PHY 694: Plasma and Wakefield Accelerators, Spring 2022

Date of this version of the Syllabus: 1/17/2022

Course Description:

This course provides an introduction to the physics of laser-driven and beam-driven plasma wakefield accelerators. Topics include the description of the motion of a single particle in the fields of a laser or relativistic particle beam, coupling of intense drivers to plasma waves, description of linear and nonlinear plasma waves in 1D and 3D, injection of particles into plasma waves and beam loading, as well as other advanced topics such as the directions of present research as time permits. In addition to the theoretical concepts, the students will also be introduced to the computational and experimental tools used to explore the relevant physical phenomena.

1-3 credits, Letter graded (A, A-, B+, etc.)

Class Meeting Times: Tuesday/Thursdays 3:00-4:20 PM in Earth and Space Sciences Building, Room 117

Course Instructor: Navid Vafaei-Najafabadi,
e-mail (For private communication, Reply in 24-48 hours):
navid.vafaei-najafabadi@stonybrook.edu
Office: Physics D101
Office hours (preferred method of contact): Wednesday 2-4 pm

Course Material:

Class Notes: Class notes on each topic will be posted on Blackboard ahead of the class.

Topics & Approximate Timeline:

The focus of the class will be on the study of coupling high-energy-density sources (i.e. laser and particle beams) to plasma and how the resulting fields can be used to accelerate particles. The topics and the approximate time devoted to each during the semester is as follows:

1. Single particle motion in fields of intense laser and particle beams (2.5 weeks)
2. Introduction to plasma and fluid equations in plasma (2 weeks)
3. Nonlinear plasma waves in 1D and 3D (2 weeks)
4. Plasma wake excitation by laser and particle beams (2.5 weeks)
5. Electron trapping conditions and mechanisms (1.5 week)
6. Beam loading and emittance preservation (1.5 weeks)
7. Paraxial wave solutions in vacuum and ponderomotive guiding center approximation (2 weeks)
8. Status of experiments in LWFA and PWFA (1 week)

Learning Objectives:

Upon completing this course, students will be able to

- Predict the motion of a charged particle inside the fields of an intense laser or e-beam
- Explain the physical interpretation of Vlasov equation and plasma fluid equations
- Summarize & explain the properties of the fields in nonlinear plasma waves
- Predict the properties of a plasma wave excited by a particular laser or beam
- Identify trapping conditions to determine whether a particular situation would lead to particle trapping
- Describe examples of trapping mechanism in plasma waves
- Explain the pondermotive guiding center approximation
- Describe the status of the LWFA and PWFA research

Grade Breakdown:

Homework: 40%

Homework will contain problem sets that will be posted on Friday and will be due by the end of the day on the next Friday.

Project: 35%

Each student will select a topic related to the physics of laser- or plasma-driven wakefield acceleration and conduct a numerical "experiment" using PIC simulation tools. Results should be presented in a short report and a recorded presentation. Students are expected to have project topics selected by week 10. Project presentation and reports are due by the last day of class, **May 5, 2022**.

Take-Home Final: 25 %

Scheduled on **Tuesday, May 10th**

Final exam questions will be posted at midnight on May 10th and will be due by the end of the day

Attendance Policy:

While attendance is strongly encouraged, no class assessment depends on it. In the event that students are not able to attend the class in person, links to Zoom recording will allow the students to stay current with material taught in class. Please don't risk the health of your fellow classmates by coming to the class ill.

How to Succeed in this Course:

- Complete all assigned work in the course
- Participate in lecture discussions
- Attend office hours with questions and topics of discussion

Notes on Homework:

Homework problems will be posted on Blackboard on Friday. The usual deadline would be the following Friday.

