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Experimental evaluation of Nano Accelerators driven at relativistic intensities

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Highly ordered nanowire arrays with sub-wavelength diameter can be engineered to absorb multi-PW laser pulses with ultra-high-contrast (<10^{-12} on ps timescales), sub-100-fs pulse duration at intensities above 10^{20} W/cm^2 with efficiency nearing 100%. A large fraction of the absorbed energy is converted to high-current ion and electron flows in a controlled manner by this Nano Accelerator [1].
We will present an experimental evaluation of the Nano Accelerator driven by 10 PW laser pulses of the HPLS laser at the Extreme Light Infrastructure for Nuclear Physics (ELI-NP), which was operated at approximately 200 J of energy on target at a pulse duration of 23 fs. The original focusing geometry was modified from F/60 to F/20 leading to intensities of 8×10^{20} W/cm^2 with a uniform focal spot volume of 16 µm FWHM and >200 µm Rayleigh length [2]. The intense laser pulse was used to irradiate highly aligned, high-aspect-ratio nanowires within a patch of 100×100 µm^2 and average electron density of ~5 n_c, where n_c is the critical density. Monitoring the specularly reflected laser light and detecting ion emission via multiple Thomson parabola & CR-39 spectrometers, we demonstrate increased ion emission from 20 µm long wires compared to 10 µm wires, with conversion to high energy ions nearing 20-30% efficiency in line with theoretical expectations [1,3].
In a second experiment, conducted at HZDR with the DRACO laser using an optical pump-probe setup to study pre-plasma dynamics in the interaction of an ultrashort high-power laser with nanostructured targets, we investigated pre-ionization and pre-expansion of the nanowires from laser pre-pulses, modifying the nanostructure and degrading performance, making these dynamics critical to resolve for reliable modeling and target optimization. Using combined scattering and Doppler spectrometry, we measure target expansion and particle dynamics under different laser contrast conditions, providing insight into how nanostructure modification influences laser-plasma coupling and ion acceleration.

[1] Ruhl and G. Korn, arXiv, 2212.1294 (2022), H. Ruhl and G. Korn, arXiv, 2302.06562 (2023)
[2] V. Scutelnic. et al., accepted for publication in High Power Laser Science and Engineering
[3] D.E. Rivas et al., in preparation

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Sitzung Einordnung: Session 6 - Short Pulse+ and other