Student Checklist (1A)

This form is required for ALL projects.

1. a. Student/Team Leader: Derek Chen Grade: 11

   Email: derekchen02@gmail.com Phone: 516-353-0927

   b. Team Member: ——— c. Team Member: ———

2. Title of Project:

   Simulating Nanoscale Imaging of Plasmonic Excitations and Cancer Cells under Near-Field Nanoscopy

3. School: Herricks High School School Phone: 516-305-8700

   School Address: 100 Shelter Rock Road, New Hyde Park, NY 11040

4. Adult Sponsor: Renee Barcia Phone/Email: r.barcia@gmail.com

5. Does this project need SRC/IRB/IACUC or other pre-approval? ☐ Yes ☒ No Tentative start date: ———

6. Is this a continuation/progression from a previous year? ☐ Yes (☐ No)

   If Yes:

   a. Attach the previous year's ☐ Abstract and ☐ Research Plan/Project Summary

   b. Explain how this project is new and different from previous years on

   ☐ Continuation/Research Progression Form (7)

7. This year's laboratory experiment/data collection:

   06/27/19 Actual Start Date: (mm/dd/yy) 10/01/19 End Date: (mm/dd/yy)

8. Where will you conduct your experimentation? (check all that apply)

   (☐ Research Institution) ☐ School ☐ Field (☐ Home) ☐ Other: ———

9. List name and address of all non-home and non-school work site(s):

   Name: Stony Brook University

   Address: 100 Nicolls Road, Stony Brook, NY 11794

   Phone/email: 631-632-6000

10. Complete a Research Plan/Project Summary following the Research Plan/Project Summary instructions and attach to this form.

11. An abstract is required for all projects after experimentation.

Research Plan/Project Summary Instructions

A complete Research Plan/Project Summary is required for ALL projects and must accompany Student Checklist (1A).

1. All projects must have a Research Plan/Project Summary
   a. Written prior to experimentation following the instructions below to detail the rationale, research question(s), methodology, and risk assessment of the proposed research.
   b. If changes are made during the research, such changes can be added to the original research plan as an addendum, recognizing that some changes may require returning to the IRB or SRC for appropriate review and approvals. If no additional approvals are required, this addendum serves as a project summary to explain research that was conducted.
   c. If no changes are made from the original research plan, no project summary is required.

2. Some studies, such as an engineering design or mathematics projects, will be less detailed in the initial project plan and will change through the course of research. If such changes occur, a project summary that explains what was done is required and can be appended to the original research plan.

3. The Research Plan/Project Summary should include the following:
   a. RATIONALE: Include a brief synopsis of the background that supports your research problem and explain why this research is important and if applicable, explain any societal impact of your research.
   b. RESEARCH QUESTION(S), HYPOTHESIS(ES), ENGINEERING GOAL(S), EXPECTED OUTCOMES: How is this based on the rationale described above?
   c. Describe the following in detail:
      - Procedures: Detail all procedures and experimental design including methods for data collection. Describe only your project. Do not include work done by mentor or others.
      - Risk and Safety: Identify any potential risks and safety precautions needed.
      - Data Analysis: Describe the procedures you will use to analyze the data/results.
   d. BIBLIOGRAPHY: List major references (e.g. science journal articles, books, internet sites) from your literature review. If you plan to use vertebrate animals, one of these references must be an animal care reference.

Items 1–4 below are subject-specific guidelines for additional items to be included in your research plan/project summary as applicable.

1. Human participants research:
   a. Participants: Describe age range, gender, racial/ethnic composition of participants. Identify vulnerable populations (minors, pregnant women, prisoners, mentally disabled or economically disadvantaged).
   b. Recruitment: Where will you find your participants? How will they be invited to participate?
   c. Methods: What will participants be asked to do? Will you use any surveys, questionnaires or tests? If yes and not your own, how did you obtain? Did it require permissions? If so, explain. What is the frequency and length of time involved for each subject?
   d. Risk Assessment: What are the risks or potential discomforts (physical, psychological, time involved, social, legal, etc.) to participants? How will you minimize risks? List any benefits to society or participants.
   e. Protection of Privacy: Will identifiable information (e.g., names, telephone numbers, birth dates, email addresses) be collected? Will data be confidential/anonymous? If anonymous, describe how the data will be collected. If not anonymous, what procedures are in place for safeguarding confidentiality? Where will data be stored? Who will have access to the data? What will you do with the data after the study?
   f. Informed Consent Process: Describe how you will inform participants about the purpose of the study, what they will be asked to do, that their participation is voluntary and they have the right to stop at any time.

2. Vertebrate animal research:
   a. Discuss potential ALTERNATIVES to vertebrate animal use and present justification for use of vertebrates.
   b. Explain potential impact or contribution of this research.
   c. Detail all procedures to be used, including methods used to minimize potential discomfort, distress, pain and injury to the animals and detailed chemical concentrations and drug dosages.
   d. Detail animal numbers, species, strain, sex, age, source, etc., include justification of the numbers planned.
   e. Describe housing and oversight of daily care
   f. Discuss disposition of the animals at the termination of the study.

3. Potentially hazardous biological agents research:
   a. Give source of the organism and describe BSL assessment process and BSL determination.
   b. Detail safety precautions and discuss methods of disposal.

4. Hazardous chemicals, activities & devices:
   - Describe Risk Assessment process, supervision, safety precautions and methods of disposal.
   - Material Safety Data Sheets are not necessary to submit with paperwork.

