

Introduction to the Introduction to Fusion Energy and Plasma Physics Course



PRINCETON
PLASMA PHYSICS
LABORATORY

Arturo Dominguez

Head of the Science
Education Department

First, a bit about myself

- From Bogotá, Colombia
- Started studying physics at the National University of Colombia at Bogota.
- Transferred to University of Texas at Austin where I finished undergrad (HOOK'EM HORNS!)



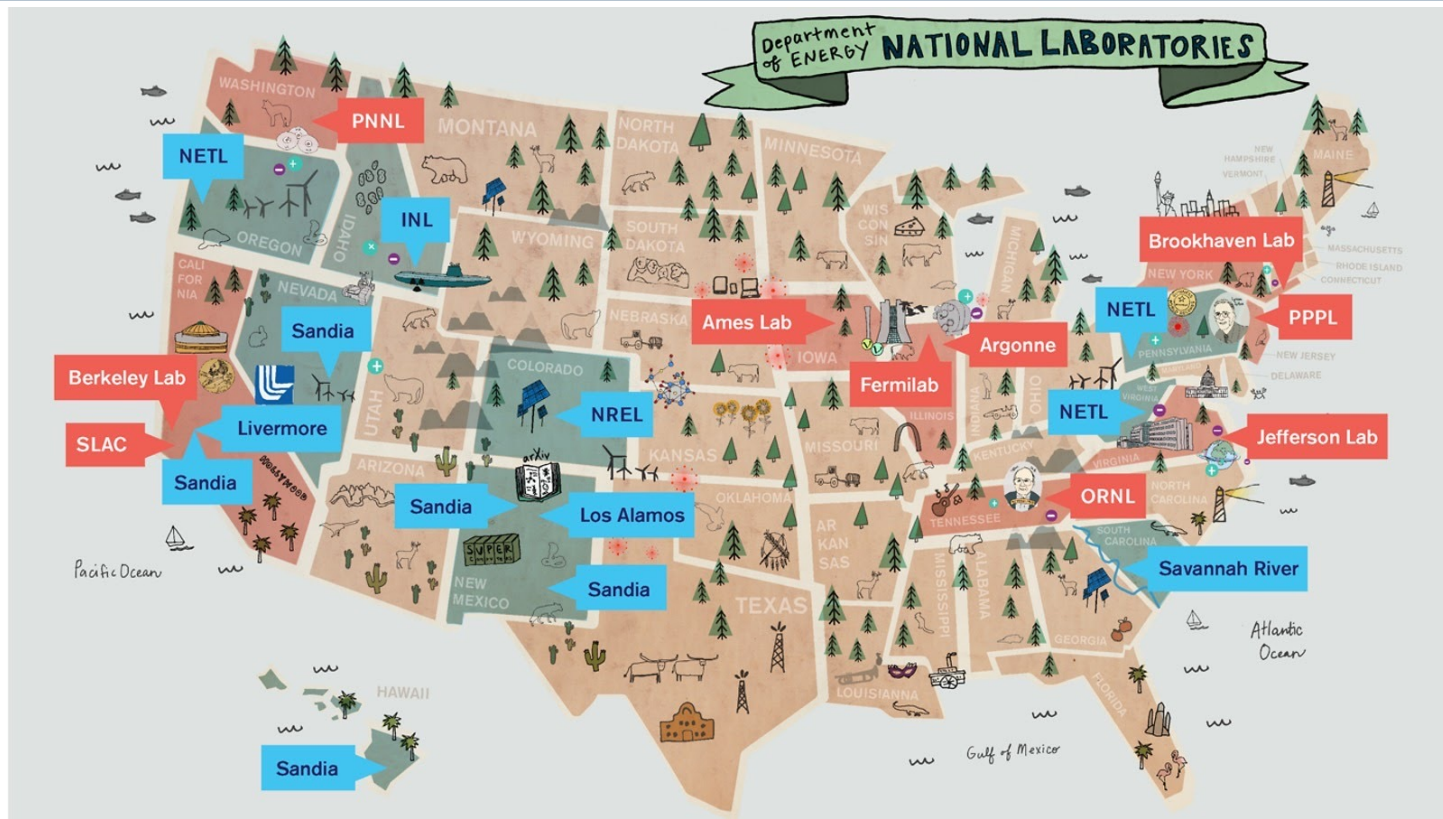
- Did my graduate work at MIT, in Boston on **fusion plasmas** (GO BEAVERS!)



