot is as small as possible is fiddly, and also tends to produce a somewhat over-collimated beam (although over-collimated is definitely better than under-collimated).

The easiest way we've found to establish the collimator position is to remove the objective lens, fit an iris diaphragm after the collimator and open it to about 80% of the collimator's diameter, and then use a mirror to reflect the beam back. The position of the collimator lens is set so that reflected beam *just* touches the edges of the iris diaphragm. We then move the collimator lens a quarter turn further forward.

[This approach becomes more accurate as the distance between the collimator lens and the mirror increases, but it gets progressively more difficult to align the mirror so that the beam is reflected at exactly on the optical axis of the collimator.]

Annotated Slides
Slide 40
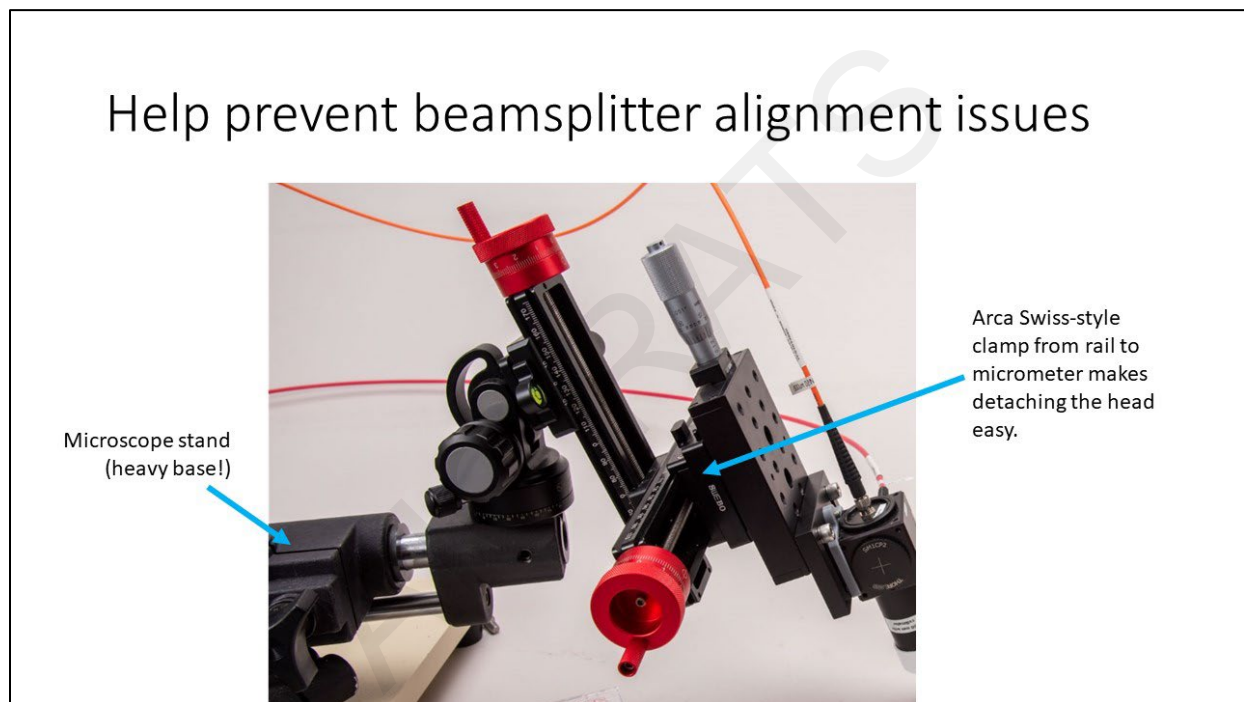
And while we are talking about the optical path, just a note that correct alignment of the beamsplitter cube is critical to the proper functioning of the retroreflective design. Unfortunately, the cubes are quite fragile - you *want* to lock the cube down, but it will be crushed if it is clamped too hard, and we have found that the cube can get jogged out of alignment if you have a bump while moving the head attached to a heavy base like a microscope stand.

With this problem in mind, when moving the head, it is probably best to
- completely decouple the MFT head from its support base,
- move the head and the base separately,
- and then rejoin them after the base is in its new position.

Adding an Arca Swiss-style clamp between the rail and the micrometer makes this quite easy.

Annotated Slides
Slide 41
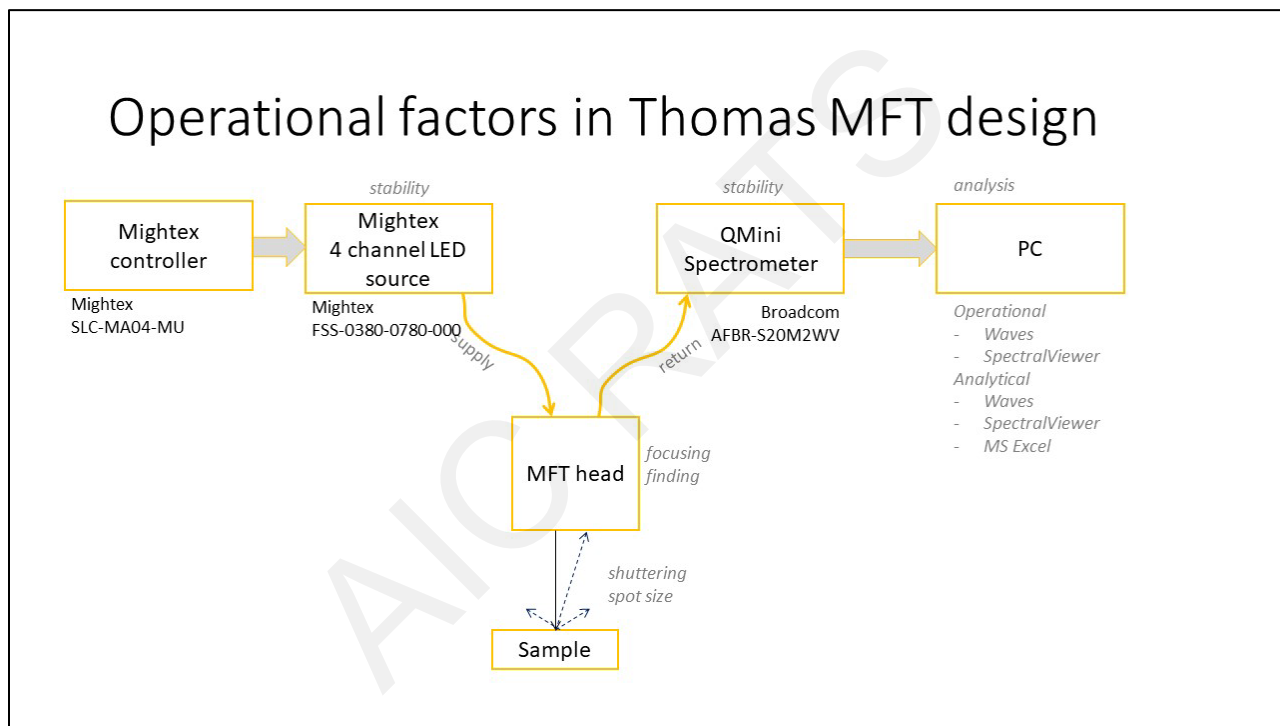
Here are the remaining operational issues we encountered with Thomas MFT unit.

The design uses a Mightex 4 channel LED light source and a Broadcom QMini spectrometer. Two important issues here are
- The stability of the light source and the spectrometer.
- Finding, focusing, shuttering, and characterizing the spot.

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Mightex 4 channel LED source - stability

Good stability (so long as the cooling fan for the source is on), ... *except* when switching power level.

- Source and controller warmed up for 10 minutes, cooling fan on.
- First 15 hour run: PM16-120 measured power at exit from supply fiber, 2 sec intervals (n=27,907).
    - Mean : 5.164 mW
    - Stdev : 0.006 mW
    - Range: 0.02 mW
- Second 15 hour run: took spectra from Spectralon white ref, 5 minute intervals (n = 186).
    - Maximum effect on ΔE^*_{00} for simulated grays (1%, 10%, 50%, 90%, 99% reflectance) and measured BW1 was ~0.07 using CIE 1931 Std Observer and D65 Std Illuminant. All except 10% gray ≤ 0.05 ΔE^*_{00}.

