

Nano and Quantum Technologies Laboratory

A student's guide to N/QTL research groups

Introduction to N/QTL

N/QTL (known as NanoteQ locally) is a research center of Wake Forest University. The main facility at 95 W 32nd Street has a wide variety of microscopy, materials synthesis, characterization, and cleanroom fabrication tools. This is, in general, a regional level facility the equal of those at our local peer institutions such as Vanderbilt, Duke, and Emory. The Lab hosts multiple WFU research groups as *members*, giving them privileged (superuser) access to tools and services. The lab also provides for external and internal non-member users who: pay for hourly use of tools, participate in training workshops or collaborate with members. Students and staff of all hosted groups mingle and share office and lab space, with the aim of generating cross pollination of disciplines.

While all member groups are expected to participate in management of the lab's equipment and preservation of capabilities, the Carroll Research Group as founding members, is unique in taking on a heavier share of the responsibility of management and training. This is in keeping with Prof. Carroll's philosophy which emphasizes technical skills combined with heuristic models.

The emphasis areas of N/QTL research are:

- **Green Worlds Tech:** photovoltaics, thermoelectrics, high efficiency lighting, active coloration and signature modification.
- **Human-Technology Interfaces:** strain, pressure and gas sensing, analyte recognition enhancement based on self-gain sensing platforms, cyborgnetics.
- **Quantum Information Processing:** metamaterial structures and new nanostructures. Materials structures for quantum information processing. Qubits, quantum computing architectures, quantum sensors.
- **Synthetic Intelligence:** Machine learning and artificial intelligence. ML and AI used in QIS to perform error suppression.

The tools we manage:

- **Microscopy:** TEM, HRTEM, XPS, SEM, AFM, STM, optical microscopes, Raman Lab
- **Cleanroom:** PECVD, RIE, optical *i*-line Lith, Sputter, ebeam, FIB, NPGS, packaging
- **Synthesis:** Chem Lab, ovens, flash chromatography, ultracentrifuge, MBE
- **Transport and Optics:** An assortment of transport and optics capabilities including 300 mK and high field transport, GHz signal generators and shapers, ps transient absorption, etc.

Scientific Style

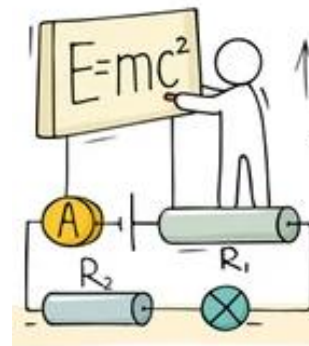
N/QTL is dedicated to the highest possible standards in the conduct, presentation, and reporting of research. We engage in the national dialogue pertaining to nano and quantum technologies, strive to be at the forefront of new phenomenology, new vistas and new paradigms, and we embrace emerging directions and the uncharted territory. To do this N/QTL and its colleagues *must* adopt an open and collaborative posture. This requires strict adherence to ethical standards and codes of interaction. [See document on Standards of Ethics for N/QTL members, adopted June 2025]

Self-Actualization

There are basic skills expected of all students studying within N/QTL. This expectation is on top of university and departmental requirements.

Inquire

1. Demonstrate the ability to form hypotheses based on calculations and estimates combined with observation, develop the ability to independently form an experimental plan of investigation, understand how to ask questions and answer scientifically, fit data and present it graphically, statistically analyze the significance of findings.
2. Develop the skills to use multiple experimental modalities to test a hypothesis. Know the chain of data collection in each experimental technique applied. Understand experimental sources of error, error propagation, and the limits of observation.
3. Demonstrate a superior knowledge of current literature in the field and be able to comment on experimental results in light of that literature.
4. Guard against biased skepticism and blind optimism. Demonstrate the ability to make accurate and conclusive statements regarding data, understanding its implications in the scientific narrative.
5. Demonstrate a knowledge of laboratory safety and basic biological impacts of your work.



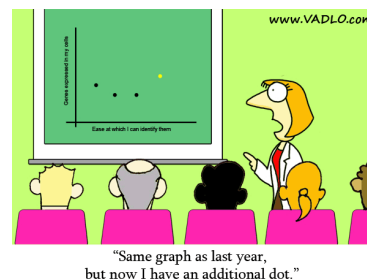
Collaborate

6. Take an interest in coworkers projects attend their talks.
7. Develop a working relationship with other group members and with the advisor.
8. Share in group laboratory activities (group meetings, cleaning, repairs, etc.).
9. Work outside of the group in a collaborative exchange arranged by the advisor.



Communicate

10. Demonstrate the ability to communicate scientific findings with an understanding that is clear and precise. Be able to present your work in written form and in presentations. Remember, "Facts are not science as the dictionary is not literature – Martin H. Fischer"
11. Develop a significant CV with publications and presentations at meetings, along with a record of collaborative work. This should clearly communicate who you are and what your accomplishments mean.



General Guidelines

All research groups have rules. Some are stricter than others and this is usually tied to the subfield or discipline in which you are working. Here are some general guidelines that are applicable across most research groups.