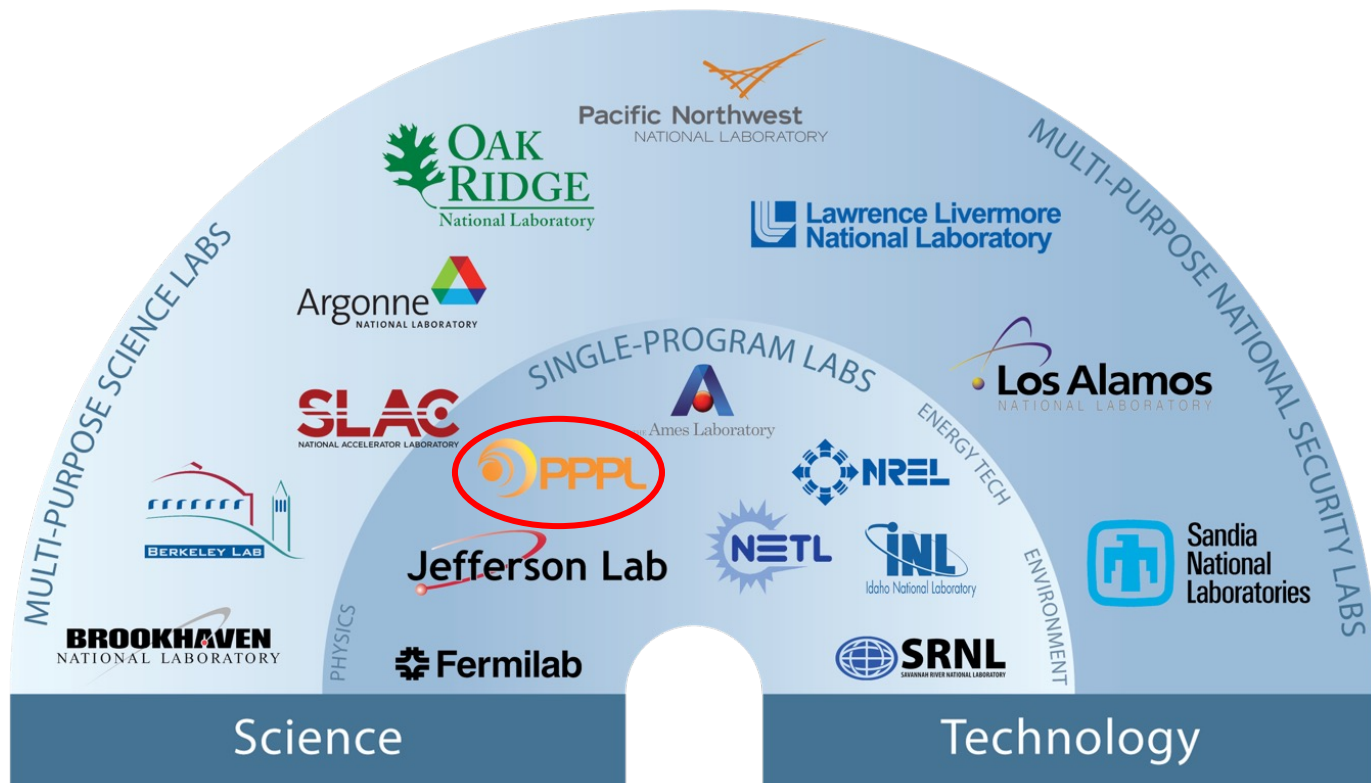
- Now I'm at the Princeton Plasma Physics Lab (GO TIGERS!)



PPPL is one of 17 Department of Energy national laboratories



PPPL is one of 17 Department of Energy national laboratories





- ~650 employees
- 19 faculty (Princeton)
- ~22 post-docs
- ~40 grad students
- Operated by Princeton U.