The good news is that the Mightex light source seems stable – the worst color variation we could find during 15 hours of continuous operation of the Mightex LED source was 0.07 ΔE^*_{00} (for simulated 10% gray).
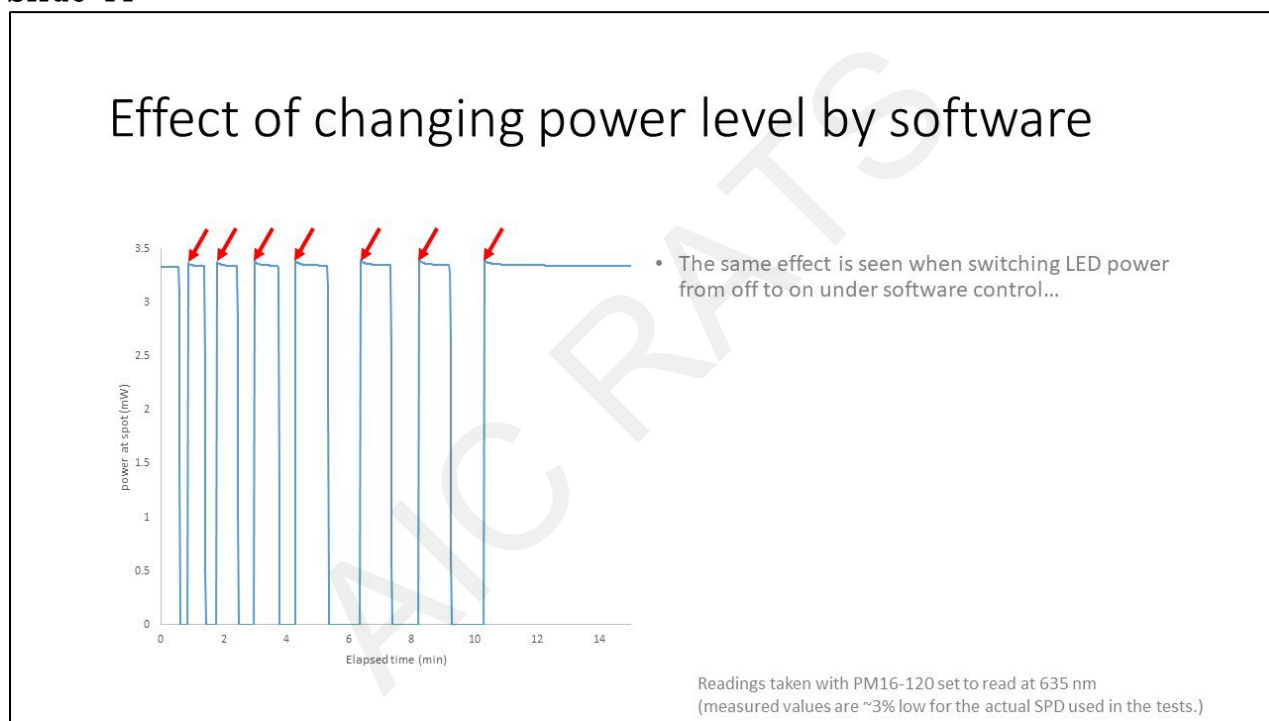
Annotated Slides
Slide 43
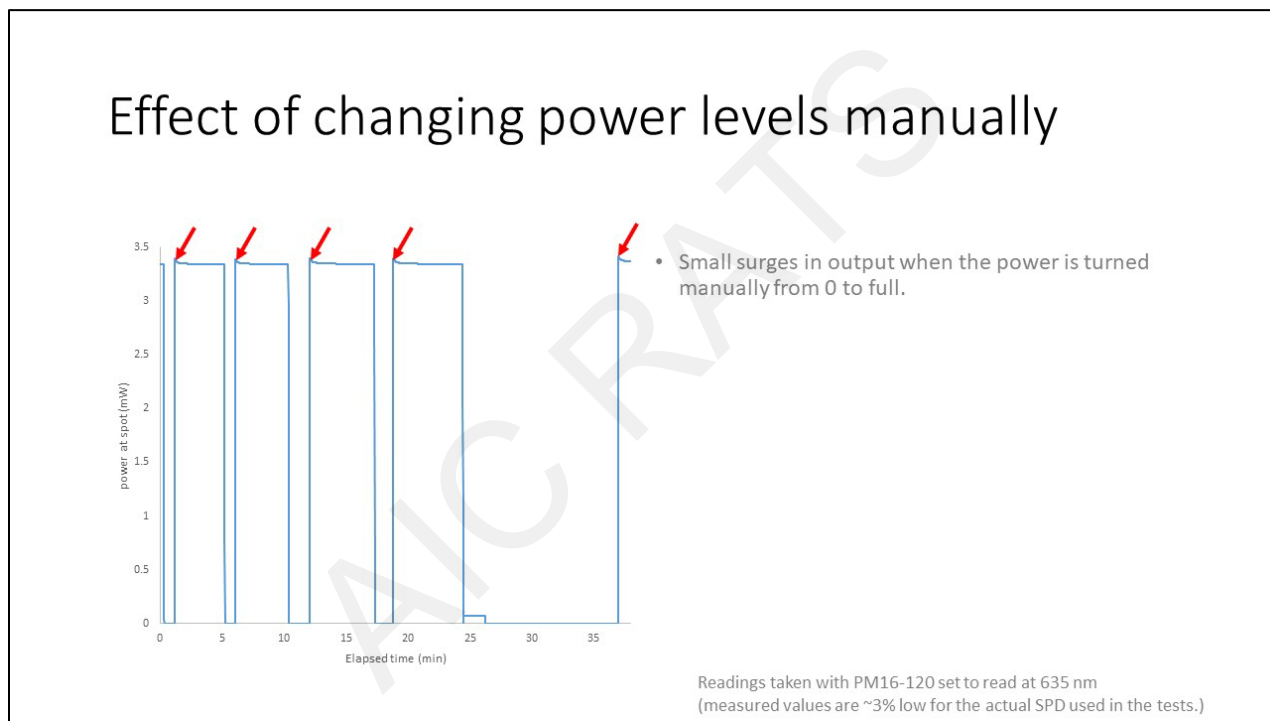
The not-so-good news is that, when the power to light source is varied, it takes a moment to get back to a steady power state.

Even after the unit is warmed up, the light output takes measurable time to stabilize after turning the main control knob all the way down to zero and then all the way back to back to full.
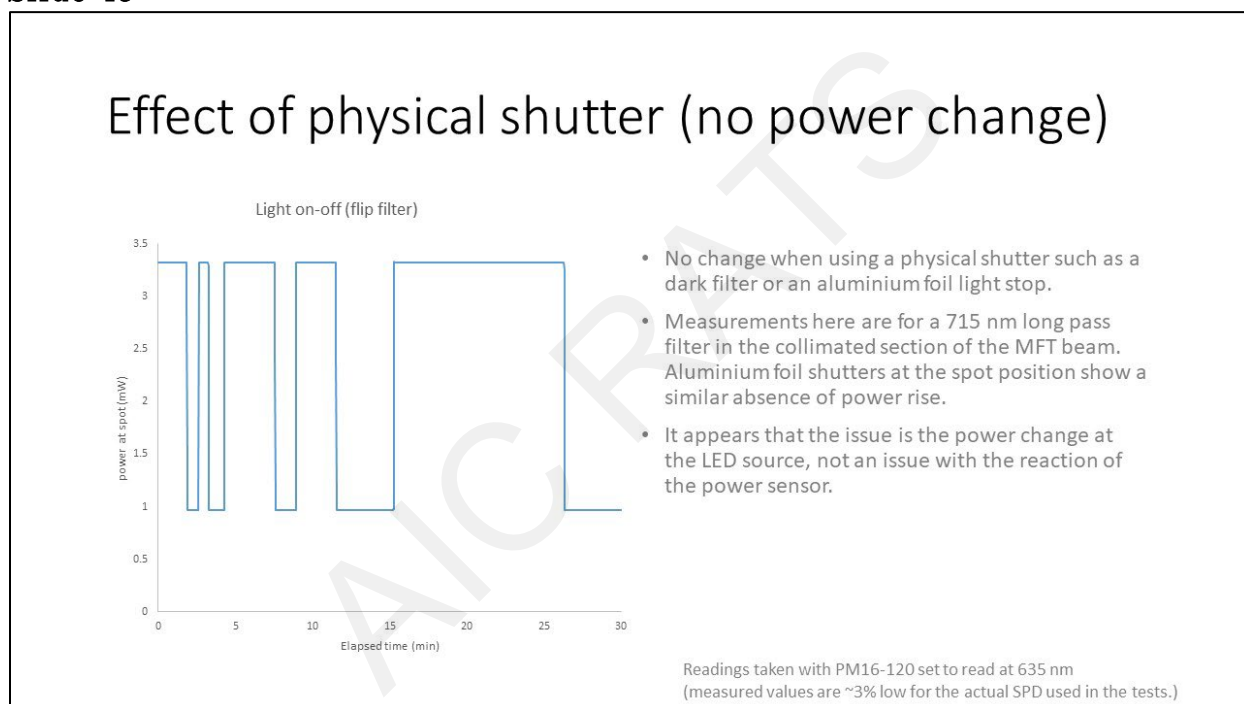
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We see the same effect when the source is under software control (i.e., this transient effect is a general result of changing the power level. not a result that is confined to *manual* control of the power level using the knobs on the unit).

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We don't see those initial small surges if we use a physical shutter (which implies that the issue is the stability of the light source's power unit, not an issue with the power measurement system).

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The forgoing observations of power stability are operationally important because the standard procedure for setting the focus depends on manually turning the light source intensity down to a very low level so as not to fade the sample during focusing, and then turning it back up to full for the reading.

One question we had was whether these power changes make a difference to the measured color change.

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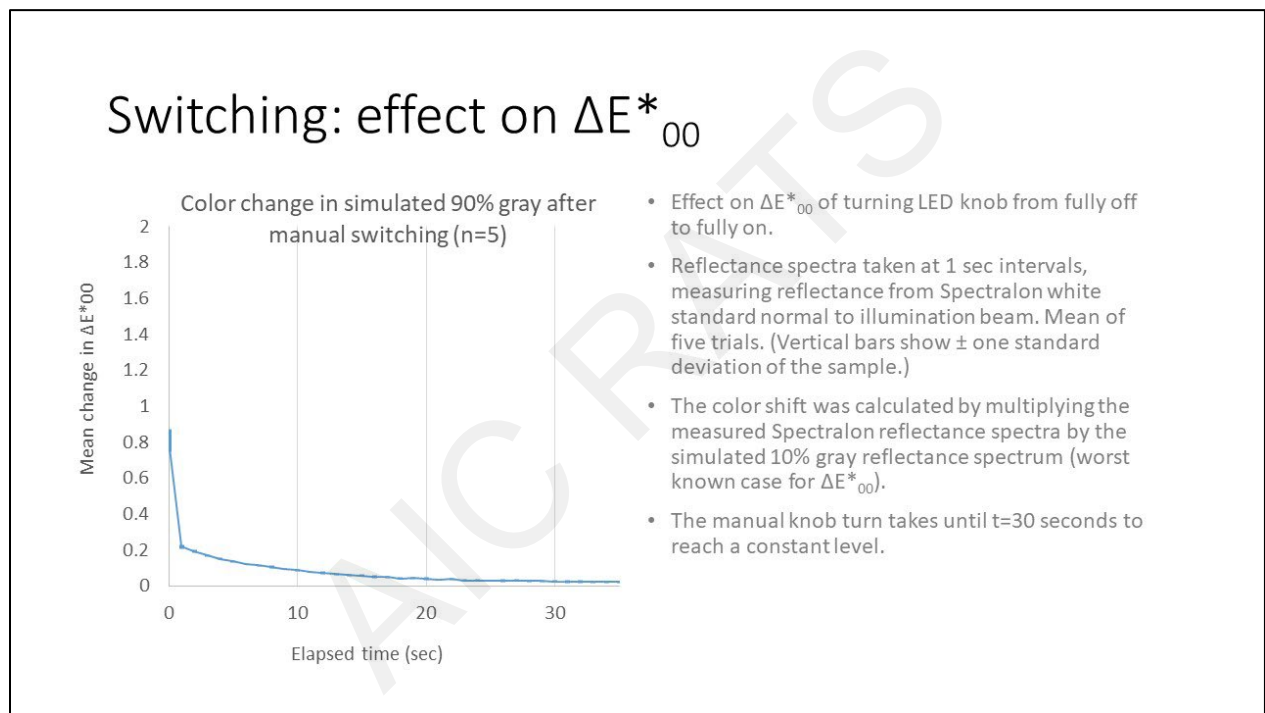
Here's the mean change in calculated ΔE^*_{00} from five tries at turning the knob from fully off to fully on.

