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Radiation pressure driven collisionless shock ion acceleration at Brookhaven National Laboratories

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Laser-plasma ion acceleration is a well established field of research, with several mechanisms being exploited to produce particle beams with high energy and short bunch lengths.
One of these techniques is radiation pressure acceleration (RPA), which turns into collisionless shock acceleration (CSA) when thermal effects become relavant.

Scaling laws show that both the vector potential of the laser, and the critical density of the plasma scale favorably with the laser wavelength. These considerations make the long wavelength ($9.2\mu m$) and high power ($a_0 > 1$) CO_2 laser at the Brookhaven National Laboratories the ideal choice for exploring and pushing the boundaries of radiation pressure acceleration using gaseous targets.

The work carried out by the Imperial College group at BNL has demonstrated steady ion production, albeit with low energy, in the scenario where the laser's main pulse interacts with a the gas jet from a supersonic conical nozzle. Clear channelling of the laser through the hydrogen plasma was observed experimentally, using an ultra short Ti-Sapphire optical probe, and in PIC simulations with very good agreement between the results.

Significant gains in the ion energies were obtained when employing the laser's pre-pulse to shape the target and form spherical blast waves. This approach consistently produced $\sim$1MeV monoenergetic ion beams. The results are backed by PIC simulations which give insights on collisionless shock acceleration dynamics. New targetry is being developed to achieve high density gradients in the target without relying on the volatile pre-pulse.

Primary authors: CASATI, Ginevra (Imperial College London); Dr POGORELSKY, Igor (Brookhaven National Laboratory); Dr POLYANSKIY, Mikhail (Brookhaven National Laboratory); DOVER, Nicholas; XU, Nuo; Dr ETTLLINGER, Oliver (Imperial College London); NAJMUDIN, Zulfikar (Imperial College London)

Presenter: CASATI, Ginevra (Imperial College London)

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