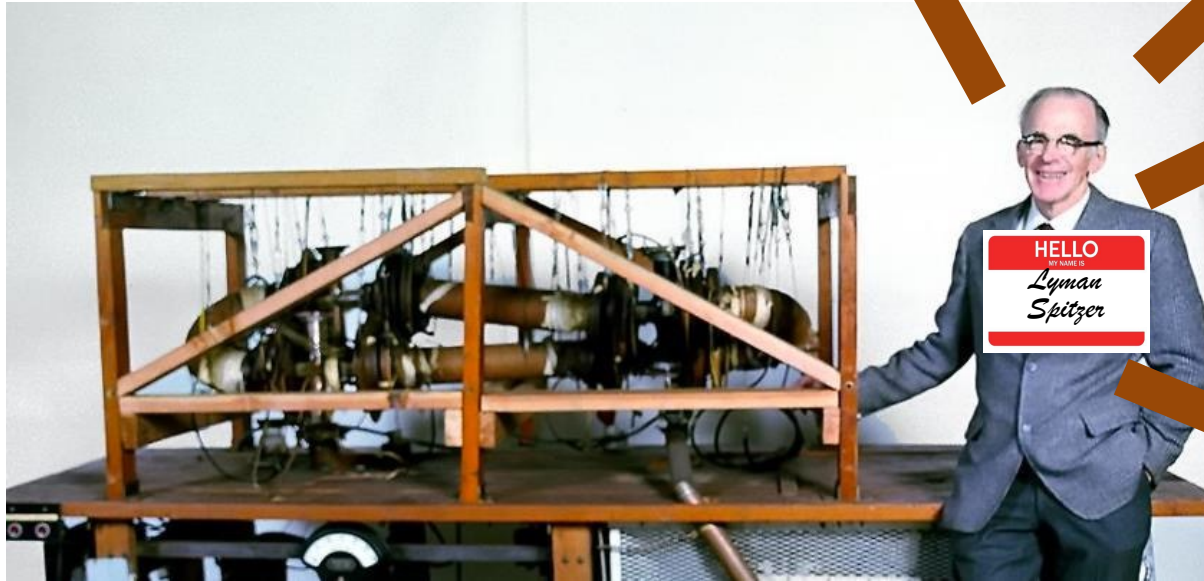
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Lyman Spitzer started PPPL (originally Project Matterhorn) in 1951...Birthplace of US fusion

Inventor of the Stellarator

Founder of the lab



Made countless advances in plasma physics (his name is everywhere)

Proposed telescopes in outer space (hence the Spitzer Space Telescope)

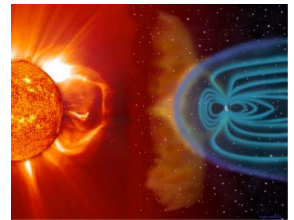
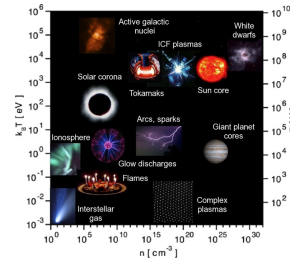
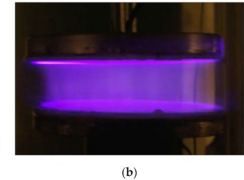
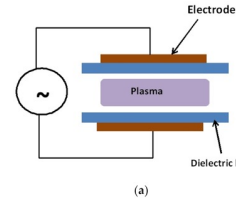
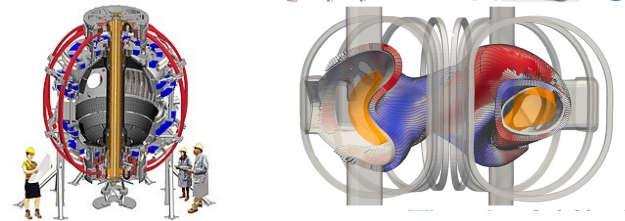
PPPL's mission goes beyond fusion

The Laboratory has three major missions:

1.Fusion: To develop the scientific knowledge and advanced engineering to enable fusion to power the U.S. and the world