The manual power control creates some noticeable error in ΔE^*_{00} at $t=0$, which decays asymptotically for around 30 seconds until it reaches a low constant level. If you do not want to wait for 30 seconds, it is better to avoid changing the intensity of the light source.
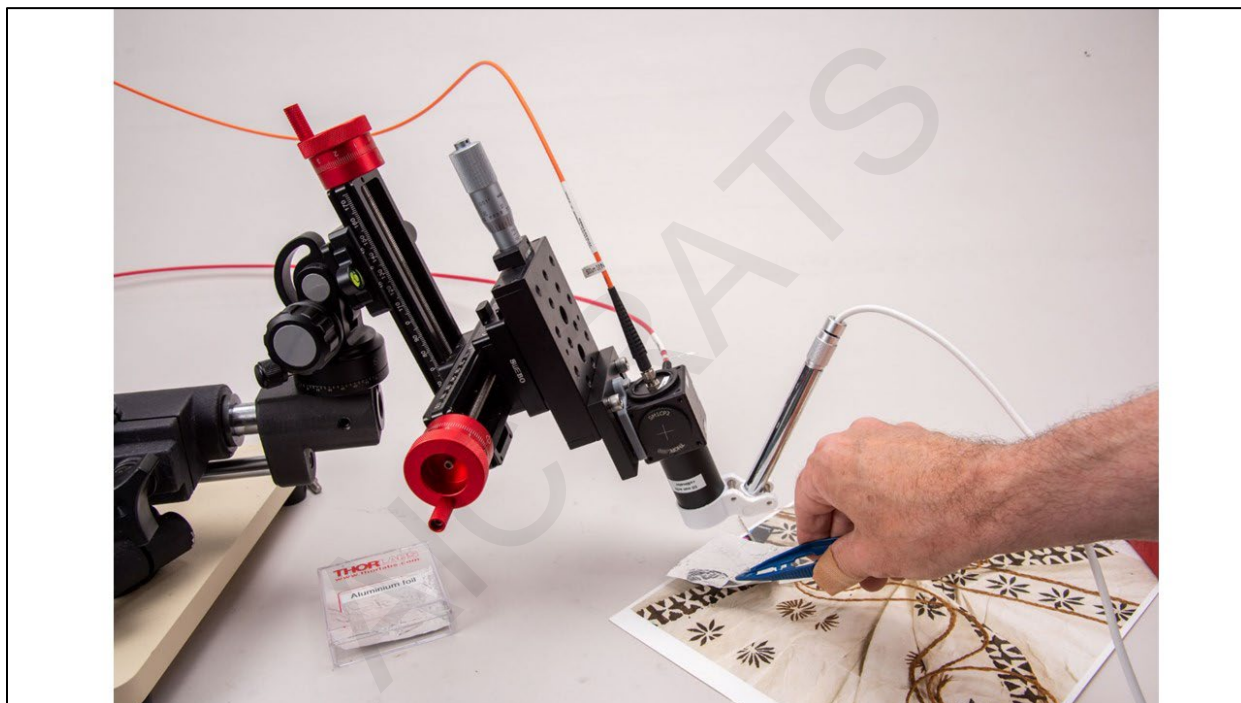
Annotated Slides
Slide 48
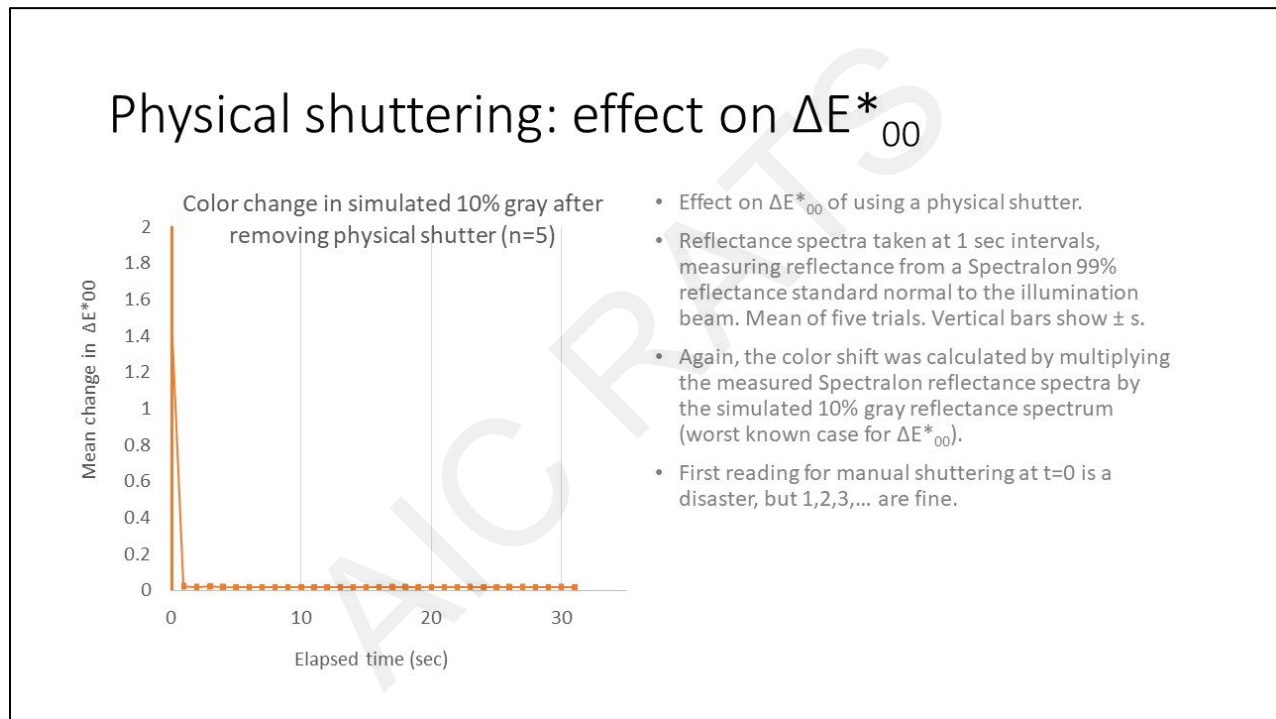
Here are the results for five tries with physical shuttering. There is a large initial error at t=0, but it has settled down in the next second, and the subsequent readings show very small deviations from correct values.

That big initial deviation is caused by what we are calling "shutter stutter".
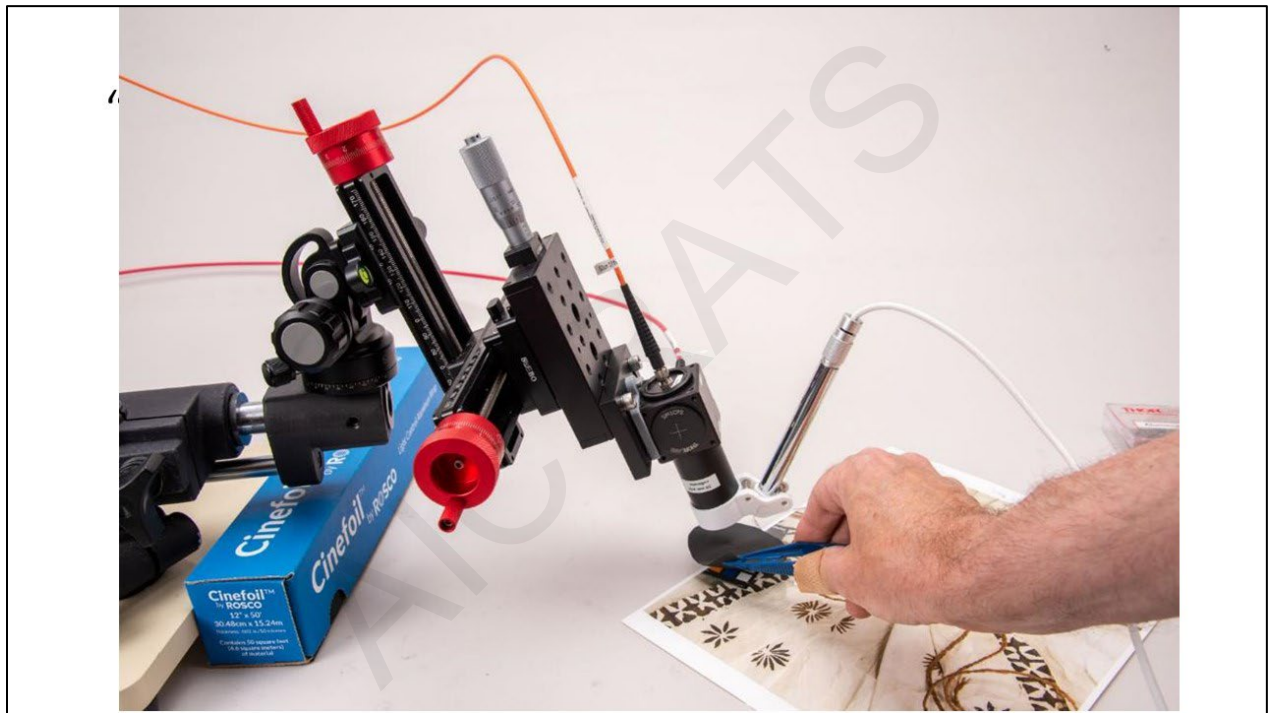
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Shutter stutter

Operationally, the Thomas unit starts taking spectra at 1 sec intervals with a physical shutter material (in this case aluminium foil) over the sample. The foil is removed to expose the sample and begin the measurement series (spectra acquired prior to removing the foil are discarded).

Spectra take measurable time to record (perhaps as much as 0.7 second). If the operator does not remove the foil in the time period between the end of one spectrum, and the beginning of the next, the sample is partially masked during one of the spectra and you get a malformed spectrum. However, the spectra after the malformed spectrum are fine.

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  Just as a side note: if you're using a foil shutter, we found that Rosco Cinefoil is easier to handle than the regular stuff.

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However, working on 3D social history items at the Field Museum, we found that the aluminium foil shutter   was difficult to use when the surface being measured was not horizontal.

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So we are moving to a system like this – a flip-out holder with two filters sandwiched between 30mm cage plates. This assembly sits in the collimated portion of the beam, and so moving the filter assembly in and out of the light path has negligible effect on the overall light path.

The iteration we are testing at the moment uses a 715 nm log pass filter (produces a dim spot in the far red) combined with a 0.7 neutral density filter to further reduce the intensity of the red spot.

When the shutter is in the closed position the head projects a low-intensity red dot which we use for positioning the spot accurately.

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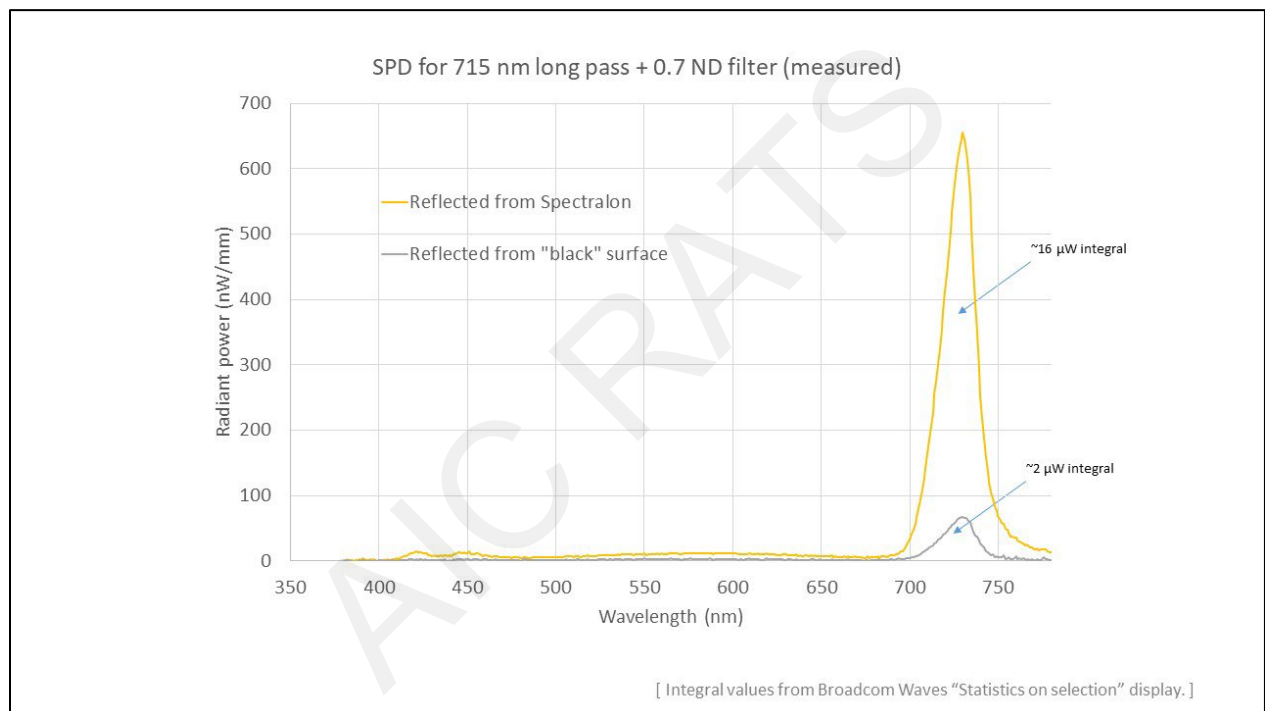
Then we *focus* by maximizing the integral of the reflectance from the red dot. The integral for the return from 99% reflectance Spectralon is pretty healthy at around 16 µW, black is not so good, but still focusable at 2 µW.

