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Ionization Front Acceleration revisited: collective GeV-scale acceleration of high-charge ion bunches by high-current electron beams

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Traditional linear accelerators (LINACS) are effective for accelerating large amounts of ion charge with high efficiency. However, their compactness is limited by the breakdown of the solid accelerating structure, typically on the order of MV/m. On the other hand, laser-target ion accelerators can produce much higher accelerating field, e.g. via a TNSA mechanism, but are limited in the resulting ion energy gain by the small size of their acceleration region. In this talk I will revisit and extend the concept of Ionization Front Acceleration (IFA), first introduced in the 1980s. The IFA approach combines the compactness of laser plasma ion accelerators with the high efficiency, brilliance, and extended acceleration distances characteristic of traditional LINACS. In this scheme, an intense relativistic electric beam is directed into a gas medium, while a sweeping external laser ionizes the gas, propelling the ionization front forward. This creates an acceleration region with gradients of sub-gigavolt per meter(~300MV/m) that co-propagates with the injected ions, offering the potential for a compact, high-yield ion accelerator. Using particle-in-cell simulations, we demonstrate the acceleration of 150 MeV few-μC hydrogen ions over a distance of < 0.5m. Additionally, we propose an innovative scheme, termed Counter-propagating Laser-Ionization Front (CLIF) acceleration, to overcome the hosing instability of the driver beam that limits the final energy – a potential challenge that was not explored in the earlier IFA research.

Working group

WG3 : Beam-driven plasma acceleration

Primary author: CHEN, Jiyuan (Cornell University)

Co-authors: KIM, Ji Hoon (Cornell University); ROOPENDRA, Rajawat (Cornell University); SHVETS, Gennady (Cornell University)

Presenter: CHEN, Jiyuan (Cornell University)

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