2.Plasma Manufacturing: To advance the science of nanoscale fabrication for industries of the future

3.Frontiers of Plasmas: To further the scientific understanding of plasmas from nano- to astrophysical-scales



History of the Intro to Fusion/Plasma Course

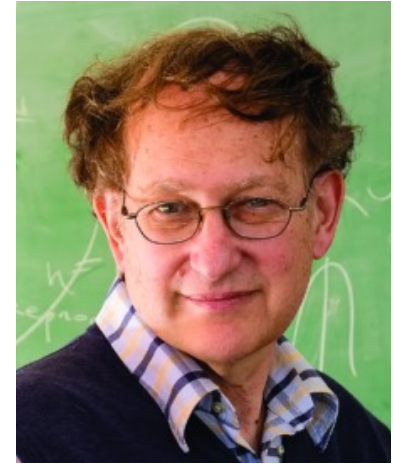
- Originally started in 1992 by Prof. Nat Fisch and former assistant director (and former congressman) Rush Holt, as part of the National Undergraduate Fellowship (NUF).



1994 NUF class



Rush Holt



Nat Fisch

Changes during the pandemic

- Fully Remote
- 2 weeks long, but 4.5 hours a day
- Shorter talks (50+10 minutes, vs. 90 minutes)
- Many more talks (25 speakers vs. 15 in the past)!
- Many more participants!
- Broader scope, covering the full spectrum of topics under the Fusion Energy Sciences and Plasma Physics umbrella

All lectures are free to watch and will be posted

- All lectures will be streamed via Zoom Webinar. No registration is needed.
- Enrollees, i.e. those who filled out the google form on the site and **which we could fit**, will have a Zoom-Brady-Bunch-Square, will get priority for questions, join the hallway discussions, and will join the networking events.
- Webinar participants can ask questions using the ask/chat feature.
- ALL written questions should be directed at the hosts and we will hold them for the Q/A portion.
- As has been done since 2015, the course lectures and the speaker videos will be posted on [the site](#).

Eastern Time	Day 1 (6/13/22)
12:00 PM	Introduction to the Course  <i>Dominguez</i>