[As a side note, most reports on *automatic* focusing give results for a white target – it would be interesting to know how they perform on darker colors.]

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The other improvements are
- to add a USB microscope for precisely locating the spot (important for repeatability when measuring results from textiles), and
- measuring through *borosilicate* glass when dealing with compressible bumpy fibrous surfaces such as textiles and fur.

Measuring through glass has some impact on the white and dark reference spectra in that it changes the power delivered at the surface, and also changes the spot diameter. It follows that it is important that you calibrate your system through glass if you are measuring through glass.

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Slide 55
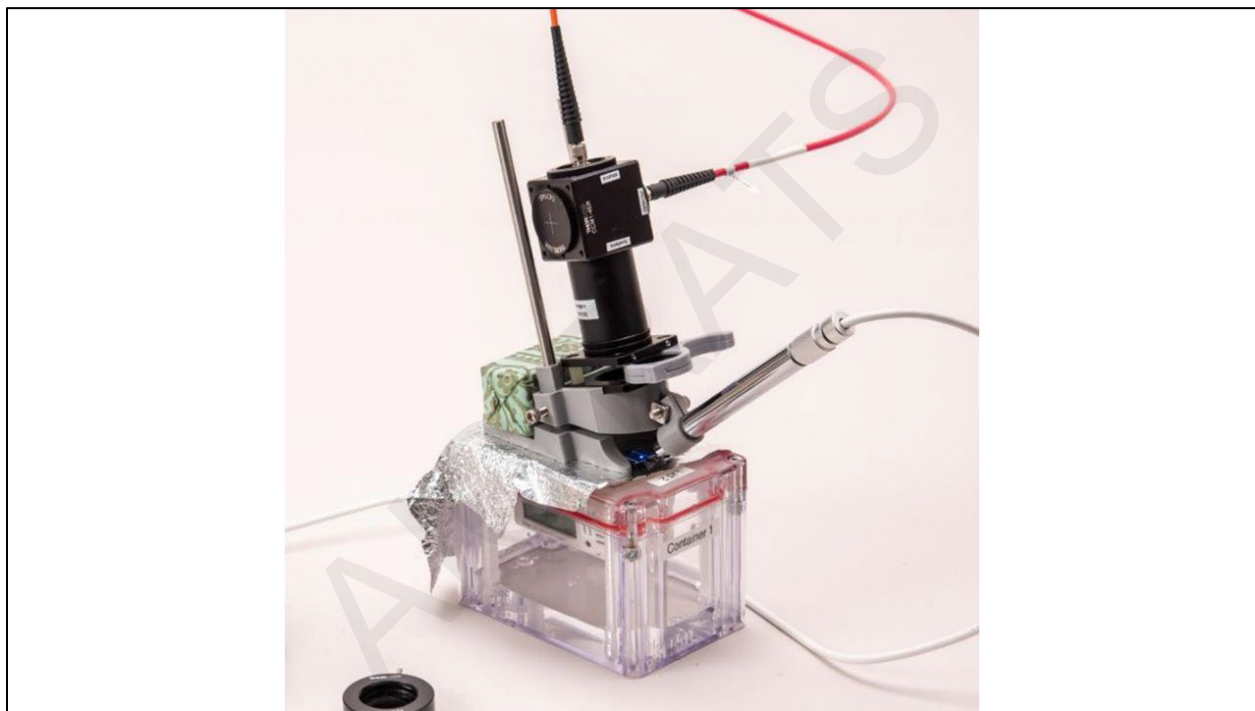
Like this experimental series that Grace Kim ran on the effect of relative humidity on the fading of blue wool standards.

In summary
- We want the light source to be stable. Using a physical shutter seems to be the best way to ensure that constant light levels are supplied.
- We want repeatable finding and focusing, and a dim red spot seems to be the best way to ensure this.

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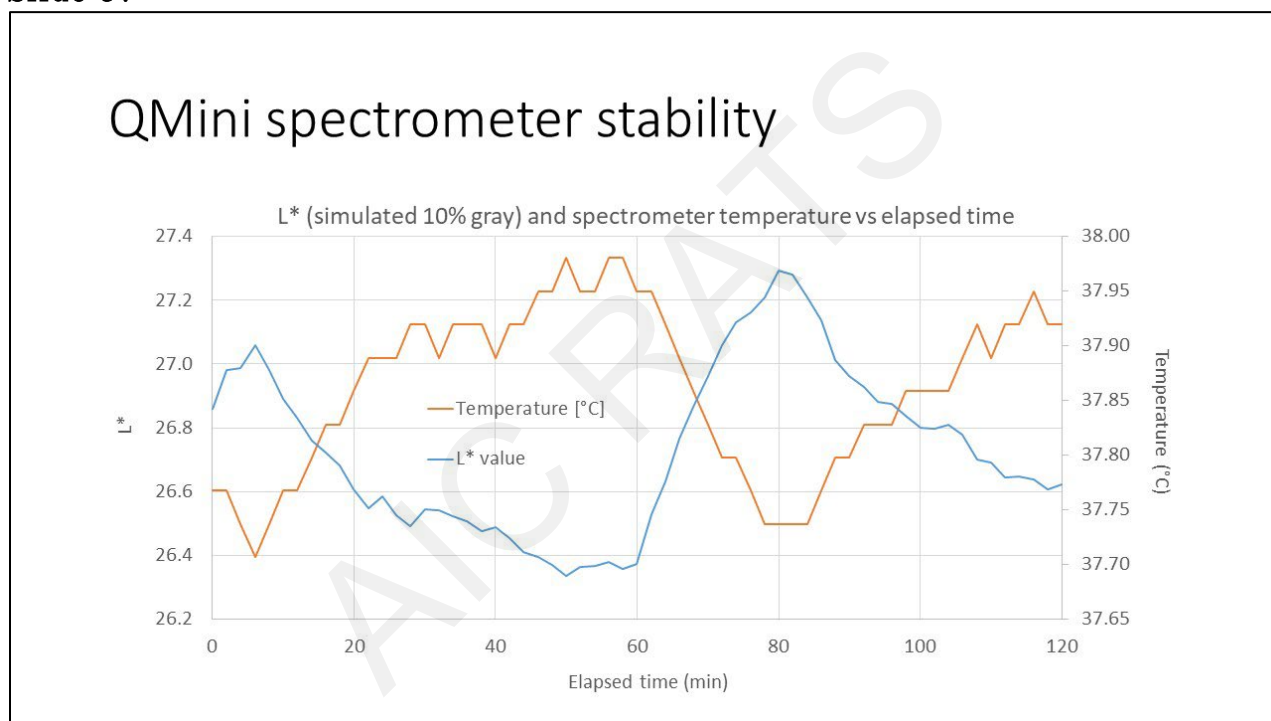We *also* want the spectrometer to be stable. It appears that the Qmini spectrometer is not stable at higher operating temperatures.
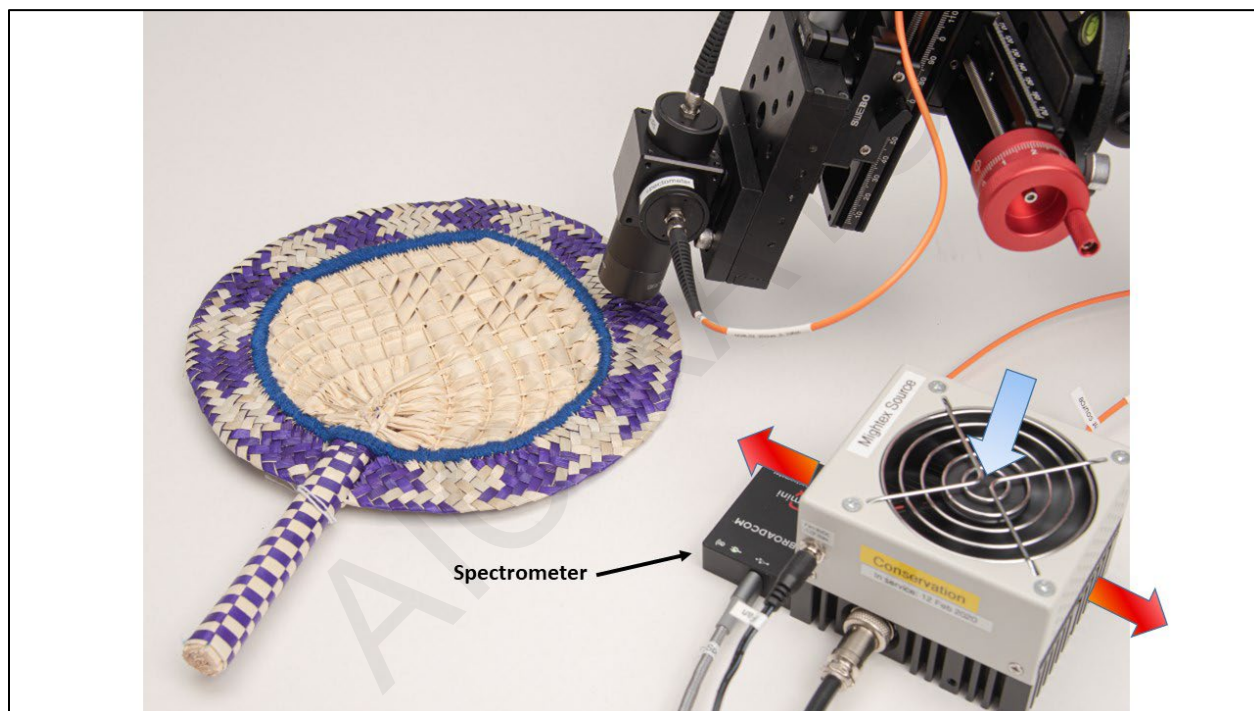
Annotated Slides
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At the Field Museum, we ran into some issues with white reference stability that seemed to be due to a shift in L* values that was inversely correlated with small shifts in the spectrometer temperature when the spectrometer was running "warm" (upper 30's °C).
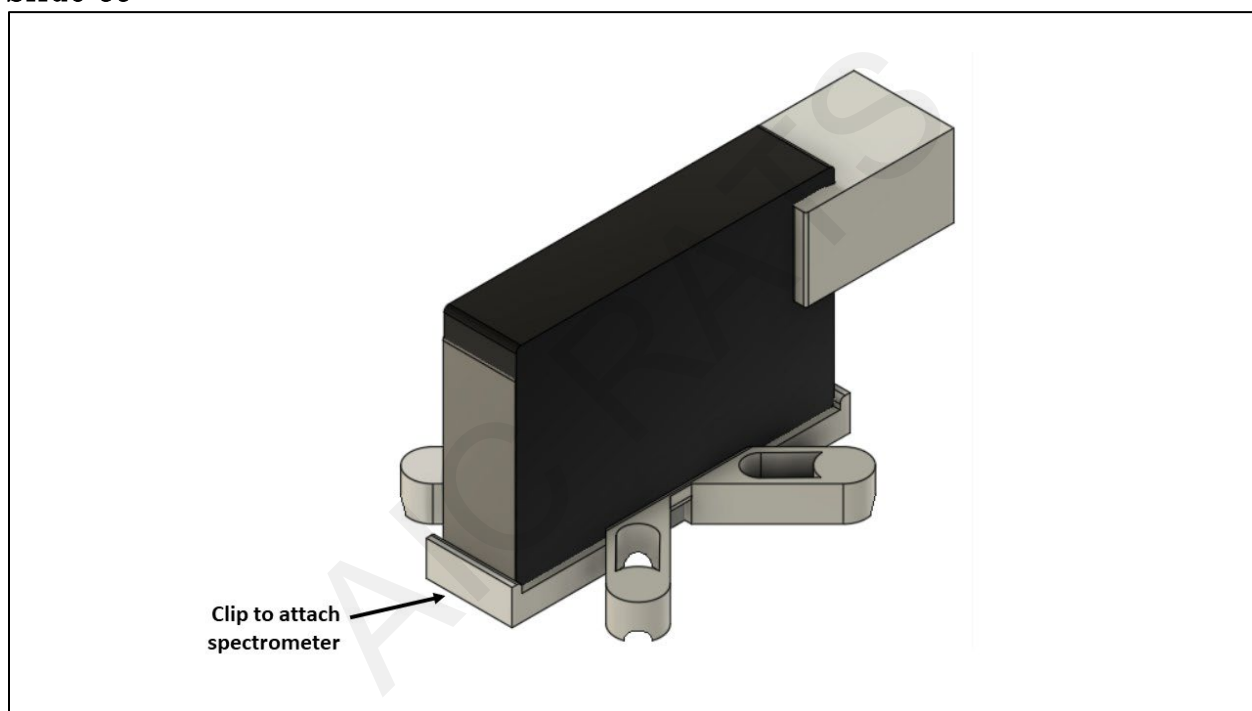
Annotated Slides
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The shifts in L* values were possibly a consequence of arranging the light source and spectrometer as shown in this image (the spectrometer is lying flat on the table at the left of the Mightex source).
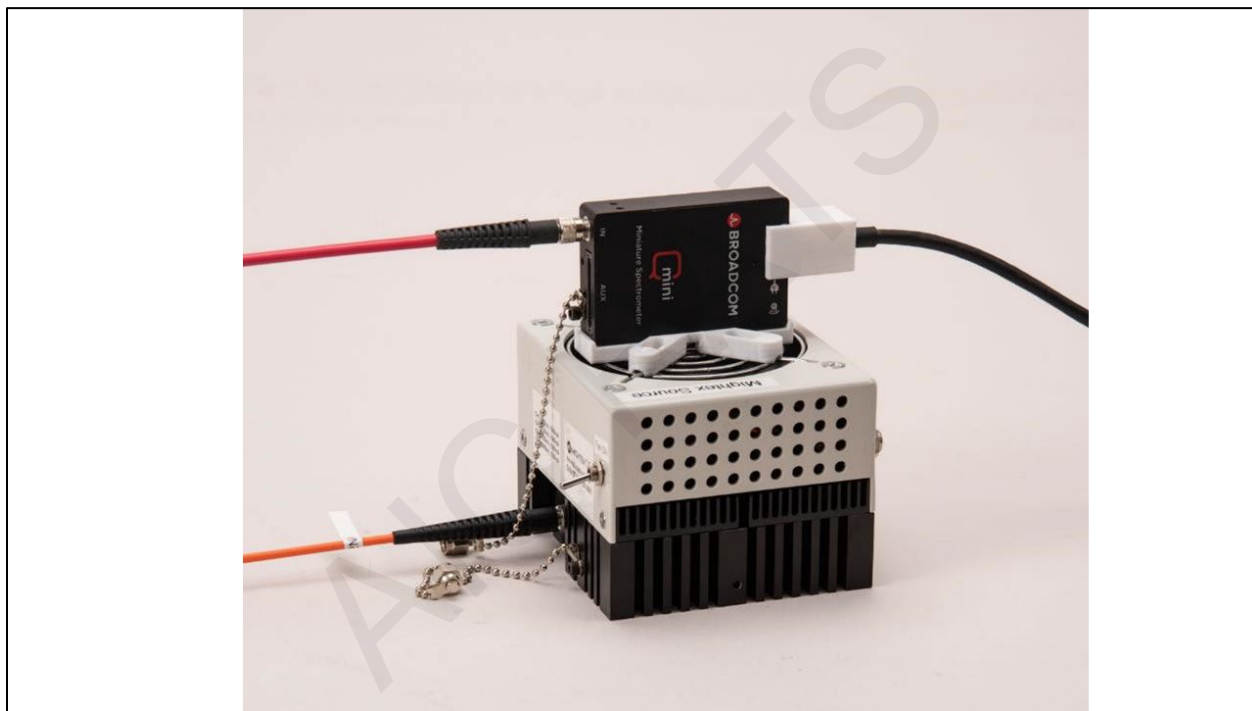
The light source cooling fan sucks room air in through the top of the controller, and the warmed air is blown out of holes in the sides. If the equipment is arranged as shown above, the effect is to increase the temperature of the spectrometer.