Rules Regarding Homework:

- You may collaborate with your classmates on the homework if you are contributing to the solution. You must personally write up the solution of all problems.
- You may (and are encouraged to) use the library and all available resources to help solve the problems. Use of Mathematica, other software tools and spreadsheets are encouraged.
- Late homework: Homework is accepted until the end of the Monday class, but will incur a 20% penalty after 9 am. Homework delivered to my office (D101 Physics) before 9 am on the Monday following a deadline is considered on time.

Course Delivery Mode and Structure

This is an ***in-person*** *course. The class meets* ***Tuesdays and Thursdays from 3:00PM - 4:20PM*** *in* ***Earth and Space Sciences Building, Room 117****.* The class recording will be shared on Blackboard. All assignments and course interactions will utilize internet technologies. In Blackboard, you will access online lessons, course materials, and resources.

How We Will Communicate:

Office hours are the primary time intended for us to discuss course-related issues. If you cannot make the office hours, e-mail me for a separate appointment. For personal/private issues, email me directly. If you use Blackboard's **email tool** from the course site, it will automatically include your full name, course name and section when you send me an email. **Please allow between 24-48 hours for an email reply.** Your Stony Brook University email must be used for all University-related communications. You must have an active Stony Brook University email account and access to the Internet. All instructor correspondence will be sent to your SBU email account. **Plan on checking your SBU email account regularly for course-related messages.** To log in to Stony Brook Google Mail, go to http://www.stonybrook.edu/mycloud and sign in with your NetID and password.
Regular announcements will be sent from Blackboard. These will be posted in the course site and may or may not be sent by email.

Technical Requirements:

This course uses Blackboard for the facilitation of communications between faculty and students, submission of assignments, and posting of grades and feedback. The Blackboard course site can be accessed at https://blackboard.stonybrook.edu
If you are unsure of your NetID, visit https://it.stonybrook.edu/help/kb/finding-your-netid-and-password for more information. You are responsible for having a reliable computer and Internet connection throughout the term. **Caution!** You will be at a disadvantage if you attempt to complete all coursework on a smart phone or tablet. It may not be possible to submit the files required for your homework assignments.

This class will also use simulation code QuickPIC. This code is freely available, but students will need access to a personal computer to install and use this code.

Academic Resources:

Posting and Updating of This Syllabus:

This Syllabus will be posted on Blackboard. When, from time to time, it may be updated, all students will be notified by an Announcement posted in Blackboard and sent via email to your official University email address. Please make sure you're looking at the most recent version: Check the first page of each one to see the date of the version you're looking at!

Ombuds Office:

The Stony Brook University Ombuds Office provides an alternative channel for confidential, impartial, independent and informal dispute resolution services for the entire University community. We provide a safe place to voice your concerns and explore options for productive conflict management and resolution. The Ombuds Office is a source of confidential advice and information about University policies and procedures and helps individuals and groups address university-related conflicts and concerns. http://www.stonybrook.edu/ombuds/

University Services

Amazon @ Stony Brook: Order your books before classes begin. Phone: 631-632-9828; email: Bookstore_Liaison@stonybrook.edu; website: http://www.stonybrook.edu/ bookstore/

Bursar: For help with billing and payment. Phone: 631-632-9316; email: bursar@stonybrook.edu; website: http://www.stonybrook.edu/bursar/

Registrar: Having a registration issue? Let them know. Phone: 631-632-6175; email: registrar_office@stonybrook.edu; http://www.stonybrook.edu/registrar/
SBU Libraries: access to and help in using databases, ebooks, and other sources for your research.

- Research Guides and Tutorials: http://guides.library.stonybrook.edu/
- Getting Help: https://library.stonybrook.edu/research/ask-a-librarian/

Support for Online Learning: https://www.stonybrook.edu/online/

University Policies

Student Accessibility Support Center (SASC) Statement:

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, 128 ECC Building, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential.
Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the Student Accessibility Support Center. For procedures and information go to the following website: https://ehs.stonybrook.edu/programs/fire-safety/emergency-

evacuation/evacuation-guide-people-physical-disabilities and search Fire Safety and Evacuation and Disabilities.

