Advanced Plasma Engineering Lab (APEL)  
Ontario Tech University

Advanced Plasma Engineering Lab also known as APEL was set up at the faculty of energy systems and nuclear science, Ontario Tech University, Canada. The main focus of the lab is development of the Nuclear Fusion Engineering, Pulsed Power Engineering, Plasma-Based Waste to Energy, Plasma Propulsion and Plasma-Surface engineering. APEL research group has expanded its horizons from high energy density pulsed plasma (100,000,000 K) to the thermal plasma torches and even low temperature plasmas (298 K). APEL research output has numerous applications in nuclear fusion, pulsed power, aerospace, oil and gas, nanotechnology, medicine, environment, and industry. APEL lab emphasizes on innovations in plasma generation, plasma confinement, industrial design and their applications on multiple disciplines. APEL research team consists of a group of enthusiastic scientists and researchers with specializations in different fields working together towards the development of advanced future technologies.
Members

Principal Investigator: Dr. Hossam Gaber, Professor – Director of APEL, Founding Chair of IEEE Nuclear and Plasma Sciences Society (NPSS) Toronto Chapter

Research Team:

- Dr. Vahid Damideh, Postdoc
- Mr. Mohammed Aboughaly, PhD Student
- Mr. Isaac Hassen, MASc Student
- Mr. Yousef Al-Shawesh, MASc Student
- Mr. Manir Isham, Research Student

Previous members:

- Dr. Emmanuel Boafo
- Dr. C. A. Barry Stoute
- Mr. Mason Verkruisen
- Mr. Paranjay Goel
- Mr. Blake Villagracia
- Mr. Vrishabh Menon
- Ms. Malika Patel
- Mr. Mitchell Finstad
- Mr. Daniel Bondarenko
- Ms. Luping Zhang
- Mr. Nicholas Tarsitano
- Mr. Shraddhey Jani
- Mr. Anas Abdel Rihem
- Mr. Stefan Sirakov
- Ms. Samskruthi Prabhu
Previous Members: Include postdocs, grad/undergrad students who graduated.
Research Capabilities and Potentials

1- Nuclear Fusion

- Compact Fusion Reactors
- High Energy Density Plasmas
- Plasma Confinement
- Magneto-Inertial Confinement Fusion
- Dense Plasma Focus, Polywell, Z-Pinch, Field Reversed Configuration, High-Beta Fusion Reactor, Tokamak
- Anuetronic Fusion (p-11B, 3He-3He)
- Nuclear/Plasma Diagnostics
- Neutron Generators
- Ion/Electron Accelerators
- Medical Isotopes, Boron Neutron Cancer Therapy (BNCT), Positron Emission Tomography (PET)
- Ion/Electron/plasma Guns
- Radiation Safety Analysis
- Spectroscopy

2- Pulsed Power

- High energy, high current Capacitor banks
- Pulse Forming Networks (PFN)
- Ultra-Fast Pulsed Power Switching
- Ultra-Fast High Voltage, High Current Sensors
- Electromagnetism
- Linear Transformer Drivers
- Ultra-High Magnetic Fields
- Direct Energy Conversion

3- Waste to Energy

- Atmospheric Pressure Plasmas
- DC/RF/Microwave Plasma Torches
- Plasma-Based Gasification and Pyrolysis
- Portable Plasma-Based Waste-to-Energy Solution
- Waste-to-Energy Reactor Chambers
- Atmospheric Pressure Plasma Diagnostics
- Dielectric Barrier Discharge (DBD)
4- Aerospace

- Ultra-High Vacuum Chambers
- Pulsed-Plasma Thrusters
- Space Propulsion
- Plasma Actuators
- Nano-Satellites

5- Plasma-Surface Engineering

- Electron Beam Physical Vapor Deposition (EBPVD)
- Plasma Surface Treatment
- Surface Hardening, Softening, Micromachining, Coating
- Lithography
- Semiconductors
- Nano-Technology
- Nano-Material Synthesis
- Plasma Spray

Advanced Plasma Engineering & Applications


Areas of expertise

**Plasma Based**
- Plasma Simulations
- DC and RF Plasma Generation
- Plasma Diagnostics
- Low Power Space Propulsion for

**Non-Plasma Based**
- Aeronautics
- Computational Fluid Dynamics
- Finite Element Analysis
- Numerical Methods and
Nanosatellites
- High Power Space Propulsion for Large Satellites
- Magnetoplasmadynamic Generation