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To solve this we 3D-printed a small plastic clip with arms.

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The spectrometer friction-fits into the top of the clip, and magnets are adhered into the clip's feet, attaching it magnetically to the steel grill that covers the light source fan intake. We used a magnetic attachment so that, if the return fiber is pulled unexpectedly, the spectrometer will detach from its position (rather than the cable fracturing).

Moving the spectrometer to this position seems to have solved the stability problem and keeps the spectrometer temperature stable at 26-28°C.
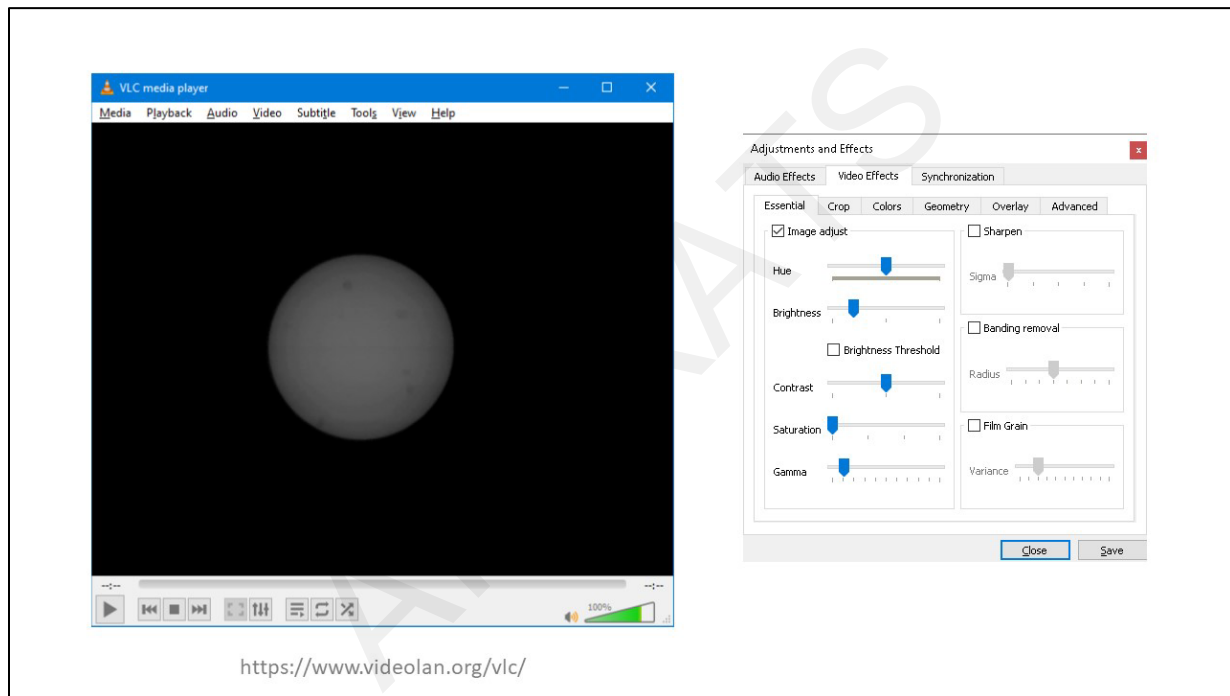
Annotated Slides
Slide 61
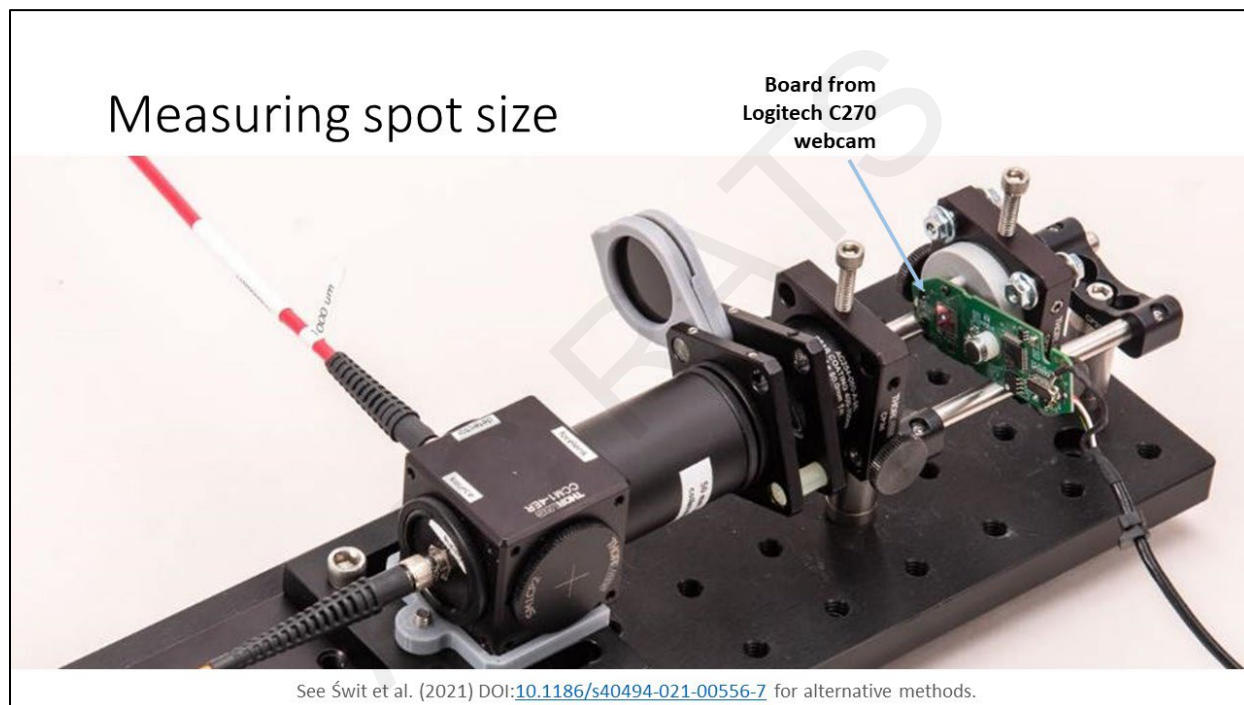
Our approach to measuring the spot size has been to turn the light source to a very low power, and focus the spot on a bare CCD sensor removed from a Logitech C270 webcam (cost about $30, sensor pixel pitch 2.8 µm).