1. Your research advisor is in charge. Group management, research directions, research assignments, group membership, and group finances, are ultimately the responsibility of the group head. This person is officially your research advisor even though you may work closely with other senior researchers. It is a good practice to keep this person informed and engaged in your activities as long as you are a member of their group. If you have a problem you should go to your research advisor first. If the problem cannot be resolved, then the next step is to go to the chair of your degree department.



2. Membership in a research group is conditional. Research advisors usually make every attempt to help students and postdocs integrate into a group. But sometimes the fit just isn't there. Generally, you must show:

- *Laboratory skill -*
- *Enthusiasm and dedication to research -*
- *Progress in research goals -*
- *Integration and service within the group -*
- *Academic performance and progress -*

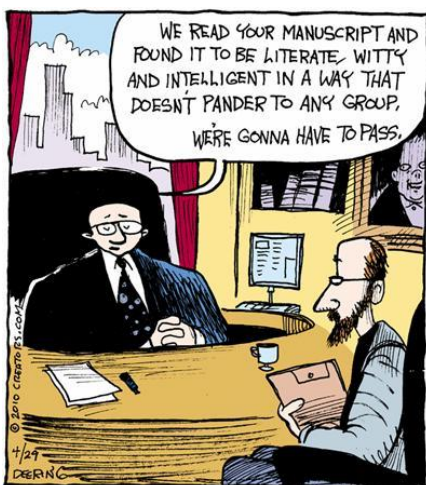
Group members not meeting expectations will receive a written evaluation outlining their disposition with the opportunity to discuss the situation. It is expected that steps to improve the

relationship with the group will be decided. If the situation doesn't improve in some agreed timeframe, the student and advisor will meet with the departmental graduate student coordinator for next steps which may involve removal from the group.



3. Financial support from any group cannot be guaranteed. Funds come from specific programs that are managed and reviewed. Continued funding is based upon: *Demonstrated Progress on project assignments, Availability of funds, and Completion of other academic responsibilities.*

It is important to realize that funding comes from people with expectations. Some of these expectations align with your thesis or publication imperatives, and some are deliverables for demonstration purposes, characterization of materials, etc. While it is important to balance these expectations with enough science to make it interesting to your degree progress, that doesn't mean that the deliverables don't have to be met. Remember, even Dirac worked on transmission lines for the phone company. This is the nature of applied research funding.



4. If you don't publish it, or patent it, or talk about it - it doesn't count. Progress in research is defined as:

- Publication of results in acceptable journals. PhD. Candidates are expected to produce 10 or more publications before graduation. 5 or more of these should be first author. Postdocs and research staff are should publish no fewer than 4 papers per year of which 2 or more should be first author. MS students should produce 4 papers 2 of which are first author.

[Publications should list funding source and the research advisor as corresponding author unless specified otherwise. Different groups have different expectations for how to publish.]

- Patenting of technology developments, which counts as a publication. In some outstanding cases, technologies developed within the lab can be patented and may lead to commercial products. Students should keep appropriate notes and testament of dates for data when working on technology related projects. Patenting is always arranged in conjunction with the research advisor.
- Presentation of results at conferences. All graduate students and postdocs are expected to present research findings at one conference per year. Only published work (or submitted work) may be presented and arrangements must be approved by the research advisor. The Lab can offer travel support for funded programs and occasionally per diems.

5. Group meetings are required and you must prepare. All groups have group meetings and members are required to attend. Group members should present progress updates at each meeting. Typically, this is one or two slides with data. Depending on the research advisor you may also be occasionally asked to provide a topical overview (a few slides) of advanced issues in your thesis area. Senior students should show significant engagement in such meetings to set a tone and example for junior members of the group



6. You should be at the lab a full week but work more than this.

Laboratory personnel are expected at the lab for 40 hours per week. The lab operates from 8:00 am until 5:00 pm Mon. – Fri. and group members should try to be at the lab during this period – at a minimum. For this time window there is time for interactions with colleagues, interaction with your advisor, completing experimental work safely, and being aware of the problems with which the group is struggling. It is not necessary to be available on weekends, holidays or after the workday, but it is typical that students and postdocs catch up on their reading, do reference searches, and do their writing on weekends and in the evenings.

- If you TA or you are taking classes, you must still make progress in your research and show up every day at the lab for some work time. A minimum of 10 hours per week research time is expected in the case of TA + classes. Otherwise, a minimum of 20 hours per week is expected.
- Six weeks of leave with financial support (if receiving such support) per year is allowed. This includes sick leave, official University holidays, national and religious holidays. Excessive,

unapproved leave, not health related, may result in a delay in graduation, or dismissal from the group.

- All leave schedules must be coordinated among other lab workers and approved by your research advisor.

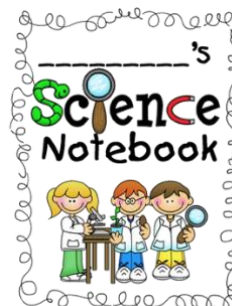


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7. No information may leave the lab. It is the policy of all research groups in the laboratory that no information pertaining to research activities, may leave the laboratory without the direct permission of the research advisor. This restriction extends to the submission of publication manuscripts, grants, white papers, or the writing of joint grants. The information and data collected by your group, including that to which you may have contributed, belongs to the group. It is *not* personal property. Data, results, experimental details, or interpretations released without the research advisor's approval, in *any form*, including: email, written, oral presentation, and conversations with anyone not associated with the research group, can result in dismissal from the lab and forfeit of financial support *from the time of disclosure*. In most cases, open interactions with collaborators and free exchange among guests is permissible but you should always check with your advisor first.