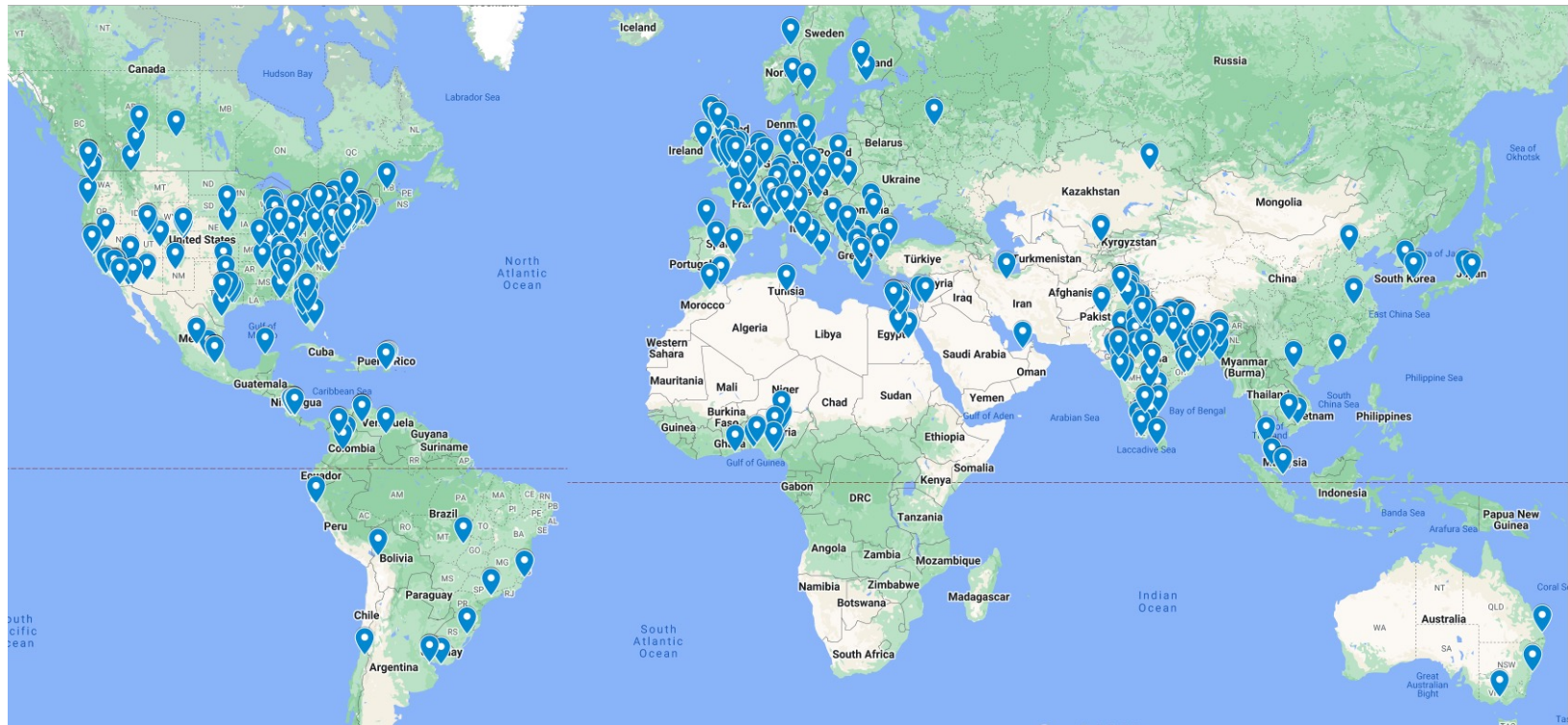
Link to slides

Link to video

We had way more submissions than we could handle!

- For the second year in a row, we got almost 1000 submissions to register for the course
- Submissions included undergraduate students, grad students, postdocs, researchers, engineers, professors, non-STEM fusioners and general public.
- Because of technical limitations, we could only **enroll** ~300 participants so priority has been given to undergraduates conducting fusion/plasma research.

Y'all are all over the world!



A birds-eye view of the undergrads

Undergraduate enrollees are based in the US and in many other countries, including: Mexico, India, Nigeria, Colombia, LUXEMBOURG, UK, and many more!

Many enrollees are conducting internships/summer research.
Some of the programs are:

- Science Undergraduate Laboratory Internship Program (SULI) and Community College Internship (CCI), run by DOE.
- Students doing internships at their own colleges
- Private companies developing fusion
- Plasma and Fusion Undergraduate Research Opportunities (PFURO) program



2021 Intro course participants

WHAT TO EXPECT IN THE NEXT COUPLE OF WEEKS

Today (6/5) we'll frame the science and regulatory challenges of fusion energy

Eastern Time	Day 1 (6/5/23)
12:00 PM	Introduction to the Course <i>Dominguez</i>
12:45 PM	Introduction to Fusion <i>Parra Diaz</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Fusion Regulatory Framework <i>Desai</i>
4:00 PM	Adjourn



- After this intro, Prof. Felix Parra-Diaz (PPPL) will present the promise and challenges of fusion energy
- Sachin Desai J.D. (Helion Energy), will introduce the regulatory challenges faced by the fusion ecosystem as it moves towards building fusion power plants

Tomorrow (6/6) we Introduce Plasmas

Eastern Time	Day 2 (6/6/23)
12:00 PM	Introduction to Plasma Physics I <i>Duarte</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Introduction to Plasma Physics II <i>Sinha</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Plasmas as a Fluid <i>Thakur</i>
4:00 PM	Adjourn



- Dr. Vinicius Duarte (PPPL) will introduce plasmas and describe their characteristic.
- Dr. Priyanjana Sinha (PPPL) will continue with the introduction of plasmas from a single-particle perspective.
- Prof. Saikat Chakraborty Thakur (Auburn) will introduce the fluid model of plasmas which is useful for describing macroscopic behaviors.

On Wednesday (6/7) we finish the plasma intro start inertial confinement fusion.