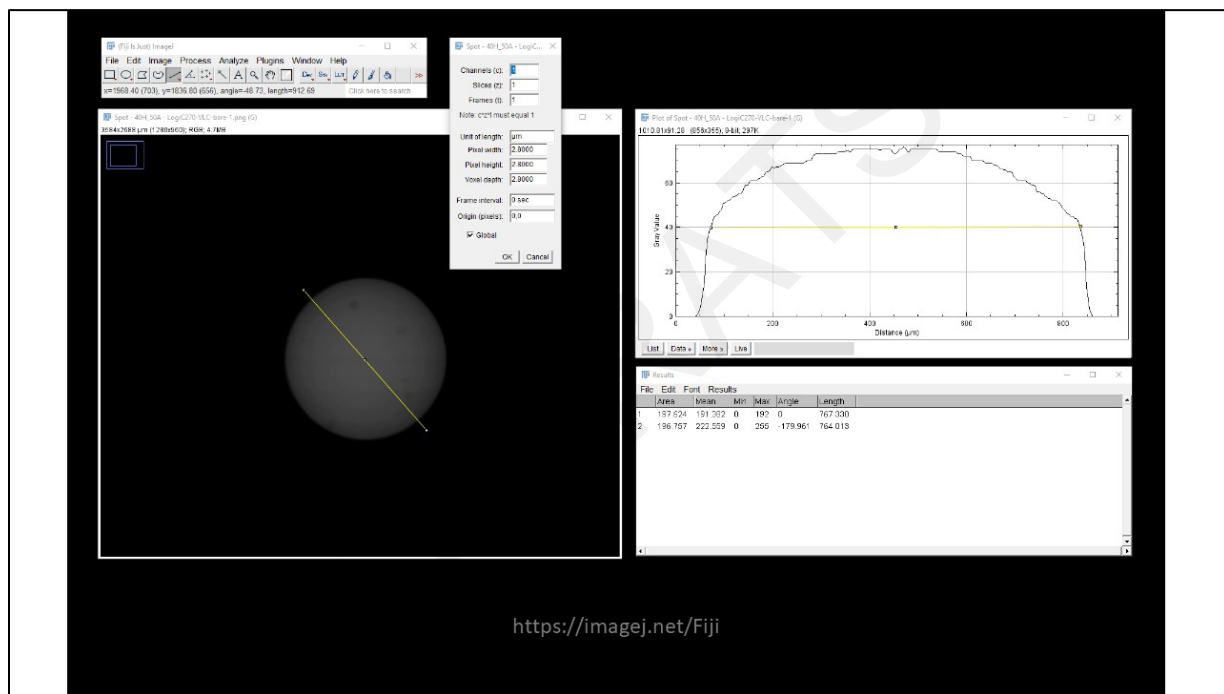**Annotated Slides**
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We capture the image from the webcam in VLC Media Player.

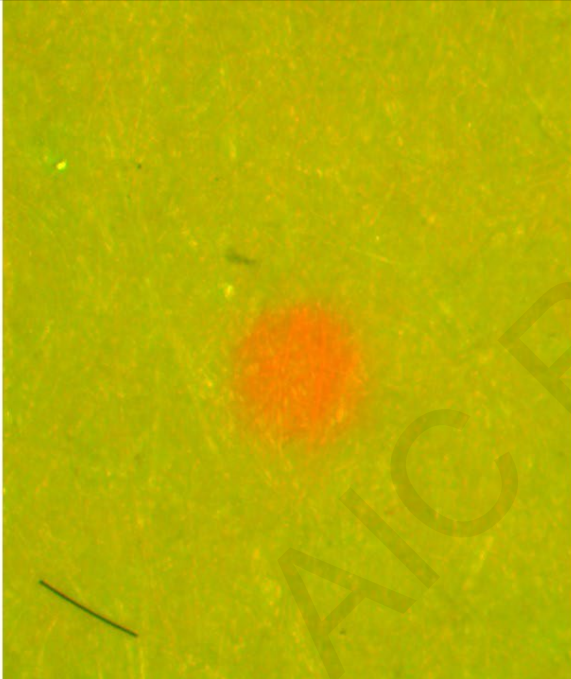**Annotated Slides**
Slide 63

And then bring the image into Fiji and measure the full-width-half-maximum diameter of the spot.

[Take the average for five individually focused spot images, and converges on a reasonable value.]

This technique gives decent agreement with predictions from ray theory.

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This measurement taken in the previous slide also gives decent agreement with physical measurements of spots burned into light-sensitive paper.

The CCD result is definitely sensitive to the light intensity used.

The light-sensitive paper method is sensitive to the SPD of the spot, the spot intensity, and the length of the exposure used to produce the color change, and also to the quality of the light-sensitive material.

At the moment, figuring out the spot diameter is the most time-consuming and uncertain of the measurements needed to fully characterize an MFT system.

Annotated Slides
Slide 65
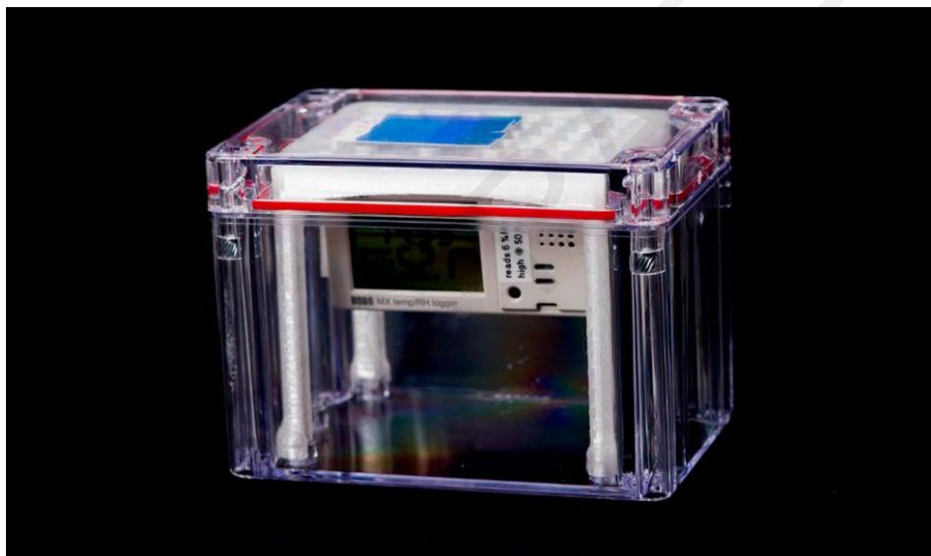
Running blue wool samples is time-consuming and costly.

Having a stable light source and a well-characterized spot means that you can take a set of blue wool readings and then re-use the data for analysis *if* you can check that there are no changes your MFT unit before you start work each day.

Checking power is quick a with a silicon photodiode, profiling the spectral power distribution is easy because you're always going to take a white reference, and we're looking at software for automating the CCD spot imaging method.

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Slide 66
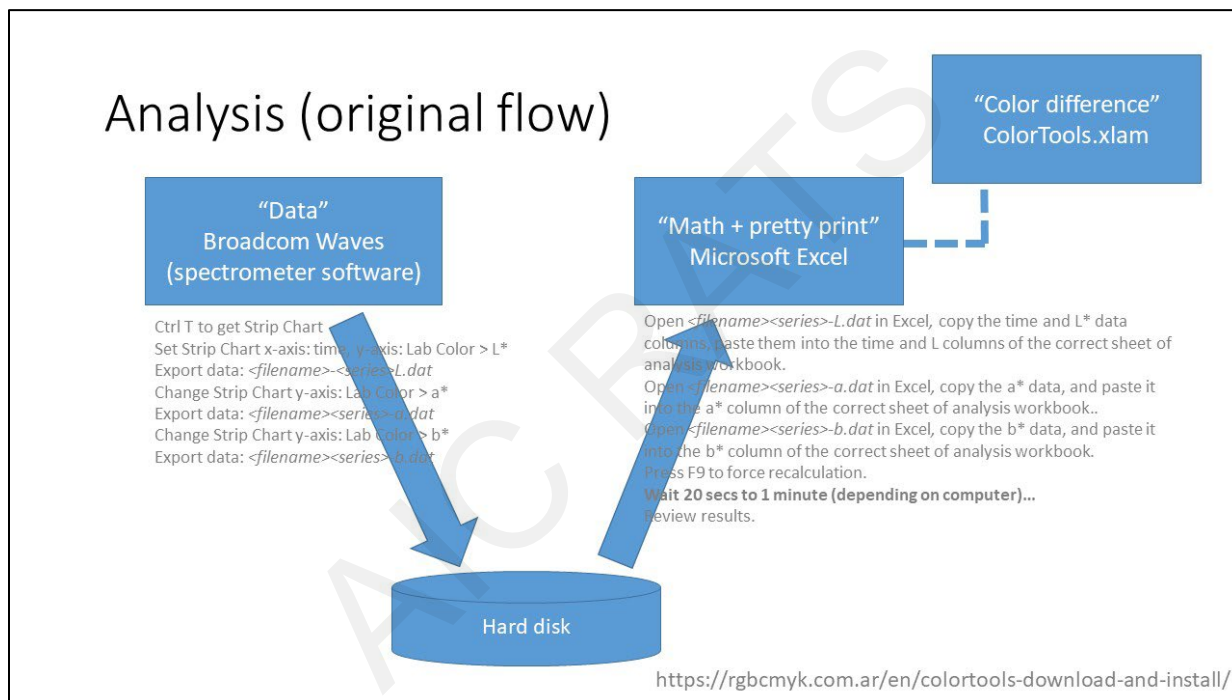
The final topic discussed here is the analysis of the spectral data series captured using MFT.

The Thomas MFT, as modified, captures pretty good spectral data series (good repeatability on most surfaces).

However, the analysis process that came with the Thomas MFT system in 2020 (summarized in the slide above) was a bit of a chore.

The procedure relied on manually exporting the L*, a*, and b* data from the Broadcom Waves spectrometer software as text files (one file for the L* data, one for the a* data, one for the b* data), manually importing the three text files into Microsoft Excel, and then copy-pasting the data from the appropriate file into the correct column in an analysis workbook.