8. Lab visitors, and lab guests are for your benefit. In many groups of the N/QTL visitors and guests are hosted to create a more dynamic and productive environment. Group members are encouraged to interact with lab visitors. Be courteous, punctual, and focused in your interactions. Respond to emails and calls right away. Discuss the scientific problems they are posing and find approaches to help. Be professional. *Note: the research advisor is responsible for establishing group visits.*

9. Lab notebooks are VERY important. Each researcher should keep a single notebook for all work performed in the laboratory. Some groups inspect lab notebooks. Notebooks typically remain the property of N/QTL and are turned in when you leave the group. *For e-notebooks, copies of the files are provided.* See the notebook template in the appendix.



10. If you use the equipment and/or funding of N/QTL, you must agree to these rules. Research Faculty and Research Staff, Guests, and Postdocs are expected to abide by the rules of the N/QTL groups as fully participating group members. While it is recognized that some positions afford a greater level of independence, support from the group (salary, use of non-centralized facilities, etc.) requires that the group's head be informed and involved in ALL activities relevant to the group and its facilities. This includes writing grants, publications, guiding students, establishing collaborations, etc. This is in keeping with expectations of Wake Forest University and with accepted practices at peer institutions.

12. Graduate students should take N/QTL courses. Graduate students should take the N/QTL course sequence for nanomaterials or for QIS. This is in addition to *the requirements of the graduate school for a PhD. in Physics.*

- *For QIS this is: quantum computing, quantum architectures, and exotic/quantum materials.*
- *For Nanomaterials this is: electron microscopy, scanning probes, nanomaterials, and kinetics.*

Appendix

A. Writing a paper

- *Give referencing, excellent clear writing, and precision a top priority in each manuscript.*
- *Construct a full manuscript in the format of the target journal. This should be complete with images, references, etc. Have coworkers check English and grammar before handing it to your advisor.*
- *After your advisor has approved the manuscript, the manuscript must be then submitted to all co-authors for approval. They are to be given one week for reply. This should be explained clearly and politely in the email using the phrase “I would like to submit by (date)…”*
- *If corrections are submitted, they are to be made and the manuscript (with support information) returned to the research advisor for final approval.*
- *Submit the manuscript and inform all co-authors.*
- *When reviews are returned begin on corrections and a response immediately.*
- *After the advisor’s approval submit response to co-authors with a timeline for submission to the journal.*
- *Resubmit.*
- *The review process takes time, so be patient. Each two months that a paper has been out for review, please send a polite reminder to the editor regarding the manuscript’s status. This is YOUR responsibility.*

It is important to realize that publishing a paper represents a serious commitment to your colleagues. Remember, your colleagues and co-authors trust you to perform the steps above in a serious and professional manner.

B. Patent applications and filings (if applicable)

Patent applications must be cleared through your research advisor before WFU is approached.

C. Presentation of results at national level conferences

All members are expected to present new research results at a minimum of one professional meeting per year. To submit an abstract to a meeting, it must first be cleared through your advisor. Once accepted, YOU are responsible for arranging travel and accommodations. Generally, the lab will cover travel and lodging in some form for funded programs.

Presentations should be practiced in front of the group before you go. Posters must be approved.

D. Lab notebooks

Notebooks can be written form or electronic. Keeping an electronic version of your lab notes requires that you regularly reduce those notes to .pdf format with time and date stamps for that file reduction. The pdfs should then match the format written notes and be stored where they are accessible and transferable.

Your notes should have an identifier that includes:

- Your name.
- The laboratory name “N/QTL, XXXX Group”.
- The department address
- Your phone number and email address
- The date you started in the laboratory.

Your laboratory notebook should contain a credible record of everything you have done. This is your documentation of your data and should be complete.

- It should show the time and date you started any experiment.
- When any experiment is interrupted or stopped you should have a sentence explaining the situation and the reason as well as the time.
- You should do the same thing when you leave the lab for the day.

As a working record of work and everything written should be indelible or electronic pdf. Notes should occur sequentially in time and date, making it difficult to *insert* after the fact. Fill in every page. If you want to start a new page for any reason, put an X through the blank region. Initial all *post facto* corrections, leave them where anyone can see a correction was made, no matter what the format. While many tape/add figures, diagrams, or sections of relevant articles into the lab book, lab books and data sets are typically separate and some reference system should be constructed between the two. The lab notes should allow anyone to understand what you did.

Information that should be included in your laboratory notebook:

- Objectives
- Questions
- References to publications, or part of an article itself
- Drawings of apparatus, circuit diagrams
- Data
- Calculations
- Graphs
- Interpretations
- Conclusions
- New ideas.
- Experimental Improvements

END