Compact plasma-based particle accelerator studies

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Particle accelerators have contributed to scientific research for decades, enabling decisive discoveries in high-energy physics and providing high-brilliance photon sources for biology, medicine, security, material science and chemistry research. Conventional particle accelerators are large, expensive machines to build and operate. The emerging technology of plasma acceleration promises to make particle accelerators much smaller, and subsequently, cheaper. In 2019, plasma accelerators demonstrated the acceleration of an electron beam to 8 GeV in 20 cm, where conventional technologies would need nearly a kilometre. Such performances make plasma accelerators an exciting alternative to conventional technologies, and constant efforts are being pursued internationally to improve the usability of these accelerators. While the properties of plasma accelerated beams are improving towards that of conventional accelerators, there are still many unanswered questions and obstacles to be overcome.

Numerical simulations bring invaluable insight into the mechanisms and processes important to plasma wakefield acceleration, but are very demanding due to timescales spanning over 12 orders of magnitude, from a kinetic regime in the first femtoseconds to a hydrodynamic regime over milliseconds. In this project, you will investigate the plasma wakefield evolution, and plasma relaxation on multiple timescales with simulation tools ranging from particle-in-cell codes to magnetohydrodynamic codes, in order to understand the physical mechanisms in detail and assist the development of plasma accelerators.

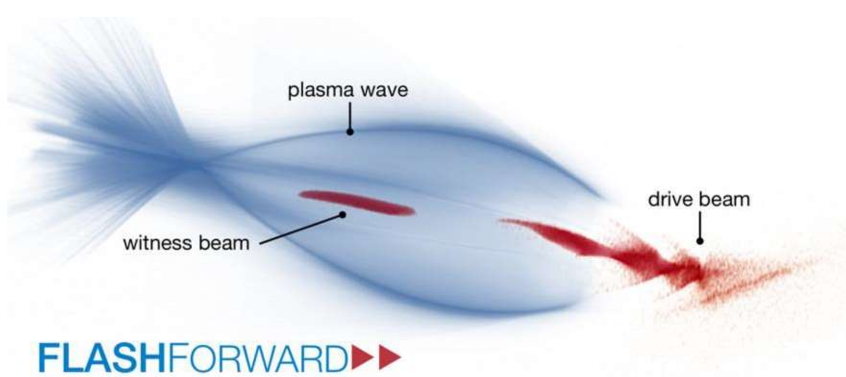

Figure 1: Drive beam creating a plasma wave that is then use to accelerate a witness beam

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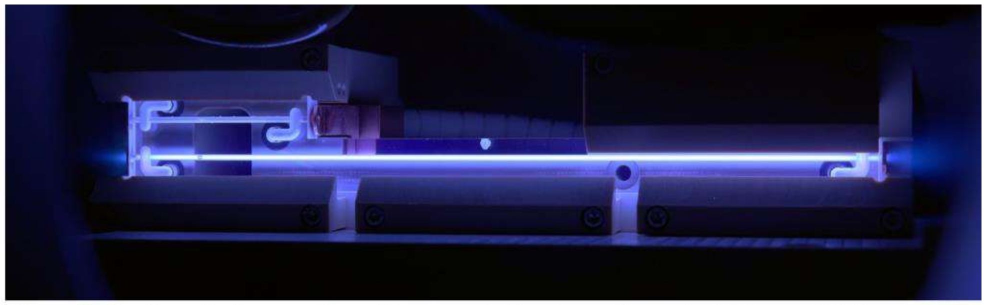

Figure 2: Capillary discharge cell used to generate the plasma through which a particle beam travels to generate a plasma wake.

Student Opportunities:

A student interested in the project will have the opportunity to work on a range of topics dependent on the students' interests. They will receive training and supervision in plasma physics and simulation.

Possible topics include:

- Variation of wakefield structure with drive-beam properties Optimization of witness-beam properties
- Instabilities in drive/witness beams
- Investigation of synchrotron radiation from a compact plasma accelerator
- Plasma beam dump design and optimization
- Tailoring of the background plasma profiles
- Capillary-discharge plasma device design.

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