Annotated Slides
Slide 67
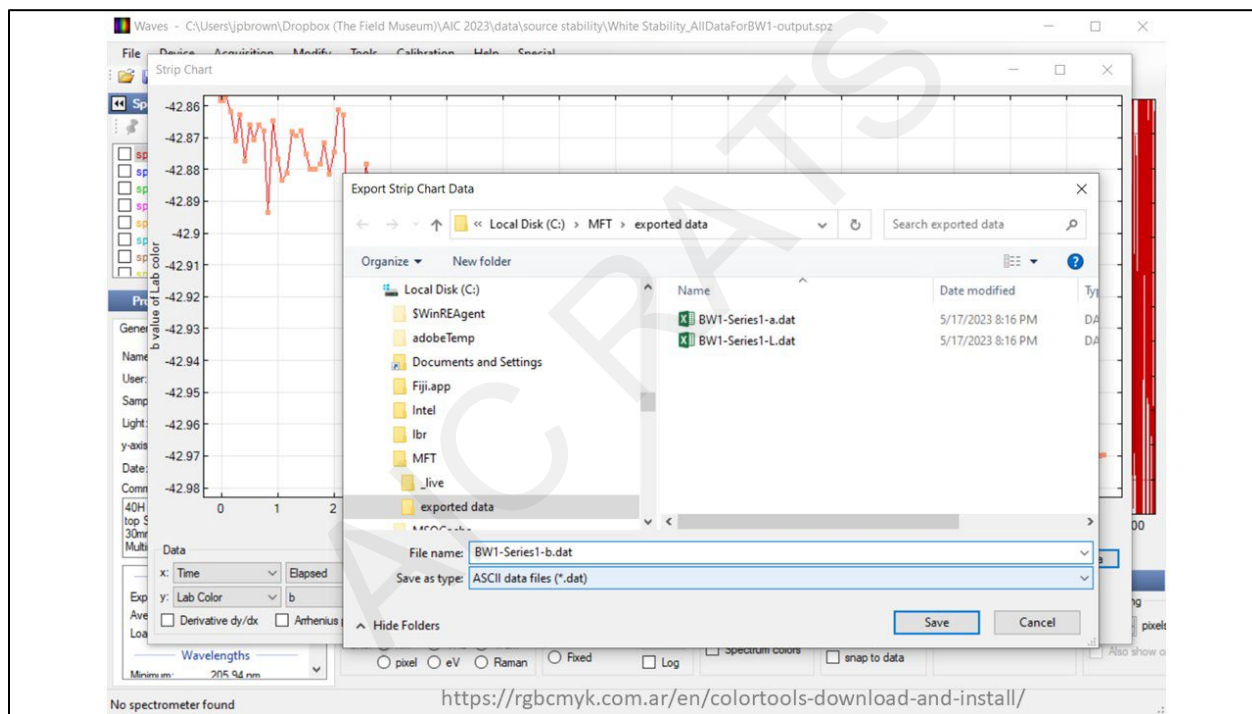
The spectrometer software end of this manual process works surprisingly well - It is reasonably quick and natural to export the necessary files at the end of a measurement run. The problem was at the Excel analysis worksheet. Apart from the problem of opening and copy-pasting the requisite L*a*b* data series correctly (which can be scripted to some extent), the calculation of color difference in the Excel spreadsheet depends on an Excel Add-In called ColorTools.xlam.

ColorTools.xlam is *very good* at calculating color differences correctly, but it is not particularly fast, and it is used over 100,000 times in the workbook. Any time you needed to change something, or save your changes, all those downstream ColorTools functions needed to recalculate, and that took between one and two minutes. *Every* time you changed something...

Annotated Slides
Slide 68
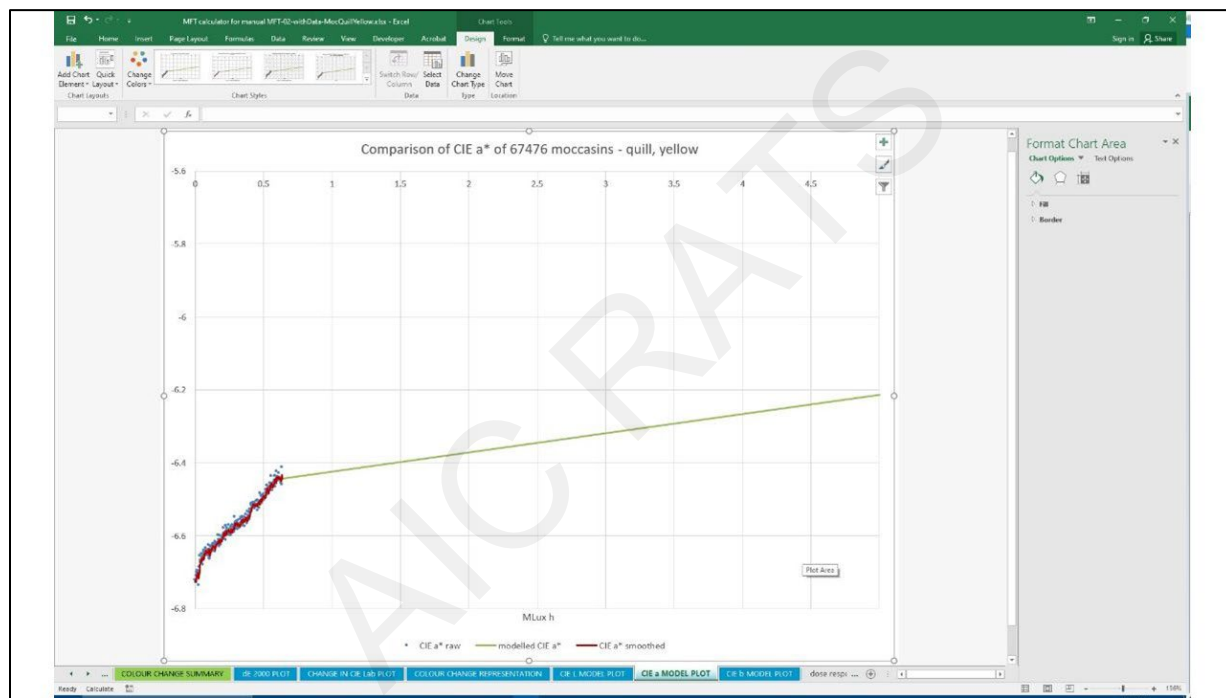
Also, the forecasting part of the analysis spreadsheet could be a bit disappointing. To be fair, nonlinear extrapolation is not really a strong point for native Excel functions, but the main problem was trying to forecast ΔE^*_{00} by forecasting the individual L^*, a^*, and b^* values.

Annotated Slides
Slide 69
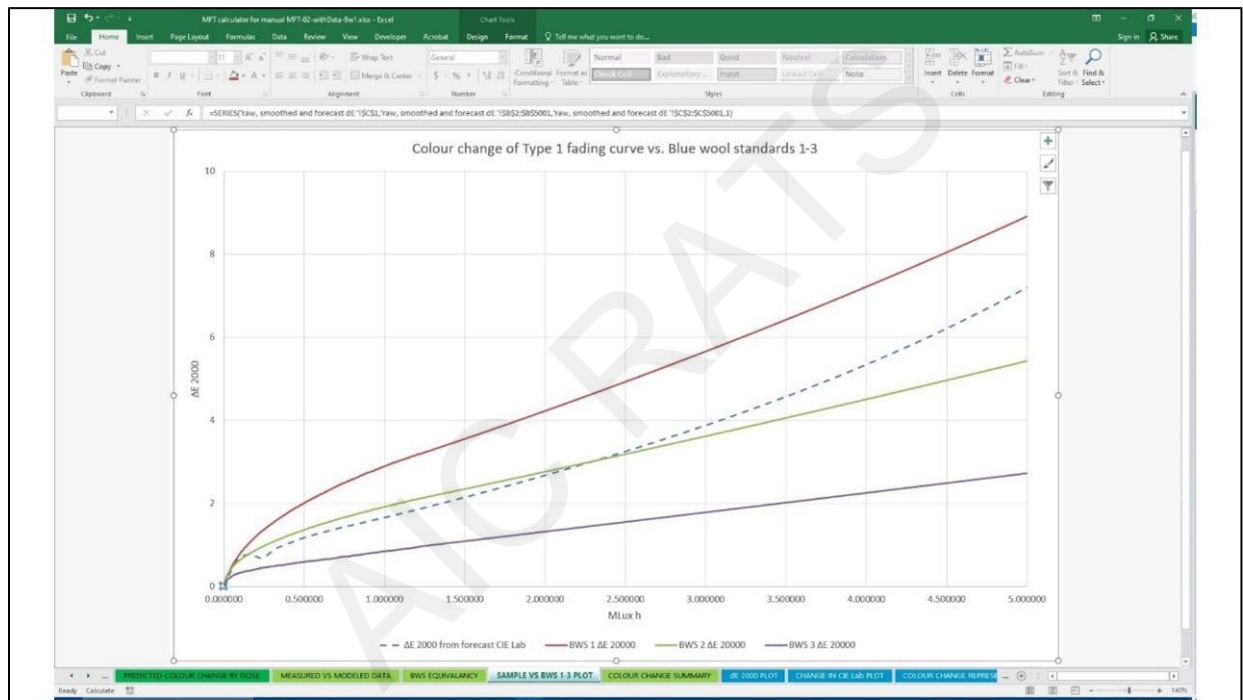
Back in 2020 we would run across upward fading curve predictions (like the dotted line in the example above) that were clearly wrong, but there was no way to modify the prediction towards something more correct, or to mark it as suspect or incorrect.

At this point our processes diverged.
- Jacob has continued to make improvements to the spreadsheet.
- JP followed along for a bit, but in the end moved all the calculation part to the new iteration of the Getty's SpectralViewer.

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The current iteration of SpectralViewer lets you monitor ΔE^*_{00} in real time while the spectrometer software is active (which allows you to track color change and stop the measurement series early if the color change is too extreme).

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Slide 71
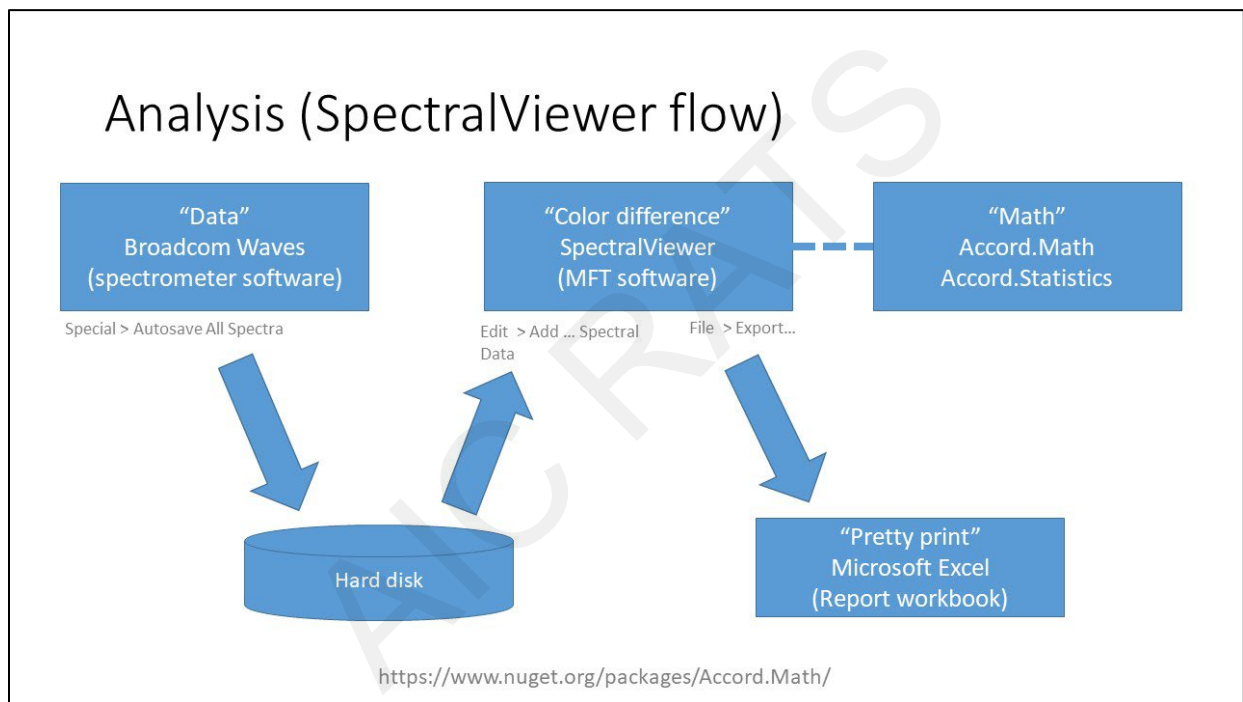
When the MFT measurements for an item are complete, you select File > Export in SpectralViewer.