Coding
- Rocketry Simulation and Experimentation
- Ramjet and Scramjet expertise

Potential Projects

Current
- Plasma Simulations
  o Computational Fluid Dynamics using Magnetohydrodynamics
  o Particle-in-Cell/Statistical Mechanics Modeling using Monte Carlo
  o Hybrid CFD/PiC modeling
- Plasma Generation
  o High Voltage – High Power DC Plasma
  o Low Power RF Plasmas
    ▪ Capacitive Discharge
    ▪ Inductive Discharge

Target
- Plasma Gasification
- Power Generation from Scramjets, Rockets, and Jet Engines
- Ion, Hall, and Magnetoplasmadynamic Thrusters
- Alternative Nuclear Fusion
- Laser Technology
- Plasma Etching for Micro- and Nanotechnology
- Ramjet and Scramjet Technology

APEL Potential Collaborations

Potential Research
- Dielectric Barrier Discharge Plasma Actuators
  o Purpose:
Control Flow Separation on an Airfoil
Control of Bluff Body Wakes
Control transition of a laminar boundary layer
  - Use of a dielectric barrier between two copper plates to create plasma using capacitive discharge
  - Function generator is to control actuation
  - Experimental Set-Up from “Characterization of the time-dependent behaviour of dielectric barrier discharge plasma actuators”
    - Dielectric Plate - Polymethyl methacrylate
    - Separation – Kapton Tape
    - Electrodes – Copper
    - Function Generator
    - High Voltage Amplifier
    - Digital Oscilloscope
    - Particle Image Velocimetry

Research Capabilities
Immediate Projects
- Ion and Hall Propulsion Systems for Satellites
  - Using Nitrogen rather than Xenon for Propellant which has an input power of up to 10 kW
  - Purpose of having ion and hall thrusters is to manoeuver satellites as commanded from the defense department
- Study of Plasma Actuation for Rockets

Extended/Long-Term Projects
- Scramjet-based missiles to reach ordinance from one location to another in a short period of time, faster than conventional missiles.
  - As for scramjet-based missiles, United States is the only known country that is researching heavily on hypersonic flight
  - Ordinance/package delivery
  - Hypersonic jets for troop delivery
  - Creating a scramjet magnetoplasmadynamic thruster for space-bound thrust
- Railgun artillery technology to use for ground-based vehicles.
  - Railgun artillery is a new technology which involves intensive research in electromagnetics.
  - Creating a proper cooling system and energy reclamation
  - Aim for use on ground and naval vehicles
Currently, there is ongoing research on Z-pinch and multi-pinch plasma generation. There are experiments being conducted to observe the benefits of increasing ionization in a Z-pinch plasma. The experiment is conducted using a standard TVAC chamber with a vacuum pump. High voltage power supply provides the DC voltage for ionization. A modified Colpitt RF circuit is implemented as an auxiliary ionization source. The plasma is observed by using a triple Langmuir probe.

Plasma Generation inside the mini-TVAC chamber at the laboratory.
5. Hossam A. Gabbar; Luping Zhang; C. A. Barry Stoute; Emmanuel Boafo; Daniel Bondarenko, Simulations of High-Current Plasma Beam Model by Magnetohydrodynamics and Monte Carlo Methods, Accepted to World Journal of Nuclear Science and Technology, March 1 2016
6. C. A. Barry Stoute; Hossam A. Gabbar; Daniel Bondarenko; Anas Abdel Rihem, RF-Assisted DC Single Beam Plasma Generation for Multi-Beam Nuclear Fusion, Submitted to Fusion Engineering and Design


13. Hossam A. Gabbar, C. A. Barry Stoute, Daniel Bondarenko, Nicholas Tarsitano, Anas Abdel Rihem, Stefan Sirakov, Samskruthi Menashi, Simulations and Experimentation of X-Pinch Plasma Beam Interaction

Conference Papers / Presentations


Theses
• Bondarenko, Daniel: Robust, Virtual-Electrode Dense Plasma Generator for Efficient Plasma Applications
• Stoute, C. A. Barry: Hybrid Electric Thruster using Gas Mixtures
• Zhang, Luping: A Study of MHD and Monte Carlo Simulations of High-Current Plasma Beams in Industrial Applications

Related Conferences / Events
Symposium on Plasma and Nuclear Systems (SPANS), IEEE NPSS, Toronto

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