Eastern Time	Day 3 (6/7/23)
12:00 PM	Plasma Waves <i>Nelson</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Plasma Turbulence <i>Avdeeva</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Introduction to Inertial Confinement Fusion <i>Malko</i>
4:00 PM	Adjourn



- Dr. Oak Nelson (Columbia) will describe a ubiquitous plasma phenomenon, plasma waves.



- Dr. Galina Avdeeva (GA) will discuss how turbulence arises in plasma systems and its physics



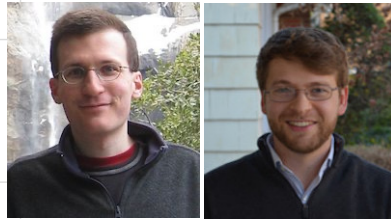
- Dr. Sophia Malko (PPPL) will introduce inertial confinement fusion and its challenges.

Thursday (6/8) we talk about a major fusion milestone recently reached...and Python

Eastern Time	Day 4 (6/8/23)
12:00 PM	Ignition <i>Kritcher</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Computational Workshop <i>Nick Murphy & Peter Heuer</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Computational Workshop <i>Nick Murphy & Peter Heuer</i>
4:00 PM	Adjourn



PlasmaPy



- Dr. Annie Kritcher (LLNL) will present on the major milestone reached by the National Ignition Facility.
- Dr. Nick Murphy (Harvard Smithsonian CFA) and Dr. Peter Heuer (LLE) will lead an interactive computational plasma physics using tools from the PlasmaPy Python package.

Friday (6/9) we will concentrate on plasmas....in space!

Eastern Time	Day 5 (6/9/23)
12:00 PM	Plasmas in the Solar System <i>Niembro Hernández</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Astrophysical Plasmas in the Lab <i>Hare</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Networking session
4:00 PM	Adjourn



- Prof. Jan Egedal (Wisconsin) will discuss magnetic reconnection, ubiquitous in astrophysical plasmas
- Dr. Yeimy Rivera (Harvard Smithsonian CFA) will touch upon plasmas within the solar system.
- Prof. Weichao Tu (West Virginia) will relate basic plasma physics concepts to the plasmas of the Van Allen belts

Friday (6/9) will also feature the first networking session

Eastern Time	Day 5 (6/9/23)
12:00 PM	Plasmas in the Solar System <i>Niembro Hernández</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Astrophysical Plasmas in the Lab <i>Hare</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Networking session
4:00 PM	Adjourn

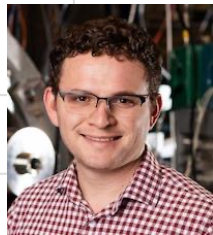
- Day 5 will also feature the first of two network sessions in which the group will be divided into groups of ~10-20 and will meet with current graduate students in the field. This is a space to ask questions about grad schools, the grad experience, the field, etc.

| Saturday and Sunday, we rest






On Day 6 (6/12) we focus on magnetic and alternate configurations

Eastern Time	Day 6 (6/12/22)
12:00 PM	Stellarators <i>Paul</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Tokamaks <i>Moser</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Alternate Configurations <i>Sutherland</i>
4:00 PM	Adjourn






- Prof. Elizabeth Paul (Columbia) will introduce the Stellarator (near and dear to PPPL's heart)
- Dr. Auna Moser (GA) will talk about the other leading magnetic approach, the Tokamak.
- Dr. Derek Sutherland (Zap Energy) will present on the innovative alternative fusion approaches that haven't been discussed yet.

On Day 7 (6/13) we describe a major international collaboration (ITER), nuclear materials, and blankets

Eastern Time	Day 7 (6/13/22)	
12:00 PM	ITER <i>Loarte</i>	
1:00 PM	Break/Hallway Discussion	
1:30 PM	Nuclear Materials <i>Dennett</i>	
2:30 PM	Break/Hallway Discussion	
3:00 PM	Blankets and Fuel Cycle <i>Ferry</i>	
4:00 PM	Adjourn	

- Dr. Alberto Loarte (ITER) will present on ITER, a major international MFE collaboration.
- Dr. Cody Dennett (CFS) will tackle one of the major fusion challenges, the structural materials.
- Dr. Sara Ferry (MIT-PSFC) will make the connection from energetic neutrons to electricity by describing the blankets and its challenges.