Academic Integrity Statement:

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at http://www.stonybrook.edu/commcms/academic_integrity/index.html

Important Note: Any form of academic dishonesty, including cheating and plagiarism, will be reported to the Academic Judiciary.

Latest Covid Guidance:

Visit the "Stronger Together" website for the latest covid guidance:
https://www.stonybrook.edu/commcms/strongertogether/latest.php
Everyone must comply with this guidance. As of August 3, we are required to wear face coverings while inside campus buildings regardless of our vaccination status. This policy will be last until at least Tuesday, September 7, when further guidance is expected.

Critical Incident Management Statement:

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Judicial Affairs any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures.

Regarding Equivalent Opportunity/Religious Absences:

https://www.stonybrook.edu/sb/bulletin/current/policiesandregulations/policies_expectations/equivopportunity_religiousabsences.php

Student Participation in University-Sponsored Activities:

By their participation in campus-related activities such as research conferences, dramatic or musical performances, intercollegiate athletic competitions, or leadership meetings, students make contributions to the University. In recognition of the students' commitment both to their regular academic programs and to related activities, the University makes every effort to accommodate unique situations.

Students are responsible for presenting a printed copy of semester obligations to all their professors at the beginning of the semester to alert them to activities that may present conflicts. Instructors are required to make arrangements for students to complete

examinations, quizzes, or class assignments early or late if the student's participation in a University-related activity results in the student's absence from the class when such work is due. Some events occur only by invitation during the semester, and instructors should make accommodations for these students.

Minimal instructional and student responsibilities:

www.stonybrook.edu/sb/bulletin/current/policiesandregulations/policies_expectations/

Understand When You May Drop This Course:

It is the student's responsibility to understand when they need to consider withdrawing from a course. Refer to the Stony Brook Academic Schedule for dates and deadlines for registration: http://www.stonybrook.edu/commcms/registrar/calendars/academic_calendars.

- Undergraduate Course Load and Course Withdrawal Policy
- Graduate Course Changes Policy

Incomplete Policy:

Under emergency/special circumstances, students may petition for an incomplete grade. Circumstances must be documented and significant enough to merit an incomplete. If you need to request an incomplete for this course, contact me for approval as far in advance as possible.

Course Materials and Copyright Statement:

Course material accessed from Blackboard, SB Connect, SB Capture or a Stony Brook Course website is for the exclusive use of students who are currently enrolled in the course. Content from these systems cannot be reused or distributed without written permission of the instructor and/or the copyright holder. Duplication of materials protected by copyright, without permission of the copyright holder is a violation of the Federal copyright law, as well as a violation of Stony Brook's Academic Integrity.

Online Communication Guidelines and Learning Resources:

Maintain professional conduct both in the classroom and online. The classroom is a professional environment where academic debate and learning take place. I will make every effort to make this environment safe for you to share your opinions, ideas, and beliefs. In return, you are expected to respect the opinions, ideas, and beliefs of other students—both in the face-to-face classroom and online communication. Students have the right and privilege to learn in the class, free from harassment and disruption. The course follows the standards set in the Student Code of Conduct, and students are subject to disciplinary action for violation of that code. If your behavior does not follow the course etiquette standards stated below, the grade you receive for a posting may suffer. I reserve the right to remove any discussion messages that display inappropriate language or content.

Online Etiquette:

- Offensive language or rudeness will not be tolerated. Discuss ideas, not the person.
- Avoid cluttering your messages with excessive emphasis (stars, arrows, exclamations).

- If you are responding to a message, include the relevant part of the original message in your reply, or refer to the original post to avoid confusion;
- Be specific and clear, especially when asking questions.
- Use standard punctuation and capitalization. Using all UPPERCASE characters gives the appearance of shouting and makes the message less legible;
- Remember that not all readers have English as their native language, so make allowances for possible misunderstandings and unintended discourtesies.