The equations for forecasting data are generated inside SpectralViewer using a spaghetti fit, with the Accord math package doing the heavy lifting. The projections resulting from this approach are more consistently believable than the 2020 version of the Thomas spreadsheet (see next figure).

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Slide 72
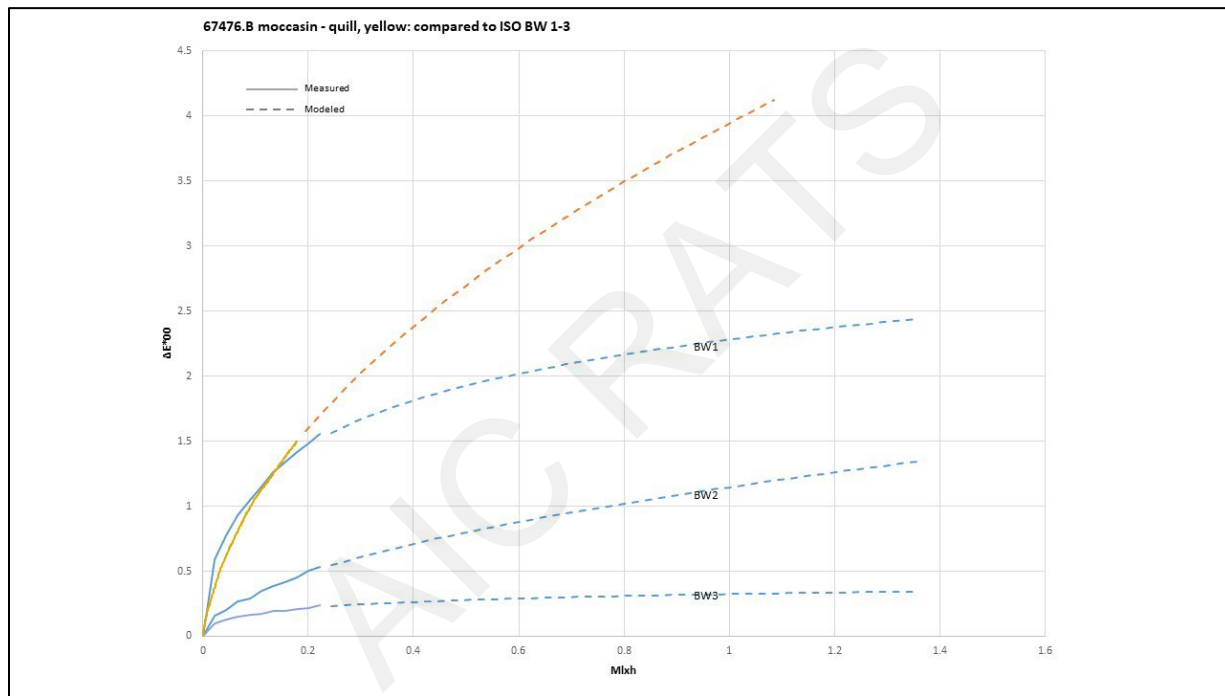
This figure shows an example of extrapolation exported to Excel from SpectralViewer.

The solid lines are the measured data and the dashed lines are the extrapolations. The results are injected into a modified version of the Thomas Excel spreadsheet. The modified spreadsheet does not require the ColorTools.xlam Add-In since the calculations of CIELAB values and ΔE^*_{00} are done in SpectralViewer. This method leaves Excel to what it is good at – simple math and pretty-printing.

(And, of course, you also don't have to manually export CIELAB data from Waves any more, or manually import those data.)

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Conclusions/Outcomes

- Match the NA of the *supply* fiber to the NA of collimator lens. A wider fiber diameter for the *return* fiber can be beneficial.
- Correct location of collimator can be verified using an iris diaphragm and a mirror.
- Si photodiode power measurement is much faster and easier than thermoelectric power measurement, and allows rapid power profiling for trouble-shooting. (The wavelength setting for the Si photodiode reading is important, and the amount of UV radiation cannot be characterized.)
- Standard tests on a cheap optical breadboard allow MFT characterization sufficient for re-use of existing BW standard fades taken under the same measurement conditions. Measuring spot size accurately is an issue.
- The Mightex 4-channel light source seems stable over multiple hours of operation, but power level changes introduce a transient that affects color shift calculations (which decays to negligibility after about 30 seconds).
- The importance of correct alignment for the beamsplitter cube suggests that the head should always be removed before moving a heavy support (such as microscope stand with a heavy base plate). Using an Arca Swiss connector to couple the head to the stand makes this easy.
- For textiles and furs, measuring through a borosilicate glass plate makes measurements easier and more repeatable. Measurement through glass requires full characterization of the MFT setup (spot size, spot power, white ref, dark ref) with the glass.
- A flip filter (far red long pass + ND) in the collimated beam allows repeatable focusing for darker colors while providing some protection from fading during focusing and finding. Rosco Cinefoil provides a good opaque barrier if you prefer manual shuttering.
- The stability of the Broadcom QMini spectrometer can be an issue when it is "warm". Mounting the spectrometer in clip magnetically attached to the Mightex light source fan intake helps stabilize temperature in the ~26°C range , and also restrains spectrometer movement in response to movement of the fiber.
- Projecting MFT data into the future is fraught with problems, but offloading the work of extrapolation from Excel to SpectralViewer makes time to analysis faster, and the results more consistently believable.

Conclusions and Outcomes are as follows:

Match the NA of the *supply* fiber to the NA of collimator lens. A wider fiber diameter for the *return* fiber can be beneficial.

Correct location of collimator can be verified using an iris diaphragm and a mirror.

Si photodiode power measurement is much faster and easier than thermoelectric power measurement, and allows rapid power profiling for trouble-shooting. (The wavelength setting for the Si photodiode reading is important, and the amount of UV radiation cannot be characterized.)

Standard tests on a cheap optical breadboard allow MFT characterization sufficient for re-use of existing BW standard fades taken under the same measurement conditions. Measuring spot size accurately is an issue.

The Mightex 4-channel light source seems stable over multiple hours of operation, but power level changes introduce a transient that affects color shift calculations (which decays to negligibility after about 30 seconds).

The importance of correct alignment for the beamsplitter cube suggests that the head should always be removed before moving a heavy support (such as microscope stand with a

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heavy base plate). Using an Arca Swiss connector to couple the head to the stand makes this easy.

For textiles and furs, measuring through a borosilicate glass plate makes measurements easier and more repeatable. Measurement through glass requires full characterization of the MFT setup (spot size, spot power, white ref, dark ref) with the glass.

A flip filter (far red long pass + ND) in the collimated beam allows repeatable focusing for darker colors while providing some protection from fading during focusing and finding. Rosco Cinefoil provides a good opaque barrier if you prefer manual shuttering.

The stability of the Broadcom QMini spectrometer can be an issue when it is "warm". Mounting the spectrometer in clip magnetically attached to the Mightex light source fan intake helps stabilize temperature in the ~26°C range , and also restrains spectrometer movement in response to movement of the fiber.

Projecting MFT data into the future is fraught with problems, but offloading the work of extrapolation from Excel to SpectralViewer makes time to analysis faster, and the results more consistently believable.

Research and Technical Studies Joint Panel with Book and Paper Specialty Group and Preventive Specialty Group: Poison Books: Is That Green Book Going to Kill Me? Bibliotoxicology Working Group Discussion Panel

Becky Fifield[1], Rosie Grayburn[2], Timothy N. Greening[3], Kimberly Harmon[4], Susan Russick[5], Melissa Tedone[6]

[1]Associate Director (Head), Collection Management, New York Public Library
[2]Head of Scientific Research and Analysis Lab, Winterthur Museum, Garden & Library; Affiliated Associate Professor Winterthur/University of Delaware Program in Art Conservation
[3]Archeological Scientist, Parks Canada Agency
[4]Industrial Hygenist, Smithsonian Office of Safety, Health, and Environmental Management
[5]Chief Conservator, Northwestern University Libraries
[6] Head of Library Materials Conservation Lab, Winterthur Museum, Garden & Library Affiliated Associate Professor Winterthur/University of Delaware Program in Art Conservation

Original Abstract

So called "poison books" have been positively identified in collections all over the world. The Bibliotoxicology Working Group is an ad-hoc, international cohort of conservators, cultural heritage scientists, librarians, collection managers, book historians, and health and safety professionals. The group explores reliable identification methodologies for toxic components of historical bookbindings and archival materials and develops best practices for managing such collections with a focus on health and safety.

This panel will address the following questions:
- What hazardous materials were used in bookbinding? In what time period(s)?
- Is it possible to safely use these materials?
- What are the OSHA requirements for labeling and handling?
- Do I need to buy an XRF to identify hazards?
- Who else in my institution needs to know about this?
- How do I get from panic to planning?

The session will combine short presentations with ample time for questions and discussion.

Presentations will be:

- Melissa Tedone, Head of Library Materials Conservation Lab, Affiliated Associate Professor WUDPAC, Winterthur Museum, Garden & Library, "The Evolution of the Bibliotoxicology Working Group."

- Rosie Grayburn, Head of Scientific Research and Analysis Lab, Affiliated Associate Professor WUDPAC, Winterthur Museum, Garden & Library, "Searching for arsenic: the scientific approaches of the Poison Book Project."

- Timothy N. Greening, Archeological Scientist, Parks Canada, "Arsenic to Dye For? A Study of Arsenic inside a 19th Century Book of Textile Samples."

- Kimberly A. Harmon, CIH, Industrial Hygienist, Office of Safety, Health and Environmental Management, Smithsonian Institution, "Exposed! Results of sampling during handling of "poisonous" books."

- Becky Fifield, Associate Director, Collection Management, Preservation and Collections Processing, The New York Public Library, "We have a plan for that! Initiating the Hazardous Collection Material Management Program at the New York Public Library."

- Susan Russick, Chief Conservator, Northwestern University Libraries, "Can we call it arsenic yet? The 19th century Green Books Project at Northwestern University Libraries."