On Day 8 (6/14) we tackle heat removal and dive into low temperature plasmas




Eastern Time	Day 8 (6/14/22)	
12:00 PM	Heat Removal for First Walls <i>Carasik</i>	
1:00 PM	Break/Hallway Discussion	
1:30 PM	Intro to Low Temperature Plasmas <i>Simeni Simeni</i>	
2:30 PM	Break/Hallway Discussion	
3:00 PM	Dusty Plasmas <i>Jaiswal</i>	
4:00 PM	Networking Session / Adjourn	

- Prof. Lane Carasik (Virginia Commonwealth U) will discuss a major engineering challenge for fusion devices: Heat removal from the walls.
- Changing topics, Prof. Marien Simeni Simeni (U. of Minnesota) will introduce low temperature plasmas and their applications.
- Prof. Surabhi Jaiswal (E. Michigan U) will present on the complex and ubiquitous systems that are dusty plasmas.

On Day 8 (6/14) we'll have the second networking session too

Eastern Time	Day 8 (6/14/22)
12:00 PM	Heat Removal for First Walls <i>Carasik</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Intro to Low Temperature Plasmas (LTP) <i>Simeni Simeni</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Dusty Plasmas <i>Jaiswal</i>
4:00 PM	Networking Session / Adjourn

On Day 9 (6/14) we finish the course with diagnostics and AI & ML

Eastern Time	Day 9 (6/15/22)	
12:00 PM	LTP Laser Diagnostics <i>Gerakis</i>	
1:00 PM	Break/Hallway Discussion	
1:30 PM	AI & ML in Fusion <i>Rea</i>	
2:30 PM	Break/Hallway Discussion	
3:00 PM	MFE Diagnostics <i>Delgado-Aparicio</i>	
4:00 PM	Closing Remarks / Adjourn	

- Dr. Alexandros Gerakis (Luxembourg Institute of Science and Technology) will discuss laser diagnostics used in LTP systems.
- Dr. Cristina Rea (MIT-PSFC) will focus on how AI & ML are being used in the fusion field.
- Dr. Luis Felipe Delgado Aparicio (PPPL) will conclude the course with a discussion of diagnostic systems used in magnetic confinement fusion.

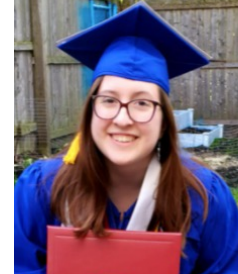
We've started a Discord server for the incoming fusion/plasma community!



- Summer of 2020, we created a venue to let the participants of this course, and, in general, undergrads and grads just starting out in the road of fusion and plasma physics, talk to each other and learn about summer opportunities. Conversations continued beyond the summer.
- With the help of Nigel DaSilva and Louise Ferris, we've created and maintained a Discord server for this purpose. **Enrollees were all invited to join.**



Nigel DaSilva, 2020 PPPL SULI
Current Columbia
grad student



Louise Ferris, 2020 LANL SULI
Current UW-Madison
grad student

Continue the conversations with the speakers!

- Some speakers will be able to stick around after their talks to continue discussions. We will share a “Hallway Discussions” zoom link with enrollees. We will announce if speakers will be available and when.
- We will also have Discord channels for topics to continue discussions and we’re inviting the speakers to join (we’ll also send them the questions that arise there).

Certificates of Completion

Do you plan to watch all the lectures (or the vast majority of them)? If you do, we'll email you a Certificate of Completion for the course!

You don't need to be an enrollee, just watch the lectures (live if you can, but prerecorded if necessary), and be sure to watch my closing remarks on June 15th.



APS-DPP abstract submissions



- The American Physical Society Division of Plasma Physics (APS-DPP) meeting is scheduled for the week of Oct 30-Nov. 3 in Denver, CO. The conference will be held as a hybrid in-person/remote event. Visit the [meeting website](#) for up to date information.
- As with every year, undergraduates are invited to present their research at a dedicated poster session. There were more than 100 undergraduate posters at the 2022 APS-DPP meeting!
- **All poster abstract submissions are due July 14th and can be submitted on the [meeting website](#)**
- Registration and APS membership is free for undergrads!