Derek Chen
Research Plan

Title: **Simulating Nanoscale Imaging of Plasmonic Excitations and Cancer Cells under Near-field Nanoscopy**

A. Rationale

Modern nanoimaging within the terahertz (THz) frequency range provide novel possibilities in imaging a variety of samples and phenomena [1], from cancer cells [2,3,4,5] to plasmonic modes and polaritonic excitations [1,6,7,8,9,10]. This is due to the low photon energy within the THz regime, which makes it applicable to biological samples which may be otherwise damaged by high-energy imaging methods [1,3]; moreover, THz imaging has been shown to be able to provide higher optical contrast and resolution in comparison to high-energy imaging methods [3]. In addition to this, THz imaging has been used with novel near-field imaging methods, such as scattering-type scanning near-field optical microscopy (s-SNOM), has been critical for the study of various materials, including strongly correlated quantum materials (SCQMs) [1, 11]. s-SNOM has been shown to be capable of spatial resolution down to 10 nm, and has been applied to the direct imaging of materials such as gold and hexagonal boron nitride [1,6,7,8,9,10]. Under s-SNOM, a probe is placed close to the surface of a sample, linking the optical properties of the sample to the probe; this thus allows for the propagation of a near-field signal, which cannot be measured through conventional optics [1]. s-SNOM, used in conjunction with THz imaging, shows promise for applications in fields ranging from the biomedical field to the field of condensed matter physics [1]. Developing accurate models for s-SNOM is thus critical for verifying experimental results; this is particularly true within the THz regime, in which high signal-to-noise ratios currently hinder experimental capabilities [1]. Accurate models are thus necessary for providing quantitative interpretation and validation of experimental results [1].

Modeling THz imaging with the usage of s-SNOM is of particular interest for cancer diagnosis, as cancer diagnosis relies on optical contrasts in imaging [3]. 25% of deaths within the United States can be attributed to cancer; to address this death rate, effective and efficient treatment necessary, which is in turn dependent on effective and efficient diagnosis, which in turn depends on precise imaging of cancer cells [3]. A possible THz probe for cancer diagnosis would address this issue due to its precision in imaging, while also being non-invasive [3]; in order to attain such a probe, accurate modeling of s-SNOM imaging in the THz range, especially with regards to cancer cells, is necessary.

B. Objectives

Research Question(s): How can s-SNOM be modeled analytically in the THz regime?

This study has several aims:

1) to create an accurate simulation method for s-SNOM microscopy and spectroscopy

2) to demonstrate the applicability of s-SNOM, especially in the THz regime, for a variety of applications, including in physics and in cancer cell imaging, through the usage of simulation. This would include the usage of this simulation method for plasmonic and polaritonic modes, as well as in the simulation of optical contrasts between normal and cancerous human cells.

The creation of an accurate and applicable simulation method would ultimately provide a method for providing more accurate verification of experimental and future results for s-SNOM and THz imaging, which could lead to novel methods for imaging materials, as well as novel methods for cancer diagnosis, such as possible probes relying on the principles of s-SNOM and THz imaging.

C. Procedures:

The semi-analytical discrete dipole approximation (DDA) [15,16,17] will be used to simulate various systems, including plasmonic modes in gold [9,10], polaritonic modes in hBN [7,8], and optical contrasts between normal and cancerous human cells [4,5]. Under the DDA, the tip-sample system of s-SNOM will be approximated using interacting dipoles [16,17,18], and has been previously applied to the study of evanescent waves with atomic force microscopy (AFM) [19] as well as near-field microscopy using total internal reflection [20]; however, the application of this simulation method to s-SNOM, particularly in the THz regime, has not yet been achieved.

The DDA will be adapted from existing Python source code [21] for s-SNOM and THz imaging. In order to do this, the source code will be adapted to create loops to sweep over spatial position; in addition to this, the source code will be adapted to create various sample and tip geometries, such as circular and triangular samples.

Risk and safety: No potential risks are applicable for this project.

Data analysis: Simulations produced will be compared against existing analytical, numerical, and experimental results for s-SNOM and THz. Spectroscopy simulations will be graphed against previous spectroscopy results [12,13], while microscopy simulations will be compared against previous analytical results [4,5,6,7,8,9,10].

References

[1] Chen, X., Hu, D., Mescall, R., You, G., Basov, D. N., Dai, Q., & Liu, M. (2019). Modern Scattering-Type Scanning Near-Field Optical Microscopy for Advanced Material Research [PDF]. *Advanced Materials*.

[2] Yang, X., Zhao, X., Yang, K., Liu, Y., Liu, Y., Fu, W., & Luo, Y. (2016). Biomedical Applications of Terahertz Spectroscopy and Imaging [PDF]. *Trends in Biotechnology*. https://doi.org/10.1016/j.tibtech.2016.04.008

[3] Yu, C., Fan, S., Sun, Y., & Pickwell-MacPherson, E. (2012). The potential of terahertz imaging for cancer diagnosis: A review of investigations to date [PDF]. *Quantitative Imaging in Medicine and Surgery*. https://doi.org/10.3978/j.issn.2223-4292.2012.01.04

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[12] Chen, X., Fan Bowen Lo, C., Zheng, W., Hu, H., Dai, Q., & Liu, M. (2017). Rigorous numerical modeling of scattering-type scanning near-field optical microscopy and spectroscopy [PDF]. *Applied Physics Letters*. https://doi.org/10.1063/1.5008663

[13] Cvitkovic, A., Ocelic, N., & Hillenbrand, R. (2007). Analytical model for quantitative prediction of material contrasts in scattering-type near-field optical microscopy. *Optics Express*. https://doi.org/10.1364/OE.15.008550

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[17] Draine, B. T., & Flatau, P. J. (1994). Discrete-dipole approximation for scattering calculations. *Journal of the Optical Society of America A*.

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1. Human participants research: Not applicable
2. Vertebrate animal research: Not applicable
3. Potentially hazardous biological agents research: Not applicable
4. Hazardous chemicals, activities & devices: Not applicable

NO ADDENDUMS EXIST