We've learned a lot from the pandemic that we shouldn't forget

- The reason the course became fully remote was because of the pandemic.
- We're still remote so that we can still reach all of the folks that can't come to PPPL.
- All talks are recorded and will be posted, so practice self-care. Take rests, sit out when you're exhausted, stretch, stay hydrated, etc.
- **YOUR HEALTH AND WELL BEING ARE THE PRIORITY!**

A healthy culture of diversity, equity and inclusion is needed for the future of fusion energy and plasma physics

- The US fusion energy and plasma physics community has a poor record on diversity, equity and inclusion, as evidenced by the few women and underrepresented minorities in the field as compared to other physics and engineering fields.
- Recent community-wide strategic plans have, for the first time, acknowledged these problems and put forth initial plans to address them. DOE and Princeton U are both fully committed to improving the status quo.
- An inclusive climate is the only way to start.

Code of conduct

Since this is a public forum we ask speakers and participants to:

- Make participation in our community a harassment-free experience for everyone
- Act in ways that contribute to an open, welcoming, diverse, inclusive, and healthy community
- We align with the [Contributor Covenant Code of Conduct](#)

Code of conduct: Unacceptable Behaviors

- The use of sexualized language or imagery, and sexual attention or advances of any kind
- Trolling, insulting or derogatory comments, and personal attacks
- Public or private harassment
- Other conduct which could reasonably be considered inappropriate in a professional setting

Code of conduct: Positive Behaviors

- Demonstrating empathy and kindness
- Being respectful of differing opinions and experiences
- Giving and gracefully accepting constructive feedback
- Accepting responsibility and apologizing to those affected by our mistakes, and learning from the experience

Code of conduct: Positive Behaviors

- Respect the pronouns of others
- Recognize that intent is not equal to impact
- **Self-Care is revolutionary!**

Thanks to the folks that make this happen

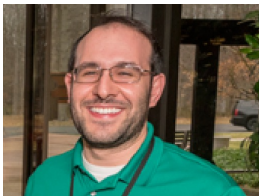
This course is a massive effort that requires many folks behind the scenes, both at PPPL and beyond. I'd like to especially thank:



Deedee
Ortiz



Britt
Albucker



Harry
Tsamutalis Jr



Louise
Ferris



Harry
Fetsch

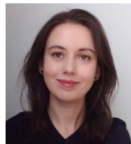


Alex
LeViness



Anthony
Pizzo

Finally, of course, thanks to all of the speakers!



Dr. Galina Avdeeva
General Atomics



Prof. Lane Carasik
Virginia Commonwealth U.



Dr. Luis Felipe Delgado Aparicio
PPPL



Dr. Cody Dennett
CFS



Prof. Jack Hare
MIT PSFC



Dr. Peter Heuer
Laboratory for Laser Energetics



Prof. Surabhi Jaiswal
Eastern Michigan U



Dr. Annie Kritcher
LLNL



Sachin Desai J.D.
Helion Energy



Dr. Vinicius Duarte
PPPL



Dr. Sara Ferry
MIT PSFC



Dr. Alexandros Gerakis
Luxembourg Institute of Science and Technology



Dr. Alberto Loarte
ITER



Dr. Sophia Malko
PPPL



Dr. Auna Moser
General Atomics



Dr. Nick Murphy
Harvard-Smithsonian CFA



Dr. Oak Nelson
Columbia University



Dr. Rosa Tatiana Niembro Hernández
Harvard Smithsonian CFA



Prof. Felix Parra Diaz
PPPL



Prof. Elizabeth Paul
Columbia University



Dr. Derek Sutherland
Zap Energy



Prof. Saikat Chakraborty Thakur
Auburn University



Dr. Cristina Rea
MIT PSFC



PlasmaPy Team



Prof. Marien Simeni Simeni
University of Minnesota



Dr. Priyanjana Sinha
PPPL